PowerLogic™ P5

Protection Relay

User Manual

05/2025

Version: P5/ANSI M/02-502A

www.se.com/us

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Table of Contents

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Purpose

This user manual is intended for electrical power engineering experts, OEMs, system integrators, communication specialists, and general users of the PowerLogic™ P5 protection and control relays.
The complete manual is arranged as follows:

- Preliminary sections, with the details of the manual (how to use it, glossary) and technical data.
- Functions of the protection relay.
  Explanations, diagrams and settings of the protection, control, monitoring and maintenance, measurement, recording and programmable logic functions are detailed in these sections.
- Installation and commissioning.
- Local control panel use, troubleshooting and maintenance instructions.

The following documents complete this manual:

- Quick Start Guide, delivered in the relay package, summarizes instructions for installation.
- Communication Manual, for the understanding and the setup of the communication protocols with PowerLogic P5.
- Application Book, for the understanding of specific applications and describing how the PowerLogic P5 protection and control relay functionality can be expanded.

All above documents are accessible at se.com under this link:https://www.se.com/ww/en/product-range/62400-powerlogic-p5-protection-relays/?parent-subcategory-id=86796&filter=business-6-medium-voltage-distribution-and-grid-automation#documents

We welcome your comments about this document. You can reach us by contacting Customer Care Centre Contact page:
http://www.se.com/CCC

Safety information and password protection

Important information

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this manual or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of this symbol to a "Danger" or "Warning" safety label indicates that an electrical hazard exists which will result in death or serious injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

⚠⚠ DANGER

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

Failure to follow these instructions will result in death or serious injury.

⚠ WARNING

WARNING indicates a potentially hazardous situation which, if not avoided, can result in death or serious injury.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

⚠ CAUTION

CAUTION indicates a potentially hazardous situation which, if not avoided, can result in minor or moderate injury, or equipment damage.

Failure to follow these instructions can result in injury or equipment damage.

NOTICE

NOTICE is used to address practices not related to physical injury.

Failure to follow these instructions can result in equipment damage.

User qualification

Electrical equipment should be installed, operated, serviced, and maintained only by trained and qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material. A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved.

Use the password protection feature in order to protect untrained person interacting with the PowerLogic P5 protection relay.

FCC Part 15 Notice

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception which can be determined by turning the equipment off and on, the user is encouraged to try to correct interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Any change or modification of the product not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC certification

The Extension Zigbee module (reference REL51044) complies with part 15 of the FCC Rules. The FCC ID is **2AHP8-JYT46620**, the IC ID is **21245- JYT46620**.

The module label includes the corresponding FCC ID. The operation is subject to the following two conditions:

- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation.
This device is limited module, since lack of shielding, additional test is requested for each installation.

IC

English: Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotopically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

French: Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Abbreviations

Table 1 - Abbreviations used in the manual

Acronyms	Indication
Ø	Diameter
AC, DC	Alternating Current, Direct Current
ACSI	Abstract Communication Service Interface
AI, AO	Analogue Input, Analogue Output: used in connection with the number of input and output contacts within the relay and - when necessary - with the slot letter.
ALF	Accuracy Limit Factor
CAE	EcoStruxure Cybersecurity Admin Expert
CB	Circuit Breaker
CLIO	Current Loop Inputs and Outputs
CS	CyberSecurity
CID	Configured IED Description
CT	Current Transformer
CTS	Current Transformer Supervision
DC	Disconnector
DCD	Device Capabilities Description
DI, DO	Digital Input, Digital Output: used in connection with the number of inputs and output contacts within the relay and - when necessary - with the slot letter.
Digital CB	A dedicated Modbus Master protocol for Digital Circuit Breaker monitoring.
DG	Distributed Generation
DIN rail	Standard metal rail used to mount equipment inside ar rack (DIN for Deutsches Institut für Normung)
DIT	Direct intertrip
DMS	Distribution Management System
EMC	Electromagnetic Compatibility
EOS-BM100	Breaker monitoring module
EOS-MCMx00	Motor controlling module
ES	Earthing Switch
ETH	Ethernet Module
f	frequency
FC	Function Code
FO	Fiber Optic
G_D	Threshold of independent time operation.
GOOSE	Generic Object Oriented Substation Events: in IEC 61850, type of generic substation event, for a peer-to-peer communication over Ethernet.
HMI	Human Machine Interface
HSR	High availability Seamless Redundancy
ICD	IED Capability Description
ICT	Inductive Current Transformer
IEC	International Electrotechnical Commission prepares and publishes international standards for electrical and electronics technology.
IED	Intelligent Electronic Device
IN.CSH	Measured neutral current from CSH core-balance CT
IN.CSH.nom	Neutral CSH CT primary nominal

Table 1 - Abbreviations used in the manual (Continued)

Acronyms	Indication
IN.calc	Calculated neutral current from 3 phase currents
IN.meas	Measured neutral current from standard 1A/5A current inputs
IN.nom	Standard neutral CT primary nominal
IN.sens	Measured neutral current from sensitive 1A input
IN.sens.nom	Sensitive neutral CT primary nominal
IVT	Inductive Voltage Transformer
I/O	Input/Output (e.g. 6I/4O: 6 inputs, 4 outputs): used in connection with the number of inputs and output contacts within the relay.
In	Phase CT primary nominal
Inom	Phase CT primary nominal
IRIG-B	Inter-Range Instrumentation Group time code B: standard for time transfer
LC	"Lucent Connector": type of optical connector
LED	Light Emitting Diode
LPCT	Low Power Current Transformer
LPIT	Low Power Instrument Transformer
LPVT	Low Power Voltage Transformer
LV, MV	Low Voltage, Medium Voltage
max.	Maximum
MSW	Motorized Switch
NERC	North American Electric Reliability Corporation
NI	Network Input
P2P	Peer-to-Peer
PCT	Protective Conductor Terminal (ground)
PIT	Permissive intertrip
PLC	Programmable Logic Controller
POC	Primary Operating Current
PRP	Parallel Redundancy Protocol
Pnom	Active nominal power
pu	Base unit which equals to primary nominal value
QR code	Quick Response code: two-dimensional barcode.
RBAC	Role Based Access Control: provides a restricting access to authorized users only (Cybersecurity).
RCA	Relay Characteristic Angle
Ref	Reference
REF	Restricted Earth Fault
RH	Relative Humidity
RJ45	Standardized type of connector (eight-wire connector) used for Ethernet networking (Registered Jack)
RMS	Root Mean Square
RoCoF	Rate of Change of Frequency
RS485 (or EIA-485)	Standard defining the electrical characteristics of a serial communication interface.
RSTP	Rapid Spanning Tree Protocol: communication protocol

Table 1 - Abbreviations used in the manual (Continued)

Acronyms	Indication
RTC	Real Time Clock
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SDLC	Synchronous Data Link Control communication protocol
SFP	Small Form-factor Pluggable
SFTP/FTP	Secured File Transfer Protocol/File Transfer Protocol
SOL	Selective Overcurrent Logic
SRL	Serial Module
SSW	Sag & Swell
ST (BFOC)	Straight Tip (Bayonet Fiber Optic Connector): type of optical connector
Snom	Apparent nominal power
TCS	Trip Circuit Supervision
THD	Total Harmonic Distortion
TLS	Transport Layer Security
TP	Time Protocol: communication protocol
UFLS	Underfrequency Load Shedding
Un	Phase VT primary nominal
USB	Universal Serial Bus
VI	Virtual Input
VN.calc	Calculated neutral voltage from 3 phase voltages
VN.meas	Measured neutral voltage from neutral voltage input
VO	Virtual Output
VT	Voltage Transformer
VTS	Voltage Transformer Supervision
Vnom	VT primary nominal (PP)
Vnom/√3	VT primary nominal (PN)

Description of the document versions

The document version rule was upgraded since the version P5/EN/M/02-501A to help in understanding of the firmware version the user manual serves for. The document version is composed by the following information:

- The product, for example, P5 stands for PowerLogic P5.
- The language and standard definition: EN, FR, IT, ES, PT, RU, CN, ANSI, and so on. By default IEC standard applies. ANSI version is always published in English language.
- The type of the document: M for manual, C for communication manual, A for application book.
- The major version of the firmware.
- The release version of the firmware.
- The document version, which loops from A to Z for a dedicated release version.

The table below introduces in detail the components of document version and their meanings:

Product	Language and standard	Type of document	Firmware major version	Firmware release version	Document version
P5	EN (IEC)	**M**anual	V**01**	500	**A**
	FR (IEC)	**C**ommunication manual	V**02**	501	B
	ES (IEC)	**A**pplication book	…	502	C
	PT (IEC)	…		503	D
	IT (IEC)			…	E
	CN (IEC)				F
	RU (IEC)				G
	ANSI (US)				H
	…				…

According to the above table, the version “P5/EN/M/02-501A” stands for the user manual of PowerLogic P5 in English, for the firmware version V02.501, since this is the first version of user manual of this firmware, the document version is A.

For the firmware versions the earlier user manual versions served for, please refer to Revision history, page 696.

Range description

PowerLogic P5 is a family of digital protection and control relays for medium voltage distribution networks dedicated to:

- Buildings and Industry:
  - Data centers
  - Retails
  - Hotels
  - Health care
  - Education and research
  - Transportation
  - Industrial buildings
- Utilities: energy distribution
- Large sites:
  - Oil and Gas
  - Mining
  - Mineral and Metals
  - Water

PowerLogic P5 protection and control relays are based on proven technology concepts developed in close cooperation with customers and available in two sizes.

- The PowerLogic P5x20 is housed in 20TE casing. It offers up to 16 digital inputs and up to 9 output contacts, one Ethernet and one serial communication port[1]. P5x20 can realize feeder, motor or transformer applications with Universal model (P5U20) and voltage/frequency applications with Voltage model (P5V20).
- The PowerLogic P5x30 is housed in 30TE casing. It offers up to 40 digital inputs and up to 16 output contacts, two Ethernet and one serial communication port[2]. P5x30 can realize feeder (P5F30), motor (P5M30), transformer differential (P5T30), and line differential (P5L30) applications. PowerLogic P5x30 offers in-built arc flash protection.

PowerLogic P5 protection relays have been designed around user-friendliness, a feature which is proven in our customer reports day after day.

- A complete set of protection functions, related to the application
- Optional arc detection (for PowerLogic P5x30) by point sensors
- Dedicated circuit breaker control with Mimic, push buttons, programmable function keys, customisable LEDs and alarm
- Multilingual local panel display for customized messaging
- eSetup Easergy Pro software for setting parameters, configuring and network fault simulation
- Both serial and Ethernet communication, including redundancy and precision time synchronization
- Compliant with IEC 61850 edition 1 and 2 standard
- Cybersecurity functionalities
- Back-up memory for fast and easy replacement
- Withdrawability for maintenance

Easergy to PowerLogic renaming

Schneider Electric, driven by its “Customer First” Core Value is fully committed to easing the customer experience with our portfolio on all fronts. With this core mission in mind, the decision of optimizing the number of brands has been taken across the entire digital Schneider Electric portfolio, to provide a more cohesive and consistent presentation of our offers across different Divisions, bringing a

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[1] Maximum configuration is 16DI/7DO+WD or 9DI/8DO+WD depending on the boards selected.

[2] Maximum configuration is 40DI/15DO+WD or 19DI/18DO+WD depending on the boards selected.

simpler and customer-centric approach, that will facilitate the navigation through all the breadth and depth of our offers and that will be a key enabler for an optimized digitization experience.

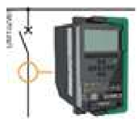
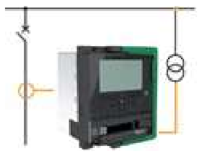
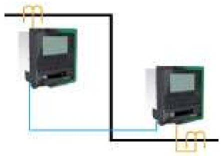
This brand optimization initiative affects Protection & Control portfolio including Easergy P5 protection and control relays. The Easergy P5 has been renamed to PowerLogic P5. It is essential to emphasize that this renaming change exclusively affects the brand name of the products and will have absolutely no consequence on the current performances, specifications, characteristics, and/or quality of the product, which remain totally unaffected by this brand name migration.

During the brand transition project, it may happen that the application of this change to different parts of the offer goes effective with different time schedules. There is absolutely no difference between Easergy and PowerLogic branded P5 products and accessories. Easergy accessories can be used with PowerLogic P5 product as long as the commercial reference is matching. The commercial references have not changed along with renaming of the offer. eSetup Easergy Pro and CET850 remain the software to configure PowerLogic P5 protection and control relays.

Introduction

Selection guide by application

Table 2 - PowerLogic P5 protection relay selection guide

		PowerLogic P5x20			PowerLogic P5x30			
								
Voltage		-		P5V20	-		-	-
Feeder		P5U20		-	P5F30		-	-
Transformer					-		P5T30	-
Motor					P5M30		-	-
Line		-		-	-		-	P5L30
Characteristics								
Ana-logue inputs	Phase current	1/5A CT (x3)	LPCT[3] (x3)	-	1/5A CT (x3)	LPCT[3] (x3)	1/5A CT (x6)	1/5A CT (x3)
	Neutral current	1/5A CT & 1A CT or CSH	CSH	-	1/5A CT & 1A CT or CSH	CSH	1/5A CT (x2)	1/5A CT & 1A CT or CSH
	Voltage	-	LPVT (x4)[4]	VT (x4)	VT (x4)	LPVT (x4)[4]	VT (x1)	VT (x4)
Arc-flash sensor inputs		-			0 to 6 point sensors			
Digital	Inputs	4 to 16			4 to 40			
	Outputs	3 to 8 + watchdog			3 to 18 + watchdog			
Temperature sensor inputs		0 to 16 (external modules)		-	0 to 16 (external modules)			
CLIO module		0 to 3 (external modules)						
Front ports	Mini-USB port for configuration tool	■			■			
	USB port for USB key	■			■			
Communication								
Rear ports	Extension port with backup memory	■			■			
	Serial port	■			■			
	Ethernet port	■			■			
	2nd Ethernet port	-			■			
	InterRelay module	-			■			
Proto-cols	IEC 61850 Ed.1 and Ed.2	■			■			

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[3] The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

[4] Resistive divider or capacitive divider LPVTs can be connected to the PowerLogic P5 protection relay.

Table 2 - PowerLogic P5 protection relay selection guide (Continued)

		PowerLogic P5x20	PowerLogic P5x30
	IEC 60870-5-103	■	■
	IEC 60870-5-101	■	■
	DNP3 serial and Ethernet	■	■
	Modbus slave serial and Ethernet	■	■
	Modbus master	■	■
	EtherNet/IP	■	■
	Digital CB	■	■
	SDLC	-	■
	Zigbee 3.0	■	■
Redundancy protocols	RSTP	■	■
	PRP	■	■
	HSR	■	■
Time synchronization	Pulse, IRIG-B	■	■
	SNTP, PTP IEEE 1588-2008 / IEC 61588:2009	■	■
Others			
Control		8 controlled objects	
Logic	Matrix	■	
	Logic equations	■	
	Advanced logic compliant IEC 61131-3 and IEC 61499	■	
Cybersecurity		RBAC according to IEC 62351 standard IEC 62443-4 Security Level 1	
Withdrawability		■	

Function table

Table 3 - PowerLogic P5 protection relay function selection table

	IEC 61850 Logical node[5]	ANSI code	P5U20 CT variant	P5U20 LPCT/ LPVT variant	P5V20 VT variant	P5F30 CT/VT variant LPCT/ LPVT variant	P5M30 CT/VT variant LPCT/ LPVT variant	P5T30 CT/VT variant	P5L30 CT/VT variant
Protection functions									
Non-directional/directional phase overcurrent[6]	OC**PTOC**x	50/51/ 67	6[7]	6	-	6	6	6	6
Non-directional/directional ground fault overcurrent[8]	DEFU**PTOC**x[9] P5DEF**PTOC**x	50N/ 51N/ 67N	6	6	-	6	6	6	6
Wattmetric ground fault	EF**PDOP**x	32N	-	-	-	2	2	-	2
Transient intermittent ground fault	IOIO**PTEF**1	67NI	-	-	-	1	-	-	1
Capacitor bank unbalance	CAP**PTOC**x	51C	2	-	-	2	-	-	-
Negative sequence overcurrent	NEG**PTOC**x	46	2	2	-	2	2	2	2
Unbalance overcurrent, broken conductor	UIBC**PTOC**1	46BC	2	2	-	2	2	2	2
Cold load pick up (CLPU)	CLP**PIOC**1		1	1	-	1	1	-	1
Selective overcurrent logic (SOL)	SOL**PIOC**1	68	1	1	-	1	1		1
Switch On To fault (SOTF)	SOTF**PIOC**1	50HS	1	1	-	1	1	-	1
5th harmonic detection	HAR5**PTOC**1	68H5	1	1	-	1	1	-	1
Circuit breaker failure	CBFP**PIOC**x	50BF	1	1	1	1	1	2	1
Directional power	REVP**PDOP**1 P5REVP**PDOP**2	32	-	2	-	2	2	-	2
Fault locator	FL**RFLO**1	21FL	-	-	-	1	-	-	1
Auto-Recloser	AR**RREC**1	79	1	1	-	1	-	-	1
Arc-flash protection	ARCM**PIOC**x	50ARC	-	-	-	8	8	8	8
Thermal overload protection for motor	THM**PTTR**1	49M	1	1	-	-	1	-	1
Thermal overload protection for feeder	THF**PTTR**1	49F	1	1	-	1	-	1	1
Temperature monitoring	RTD**STMP**1...16	38	16	16	-	16	16	16	16
Phase undercurrent	UC**PTUC**x	37	1	1	-	1	1	-	1
Motor start-up supervision, locked rotor	STAL**PMSS**1 P5LR**PMSS**1	48/ 51LR	1	1	-	-	1	-	-
Motor restart inhibition	FST**PMRI**1	66	1	1	-	-	1	-	-
Motor speed detection[10]	MSPD**PMSS**1		1	1	-	-	1	-	-
Motor overspeed[10]	MOT**POVS**x	12	2	2	-	-	2	-	-
Motor underspeed[10]	MOT**PZSU**x	14	2	2	-	-	2	-	-
Motor Anti-backspin ABS[10]	MABS**PMSS**1	ABS	1	1	-	-	1	-	-
Emergency restart	EMG**PMSS**1		1	1	-	-	1	-	-

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[5] The x at the end of the logical node name in this column corresponds to the number of the stages of protection functions and the number of the objects for control and monitoring functions.
[6] Only non-directional phase overcurrent is available in P5U20 and P5T30.
[7] Non-directional only
[8] Only non-directional ground fault overcurrent is available in P5U20.
[9] Dedicated for P5U20.
[10] This protection function is only available when 12I4O module is fitted in the PowerLogic P5 protection relay.

Table 3 - PowerLogic P5 protection relay function selection table (Continued)

	IEC 61850 Logical node[11]	ANSI code	P5U20 CT variant	P5U20 LPCT/ LPVT variant	P5V20 VT variant	P5F30 CT/VT variant LPCT/ LPVT variant	P5M30 CT/VT variant LPCT/ LPVT variant	P5T30 CT/VT variant	P5L30 CT/VT variant
Inrush detection	ID**PHAR**1	68H2	1	1	-	1	1	2	1
Overvoltage	OV**PTOV**x	59	-	3	3	3	3	-	3
Undervoltage	UV**PTUV**x	27	-	3	3	3	3	-	3
Positive sequence undervoltage	UVPS**PTUV**x	27P	-	-	2	-	2	-	-
Capacitor overvoltage	CAP**PTOV**1	59C	1	-	-	1	-	-	1
Neutral overvoltage	UO**PTOV**x	59N	-	3	3	3	3	3	3
Overfrequency	OF**PTOF**x	81O	-	2	2	2	2	-	2
Underfrequency	UF**PTUF**x	81U	-	8	8	8	8	-	8
Rate of Change of Frequency (RoCoF)	DFDT**PFRC**x	81R/ 81FR	-	9	9	9	-	-	9
Synchro-check	**RSYN**1	25	-	-	1	1	-	-	1
Lockout relay		86	1	1	1	1	1	1	1
Programmable stages	PS**GAPC**x	99	8	8	8	8	8	8	8
Programmable curves			3	3	3	3	3	3	3
Negative sequence overvoltage	NEG**PTOV**x	47	-	2	2	2	2	-	2
Neutral admittance	EF**PADM**x	21YN	-	-	-	2	2	-	2
Restricted ground fault (low impedance)	REF**PDIF**1	64	1[12]	-	-	1[12]	1[12]	2[12]	1[12]
Restricted ground fault with external connection (high-impedance)		87N	A[12]	-	-	A[12] [13]	A[12] [13]	A[12] [13]	A[12] [13]
High impedance busbar differential		87Z	A[12] [13]	-	-	A[12] [13]	A[12] [13]	A[12] [13]	-
Line differential protection		87L	-	-	-	-	-	-	1
Transformer differential protection (2-winding transformer differential)		87T	-	-	-	-	-	1	-
Transformer overfluxing protection	TVF**PVPH**x	24	-	-	-	-	-	3	-
Voltage-controlled overcurrent		51V	A[13]	A[13]	-	A[13]	A[13]	-	A[13]
Analogue inputs and outputs	CLIO**GGIO**1...3		12[14]	12[14]	12[14]	12[14]	12[14]	12[14]	12[14]
Setting groups			4	4	4	4	4	4	4
Monitoring functions									
CT supervision	CTS**GGIO**1	60	1	1	-	1	1	2	1
VT supervision	VTS**GGIO**1	60	-	1	1	1	1	-	1
Trip circuit supervision		74	1	1	1	1	1	2	1
Transformer monitoring	TRF**SIML**x	26/63	2	2	-	2	2	2	-
Circuit breaker monitoring	CBWA**GGIO**1		1	1	-	1	1	1	1
Relay monitoring			■	■	■	■	■	■	■

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[11] The x at the end of the logical node name in this column corresponds to the number of the stages of protection functions and the number of the objects for control and monitoring functions.

[12] Only available with conventional (phase or neutral) CTs.

[13] Function can be realized by application guidelines.

[14] Supports maximum 3 x CLIO modules, with 12 AI and 12 AO inputs maximum.

Table 3 - PowerLogic P5 protection relay function selection table (Continued)

	IEC 61850 Logical node[15]	ANSI code	P5U20 CT variant	P5U20 LPCT/ LPVT variant	P5V20 VT variant	P5F30 CT/VT variant LPCT/ LPVT variant	P5M30 CT/VT variant LPCT/ LPVT variant	P5T30 CT/VT variant	P5L30 CT/VT variant
Digital Circuit Breaker monitoring	BM100**GGIO**1 Main**XCBR**1 Main**SCBR**1 Trip**SCOL**x Close**SCOL**1 RD**XSWI**1 RD**SSWI**1 Spring**SOPM**1 VI**SCBR**1 VIA**SCBR**1 VIB**SCBR**1 VIC**SCBR**1 MCMx00**GGIO**1 MSW**SOPM**x MSW**XSWI**x MSW**SSWI**x	■	■	■	■	■	■	■	■
Control functions									
Switchgear control and monitoring	OBJ**CSWI**x		8	8	8	8	8	8	8
Programmable switchgear interlocking			■	■	■	■	■	■	■
Local control on single-line diagram			■	■	■	■	■	■	■
Local control with O/I keys			■	■	■	■	■	■	■
Local/remote function			■	■	■	■	■	■	■
Function keys			1	1	1	7	7	7	7
Custom logic (logic equations)			■	■	■	■	■	■	■
Advanced logic engine			■	■	■	■	■	■	■
Control with EcoStruxure Power Device (smartphone, tablet application)			■	■	■	■	■	■	■
Logs and Records									
Sequence of event record			■	■	■	■	■	■	■
Last fault record			■	■	■	■	■	■	■
Disturbance record	DR**RDRE**1		■	■	■	■	■	■	■
Tripping context record			■	■	■	■	■	■	■
Relay maintenance data log			■	■	■	■	■	■	■
Security data log			■	■	■	■	■	■	■
Measurement									
RMS current values	RMSA**MMXU**1		■	■	-	■	■	■	■

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[15] The x at the end of the logical node name in this column corresponds to the number of the stages of protection functions and the number of the objects for control and monitoring functions.

Table 3 - PowerLogic P5 protection relay function selection table (Continued)

	IEC 61850 Logical node[16]	ANSI code	P5U20 CT variant	P5U20 LPCT/ LPVT variant	P5V20 VT variant	P5F30 CT/VT variant LPCT/ LPVT variant	P5M30 CT/VT variant LPCT/ LPVT variant	P5T30 CT/VT variant	P5L30 CT/VT variant
RMS voltage values	RMSV**MMXU**1		-	■	■	■	■	■[17]	■
RMS active, reactive and apparent power	RMSP**MMXU**1		-	■	-	■	■	-	■
Frequency	VECA**MMXU**x		■	■	■	■	■	■	■
Fundamental frequency current values			■	■	-	■	■	■	■
Fundamental frequency voltage values	VECV**MMXU**1		-	■	■	■	■	■[17]	■
Fundamental frequency active, reactive and apparent power values			-	■	-	■	■	-	■
Power factor	VECP**MMXU**1		-	■	-	■	■	-	■
Phase differential currents			-	-	-	-	-	■	■
Phase bias currents			-	-	-	-	-	■	■
Active and reactive energy values			-	■	-	■	■	-	■
Demand values: phase currents			■	■	-	■	■	■	■
Demand values: active, reactive, apparent power and power factor			-	■	-	■	■	-	■
Maximum demand values: phase currents			■	■	-	■	■	■	■
Minimum and maximum demand values: RMS phase currents			■	■	-	■	■	■	■
Minimum and maximum demand values: active, reactive, apparent power and power factor	SRD**MMXU**x		-	■	-	■	■	-	■
Minimum and maximum demand values over the last 31 days and 12 months: active, reactive and apparent power			-	■	-	■	■	-	■
Minimum and maximum values: currents			■	■	-	■	■	■	■
Minimum and maximum values: voltages			-	■	■	■	■	■[17]	■
Minimum and maximum values: frequency			■	■	■	■	■	■	■
Minimum and maximum values: active, reactive, apparent power and power factor			-	■	-	■	■	-	■
Harmonic values of phase current and THD	HI**MHAI**1 P5THDI**MHAI**1		■	■	-	■	■	■	■
Harmonic values of voltage and THD	HU**MHAI**1 P5THDU**MHAI**1		-	■	■	■	■	■[17]	■
Voltage sags and swells			-	■	■	■	■	■[17]	■

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16. The x at the end of the logical node name in this column corresponds to the number of the stages of protection functions and the number of the objects for control and monitoring functions.
17. For 1 voltage.

Technical characteristics

Table 4 - PowerLogic P5 protection relay technical characteristics

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
Power system frequency		
Rated frequency	50 Hz or 60 Hz	
Power supply		
Operating range	DC: 24 to 250 V DC, ±20% AC: 100 to 230 V AC, ±20%	DC: 48 to 250 V DC, ±20% AC: 100 to 230 V AC, ±20% Optional: DC: 24 to 48 V DC, ±20%
AC frequency operating range	50 Hz, ±10%; 60 Hz, ±10%	
Maximum continuous withstand	300 V DC max, 276 V AC max	
Inrush current for start-up	I < 3 A , t < 5 ms, 100 V AC I < 5 A , t < 6 ms, 230 V AC I < 4 A, t < 6 ms, 48 V DC I < 8 A, t < 4 ms, 250 V DC	
Burden DC	Quiescent stage: 4 W, maximum load: 6 W at 48 V DC Quiescent stage: 4 W, maximum load: 6 W at 250 V DC	Quiescent stage: 8 W, maximum load: 11 W at 48 V DC Quiescent stage: 8 W, maximum load: 11 W at 250 V DC
Burden AC	Quiescent stage: 10 VA, maximum: 15 VA at 230 V AC Quiescent stage: 8 VA, maximum: 10 VA at 100 V AC	Quiescent stage: 20 VA, maximum: 22 VA at 230 V AC Quiescent stage: 13 VA, maximum: 15 VA at 100 V AC
RTC retention time		
RTC retention time	1 month typical[18]	
Phase CT inputs		
CT rated primary current	1 A to 20 kA	
CT rated secondary phase current	1 A or 5 A	
Linear range	60 x CT rated current	
Thermal withstand	Continuous: 20 A; 1 s: 500 A	
Input impedance	< 0.003 Ω	
Burden	< 0.02 VA at 1 A; < 0.5 VA at 5 A	
LPCT inputs[19]		
Nominal current	2.5 A to 20 kA	
LPCT rated primary current	10 A to 5 kA	
LPCT rated secondary voltage	22.5 mV	
Current factor	0.25; 0.50; 1.00; 1.25; 1.33; 2.00; 2.50; 3.20; 4.00; 5.00; 6.30; 6.66; 10; 16; 20; 25; 31.5	
Linear range	45 x Nominal current	
Standard ground fault CT inputs		
CT rated primary current	1 A to 20 kA	
CT rated ground fault current	1 A, 2 A or 5 A	
Linear range	30 x CT rated current	
Thermal withstand	Continuous: 20 A; 1 s: 500 A	

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[18] This value can be impacted by high temperature exposition during a long time.

[19] The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

Table 4 - PowerLogic P5 protection relay technical characteristics (Continued)

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
Input resistance	< 0.003 Ω (not connected)	
Burden	< 0.02 VA at 1 A; < 0.08 VA at 2 A; < 0.5 VA at 5 A	
CSH core balance inputs		
CSH rated primary current	2 A or 20 A	
CT ratio	1/470	
Linear range	42.5 x rated primary current	
Thermal input withstand	Continuous: 300 A (primary); 1 s: 18 kA (primary)	
Input impedance	< 0.02 Ω (not connected) < 4 Ω between CSH120, CSH200, CSH300 or GO 110 and the PowerLogic P5 protection relay	
Burden	< 10 mVA at 0.1 A; < 50 mVA at 5 A	
CSH30 core balance inputs		
CT rated primary current	1 A to 20 kA	
CT rated ground fault current	1 A or 5 A	
Burden	< 10 mVA at 0.1 A; < 50 mVA at 5 A	
VT inputs		
VT rated primary voltage	100 V to 500 kV	
VT rated secondary rated range	25 V to 250 V	
Voltage withstand	Continuous: 276 V AC	
Input impedance	> 100 kΩ	
Rated frequency	50 Hz and 60 Hz	
Burden	< 0.1 VA at 75 V; < 0.5 VA at 200 V	
LPVT inputs		
Nominal voltage	18.75 V to 500 kV	
LPVT rated primary voltage	75 V to 500 kV	
LPVT rated secondary voltage	3.25 V / √3	
Voltage factor	0.25 to 1.5	
Digital inputs		
Operating nominal voltage	24 V DC to 250 V DC 90 V AC to 230 V AC	
Voltage threshold	40% to 80% of nominal voltage	
Voltage withstand	300 V DC / 275 V AC	
Common mode insulation	Basic insulation 2500 V DC 1 min	
Reset threshold	20% to 60% of nominal voltage	
Voltage threshold resolution	1%	
Debounce filter[20]	Settable: 0 ms to 100 ms (Default value: 10 ms)	
Threshold accuracy	± 10% of nominal voltage or ± 2 V	
Max. current	< 2 mA	
Input current	Nominal voltage: 24 V to 110 V Inrush: 9.0 mA last 10 ms Continuous: 2.1 mA	

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[20] A setting below 10 ms can be used for testing only. It is not recommended during operation.

Table 4 - PowerLogic P5 protection relay technical characteristics (Continued)

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
	Nominal voltage: 110.1 V to 220 V Inrush: 4.5 mA last 10 ms Continuous: 1.3 mA	
Maximum activation time	DC < 1 ms AC < 20 ms	
Reset time	< 0.5 ms	
Debounce time	Adjustable (by software) from 1 ms up to 20 ms, with 1 ms steps	
Burden	< 0.5 W in DC < 0.5 VA in AC	
SFP module		
Transmitter Optical Characteristics		
Output Optical Power 62.5/125 µm NA = 0.275 Fiber		-20.0 dBm ... -14.0 dBm, typical -17.0 dBm[21]
Output Optical Power 50/125 µm NA = 0.20 Fiber		-23.5 dBm ... -14.0 dBm, typical -20.0 dBm[21]
Extinction Ratio		10 dB
Central Wavelength		1270 nm ... 1380 nm, typical 1310 nm
Spectral Width – FWHM		147 nm
Optical Rise Time (10%-90%)		0.6 ns ... 3.0 ns, typical 1.0 ns
Optical Fall Time (10%-90%)		0.6 ns ... 3.0 ns, typical 1.0 ns
Duty Cycle Distortion Contributed by the Transmitter		≤ 0.6 ns[22][23]
Data Dependent Jitter Contributed by the Transmitter		≤ 0.6 ns[23]
Random Jitter Contributed by the Transmitter		≤ 0.69 ns, Peak-to-peak[23] 0.52 ns, typical 1.0 ns, Peak-to-peak, OC-3[24]
Systematic Jitter Contributed by the Transmitter OC-3		Max 1.2 ns, typical 0.25 ns, Peak-to-peak, OC-3[25]
Transmitter Disable (High)		≤ -45 dBm
Receiver Optical and Electrical Characteristics		
Optical Input Power		-31.0 dBm ... -14.0 dBm average power[26] -31.0 ... -14.0 average power, OC-3[26][27]
Operating Wavelength		1270 nm ... 1380 nm
Duty Cycle Distortion Contributed by the Receiver		≤ 0.4 ns[28][23]
Data Dependent Jitter Contributed by the Receiver		≤ 1.0 ns[23]

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[21] These optical power values are measured over the specified operating voltage and temperature ranges. The average power value can be converted to a peak power value by adding 3 dB.

[22] Duty Cycle Distortion contributed by the transmitter is measured at the 50% threshold of the optical output signal.

[23] Characterized with PRBS27-1 pattern.

[24] Random Jitter contributed by the transmitter is specified with a 155.52 MBit/s (77.76 MHz square-wave) input signal.

[25] Systematic Jitter contributed by the transmitter is defined as the combination of Duty Cycle Distortion and Data Dependent Jitter. It's measured with 50% threshold using 2^23-1 PRBS input pattern at 155.52 MBit/s.

[26] This specification is intended to indicate the performance of the receiver section of the transceiver when Optical Input Power signal characteristics are present per the following definitions:

- Over the specified operating temperature and voltage ranges
- Bit Error Rate (BER) is better than or equal to 1 x 10^{-10}
- Transmitter is operating to simulate any cross-talk present between the transmitter and receiver sections of the transceiver.
- Fiber: 62.5/125 µm, NA = 0.275; or 50/125 µm, NA = 0.20

[27] Measured per 50/125 µm (NA = 0.2) fiber with a 155.52 MBd (77.76 MHz square-wave) input pattern.

[28] Duty Cycle Distortion contributed by the receiver is measured at the 50% threshold of the electrical output signal.

Table 4 - PowerLogic P5 protection relay technical characteristics (Continued)

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
Random Jitter Contributed by the Receiver		0.10 ns ... 2.14 ns Peak-to-peak[29] 0.10 ns ... 1.91 ns Peak-to-peak, OC-3[30]
Systematic Jitter Contributed by the Receiver OC-3		0.16 ns ... 1.2 ns Peak-to-peak, OC-3[31]
Loss of Signal – De-asserted		≤ -32 dBm average
Loss of Signal – Asserted		≥ -45 dBm average
Loss of Signal – Hysteresis		≥ 0.5 dB, typical 1.8 dB
Control relay outputs **PowerLogic P5x20 power supply DO1 - DO2 - DO3 Slot B** **PowerLogic P5x30 power supply DO2 - DO3 Slot B** **PowerLogic P5x20 5I5O module DO1 - DO2 - DO3 Slot C** **PowerLogic P5x30 5I5O module DO1 - DO2 - DO3 Slot C, D, E** **PowerLogic P5x30 arc-flash module DO1 - DO2 Slot D, E**		
According to IEC 60255-1 and IEC 61810-1		
Contact rated voltage	250 V DC or 230 V AC, 50/60 Hz	
Continuous current	8 A	
Short duration carry current	30 A for 3 s	
Making capacity	10000 operations 1000 W with L/R = 40 ms, 250 V DC 2000 VA 230 V AC Duty cycle 1 s ON, 9 s OFF	
Breaking capacity	10000 operations 50 W with L/R = 40 ms, 250 V DC 2000 VA 230 V AC Duty cycle 1 s ON, 9 s OFF	
Dielectric withstand across normally open contacts	1 kV rms AC for 1 minute	
According to IEEE C37.90 standard		
Make and carry	2000 operations make and carry 30 A DC Duty cycle 200 ms ON, 15 s OFF (current is interrupted by independent means at the end of each ON cycle)	
Dielectric withstand across normally open contacts	1.5 kV rms AC for 1 minute	
Other characteristics		
Making capacity	2000 operations 5 A DC with L/R = 50 ms Duty cycle 1 s ON, 9 s OFF	
Breaking capacity	10000 operations 0.25 A DC with L/R = 50 ms Duty cycle 1 s ON, 9 s OFF	
Short duration making capacity	20 A for 0.5 s; 30 A for 0.2 s	
Minimum making current	10 mA with 50 mW minimum	
Closing/opening time	7 ms (typical value), 3.5 ms + 3.5 ms for contact bounce, resistive load	
Contact material	Ag alloy	
Number of operations unloaded	100000	

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[29] Characterized with PRBS27-1 pattern.

[30] Random Jitter contributed by the Receiver is specified with a 155.52 MBd (77.76 MHz square-wave) input signal.

[31] Systematic Jitter contributed by the receiver is definied as the combination of Duty Cycle Distortion and Data Dependent Jitter. It's measured with 50% threshold using 2^23-1 PRBS input pattern at 155.52 MBd.

Table 4 - PowerLogic P5 protection relay technical characteristics (Continued)

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
High speed, high break control relay output PowerLogic P5x30 power supply DO1 Slot B PowerLogic P5x20 5I5O module DO4 - DO5 Slot C PowerLogic P5x30 5I5O module DO4 - DO5 Slot C, D, E		
According to IEC 60255-1 and IEC 61810-1		
Contact rated voltage	250 V DC	
Continuous current	10 A	
Short duration carry current	30 A for 3 s	
Making and breaking capacity	10000 operations 2500 W with L/R = 40 ms 250 V DC Duty cycle 1 s ON, 9 s OFF	
Dielectric withstand across normally open contacts	None – due to Solid State Devices across normally open contact	
According to IEEE C37.90 standard		
Make and carry	2000 operations make and carry 30 A DC Duty cycle 200 ms ON, 15 s OFF (current is interrupted by independent means at the end of each ON cycle)	
Dielectric withstand across normally open contacts	None – due to Solid State Devices across normally open contact	
Other characteristics		
Making capacity	2000 operations 5 A DC with L/R = 50 ms	
Breaking capacity	10000 operations 0.25 A DC with L/R = 50 ms	
Short duration making capacity	20 A for 0.5 s; 30 A for 0.2 s	
Minimum making current	10 mA with 50 mW minimum	
Closing time	1 ms (typical value) for the high-speed contact relay DO1 (PowerLogic P5x30)	
Opening time	20 ms (typical value), resistive load	
Contact material	Ag alloy	
Number of operations unloaded	100000	

Table 4 - PowerLogic P5 protection relay technical characteristics (Continued)

Characteristic	Value	
	PowerLogic P5x20	PowerLogic P5x30
Signalling relay outputs **Watchdog power supply, Slot B** **PowerLogic P5x20 6I4O/12I4O module all DOs Slot C** **PowerLogic P5x30 6I4O/12I4O module all DOs Slot C, D, E** **PowerLogic P5x30 arc-flash module DO3 Slot D, E**		
According to IEC 60255-1 and IEC 61810-1		
Contact rated voltage	250 V DC or 230 V AC, 50/60 Hz	
Continuous current	2 A	
Short duration carry current	30 A for 200 ms	
Making capacity	10000 operations 1000 W with L/R = 40 ms 250 V DC 1150 VA 230 V AC Duty cycle 1 s ON, 9 s OFF	
Breaking capacity	10000 operations 30 W with L/R = 40 ms 250 V DC 1150 VA 230 V AC Duty cycle 1 s ON, 9 s OFF	
Dielectric withstand across normally open contacts	1 kV rms AC for 1 minute	
Other characteristics		
Making and breaking capacity	10000 operations 1 A DC with L/R = 20 ms	
Minimum making current	10 mA with 50 mW minimum	
Closing/opening time	7 ms (typical value) 3.5 ms + 3.5 ms for contact bounce, resistive load	
Contact material	Ag alloy	
Number of operations unloaded	100000	
Size and weight		
Size (Width x Height x Depth)	102/180/224 mm (4.01/7.08/ 8.82 in)	152.4/180/224 mm (6/7.08/8.82 in)
Weight	≤ 2.5 kg (5.51 lb)	≤ 3.3 kg (7.28 lb)

NOTE:

Control relay outputs, both conventional hinged-armature relays and high speed, high break outputs, should be used for operating the open (trip) and close control circuits of the circuit breaker and for circuits with similar high requirements regarding make, carry and break currents.

It is worthy to note,

- the signaling of the raising edge (“make”) with high speed output is at least 5 ms faster than with conventional hinged-armature relay output;
- the signaling of the falling edge (“break”) with high speed output is at maximum 15 ms slower than with conventional hinged-armature relay output.

Such differences also need to be considered in the set up of protection scheme timing.

Signalling relay outputs should be used for conventional transfer of digital data to other secondary equipment or control systems, where requirements for make, carry and break of currents are low. Also, such outputs are often wired with common return, to allow more output signals with a given (limited) number of terminal contacts.

Environmental characteristics

⚠WARNING

UNEXPECTED OPERATION

Install PowerLogic P5 according to the environmental characteristics described in the table below.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

According to the informative annex of IEC 60255-1 standard edition 2, all the environmental tests are performed at the minimum settings which helps ensure the robustness of the PowerLogic P5 protection relay.

The digital inputs have been tested with 10 ms of debounce filter.

Table 5 - PowerLogic P5 protection relay environmental characteristics

Characteristic	Description/Value		
Power Supply			
Characteristics	**Standard**	**Level/Class**	**Value**
Voltage dips (DC)	IEC 61000-4-29 GOST 30804.4		500 ms voltage dips 0%, 250 V DC and above, Criteria A; 150 ms voltage dips 0%, 110 V DC; 100 ms voltage dips 0%, 48 V DC; 50 ms voltage dips 0%, 24 V DC
Ripple (DC)	IEC 61000-4-17		15%; 100 Hz / 120 Hz, Criteria A
Voltage dips (AC)	IEC 61000-4-11 GOST 30804.4		Criteria A, 30 cycles, voltage dips 0%, 230 V AC; 10 cycles, voltage dips 0%, 110 V AC
Product Safety			
Insulation Characteristics	**Standard**		**Value**
Insulation resistance	IEC 60255-27		> 100 MΩ at 500 V DC Using only electronic/brushless insulation tester.
Protection class	IEC 60255-27	Class I	
Creepage distances and clearances	IEC 60255-27		Pollution degree 2, Overvoltage category III
High voltages withstand (dielectric)	IEC 60255-27		2.2 kV rms AC, 1 min.: between all terminals connected together (except ETH/RS485/EXT), and the case ground; 1.0 kV rms AC or 1.5 kV DC, 1 min.: between ETH/RS485 (except EXT), and case ground; 2.2 kV rms AC, 1 min.: between all terminals of independent circuits (except EXT) 1 kV rms AC for 1 min.: across normally open control and signalling contacts; None for High Speed, High Break control relay output due to solid state devices across normally open contact.
	IEEE C37.90		1.5 kV rms AC for 1 min.: across open tripping contacts; 1.0kV rms AC for 1 min.: for signal Relay.
Impulse voltage	IEC 60255-27		5 kV, 1.2/50 µs, 0.5 J: between all terminals of independent circuits (except ETH/RS485/EXT) and case ground; 1.5 kV, 1.2/50 µs, 0.5 J: between ETH/RS485 (except EXT) and case ground; 5 kV, 1.2/50 µs, 0.5 J:

Table 5 - PowerLogic P5 protection relay environmental characteristics (Continued)

Characteristic	Description/Value		
			between all terminals of independent circuits (except ETH/ RS485/EXT); 1.5 kV, 1.2/50 µs, 0.5 J: between ETH/RS485 (except EXT) and all terminals of independent circuits; 5 kV, 1.2/50 µs, 0.5 J: between the polarities of input circuits (PSU/CT/VT/DI)
Electromagnetic Compatibility			
Characteristics	**Standard**	**Level/Class**	**Value**
Emission test			
Radiated disturbances	CISPR32 CISPR11 IEC 60255-26 GOST 30805.22	Class A	
	IACS E10		For equipment installed in the general power distribution zone.
Conducted disturbances	CISPR32 IEC 60255-26 GOST 30805.22	Class A	
	IACS E10		For equipment installed in the general power distribution zone.
Radiated disturbances immunity tests			
Radiated radio frequency fields	IEC 61000-4-3	Level 3	10 V/m, 80 MHz to 6 GHz, 80% AM (1 kHz)
	ANSI C37.90.2		20 V/m, 80 MHz to 1GHz, 80% AM (1 kHz)
	GOST R 50746		10 V/m, 80 MHz to 1 GHz AM 80% (1 kHz and pulse 200 Hz) 30 V/m, 800 MHz to 960 MHz/1.4 GHz to 6 GHz
	IACS E10	Level 3	10 V/m, 100 kHz and 1 MHz, 2 s
Electrostatic discharges	IEC 61000-4-2	Level 4	15 kV air, 8 kV contact
	ANSI C37.90.3		15 kV air, 8 kV contact
Magnetic field at power frequency	IEC 61000-4-8	Level 5	100 A/m continuous; 1000 A/m, 1 to 3 s
Pulse magnetic fields	IEC 61000-4-9	Level 5	1000 A/m
Oscillatory magnetic fields	IEC 61000-4-10	Level 5	100 A/m, 100 kHz and 1 MHz
Conducted Radio Frequency disturbances			
Conducted Radio Frequency disturbance	IEC 61000-4-6	Level 3	10 V rms common mode, 0.15 MHz to 80 MHz, 80% AM (1 kHz)
Fast transient bursts[32]	IEC 61000-4-4	Level 4	4 kV common mode, 5 kHz, 100 kHz
	ANSI C37.90.1		4 kV, 5 kHz, common mode and transversal mode
	IACS E10		2 kV power supply, 1 kV digital I/O, 5 min, 5 kHz
Slow damped oscillatory waves	IEC 61000-4-18	Level 3	2.5 kV common mode 1 kV differential mode, 100 kHz, 1 MHz
	ANSI C37.90.1		2.5 kV, 1 MHz, common mode and transversal mode
	IEC 61000-4-12 GOST 30804.4.12	Level 3	2 kV common mode; 1 kV, differential mode, 100 kHz, Source impedance: 12 Ω
Fast damped oscillatory waves	IEC 61000-4-18	Level 3	2 kV common mode, 3 MHz, 10 MHz, 30 MHz

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[32] ANSI C37.90.1 test passed with 20 ms of digital inputs debounce filter in DC mode, 50 ms of digital inputs debounce filter in AC mode.

Table 5 - PowerLogic P5 protection relay environmental characteristics (Continued)

Characteristic	Description/Value		
Conducted disturbances 0 to 150 kHz	IEC 60255-26	Zone A	150 V rms, differential mode; 300 V rms, common mode.
	GOST 51317.4.6	Level 3	Continuous: 30 V rms Short: 300 V rms 5 Hz – 150 kHz: 30 V rms
Surges[33]	IEC 61000-4-5	Level 4	4 kV, common mode; 2 kV, differential mode
Harmonics and inter-harmonics (AC)	IEC 61000-4-13	Level 3	Criteria A
Power voltage fluctuation (AC)	IEC 61000-4-14	Level x Level 3	±ΔU 15% for (Un, Un – 10 %Un, Un + 10 %Un) ±ΔU 12% (Un, Un – 10 %Un, Un + 10 %Un)
Fiber optic			
Characteristics	**Standard**	**Level/Class**	**Value**
Electrostatic Discharge (ESD) to the Electrical Pins	MIL-STD-883C		HBM 2 kV
Electrostatic Discharge (ESD) to the Duplex LC Receptacle	Variation of IEC 61000-4-2		Typically withstand at least 25 kV without damage when the LC connector receptacle is contacted by a Human Body Model probe.
Electromagnetic Interference (EMI)	CENELEC CEN55022	Class B	System margins are dependant on customer board and chassis design.
Immunity	Variation of IEC 61000-4-3		Typically shows a negligible effect from a 10 V/m field swept from 80 to 450 MHz applied to the transceiver without a chassis enclosure.
Eye Safety	EN60825-1 (+A11)	AEL Class 1	Compliant per Avago testing under single fault conditions.
RoHS Compliance			Reference to EU RoHS Directive 2015/863/EU
Environmental conditions			
Operation			
Characteristics	**Standard**	**Test Method**	**Value**
Exposure to cold	IEC 60068-2-1	Ae	-40°C (-40°F), 96 hours.
Exposure to dry heat	IEC 60068-2-2	Be	+70°C (+158°F), 96 hours; +85°C (+185°F), 16 hours
Exposure to damp heat	IEC 60068-2-78	Cab	40 °C (+104 °F), 93% ± 3% RH, 56 days, without condensation
Temperature variation	IEC 60068-2-14	Nc	-40°C to +70°C (-40°F to +158°F), 10°C/min (18°F/min) 96 hours
Damp heat cyclic test	IEC 60068-2-30	Db Variant 1	55°C (131 °F), 93% ± 3% RH and 25°C (77 °F), 97% -2% +3% RH, with condensation, 6 cycles (12 h + 12 h)
Storage			
Exposure to cold	IEC 60068-2-1	Ab	-40°C (-40°F), 96 hours
Exposure to dry heat	IEC 60068-2-2	Bb	+85°C (+185°F), 96 hours
Exposure to damp heat	IEC 60068-2-78	Cab	40 °C (+104°F), 93% ± 3% RH, 21 days
Temperature variation	IEC 60068-2-14	Nc	-40°C to +70°C (-40°F to +158°F) transfer time: 10°C/min (18°F/min), 96 hours
Corrosive atmosphere			
Salt mist	IEC 60068-2-52	Kb Severity 1	4 spraying periods of 2 hours with a storage of 7 days after each
2 Gas	IEC 60068-2-60	Ke	+25°C (+77°F), 75% RH, 21 days, method 1: 0.5 ppm SO_2; 0.1 ppm H_2S.
4 Gas	IEC 60068-2-60	Ke	+25°C (+77°F), 75% RH, 21 days, method 4: 1.85 ppm SO_2; 2.1 ppm H_2S; 0.1 ppm Cl_2; 1.56 ppm NO_2.

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[33] When protection function 50N/51N/50G/51G/67N is used and IN is measured with CSH core balance CT, it is recommended to use operation time of 50 ms at the lowest pickup value setting.

Table 5 - PowerLogic P5 protection relay environmental characteristics (Continued)

Characteristic	Description/Value		
			(according to IEC 60721-3-3 level 3C3 concentration)
Mechanical Robustness			
Characteristics	**Standard**	**Level**	**Value**
In operation (flush mounted case with REL51032: panel mounting kit with flush mounting accessory)			
Vibrations	IEC 60255-21-1	Class 2	1 Gn, 10 Hz to 150 Hz
	GOST 17516.1		0.015 mm peak, 0.5 Hz to 57.6 Hz 1 Gn, 57.6 Hz to 150 Hz
	IACS E10		2 Hz to 13.2 Hz - amplitude ±1mm 13.2 Hz to 100 Hz - acceleration ±0.75 Gn
Shocks	IEC 60255-21-2	Class 2	10 Gn, 11 ms
Earthquakes	IEC 60255-21-3	Class 2	2 Gn horizontal; 1 Gn vertical
Storage (flush mounted case with REL51032: panel mounting kit with flush mounting accessory)			
Vibration	IEC 60255-21-1	Class 2	2 Gn, 10 Hz to 150 Hz
	GOST 17516.1		2 Gn, 0.5 Hz to 150 Hz
Shocks	IEC 60255-21-2	Class 2	30 Gn, 11 ms
Bumps	IEC 60255-21-2	Class 2	20 Gn, 16 ms

Table 5 - PowerLogic P5 protection relay environmental characteristics (Continued)

Characteristic	Description/Value		
Enclosure			
Local panel	IEC 62262	IK07	Degree of protection against mechanical impacts
	IEC 60529	IP54	Front panel
		IP54	Mounted in panel with flush mounting accessory
		IP41	Mounted in panel without accessory
	NEMA	Type 12	
Rear panel	IEC 60529	IP20	Except area with ring terminal connection (analogue inputs)
Fire resistance			
Flammability	IEC 60695-11-10		class V-1 minimum
Packaging			
Resistance to shocks by free fall (with packaging)	IEC 60068-2-31		1 m (3.28 ft)
Cybersecurity			
Certification	Achilles[34]	Level I	Certification number: 453–071119
		Level II[35]	Certification number: WA653-111824
	IEC 62443-4-1		Security for industrial automation and control systems: Secure product development life-cycle requirements.
	IEC 62443-4-2 Security Level 1 (SL 1)[36] [37]		Security for industrial automation and control systems: Technical security requirements for IACS components.
Certification/declaration			
CE European Commission's directives	EN/IEC 60255-26		Electromagnetic Compatibility (EMC) directive 2014/30/EU
	EN 60255-27/IEC 60255-27		Electrical Equipment (Safety) directive 2014/35/EU
	EN IEC 63000/IEC 63000		Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (ROHS) directive 2015/863/EU
	ETSI EN 300 328 (V2.2.2)		Radio Equipment Directive 2014/53/UE
	ETSI EN 301 489-1 (V2.2.3)		
	ETSI EN 301 489-17 (V3.2.4)		
c UL us UL Standards	UL 508 ANSI/IEEE C37.90 CAN/CSA C22.2 No.14		File E354250, NRGU
EAC Eurasian Customs Union	ЕАЭС RU C-FR.HA46.B.05269/22		Hardware variants with P5xxx-xxxx-xxxx-xxxH

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[34] Zigbee communication protocol is not included in the Achilles certification.

[35] EtherNet/IP protocol is not included in Level II certification.

[36] PowerLogic P5 with Advanced Cybersecurity level enabled and Cybersecurity Admin Expert (CAE) is certified basing on the V01.401 firmware version. V02.501 firmware based certification will be completed by the end of 2024.

[37] Zigbee communication protocol available thru communication modules REL51068 and REL51044 is not yet included in this certification.

Table 5 - PowerLogic P5 protection relay environmental characteristics (Continued)

Characteristic	Description/Value	
UK CA United Kingdom regulations	BS EN 60255-26/IEC 60255-26	Electromagnetic Compatibility (EMC) regulations SI 2016 No. 1091
	BS EN 60255-27/IEC 60255-27	Electrical Equipment (Safety) regulations SI 2016 No. 1101
	BS EN IEC 63000/IEC 63000	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (ROHS) regulations SI 2012 No. 3032
	ETSI EN 300 328 (V2.2.2)	Radio Equipment Regulations SI 2017 No. 1206
	ETSI EN 301 489-1 (V2.2.3)	
	ETSI EN 301 489-17 (V3.2.4)	
FCC/IC certificate	FCC ID: 2AHP8-JYT46620 IC ID: 21245-JYT46620	Federal regulation part 15

Installation

Safety instructions

This page contains important safety instructions that must be followed precisely before attempting to install, repair, service or maintain electrical equipment. Carefully read and follow the safety instructions described below. Only qualified personnel, equipped with appropriate individual protection equipment, may work on or operate the equipment. Qualified personnel are:

- Familiar with the installation, commissioning, and operation of the equipment and of the system to which it is being connected.
- Able to safely perform switching operations in accordance with accepted safety engineering practices and are authorized to energize and de-energize equipment and to isolate, ground, and label it.
- Trained in the care and use of safety apparatus in accordance with safety engineering practices.
- Trained in emergency procedures (for example, first aid).

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Turn off all power supplying the protection relay and the equipment in which it is installed before working on it.
- Always use a properly rated voltage sensing device to confirm that power is off.
- Apply appropriate personal protective equipment and follow safe electrical work practices. See local regulation.
- Do not install this product in ATEX class 0, 1 and 2 areas.

Failure to follow these instructions will result in death or serious injury.

⚠DANGER

FIRE HAZARD

If you are authorized to withdraw the relay:

- Disconnect the power supply before removing or replacing a module or the withdrawable part of the protection relay.
- Never touch electronic parts.
- Before replacing the withdrawable part, clean all debris and contaminants from the case, the withdrawable part, and the connectors.
- Apply proper tightening torque to all wire connections.

Failure to follow these instructions will result in death or serious injury.

⚠WARNING

UNINTENDED OPERATION

Do not energize the primary circuit before this protection relay is properly configured.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Protection Class I equipment

Before energizing the equipment it must be grounded using the protective conductor terminal, if provided, or the appropriate termination of the supply plug in the case of plug connected equipment.

The protective conductor (ground) connection must not be removed since the protection against electric shock provided by the equipment would be lost.

When the protective (ground) conductor terminal (PCT) is also used to terminate cable shields, etc., it is essential that the integrity of the protective (ground) conductor is checked after the addition or removal of such functional ground connections. For M4 stud PCTs the integrity of the protective (ground) connections should be ensured by use of a locknut or similar.

The recommended minimum protective conductor (ground) wire size is 2.5 mm² (AWG 14) (3.3 mm² (AWG 12) for North America) unless otherwise stated in the technical data section of the equipment documentation, or otherwise required by local or country wiring regulations.

The protective conductor (ground) connection must be low-inductance and as short as possible.

All connections to the equipment must have a defined potential. Connections that are pre-wired, but not used, should preferably be grounded when digital inputs and output relays are isolated. When digital inputs and output relays are connected to common potential, the pre-wired but unused connections should be connected to the common potential of the grouped connections.

Transport, handling and storage

Transport

In its original packing, a protection relay can be shipped to any destination by all usual means of transport.

If installed in a cubicle, the protection relay can be transported by all usual means of transport in the customary conditions used for cubicles. Storage conditions should be taken into consideration for a long period of transport.

Handling

Protective relays, although generally of robust construction, require careful handling: handle the PowerLogic P5 protection relays in their original packing in order to help protect it against damage.

If installed in a cubicle: should the protection relay fall out of a cubicle, check its condition by visual inspection and energizing.

Storage

NOTICE

WATER DAMAGE

- Do not expose the products to sustained humidity during storage.
- Electrically energize the products within three months of unpacking.
- Where electrical equipment is being installed, allow sufficient time for acclimatization to the ambient temperature of the environment before powering on.
- Supply power to the protection relay every two years for at least one hour.

Failure to follow these instructions can reduce the product life span.

If PowerLogic P5 protection relays are not to be installed immediately upon receipt, they should be stored in a place free from dust, humidity and moisture in their original packaging. PowerLogic P5 can be stored in its original packaging, in an appropriate location for several years:

- Temperature between -25℃ and +70℃ (between -13℉ and +158℉)
- Humidity < 90%

Care should be taken on subsequent unpacking so that any dust collected on the carton does not fall inside. In locations of high humidity, the carton and packing may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

Periodic, yearly checking of the environment and the packaging condition is recommended: the relay should be powered on for one hour every two years.

Once the protection relay has been unpacked, it shall be energized as soon as possible in an appropriate environment in terms of temperature, humidity and pollution.

If protection relay is installed in a cubicle, keep the cubicle protection packing as long as possible. The protection relay, like all electronic units, should not be stored in a damp environment for more than a month. The protection relay shall be energized as quickly as possible. If this is not possible, the cubicle reheating system shall be activated.

Unpacking

Equipment receipt

NOTICE

PRODUCT TAMPERING

Our products leave our factory in closed, sealed original packaging. At delivery, if the packaging is opened or the seal is broken, Schneider Electric must be informed.

Failure to follow these instructions can result in compromised confidentiality and authenticity of the information contained in the products.

A PowerLogic P5 protection relay is shipped in a cardboard box which helps protect it against any shocks received in transport.

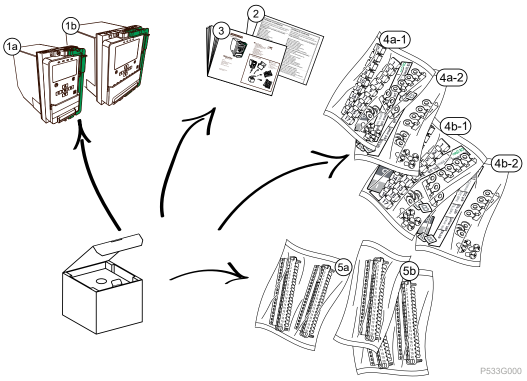
Protection relays that are supplied unmounted and not intended for immediate installation should be returned to their protective plastic bags and delivery carton.

Package contents

Each PowerLogic P5 protection relay is delivered in an independent package containing:

- A PowerLogic P5 protection relay
  - **1a**: PowerLogic P5x20
  - **1b**: PowerLogic P5x30
- A certificate of conformity ②
- An installation sheet providing main information about installation and use ③
- One plastic bag including a set of labels and stickers, and the cabling kit for connector A
  - **4a-1**: pack for PowerLogic P5x20 of CT/VT analogue input type
  - **4a-2**: pack for PowerLogic P5U20 of LPCT/LPVT analogue input type
  - **4b-1**: pack for PowerLogic P5x30 of CT/VT analogue input type
  - **4b-2**: pack for PowerLogic P5x30 of LPCT/LPVT analogue input type
- One plastic bag including one to four rear connectors
  - **5a**: pack for PowerLogic P5x20
  - **5b**: pack for PowerLogic P5x30

Figure 1 - PowerLogic P5 package contents

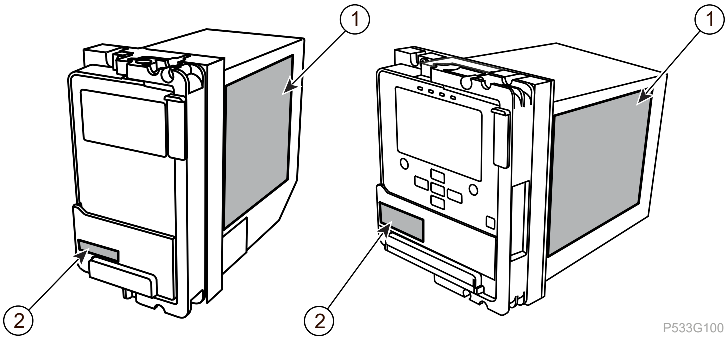


Accessories, such as the mounting accessory with panel mounting kit, communication modules and cables can be delivered in a separate package.

Equipment identification

Different kinds of labels and stickers are used on the PowerLogic P5 protection relay to identify its model type and its different components.

Figure 2 - Label examples on the PowerLogic P5 protection relay



① Rear panel connection instructions label

② Reference label

Reference label

The reference label contains the commercial reference, the serial number, the power supply voltage of the relay and a QR code. The QR code can be used to access the specific product website through **mySchneider** App (available in App Store and Google Store) to get basic product documents and product life cycle documents like Certificate of Conformity and Test.

Figure 3 - Reference label on PowerLogic P5x20

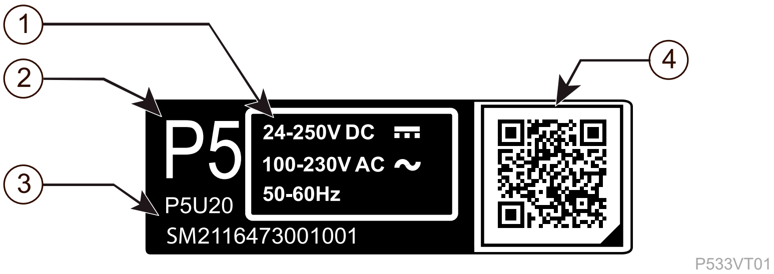
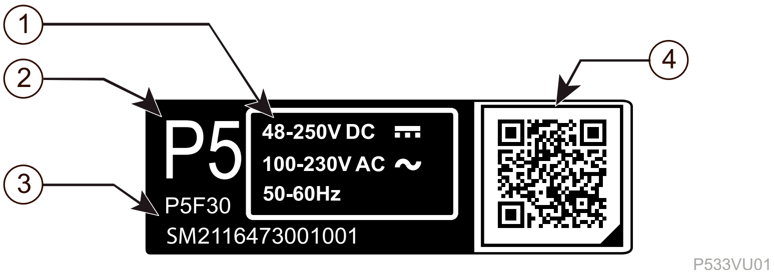


Figure 4 - Reference label on PowerLogic P5x30



① Power supply voltage (Optional 24–48 V DC for PowerLogic P5x30)

② Reference

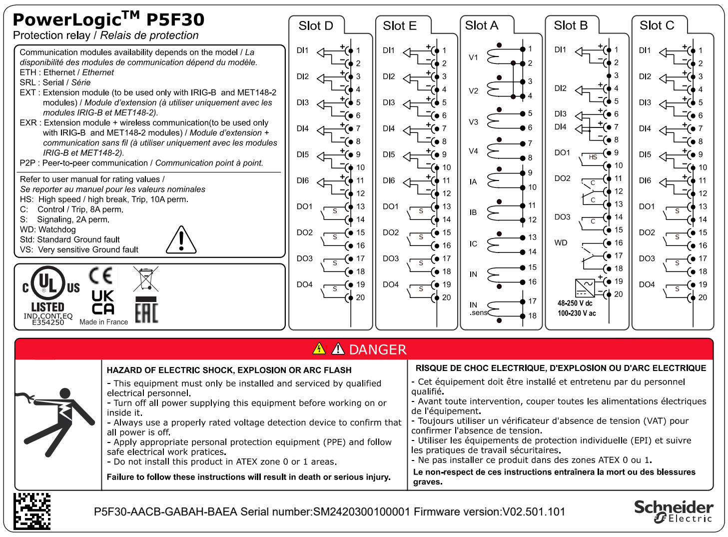
③ Serial number

④ Access to product website

Rear panel connection instructions label

The rear panel connection label contains the designation of the rear panel terminals together with instructions for installing and wiring the protection relay.

Figure 5 - Example rear panel connection instructions label



PowerLogic™ P5F30
Protection relay / *Relais de protection*

Communication modules availability depends on the model / *La disponibilité des modules de communication dépend du modèle.*
ETH : Ethernet / *Ethernet*
SRL : Serial / *Série*
EXT : Extension module (to be used only with IRIG-B and MET148-2 modules) / *Module d'extension (à utiliser uniquement avec les modules IRIG-B et MET148-2).*
EXR : Extension module + wireless communication(to be used only with IRIG-B and MET148-2 modules) / *Module d'extension + communication sans fil (à utiliser uniquement avec les modules IRIG-B et MET148-2).*
P2P : Peer-to-peer communication / *Communication point à point.*

Refer to user manual for rating values /
Se reporter au manuel pour les valeurs nominales
HS: High speed / high break, Trip, 10A perm.
C: Control / Trip, 8A perm.
S: Signaling, 2A perm.
WD: Watchdog
Std: Standard Ground fault
VS: Very sensitive Ground fault

DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH
- This equipment must only be installed and serviced by qualified electrical personnel.
- Turn off all power supplying this equipment before working on or inside it.
- Always use a properly rated voltage detection device to confirm that all power is off.
- Apply appropriate personal protection equipment (PPE) and follow safe electrical work pratices.
- Do not install this product in ATEX zone 0 or 1 areas.

Failure to follow these instructions will result in death or serious injury.

RISQUE DE CHOC ELECTRIQUE, D'EXPLOSION OU D'ARC ELECTRIQUE
- Cet équipement doit être installé et entretenu par du personnel qualifié.
- Avant toute intervention, couper toutes les alimentations électriques de l'équipement.
- Toujours utiliser un vérificateur d'absence de tension (VAT) pour confirmer l'absence de tension.
- Utiliser les équipements de protection individuelle (EPI) et suivre les pratiques de travail sécuritaires.
- Ne pas installer ce produit dans des zones ATEX 0 ou 1.

Le non-respect de ces instructions entraînera la mort ou des blessures graves.

P5F30-AACB-GABAH-BAEA Serial number:SM2420300100001 Firmware version:V02.501.101

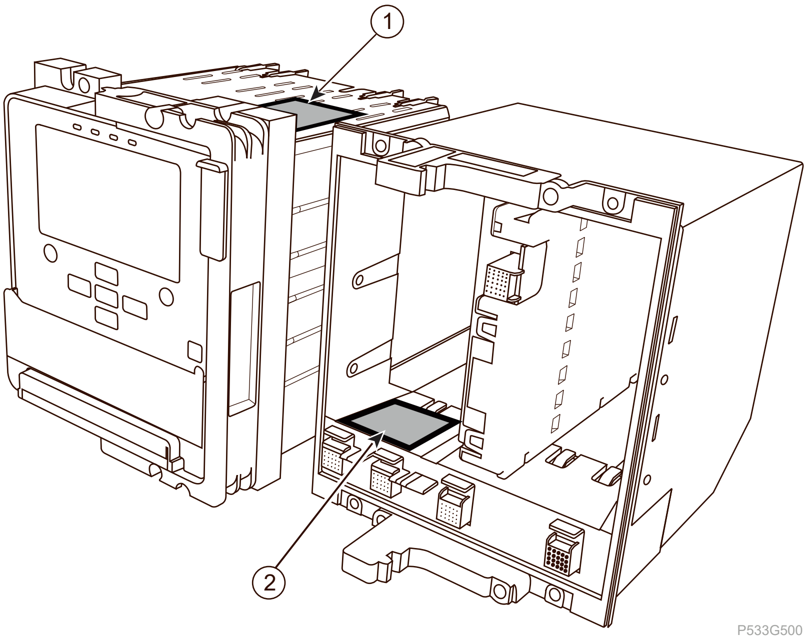
As built configuration

The information about model number, serial number and firmware number can be found on the bottom side of rear panel connection instructions label, as shown above. It informs on how the product was built and left the factory. If there are further manipulations on the product (for example, firmware upgrade), it is recommended to update the information on the label.

Model number label

Two model number labels containing the first digits of the device model number are available on both the withdrawable internal part ① and the static case ②. They are placed on the device for the purpose of correctly coupling the two parts during maintenance. If the withdrawable internal part of the protection relay is removed from the case, check that their model numbers are identical before assembling.

Figure 6 - Model number labels (PowerLogic P5x30 shown as an example)



① Model number label on the withdrawable internal part

② Model number on the static case

Rear panel identification stickers

Two kinds of identification stickers are available for the analogue input connector, the digital I/O connectors and the communication ports on the rear panel:

- Stickers on analogue input and digital I/O connectors ①:

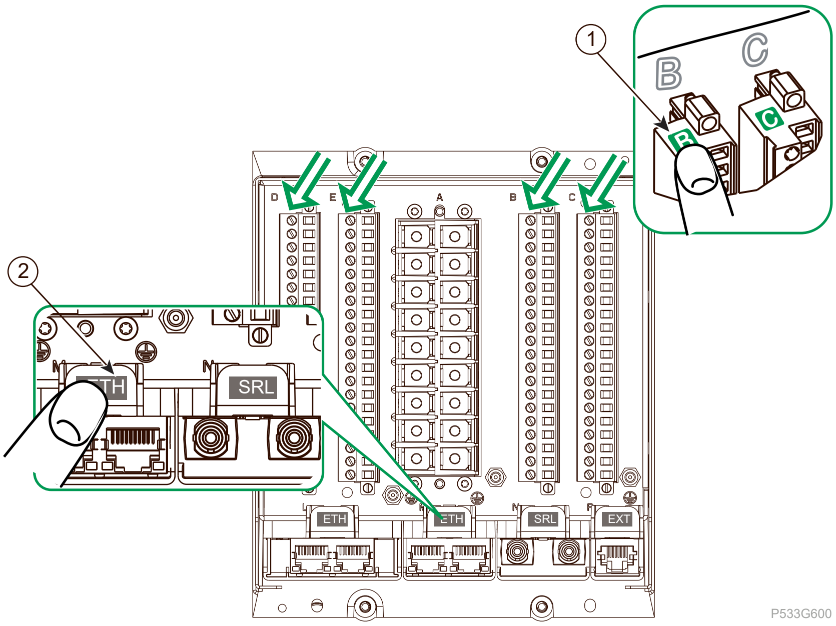
  Each analogue or digital connector on the rear panel is identified using a sticker. Stickers for additional, optional connectors are found in the product package.

- Communication port stickers ②:

  The rear ports of the communication modules are marked as follows:

ETH	Dual port copper (RJ45) or fiberoptic (multi-mode glass fiber) Ethernet ports
SRL	RS485 or fiber optic serial communication ports
EXT	Extension port for external modules (IRIG-B time synchronization module, RTD inputs module, CLIO module) with backup memory
EXR	Extension port for external modules (IRIG-B time synchronization module, RTD inputs module, CLIO module) with backup memory and Zigbee receiver.
P2P	Peer to peer port with InterRelay module(FO)

Figure 7 - Rear panel identification stickers



Dimensions

Product dimensions

Dimensions of the PowerLogic P5 protection relays are shown below:

Figure 8 - PowerLogic P5x20 dimensions

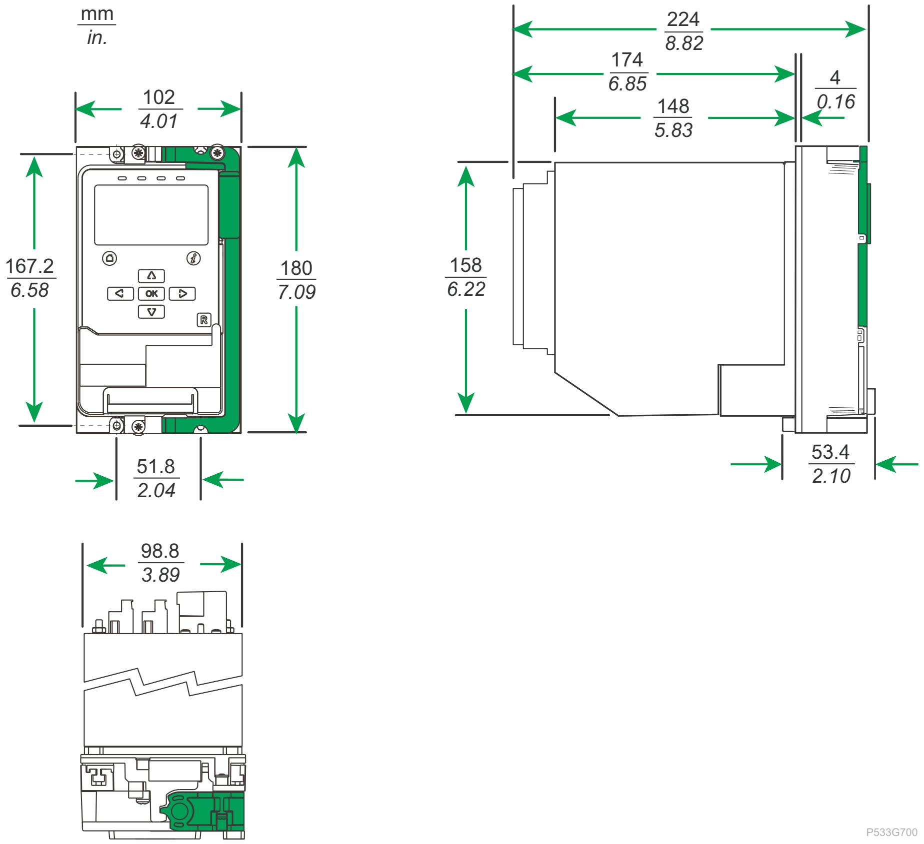


Figure 9 - PowerLogic P5x30 dimensions

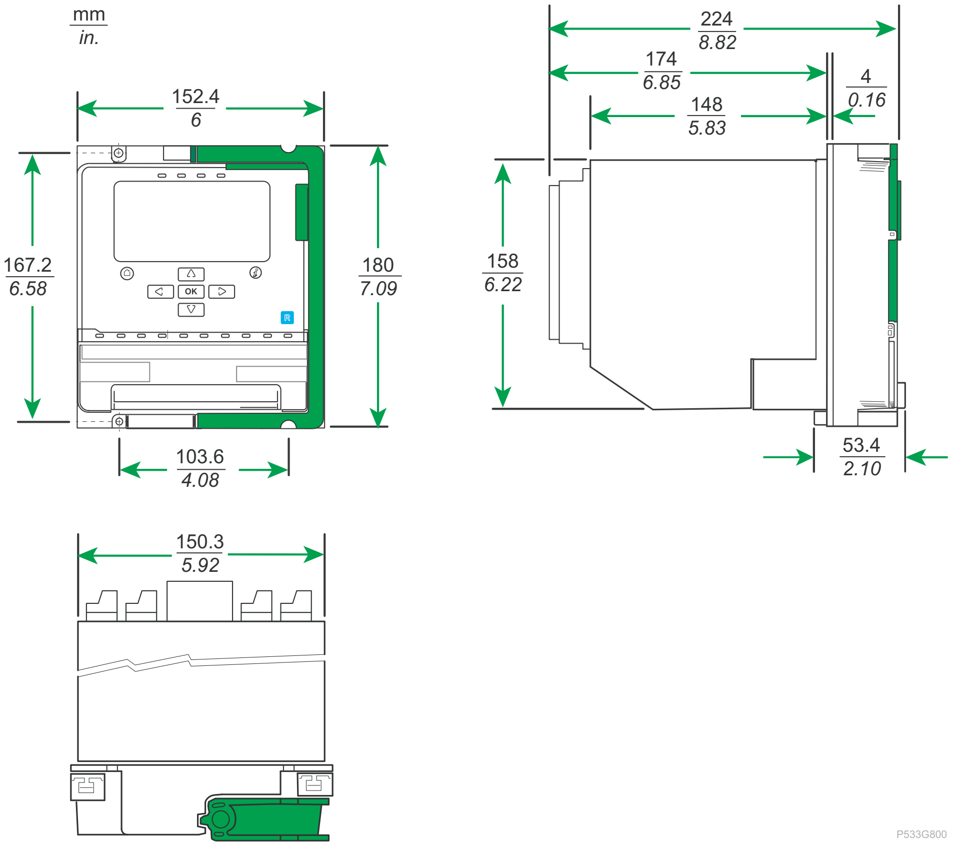
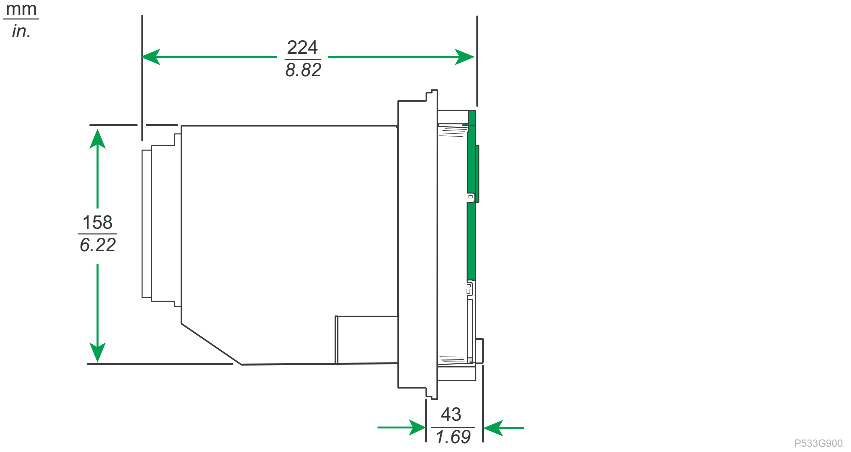


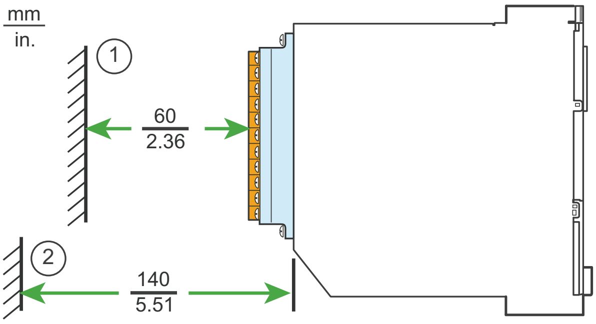
Figure 10 - PowerLogic P5 flush mounting dimension



Rear clearances

For easy access to the rear panel, the rear clearances illustrated below are recommended:

Figure 11 - Rear clearances illustrated



P533GA00

① This clearance must be available permanently for PowerLogic P5 protection relay wiring and assembly.

② This clearance should be transiently available during maintenance operations when communication modules are replaced.

Operating environment

Operating temperature and humidity

NOTICE

POTENTIAL DAMAGE FROM ENVIRONMENTAL CONDITIONS

- The PowerLogic P5 protection relay must be installed in an environment within the specified operation temperature and humidity.
- Avoid condensation on the PCB boards inside the protection relay.

Failure to follow these instructions can result in equipment damage.

The PowerLogic P5 protection relay is intended for indoor installation and use only. If it is required for use in an outdoor environment, it must be mounted in a specific cabinet that will enable it to meet the requirements of IEC 60529 with the classification of protection degree IP54 (dust and splashing water protected).

The temperature/relative humidity factors must be compatible with the environmental withstand characteristics of the PowerLogic P5 protection relay:

- Recommended operating range of temperature: -10°C to +55°C (+14°F to +131°F).
- Maximum operating temperature: -40°C to +70°C (-40°F to +158°F).
- Average humidity: <75% RH over the year.
- Temporary permissible humidity: <93% RH (less than 80 hours per year)
- No condensation.

If the operating conditions are outside the normal range, special arrangements should be made before commissioning, such as air conditioning of the premises.

Operation in a polluted atmosphere

A contaminated industrial atmosphere (such as the presence of chlorine, hydrofluoric acid, sulphur, solvents, etc.) can cause corrosion of the electronic components and terminals, in which case environmental control arrangements should be made (such as pressurized premises with filtered air, etc.) before commissioning.

To improve robustness of PowerLogic P5 protection relays against such environment, all the electronic boards of PowerLogic P5 protection relays have a conformal coating, type AVR80 BA.

Mounting

General mounting operations

Mounting the protection relay in panels or on rack frame

The PowerLogic P5 protection relays are available for flush mounting or rack mounting.

The PowerLogic P5 protection relay is fixed by four M4 x 20 mm (0.787 in.) self-tapping screws with washers (with diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) at lower and upper parts.

Figure 12 - Mounting the PowerLogic P5x20 protection relay

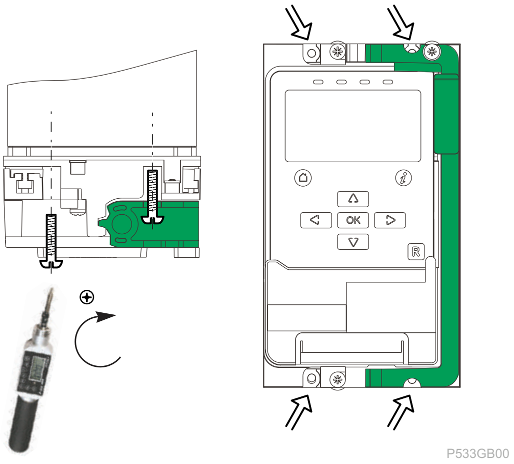
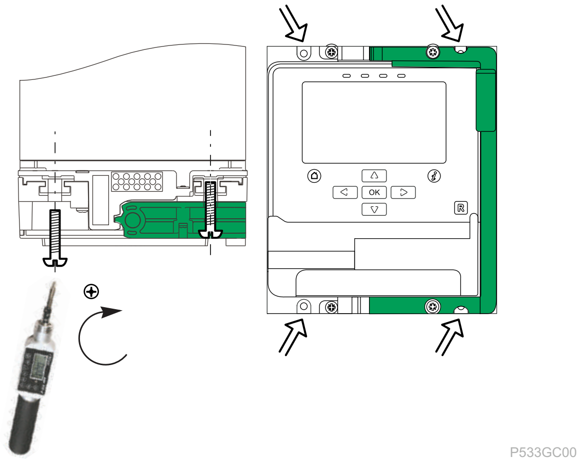


Figure 13 - Mounting the PowerLogic P5x30 protection relay



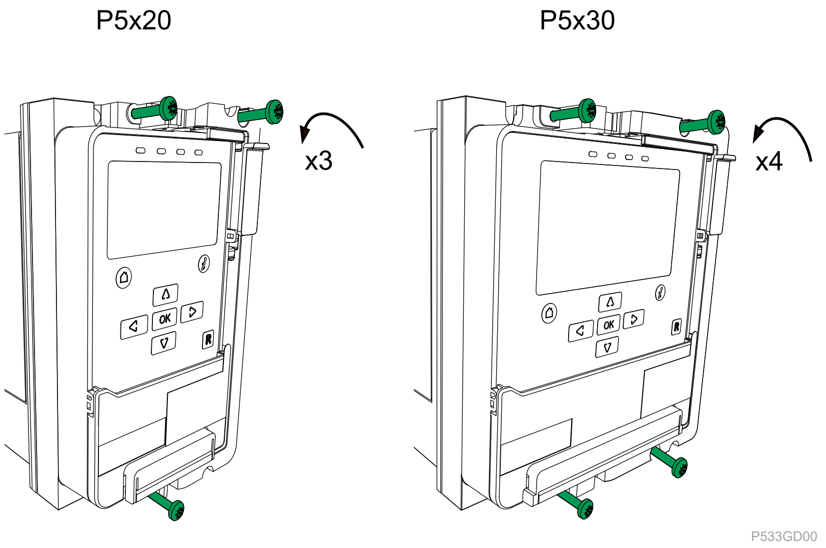
Screw	M4 x 20 mm (0.787 in.) self-tapping screws with washers (with diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) x 4
Tightening torque	1N·m (8.85 lb-in)
Tool	Digital torque screwdriver

Unlocking the withdrawable part from its outer case

In order to maintain the withdrawable part (internal part) with the fixed part (outer part) of the relay during transportation, locking screws are used on the front face to fix the two relay parts together.

The front face locking screws can be unscrewed as shown in the figure below.

Figure 14 - Unscrewing the front face locking screws

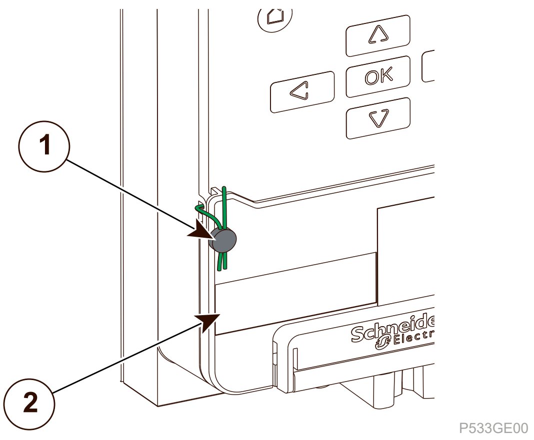


Screw	3 screws mounted on PowerLogic P5x20; 4 screws mounted on PowerLogic P5x30
Tightening torque for installing back the screws	1N·m (8.85 lb-in)
Tool	Digital torque screwdriver

Lock the shutter and handle

In order to help prevent unauthorized access to the command keys and USB ports on the local panel of the PowerLogic P5 protection relay, the shutter for covering the lower section of the protection relay needs to be locked with a wired lead seal.

Figure 15 - Lock the shutter

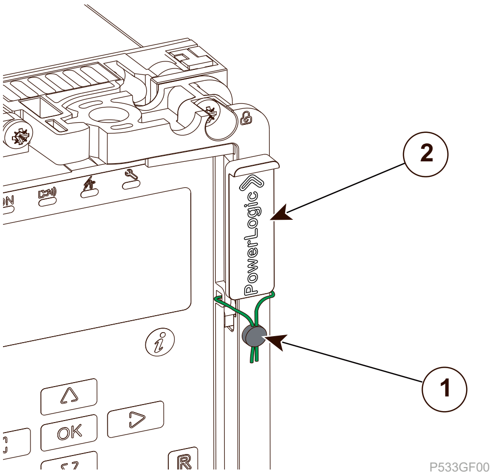


① Wired lead seal

② Protective panel

The handle on the front face of the protection relay is used to separate the withdrawable part from the fixed outer case. In order to help prevent unauthorized dismantling fix the lock tab on the handle with a wired lead seal to restrict the rotation of the handle.

Figure 16 - Lock the handle



① Wired lead seal

② Lock tab on the handle

Flush mounting with accessory

⚠CAUTION

CUTS AND PHYSICAL IMPACT

- Wear gloves and safety shoes.
- Trim the edges of the cut-out plates to remove any jagged edges.
- Carry the assembled relay with withdrawable part locked.
- When cases are mounted on a rack (with withdrawable part not inserted), stay far enough from the protruding parts of the cases.

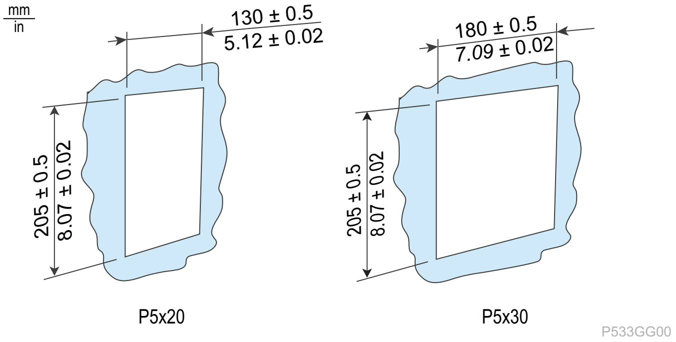
Failure to follow these instructions can result in injury or equipment damage.

The PowerLogic P5 protection relay can be mounted onto panels with the provided accessory. It is recommended to use the flush mounting with accessory for PowerLogic P5 protection relay.

Mounting Procedure

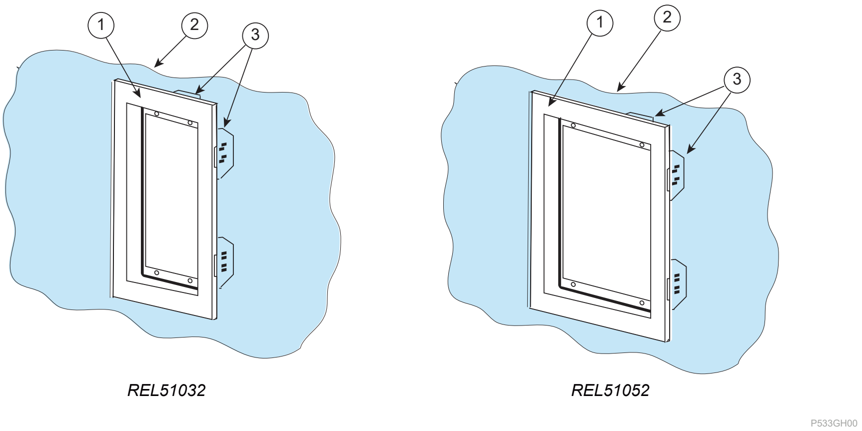
1. Prepare cut-out on the panel according to the following dimensions.

Figure 17 - Panel cut-out for PowerLogic P5x20/PowerLogic P5x30



2. Insert the flush mounting accessory ① in the panel ② and check that the rear mounting supports ③ are accessible for panel mounting kits to be inserted.

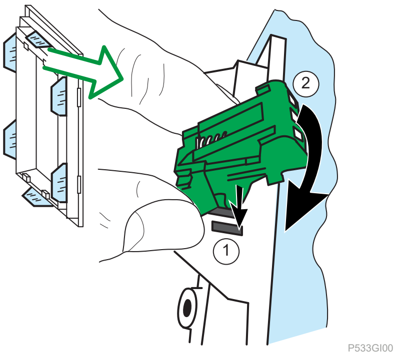
Figure 18 - Flush mounting accessories



Accessory Ref. No.	REL51032 (for use with PowerLogic P5x20)
Accessory Ref. No.	REL51052 (for use with PowerLogic P5x30)

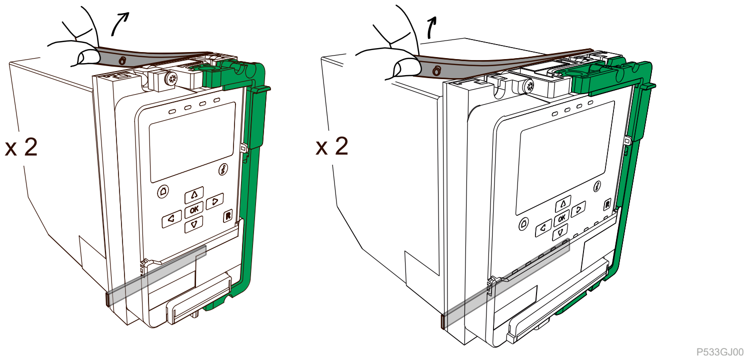
3. Insert the panel mounting kits in the mounting support holes ① and then push down the front parts (flush panel side) ② to lock the flush mounting accessory on the panel.

Figure 19 - Insert the mounting kits



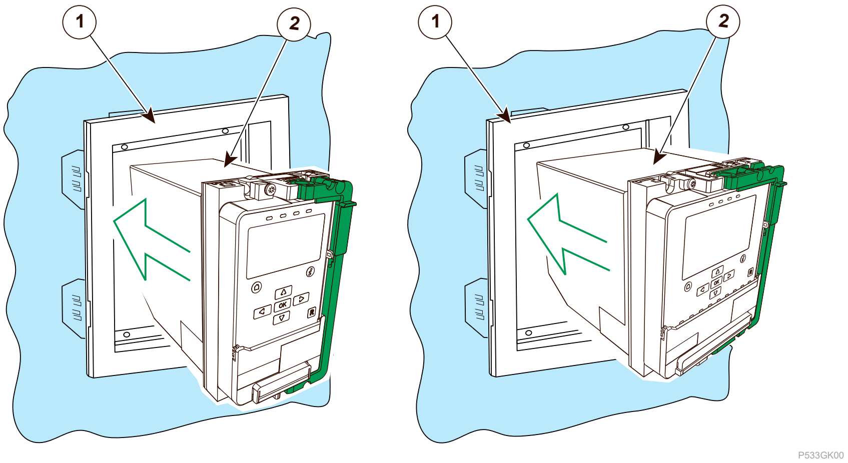
4. Remove the top and bottom seal straps from the rear mounting surface of the protection relay.

Figure 20 - Remove the seal straps from the relay



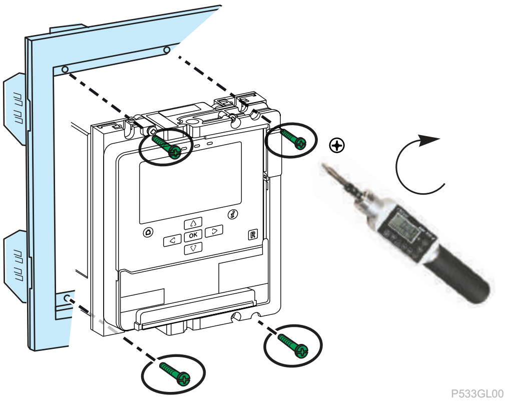
5. Insert the protection relay ② into the mounting accessory ① and hold it in the mounting position.

Figure 21 - Insert the protection relay



6. Fix the protection relay on the accessory with the screws provided in the flush mounting accessory.

Figure 22 - Fix the protection relay (PowerLogic P5x30 shown as an example)



Screw	4 screws provided with the flush mounting accessory
Tightening torque	1 N·m (8.85 lb-in)
Tool	Digital torque screwdriver

Flush mounting without accessory

⚠CAUTION

CUTS AND PHYSICAL IMPACT

- Wear gloves and safety shoes.
- Trim the edges of the cut-out plates to remove any jagged edges.
- Carry the assembled relay with withdrawable part locked.
- When cases are mounted on a rack (with withdrawable part not inserted), stay far enough from the protruding parts of the cases.

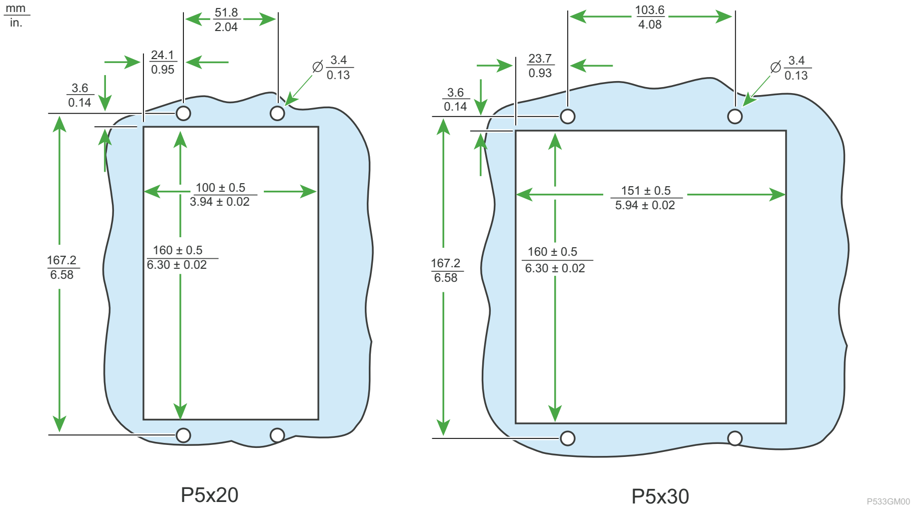
Failure to follow these instructions can result in injury or equipment damage.

The PowerLogic P5 protection relay can be mounted directly onto panels without any accessory.

Mounting Procedure

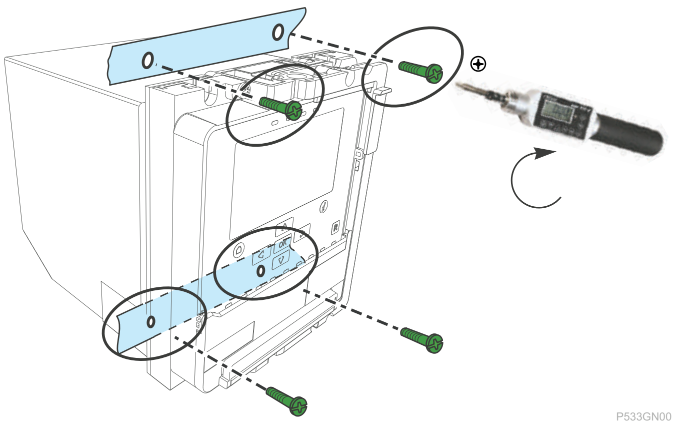
1. Prepare the cut-out in the panel for flush mounting according to the following dimensions.
   The thickness of the panel plate should be a minimum of 3 mm (0.12 in.).

Figure 23 - Panel cut out for PowerLogic P5x20/PowerLogic P5x30



2. Fasten the PowerLogic P5 protection relay in its position with four M4 x 20 mm (0.787 in.) self-tapping screws with washers (diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) at lower and upper parts.

Figure 24 - Fastening the PowerLogic P5 onto panel (PowerLogic P5x30 shown as an example)



Screw	M4 x 20 mm (0.787 in.) self-tapping screws with washers (with diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) x 4
Tightening torque	1 N·m (8.85 lb-in)
Tool	Digital torque screwdriver

Rack mounting

⚠CAUTION

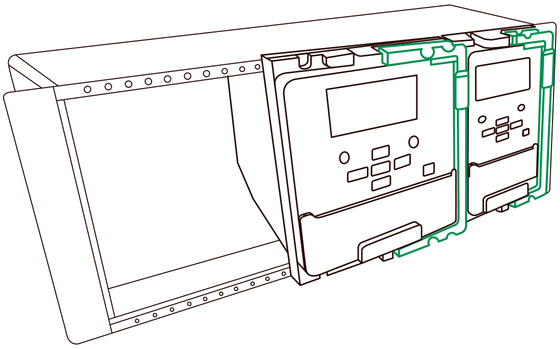
FALLING DEVICES

- Wear gloves and safety shoes.
- Carry the assembled relay with withdrawable part locked.
- When cases are mounted on a rack (with withdrawable part not inserted), stay far enough from the protruding parts of the cases.

Failure to follow these instructions can result in injury or equipment damage.

PowerLogic P5 protection relays may be rack mounted using single rack mounting frames (ref: REL51021), as illustrated in the figure below.

Figure 25 - Rack mounted protection relays



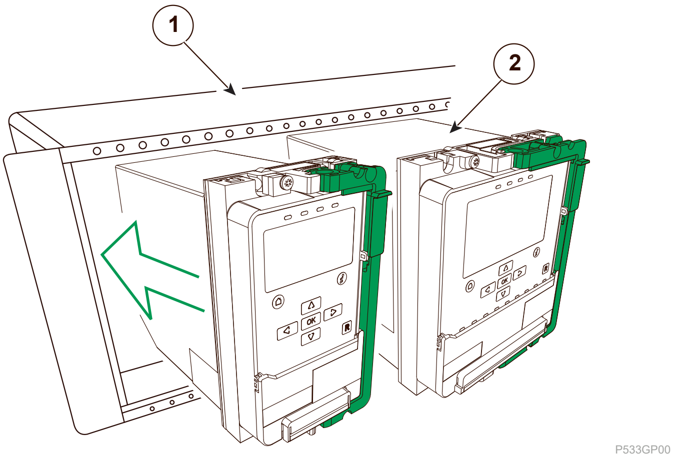
The two horizontal rails of the rack frame are drilled of holes at approximately 26 mm (10 in.) intervals. The PowerLogic P5 protection relays are fixed by their mounting flanges using M4 x 20 mm (0.787 in.) self-tapping screws with washers (diameter 4 x 8 mm (0.157 x 0.315 in.) maximum).

Relays can be mechanically grouped into single tier or multi-tier arrangements by means of the rack frame. This enables schemes using products from the PowerLogic P5 product ranges to be pre-wired together prior to mounting (rack mounting with M4 self-tapping screws, washers and nut).

Mounting Procedure

1. Insert the PowerLogic P5 protection relay ② into the rack frame ①.

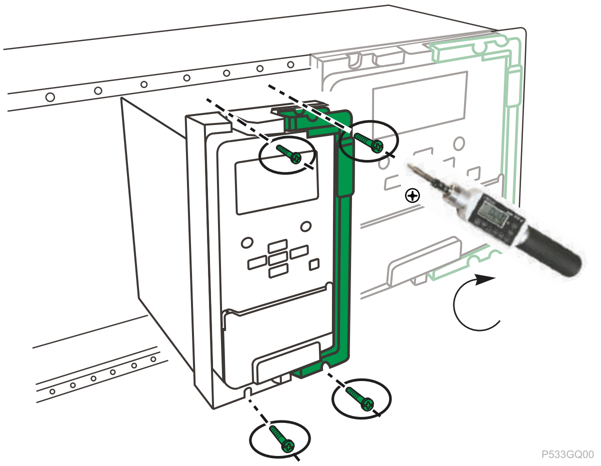
Figure 26 - Insert the protection relay into the rack frame



Rack frame Ref. No.	REL51021

2. Fasten the protection relay onto the rack frame with four M4 x 20 mm (0.787 in.) self-tapping screws and washers (diameter 4 x 8 mm (0.157 x 0.315 in.) maximum).

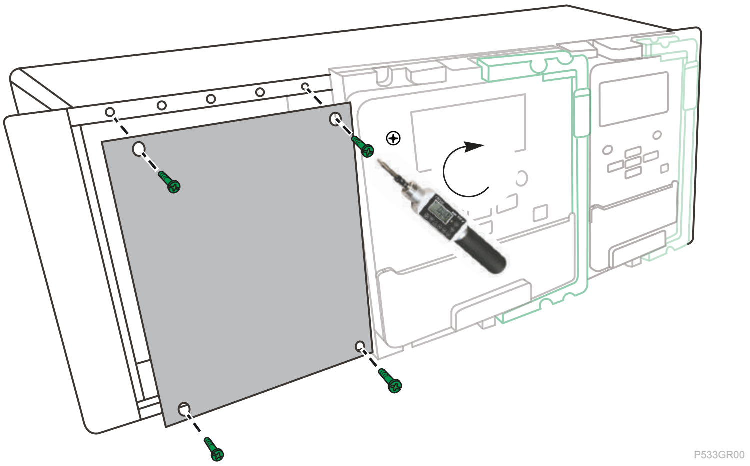
Figure 27 - Fasten the protection relay onto the rack frame (PowerLogic P5x20 shown as an example)



Screw	M4 x 20 mm (0.787 in.) self-tapping screws with washers (with diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) x 4
Tightening torque	1 N·m (8.85 lb-in)
Tool	Digital torque screwdriver

3. Cover up the open section of the rack frame with blank plates if there is still space left for future installation of protection relays or ancillary components.

Figure 28 - Install the blank plate



Blank plate Ref. No.	REL51018: 30TE 206.8 mm x 177 mm (6 in. x 6.97 in.) REL51019: 20TE 103.2 mm x 177 mm (4 in. x 6.97 in.); REL51020: 10TE 50.2 mm x 177 mm (2 in. x 6.97 in.);
Screws	M4 x 20 mm (0.787 in.) self-tapping screws with washers (with diameter 4 x 8 mm (0.157 x 0.315 in.) maximum) x 4
Tightening torque	1.0 N·m (8.85 lb-in)
Tool	Digital torque screwdriver
Subsequent operation	Mount the rack frame on the rack using the mounting flanges on both sides of the frame.

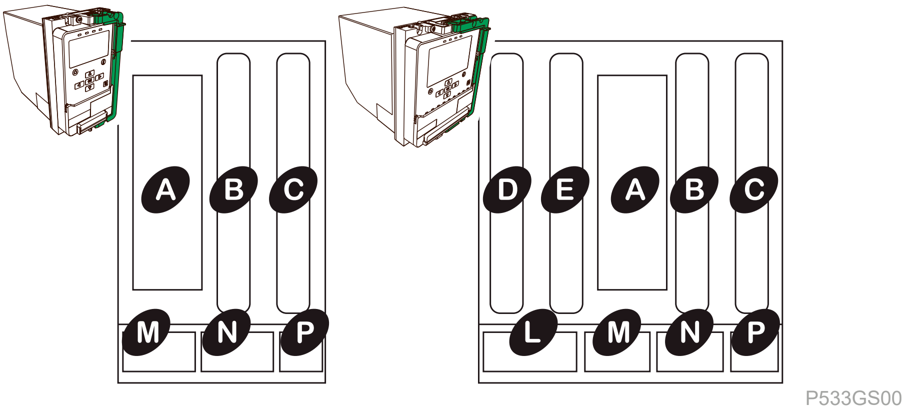
Rear panel connectors and application diagrams

PowerLogic P5 rear panel

Rear panel layout

The PowerLogic P5 protection and control relay rear panels contain the following modules installed in slots and identified by letters:

Figure 29 - PowerLogic P5 protection and control relay rear panels



PowerLogic P5x20	PowerLogic P5x30	Slot: Module
✓	✓	A: Analogue input module
✓	✓	B: Power supply
✓	✓	C: Empty or additional digital input/output module
	✓	D: Empty or additional digital input/output module
	✓	E: Empty or additional digital input/output module
	✓	L: Empty or ETH, Ethernet module (TP)
	✓	L: Empty or P2P, InterRelay module(FO) **NOTE:** This board is fitted by default with P5L30 (not an option).
✓	✓	M: Empty or ETH, Ethernet module (TP or FO)
✓	✓	N: Empty or SRL, Serial communication module (RS485 or FO)
✓	✓	M and N: Empty or Combined Ethernet HSR/PRP 2TP + RS485 module or Combined Ethernet HSR/PRP FO + RS485 module
✓	✓	P: Empty or EXT, Extension module or P: EXR, Extension Zigbee module

NOTE: For the slot occupation rules of PowerLogic P5x30 slot C, D and E, refer to Slot occupation rules, page 704.

PowerLogic P5U20 rear panel (CT version)

Figure 30 - PowerLogic P5U20 rear panel (CT version)

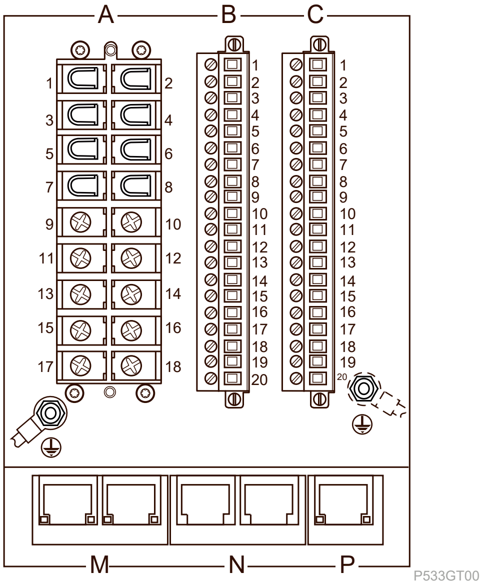
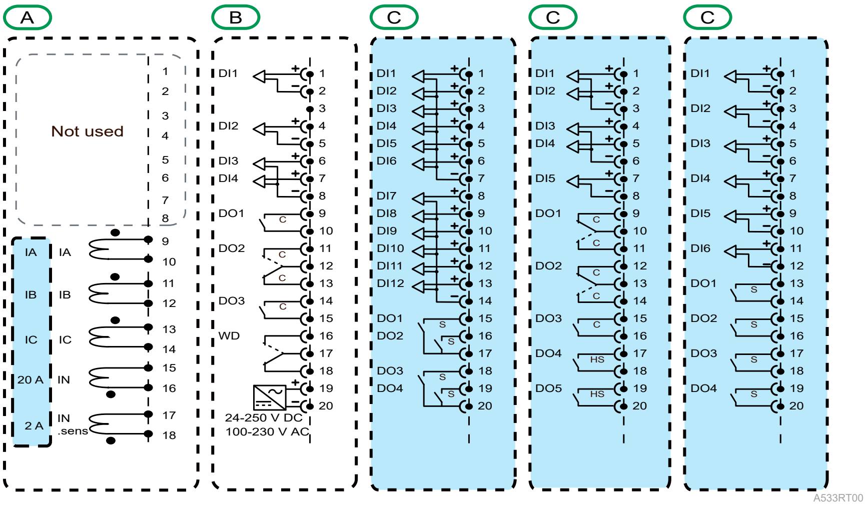


Figure 31 - PowerLogic P5U20 (CT version) rear terminal designations



▭	Optional		
IX	Phase current	IN	Standard neutral current input (IN.meas)
DIx	Digital input	IN.sens	Sensitive neutral current input
DOx	Digital output	WD	Watchdog contact
- HS	High speed / high break, Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

PowerLogic P5U20 rear panel (LPCT/LPVT version)

Figure 32 - PowerLogic P5U20 rear panel (LPCT/LPVT version)

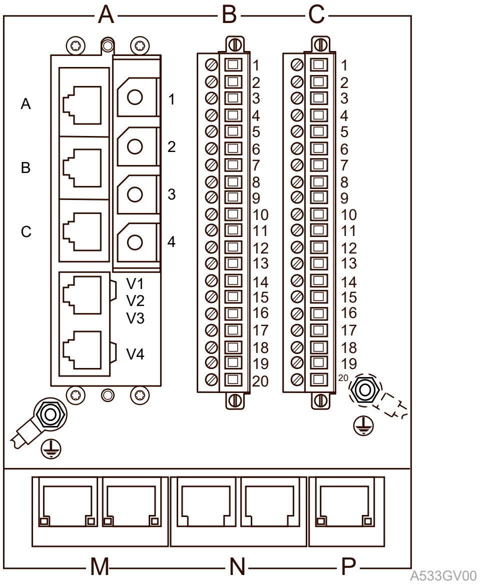
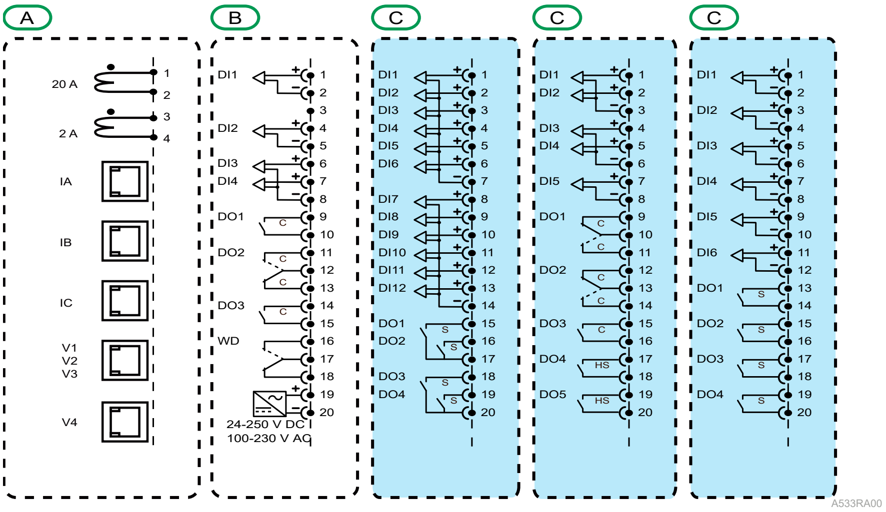


Figure 33 - PowerLogic P5U20 (LPCT/LPVT version) rear terminal designations



▭	Optional		
IX	Phase current	VX	phase to neutral voltage
DIx	Digital input	WD	Watchdog contact
DOx	Digital output		
- HS	High Speed / high break, Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

NOTE: The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

PowerLogic P5V20 rear panel

Figure 34 - PowerLogic P5V20 rear panel

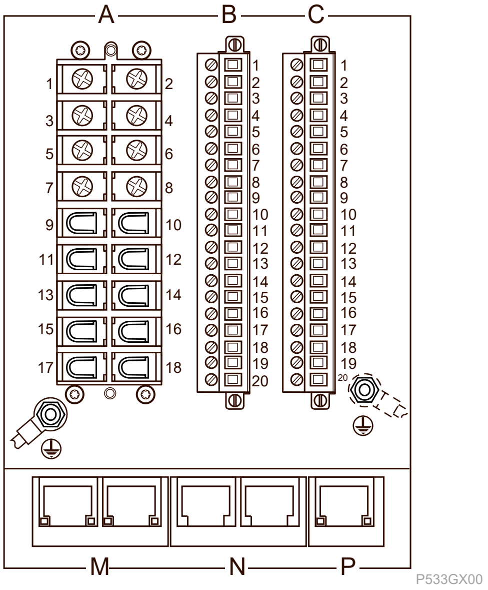
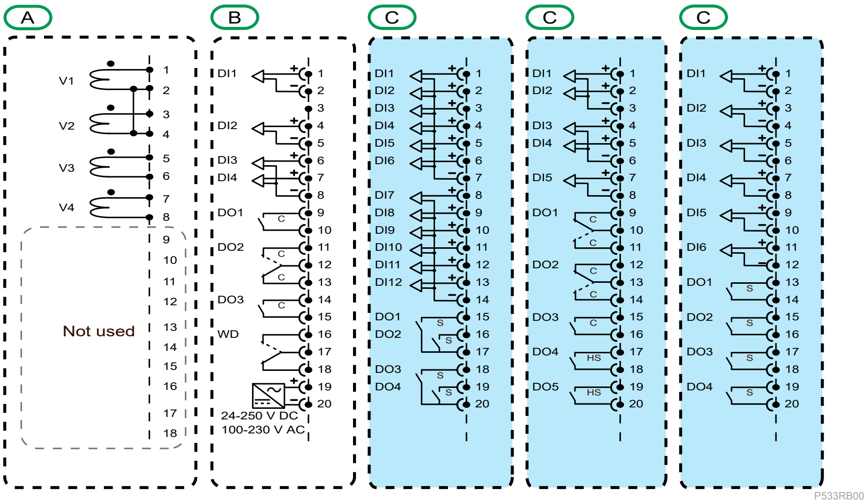


Figure 35 - PowerLogic P5V20 rear terminal designations



🟦	Optional		
VX	Phase to neutral voltage	WD	Watchdog contact
DOx	Digital output	DIx	Digital input
- HS	High Speed / high break,Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

PowerLogic P5F30/P5M30/P5L30 rear panel (CT/VT version)

Figure 36 - PowerLogic P5F30/P5M30/P5L30 rear panel (CT/VT version)

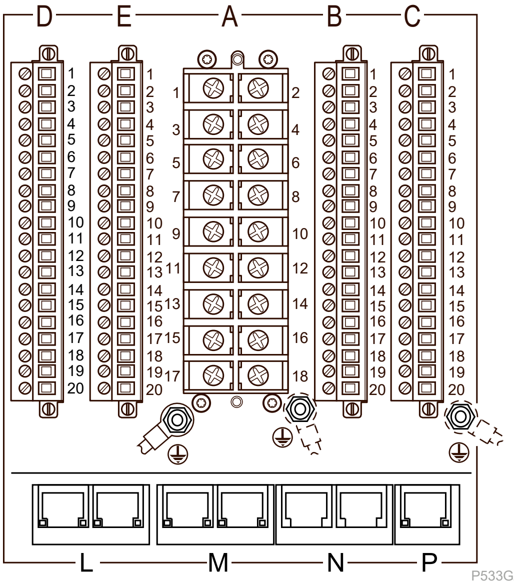
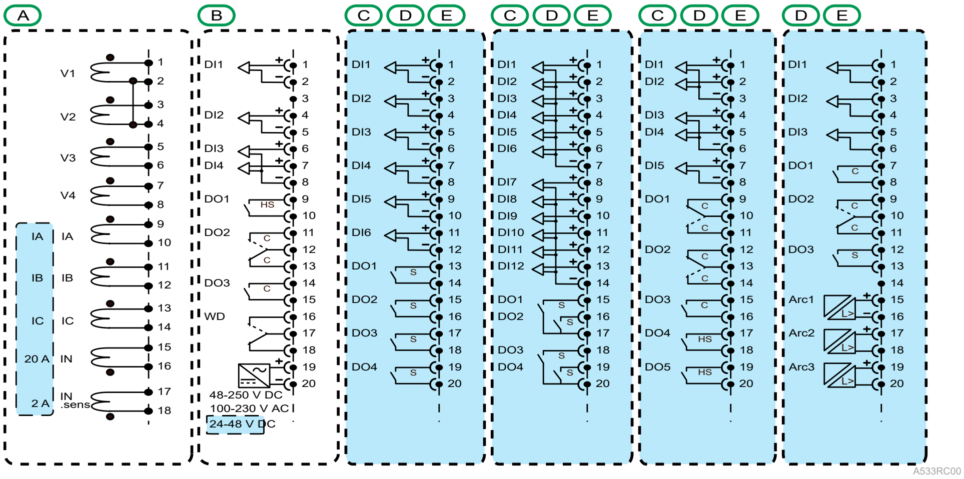


Figure 37 - PowerLogic P5F30/P5M30/P5L30 (CT/VT version) rear terminal designations



🟦	Optional		
IX	Phase current	IN.sens	Sensitive neutral current input
VX	Phase to neutral voltage	IN	Standard neutral current input (IN. meas)
DIx	Digital input	Arc	Arc sensor
DOx	Digital output	WD	Watchdog contact
- HS	High Speed / high break, Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

PowerLogic P5F30/P5M30 rear panel (LPCT/LPVT version)

Figure 38 - PowerLogic P5F30/P5M30 rear panel (LPCT/LPVT version)

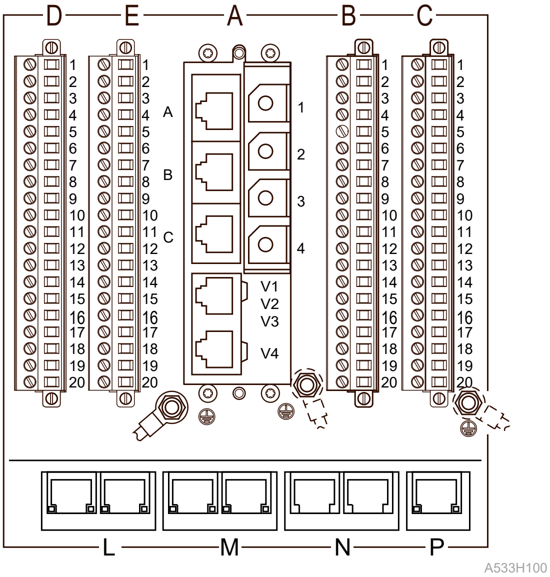
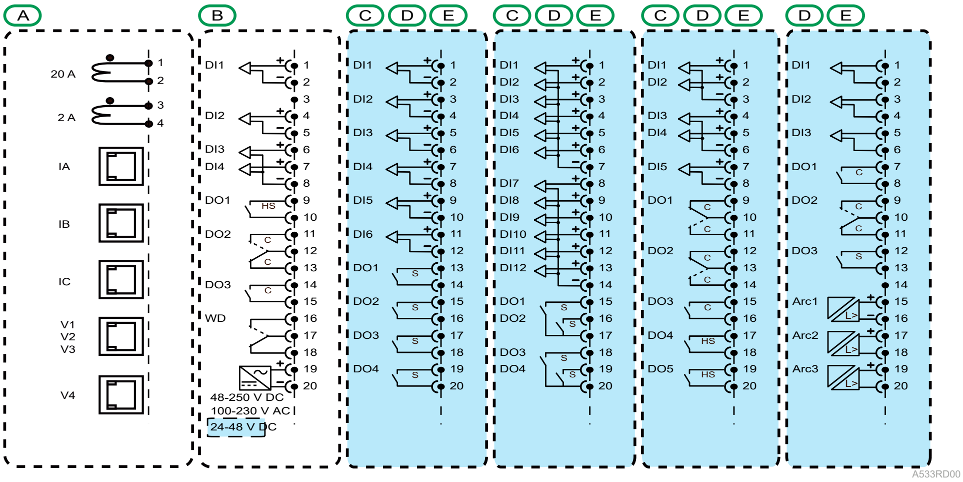


Figure 39 - PowerLogic P5F30/P5M30 (LPCT/LPVT version) rear terminal designations



▭	Optional		
IX	Phase current	VX	Phase to neutral voltage
DIx	Digital input	Arc	Arc sensor
DOx	Digital output	WD	Watchdog contact
- HS	High Speed / high break, Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

NOTE: The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

PowerLogic P5T30 rear panel (CT/VT version)

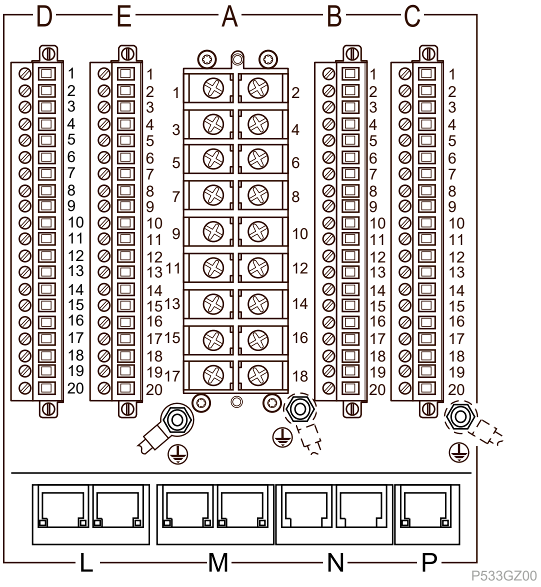


Figure 40 - PowerLogic P5T30 rear panel (CT/VT version)

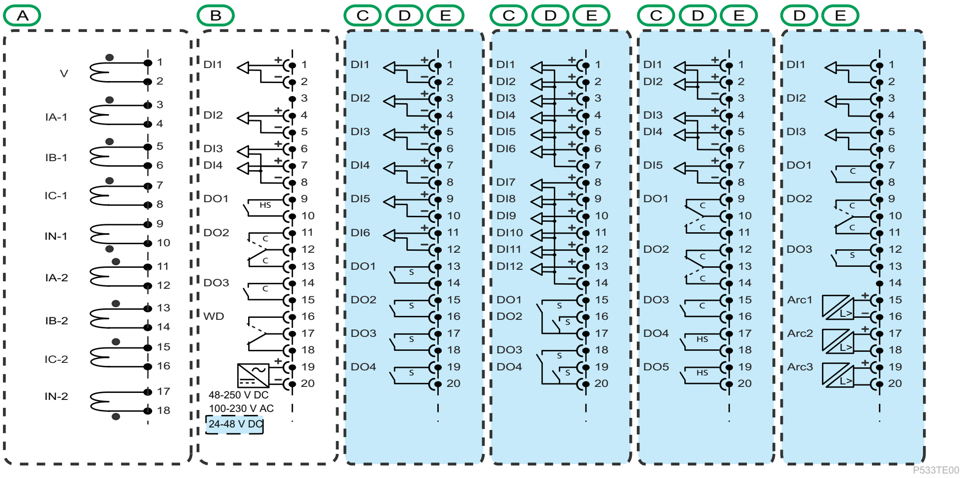


Figure 41 - PowerLogic P5T30 (CT/VT version) rear terminal designations

▨	Optional		
V	Voltage	IN-1/2	Standard neutral current input (IN.meas)
IX-1/2	Phase current	Arc	Arc sensor
DIx	Digital input	WD	Watchdog contact
DOx	Digital output		
- HS	High Speed / high break, Trip, 10 A perm.		
- C	Control / Trip, 8 A perm.		
- S	Signalling, 2 A perm.		

Default DI/DO configuration of the slot B terminals

The following table lists the default configuration of the digital input and digital output terminals in slot B of the PowerLogic P5 protection and control relay.

Table 6 - Default DI/DO configuration of the slot B terminals

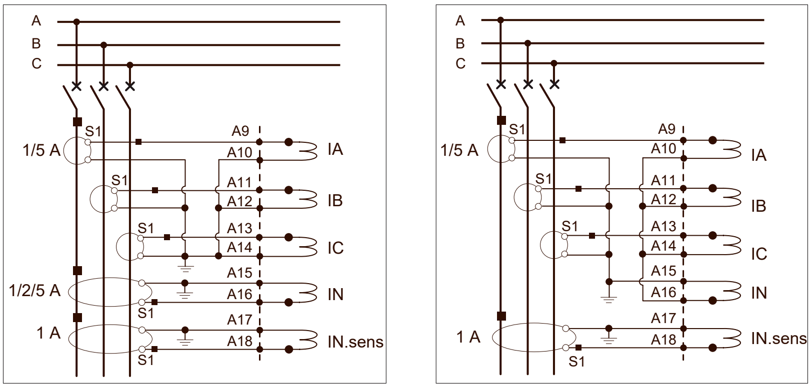
DI1	CB open
DI2	CB close
DI3	Free
DI4	Free
DO1	CB trip
DO2	CB trip lockout
DO3	CB close
WD	Watchdog (not configurable)

Typical application diagrams

The following sections describe typical application diagrams.

CT and LPCT typical application

Figure 42 - 3 x 1/5A CTs and neutral current measured by 1 x 1/2/5A CT and 1 x 1A CT



A533CH00

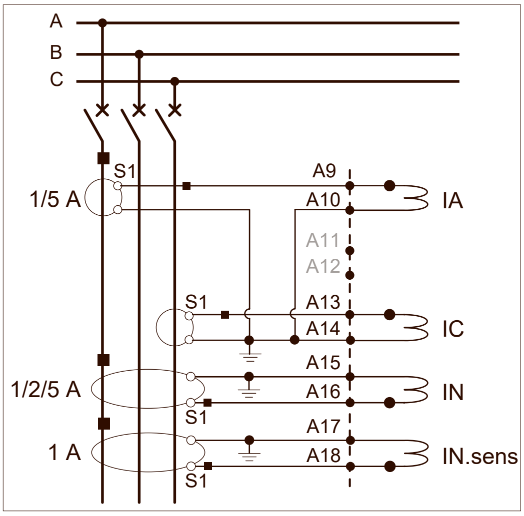
IN: Standard neutral current input (IN.meas)

IN.sens: Sensitive neutral current input

NOTE: For an application with 2 CTs, only IA and IC are used by PowerLogic P5 protection relay (see figure below).

Such so-called 2 CT mode further requires firmware adjustment with setting **Number of connected phase CT** = *A/C* in the **GENERAL** menu/**Scaling** sub-menu. It impacts power measurements as well as protection and monitoring functions using negative sequence currents as detailed in the function descriptions.

Figure 43 - 3 x 1/5A CTs (with IB not connected) and neutral current measured by 1 x 1/2/5A CT and 1 x 1A CT

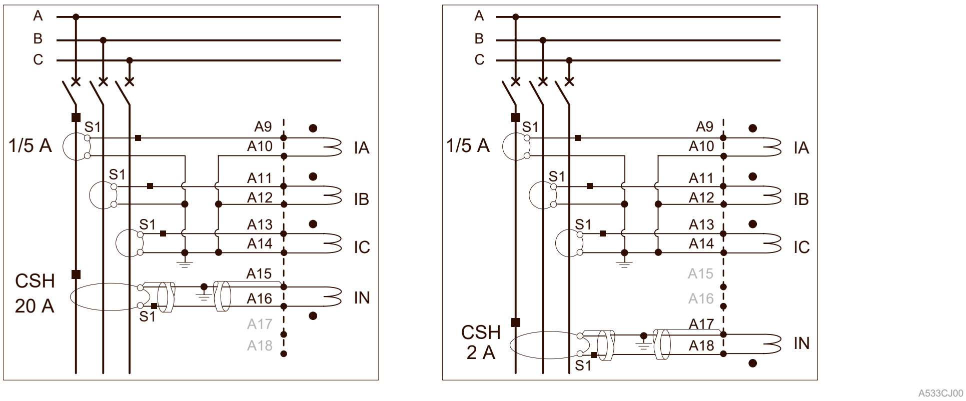


A533CI00

IN: Standard neutral current input (IN.meas)

IN.sens: Sensitive neutral current input

Figure 44 - 3 x 1/5A CTs and 1 neutral current measured by CSH



NOTE: For an application with 2 CTs, only IA and IC are used by PowerLogic P5 protection relay (see figure below).

Such so-called 2 CT mode further requires firmware adjustment with setting **Number of connected phase CT** = *A/C* in the **GENERAL** menu/**Scaling** sub-menu. It impacts power measurements as well as protection and monitoring functions using negative sequence currents as detailed in the function descriptions.

Figure 45 - 3 x 1/5A CTs (with IB not connected) and 1 neutral current measured by CSH

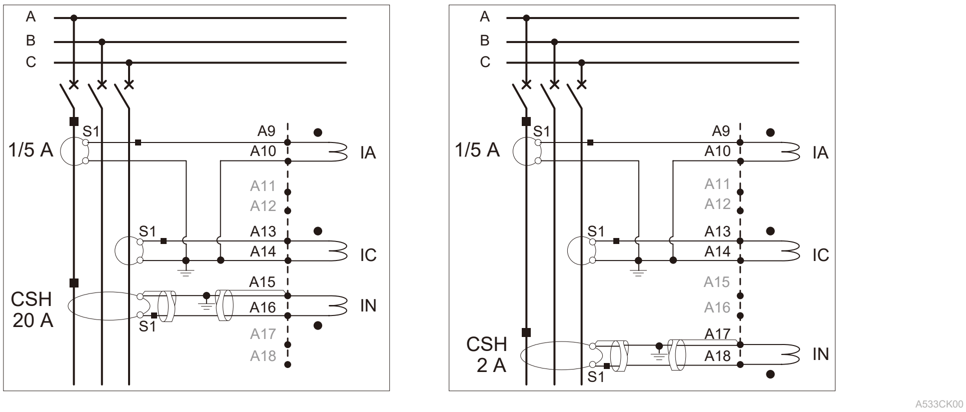
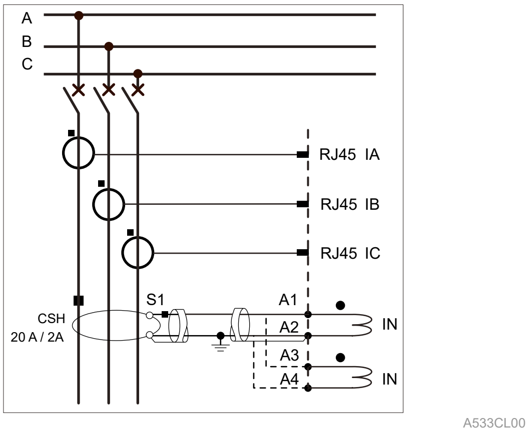
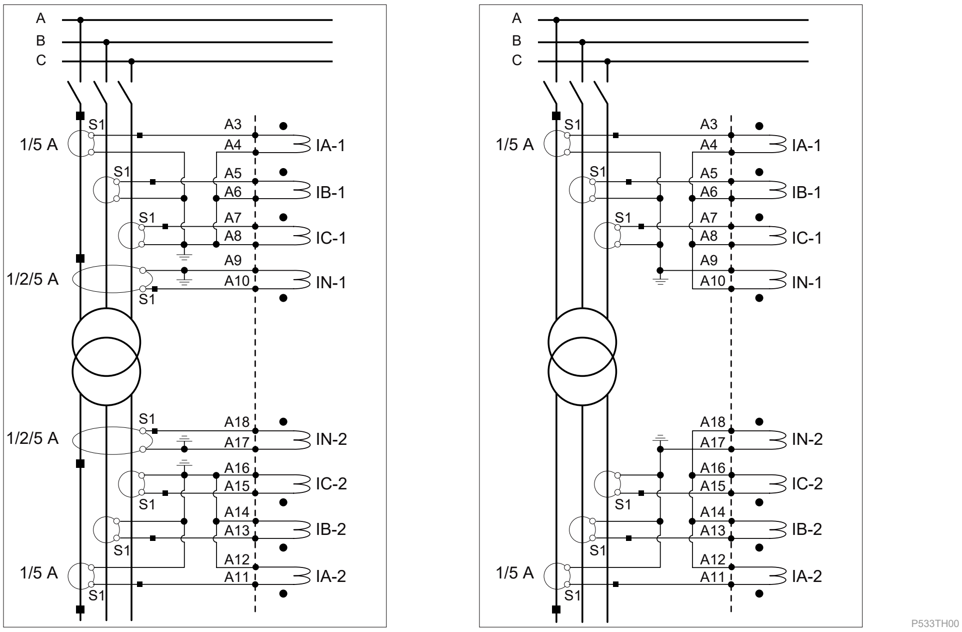


Figure 46 - 3 LPCT and 1 neutral current measured by CSH



NOTE: All 3 LPCTs must always be connected to the PowerLogic P5 protection relay for proper measurement.

Figure 47 - P5T30 with 6 x 1/5A CTs and neutral currents measured by 2 x 1/2/5A CTs



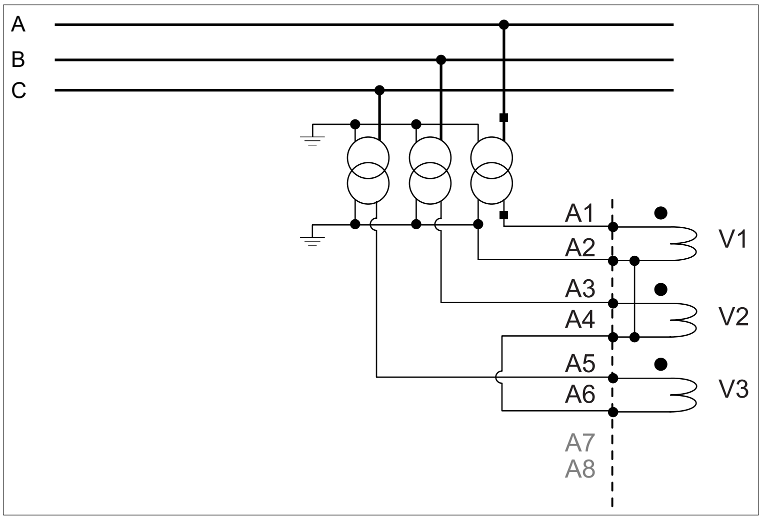
NOTE: Figures show standard connection with phase CTs common points on transformer side.

NOTE: Neutral CTs can also be used to measure the current in a star point grounding of wye or zigzag connected transformer windings; or in the measuring path of a high-impedance ground fault protection scheme.

VT typical application

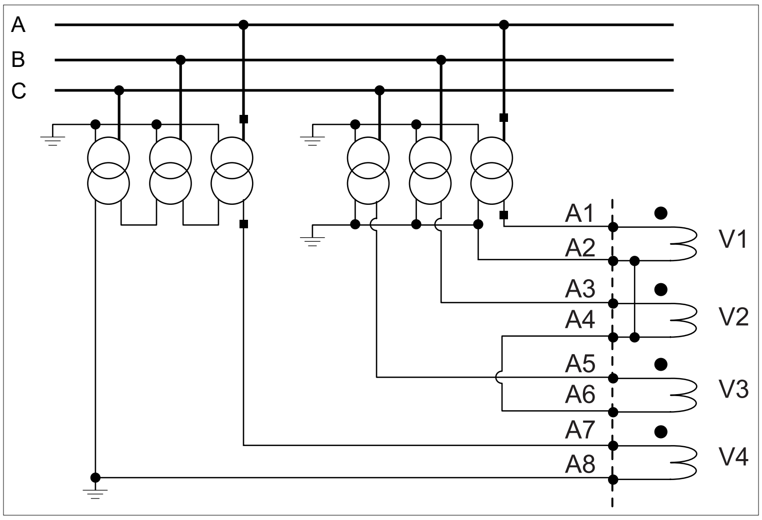
Voltage input terminals A2 and A4 have been connected internally. For three phase to neutral applications, short terminals A4 and A6 together.

Figure 48 - 3 phase to neutral voltages (3VP)



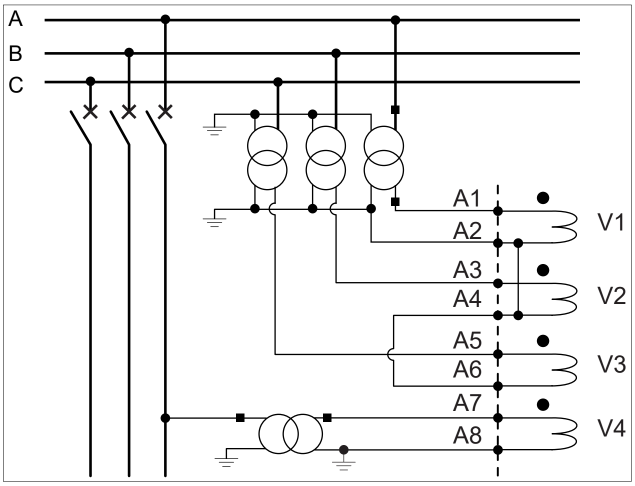
A533CM00

Figure 49 - 3 phase to neutral voltages + 1 neutral voltage (3VP+VN)



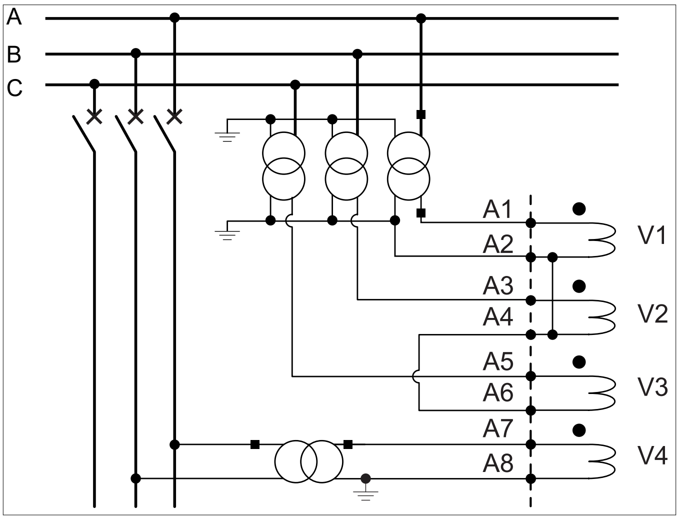
A533CN00

Figure 50 - 3 phase to neutral voltages + 1 phase to neutral voltage (3VP/VPy)



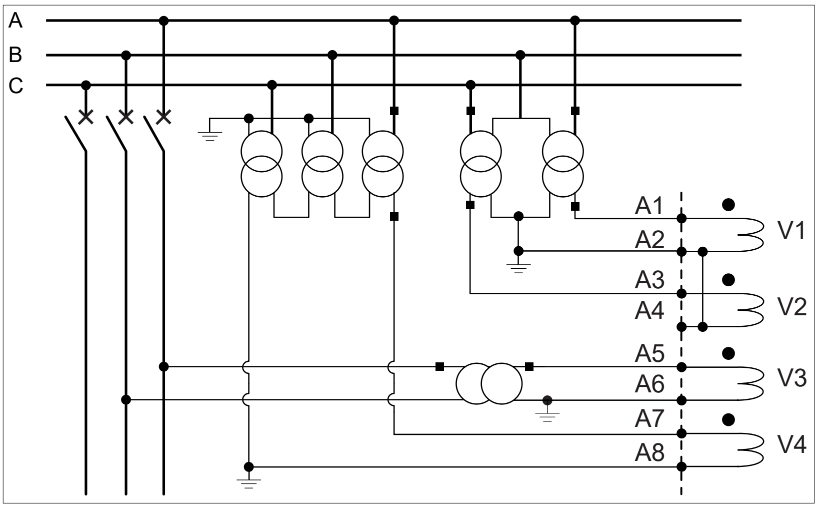
A533CO00

Figure 51 - 3 phase to neutral voltages + 1 phase to phase voltage (3VP/VPPy)



A533CP00

Figure 52 - 2 phase to phase voltages + 1 neutral voltage + phase to phase voltage (2VPP+VN+VPPy)



A533CQ00

Figure 53 - 2 phase to phase voltages + 1 neutral voltage (2VPP + VN)

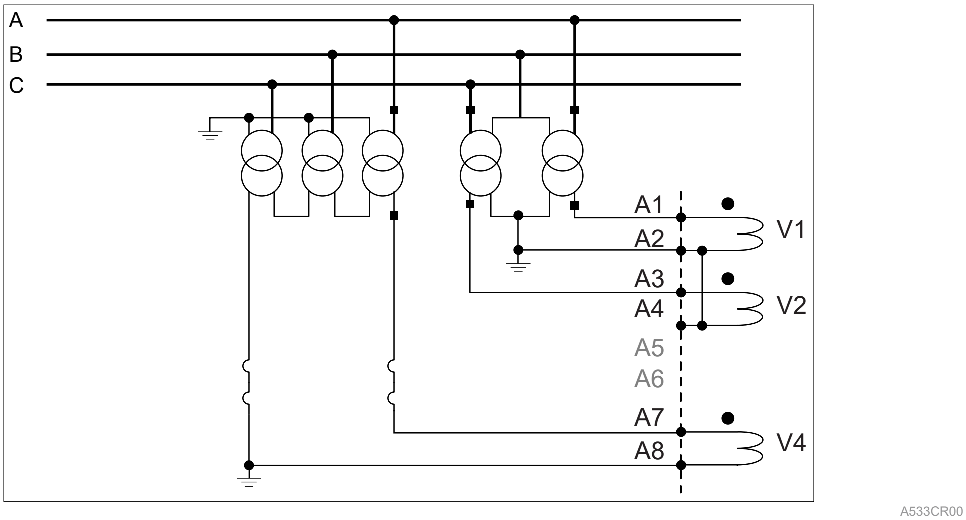


Figure 54 - 1 phase to phase voltage + 1 phase to phase voltage (VPP/VPPy)

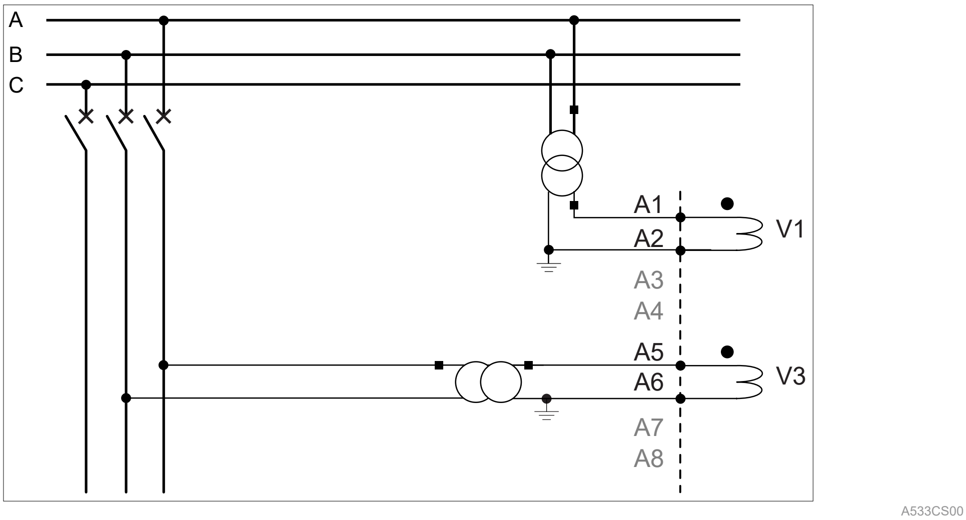
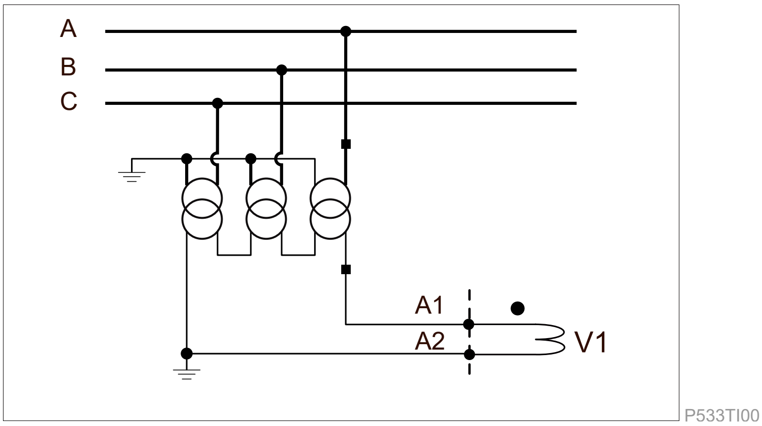
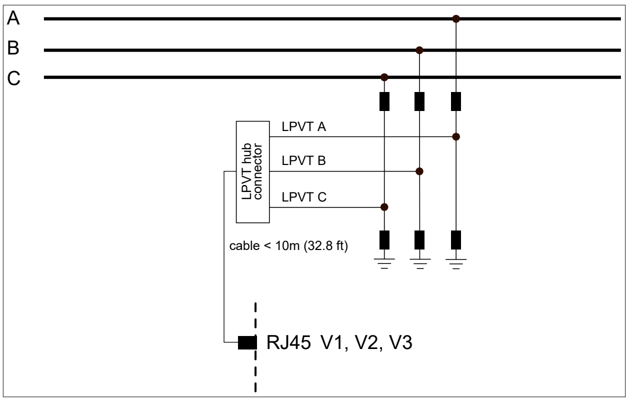


Figure 55 - P5T30 with neutral voltage (VN)



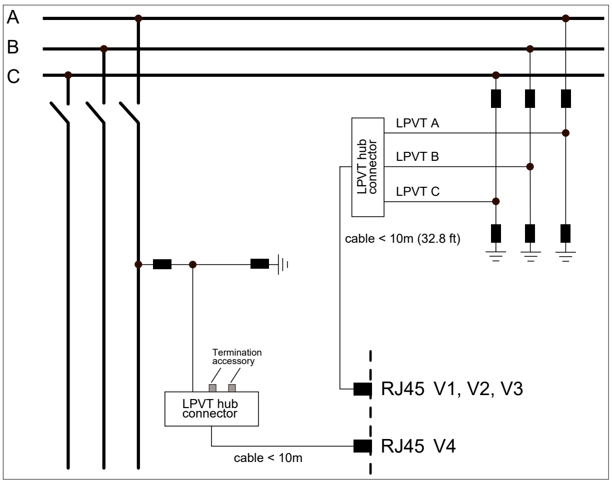
LPVT typical application

Figure 56 - 3 phase to neutral LPVT (3VP)



A533CT00

Figure 57 - 3 phase to neutral LPVT + 1 phase to neutral LPVT (3VP/VPy)

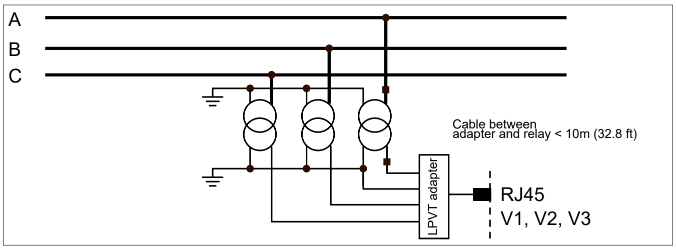


A533CU00

NOTE: If one or two LPVTs are connected to the LPVT hub connector (accessory ref. EMS59573), the termination accessories should be plugged to the 2nd and third input. These termination accessories are delivered with each LPCT/LPVT hardware variant in accessories bag. In case the accessories are lost, it is recommended to order spare part accessories for LPCT/LPVT variant (REL51079).

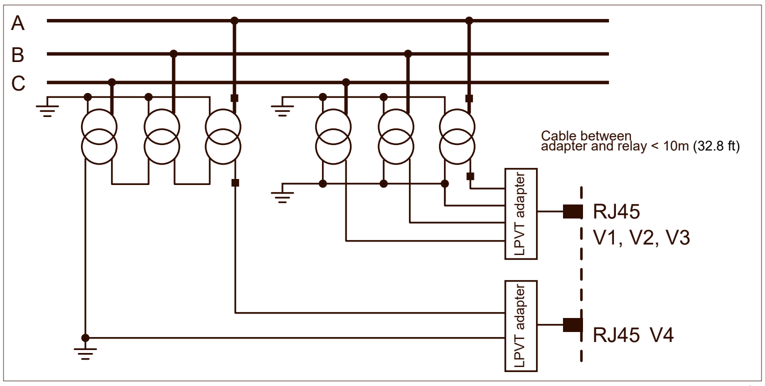
LPVT adapter typical application

Figure 58 - 3 phase to neutral voltages (3VP)



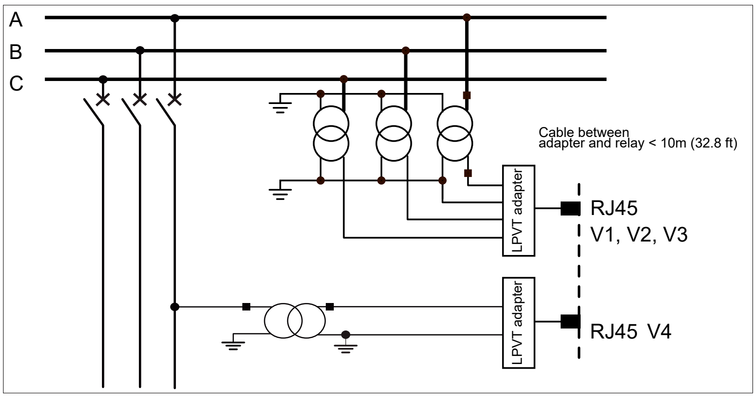
A533CW00

Figure 59 - 3 phase to neutral voltages + 1 neutral voltage (3VP+VN)



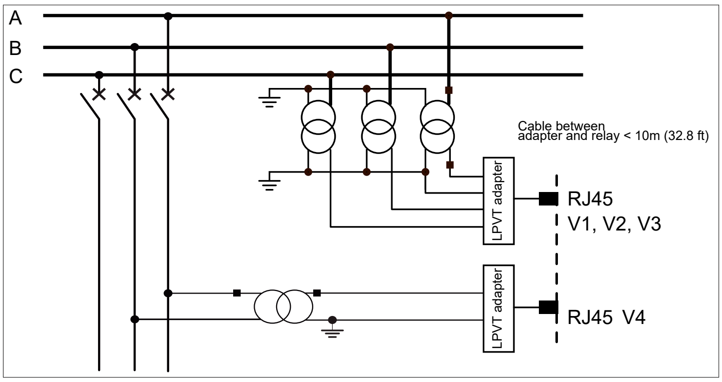
A533CY00

Figure 60 - 3 phase to neutral voltages + 1 phase to neutral voltage (3VP/VPy)



A533D000

Figure 61 - 3 phase to neutral voltages + 1 phase to phase voltage (3VP/VPPy)



A533D200

Wiring on the rear panel

⚠DANGER

FIRE HAZARD

Apply proper tightening torque to all wire connections.

Failure to follow these instructions will result in death or serious injury.

Slot A: analogue module

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Use the appropriate (3 or 4-terminal) copper jumper for common connections.
- After cabling, protect the rear connector A with the two protective caps.

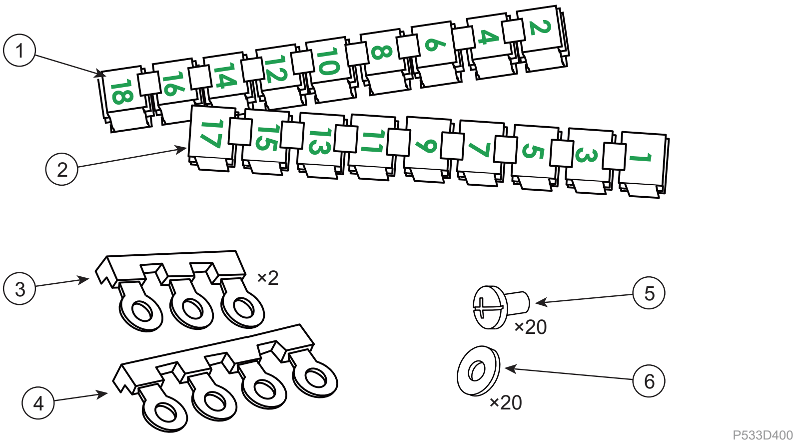
Failure to follow these instructions will result in death or serious injury.

Cabling kit for connector A

The PowerLogic P5 protection relays are delivered with a cabling kit for connector A. Depending on the type of analogue inputs of the protection relay, one of the following packages will be provided for your device:

- Cabling kit for CT/VT analogue inputs, including:

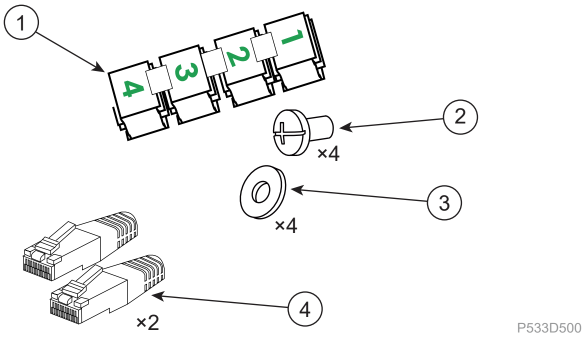
Figure 62 - Connector A cabling kit for CT/VT analogue inputs (REL51078)



  - One protective cap with even numbers marked ①
  - One protective cap with odd numbers marked ②
  - Two three-terminal jumpers ③
  - One four-terminal jumper ④
  - Twenty mounting screws ⑤ and washers ⑥

- Cabling kit for LPCT/LPVT analogue inputs, including:

Figure 63 - Connector A cabling kit for LPCT/LPVT analogue inputs (REL51079)



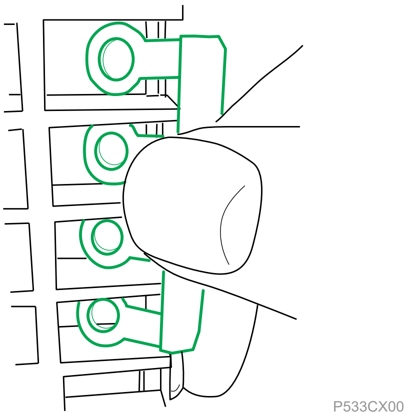
  - One four-terminal protective cap ①
  - Four mounting screws ② and washers ③
  - Two termination accessories ④

General cabling operation on connector A

The following procedure presents the general mounting and cabling operation on the connector A (for PowerLogic P5 model with 2 neutral CTs only):

1. Insert and connect the terminal jumper for common connections.

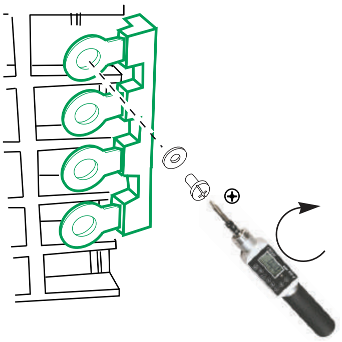
Figure 64 - Insert the terminal jumper (example with 4-pin comb-busbar)



Tools	Application connection diagram

2. Fasten the terminal jumper with the provided mounting screws and washers.

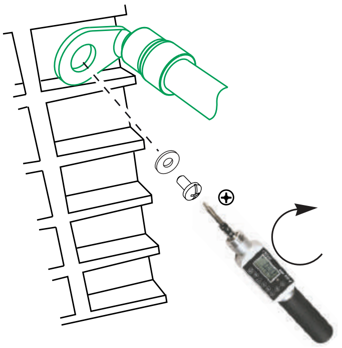
Figure 65 - Fasten the terminal jumper (example with 4-pin comb-busbar)



Fasteners	Mounting screws and washers included in the package
Tightening torque	1.2 N·m (10.6 lb-in)
Tool	Digital torque screwdriver with + PZ2 tip

3. Connect the bent ring lug end of the cables to the terminal using the provided mounting screws and washers.

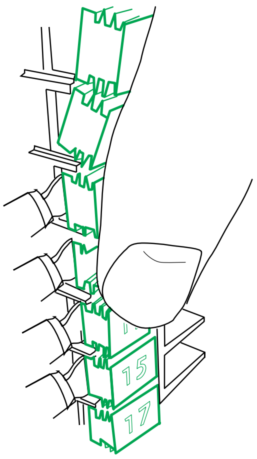
Figure 66 - Connect the cable with bent ring lug



Fasteners	Mounting screws and washers included in the package
Tightening torque	1.2 N·m (10.6 lb-in)
Tool	Digital torque screwdriver with + PZ2 tip

4. After cabling, place and insert the protective caps on the terminal.

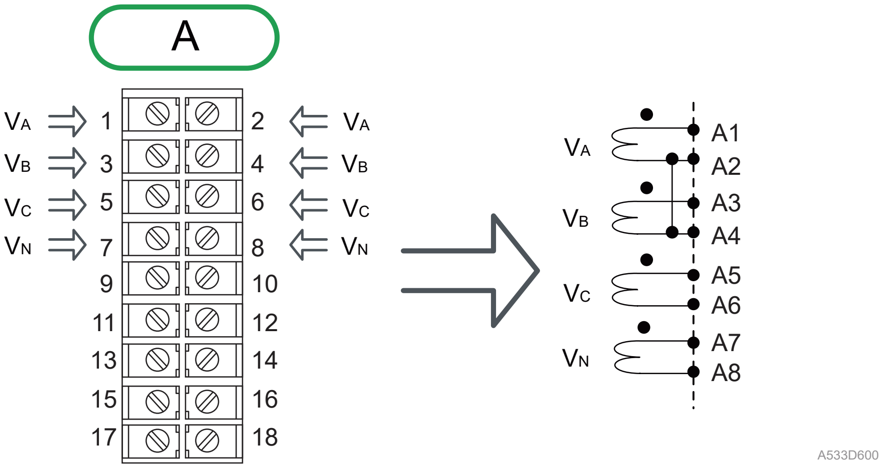
Figure 67 - Insert the protective cap



Phase voltage with VT inputs

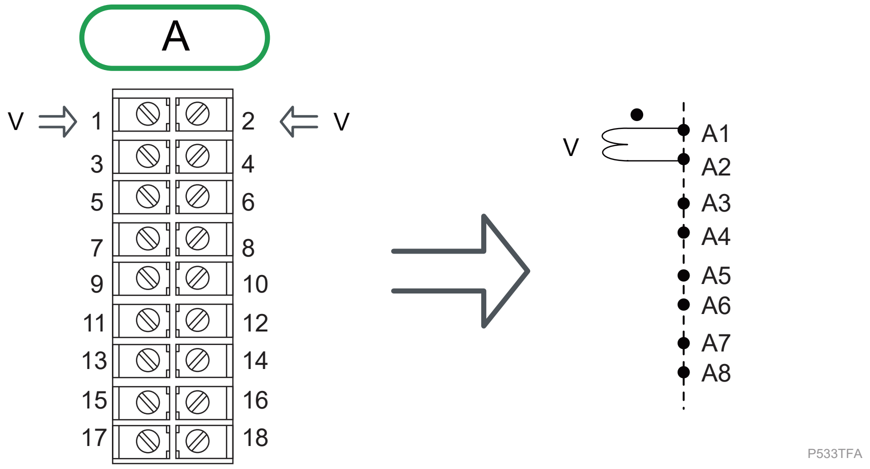
The phase voltage inputs of PowerLogic P5F30/P5M30/P5L30 are situated in the upper part of the rear connector "A", terminals A1 to A8. The voltage measuring inputs are the following:

Figure 68 - Phase voltage inputs on connector A of PowerLogic P5F30/ P5M30/P5L30



The phase voltage input of PowerLogic P5T30 is situated in the upper part of the rear connector "A", terminals A1 and A2. The voltage measuring inputs are the following:

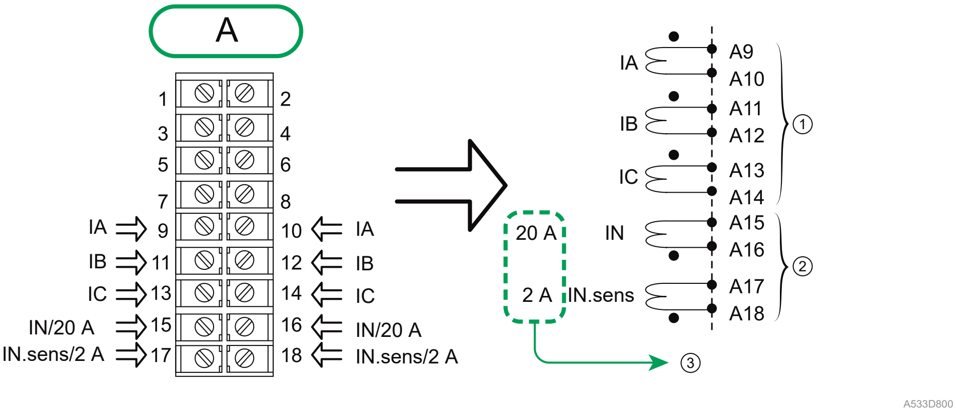
Figure 69 - Phase voltage inputs on connector A of PowerLogic P5T30



Phase currents with CT inputs and neutral current inputs

The current inputs of PowerLogic P5F30/P5M30/P5L30 are situated in the lower part of the rear connector A, terminals A9 to A18. The current measuring inputs are the following:

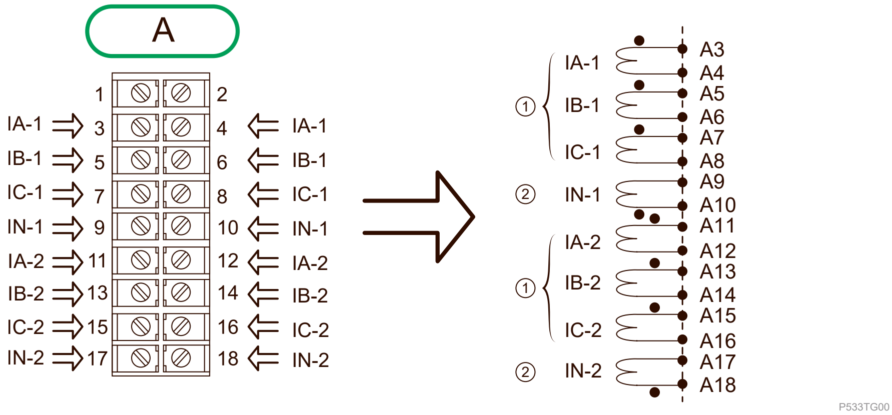
Figure 70 - Current inputs on connector A of PowerLogic P5F30/P5M30/P5L30



①	Current inputs
②	Neutral current inputs
③	Option with CSH core balance CT 2A or 20A
IN:	Standard neutral current input (IN.meas)
IN.sens:	Sensitive neutral current input

The current inputs of PowerLogic P5T30 are situated in the lower part of the rear connector A, terminals A3 to A18. The current measuring inputs are the following:

Figure 71 - Current inputs on connector A of PowerLogic P5T30



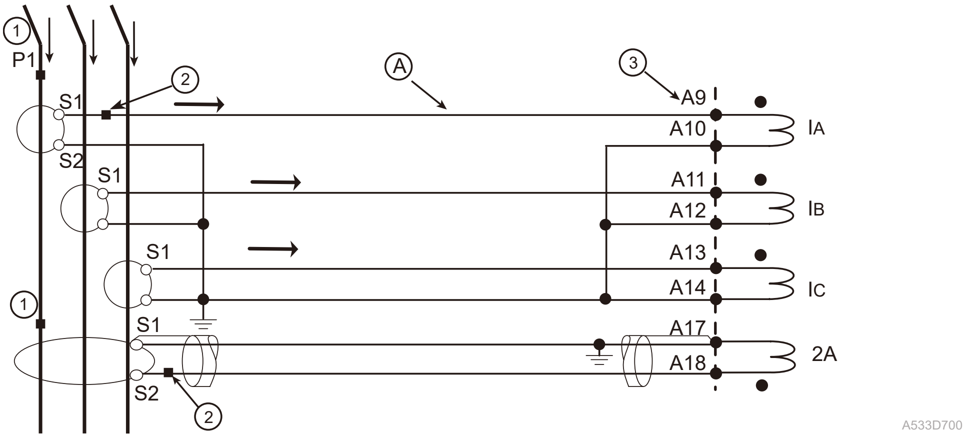
①	Current inputs
②	Neutral current inputs

NOTE: Communication modules may be replaced (for example, when communication network is modified). Take into account the access to these modules when you install and clamp rear connector wires.

Current Transformer Connections

The PowerLogic P5 protection relays use current transformers to measure phase or neutral currents. The current transformer connections are as follows:

Figure 72 - Connecting the current transformers with example of CSH ground fault connection (shielded)



where:

① Terminal P1[38] (primary current).

② Terminal S1[38] (secondary current).

③ Connector A + terminal number.

Ⓐ Implementation of the cabling between the CTs and the connector:

- Conductors contained in the same strand, in a sheath
- Conductors run along the metal structures of the MV cubicle

Recommended cable for Schneider Electric's CSH120, CSH200, CSH300 and GO110 core balance CTs:

- Sheathed cable (to be compliant with electromagnetic compatibility requirements), shielded by tinned copper braid.
- Resistance per unit length < 100 mΩ/m (30.5 mΩ/ft).
- Minimum dielectric strength: 1000 V (700 Vrms).
- Connect the cable shielding in the shortest manner possible to PowerLogic P5.
- Flatten the connection cable against the metal frames of the cubicle.

The maximum resistance of the connection wiring must not exceed 4 Ω (20 m maximum for 100 mΩ/m or 66 ft maximum for 30.5 mΩ/ft).

Wiring details

Refer to the table below for the detailed information on wiring the screw-type input connectors of the analogue module in slot A:

Applicable cable end	Wire gauge	Tightening torque	Tool	
 Ø 1 = 4 mm (0.16 in.) Ø2 < 8.5 mm (0.33 in.)	0.5 ... 1.5 mm² (AWG 20 ... 16) 1.5 ... 2.5 mm² (AWG 16 ... 14) 2.5 ... 6 mm² (AWG 14 ... 10)	1.2 N·m (10.6 lb-in)	(-) 6.5 mm (1/4 in.) screwdriver	(+) PZ2 screwdriver

---

38. Markings of current transformer terminals S1, S2, P1 and P2 according to IEC 61869-1 Standard

LPCT inputs

NOTICE

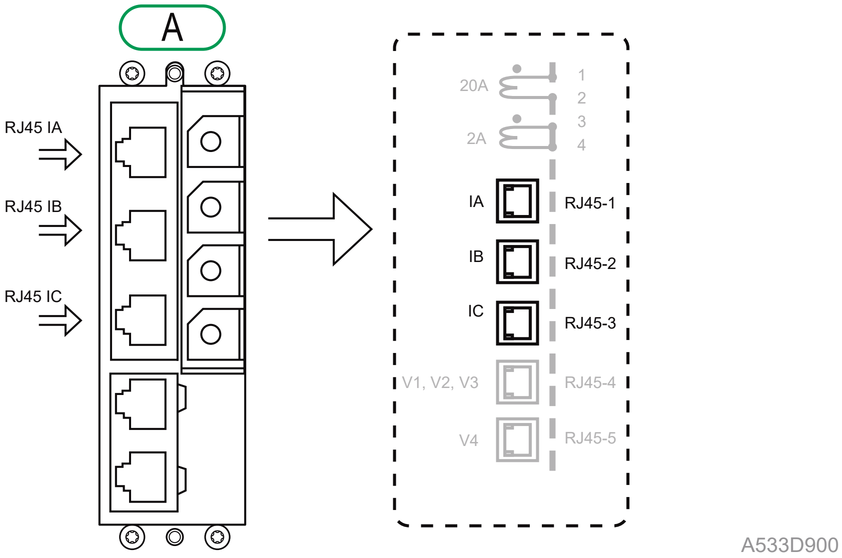
UNINTENDED EQUIPMENT OPERATION

Use the original cable from OEM with a cable no longer than 10 m (32.8 ft) for EMC immunity.

Failure to follow these instructions can result in improper operation.

NOTE: The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

Figure 73 - LPCT inputs on slot A



An LPCT sensor is characterized among other parameters by:

- The rated primary current I_{pr} (value of the primary current for U_{ser} secondary voltage output)
- The rated extended primary current I_{epr}
- The rated secondary voltage is 22.5 mV

The LPCT input of the PowerLogic P5 protection relay is characterized by the rated input voltage that depends on the rated extended primary current of the sensor. As an LPCT sensor covers a wide range of primary current and therefore has a high dynamic input here it is necessary to adapt the input interface of the relay to the primary current selected. More generally the LPCT inputs must be compliant with the IEC61869-10 standard.

Parameter	Value	Comment
Rated secondary voltage	22.5 mV	
Rated primary current factor	0.25 - 0.50 - 1.00 - 1.25 - 1.33 - 2.00 - 2.50 - 3.20 - 4.00 - 5.00 - 6.30 - 6.66 - 10 - 16 - 20 - 31.5	This configuration parameter corresponds to the rated extended primary current factor of the LPCT.

NOTE: The pins 3-6 of the LPCT of Schneider Electric are shorted during fabrication, see LPCT/LPVT pins mapping definition, page 153 for the LPCT pins mapping definition.

LPVT inputs

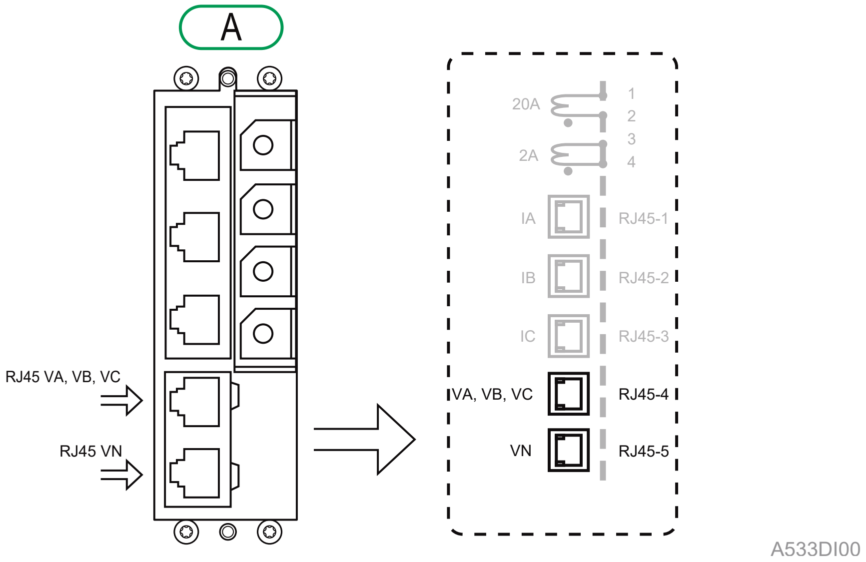
NOTICE

UNITENDED EQUIPMENT OPERATION

Use the original cable from OEM to connect to the hub or merger. The total cable length between LPVT and P5 cannot exceed 10 m (32.8 ft) for EMC immunity.

Failure to follow these instructions can result in improper operation.

Figure 74 - LPVT inputs on slot A



More generally the LPVTs inputs must be compliant with the IEC61869-11 standard.

The table below lists the technical data concerning the ratings and limits of the LPVT channels:

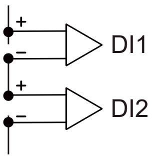
Parameter	Value
Rated secondary voltage	3.25 V / √3
Extended rated voltage	0.25 to 1.5 rated voltage

NOTE: The pins 3-6 of the LPVT of Schneider Electric are shorted during fabrication, see LPCT/LPVT pins mapping definition, page 153 for the LPVT pins mapping definition.

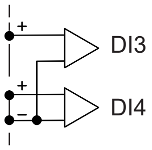
Digital input connections

The PowerLogic P5 protection relays provide two types of digital inputs:

- Digital inputs isolated from ground and independent.
- Digital inputs isolated from ground, with a common connection point.



P533RE00



P533RF00

The operating nominal voltage for digital inputs is:

- 24 V DC to 250 V DC
- 90 V AC to 230 V AC

The activation voltage threshold is software settable. More information can be found on Digital inputs, page 545 section.

The isolated independent digital inputs are isolated from ground, and each other. They should be used to acquire data from the following digital sensors:

- Non-isolated sensors (grounded).
- Remote sensors.
- Sensors from several zones in the installation that do not have equipotential bonding.
- Sensors from different devices.

To help ensure that each digital input is isolated, each digital input must be connected with an independent cable.

The isolated digital inputs with a common connection point are isolated from ground, but are not isolated in relation to one another (common point). They should be used to acquire data from the following digital sensors:

- Isolated sensors.
- Sensors that are not isolated but come from the same zone of an installation with equipotential bonding.
- Sensors that preferably come from the same equipment. The different digital inputs are contained in the same cable.

The electrical conductors connected to the digital inputs of the PowerLogic P5 protection relays should run along the metal structures of the cubicle to reduce ground loops. The conductors are contained in the same strand and, if possible twisted, to avoid the creation of cabling loops.

NOTICE

UNITENDED EQUIPMENT OPERATION

When connecting the digital inputs:

- Avoid large cabling loops in the various power supplies.
- Do not short-circuit any of the galvanic insulation.

Failure to follow these instructions can result in improper operation or equipment damage.

When the environmental and installation conditions are highly unfavorable for the PowerLogic P5 protection relay, a shielded twisted pair should be used. In such cases, the cable shielding is connected to the local ground at both ends (provided that the installation has an equipotential bonding network).

Slot B: power supply + digital 4-input/4-output

Power supply

⚠DANGER

FIRE HAZARD

- Protect the power supplying circuit of the PowerLogic P5 protection relay against overcurrents.
- For breaking capacity higher than 40W with L/R = 40 ms, protect the digital output contacts with an additional customer protection (RC or zener diode).

Failure to follow these instructions will result in death or serious injury.

The power supply range and inrush currents are provided for easier selection of Miniature Circuit Breaker (MCB).

Protection relay	Power supply range	Inrush current
PowerLogic P5x20	100...230 V AC	< 5 A 230 V AC
	24...250 V DC	< 8 A 250 V DC
PowerLogic P5x30	100...230 V AC	< 5 A 230 V AC
	48...250 V DC	< 8 A 250 V DC
	24...48 V DC	< 4 A 48 V DC

The nominal voltage range of PowerLogic P5 protection relays is specified on the reference label (local panel).

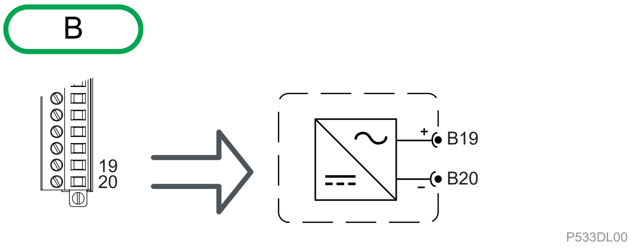
NOTICE

POWER SUPPLY DAMAGE

Before connecting the auxiliary voltage to the PowerLogic P5 protection relay, make sure the nominal value of the auxiliary device voltage corresponds with the nominal value of the auxiliary system voltage.

Failure to follow these instructions can result in equipment damage.

Figure 75 - Power supply terminals on connector B



Digital inputs/outputs

The digital 4-input/4-output module (4I4O) is always mounted in slot B of an PowerLogic P5 protection relay. Digital outputs DO1, DO2 and DO3 are specifically enhanced for circuit breaker (CB) control. Digital output WD is defined as a Watchdog.

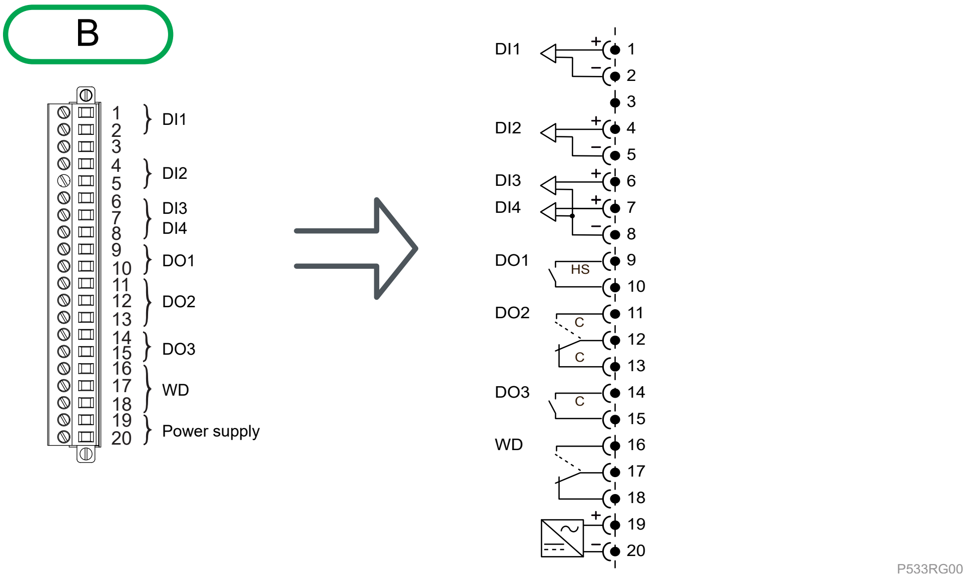
The operating nominal voltage for digital inputs is:

- 24 V DC to 250 V DC

- 90 V AC to 230 V AC

The configuration of the 20-terminal connector of the module is shown in the following figure:

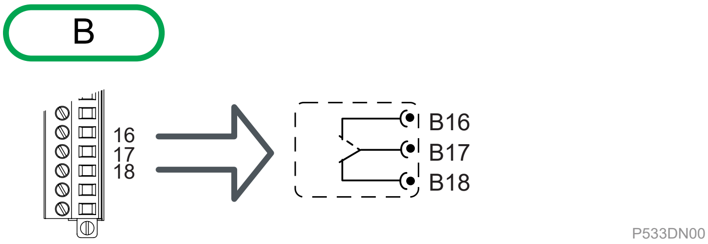
Figure 76 - Configuration of connector B



Watchdog

The watchdog (self-monitoring) is a changeover contact provided on slot B, digital output WD, to indicate the health of the device (refer to Watchdog relay, page 657). Schneider Electric strongly recommends that these contacts are hardwired into the substation's automation system for alarm purposes.

Figure 77 - Watchdog terminals on connector B

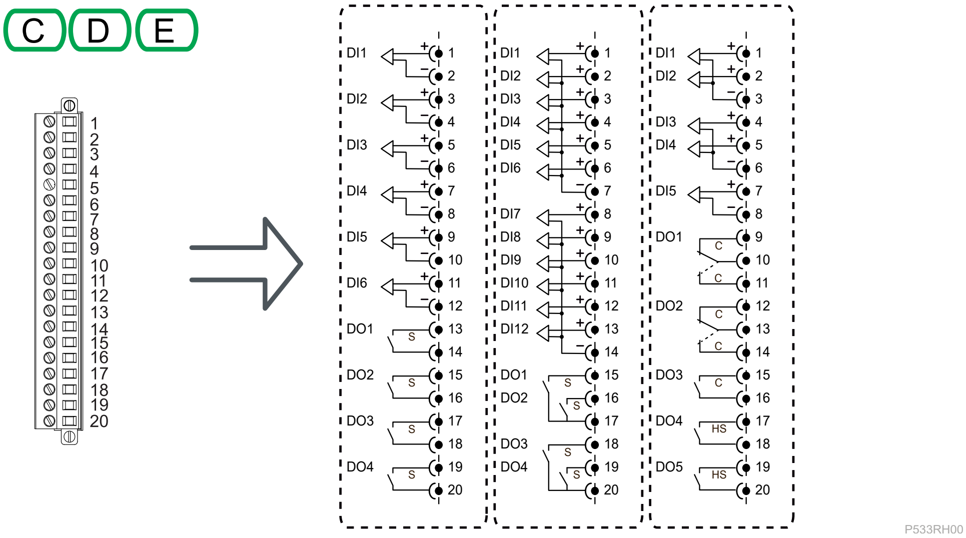


NOTE: Refer to Wiring accessories for Slot B, C, D, E, page 94 for the detailed information on wiring the terminals of this module.

Slot C, D, E: additional digital input/output modules (6I4O/12I4O/5I5O)

The PowerLogic P5 protection relay can be provided with additional digital input/output modules (6I4O, 12I4O and 5I5O) in slot C, D and E (only slot C in P5x20). The configuration of the 20-terminal connector of the module is shown in following image:

Figure 78 - Configuration of connector



NOTE: Refer to Wiring accessories for Slot B, C, D, E, page 94 for the detailed information on wiring the terminals of this module. And refer to Slot occupation rules, page 704 for the information on the slot occupation rules.

The DI1 input on 12I4O can be used as a standard digital input (by default) or as a counting input.

NOTICE

UNINTENDED EQUIPMENT OPERATION

Specific wiring requirements for the counting input 12I4O DI1:

- Unshielded twisted pair cable between pin 1 and pin 7
- 0.4 to 1.5 mm² cross section
- Example of recommended cable : Belden 9409 or equivalent
- No ground connection on the PowerLogic P5 side or on the other side to keep the line symmetrical
- Maximum cable length: 10 m

Failure to follow these instructions can result in equipment damage.

NOTICE

UNINTENDED EQUIPMENT OPERATION

When the counting input DI1 on 12I4O is selected, this input cannot be used by any other protection functions.

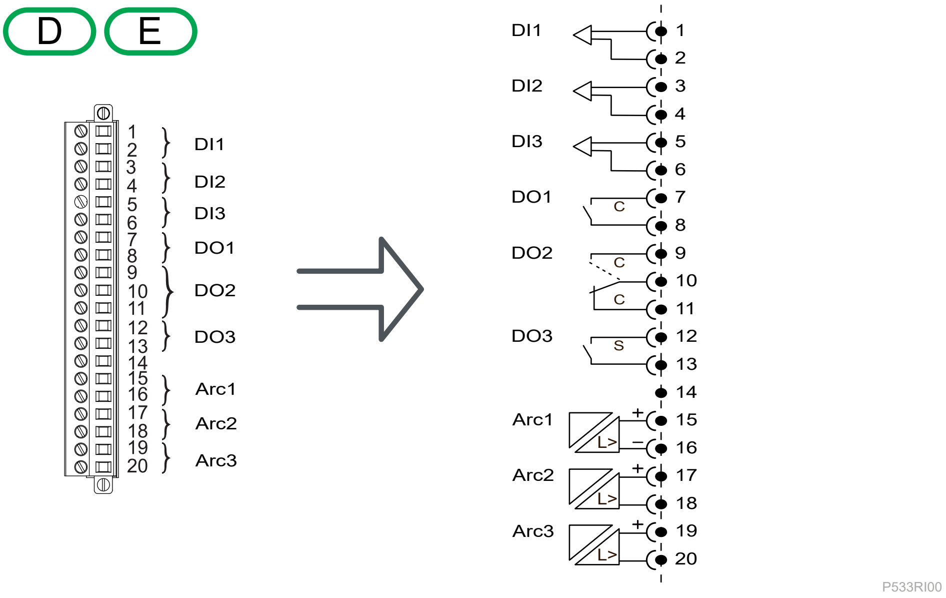
Failure to follow these instructions can result in equipment damage.

Slots D and E: Arc-flash module (for PowerLogic P5x30 only)

The PowerLogic P5x30 can be equipped with up to 2 Arc-flash modules (with 3 light sensor inputs, 3 digital inputs and 3 digital outputs each) in its slot D and E.

The configuration of the 20-terminal connector of the Arc-flash module is shown in following image:

Figure 79 - Configuration of terminals in Slot D and E

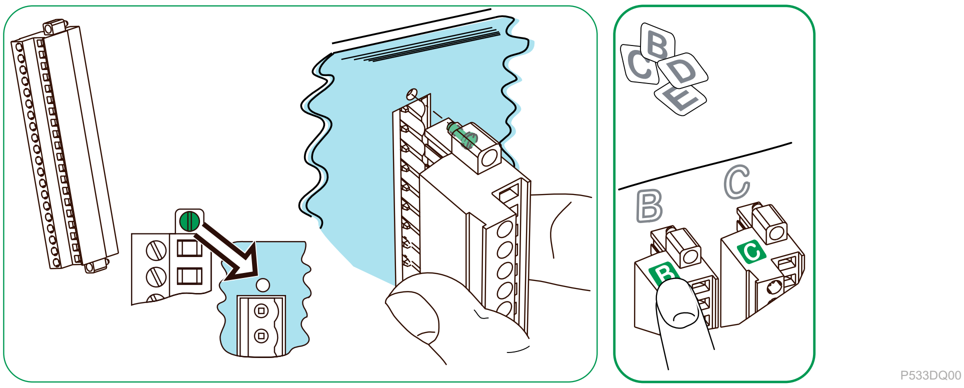


NOTE: Refer to Wiring accessories for Slot B, C, D, E, page 94 for the detailed information on wiring the terminals of this module.

Installing the digital I/O connectors

The digital I/O connectors provided with the protection relay are mounted on the rear panel fixed with screws came with the connectors.

Figure 80 - Installing digital I/O connectors on the rear panel

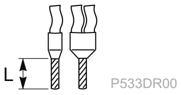


Tool	2.5 mm (3/32 in.) flat screwdriver
Tightening torque	0.4 N·m (3.5 lb-in)
Subsequent operation	Identification labels of connector are included in the package. After connectors installed, stick the labels on rear top of the connectors.

Wiring accessories for Slot B, C, D, E

Wiring the screw-type terminals

The detailed information for wiring the screw-type DI/DO terminals in slot B, C, D, and E is listed in the table below:

Cable end	Wire gauge	Tightening torque	Tool
 Contact tip length L = 12 mm (0.5 in.)	Single wire: 0.2 ... 2.5 mm² (AWG 24 ... 14) Double wires: 0.2 ... 1.5 mm² (AWG 24 ... 16)	0.4 ... 0.5 N·m (3.5 ... 4.4 lb-in)	(—) 2.5 mm (3/32 in.) flat blade screwdriver

Connecting ground

DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Connect the PowerLogic P5 protection relay to ground with a nut and washer using any of the indicated stud terminals (see figure Fixing the grounding cable to the PowerLogic P5 protection relay, page 95).
- Check equipotential grounding network and test ground during installation.

Failure to follow these instructions will result in death or serious injury.

The ground connections are accessible on the rear panel of the protection relays. For PowerLogic P5x20, there are two connectors located in the bottom left and right corner of the protection relays; for PowerLogic P5x30, there are three, one in the bottom right corner and the other two near Connector A.

Figure 81 - Ground studs on PowerLogic P5x20

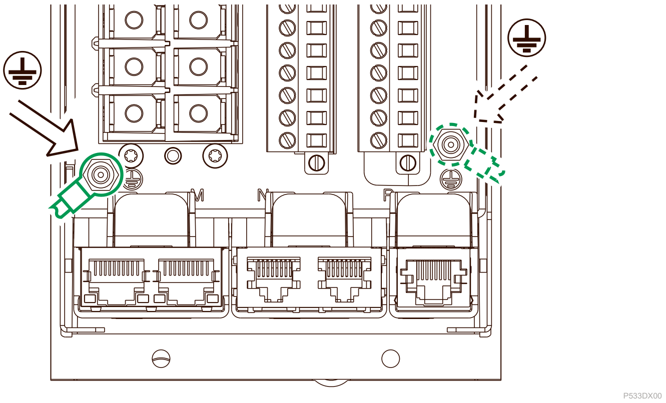


Figure 82 - Ground studs on PowerLogic P5x30

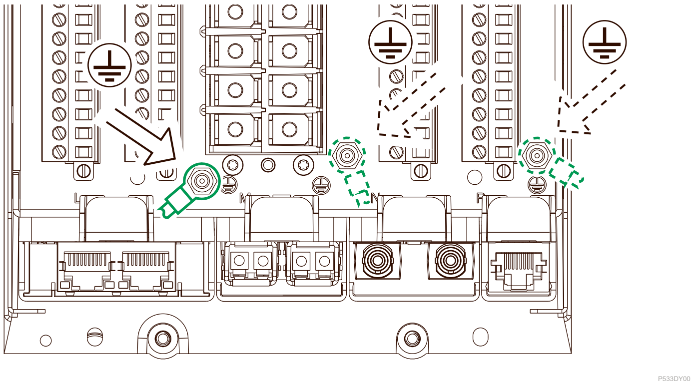
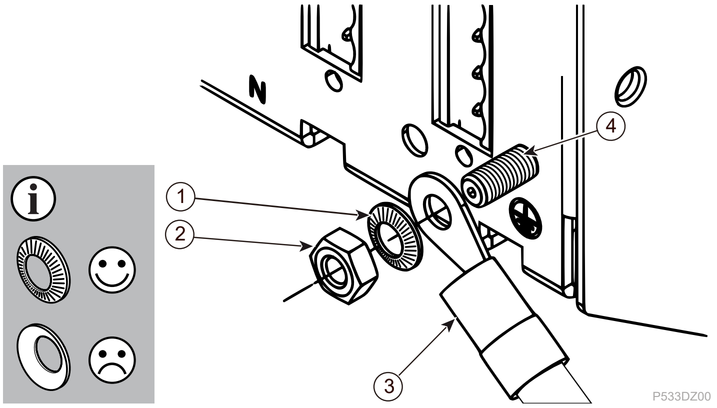


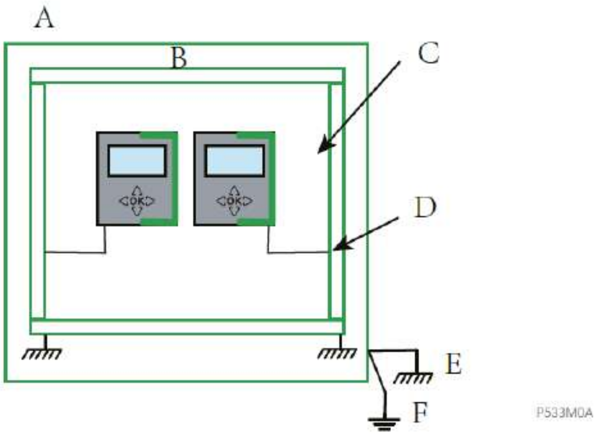
Figure 83 - Fixing the grounding cable to the PowerLogic P5 protection relay



①	Washer	③	Grounding cable
②	M4 hexagon nut	④	Ground stud on the protection relay

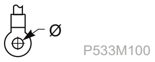
Every PowerLogic P5 must be connected to the local ground bar using one M4 ground stud on the relay case to help prevent dangerous voltages being present in case of a wiring fault or damage to the product. Also, it helps ensure that the PowerLogic P5 protection relay meets EMC claims.

Figure 84 - Compartment grounding terminal



A	Metal upright of the LV compartment	D	Ground connection made to a surface with no paint, varnish or any insulating material. Spring washers must be used.
B	LV compartment	E	Local ground
C	The PowerLogic P5 protection relay is installed in the LV compartment near the grounding terminal or near one of the metal uprights.	F	Electrical protection

The minimum recommended wire size is 2.5 mm^2 (AWG 14) and should have a ring terminal at the relay end. Due to the limitations of the ring terminal, the maximum wire size that can be used is 6.0 mm^2 (AWG 10) per wire.

Terminal type	Applicable cable end	Wire gauge	Max. wire length	Tightening torque	Tool
ground stud	 Ø = 4 mm (0.16 in.)	2.5 ... 6 mm^2 (AWG 14 ... 10)	50 cm (21 in.)	1.2 N·m (10.6 lb-in)	socket wrench for M4 screw

NOTE: To avoid any possibility of electrolytic action between brass or copper ground conductors and the rear panel of the protection relay, precautions should be taken to isolate them from one another. It is recommended to place a nickel-plated or insulating washer between the conductor and PowerLogic P5 case or to use tinned ring terminals.

Optional rear communication ports and modules

Location of the communication ports

NOTICE

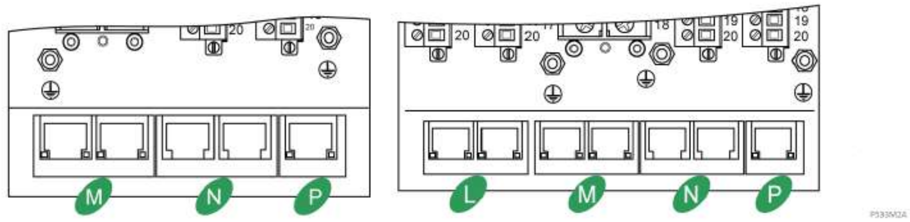
UNITENDED EQUIPMENT OPERATION

Use RJ45 cable no longer than 100 m (328 ft).

Failure to follow these instructions can result in improper operation.

The PowerLogic P5 protection relay range includes optional rear communication ports and modules with RJ45 or fiber optic connections. The ports and modules are accessible in the lower part of the rear panel. The following figure shows the location of these single or dual communication ports and modules:

PowerLogic P5x20 PowerLogic P5x30



<table>
<tr><th></th><th>PowerLogic P5x20</th><th>PowerLogic P5x30</th></tr>
<tr><td rowspan="2">Slot L</td><td>-</td><td>Dual port Ethernet TP module with RSTP redundancy</td></tr>
<tr><td>-</td><td>InterRelay module(FO)</td></tr>
<tr><td>Slot M</td><td colspan="2">Dual port Ethernet TP or fiber optic module, configurable to RSTP redundancy mode or Dual IP mode without redundancy</td></tr>
<tr><td>Slot N</td><td colspan="2">Dual port RS485 or fiber optic serial communication module</td></tr>
<tr><td>Slot M + N</td><td colspan="2">Combined Ethernet HSR/PRP 2TP + RS485 module or Combined Ethernet HSR/PRP FO + RS485 module</td></tr>
<tr><td rowspan="2">Slot P</td><td colspan="2">Extension port for external modules (IRIG-B time synchronization module, RTD inputs module, CLIO module) with backup memory</td></tr>
<tr><td colspan="2">Extension port for external modules (IRIG-B time synchronization module, RTD inputs module, CLIO module) with backup memory and Zigbee receiver.</td></tr>
</table>

Installing the modules

NOTICE

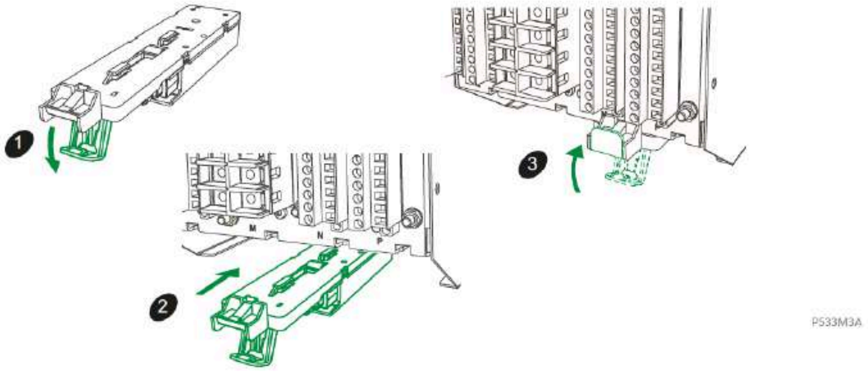
UNITENDED EQUIPMENT OPERATION

- Verify that the communication modules are locked on the protection relay.
- Never plug in or draw out the communication modules while the PowerLogic P5 protection relay is in service, otherwise the PowerLogic P5 protection relay will reboot and consequently lose the setting changes made within the last 30 minutes.

Failure to follow these instructions can result in setting change erasure and consequently mis-operation of the protection relay.

The communication modules are designed with a self-locking structure. After sliding along the bottom slots and fixing into position, the module locks itself in final place. The green flippable locker at one end locks the communication module in place.

Figure 85 - Installing the communication module



Slot L: Ethernet communication module with RSTP redundancy (reference REL51042)

Used for PowerLogic P5x30 only

The Ethernet communication module is installed in slot L of PowerLogic P5x30. It is an optional selection when ordering the device or can be purchased after on-site installation.

It works with RSTP protocol, which allows fast reconfiguration of the communication system.

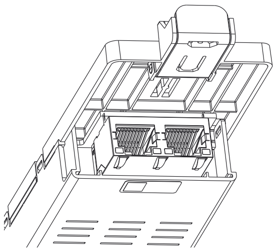


Figure 86 - Example of Ethernet module connection

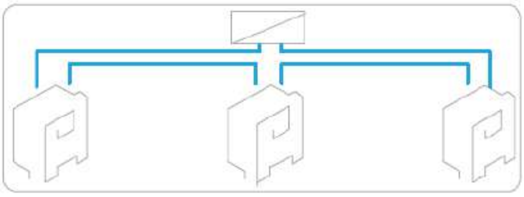
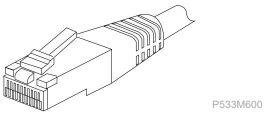


Table 7 - Characteristics of the Ethernet communication module (reference REL51042)

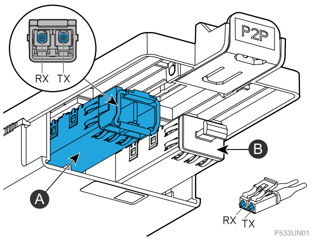
Characteristics	
Location	Slot L
Connection	2 x RJ45 connectors with communication indicators 
Ethernet connection	10/100 Mbps
Protocol	TP or RSTP
Maximum cable length	100 m (328 ft)

Slot L: Protection communication module with SDLC (references REL51053 and REL51043)

Used for PowerLogic P5x30 only

The serial communication module is mounted in slot L of PowerLogic P5x30. It is a necessary module for P5L30 and can be selected as an option when ordering the device or purchased later and installed on site.

It provides proprietary InterRelay communication between any 2 P5x30 relays, and additionally data exchange for line differential protection between 2 P5L30 relays.



A	Available port for the SFP module	B	Port currently not used

⚠CAUTION

EYE DAMAGE AND BLINDNESS

Never look into the end of the fiber optic.

Failure to follow these instructions can result in serious injury.

NOTICE

RISK OF MALOPERATION/FALSE TRIPPING

- Both ends of InterRelay shall use the same SFP modules.
- The fibre type must match the installed SFP module.

Failure to follow these instructions can result in maloperation/false tripping.

Figure 87 - Example of InterRelay module connection

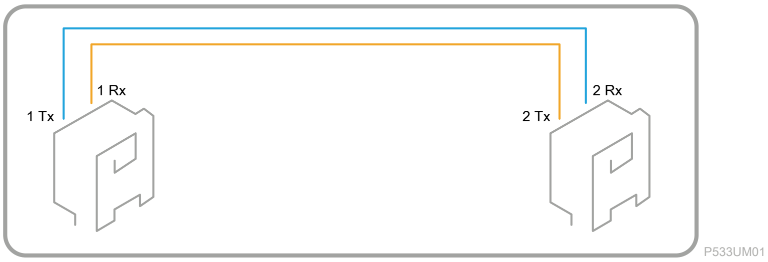
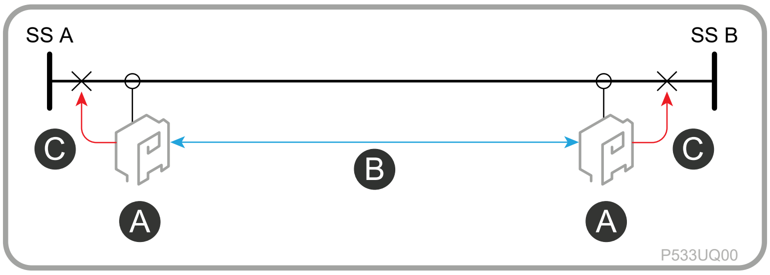


Figure 88 - Example of InterRelay connection



A	PowerLogic P5x30	B	Protection communication, transfer of digital data (start, trip, direction...).
C	Trip		

There are 2 InterRelay modules for selection, REL51053 for 2 km and REL51043 for 40 km communication distance. Their characteristics are listed separately in the 2 following tables.

Table 8 - Characteristics of the InterRelay module with 2 km multi-mode SFP (reference REL51053)

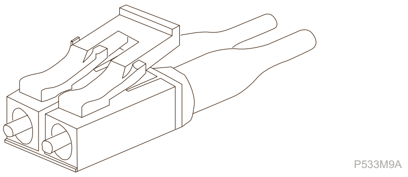
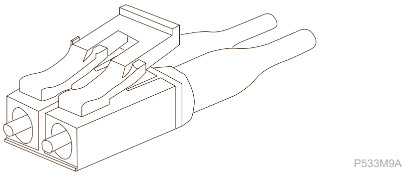
Characteristics	
Location	Slot L
Connection	2 LC connectors 
Baud rate	56 Kbps, 64 Kbps, 115.2 Kbps, 2 Mbps
Protocol	SDLC
Optical wavelength	1310 nm
Fibre type	Multi-mode
Maximum attenuation (fibre optic + connectors)	11.6 dB
Maximum range	2 km (1.2 mi)

Table 9 - Characteristics of the InterRelay module 40 km single-mode SFP (reference REL51043)

Characteristics	
Location	Slot L
Connection	2 LC connectors 
Baud rate	56 Kbps, 64 Kbps, 115.2 Kbps, 2 Mbps
Protocol	SDLC
Optical wavelength	1310 nm
Fibre type	Single-mode
Maximum attenuation (fibre optic + connectors)	30 dB
Maximum range	40 km (24.9 mi)

NOTE: The SFP modules in the list below have been validated to work properly with PowerLogic P5:

Maximum distance	Module
2 km	HFBR-57E5APZ (Avago or Broadcom)
40 km	AFCT-5765ANLZ (Avago or Broadcom) FTLF1323P1BTL (Finisar)

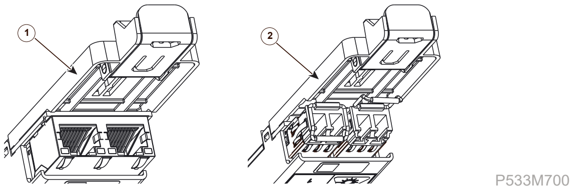
The SFP module FTLF1518P1BTL of Finisar can be used for communication for distance up to 80 km distance at 2 Mbps baud rate, 1550 nm wavelength single-mode.

Slot M: Ethernet communication module with RSTP redundancy

The Ethernet communication module is installed in slot M of the device. It is an optional selection when ordering the device or can be purchased after on-site installation.

It is available in two versions for cable connection ① or fiber optic ② connection.

It works with RSTP redundancy protocol, which allows fast reconfiguration of the communication system.



Ethernet module with RJ45 connectors (reference REL51038)

Figure 89 - Example of Ethernet module connection

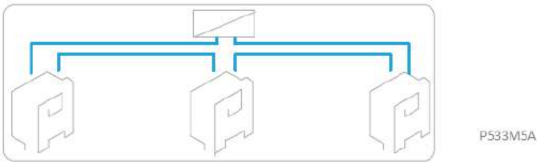
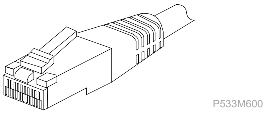


Table 10 - Characteristics of the Ethernet communication module (reference REL51038)

Characteristics	
Location	Slot M
Connection	2 x RJ45 connectors with communication indicators 
Ethernet connection	10/100 Mbps
Protocol	TP or RSTP
Maximum cable length	100 m (328 ft)

Ethernet module with fiber optic connectors (reference REL51039)

⚠CAUTION

EYE DAMAGE AND BLINDNESS

Never look into the end of the fiber optic.

Failure to follow these instructions can result in serious injury.

NOTICE

IMPROPER EQUIPMENT OPERATION

- Use only Schneider Electric approved optical transceiver components.
- Never replace the optical transceiver components with unauthorized manufactured parts.
- When replacing the SFP module, the entire Ethernet module equipped with fibre optic connectors (model REL51039) must be replaced entirely.

Failure to follow these instructions can result in equipment damage.

Use optical power meters to determine the operation or signal level of the device.

In case of electrical-to-optical converters used, the converters must be equipped with character idle state management (when the fiber optic cable interface is "Light off").

The bending radius of fibers should be especially taken care of, and it is not recommended to use optical shunts, they can decrease the communication performance of the transmission path over time.

Figure 90 - Example of Ethernet module connection

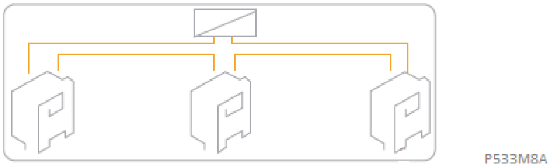
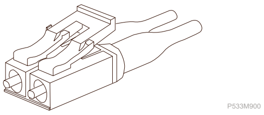
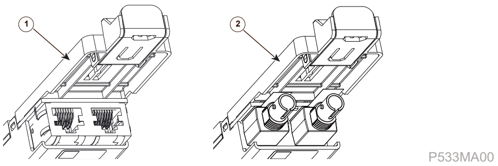


Table 11 - Characteristics of the Ethernet communication module (reference REL51039)

Characteristics	
Location	Slot M
Connection	2 LC connectors 
Ethernet connection	100 Mbps
Protocol	TP or RSTP
Optical wavelength	1310 nm
Fiber type	Multi-mode glass fiber
Maximum attenuation (fiber optic + connectors)	14 dB (at fiber optic diameter: 62,5/125 µm or 50/125 µm)
Minimum range	2000 m (6561,7 ft)

Slot N: serial line communication modules

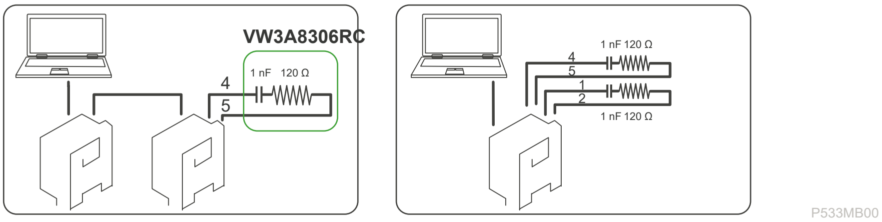
The Serial line communication module is installed in slot N of the device. It is an optional selection when ordering the device or can be purchased after on-site installation. It is available in 2 versions for RS485 ① or fiber optic ② connection.



RS485 serial line module (reference REL51036)

The PowerLogic P5 protection relay can be connected to any RS485 full duplex or half duplex communication network and can exchange data with SCADA. The serial RS485 ports are designed for RJ45 connections with the following characteristics for each terminal.

Figure 91 - Examples of RS485 serial link module connection



The integrated polarization resistor 120 Ω can be enabled or disabled with eSetup Easergy Pro (see parameter "poll line" in the communication manual).

In order to avoid signal reflections on the line, data transmission lines should always be terminated with a RC terminating impedance (120 Ω/1 nF, reference VW3A8306RC), or with a 4 line option that includes 2 pairs of 120 Ω/1 nF RC terminating impedance, fitted at both ends across the signal wires.

Figure 92 - Terminating the transmission line with a RC terminating accessory

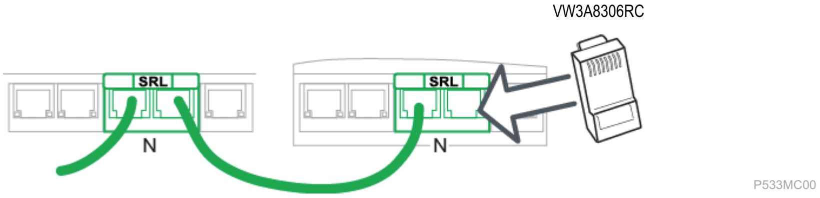


Table 12 - Characteristics of the RS485 serial line module (reference REL51036)

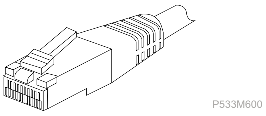
Characteristics	
Location	Slot N
Standard	EIA 2-wires RS485 differential or EIA 4-wires RS485 differential
Connection	2 x RJ45 connectors 
Protocol	TP
Line polarization	120 Ω
Communication network	Half or full duplex
Maximum cable length	100 m (328 ft)

Figure 93 - RJ45 female connector viewed from front

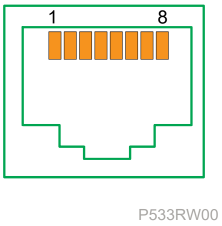


Figure 94 - RJ45 female connector wiring

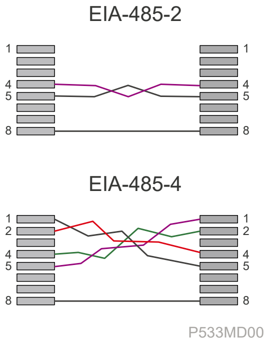
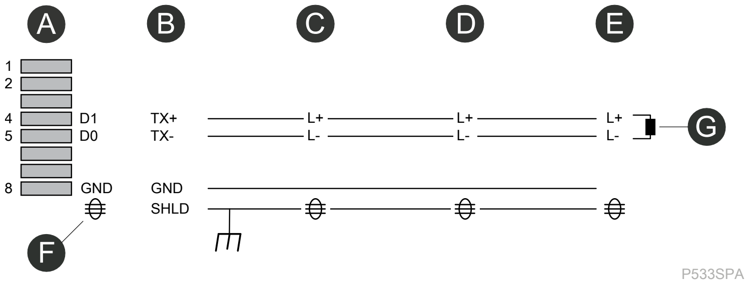


Figure 95 - RJ45 for RS485 interface



A	Gateway RJ45	B	Adapter
C	Slave 1	D	Slave 2
E	Slave 3	F	Shield
G	Termination		

Fiber optic serial line module (reference REL51040)

⚠CAUTION

EYE DAMAGE AND BLINDNESS

Never look into the end of the fiber optic.

Failure to follow these instructions can result in serious injury.

Use optical power meters to determine the operation or signal level of the device.

In case of electrical-to-optical converters used, the converters must be equipped with character idle state management (for when the fiber optic cable interface is "Light off").

The bending radius of fibers should be especially taken care of, and it is not recommended to use optical shunts, they can decrease the communication performance of the transmission path over time.

The relay uses 850 nm multi-mode 100BaseFx ST(BFOC) 2.5 connectors (one Tx/optical emitter, one Rx/optical receiver).

Figure 96 - Example of fiber optic serial line module connection

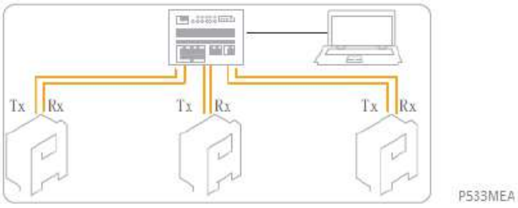
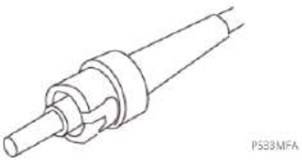


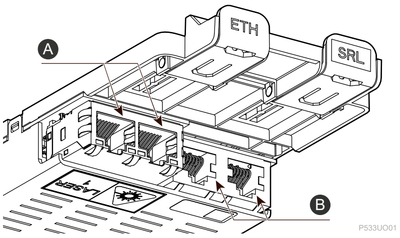
Table 13 - Characteristics of the fiber optic serial line module (reference REL51040)

Characteristics	
Location	Slot N
Connection	2 x ST (BFOC) connectors 
Optical wavelength	820 nm
Maximum attenuation (fiber optic + connectors)	• 5.6 dB at fiber diameter 50/125 μm • 9.4 dB at fiber diameter 62.5/125 μm • 14.9 dB at fiber diameter 100/140 μm • 19.2 dB at HCS (Hard Clad Silica) fiber diameter 200 μm
Maximum range	2000 m (6561,7 ft)

Slot M & N: Combined Ethernet HSR/PRP 2TP + RS485 module (reference REL51048)

The Ethernet communication module is inserted in both slot M and N of the device. It can be selected as an option when ordering the device or purchased later and installed on site. It provides PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) and is selectable by configuration.

The module allows instantaneous reconfiguration of the communication system without communication packet loss.



A	Ethernet RJ45 ports	B	RS485 serial link ports

For the RS485 serial line module, please refer to Slot N: serial line communication modules, page 105.

Figure 97 - Example of Ethernet module connection

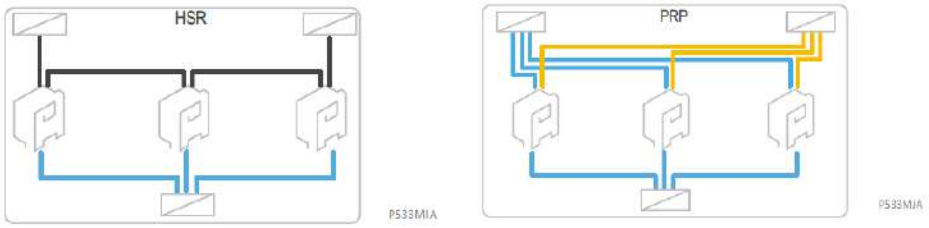
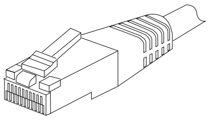


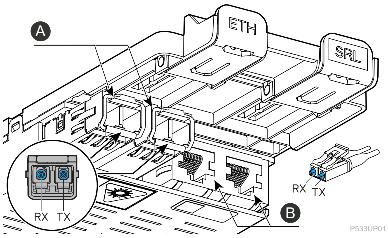
Table 14 - Characteristics of the Combined Ethernet HSR/PRP 2TP + RS485 module (reference REL51048)

Characteristics	
Location	Both slot M and N
Connection	2 x RJ45 connectors 
Type of cable	The following cables (Reference numbers) can be selected for connection: • Reference 59660, length: 0.6 m (1.97 ft); • Reference 59661, length: 2 m (6.56 ft); • Reference 59662, length: 4 m (13.1 ft);
Protocol	TP or RSTP
Ethernet connection	100 Mbps
Line polarization	620 Ω
Communication network	Half or full duplex
Maximum cable length	100 m (328 ft)

Slot M & N: Combined Ethernet HSR/PRP FO + RS485 module (reference REL51049)

The Ethernet communication module is inserted in both slot M and N of the device. It can be selected as an option when ordering the device or purchased later and installed on site. It provides PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) and is selectable by configuration.

The module allows instantaneous reconfiguration of the communication system without communication packet loss.



A	FO ports	B	RS485 serial link ports

⚠ CAUTION

EYE DAMAGE AND BLINDNESS

Never look into the end of the fiber optic.

Failure to follow these instructions can result in serious injury.

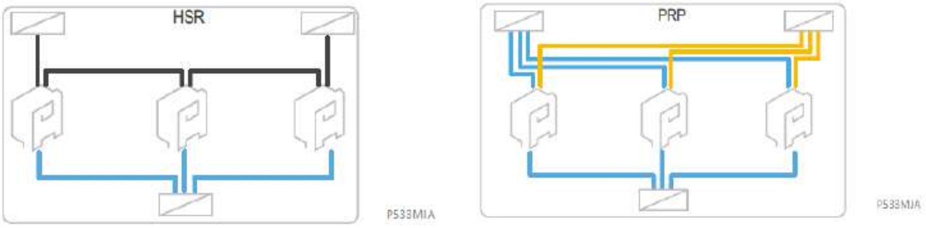
Use optical power meters to determine the operation or signal level of the device.

If electrical-to-optical converters are used, they shall have management of character idle state capability (when the fiber optic cable interface is "Light off").

Specific care shall be taken with the bending radius of the fibers. The use of optical shunts is not recommended as these can decrease the communication performance of the transmission path over time.

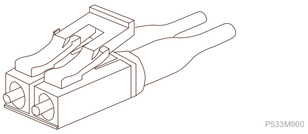
For the RS485 serial line module, please refer to Slot N: serial line communication modules, page 105.

Figure 98 - Example of Ethernet module connection



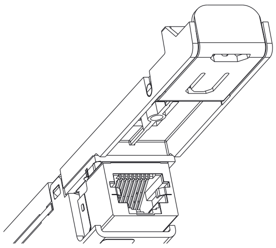
See Ethernet module with fiber optic connectors (reference REL51039), page 104 for the detail of the Ethernet module with fibre optic connectors.

Table 15 - Characteristics of the Combined Ethernet HSR/PRP FO + RS485 module (reference REL51049)

Characteristics	
Location	Both slot M and N
Connection	2 x LC connectors 
Ethernet connection	100 Mbps
Optical wavelength	1310 nm
Fiber type	Multi-mode glass fiber
Maximum attenuation (fiber optic + connectors)	14 dB (at fiber diameter 50/125 µm or 62.5/125 µm)
Maximum range	2 km (1.2 mi)

Slot P: extension module (reference REL51034)

The extension module is installed in slot P of the device. It is an optional selection when ordering the device or can be purchased after on-site installation.



NOTICE

ETHERNET PORT DAMAGE

Connect only PowerLogic P5 accessories to the extension module.

Failure to follow these instructions can result in equipment damage.

Connection of other equipment such as computer, switch, low power current transducer (LPCT) type sensor or other protection relay can result in the damage of its Ethernet port.

The extension module provides:

- Automatic back-up of data (refer to Backup memory, page 664):
  - Active configuration file
  - Disturbance records
  - Sequence of events records
  - Power system maintenance data log
- Connection to the external modules

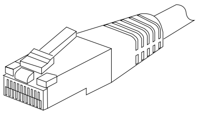
The following PowerLogic P5 accessories can be connected to the extension module:

- IRIG-B module
- MET148-2 temperature sensor module
- CLIO module

Table 16 - Accessories that can be cable connected to slot P and their sequence

Accessory	Sequence	Maximum connection (module(s))
IRIG-B module (REL51045)	Shall be the first module connected to slot P, see IRIG-B module (reference REL51045), page 138 for more information.	1
MET148–2 temperature sensor module (REL59641)	No limit of sequence, but if there is IRIG-B module connected, the IRIG-B module shall be the first module connected to slot P. See MET148-2 - temperature sensor module (reference 59641), page 135 for more information.	2
CLIO module (REL70071)	No limit of sequence, but if there is IRIG-B module connected, the IRIG-B module shall be the first module connected to slot P. See CLIO module (REL70071), page 141 for more information.	3

Table 17 - Characteristics of the extension module (reference REL51034)

Characteristics	
Location	Slot P
Connection	RJ45 connector 
Type of cable	The following cables (Reference numbers) can be selected for connection: • Reference 59660, length: 0.6 m (1.97 ft); • Reference 59661, length: 2 m (6.56 ft); • Reference 59662, length: 4 m (13.1 ft);

Slot P: extension Zigbee module (reference REL51044)

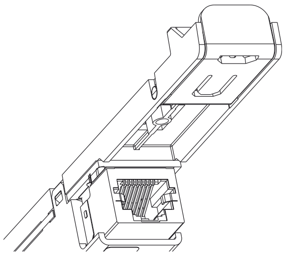
⚠CAUTION

EXPOSURE TO RADIO FREQUENCY

- Read and understand this guide before performing any installation with the extension Zigbee module (reference REL51044).
- FCC: This device complies with FCC RF radiation exposure limits set forth for general population. This device must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.
- IC: This device complies with Industry Canada RF radiation exposure limits set forth for general population. This device must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.
- Le présent appareil est conforme aux niveaux limites d’exigences d’exposition RF aux personnes définies par Industrie Canada. L’appareil doit être installé afin d’offrir une distance de séparation d’au moins 20 cm avec l’utilisateur, et ne doit pas être installé à proximité ou être utilisé en conjonction avec une autre antenne ou un autre émetteur.

Failure to follow these instructions can result in injury.

The extension Zigbee module is installed in slot P of the device. It is an optional selection when ordering the device or can be purchased after on-site installation.



P533MGA

NOTICE

ETHERNET PORT DAMAGE

Connect only PowerLogic P5 accessories to the extension module.

Failure to follow these instructions can result in equipment damage.

Connection of other equipment such as computer, switch, low power current transducer (LPCT) type sensor or other protection relay can result in the damage of its Ethernet port.

The extension module provides:

- Automatic back-up of data (refer to Backup memory, page 664):
  - Active configuration file
  - Disturbance records
  - Sequence of events records
  - Power system maintenance data log
- Connection to the external modules through Zigbee Green Power protocol with the sensors located in neighborhood of PowerLogic P5

The following PowerLogic P5 accessories can be connected to the extension module:

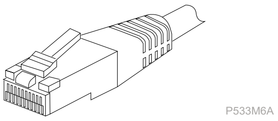
- IRIG-B module
- MET148-2 temperature sensor module
- CLIO module

- PowerLogic TH110: thermal sensors, connected through Zigbee
- PowerLogic CL110: environmental sensors, connected through Zigbee

Table 18 - Accessories that can be cable connected to slot P and their sequence

Accessory	Sequence	Maximum connection (module(s))
IRIG-B module (REL51045)	Shall be the first module connected to slot P, see IRIG-B module (reference REL51045), page 138 for more information.	1
MET148–2 temperature sensor module (REL59641)	No limit of sequence, but if there is IRIG-B module connected, the IRIG-B module shall be the first module connected to slot P. See MET148-2 - temperature sensor module (reference 59641), page 135 for more information.	2
CLIO module (REL70071)	No limit of sequence, but if there is IRIG-B module connected, the IRIG-B module shall be the first module connected to slot P. See CLIO module (REL70071), page 141 for more information.	3

Table 19 - Characteristics of the extension Zigbee module (reference REL51044)

Characteristics	
Location	Slot P
Connection	RJ45 connector 
Type of cable	The following cables (Reference numbers) can be selected for connection: • Reference 59660, length: 0.6 m (1.97 ft); • Reference 59661, length: 2 m (6.56 ft); • Reference 59662, length: 4 m (13.1 ft);
Zigbee RSSI (Received Signal Strength Indicator)	minimum -83 dBm

Installation of sensors and connection of modules for Digital Circuit Breaker monitoring

Installation of Zigbee sensors

NOTE: PowerLogic P5 communicates with the Zigbee Green Power sensors through extension module installed in slot P. For the detail of the extension module, refer to Slot P: extension Zigbee module (reference REL51044), page 113.

Installation of PowerLogic TH110

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Turn off all power supplying the protection relay and the equipment in which it is installed before working on it.
- Always use a properly rated voltage sensing device to confirm that power is off.
- Apply appropriate personal protective equipment and follow safe electrical work practices. See local regulation.
- Do not install this product in ATEX class 0, 1 and 2 areas.

Failure to follow these instructions will result in death or serious injury.

The PowerLogic TH110 is a temperature sensor powered by induced current from monitored conductor. Its measured data are transmitted using Zigbee Green Power protocol. It measures temperature of electrical equipment inside MV cubicle.

The PowerLogic TH110 sensors can be installed on circuit breaker upper arms, circuit breaker lower arms, busbar joints, and cable joints of each phase A/B/C.

The work steps to install the TH110 sensor are:

1. Prepare the metal band, thread the metal band through the gap at the bottom of TH110.
2. Fasten TH110 to the place to be monitored on the equipment by the metal band.
3. Cut-off the excess part of the metal band with dedicated tool.
4. Secure in place the TH110 with Velcro securing strap, cut-off the excess part.

For more detailed information of the installation, please refer to the installation guide (document reference: MFR7945801) of PowerLogic TH110 through this link: https://www.se.com/us/en/download/document/MFR7945801/.

Installation of PowerLogic CL110

⚠CAUTION

EXPOSURE TO HIGH TEMPERATURES

Do not test the temperature beyond the sensor rating, which may cause damage to the sensor.

Failure to follow these instructions can result in equipment damage.

The PowerLogic CL110 is an indoor battery powered and wireless communication thermal and humidity sensor using Zigbee Green Power 2.4GHz protocol according to the IEEE 802.15.4. The PowerLogic CL110 is a mobile device as defined by FCC. It is intended to be used within indoor high and low voltage electrical distribution products or assemblies to monitor temperature and humidity change over a de-energized surface.

Sensors are affixed to magnetic surfaces through four high-strength magnets. The sensor should be used with a Schneider-Electric access point, which can be used for multiple sensors, using Zigbee Green Power wireless communication protocol. If the surface where the CL110 is going to be installed is not of steel, there is another option to fix it on this surface with the help of an installation kit.

For the detailed information of the installation, refer to the user guide (document reference: QGH40088) of PowerLogic CL110 through this link: https://www.se.com/uk/en/download/document/QGH40088/.

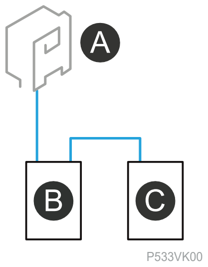
Connection of PowerLogic P5 with EOS-BM100/EOS-MCMx00

NOTE: Before connecting the modules of the Digital Circuit Breaker monitoring, ensure the extension module is installed in slot N or slot M & N. For the details of the extension module, refer to Slot N: serial line communication modules, page 105, Slot M & N: Combined Ethernet HSR/PRP 2TP + RS485 module (reference REL51048), page 108 and Slot M & N: Combined Ethernet HSR/PRP FO + RS485 module (reference REL51049), page 109.

Connect the EOS-BM100/EOS-MCM100/EOS-MCM200 to PowerLogic P5 by Daisy chain with RJ45 cables in the following sequence:

1. Wire the PowerLogic P5 to EOS-BM100.
2. Wire the EOS-BM100 to EOS-MCM100/EOS-MCM200.

Figure 99 - Daisy chain of PowerLogic P5, EOS-BM100 and EOS-MCMx00



A	PowerLogic P5	B	EOS-BM100
C	EOS-MCM100/EOS-MCM200		

The slot used in PowerLogic P5 is Slot N or Slot M+N. One PowerLogic P5 can connect with up to one EOS-BM100 and one EOS-MCM100/EOS-MCM200.

PowerLogic P5 will communicate with EOS-BM100 automatically when the connection is established and Digital CB protocol is configured. A Digital CB icon will be shown on the local HMI of PowerLogic P5. When PowerLogic P5 is connected to eSetup Easergy Pro, a **DIGITAL CB** menu tab will be displayed, it’s both for the monitoring function and the configuration of the Digital Circuit Breaker monitoring.

NOTE: The Modbus slave ID setting ranges of EOS-BM100/EOS-MCM100/EOS-MCM200 are:

- 11 to 19 for EOS-BM100 module, default ID is 11;
- 21 to 29 for EOS-MCM100/EOS-MCM200 module, default ID is 21.

Other accessories

CSH120 (reference 59635), CSH200 (reference 59636), CSH300 (reference 59637) and GO110 (reference 50134)

Description

The CSH120, CSH200, CSH300 and GO110 core balance current transformers (CT) are designed for direct neutral current measurement. Due to their low voltage insulation, they can only be used around insulated cables.

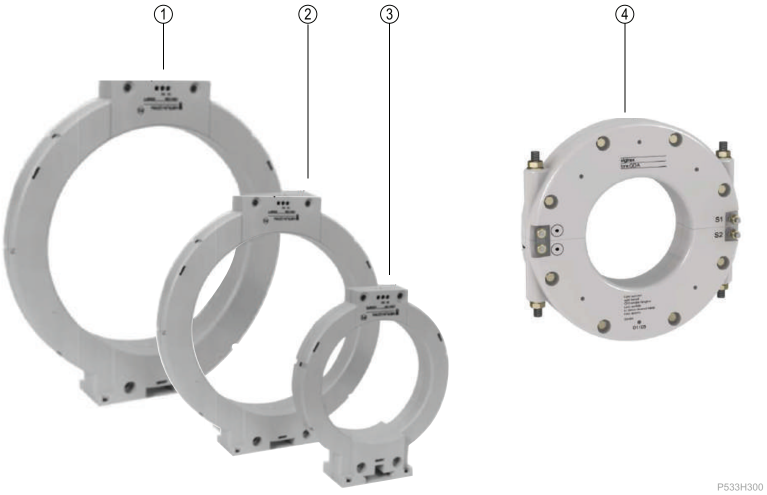
CSH300 ①, CSH200 ② and CSH120 ③ are closed CTs, with different inner diameters:

- Inner diameter of CSH300 ①: 291mm (11.46 in.)
- Inner diameter of CSH200 ②: 196 mm (7.72 in.)
- Inner diameter of CSH120 ③: 120 mm (4.72 in.)

GO110 ④ is a split CT, with an inner diameter of 110 mm (4.33 in.).

> **NOTE:** GO110 core balance transformer is not sold anymore. However, for any refurbishing projects, the PowerLogic P5 protection relay is compliant with this core balance transformer and therefore can be connected together as shown in Typical application diagrams, page 73.

Figure 100 - Core balance current transformers (CT)



① CSH300 core balance CT

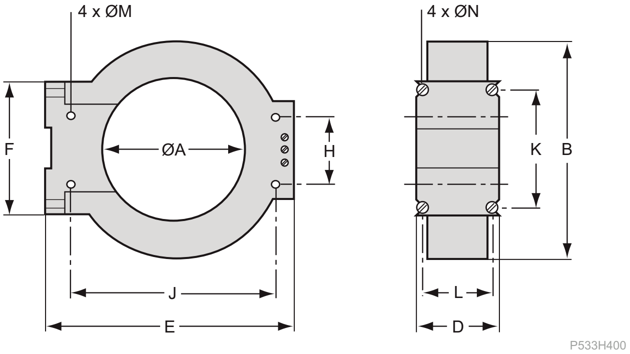
② CSH200 core balance CT

③ CSH120 core balance CT

④ GO110 core balance CT

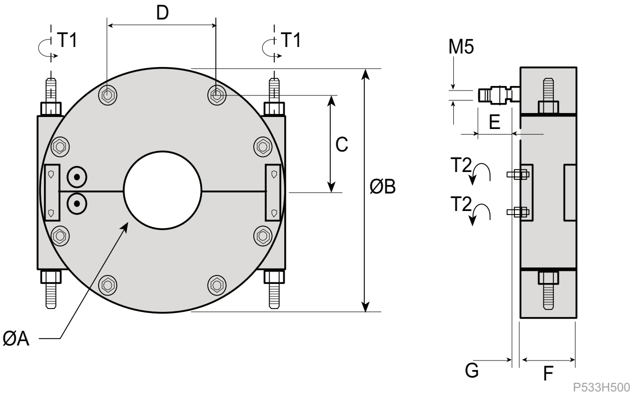
Dimensions

Figure 101 - CSH120, CSH 200 and CSH300 dimensions



	A	B	D	E	F	H	J	K	L	M	N
CSH120	120 mm (4.72 in.)	164 mm (6.46 in.)	44 mm (1.73 in.)	190 mm (7.48 in.)	80 mm (3.15 in.)	40 mm (1.57 in)	166 mm (6.54 in.)	65 mm (2.56 in.)	35 mm (1.38 in.)	6 mm (0.24 in.)	5 mm (0.2 in.)
CSH200	196 mm (7.72 in.)	256 mm (10.1 in.)	46 mm (1.81 in.)	274 mm (10.8 in.)	120 mm (4.72 in.)	60 mm (2.36 in.)	254 mm (10 in.)	104 mm (4.09 in.)	37 mm (1.46 in.)		
CSH300	291 mm (11.46 in.)	360 mm (14.17 in.)	46 mm (1.81 in.)	390 mm (15.35 in.)	120 mm (4.72 in.)	60 mm (2.36 in.)	369 mm (14.53 in.)	104 mm (4.09 in.)	37 mm (1.46 in.)		

Figure 102 - GO110 dimensions



A	B	D	E	F	G
110 mm (4.33 in.)	224 mm (8.82 in.)	92 mm (3.62 in.)	16 mm (0.63 in.)	44 mm (1.73 in.)	8 mm (0.31 in.)

Opening and closing the GO110 CT

To open the GO110 CT:

- Undo both T1 nuts and remove the two pins.
- Undo both T2 nuts and remove the two bars.

To close the GO110 CT:

- Replace the two bars and tighten both T2 nuts (T2 tightening torque: 30 N·m or 0.34 lb-in).
- Replace the two pins and tighten both T1 nuts (T1 tightening torque: 70 N·m or 0.79 lb-in).

Assembly

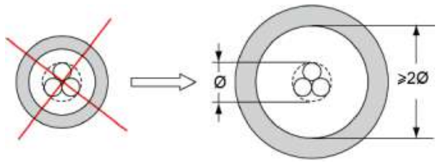
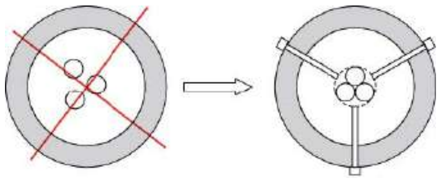
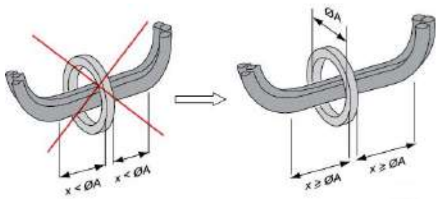
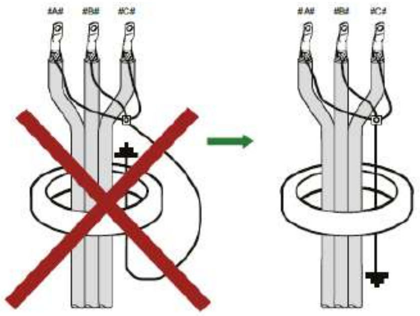
⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Only qualified personnel should install this equipment. Such work should be performed only after reading this entire set of instructions.
- NEVER work alone.
- Turn off all power supplying this equipment before working on or inside it. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing device to confirm that all power is off.
- Only CSH120, CSH200, CSH300 and GO110 core balance CTs can be used for direct neutral current measurement.
- Install the core balance CTs on insulated cables.
- Cables with a rated voltage of more than 1000 V must also have an grounded shielding.

Failure to follow these instructions will result in death or serious injury.

Table 20 - Instructions for assembling the core balance CTs

	Select a CT with a diameter at least twice the size of the cable harness going through it.
	Group the cable(s) in the middle of the CT and use non-conducting binding to hold the CT in place around the cable harness.
	Do not bend the cable(s) close to the CT; install the CT on a straight section of the cable(s) that is at least twice as long as the CT diameter.
	Remember to pass the shielded grounding braid on the cables back through the CT. Check that the braid goes the right way through the CT.

When assembling the core balance CTs, group the medium voltage cable (or cables) in the middle of the core balance CT, use non-conductive binding to hold the cables, and remember to insert the shielded grounding braid of the medium voltage cable through the core balance.

Connection

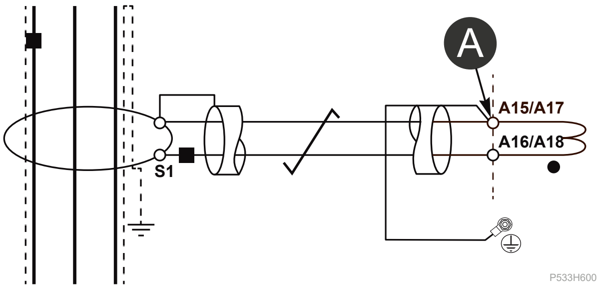
Recommended cable:

- Sheathed cable (to be compliant with electromagnetic compatibility requirements), shielded by tinned copper braid.
- Resistance per unit length < 100 mΩ/m (30.5 mΩ/ft).
- Minimum dielectric strength: 1000 V (700 Vrms).
- Connect the cable shielding in the shortest manner possible to the protection relay.
- Flatten the connection cable against the metal frames of the cubicle.

Core balance CT	Wiring	Type of terminal	Tools	Tightening torque
CSH120 CSH200 CSH300	1 to 2.5 mm^2 (AWG 18 to 14) wire[39] Stripped length: 8 mm (0.31 in.)	M3.5 screw	Flat blade screwdriver 3.5 mm (0.14 in.)	0.8 to 1 N·m (7.1 to 8.8 lb-in.)
GO110	1.5 to 6 mm^2 (AWG 16 to 10) wire[39] Lug with inner diameter: 5 mm (0.2 in.)	M5 screw	Flat spanner for M5 nut	30 N·m (0.34 lb-in.)

The maximum resistance of the connection wiring must not exceed 4 Ω (20 m maximum for 100 mΩ/m or 66 ft maximum for 30.5 mΩ/ft).

Figure 103 - Connecting the core balance CT



A	CSH 20 A input on P5: terminals A15–A16 on standard CV/VT board or A1–A2 on LPCT/LPVT board CSH 2 A input on P5: terminals A17–A18 on standard CV/VT board or A3–A4 on LPCT/LPVT board

Note that for specific application, it is possible to connect 2 CSH200 core balance CTs in parallel, for example, when the medium-voltage cables have a large diameter, and the installation uses 2 or 3 conductors per phase.

NOTICE

UNINTENDED AND NUISANCE TRIPPING

The shield of the CSH cable must be connected to the nearest PowerLogic P5 protection relay stud with a cable of less than 12 cm (4.72 in.).

Failure to follow these instructions can result in equipment misoperation.

---

[39] Depending on the ground fault current input selected (2 A or 20 A).

Characteristics

Table 21 - Characteristics of the core balance CTs

Characteristics	CSH120	CSH200	CSH300	GO110
Inner diameter	120 mm (4.72 in)	196 mm (7.72 in)	291 mm (11.46 in.)	110 mm (4.33 in.)
Weight	0.6 kg (1.32 lb)	1.4 kg (3.09 lb)	2.5 kg (5.51 lb)	3.2 kg (7.04 lb)
Accuracy (1CT)	±5% at +20°C (68°F) ±6% max. at -25°C to 70°C (-13°F to +158°F)			< 0.5% (10 A to 50 A)
Accuracy (2 CTs in parallel)	-	±10%	±10%	-
Transformation ratio	470/1			
Maximum permissible current (1CT)	20 kA - 1s			
Operating temperature	-25°C to +70°C (-13°F to +158°F)			
Storage temperature	-40°C to +85°C (-40°F to +185°F)			

Interposing CSH30 (reference 59634)

Description

The interposing CSH30 is a ring-core CT which is used as an interface where the neutral current is measured using standard 1 A or 5 A current transformers and the P5 device is equipped with CSH 2/20A inputs. Such application may be present when using LPCTs for phase current measurement, but keeping conventional CT for neutral current measurement.

It is adapted for the type of current transformer, 1 A or 5 A, by the number of turns of the CT secondary wiring through the interposing CSH30 ring CT:

- 5 A rating - 4 turns
- 1 A rating - 2 turns

Figure 104 - Connection to 5 A secondary circuit: 4 turns

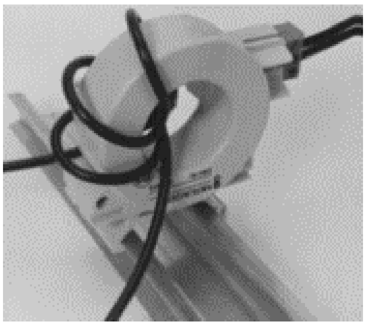
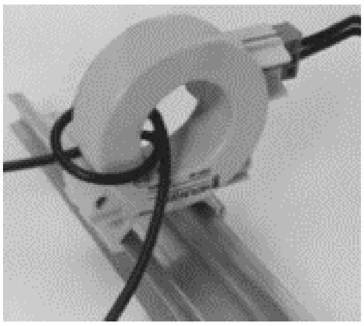


Figure 105 - Connection to 1 A secondary circuit: 2 turns

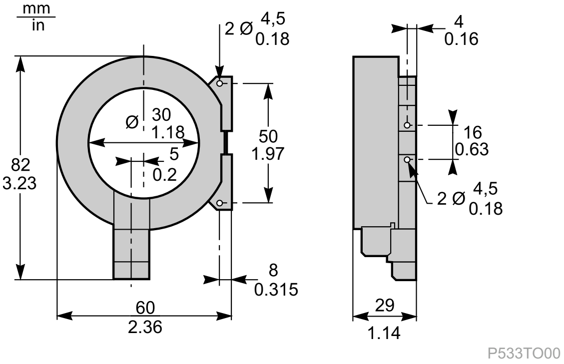


Dimensions

The CSH30 is mounted on symmetrical DIN rail, either in vertical or horizontal position.

Mechanical dimensions are given in the figure below:

Figure 106 - Dimensions for CSH30



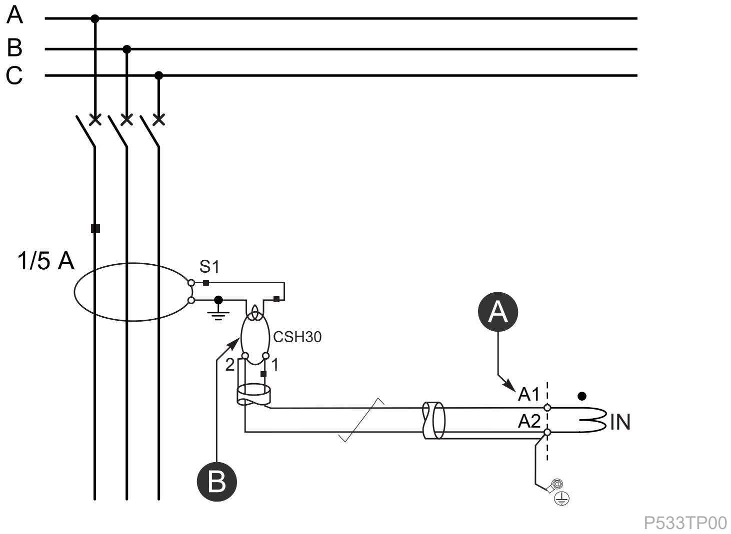
Connection

Recommended cable:

- Sheathed cable, shielded by tinned copper braid
- Minimum cable cross-section 0.93 mm² (AWG 18) (max. 2.5 mm², AWG 12)
- Resistance per unit length < 100 mΩ/m (30.5 mΩ/ft)
- Minimum dielectric strength: 1000 V (700 Vrms)
- Maximum length: 2 m (6.6 ft)

The connection cable shielding has to be grounded on PowerLogic P5 end at one of the ground connections on the back plate. Do not ground the cable by any other means.

Figure 107 - Connection diagram of CSH30 interposing ring CT and P5 (CSH 20 A/CSH 2 A)



A	CT 1 A - interposing CSH30 - CSH 2 A input on P5 (terminals A17–A18 on standard CT/VT board or A3–A4 on LPCT/LPVT board) CT 5 A - interposing CSH30 - CSH 20 A input on P5 terminals A15–A16 on standard CT/VT board or A1–A2 on LPCT/LPVT board)	B	CT 1 A: 2 turns CT 5 A: 4 turns

Note that following terminals have to be connected to earth/ground:

- A15, A17 for standards CT/VT board
- A2, A4 for LPIT board

Characteristic

Table 22 - Characteristics of the interposing CSH30

Characteristics	CSH30
Weight	0.12 kg (0.265 lb)
Accuracy	±5% at +20°C (68°F) ±6% max. at -25°C to +70°C (-13°F to +158°F)
Operating temperature	-25°C to 70°C (-13°F to +158°F)
Storage temperature	-40°C to 85°C (-40°F to +185°F)

LPVT hub connector (reference EMS59573)

Description

The LPVT hub connector is a simple passive device that combines three LPVT signals coming from 3 different connectors on one single RJ45 connection.

The output of the LPVT hub connector is directly connected to the LPVT input of PowerLogic P5 protection relay.

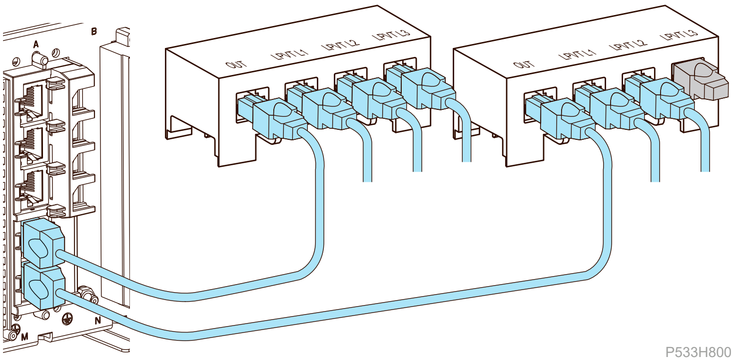
The LPVT hub connector also manages the presence of each LPVT connection thanks to a daisy chain across the three sensors. If at least one LPVT is missing or one cable is damaged, an alarm event is logged and displayed on the local panel.

Figure 108 - LPVT hub connector

Connection

The LPVT hub connector is connected to protection relay through its RJ45 output connector and to the LPVT sensors through the RJ45 input connectors.

Figure 109 - LPVT hub connector connected to PowerLogic P5x30 protection relay



Characteristics

Table 23 - Characteristics of the LPVT hub connector

Characteristics	Values	
Electric		
Input voltage	< 10 V	
Input voltage limits	< 30 V	
Network frequency	50/60 Hz	
Electrical connection	Output: RJ45 connector Input: 3 RJ45 connector	
Form factor		
Dimension (L x W x H)	95 mm x 40 mm x 40 mm (3.74 x 1.57 x 1.57 in)	
Weight	0.25 kg (0.55 lb)	
Mounting support	DIN rail	
Environment		
IP degree of protection	IEC 60529	IP30
IK degree of protection	IEC 62262	IK07
Ambient air temperature for operation	-	-40℃ to 85℃ (-40℉ to 185℉)
Ambient air temperature for storage	-	-40℃ to 85℃ (-40℉ to 185℉)
Fire resistance	IEC 60695-2-11	850℃ (1562℉)
Environmental characteristic	IEC 60068-2-11	Salt mist: 200 hours
Relative humidity	IEC 60068-2-30	95%
Operating altitude	-	≤ 3000 m (1.86 miles)

Voltage adapters (references EMS59572/EMS59574)

Description

The voltage transformer adapter is made with 4 resistor bridges used to interface conventional voltage transformers (VTs) with the PowerLogic P5 protection relay equipped for LPCT/LPVT sensors (please order this accessory separately from Schneider Electric).

Connection

NOTICE

INCORRECT VOLTAGE MEASUREMENT

- The ground of the connection diagrams below must be the same of the whole PowerLogic P5 protection relay. The 0 V of the PowerLogic P5 power supply input must be connected to this ground.
- Ground connection point of AC voltage adapter must be connected to the isolated ground of VT sensor (LV transformer). For other wiring cases, consult Schneider Electric.

Failure to follow these instructions can result in measurement error.

Figure 110 - 3 phase to neutral voltages connection

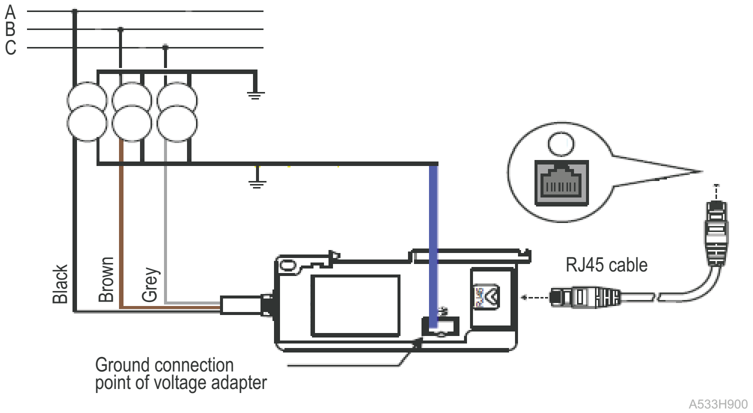


Figure 111 - 2 phase to phase voltages connection

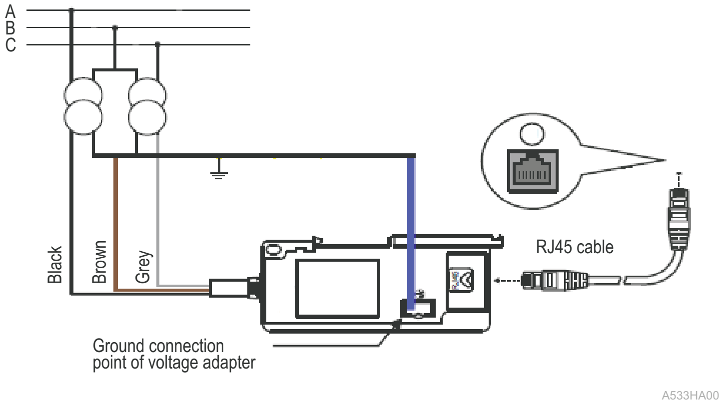


Figure 112 - 1 additional phase to phase voltage connection

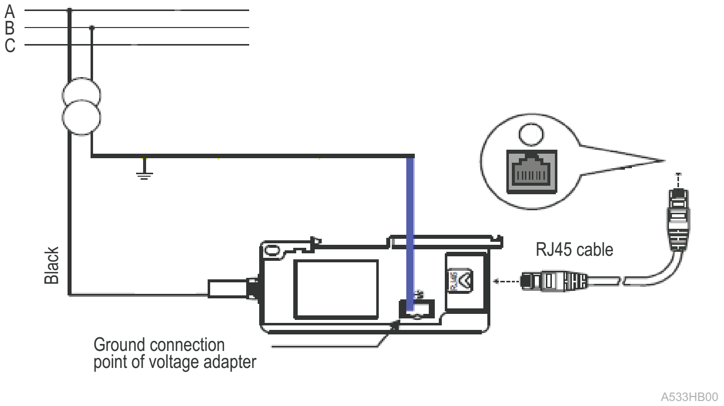
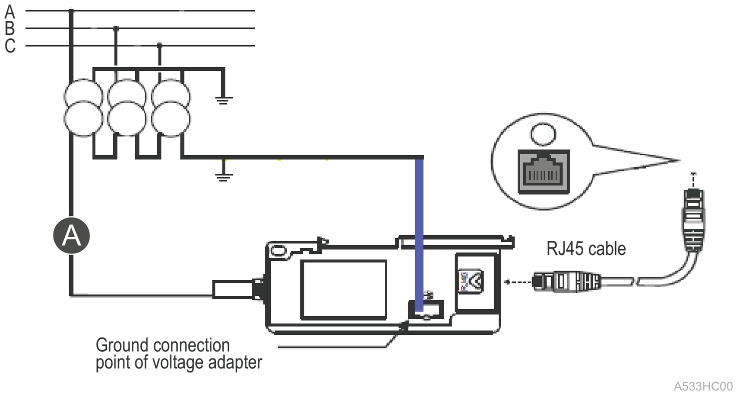


Figure 113 - Open-delta voltage connection



A	Cable: - Black for P5x30 - Brown for P5U20

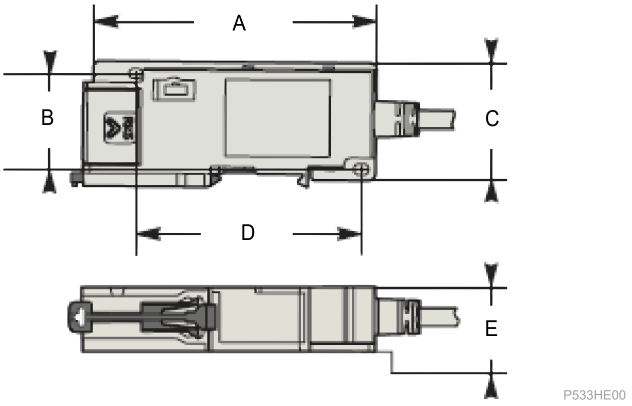
The Ethernet RJ45 cable is connected to the PowerLogic P5 protection relay. Length maximum: 4 m (13.12 ft)

- CCA770 - 0.6 m (1.97 ft) (reference: 59660)
- CCA772 - 2 m (6.56 ft) (reference: 59661)
- CCA774 - 4 m (13.12 ft) (reference 59662)

NOTE: The voltage adapter is delivered with black, brown, grey and light blue cable. The light blue cable in the voltage transformer adapter input is not used.

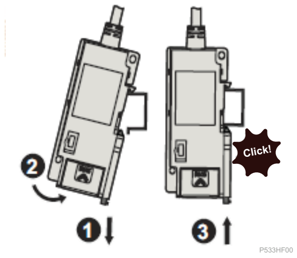
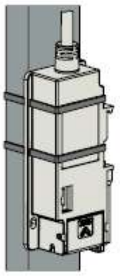
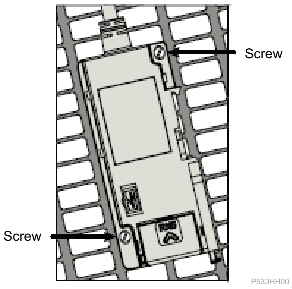
Dimensions

Figure 114 - External dimensions of the AC voltage adapter



A	B	C	D	E
120 mm (4.72 in.)	38 mm (1.49 in.)	52 mm (2.04 in.)	90 mm (3.54 in.)	25 mm (0.98 in.)

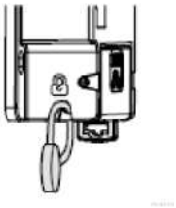
Mounting

DIN rail mounting	Fastening with collar	Mounting on telequick grid
		
Mounting the adapter by its fixture structure on rail	Mounting the adapter using two fastening collars (width: 4 mm/0.16 in)	Mounting the adapter on Telequick grid using two screws (4 mm/0.16 in)

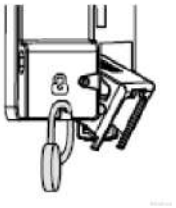
RJ45 terminal locking

The RJ45 input of the voltage transformer adapter can be locked in the open or closed position by placing a seal in the hole marked with a lock symbol (see figure below). This allows to lock the RJ45 connector of the Ethernet cable in its slot or helps prevent its connection.

Figure 115 - RJ45 terminal lock



Locked in close position



Locked in open position

Characteristics

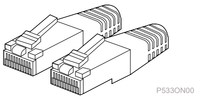
Table 24 - Characteristics of the voltage adapter

Characteristics	Standard	Value
Input voltage		100 V adapter (EMS59572): 50 V AC to 200 V AC (phase to phase) 400 V adapter (EMS59574) [40]: 38 V AC to 400 V AC (phase to phase)
Voltage max		600 V max permanent
Network frequency		50/60 Hz
Ambient air temperature for operation	IEC 60068-2-1 IEC 60068-2-2	-40℃ to 70℃ (-40℉ to 158℉)
Ambient air temperature for storage	IEC 60068-2-1 IEC 60068-2-2	-40℃ to 85℃ (-40℉ to 185℉)
Humidity	IEC 60068-2-30	95% HR; 144 hours (6 cycles of 12 hours at 55°C (131°F) and another 12 hours at 25°C (77°F))
Salt spray	IEC 60068-2-11	168 hours
Vibration	IEC 60068-2-6	10 Hz to 2000 Hz; 10 cycles at 2 Gn (peak value)
Bump	IEC 60068-2-29	20 Gn/16 ms/1000 bumps, module de-energized
Shock	IEC 60068-2-27	10 Gn; 11ms; 3 pulses, module in operation
Seismic	IEC 60255-21-3	Class 2 - module in operation: 3 to 35 Hz/15 mm/2 Gn/1 cycle Horizontal axe 3 to 35 Hz/7 mm/1 Gn/1 cycle Vertical axe
High voltage withstand (dielectric)	IEC 60255-27	2 kV for 1 minute
Impulse voltage	IEC 60255-27	5 kV, 1.2/50 µs, 0.5 J
Robustness	IEC 62262	IK7, 2J
Degree of protection	IEC 60529	IP20, module body (without wires)
Weight		150 g (0.33 lb)
Mounting support		Symmetrical DIN rail

RJ45 LPCT/LPVT plug

This RJ45 LPCT/LPVT plug (REL51079) (see Connector A cabling kit for LPCT/ LPVT analogue inputs (REL51079), page 82) can be used on LPCT or LPVT input ports of PowerLogic P5, or on the LPVT hub connector (reference EMS59573).

Figure 116 - RJ45 LPCT/LPVT plug

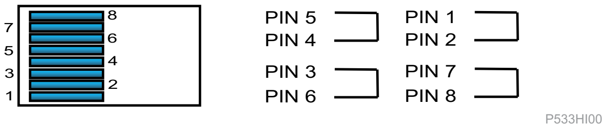


The pins of this plug are shorted between 1-2, 3-6, 4-5, and 7-8. The shorted 3-6 pins will close the loop of the sensor presence detection. The shorted 1-2, 4-5 and 7-8 pins zero the low voltage inputs.

---

[40] The minimum required versions of PowerLogic P5 firmware and LPVT board for EMS59754 are:
- PowerLogic P5 firmware V02.502 or later
- LPVT board version 2.1 or newer

Figure 117 - Pairs of the RJ45 connector



Arc-flash sensor (reference REL52801 to REL52810)

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

Clean the arc sensor periodically as instructed in this user manual and after an arc-flash fault.

Failure to follow these instructions will result in death or serious injury.

Description

The arc-flash sensors are used by PowerLogic P5x30 to detect light coming from an arc-flash incident. They are installed in the protection zone and connected to the connector terminal on the protection relay.

The arc-flash sensor is activated by strong light caused by an arcing fault. The sensor transforms light to electrical signal, which is used by the protection relay to detect an arc-flash and provides the corresponding protection function.

Dimensions

Figure 118 - Dimensions of the standard arc-flash sensors

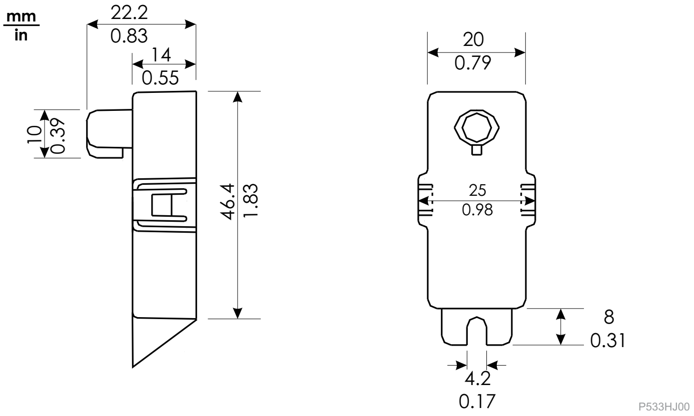
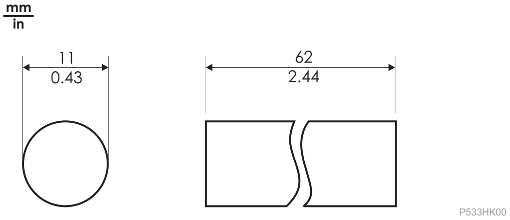


Figure 119 - Dimensions of the pipe type arc-flash sensors



Characteristics

Table 25 - Characteristics of the standard arc-flash sensors

Characteristics	REL52801	REL52802	REL52803	REL52804	REL52805	REL52806
Cable length (m)[41]	6	20	20	6	6	6
Shielded cable	-	-	■	-	-	■
Halogen free	-	■	-	■	-	-
Material	Plastic					
Weight (g/lb)	1,000/2.2	1,300/2.87	1,300/2.87	300/0.66	400/0.88	400/0.88
Environment	Pollution Degree 2					
Operation temperature	-25°C to +70°C (-13°F to +158°F)					
Light spectrum sensitive area	400 – 1100 nm					
Detection time	100 to 300 µs depending on the flashlight received					
Light sensitivity	8,000 – 10,000 lux					
Loop supervision	Yes					

Table 26 - Characteristics of the pipe type arc-flash sensors

Characteristics	REL52807	REL52808	REL52809	REL52810
Cable length (m)[41]	20	20	6	6
Shielded cable	-	■	-	■
Halogen free	-	-	-	-
Material	Plastic			
Weight (g/lb)	1,000/2.2	1,300/2.87	300/0.66	400/0.88
Environment	Pollution Degree 2			
Operation temperature	-25°C to +70°C (-13°F to +158°F)			
Light spectrum sensitive area	400 – 1100 nm			
Detection time	100 to 300 µs depending on the flashlight received			
Light sensitivity	8,000 – 10,000 lux			
Loop supervision	Yes			

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

Do not extend the length of arc-flash sensor cables.

Failure to follow these instructions will result in death or serious injury.

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[41] To connect the interface in the PowerLogic P5 protection relay, use REL52883 cable.

Mounting the sensors to the switchgear

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, NOM-029-STPS-2011, or CSAZ462.
- The arc fault detection system is not a substitute for proper PPE when working on or near equipment being monitored by the system.
- Information on this product is offered as a tool for conducting arc-flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.
- Only qualified personnel is allowed to install and service this equipment. Read this entire set of instructions and check the technical characteristics of the device before performing such work.
- Perform wiring according to national standards (NEC) and any requirements specified by the customer.
- Observe any separately marked notes and warnings.
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on this equipment, disconnect all sources of electric power. Assume all circuits are live until they are completely de-energized, tested, and tagged. Pay particular attention to the design of the power system. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing relay to ensure that all power is off.
- The equipment must be properly grounded.
- Connect the device's protective ground to functional earth according to the connection diagrams presented in this document.
- Do not open the device. It contains no user-serviceable parts.
- Install all devices, doors and covers before turning on the power to this device.

Failure to follow these instructions will result in death or serious injury.

Install arc-flash sensors inside the switchgear. There are two options for the mounting:

- in customer-drilled holes on the switchgear
- on VYX001 Z-shape or VYX002 L-shape mounting plates available from Schneider Electric or locally fabricated from supplied drawings

Figure 120 - VYX 001 mounting plate for sensor

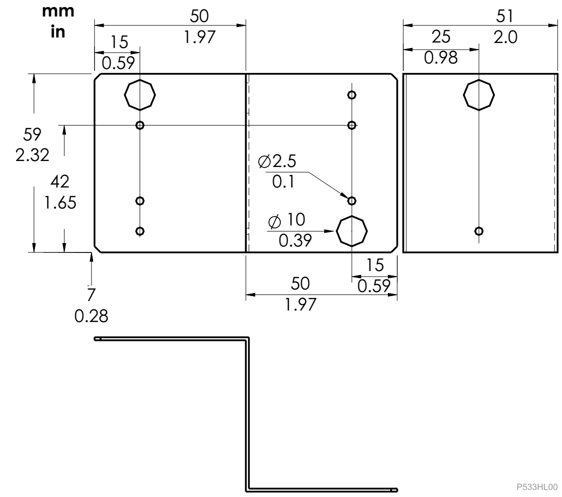


Figure 121 - VYX 002 mounting plate for sensor

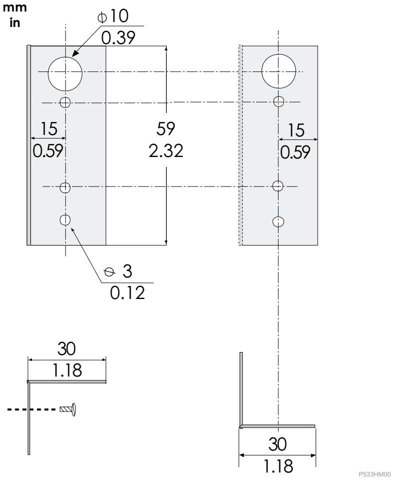
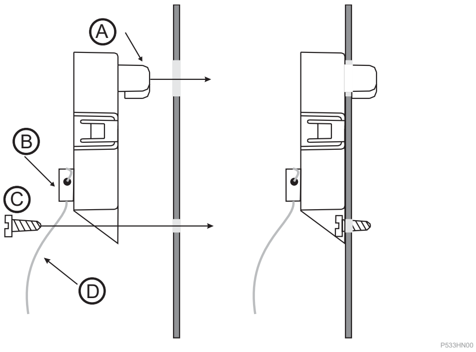


Figure 122 - Mounting the sensor



Ⓐ Active part of the sensor

Ⓑ Cable clamp

Ⓒ Fastening with M4 x 15 mm (0.59 in) screw

Ⓓ Sensor cable

- Press the active part of the sensor through the 10 mm hole on the panel.
- Fix it with an M4 screw.

Connecting the sensors to the device

The sensors are delivered with 6 m (19.7 ft) or 20 m (65.6 ft) cables.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

Do not extend the length of arc-flash sensor cables.

Failure to follow these instructions will result in death or serious injury.

After mounting the sensors, connect them to the device.

1. Route the wire to the nearest device with the shortest route possible.

   Cut the wire to a suitable length.

   Take into account the wiring methods inside the equipment. This should be compliant with local regulations.

2. Connect the arc sensors to the screw terminals.

   The polarity of the arc sensor cables is not critical.

Figure 123 - Point sensor connections

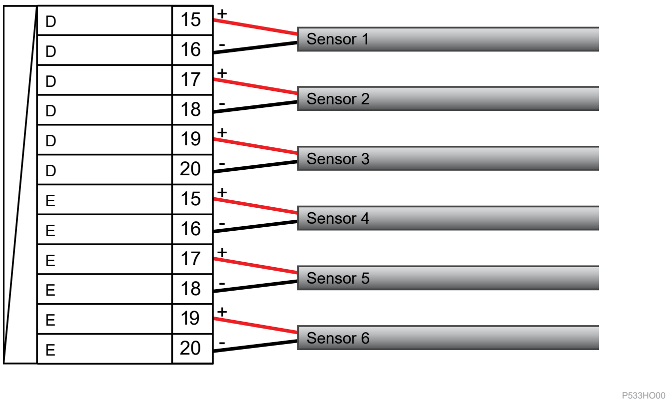


Table 27 - Point sensor connections

Slot	Pin no.	Description
D	15	Arc sensor 1 positive terminal
	16	Arc sensor 1 negative terminal
	17	Arc sensor 2 positive terminal
	18	Arc sensor 2 negative terminal
	19	Arc sensor 3 positive terminal
	20	Arc sensor 3 negative terminal
E	15	Arc sensor 4 positive terminal
	16	Arc sensor 4 negative terminal
	17	Arc sensor 5 positive terminal
	18	Arc sensor 5 negative terminal
	19	Arc sensor 6 positive terminal
	20	Arc sensor 6 negative terminal

3. Connect the cable shield to the corresponding grounding stud connector on slot D or E when using sensors with shielded cables.

MET148-2 - temperature sensor module (reference 59641)

Up to 2 MET148-2 temperature sensor modules can be connected to PowerLogic P5 protection relay.

DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

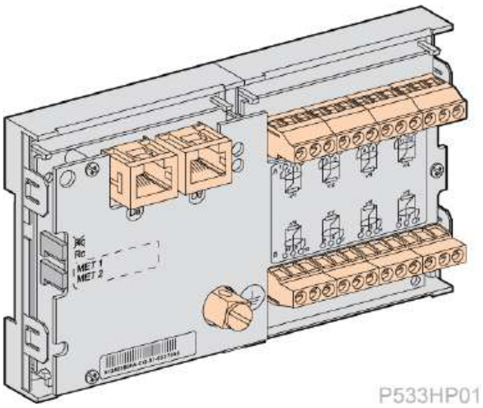
Verify that the temperature sensors are isolated from dangerous voltages.

Failure to follow these instructions will result in death or serious injury.

Description

The temperature sensor module is an external module used for temperature measurement with Resistance Temperature Detectors (RTDs). It is connected to the extension module. It is an optional selection when ordering the device or can be purchased after on-site installation. It provides 8 RTD inputs.

Figure 124 - MET148-2 temperature sensor module



The MET148-2 module can be used to connect 8 temperature sensors (RTDs) of the same type:

- Pt100, Ni100 or Ni120 type RTDs, according to parameter setting
- 3-wire temperature sensors
- A single module can be connected to a PowerLogic P5 relay by one of the CCA770 (0.6 m or 2 ft), CCA772 (2 m or 6.6 ft) or CCA774 (4 m or 13.1 ft) cords

The temperature measurement (for example, in a transformer or motor winding) can be used by the following protection functions:

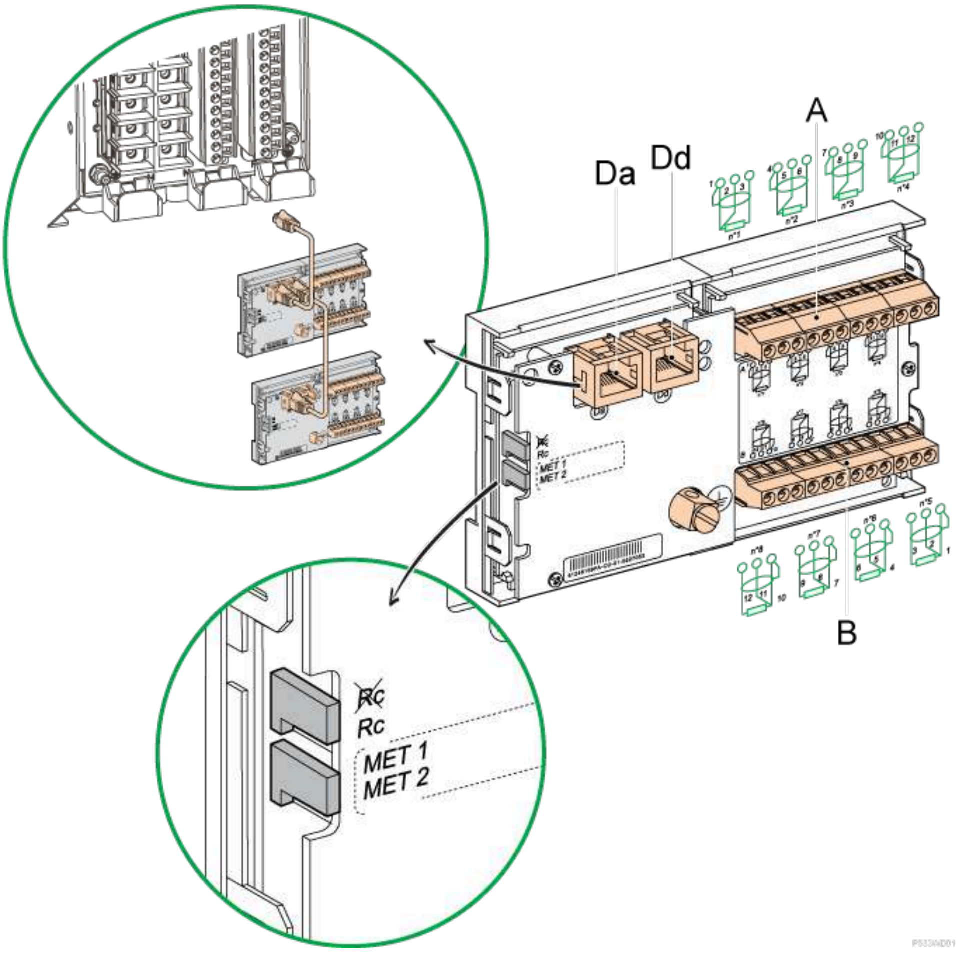
- Thermal overload (to take ambient temperature using RTD number 8)
- Temperature monitoring.

Connection

The MET148-2 temperature sensor module is connected to the extension port slot P of the PowerLogic P5 protection relay by using the EXT IN port and OUT port of IRIG-B. The cable used for connection must be shielded and of a length not exceeding 10 m (32.8 ft).

Since there are other modules that can also be connected to the slot P, refer to Accessories that can be cable connected to slot P and their sequence, page 111 for their sequence of connection.

Figure 125 - Connection of the MET148-2 temperature sensor module



Connectors and terminals on the module:

- A: Terminal block for RTDs 1 to 4
- B: Terminal block for RTDs 5 to 8
- Da: RJ45 connector to connect the module to the PowerLogic P5 protection relay with a CCA77x cord
- Dd: RJ45 connector to link up the next remote module with a CCA77x cord

Jumper for impedance matching terminal with load resistor (Rc) to be set to:

- ~~RC~~ - if the module is not the last interlinked module (default position).
- RC - if the module is the last interlinked module.

Jumper used to select module number, to be set to:

- MET1: first MET148-2 module, to measure temperatures T1 to T8 (default position)
- MET2: second MET148-2 module, to measure temperatures T9 to T16.

LED indication

There are 2 LEDs indicating the status of the MET148-2 module.

Green LED status	Red LED status	Status of the MET148-2 module
On	On	Initialization of the MET148-2 module.
On	Off	The connection between the MET148-2 module and PowerLogic P5 is in normal state.
On	Flashes	The MET148-2 module and PowerLogic P5 is not connected.

For the other LED indications, see Troubleshooting the MET148-2 module, page 680.

Characteristics

Table 28 - Characteristics of the MET148-2 temperature sensor module

Characteristics	Values	
Dimensions (L × W × D)	144 mm × 88 mm × 30 mm (5.67 in × 3.46 in × 1.81 in)[42]	
Weight	0.2 kg (0.441 lb)	
Mounting support	On symmetrical DIN rail	
Operating temperature	-40°C - +70°C (-40°F - +158°F)	
Temperature sensors		
Type of sensors	Pt100	Ni100/Ni120
Isolation from ground	None	None
Current to RTD	4 mA	4 mA
Maximum distance between sensor and MET148-2	1 km (0.62 mi)	

Recommended cross-sections according to distance:

- Up to 100 m (330 ft) ≥ 1 mm^2 (AWG 18)
- Up to 300 m (990 ft) ≥ 1.5 mm^2 (AWG 16)
- Up to 1 km (0.62 mi) ≥ 2.5 mm^2 (AWG 12)

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[42] Depth is 70 mm (2.8 in) with cable connected

IRIG-B module (reference REL51045)

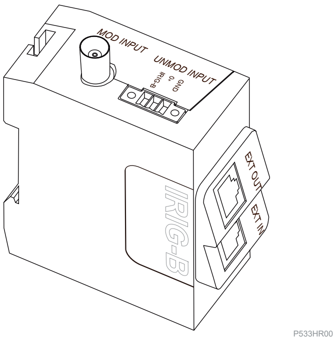
Description

The IRIG-B module is an external module used for accurate time synchronization. It is connected to the extension module. It is an optional selection when ordering the device or can be purchased after on-site installation.

The module provides both a modulated (MOD INPUT) and an unmodulated input (UNMOD INPUT) and automatically detects the type of input. No configuration of input type is needed in the PowerLogic P5 protection relay.

It requires no auxiliary supply.

Figure 126 - IRIG-B module



Characteristics

Table 29 - Characteristics of the IRIG-B module

Characteristics	Values
Standard	
Standard	IRIG 200-04
Form factor	
Height	95 mm (3.7 in)
Width	36 mm (1.4 in)
Depth	87 mm (3.4 in)
Weight	100 g (3.53 oz)
Mounting support	Symmetrical DIN rail
Modulated IRIG-B input	
Connection	BNC socket
Type of cable	50 Ohm coaxial
Length of cable	< 150 m (492.13 ft)
Time code format	B120 to B127
Input signal level	200 mV to 10 V
Unmodulated IRIG-B input	
Connection	Screw-type terminals
Type of cable	Twisted pair
Length of cable	< 50 m (164.04 ft)
Time code format	B000 to B007
Input impedance	10 kΩ
Input signal level	2 V to 6 V peak

Connection

DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Install IRIG-B module between the PowerLogic P5 protection relay and any other accessories like MET148-2 temperature module.
- Do not connect any accessories between the PowerLogic P5 protection relay and the IRIG-B module.

Failure to follow these instructions will result in death or serious injury.

The IRIG-B module is connected to the PowerLogic P5 protection relay at its EXT IN port. The cable used for connection must be shielded and of a length not exceeding 10 m (32.8 ft).

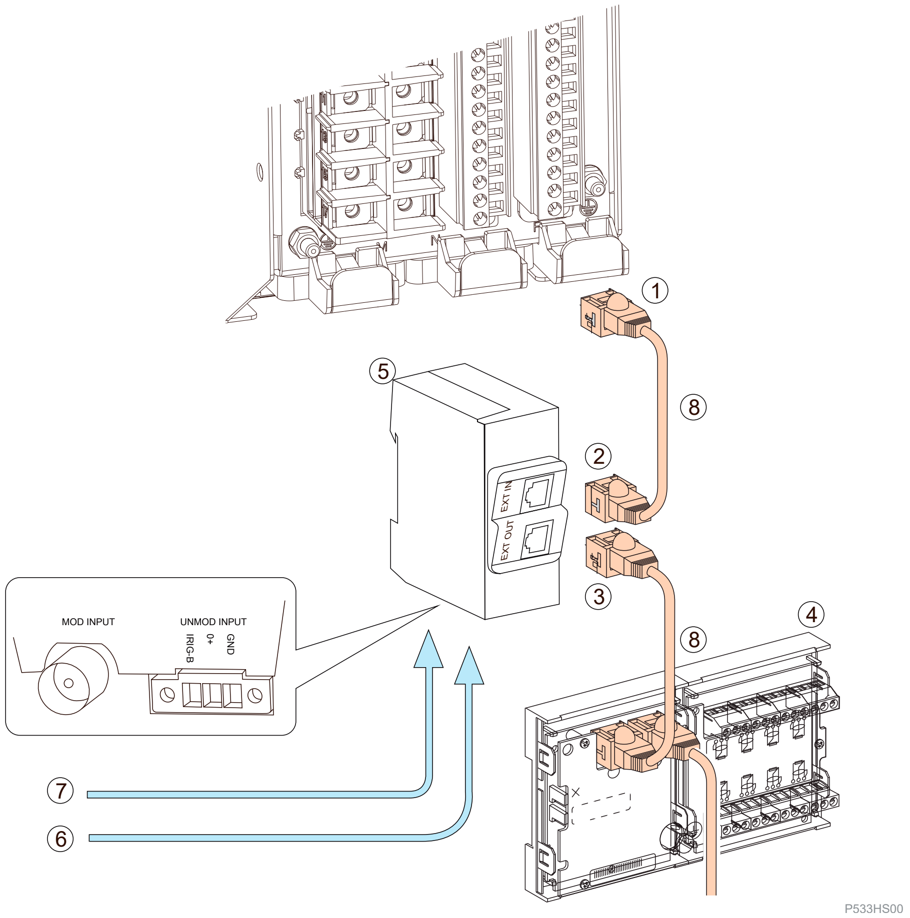
The IRIG-B module provides an additional extension port (EXT OUT) to connect other accessories such as the MET148-2 module with CCA77x cords.

The time source is connected to the module through the modulated input, or through the unmodulated input by connecting signal + to the IRIG-B terminal, and signal - to the 0+ terminal.

> **NOTE:** If one source is connected on the modulated input and another one on the unmodulated input, the modulated signal is prioritized.

Since there are other modules that can also be connected to the slot P of PowerLogic P5, refer to Accessories that can be cable connected to slot P and their sequence, page 111 for their sequence of connection.

Figure 127 - Connection of IRIG-B



①	to extension port P of relay	⑤	IRIG-B module
②	to EXT IN port of IRIG-B	⑥	Time source to unmodulated IRIG-B input

③ to EXT OUT port of IRIG-B

④ MET148-2 module

⑦ Time source to modulated IRIG-B input

⑧ CCA77x cord

CLIO module (REL70071)

Description

Each CLIO (current loop input/output) module provides:

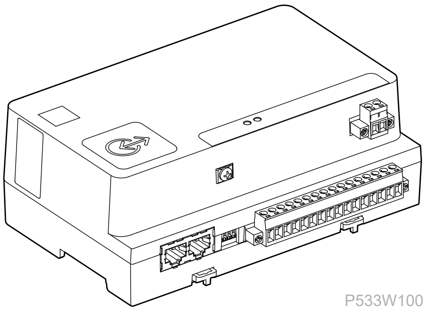
- four analog (or current loop) inputs for transducers, which provide DC currents proportional to monitored signals like speed, pressure or temperature;
- four analog outputs to feed measured analog signals (such as voltage, current, power, and so on) from PowerLogic P5 into standard current loops, for example to supply moving coil ammeters for indication or feeding into analog RTUs of a SCADA.

Four standard DC current ranges are supported: 0 to 1 mA, 0 to 10 mA, 0 to 20 mA or 4 to 20 mA.

PowerLogic P5 supports the connection to 3 CLIO modules maximum.

The CLIO modules can be linked with MET148-2 and IRIG-B module in series (Daisy chain connection). See Accessories that can be cable connected to slot P and their sequence, page 111 for their connection sequence and maximum number.

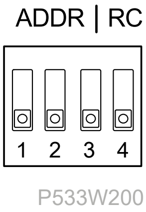
Figure 128 - CLIO module



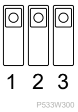
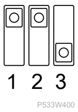
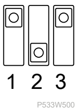
Setting the address

PowerLogic P5 supports the connection with maximum 3 CLIO modules, therefore, the modules must be set to different addresses to ensure the communication with correct module. The setting of address is made by the ADDR switch at the bottom of the CLIO module.

Figure 129 - The ADDR switch and RC switch



The addresses of the CLIO modules are set as per following table.

ADDR switch positions			
Module address	000	001	010

NOTE: The address settings of the CLIO modules must not be the same to avoid that the connection to the module with repeated address will be lost.

Use of termination option

The connection between PowerLogic P5 and the CLIO modules is made by Daisy chain. If a CLIO module is the last interlinked module, the termination of the chain is done by activating its RC switch.

Such termination must not be active in other modules in the chain.

Termination active	
Termination not active	

Installation/uninstallation

The CLIO module is mounted on DIN rail.

⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- NEVER work alone.
- Turn off all power supplying this equipment before working on or inside it.
- Verify that all power is off using a properly rated voltage sensing device.
- Connect the device to the ground with a ring terminal attached to the ground screw.
- Check the equipotential grounding network and test the grounding during installation.

Failure to follow these instructions will result in death or serious injury.

NOTE: Consider all sources of power when turning off the power supply, including the possibility of backfeeding.

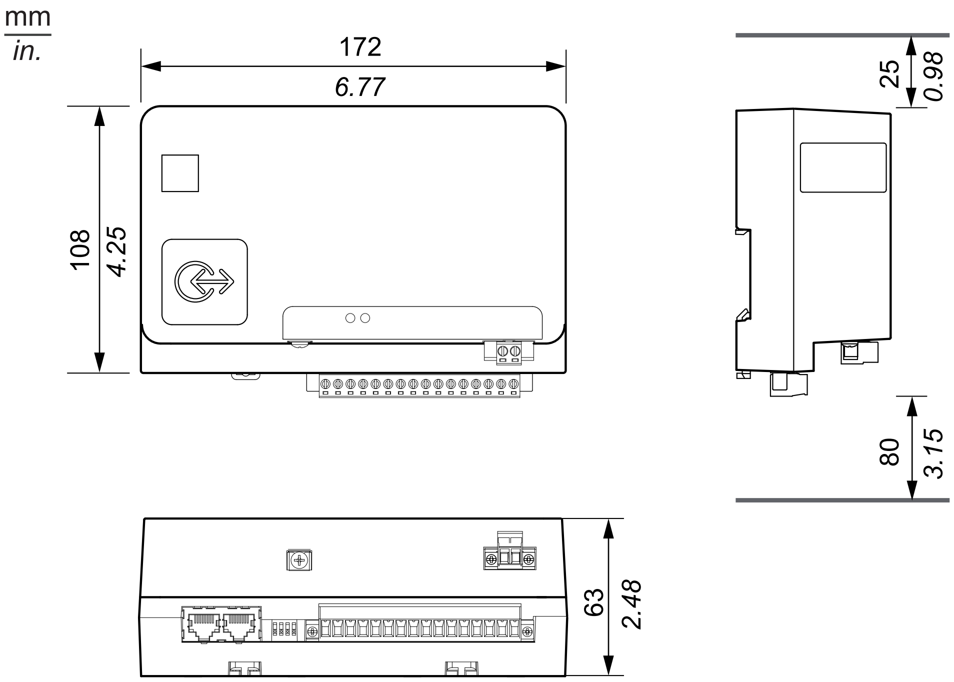
⚠DANGER

FIRE HAZARD

- Apply proper tightening torque to all wire connections.
- Never touch electronic parts.

Failure to follow these instructions will result in death or serious injury.

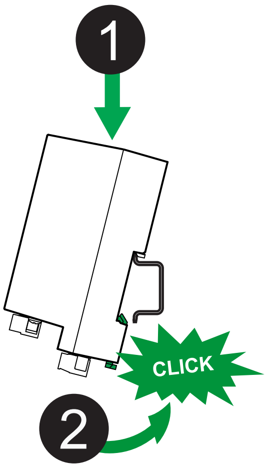
Figure 130 - Dimension and clearance of CLIO module



P533W800

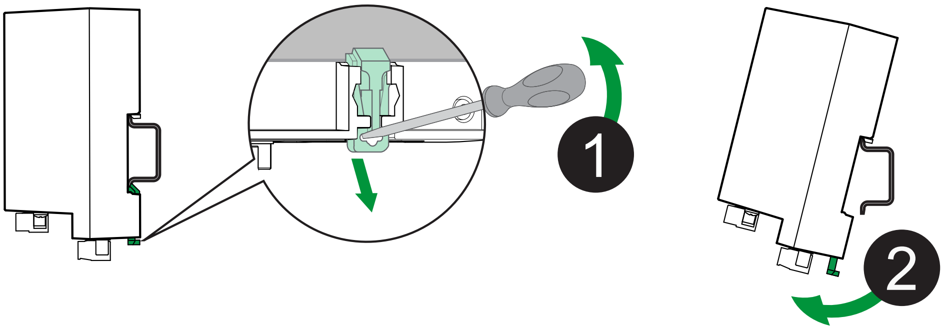
Figure 131 - DIN rail mounting and unmounting of CLIO module

Mounting



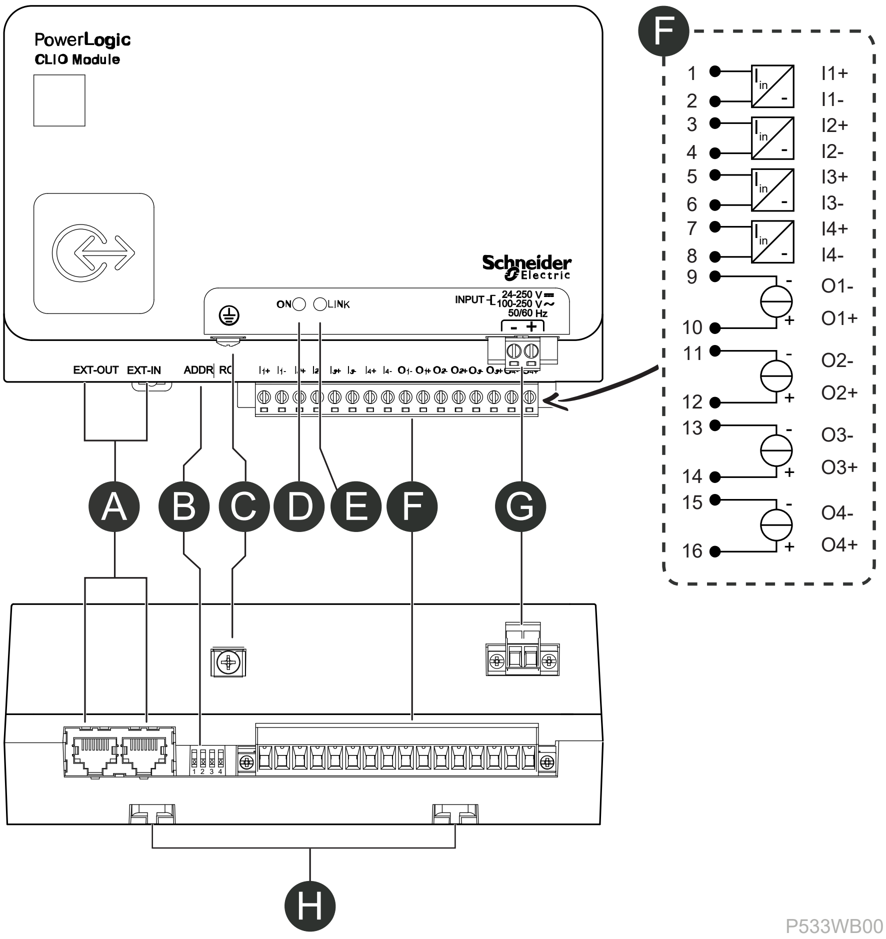
P533W900

Unmounting



P533WA00

Figure 132 - Parts and wiring of CLIO module



A	Communication port	B	DIP switches
C	Functional ground	D	Power LED
E	LINK LED	F	Analog inputs/outputs
G	24...250 V DC power supply input 100...250 V AC power supply input 50 Hz or 60 Hz	H	DIN mounting clips

Table 30 - LED indications

Power LED		Link LED	
LED status	Module status	LED status	Module status
Off	Power is off	Off	No data received from the IED
Green	Power is on	Yellow	Handshaking with the IED
		Flashing yellow every 5 s	Handshake successfully with the IED

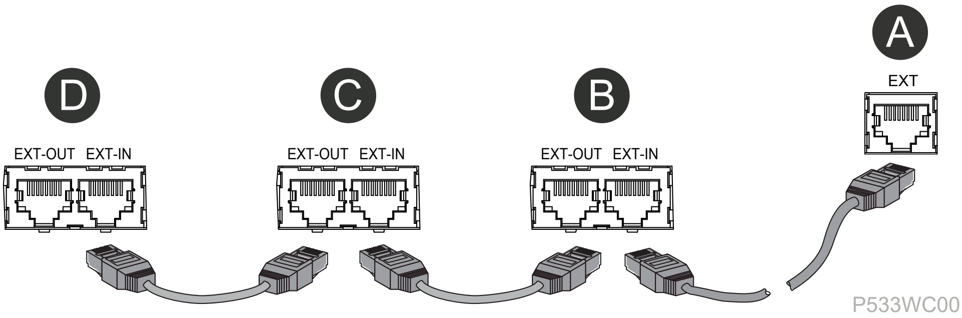
Connection

The connection between PowerLogic P5 and the CLIO modules is made by Daisy chain with twisted pair, shielded RJ45 cables, maximum length of the cable is 3 m (10 ft). The cable is connected to Slot P of PowerLogic P5.

NOTE: Before making connection, make sure you have installed the extension module (reference REL51034) or the extension Zigbee module (reference REL51044) to the slot P of PowerLogic P5.

Since there are other modules that can also be connected to the slot P, refer to Accessories that can be cable connected to slot P and their sequence, page 111 for their sequence of connection.

Figure 133 - Connection between PowerLogic P5 and the CLIO modules



A	PowerLogic P5, Slot P	B	CLIO module 1
C	CLIO module 2	D	CLIO module 3

NOTE: Make sure you have correctly set the addresses of CLIO modules and made the termination setting, refer to Setting the address, page 141 and Use of termination option, page 142 for detail.

Configuration with eSetup Easergy Pro

Number of CLIO modules installed

This setting can be found in eSetup Easergy Pro in **GENERAL / Analogue I/O configuration**, it defines the number of connected CLIO modules, with selectable values from 0 to 3. When no CLIO module is needed, simply set 0.

Configuration of CLIO module

The settings of CLIO module are made in eSetup Easergy Pro in **PROTECTION / Analogue I/O n**, where n = 1 to 3 depends on the number of connected CLIO modules. The input settings, enabling/disabling the monitor and alarm settings are configured in **Input configuration** and **Input settings**. The output settings are configured in **Output configuration**.

NOTICE

RISK OF CONNECTED EXTERNAL DEVICE DAMAGE

- Disable the analog output channel before changing the DC range setting of the channel.
- Before enabling the analog output channel, check consistency of output range setting with input range of the connected external device.

Failure to follow these instructions can result in equipment damage.

For further details refer to Analogue inputs and outputs, page 510.

Characteristics

Characteristics	Values
Operating temperature	-40 °C...+70 °C (-40 °F...+158 °F)
Current loop input range	-20...+20 mA
Current loop output range	0...20 mA
Maximum output load	600 Ω

CT requirements

⚠ WARNING

UNINTENDED EQUIPMENT OPERATION

Select the CT size according to the requirement from the electric network.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

The PowerLogic P5 phase current inputs are connected to standard 1 A or 5 A CTs.

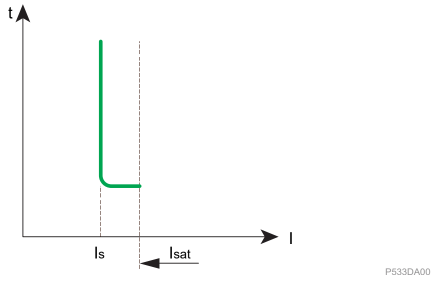
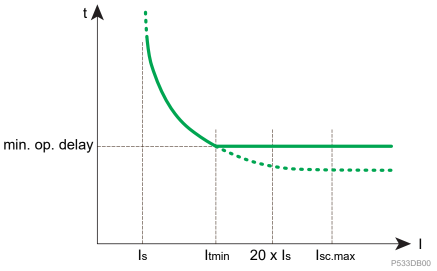
Sizing rules of phase and neutral CTs are specific for each function and depend on which of the following have to be considered:

- Phase overcurrent protection
- Neutral overcurrent protection
- Restricted ground fault protection
- Transformer differential protection
- Line differential protection

Phase and neutral overcurrent protection

The CTs must be sized to avoid saturation during steady state short circuit currents where accuracy is required, according to the rules described below for Definite Time (DT) or Inverse Definite Minimum Time (IDMT) operation.

The required CT saturation current level (I_{sat}) depends on the setting of the overcurrent protection pick-up level and operating curve settings:

Time Delay	Condition to be fulfilled	Illustration
DT	I_{sat} > 1.5 x set point (Is)	
IDMT	I_{sat} > 1.5 x the smallest of the following values: • $I_{sc.max}$, maximum installation short-circuit current • 20 x set point (Is) • Itmin, the minimum operate delay equivalent current	

The method for calculating the saturation current depends on the CT accuracy class as indicated further below.

Practical information

In the absence of any information about the settings, the characteristics below are suitable for most applications:

Rated Secondary Current ($I_{sec.nom}$)	**Rated Burden (VA_{CT})**	**Accuracy Class and Accuracy Limit Factor**	**CT Secondary Resistance (R_{CT})**	**Wiring Resistance (R_w)**
1 A	2.5 VA	5P20	< 3 Ω	< 0.075 Ω
5 A	7.5 VA	5P20	< 0.2 Ω	< 0.075 Ω

Restricted ground fault protection

For accuracy, Class PX, Class 5P or 5PR CTs should be used for low impedance Restricted ground fault (64REF) applications.

A series of tests with internal and external faults were performed to determine the CT requirements for the 64REF function. These tests were performed according to IEC 60255-187 standard for different primary system constants (X/R ratios up to 64), CT burdens, fault currents, fault types and points on wave.

Both bias characteristics of 64REF protection were checked at their default settings:

- Low set Id1 = 0.20 pu

Further in Max (IP) bias mode:

- Slope k1 = 20%
- Bias current Ib1 = 1.00 pu
- Slope k2 = 150%
- Min measured IG = 0.1 pu

According to the test results, to achieve fast trip during internal faults and to keep stability for through faults, the CT dimensioning must comply with the following requirements:

- CT class 5P with an operational accuracy limit factor ALF’ = 8, hence an equivalent limiting secondary e.m.f. $E_{al} \geq 8 \times I_{sr} \times (R_{CT} + R_b)$,

  where:
  - I_{sr} = rated secondary current (1 A or 5 A)
  - R_{CT} = CT secondary winding resistance (at 75°C)
  - R_b = connected resistive burden
- or equivalent class PX CT with a kneepoint voltage $V_K \geq 0.85 \times \max(E_{al.int}, E_{al.ext})$.

Transformer differential protection

For accuracy, CTs of Class PX(R) or Class 5P(R) should be used for transformer differential protection applications.

A series of tests with internal and external faults were performed to determine the CT requirements for the transformer differential protection function. These tests were performed according to IEC 60255-187-1 standard for different transformer configurations, primary system voltages and time constants (X/R ratios up to 64), CT ratios and burdens, fault currents, fault types and points on wave.

The protection was checked with both bias calculation modes provided from differential function at its default characteristic, as recommended by the IEC standard:

- Low set Id = 0.20 pu

- Slope 1 = 30%
- Ib for start of slope 2 = 2.00 pu
- Slope 2 = 70%
- High set Id = 30.00 pu

According to the test results, the CT dimensioning must comply with the following requirements:

- a CT class 5P with an equivalent limiting secondary e.m.f. E_{al} greater or equal to the maximum value calculated for the following conditions:
  - to achieve fast trip during internal faults:
    $E_{al.int} \geq 1.0 \times (I_{f.int} / I_{pr}) \times I_{sr} \times (R_{CT} + R_b)$
  - and to keep stability for external faults:
    $E_{al.ext} \geq 1.8 \times (I_{f.ext} / I_{pr}) \times I_{sr} \times (R_{CT} + R_b)$

  where:
  - $I_{f.int}$ = Maximum primary fault current in case of internal fault
  - $I_{f.ext}$ = Maximum primary (through-flowing) fault current in case of external fault
  - I_{pr} = CT rated primary current
  - I_{sr} = CT rated secondary current (1 A or 5 A)
  - R_{CT} = CT secondary winding resistance (at 75°C)
  - R_b = connected resistive burden
- or equivalent class PX CT with a kneepoint voltage
  $V_K \geq 0.85 \times \max(E_{al.int}, E_{al.ext})$.

Line differential protection

For accuracy, CTs of Class PX(R) or Class 5P(R) should be used for line differential protection applications.

A series of tests with internal and external faults were performed to determine the CT requirements for the line differential protection function. These tests were performed for different line configurations (including in-zone transformer), primary system time constants (X/R ratios up to 64), CT ratios and burdens, fault currents, fault types and points on wave.

The protection was checked at its default characteristic:

- Low set Id = 0.20 pu
- Slope 1 = 30%
- Ib for start of slope 2 = 2.00 pu
- Slope 2 = 70%
- High set Id not enabled

According to the test results, the CT dimensioning must comply with the following requirements:

- a CT class 5P with an equivalent limiting secondary e.m.f. E_{al} greater or equal to the value calculated with the following equation:

  $E_{al} \geq K \times I_{sr} \times (R_{CT} + R_b)$

  where:

  K = is the dimensioning factor which must be:

  - For a plain line application:
    - X / R up to 31.5: K = (0.9 * If) – 3, but minimum K = 4
    - X / R above 31.5: K = (1.8 * If) – 6, but minimum K = 8
  - For an application with in-zone transformer the highest of
    $K = 7 + (1.6 + 0.03125 \times (X / R)) \times (I_f / I_{pr})$
    or
    $K = 14 + 0.125 \times (X / R)$

  where:

  - I_f = Maximum primary fault current
  - I_{pr} = CT rated primary current
  - I_{sr} = CT rated secondary current (1 A or 5 A)
  - R_{CT} = CT secondary winding resistance (at 75°C)
  - R_b = connected resistive burden
  - X / R = primary system impedance ratio
- or equivalent class PX CT with a kneepoint voltage $V_K \geq 0.85 \times (E_{al})$.

Calculating the saturation current in class P

A class P CT is characterized by:

- I_{pr}: Rated primary current (in A)
- I_{sr}: Rated secondary current (in A)
- Accuracy class, expressed by a percentage, 5P or 10P, followed by the Accuracy-Limit Factor (ALF), whose usual values are 5, 10, 15, 20, 30
- VA_{CT}: Rated burden, whose usual values are 2.5/ 5/ 7.5/ 10/ 15/ 30 VA
- R_{CT}: Resistance of the secondary winding (in Ω)

The installation is characterized by the burden resistance R_b at the CT secondary (wiring + protection relay). If the CT load complies with the rated burden, which means $R_{br} \times I_{sr}^2 = VA_{CT}$, the saturation current is equal to $I_{sat} = ALF \times I_{pr}$.

If the CT winding resistance R_{CT} is known, it is possible to calculate the actual CT ALF, which takes account of the actual CT load. The saturation current then equals actual ALF x I_{pr}, where:

$$\textit{Actual ALF} = \text{ALF} \times \frac{R_{CT} \times I_{sr}^2 + VA_{CT}}{(R_{CT} + R_b) \times I_{sr}^2}$$

P533DC00

Hence if the actual CT load is less than its rated burden ($R_b < R_{br}$), a higher short-circuit current can be transmitted without saturation.

Example:

A CT with the following characteristics is given:

- Transformation ratio: 100 A / 5 A
- Accuracy class and accuracy limit factor: 5P20
- Rated burden: 2.5 VA
- Resistance of the secondary winding: 0.1 Ω

To get an ALF of at least 20, in other words, a saturation current of 20 x I_{pr} = 2 kA, the load resistance R_b of the CT must be less than:

$$R_{b,max} = \frac{VA_{CT}}{I_{sr}^2} = \frac{2.5\ VA}{(5\ A)^2} = 0.1\ \Omega$$

P533PH00

This represents 12 m (39 ft) of wire with cross-section 2.5 mm² (AWG 13) for a resistance per unit length of 7 mΩ/m (2.1 mΩ/ft) approximately.

For an installation with 50 m (164 ft) of wiring with section 2.5 mm² (AWG 13), the actual resistance is R_b = 0.4 Ω, and hence actual ALF is:

$$\textit{Actual ALF} = ALF \times \frac{R_{CT} \times I_{sr}^2 + VA_{CT}}{(R_{CT} + R_b) \times I_{sr}^2} = \frac{0.1 \times 25\ + 2.5}{(0.1 + 0.4) \times 25} = 8$$

P533DE00

Therefore, the saturation current for this CT installation is:
$I_{sat} = 8\ x\ I_{pr} = 800$ A.

> **NOTE:** The actual CT burden R_b connected on its secondary side is given as follows:
>
> - For phase to ground faults: $R_b = 2\ R_W + R_{rel}$
> - For phase to phase faults: $R_b = R_W + R_{rel}$
>
> Where the wire lead burden is calculated as:
>
> $$R_W = \rho \times \frac{l}{A}$$
>
> P533PI00
>
> with ρ = specific conductor resistance, for example, for copper 0.019 Ω mm²/m at 75°C
>
> l = wire length in [m]
>
> A = wire cross section in [mm²]
>
> The impedance of PowerLogic P5 protection relays current inputs (R_{rel} = 20 mΩ) is often negligible compared to the wiring resistance.

Calculating the saturation current in class PX

A class P CT is characterized by:

- I_{pr}: Rated primary current (in A)
- I_{sr}: Rated secondary current (in A)
- Vk: Rated knee-point voltage (in V)
- R_{CT}: Maximum resistance of the secondary winding (in Ω)

The saturation current is calculated with the actual load resistance R_b at the CT secondary (wiring + protection relay):

$$I_{sat} = \frac{Vk}{R_{CT} + R_b} \times \frac{I_{pr}}{I_{sr}}$$

P533PK00

Examples:

CT with transformation ratio 100 A / 5 A, Vk = 20 V, R_{CT} = 0.13 Ω, R_b = 0.4 Ω

$$I_{sat} = \frac{20}{0.13 + 0.4} \times \frac{100}{5} = 754\ A$$

P533PJ00

CT with transformation ratio 100 A / 1 A, Vk = 90 V, R_{CT} = 3.5 Ω, R_b = 0.4 Ω

$$I_{sat} = \frac{90}{3.5 + 0.4} \times \frac{100}{1} = 2307A$$

P533PL00

Use of IEEE C class CTs

PowerLogic P5 series protection is compatible with ANSI/IEEE current transformers as specified in the IEEE C57.13 standard. The applicable class for protection is class C, which specifies a non air-gapped core. The CT design is identical to IEC class P, or British Standard class X, but the rating is specified differently. The following table allows IEEE C57.13 ratings to be translated into an equivalent IEC/BS knee-point voltage.

Table 31 - IEC/BS knee-point voltage V_K offered by C class CTs

		IEEE C57.13 – C classification (volts)				
		C50	C100	C200	C400	C800
CT Ratio	RCT (ohm)	V_K	V_K	V_K	V_K	V_K
100/5	0.04	56.5	109	214	424	844
200/5	0.8	60.5	113	218	428	848
400/5	0.16	68.5	121	226	436	856
800/5	0.32	84.5	137	242	452	872
1000/5	0.4	92.5	145	250	460	880
1500/5	0.6	112.5	165	270	480	900
2000/5	0.8	132.5	185	290	500	920
3000/5	1.2	172.5	225	330	540	960

844 Assumptions:

1. For 5A CTs, the typical resistance is 0.0004 ohm secondary per primary turn (for 1A CTs, the typical resistance is 0.0025 ohm secondary per primary turn).
2. IEC/BS knee-point voltage is typically 5% higher than ANSI/IEEE knee-point voltage.

Given:

1. IEC/BS knee-point voltage is specified as an internal EMF, whereas the C class voltage is specified at the CT output terminals. To convert from ANSI/IEEE to IEC/BS requires to add the voltage drop across the CTs secondary winding resistance.
2. IEEE CTs are always rated at 5A secondary.
3. The rated dynamic current output of a C class CT (K_{SSC}) is always 20 x nominal current.

Hence knee-point voltage can be calculated using the following formula:

$V_K = (C \times 1.05) \times (I_{sec.nom} \times R_{CT} \times K_{SSC})$

Where:

- V_K = Equivalent IEC/BS knee point voltage
- C = CT classification per IEEE C57.13
- $I_{sec.nom}$ = Rated secondary current of CT (in A)
- R_{CT} = Resistance of the secondary winding (in Ω)
- K_{SSC} = 20

LPCT/LPVT configuration

LPCT/LPVT pins mapping definition

NOTICE

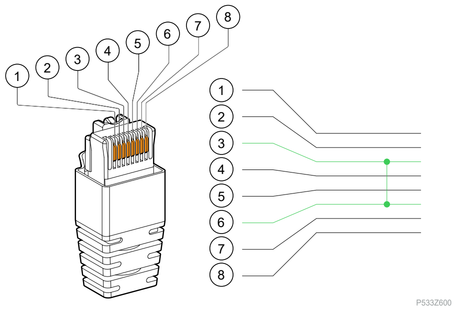
UNEXPECTED LOSS OF SENSOR CONNECTION

When using LPCT/LPVT other than the brand of Schneider Electric, short the pins 3-6 to avoid the “LPCT connection loss” or “LPVT loss” alarm.

Failure to follow these instructions can result in loss of sensor connection.

The pins 3-6 of the LPCT/LPVT of Schneider Electric are shorted during fabrication, therefore, the LPCT/LPVT connection supervision function will not raise the “LPCT connection loss” or “LPVT loss” alarm.

Figure 134 - LPCT/LPVT pins mapping



If a LPCT/LPVT is not connected to the PowerLogic P5, or not connected to the LPVT hub connector (reference EMS59573), the RJ45 LPCT/LPVT plug shall be connected to the idle port. If not, the “LPCT connection loss” or “LPVT loss” alarm will be raised.

LPCT configuration

Introduction

This section gives an overview of some reasons to move from traditional CT to LPCT, what is an LPCT and how to configure them in eSetup Easergy Pro (at least V3.0.0).

Further details, such as how to wire the LPCT or the VT adapter is described in the following sections.

NOTE: The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

Benefits of LPCTs

In short, the use of Low Power Instrument Current Transformers (LPCTs) brings many benefits through-out the project lifecycle, which are detailed below.

Personal safety is improved during testing and operation

With LPCT technology, the safety risk of accidental opening of the secondary circuit is greatly reduced due to its special design, as the output is always low voltage:

- The 1 A or 5 A rated secondary current of an inductive CT (ICT) is replaced by either 22.5 mV, 150 mV, or 225 mV in LPCTs.
- As these secondaries can be left open or short-circuited without risk, there is no longer the need for short-circuit devices that were designed to mitigate those risks.

One LPCT can replace the needs of dedicated measurement and protection CTs

As LPCTs commonly saturate at much higher currents than Inductive Current Transforms (ICTs), they can allow fault measurement ranging from 5 kA to 80 kA primary.

The measurement accuracy of an LPCT could range from 5% of rated primary current to the extended primary current. It may be specified as class 0.1, 0.2, 0.5, or 1.

However, its protection accuracy could range from the extended primary current to the accuracy limit of primary current. It may be specified as either class 5P, 10P or 5TPE[43].

For example, a 100 A LPCT may be labelled as 0.5/5P 25000 A, meaning:
M class = 0.5%, P class = 5P up to 25 kA (250 times primary current rating).

Since the LPCTs support a larger range of extended rated primary current, they can be applied to a larger scope. The primary rating of LPCT is not requested to be as close as possible to the nominal current, therefore, in specifications, the rated primary current become no longer a major determinant factor for the LPCTs.

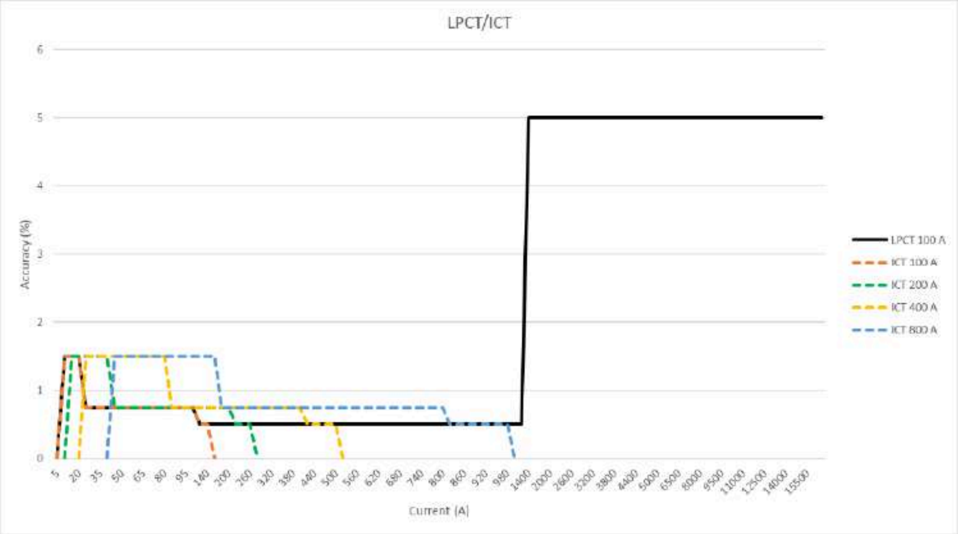
For measurement class

In this example, a multipurpose normalized LPCT with a rated primary current of 100 A and an extended primary current of 1000 A can be used in place of the 10 different ICTs with the following primary currents:
100, (125), 150, 200, (250), 300, (400), 500, (600), 750** (but not 1000**)

NOTE: ** The extended primary current of an ICT is limited to 120% of its rated current.

- 750 A x 1.2 = 900 A is less than the 1000 A extended primary current.
- 1000 A x 1.2 = 1200 A is greater than the 1000 A extended primary current.

Figure 135 - LPCT measurement accuracies for primary currents



If we know that the initial nominal current to be measured is between 100 A and 750 A, we can take an LPCT of 100 A rated current and with 1000 A extended

---

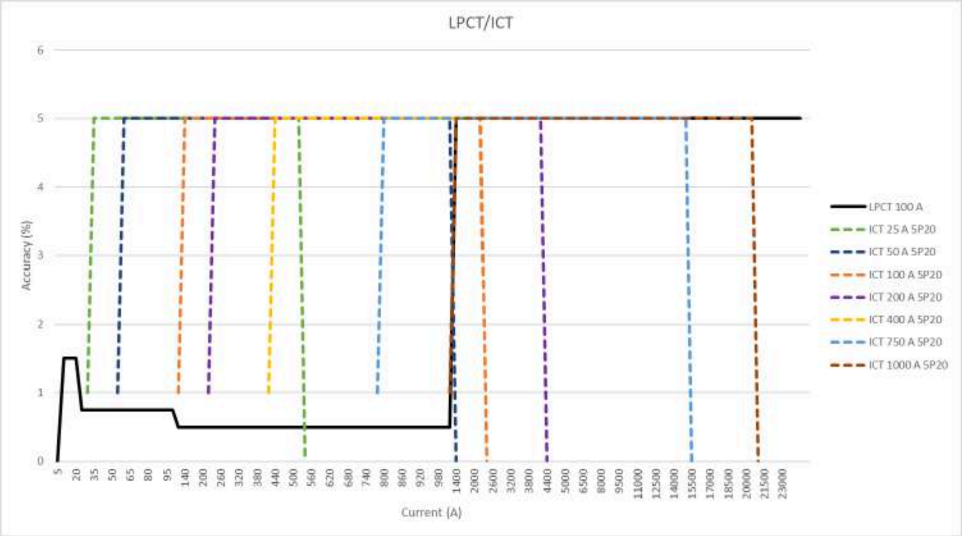
43. TPE is a LPIT class defined in 61869-6: Class TPE low-power current transformers are designed for relay protection applications.

primary current which will still be flexible to last-minute changes or when load flow may increase subsequently.

For protection class

Same example, a multipurpose normalized LPCT with a 100 A rated primary current and a 1000 A extended primary current can be used in place of the 13 different ICTs with the following primary currents:
25, 50, 100, (125), 150, 200, (250), 300, (400), 500, (600), 750 and 1000

Figure 136 - LPCT protection accuracies for primary currents



If we know that the initial nominal current for protection is between 25 and 1000 A, we can take an LPCT of 100 A rated current and with 1000 A extended primary current which will still be flexible to last-minute changes or when load flow may increase subsequently.

Save time and money during project planning and execution

Standardized products can now be used for a wider range of application, providing faster and simpler integration. There is no need to wait to wait for CT sizing clarifications, because fewer designs cover the majority of requirements, providing many other benefits.

- Reduced number of order variants
- Simplified and improved quality of project documentation
- In-stock products with fast delivery
- Simplified installation

Compact switchgear with reduced footprint is more sustainable

The size and weight of the LPCTs are reduced to less than 10% compared to ICTs. This allows future switchgear designs to be more compact, reducing materials used and the environmental impact. Switchgear handling, transport, installation and replacement are also much simplified.

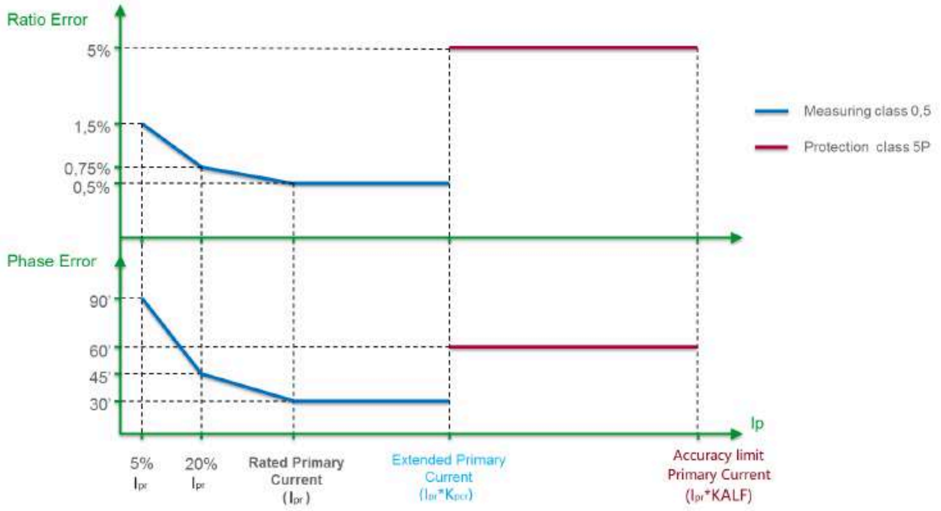
LPCT characteristics

The multipurpose LPCT is designed to measure from 5% of I_{pr} to KALF x I_{pr} and is defined with a:

- Rated primary current (I_{pr}) (minimum current for measuring accuracy class)
- Rated extended primary current ($I_{e.pr}$= I_{pr}× K_{pcr}) (maximum current for measuring accuracy class)

- Rated accuracy limit ($I_{sc.pr}$= I_{pr}× KALF) (maximum current for protection accuracy class)

Figure 137 - Magnitude and phase errors across the measurement range



For example, the Schneider Electric LPCTs have the characteristics as shown below.

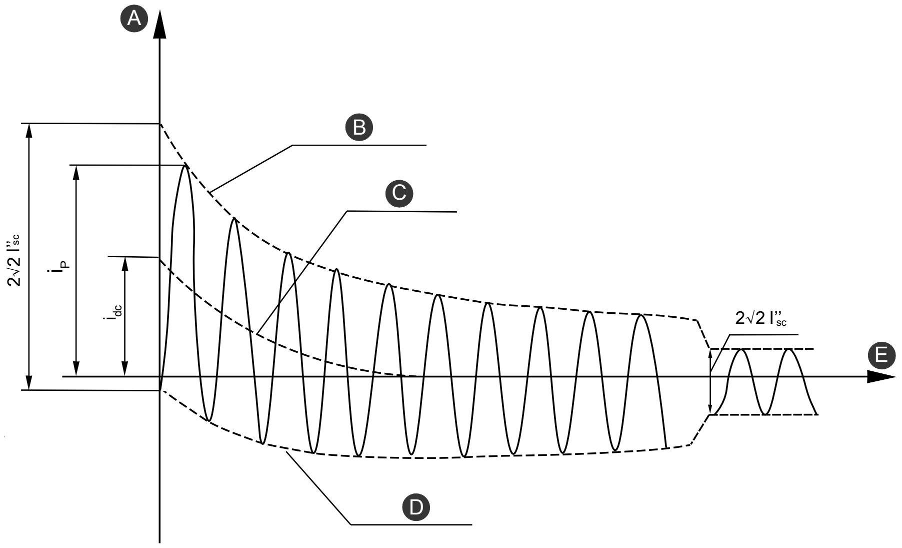
Table 32 - Characteristics of the LPCT

Characteristics	I_{pr} (A)	$I_{e.pr}$ (A)	$I_{sc.pr}$ (A)
CLV1	100	1250	16000
TLPU1	100	630	25000
TLP130	100	1250	25000
TLP160 or 190	100	2500	40000
CLP2 100 1250 40000	100	1250	40000
CLP3	100	2500	40000
CLP1	100	1250	50000

LPCT input characteristics

The LPCT input measuring range is 45 I_r. That means 25 I_r fully offset:

Figure 138 - Fault characteristic



P533S3A

A	Current	B	Top envelope
C	*Idc*	D	Bottom envelope
E	Time		

NOTE:

- I''_{sc} = initial symmetrical short-circuit current
- i_P = peak short-circuit current
- I_{sc} = steady-state short-circuit current
- i_{dc} = dc component of short-circuit current
- A = initial value of the dc component i_{dc}
- $2\sqrt{2}\, I''_{sc}$ = the peak to peak value of the initial (sub-transient) short circuit current
- $2\sqrt{2}\, I_{sc}$ = the peak to peak value of the steady state short circuit current

LPCT configuration procedure

Unlike CTs that need to meet the application CT requirements, LPCTs do not have any saturation. LPCT suitability needs to be calculated according to the two following main rules:

1. Select or check the LPCT suitability

   The maximum short circuit ($I_{sc.max}$) must be below the LPCT protection rated accuracy limit:

   - $I_{sc.max} < I_{sc.pr}$

2. In eSetup Easergy Pro (V3.0.0 or later), under **GENERAL**/**Scaling** menu, LPCT characteristics can be set.

Figure 139 - LPCT setting

Scaling

LPCT rated primary current (Ipr): 100 A

Current factor: 1

The nominal current In is equal to (I_{pr} x Current factor)

a. For LPCT secondary nominal voltage V_{sec} = 22.5 mV

   i. Set the LPCT rated primary current I_{pr}, for example 100 A

   ii. Then set the "Current factor" to adjust the nominal current, for example, 2 for I_n = 200 A or 4 for I_n = 400 A

b. For other LPCT secondary nominal voltage V_{sec}

   i. For V_{sec}= 150 mV select first "Current factor"= 6.66 or for V_{sec}= 225 mV select first "Current factor"= 10

   ii. Then set the "LPCT rated primary current I_{pr}" = (I_{pr} [of LPCT] / Current factor)

   iii. Then finetune the "Current factor" to adjust the nominal current, for example, 5 instead of 6.66 for I_n = 75 A or 20 instead of 10 for 200 A

The nominal current I_n:

- must be below the LPCT rated accuracy limit divided by 25: $I_n < I_{sc.pr} / 25$
- should be below the LPCT rated extended primary current: $I_n < I_{e.pr}$ whenever possible
- must be above 20% of the LPCT rated primary current: $I_n > 0.2 * I_{pr}$
- should be as close as possible to the nominal load current. It does not need to be among the standardized values.

Three examples for a multipurpose LPCT with a 100 A rated primary current, a 1250 A extended primary current and an accuracy limit of 16 kA:

Example 1: Maximum short circuit current of 10 kA and a nominal current of 200 A

1. The maximum short circuit current must be below the LPCT rated accuracy limit:
   - $I_{sc.max} < I_{sc.pr}$:
     10 kA < 16 kA (= OK)
2. The maximum nominal current:
   - must be below the LPCT rated accuracy limit divided by 25: $I_n < I_{sc.pr}$ / 25 = 16 kA / 25 = 640 A (= OK)
   - should be below the LPCT rated extended primary current: $I_n < I_{e.pr}$ = 1250 A (= OK)
   - must be above 20% of the LPCT rated primary current: $I_n > 0.2 * I_{pr}$ = 0.2 * 100 A = 20 A (= OK)
   - should be as close as possible to the nominal load current. It does not need to be among the standardized values.

   So, 200 A can be chosen (fine for measurement and protection).

Example 2: Maximum short circuit current of 20 kA and a nominal current of 400 A

1. The maximum short circuit current must be below the LPCT rated accuracy limit:
    - $I_{sc.max} < I_{sc.pr}$ BUT actually 20 kA is bigger than 16 kA.
      This is NOT OK. A different LPCT must be chosen. For example, a multipurpose LPCT with a 100 A rated primary current, a 1250 A extended primary current and an accuracy limit of 25 kA.
2. The maximum nominal current:
    - must be below the LPCT rated accuracy limit divided by 25:
      $I_n < I_{sc.pr}$ / 25 = 25 kA / 25 = 1000 A (= OK)
    - should be below the LPCT rated extended primary current:
      $I_n < I_{e.pr}$ = 1250 A (= OK)
    - must be above 20% of the LPCT rated primary current:
      $I_n > 0.2 * I_{pr}$ = 0.2 * 100 A = 20 A (= OK)
    - should be as close as possible to the nominal load current. It does not need to be among the standardized values.

   So, 400 A can be chosen (fine for measurement and protection).

Example 3: Maximum short circuit current of 50 kA and a nominal current of 1500 A

1. The maximum short circuit current must be below the LPCT rated accuracy limit:
    - $I_{sc.max} < I_{sc.pr}$ BUT actually 50 kA is bigger than 16 kA.

   This is NOT OK. A different LPCT must be chosen. For example, a multipurpose LPCT with a 100 A rated primary current, a 1250 A extended primary current and an accuracy limit of 50 kA.
2. The maximum nominal current:
    - must be below the LPCT rated accuracy limit divided by 25:
      $I_n < I_{sc.pr}$ / 25 = 50 kA / 25 = 2000 A (= OK)
    - should be below the LPCT rated extended primary current:
      $I_n < I_{e.pr}$ = 1250 A (= OK)
    - must be above 20% of the LPCT rated primary current:
      $I_n > 0.2 * I_{pr}$ = 0.2 * 100 A = 20 A (= OK)
    - should be as close as possible to the nominal load current. It does not need to be among the standardized values.

   So, 2000 A can be chosen (fine only for protection).

LPVT configuration

Introduction

This section gives an overview of LPVTs, reasons to move from traditional VTs to LPVTs, and how to configure them in eSetup Easergy Pro (V3.0.0 or later).

Further details, such as how to wire the LPCT or the VT adapter is described in the following section.

Benefits of LPVTs

In short, the use of Low Power Voltage Transformers brings many benefits throughout the project lifecycle, which are detailed below.

Personal safety is improved during testing and operation

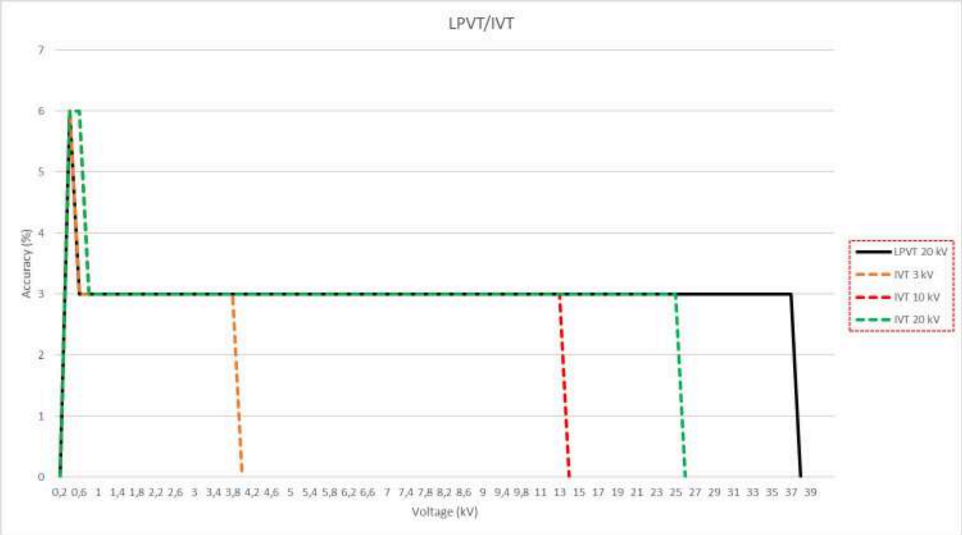
With LPVT technology, the output is low voltage.

- The VT (phase to neutral) secondary rated voltages, ranging from 57.73 V to 69.3 V and/or 115.47 V to 132.79 V, are now reduced to 1.88 V (3,25/√3 V) in LPVTs.
- As the impact of a short circuited secondary disappears, it also removes the need for VT fuses.
- The effect of ferroresonance has disappeared as well.

One LPVT can replace the need of several nominal voltage rated VTs

An LPVT is now defined for a wider range of ratings compared to an Inductive Voltage Transformer (IVT), for example, 3 to 20 kV, class 0.5P, from 2% to 190% of its rated voltage which is better than the former 0.5 / 3P classification. Redundant to 3rd bullet point just few lines above.

Figure 140 - LPVT accuracies for primary voltages



For protection, the above LPVT can be used in place of the 5 different VTs with the following primary voltages (in kV): 3, 6, 10, (15), 20.

Save time and money during project planning and execution

Standardized products can now be used with a wider range of application, providing faster and simpler integration. No longer do you need to wait for sizing clarifications, because fewer designs cover the majority of requirements, providing many other benefits.

- Reduced variation of ordering
- Simplified and improved quality of project documentation
- In-stock products with fast delivery
- Simplified installation

Compact switchgear with reduced footprint is more sustainable

The size and weight of the Low Power Voltage Transformers are reduced to less than 10% compared to IVTs. This allows future switchgear designs to be more compact, reducing materials used and the environmental impact. Switchgear handling, transport, installation and replacement are also simplified.

LPVT characteristics

The multipurpose LPVT is designed to measure from 2% of V_{pr} (min) to 1.9 x V_{pr} (Max) and is typically defined with a:

- Rated primary voltage V_{pr}
- Range of rated primary voltage ($V_{pr.min}$, $V_{pr.max}$) (minimum and maximum voltage for measuring and protecting accuracy classes)
- Rated secondary voltage V_{sr}

Figure 141 - Magnitude accuracy

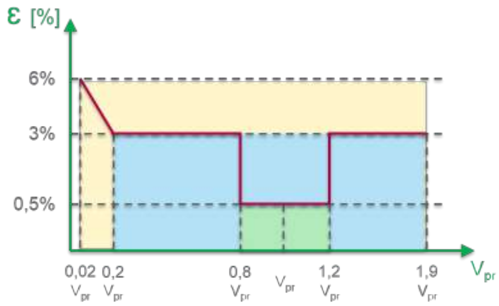
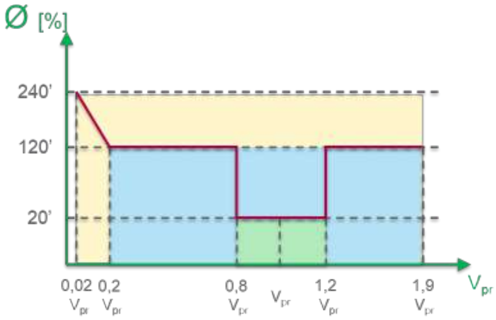


Figure 142 - Phase accuracy



For example, the Schneider Electric LPVTs have the following characteristics.

Table 33 - Characteristics of the LPVT

Characteristics	V_{pr} (kV)	$V_{pr.min}$ (kV)	$V_{pr.max}$ (kV)	$V_{pr.max}/V_{pr}$
Ref.1	10	2.4	11	1.1
Ref.2	20	3	20	1
Ref.3	20	10	22	1.1
Ref.4	30	20	33	1.1

NOTE: The LPVTs need to be connected to the P5 by the LPVT hub connector, the figure below shows the look of LPVT hub connector. See the LPVT hub connector (reference EMS59573), page 124 section for supplementary information on this topic.

Figure 143 - LPVT hub connector

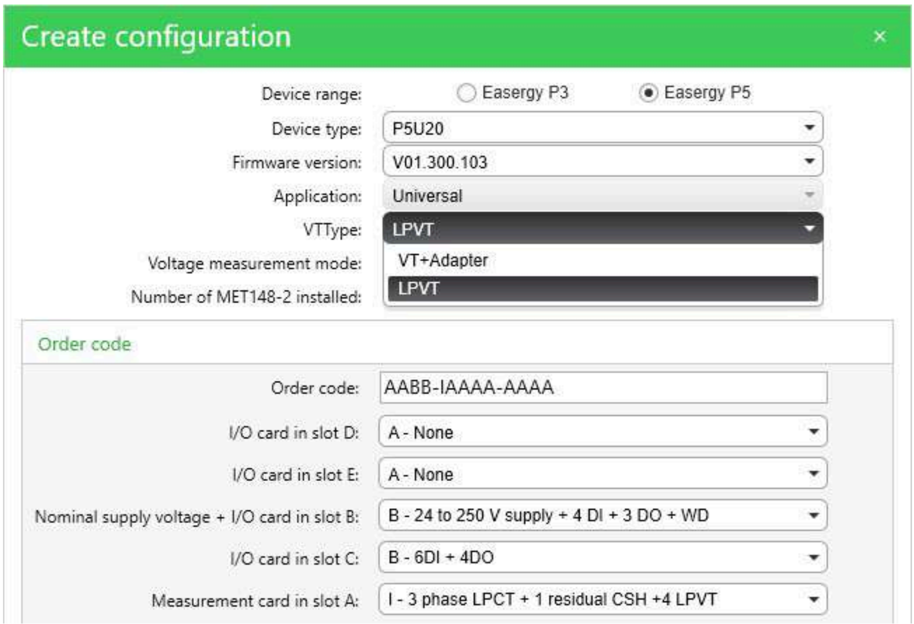
LPVT input characteristics

The PowerLogic P5 LPVT input measuring range is bigger than 1.5 x 1.9 x V_{sr} (with 1.5 as biggest ratio between $V_{pr.max}$ and V_{pr}).

PowerLogic P5 can be connected to either an LPVT or a VT (thanks to the EMS59572 adapter).

The selection for the direct LPVT is done in eSetup Easergy Pro (V3.0.0 or later), at the creation of the configuration file once the **Measurement card in slot A** has been set to the LPIT option.

Figure 144 - Selection of the LPIT option



Create configuration

Device range: ○ Easergy P3 ● Easergy P5

Device type: P5U20

Firmware version: V01.300.103

Application: Universal

VT Type: LPVT

Voltage measurement mode:

Number of MET148-2 installed:

Order code

Order code: AABB-IAAAA-AAAA

I/O card in slot D: A - None

I/O card in slot E: A - None

Nominal supply voltage + I/O card in slot B: B - 24 to 250 V supply + 4 DI + 3 DO + WD

I/O card in slot C: B - 6DI + 4DO

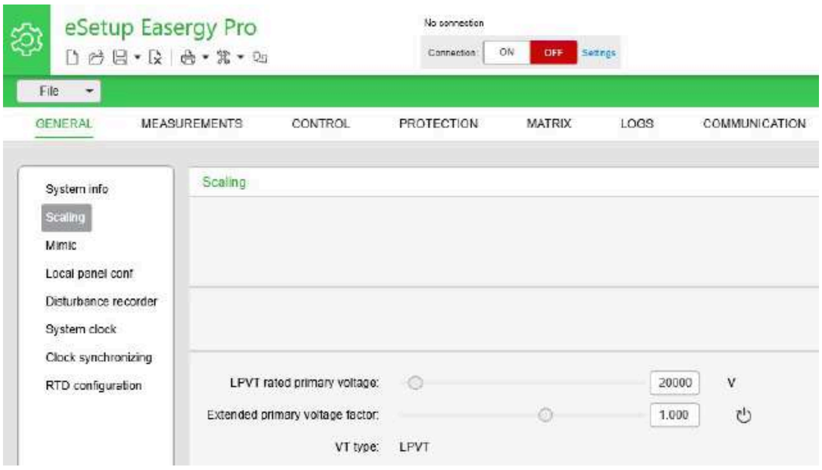
Measurement card in slot A: I - 3 phase LPCT + 1 residual CSH +4 LPVT

LPVT configuration procedure

Two main simple rules are required to follow:

1. Select or check the LPVT suitability
   The nominal voltage (V_n) must be within the LPVT range of rated primary voltage: $V_{pr.min} < V_n < V_{pr.max}$
2. In eSetup Easergy Pro (V3.0.0 or later), under **GENERAL**/**Scaling** menu, LPVTs are configured to be connected to devices with different measuring input burden.

Figure 145 - LPVT settings



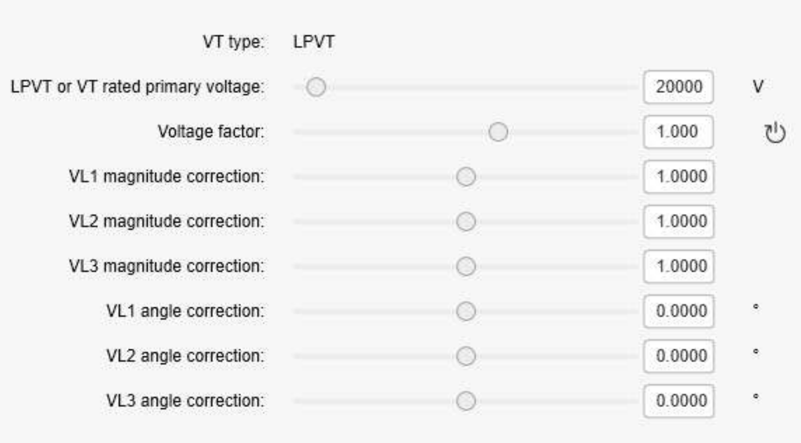
LPVT rated primary voltage: 20000 V

Extended primary voltage factor: 1.000

VT type: LPVT

   a. For both 2 MΩ (IEC 61869-11) and 10 MΩ LPVT output burden
      - Set the LPVT Rated primary Voltage (V_{pr}) in “LPVT rated primary voltage”
      - Set the nominal voltage (V_n) in “Extended primary voltage factor” by adjusting the coefficient to the primary rating (for example, if V_n is 10kV and (V_{pr} is 20 kV then set 0.5)
   b. Only for 2 MΩ (IEC 61869-11) LPVT output burden, the following additional correction settings are relevant:

Figure 146 - Correction factors



VT type: LPVT

LPVT or VT rated primary voltage: 20000 V

Voltage factor: 1.000

VL1 magnitude correction: 1.0000

VL2 magnitude correction: 1.0000

VL3 magnitude correction: 1.0000

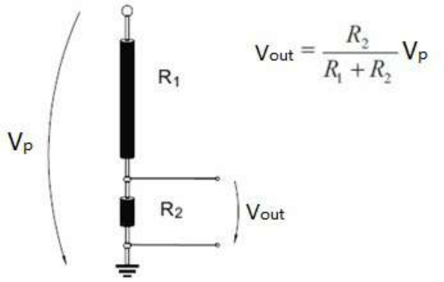
VL1 angle correction: 0.0000 °

VL2 angle correction: 0.0000 °

VL3 angle correction: 0.0000 °

- Measure the resistance of R_2 for each LPVT (RJ45 output pin 7&8)
- Set for each phase “VLx magnitude correction” to:
    - ((R_2+10000) / (R_2+2000)) / 5 with R_2 in kΩ
    - For example, if R_2 = 32.51 kΩ then VLx correction = 0.987

Figure 147 - Resistive divider



LPVT configuration with VT adapter

Introduction

This section gives an overview of some reasons to use the EMS59572 adapter, what it is, and how to configure it in eSetup Easergy Pro (V3.0.0 or later).

Please also read the application guidelines:

- LPCT configuration, page 153
- LPVT configuration, page 160

Further details, such as how to wire the LPCT or the VT adapter is described in the chapter Installation, page 43.

Benefits of VT adapter

Traditionally, a protection relay is either designed to be connected to CTs and VTs or LPCTs and LPVTs. When the switchgear is equipped with LPCTs and VTs, it is easier to adapt the VT outputs to low level signals compatible with the relay LPVT inputs with the EMS59572.

When the primary voltage is up to 415 (phase to phase), it can be easier and safer to adapt the voltage to low level signals compatible with the relay LPVT inputs with the EMS59574.

EMS59572/EMS59574 adapters characteristics

NOTE: The minimum required versions of PowerLogic P5 firmware and LPVT board for EMS59754 are:

- PowerLogic P5 firmware V02.502 or later
- LPVT board version 2.1 or newer

You can check the firmware version and the LPVT board version from eSetup Easergy Pro in **DEVICE/TEST / Device information**.

EMS59572 adapter characteristics

The VT (phase to neutral) secondary rated voltages, ranging from 57.73 V to 69.3 V and/or 115.47 V to 132.79 V, need to be converted to signals close to the rated 1.88 V (3,25/√3 V) in LPVTs.

The conventional VT output voltages or directly measured LV voltages need to be converted to the low voltages of the LPVT input. This voltage adaptation is made by resistive dividers. See the Voltage adapters (references EMS59572/ EMS59574), page 126 for supplementary information of this topic.

Figure 148 - VT adapter (references EMS59572)

The nominal ratio is 50.6 and the accurate ratios are written on its label for each phase.

EMS59574 adapter characteristics

Phase to phase voltage from 190 V to 415 V can be converted to signals close to the rated 1.88 V (3,25/√3 V) of LPVTs. The EMS59574 adapter is made of resistive dividers to directly connect the PowerLogic P5 LPVT inputs to the primary voltage.

Figure 149 - VT adapter (references EMS59574)

The nominal ratio is 150.6 and the accurate ratios are written on its label for each phase.

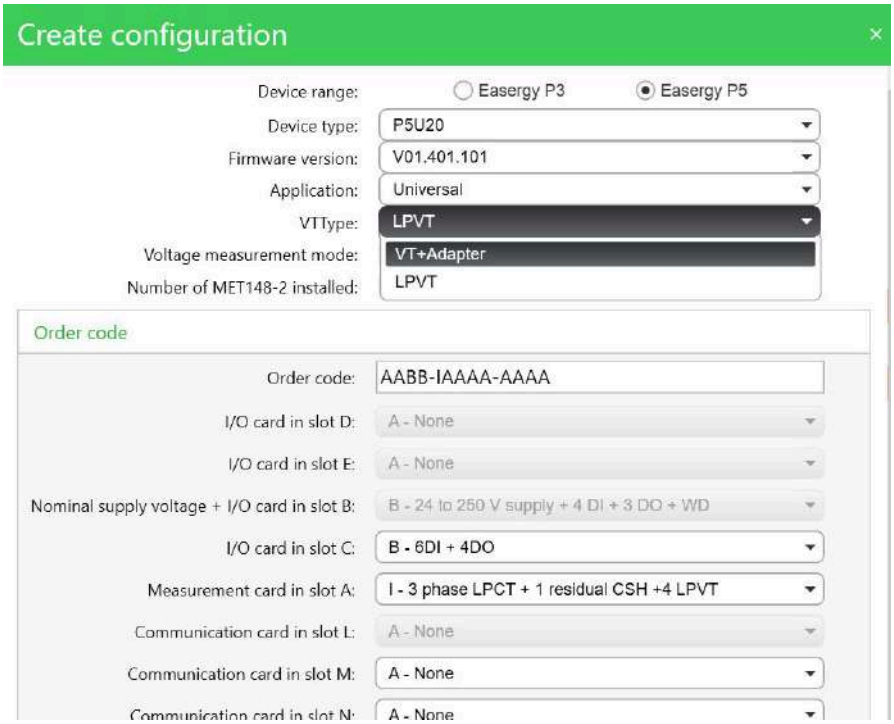
LPVT input characteristics

The PowerLogic P5 LPVT input measuring ranges are above 1.9 the chosen rated.

PowerLogic P5 can be connected to either a LPVT or a VT thanks to the EMS59572 adapter or to the primary voltage thanks to the EMS59574.

The selection to use the dedicated EMS59572 or EMS59574 is done in the latest eSetup Easergy Pro, at the **Creation configuration** window, once the **Measurement card in slot A** has been set to the LPIT option, by selecting *VT +Adapter*:

Figure 150 - Selection of the VT+Adapter option



Device range: ○ Easergy P3 ● Easergy P5
Device type: P5U20
Firmware version: V01.401.101
Application: Universal
VTType: LPVT
Voltage measurement mode: VT+Adapter
Number of MET148-2 installed: LPVT

Order code: AABB-IAAAA-AAAA
I/O card in slot D: A - None
I/O card in slot E: A - None
Nominal supply voltage + I/O card in slot B: B - 24 to 250 V supply + 4 DI + 3 DO + WD
I/O card in slot C: B - 6DI + 4DO
Measurement card in slot A: I - 3 phase LPCT + 1 residual CSH +4 LPVT
Communication card in slot L: A - None
Communication card in slot M: A - None
Communication card in slot N: A - None

EMS59572/EMS59574 VT adapters configuration

The configuration of VT adapters can be made in eSetup Easergy Pro (V3.0.0 or later), go to **GENERAL/Scaling** menu to perform the configuration.

1. Set the VT rated primary Voltage in **LPVT or VT rated primary voltage**. For EMS59574, the “LPVT or VT rated primary voltage” = “VT secondary” = the primary voltage.
2. Set the VT rated secondary Voltage in **VT secondary**.
3. Copy the values written on the EMS59572/EMS59574 for VL1, VL2 and VL3 in **VIx adapter mag correction**, x = 1, 2, 3.
    a. CH1 value in VL1
    b. CH2 value in VL2
    c. CH3 value in VL3
    d. When a second adapter is connected for Vo then
        (1) CH1 value in Uo in P530 (black connection)
        (2) CH2 value in Uo in P520 (brown connection)

Refer to LPVT configuration, page 160 for the introduction of LPVT configuration.

LPVT voltage sharing application

Similarly to conventional scheme, LPVT signals can be shared across multiple PowerLogic P5 protection relays (up to 10 per LPVT transducer). All connections are made with shielded RJ45 cables resilient to potential electromagnetic disturbances met in medium voltage compartments.

LPVT transducer (P7M12025)

The LPVT Transducer allows an accurate transmission of the low voltage output signal from LPVT sensors (3.25/√3 V) across up to 10 PowerLogic P5 protection relays equipped with LPVT measuring inputs. The low voltage input is provided through a single RJ45 connector that brings the 3 phase LPVT signals merged by LPVT hub connector EMS59573. P7M12025 can be installed on DIN rails complying with EN/IEC 60715.

The connections between all the elements are done with RJ45 wires that can be ordered with commercial references: 59660 (0.6 m) 59661 (2 m), 59662 (4 m). The branching between LPVT bus and each PowerLogic P5 protection relay is done with a 3-way RJ45 junction box (T-box) REL51095.

Table 34 - Characteristics of LPVT transducer

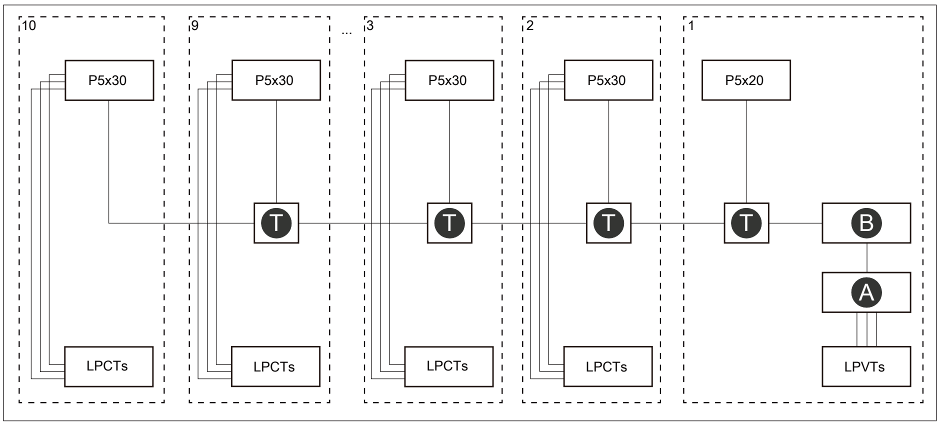
Characteristics	Description
Nominal voltage input / output	1.876 V (3.25/√3 V) / 1.876 V (3.25/√3 V)
Voltage factor	1.2 nominal voltage continuously 1.9 nominal voltage for 8 hours
Accuracy	Measurement class 0.5 Protection class 3P Input burden 10 MΩ // 2.2 pF For -5°C...+40°C
Power supply	24...48 V DC, 125 V DC or 120 V AC
Operating temperature	-25°C...+70°C
Dimensions (L x W x H)	160 x 60 x 90 mm (6.30 x 2.36 x 3.54 in)

Figure 151 - LPVT transducer

Voltage sharing applications

For LPVTs voltage sharing applications, refer to the following cases.

Figure 152 - LPVT sharing application without test sockets/plugs

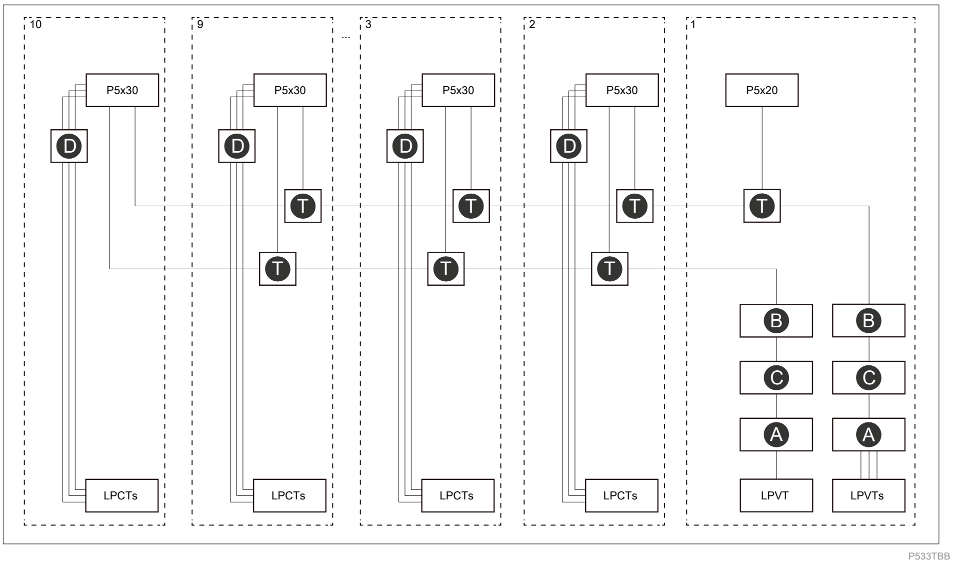


P533TAB

A	LPVT hub connector	EMS59573	B	LPVT transducer	P7M12025
T	T-box 3 way RJ45 junction	REL51095			

- 0.6 m remote module connection cord: 59660
- 2 m remote module connection cord: 59661
- 4 m remote module connection cord: 59662

Figure 153 - LPVT sharing application including the 4th voltage (sync-check) and with test sockets/plugs



A	LPVT hub connector	EMS59573	B	LPVT transducer	P7M12025
C	LPVT test plug LPVT test socket with cover	REL51093 REL51092	D	LPCT test plug LPCT test socket with cover	REL51090 REL51089
T	T-box 3 way RJ45 junction	REL51095			

Commissioning

Principles

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- NEVER work alone.
- Only qualified personnel should commission this equipment. Such work should be performed only after reading this entire set of instructions.
- Obey all existing safety instructions when commissioning and maintaining high-voltage equipment.
- Beware of potential hazardous voltages from open circuited current transformers, any voltage transformers and any capacitors which could be charged to hazardous voltages.
- Before energizing check that the protection relay and other devices are connected to a protective ground in accordance with the instructions provided.

Failure to follow these instructions will result in death or serious injury.

⚠DANGER

FIRE HAZARD

Apply proper tightening torque to all wire connections.

Failure to follow these instructions will result in death or serious injury.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Never open the secondary circuit of a live CT.
- The secondary of the line CT must be shorted before opening any connections to it.

Failure to follow these instructions will result in death or serious injury.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, CSA Z462 or national equivalent.
- Do not choose lower personal protective equipment (PPE) while working on energized equipment.

Failure to follow these instructions will result in death or serious injury.

PowerLogic P5 protection relays are tested prior to commissioning, with the dual aim of maximizing availability and minimizing the risk of malfunctioning of the assembly being commissioned.

PowerLogic P5 protection relays are fully numerical in their design, implementing all protection and non-protection functions in the firmware. The protection relays use a high degree of self-checking and give an alarm. Therefore, the commissioning tests do not need to be as extensive as with non-numeric electronic or electro-mechanical relays.

To commission PowerLogic P5 protection relays, it is necessary to verify that the hardware is functioning correctly and the application function settings have been applied as expected. To confirm that the protection relay is operating correctly once the settings have been applied, it is necessary to perform basic functional tests on each active protection element one by one.

The main tasks for the commissioning test are as follow:

- PowerLogic P5 protection relay check
- Secondary injection test
- Primary injection test
- Final check

⚠WARNING

UNINTENDED OPERATION

Do not energize the primary circuit before this protection relay is properly configured.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Testing tools and equipment

The following tools and equipment are needed in the commissioning:

- AC current and voltage injection sources
    - For secondary injection test, on conventional CTs and VTs, to check the protection relay functions, the injection source should be at such a rating that the current is adjustable up to at least 5 A and the voltage is adjustable up to at least 110 V.
    - For secondary injection test, on LPCT and LPVT, to check the protection relay functions, the injection source should be at such a rating that the voltage is adjustable up to at least 10 V for LPVT and at least 30 V for LPCT to be able to test with the maximum setting ranges.
    - If the primary injection test is necessary to check the CT/LPCT, VT/LPVT primary connection and polarity, the injection source should be at such a rating that the minimum current at the CT secondary is larger than 20 mA (2% of the nominal current) and the minimum voltage at the secondary is larger than 750 mV (1% of the nominal voltage).
- DC voltage source

  Adjustable from 48 to 250 V DC, for adaptation to the voltage level of the logic input being tested.
- Multimeters
    - With suitable AC current range, and AC/DC voltage ranges
    - Phase angle meter
- A portable PC with eSetup Easergy Pro installed
- USB cable with mini-USB type B interface or RJ45 Ethernet cable
- For CT/VT, test block and test plug for secondary injection testing
    - Plug with cord to match the "current" test block installed
    - Plug with cord to match the "voltage" test block installed
- For LPCT/LPVT, test plug for secondary injection testing
    - Cable with RJ45 terminal compliant with IEC 61869-10/11
    - LPVT hub connector (to be used if the LPVT hub connector installed in the cubicle is not accessible)

Check the digital outputs

Before any functional testing, it is needed to check the contact relays of the PowerLogic P5 protection relays:

- Set the IED mode to Test mode

  The PowerLogic P5 protection relay has its dedicated test modes (See Mode of use for testing purposes, page 283).

- Force output relay contacts

  With eSetup Easergy Pro, setting the output relay fields to 1 or 0 in **DEVICE/ TEST** menu, in the **Relays** view to forces the output relay to On or Off.

  There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, and internal digital signals to be monitored.

PowerLogic P5 protection relay check

Check with the PowerLogic P5 protection relay de-energized

The following group of tests should be carried out without the auxiliary power supply applied to PowerLogic P5 protection relay and with the trip circuit isolated. The current and voltage transformer connections must be isolated from the protection relay for these checks. It is suggested to apply the test block to isolate the primary system, as shown in Typical test block connection diagram, page 172.

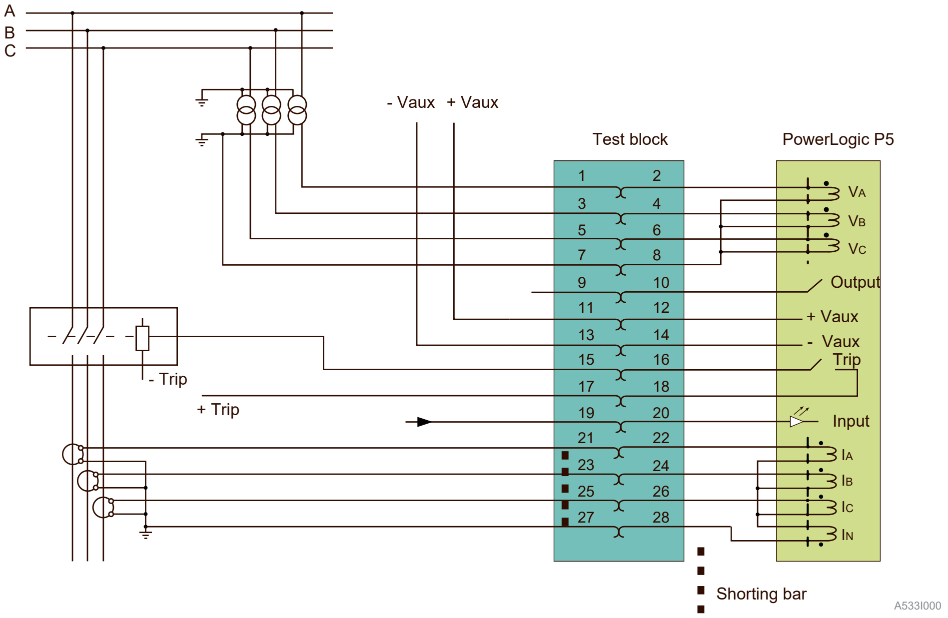
DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Never open-circuit the secondary circuit of a current transformer.
- Before the test plug is inserted into the test block, make sure the sockets in the test plug which correspond to the current transformer secondary windings are linked.

Failure to follow these instructions will result in death or serious injury.

Figure 154 - Typical test block connection diagram



Before inserting the test plug, refer to the scheme diagram. For example, the test block may be associated with protection current transformer circuits. If a PowerLogic P5 protection relay is installed in the switchgear, the test block is not always provided. In the application case without a test block, it is mandatory to isolate the voltage transformer supply to the PowerLogic P5 protection relay using the panel links or connecting blocks, and to short-circuit and disconnect the line current transformers from the protection relay terminals. Where means of isolating the auxiliary power supply and trip circuit (such as isolation links, fuses and MCB) are provided, these should be used. If this is impossible, the wiring to these circuits must be disconnected and the exposed ends suitably terminated.

Visual inspection

The visual inspection should include the following aspects:

- Check the rating information on the PowerLogic P5 protection relay.
- Check that the PowerLogic P5 protection relay being tested is correct for the protected objective.
- Check that the circuit reference and system details are entered onto the setting record sheet (not provided).
- Carefully examine the PowerLogic P5 protection relay to see that no physical damage has occurred since installation.
- Check that the case grounding connections, at the rear of the protection relay case, are used to connect the protection relay to a local ground bar using an adequate conductor (see Connecting ground, page 94).

External wiring

- Check that the external wiring is correct to the relevant protection relay diagram and wiring scheme. Check that the phase rotation appears as expected.
- Check the connections against the wiring diagram if a test block is provided.
- Check the connected tripping circuit(s) are correct to the wiring scheme.

Auxiliary power supply

PowerLogic P5 protection relay can be operated from either a DC or AC auxiliary power supply. The acceptable voltage variation is ±20%.

- For PowerLogic P5x20 protection relay, the rated voltage is 24 to 250 V DC/ 100 to 230 V AC. So, the incoming voltage must be within the operating range specified as 19.2 to 300 V DC/80 to 276 V AC.
- For PowerLogic P5x30 protection relay, the rated voltage is 48 to 250 V DC/ 100 to 230 V AC. So, the incoming voltage must be within the operating range specified as 38.4 to 300 V DC/80 to 276 V AC.
- Another option for PowerLogic P5x30 protection relay, the rated voltage is 24 to 48 V DC. So, the incoming voltage must be within the operating range specified as 19.2 to 57.6 V DC.

Without energizing the protection relay, measure the auxiliary power supply to help ensure it is within the operating range.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

The power supply must be turned off for at least 5 seconds before the power supply module is removed.

Failure to follow these instructions will result in death or serious injury.

NOTICE

POWER SUPPLY DAMAGE

Before connecting the auxiliary voltage to the PowerLogic P5 protection relay, make sure the nominal value of the auxiliary device voltage corresponds with the nominal value of the auxiliary system voltage.

Failure to follow these instructions can result in equipment damage.

Watchdog

Using a continuity tester, check that the watchdog contacts (DO4 of slot B) are in the states shown in the Watchdog contact status table for a de-energized protection relay.

Testing with the PowerLogic P5 protection relay energized

The following group of tests verify that the PowerLogic P5 protection relay hardware and software is functioning correctly and should be carried out with the auxiliary power supply applied to the protection relay.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- The current and voltage transformer connections must remain isolated from the protection device for these checks.
- The trip circuit must remain isolated to help prevent accidental operation of the associated circuit breaker.

Failure to follow these instructions will result in death or serious injury.

Energizing the protection relay

The PowerLogic P5 protection relay initializes in the following procedure after being energized:

- Switch on the auxiliary power supply.
- Check that PowerLogic P5 protection relay performs the following initialization sequence:
    1. LED ⏻ is illuminated green and LED 🔧 is illuminated red. The screen will display the self-test progress.
    2. The screen will display the progress of "Firmware Loading" and LED 🔧 is illuminated yellow.
    3. When the initialization of PowerLogic P5 protection relay is complete, LED 🔧 is off.
       The default screen (Single Line Diagram of one bay) is displayed.

  NOTE: If a backup memory (extension board) is present in the PowerLogic P5 protection relay, the device checks the consistency of the settings and configuration stored in the protection relay and in the backup memory. If there is any gap, the protection relay will invite the operator to select the options for handling the backup memory content.

  Only when this operation is successfully completed will the LED 🔧 turn off and the default screen (Single Line Diagram of one bay) is displayed.

Watchdog

Using a continuity tester, check that the watchdog contacts (DO4 of slot B) are in the states shown in the Watchdog contact status diagram for an energized protection relay.

Date and time

The data and time should be set.

With IRIG-B module

If the IRIG-B module is connected and time clock signal is received by the PowerLogic P5 protection relay, the synchronization source field in the Clock synchro view of the General menu will show "IRIG-B" and the protection relay will adjust the Date and Time automatically. If the IRIG-B signal is lost, the protection relay will change the time synchronization source from "IRIG-B" to "internal" after 400 seconds.

Without IRIG-B module or SNTP

If the time and date is not being maintained by an IRIG-B signal, set the date and time to the correct date and local time using the Date setting field and the Time of day setting field in the System clock view of the General settings menu.

LED and screen

To trigger the LED and screen test, on the local panel of PowerLogic P5 protection relay, locate to main menu by keep pressing ⌂ button, press the ℹ button, then press the ◁ button, the protection relay will automatically test the LEDs and the screen by the following sequence:

1. The 4 LEDs on the top: the power ON/OFF LED, alarm LED, trip LED, and the maintenance/test LED will be lit one by one.
2. The 6 or 10 user programmable LEDs will be lit one by one for 3 loops, one loop in green, one loop in yellow, and one loop in red.
3. The LCD will be tested by displaying according to different values of background colors and contrasts.

For the detail of local panel, refer to Local panel, page 251.

Digital inputs

This test checks that all the PowerLogic P5 protection relay’s digital inputs (opto-isolated) are functioning correctly. Check the terminal configuration schemes in PowerLogic P5 rear panel, page 65 for terminal numbers. Check the polarity and connect the external 48 V DC supply voltage to the appropriate terminals for the input being tested. Energize the opto-isolated input one by one.

> **NOTE:** The external power supply is used for this test, but only after confirming that it is suitably rated, with the variation less than 20%.

The status of each opto-isolated input can be viewed in the Digital inputs view of the Control menu; a "1" indicating an energized input and a "0" indicating a de-energized input. When each opto-isolated input is energized, the related DI status changes to indicate the new state of the inputs.

Digital outputs

This test checks that all the output contact relays are functioning correctly using the Test mode. To enable testing:

- Frst set the PowerLogic P5 ode of use to test mode per Mode of use for testing purposes, page 283.

- Connect a continuity tester across the terminals corresponding to output relay as shown in the relevant terminal configuration schemes in PowerLogic P5 rear panel, page 65. To operate the output relay DO1 in Slot B, from **Home** menu / **Control** sub-menu / **digital outputs** menu item / **digital output Slot X** view, set the field DO1(B) to 1. Operation is confirmed by the continuity tester operating for a normally open contact and ceasing to operate for a normally closed contact.
- Measure the resistance of the contacts in the closed state. Reset the output relay by setting the DO1(B) field to 0.
- Repeat the test for the rest of the output relays then return the PowerLogic P5 protection relay to service by setting the IED mode back to "Normal".

NOTE: Ensure that the thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the over-operated output contact relays. Keep the time between application and removal of contact test to a minimum.

Communication ports

The PowerLogic P5 protection relay supports both serial communication ports and Ethernet communication ports.

There are six protocols that can be selected and used to communicate through the serial ports.

- DNP3
- IEC 60870-5-101
- IEC 60870-5-103
- Modbus slave
- Modbus master
- Digital CB

If one of these protocols is configured, the PowerLogic P5 protection relay can exchange data with protocol master or slave. The serial port parameters, for example, the baud rate, parity, wire number, can be selected and will take effect after reboot.

There are four protocols that can be selected and used to communicate through the Ethernet ports.

- IEC 61850
- DNP3
- Modbus
- EtherNet/IP

Three Ethernet protocols can be selected at the same time, and for each protocol IP address needs to be selected to communicate with clients.

Virtual injections

Enable virtual injection

The PowerLogic P5 protection relay has the capability to test all the functionalities according to the relevant access rights by:

- Simulation of voltage and current signals
- Injection of a Comtrade file

The virtual injection is done using eSetup Easergy Pro connected to the local panel.

> **NOTE:** To use the virtual injections the first time, eSetup Easergy Pro proposes to install WinPcap library delivered with the software. This installation is mandatory to simulate injections.

To enable virtual injection in eSetup Easergy Pro:

1. Click on the green button with a left arrow on right-hand side to expand the injector view that is by default hidden in eSetup Easergy Pro.
2. Check the **Enable virtual injections** option.
3. Select Test mode or Test Block mode for the virtual injection test.

   Virtual injections are available only in Test mode or Test Block mode (see Mode of use for testing purposes, page 283 for more information).
4. Set **Auto read** to On in the menu bar of eSetup Easergy Pro in order to read the measurements.

Manual injection

In the **Manual** tab of the **Virtual injection** setting view, set the following parameters:

- **Cycles:**

  Set the value to the number of signal period to apply for the signal simulation.
- **Frequency:**

  Set the frequency of the signal to inject.
- **Scalings:**

  Set the maximum values and angles.
- **Measurements:**

  Set the injection values for the testing.

The injection time can be set in cycles or in real time. For example, for 50 Hz nominal frequency, one cycle is 20 ms, so 100 cycles equal to 2 s of injection time.

All the signals are simulated with their fundamental value (no harmonics) and instantaneously displayed in the Graph section of the view.

Comtrade file play-back

In the **File** tab of the Virtual injection view, it is possible to replay the analogue signals recorded in a Comtrade file (ASCII format, IEC 60255–24, IEEE Std C37.111, edition 1999 and 2013):

1. Select the Comtrade file using the **Open** button in the bottom right corner of the setting view.
2. Select the mode of injection:
   - **Single injection**: play the comtrade file once.
   - **Loop mode**: repeated the injection until a manual stop.
   - **Followed by zero**: single injection of the comtrade file followed by 0.
3. Select the assigned injection for each analogue channel.

Injection

Press on the **Start** button in the upper section of the view for the injection.

Any protection function that is enabled and of which the threshold setting is below the injection will activate, with the magnitudes displayed in the **MEASUREMENTS** section of the view.

The PowerLogic P5 protection relay will trip and activate digital outputs physically in the Test mode and will stay frozen in the Test-block mode.

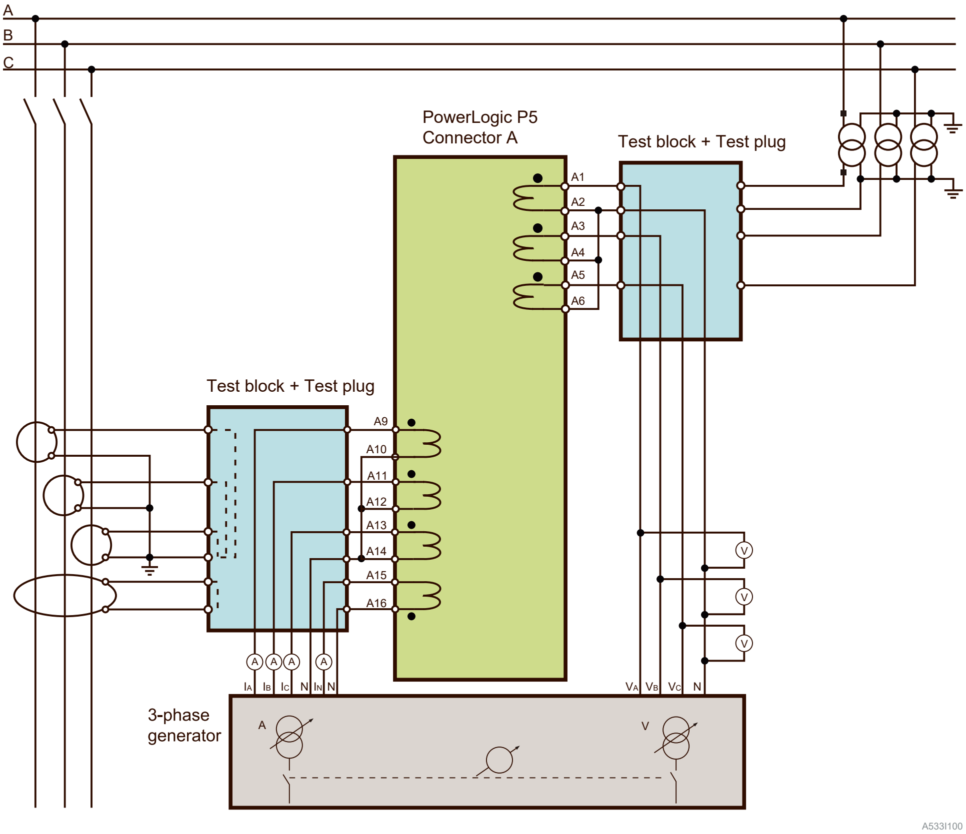
NOTE: Do not try to manually change the mode while using the injector.

Secondary injection test

The secondary injection test is to check the protection relay analogue input modules and check the basic protection functions with the application-specific settings.

The connection diagram for the secondary injection test with test block and test plug mounted is illustrated in the Secondary injection test connection diagram with test block, page 179.

Figure 155 - Secondary injection test connection diagram with test block



In the application case without test block, it is mandatory to remove the voltage transformer cable. The trip circuit shall be disconnected to avoid the spurious circuit breaker trip during the secondary injection test. The secondary injection test can be performed by injecting the current and voltage into the related analogue connection terminals on the rear panel of the PowerLogic P5 protection relay via the test block.

Apply application-specific settings

There are different methods of applying the settings:

- Local panel

  If the application is simple without specific logic and only limited specific settings are applied, the setting configuration can be easily performed via the PowerLogic P5 protection relay's local panel by entering the settings manually.

- eSetup Easergy Pro

  If specific logic (not the default logic) is applied, or many specific settings are applied, setting configuration through eSetup Easergy Pro is the recommended method for configuring as it is much faster and there is less margin for error.

  NOTE: If the application-specific settings are not available, the secondary injection test can be performed based on the default settings.

After the setting configuration, it is suggested to disable all the protection functions applied before the current and voltage injection, to help ensure that spurious circuit breaker trips will not happen. During the protection function test, only the protection function under test can be enabled. After the completion of the injection tests, all the protection functions applied must be enabled during the final check stage.

Current inputs

This test verifies that the accuracy of current measurement is within acceptable tolerances.

- Double check the connection and then start the injection test.
- Apply current equal to the related CT secondary rated current.
- Check its magnitude using a multimeter or reading from the test equipment.
- Check the current magnitude displayed on the local panel of the PowerLogic P5 protection relay.
- Calculate the current measurement accuracy, it shall be within ±1%.

Typical voltage measurement modes in PowerLogic P5

According to the ordered analogue module in slot A of a PowerLogic P5 protection relay, the application of voltage measurement modes can be various.

Following table indicates the selection of the voltage measurement modes based on the voltage inputs type of PowerLogic P5 protection relays.

Voltage inputs type		Voltage measurement mode									
		3VP	3VP + VN	3VP/ VPPy	3VP/VPy	2VPP + VN	2VPP + VN + VPPy	VPP/ VPPy	VP	VPP	VN
P5F30	VT	■	■	■	■	■	■	■			
	LPVT	■			■						
	LPVT + VT Adapter	■	■	■	■						
P5M30	VT	■	■			■					
	LPVT	■									
	LPVT + VT Adapter	■	■								
P5V20	VT	■	■	■	■	■	■	■			
P5U20	LPVT	■			■						
	LPVT + VT Adapter	■	■	■	■						
P5T30	VT								■	■	■
P5L30	VT	■	■	■	■	■	■	■			

Voltage inputs

This test verifies that the accuracy of voltage measurement is within the acceptable tolerances.

Seven modes of connection are available on the PowerLogic P5 protection relay:

Mode	U1	U2	U3	U4
3VP	VA	VB	VC	-
3VP + VN	VA	VB	VC	VN
3VP/VPPy	VA	VB	VC	VABy
3VP/VPy	VA	VB	VC	VAy
2VPP + VN	VAB	VCB	-	VN

Mode	U1	U2	U3	U4
2VPP + VN + VPPy	VAB	VCB	VABy	VN
VPP/VPPy	VAB	-	VABy	-

The following tests will be realized with the VT Connecting Mode set to 3 VT which is the most used configuration.

- Double check the connection and then start the injection test.
- Apply voltage equal to the related VT secondary rated voltage.
- Check its magnitude using a multimeter or reading from the test equipment.
- Check the voltage magnitude on the local panel of the PowerLogic P5 protection relay.
- Calculate the voltage measurement accuracy, it shall be within ±1%.

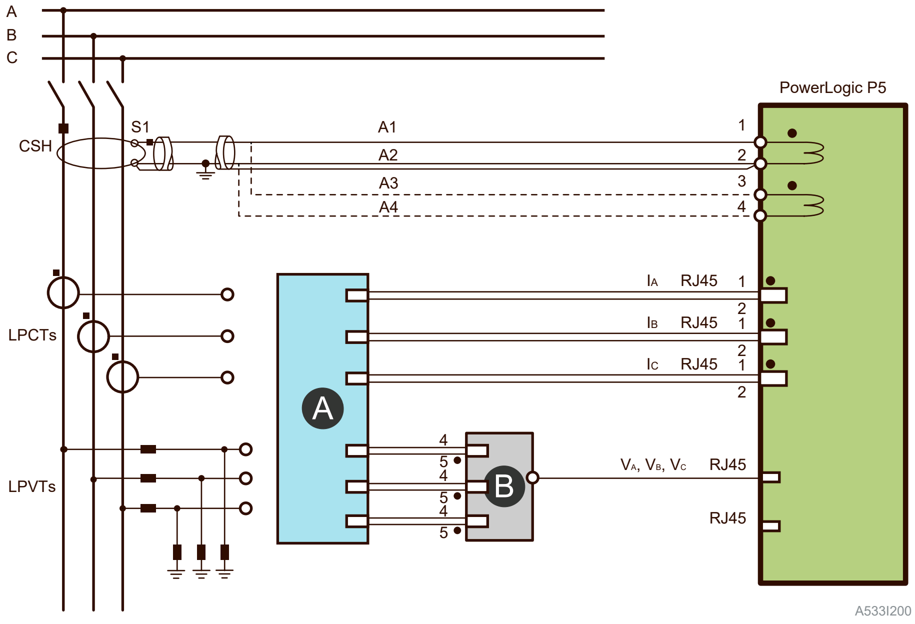
LPCT and LPVT inputs

These tests verify that the accuracy of the LPCT/LPVT measurements are within acceptable tolerances.

Connection diagram for testing the LPCT and LPVT measurement accuracy, page 181 shows the connection diagram that includes the PowerLogic P5 protection relay and a low frequency generator as described in Testing tools and equipment, page 171.

> **NOTE:** To avoid any slow fluctuation of current measurements during testing, it is recommended to disconnect the signal generator ground link or use an isolator transformer.

Figure 156 - Connection diagram for testing the LPCT and LPVT measurement accuracy



A	Voltage Generator	B	LPVT hub

LPCT measurement

This test verifies that the accuracy of LPCT measurement is within acceptable tolerances.

- Disconnect the secondary of LPCTs from the PowerLogic P5 protection relay.

- Use a generator with low voltage output (30 V max) and connect it directly to the PowerLogic P5 protection relay as described in Testing tools and equipment, page 171.
- Apply current equal to the related LPCT secondary rated current.
- Check its magnitude using a multimeter or reading from the test equipment.
- Check the current magnitude displayed on the local panel of the PowerLogic P5 protection relay.
- Calculate the LPCT measurement accuracy, it shall be within ±1%.

NOTE: To be sure everything is well reconnected after test, it is recommended to perform a primary injection, at low level.

LPVT measurement

This test verifies that the accuracy of LPVT measurement is within acceptable tolerances.

- Disconnect the secondary of LPVTs from the LPVT hub.

  If the LPVT hub is not accessible inside the cubicle, disconnect the secondary of the LPVT hub from the PowerLogic P5 protection relay, and connect another one to replace it during the tests.
- Use a generator with low voltage output (10 V max) and connect it directly to the LPVT hub as described in Testing tools and equipment, page 171.
- Apply voltage equal to the related LPVT secondary rated voltage.
- Check its magnitude using a multimeter or reading from the test equipment.
- Check the voltage magnitude on the local panel of the PowerLogic P5 protection relay.
- Calculate the LPVT measurement accuracy, it shall be within ±1%.

NOTE: To be sure everything is well reconnected after test, it is recommended to perform a primary injection, at low level.

Check the protection functions

The tests described in PowerLogic P5 protection relay check, page 172, Current inputs, page 180, LPCT and LPVT inputs, page 181, and Voltage inputs, page 180 have already demonstrated that the protection relay inputs and outputs work correctly and the analogue inputs are within calibration, thus the purpose of the tests for protection functions is as follows:

- To determine that each active protection function of the protection relay can trip according to the correct application settings.
- To verify correct assignment of the trip and alarm contacts by monitoring the response to the related fault injection.

The following sections only present the test procedures for current protection and voltage protection. The basic test procedures are similar for the other protection functions.

Current protection

This test, performed on stage 1 of the overcurrent protection function in setting group 1, is to check that the protection relay is operating correctly at the application-specific settings.

1. Determine which output relay has been selected to operate when an 50/51-1 trip occurs.
2. Connect the output relay so that its operation will trip the test set and stop the timer of the injection box.

3. Connect the current outputs of test set (current injection source) to the protection relay current input terminals.
4. Apply a current of 120% of the current setting to the protection relay and the relay shall trip according to the operation time setting.
5. Check the tripping time from the test set and compare with the operation time setting.
6. Check the related fault recorder, events, and the related LEDs for trip indications.

A similar test procedure can be applied for the secondary injection test to check the other protection functions with the application-specific settings.

Voltage protection

This test, performed on stage 1 of the undervoltage protection function in setting group 1, is to check that the protection relay is operating correctly at the application-specific settings.

1. Determine which output relay has been selected to operate when a 27-1 trip occurs.
2. Connect the output relay so that its operation will trip the test set and stop the timer.
3. Connect the voltage outputs of the test set (voltage injection source) to the protection relay voltage input terminals.
4. Apply normal voltage first and then a voltage of 80% of the voltage setting to the protection relay. The relay shall trip according to the operation time setting.
5. Check the tripping time from the test set and compare with the operation time setting.
6. Check the related fault recorder, events, and the related LEDs for trip indications.

A similar test procedure can be applied for the secondary injection test to check the other protection functions with the application-specific settings.

Testing with LPIT test box (reference REL51037)

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- This equipment must be only be installed and serviced by qualified electrical personnel.
- Turn off all power supplying this equipment before working on or inside it.
- Always use a properly rated voltage sensing device to confirm that all power is off.
- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices.
- Do not install this product in ATEX zone 0 or 1 areas.

Failure to follow these instructions will result in death or serious injury.

Introduction

The secondary injection tests can be carried out with the LPIT test box. This test box is an adapter for secondary testing of PowerLogic P5 protection relays with LPCT/LPVT measuring inputs. It is an interface between the OMICRON[44] testing kit's low-power outputs and PowerLogic P5 inputs. Thanks to this adapter, the testing is comfortable and the right accuracy in the entire measuring range is ensured. For the LPCT signal testing, the LPIT Test Box offers 4 sets of current and 2 sets of voltage outputs depending on the measuring ranges tested. The LPIT test box is delivered with all cables required to perform the tests.

The OMICRON CMC 356, CMC 256plus and CMC 353 low level output allows 2 sets of three phase injections (LL1,2,3 and/or LL4,5,6).

The injection accuracy of these outputs is 0.07% from 0.71 V to 7.10 V (phase to neutral).

The overall accuracy (OMICRON + LPIT test box) is 0.25%[45] from 0.71 V to 7.10 V (phase to neutral).

Figure 157 - LPIT test box

For the model number of the LPIT test box, refer to Order codes of LPIT test box and test sockets/plugs, page 190 section for details.

The LPIT test box can be connected to the OMICRON low-level outputs with 3 inputs as shown below.

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[44] Omicron is a trademark of OMICRON Electronics GmbH, Oberes Ried 1, 6833 Klaus, Austria

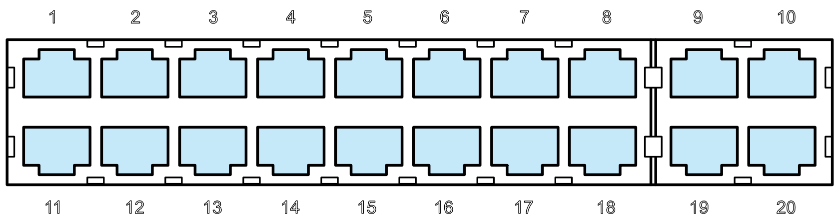
[45] Typical value at 25 °C and variable in range of ultimate operation temperature 0 °C to 50 °C.

Figure 158 - The rear panel of LPIT test box

The LPIT test box can output different voltages in relation to the rated voltages of LPCTs (22.5 mV or 225 mV) and/or LPVTs (3.25 V (phase to phase)/1.88 V (phase to neutral)) linked to the three inputs shown above.

Figure 159 - The front panel of LPIT test box

Table 35 - Output ports on LPIT test box front panel

Current/ voltage	IA	IB	IC	IA,B,C	IA	IB	IC	IA,B,C	VA,B,C	VA,B,C
Input Output	2 V 225 mV				1 V 22.5 mV				1.88 V 1.88 V	1.88 V 1.88 V
LPCT/ LPVT	LPCT Input 1 (a: LL 1,2,3)				LPCT Input 1 (b: LL 4,5,6)				LPVT (2a)	LPVT (2b)
Port	1	2	3	4	5	6	7	8	9	10
										
Port	11	12	13	14	15	16	17	18	19	20
LPCT/ LPVT	LPCT Input 3 (a: LL 1,2,3)				LPCT Input 3 (b: LL 4,5,6)				LPVT (2c)	Test
Current/ voltage	IA	IB	IC	IA,B,C	IA	IB	IC	IA,B,C	VA,B,C	
Input Output	2 V 22.5 mV				1 V 1 V				1 V 1 V	Pin 1 to 8

NOTE: The 20th RJ45 is not an output but an input. As an example, it distributes its pins to the pin connections listed below of the LPIT output for test purposes. See Test input (20th RJ45), page 189 section for more details.

The outputs 1, 2, 3, 5, 6, 7, 11, 12, 13, 15, 16 and 17 are dedicated to single phase LPCT direct injections to IEDs.

The outputs 4, 8, 14 and 18 are dedicated to three phase LPCT injections through ESSAILEC® test plugs.

The outputs 9, 10 and 19 are dedicated to three phase LPVT injections.

When Input 1 is used, the possible LPCT outputs are:

- 2 V OMICRON outputs 1 to 3 to 225 mV scaling for outputs 1 to 3 (single phase) and 4 (three phase) LPCT
- 1 V OMICRON outputs 4 to 6 to 22.5 mV scaling for outputs 5 to 7 (single phase) and 8 (three phase) LPCT

When Input 2 is used, the possible LPVT outputs are:

- 3.25 V/1.88 V OMICRON outputs 1 to 3 with no scaling for outputs 9 (three phase) LPVT
- 3.25 V/1.88 V OMICRON outputs 4 to 6 with no scaling for outputs 10 (three phase) LPVT

When Input 3 is used, the possible LPCT and LPVT outputs are:

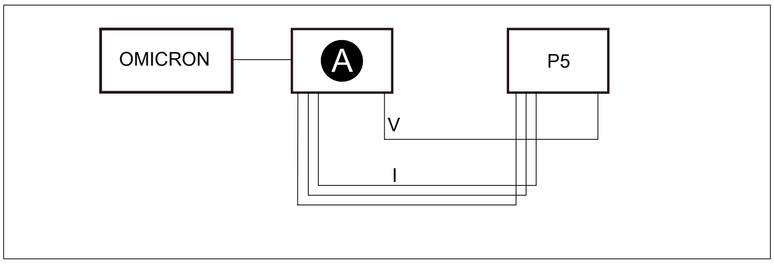
- 2 V OMICRON outputs 1 to 3 to 22.5 mV scaling for outputs 11 to 13 (single phase) and 14 (three phase) LPCT
- OMICRON outputs 4 to 6 with no scaling for outputs 15 to 17 (single phase) and 18 (three phase) LPCT and 19 (three phase) LPVT

LPCT/LPVT testing diagram

There are two cases for LPCT/LPVT testing:

- direct testing without test socket/plugs
- with test socket/plugs

Figure 160 - LPCT/LPVT direct testing without test sockets/plugs



P533SNA

A	LPIT test box	REL51037

NOTE:

- For current, use 1st/2nd/3rd connector of each scaling block.
- Test cables are connected in place of LPCT/LPVT cables during the testing.
- To find out the order codes, refer to Order codes of LPIT test box and test sockets/plugs, page 190 section for details.

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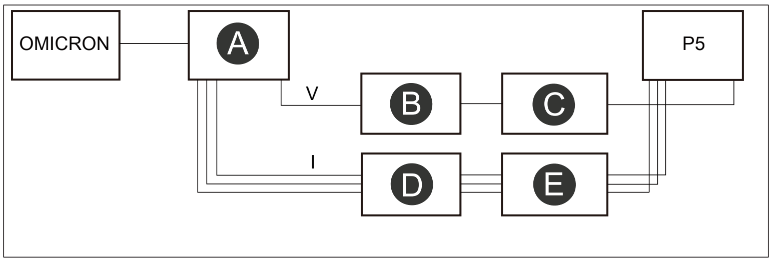
Figure 161 - LPCT/LPVT testing with test sockets/plugs



P533SOA

A	LPIT test box	REL51037	B	LPVT test plug	REL51093
C	LPVT test socket (with cover)	REL51092	D	LPCT test plug	REL51090
E	LPCT test socket (with cover)	REL51089			

NOTE:

- For current, use 4th connector of each scaling block.
- To find out the order codes, refer to Order codes of LPIT test box and test sockets/plugs, page 190 section for details.

Current injection test

For a 22.5 mV rated LPCT

1. From 0 to 3.5 In with accuracy needed from 0.35 In to 3.5 In
   - Connect to input 3
   - Outputs to be used are 11 to 14
   - Set 2 V rated OMICRON output on LL1,2,3
   - Example In = 100 A, injection is from 0 A to 350 A (accuracy from 35 A to 350 A)
2. From 0 to 7.1 In with accuracy needed from 0.71 In to 7.1 In
   - Connect to input 1
   - Outputs to be used are 5 to 8
   - Set 1 V rated OMICRON output on LL4,5,6
   - Example In = 100 A, injection is from 0 A to 710 A (accuracy from 71 A to 710 A)
3. From 0 to 35 In with accuracy needed from 3.5 In
   - Connect to input 1
   - Outputs to be used are 1 to 4
   - Set 2 V rated OMICRON output on LL1,2,3
   - Example In = 100 A, injection is from 0 A to 3500 A (accuracy from 350 A to 3500 A)

For a 225 mV rated LPCT

1. From 0 to 0.35 In with accuracy needed from 0.035 In to 0.35 In
   - Connect to input 3
   - Outputs to be used are 11 to 14
   - Set 2 V rated OMICRON output on LL1,2,3
   - Example In = 100 A, injection is from 0 A to 35 A (accuracy from 3.5 A to 35 A)
2. From 0 to 0.71 In with accuracy needed from 0.071 In to 0.71 In
   - Connect to input 1
   - Outputs to be used are 5 to 8
   - Set 1 V rated OMICRON output on LL4,5,6
   - Example In = 100 A, injection is from 0 A to 71 A (accuracy from 7.1 A to 71 A)

3. From 0 to 3.5 In with accuracy needed from 0.35 In to 3.5 In
   - Connect to input 1
   - Outputs to be used are 1 to 4
   - Set 2 V rated OMICRON output on LL1,2,3
   - Example In = 100 A, injection is from 0 A to 350 A (accuracy from 35 A to 350 A)
4. From 0 to 35 In with accuracy needed from 3.5 In to 35 In
   - Connect to input 3
   - Outputs to be used are 15 to 18
   - Set 1 V rated OMICRON output on LL4,5,6
   - Example In = 100 A, injection is from 0 A to 3500 A (accuracy from 350 A to 3500 A)

Voltage injection test

For a 3.25 V (phase to phase) rated LPVT (= 1.88 V (phase to neutral))

1. From 0 to 3.8 Vn with accuracy needed from 0.38 Vn to 3.8 Vn

   Method 1:
   - Connect to input 2
   - Outputs to be used are 9 and 10
   - Set 3.25 V rated OMICRON output on LL1,2,3 or LL4,5,6

   Method 2:
   - Connect to input 3
   - Output to be used is 19
   - Set 3.25 V rated OMICRON output on LL4,5,6
2. If lower voltage injection is needed:
   a. From 0 to 0.42 Vn with accuracy needed from 0.042 Vn to 0.42 Vn
      - Connect to input 1 to obtain 0.188 V rated output
      - Output to be used is 4
      - Set 1.668 V rated OMICRON output on LL1,2,3

   b. From 0 to 0.042 Vn with accuracy needed from 0.0042 Vn to 0.042 Vn
      - Connect to input 1 to obtain 0.188 V rated output
      - Output to be used is 14
      - Set 1.668 V rated OMICRON output on LL1,2,3

Current and voltage injections test

NOTE: The simultaneous current and voltage injection test is only possible connected to input 3 of the LPIT test box.

Use one of the above solutions described in current injection test and voltage injection test for outputs 11 to 19.

Test input (20th RJ45)

This input allows for an easy multimeter connection to measure either voltages or resistances between different pinouts of an IEC 61869-11 LPVT (or an IEC 61869-10 LPCT) connected to this RJ45 input.

Table 36 - Pin assignment for RJ45 connectors

RJ45 Pin	1	2	3	4	5	6	7	8
LPCT	S1	S2						
LPVT							a	n
LPVT (old)				n	a			

LPCT/LPVT Test Sockets and Plugs ESSAILEC®

Description

The Essailec® LPCT/LPVT test sockets and plugs from TE Connectivity allow the PowerLogic P5 protection relay LPCT/LPVT measuring inputs to be tested using RJ45 cable connections. The test socket is installed on the front panel of medium voltage switchgear, interconnecting the LPCT/LPVTs and PowerLogic P5 protection relay. The solution offers "make before break" principle so the test procedure is exactly the same as for protection relays with conventional measuring inputs.

- RJ45 connection type (Cat.5)
- Allow easy measurement and injection operations
- Signal protection against emission and radio frequency interferences thanks to a shielded cover on the shielded socket
- Shielding tests according to IEC 62271-1 Annex J
- Grounding point: M5 screw to be wired with an adapted ring lug termination. Ø = 4 mm (0.16 in.), torque = 1.2 Nm (10.8 lb.in).

Make before break principle:

- The circuits are automatically disconnected with the insertion of the plug,
- The circuits close automatically when the plug is removed.

Figure 162 - LPCT/LPVT Test Sockets and Plugs ESSAILEC®

REL51089 LPCT Test Socket with cover

REL51090 LPCT Test Plug

Test socket cover

LPCT test socket

LPCT test plug

REL51092 LPVT Test Socket with cover

Test socket cover

LPVT test socket

REL51093 LPVT Test Plug

LPVT test plug

Main technical data

Connecting capacity	IEC 947-1
Body	Polycarbonate UL94 V0
Conductive parts	Silver-plated
Rated voltage	125 V
Impulse withstand voltage	1000 V
Rated current	1.5 A
Accuracy	0.5 %
Storage temperature range	-40 ... +85 °C
Working temperature range	-40 ... +85 °C
Protection without lid / with lid	IP20 / IP40
Pollution degree	3

Ordering table

Please refer to Model numbers of test sockets/plugs, page 191 for ordering information of test sockets/plugs.

Model numbers for LPCT/LPVT accessories

The model numbers for the LPIT test box and test sockets/plugs are listed in the following two tables.

Table 37 - Model numbers of LPIT test box

Order code	Description
REL51037	LPIT test box including: Test box × 1 Test cable for test box × 1 RJ45 2m cable × 8
REL51088	Spare cable for LPIT test box
59660	0.6 m remote module connection cord
59661	2 m remote module connection cord
59662	4 m remote module connection cord

Table 38 - Model numbers of test sockets/plugs

Order code	Description
REL51089	LPCT test socket with cover
REL51090	LPCT test plug
REL51092	LPVT test socket with cover
REL51093	LPVT test plug

Primary injection test

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

The primary injection test shall be performed by the qualified electrical engineers and strictly follow the related primary injection testing instructions from the utility.

Failure to follow these instructions will result in death or serious injury.

Primary injection testing is recommended to:

- Confirm the external wiring to the current and voltage inputs is correct
- Check the polarity of the current transformers at each end is consistent
- Check the directionality of the directional elements

For the application where the directional overcurrent or ground fault protection, distant protection or current differential protection is installed, it is mandatory to check the correct polarity of the current transformers. If the current or voltage positive or negative sequence components are applied in the protection functions, it is mandatory to help ensure the correct phase sequence of current or voltage inputs.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

If any of the external wiring was disconnected from the protection device to run any tests, make sure that all connections are restored according to the external connection or scheme diagram.

Failure to follow these instructions will result in death or serious injury.

For primary injection testing on conventional CT's, it is necessary to calculate the current and voltage magnitudes to be injected in the primary side according to the actual application scenario, check that the current magnitude is more than 20 mA and the voltage magnitude is more than 100 mV on the secondary side. Normally the auxiliary 380 V power supply in the substation or power plant can be applied for primary injection tests.

Voltage connections

NOTICE

CIRCUIT OVERLOAD

- Using a multi-meter, measure the voltage transformer secondary voltages to ensure they are compliant with the PowerLogic P5 protection relay's input ratings.
- Check that the system phase rotation is correct using a phase rotation meter.

Failure to follow these instructions can result in equipment damage.

Primary Voltage Injection:

- Inject the voltage into the voltage transformer primary connection terminals.
- Check that the voltage magnitudes and angles are displayed on the protection relay's HMI in primary values.
- The voltage magnitudes should be equal to the applied voltage.
- The voltage angles should be correct according to the phase sequence.

Thus, the VT ratio, polarity, phase sequence and the external wiring from the primary system to the protection relay can be verified by the primary voltage injection.

Current connections

NOTICE

CIRCUIT OVERLOAD

Measure the current transformer secondary values for each input using a multimeter connected in series with corresponding protection device current input.

Failure to follow these instructions can result in equipment damage.

Primary Current Injection:

- Inject current into the primary system through the phase under test.
- Check that the current magnitudes and angles are displayed on the protection relay’s HMI in primary values.
- The current magnitudes should be equal to the applied current.
- The current angles should be correct according to the phase sequence.
- Check that the current transformer polarities are correct against a phase meter already installed on site and known to be correct by measuring the phase angle between the current and voltage, or by contacting the system control center for the direction of power flow.

When using a neutral current transformer (core balance) or a sensitive current transformer, inject a single phase to validate the functionality.

Therefore, the CT ratio, polarity, phase sequence and the external wiring from the primary system to the protection relay can be verified by primary current injection.

LPCT connections

NOTICE

MEASUREMENT LOSS

Make sure that the LPCTs are connected to all 3 phases with low power sensors or with RJ45 plug.

Failure to follow these instructions can result in no current measured.

Primary Current Injection:

- Inject current into the primary system through the phase under test.
- Check that the current magnitudes and angles are displayed on the protection relay’s HMI in primary values.
- The current magnitudes should be equal to the applied current.
- The current angles should be correct according to the phase sequence.
- Check that the current transformer polarities are correct against a phase meter already installed on site and known to be correct by measuring the phase angle between the current and voltage, or by contacting the system control center for the direction of power flow.

Therefore, the CT ratio, polarity, phase sequence and the external wiring from the primary system to the protection relay can be verified by primary current injection.

NOTE: The passive Rogowski coils are not compatible with our LPCT input of PowerLogic P5.

Demonstrate circuit breaker operation

The correct operation of the circuit breaker shall be verified sufficiently during the commissioning test. Circuit breaker operation can be controlled by the local or remote-control commands.

Circuit breaker Operation Test:

- Check the actual circuit breaker position and read the circuit breaker position status from the protection relay HMI if the related circuit breaker position (52a, 52b) has been connected to the protection relay opto-isolated inputs.
- Perform a local circuit breaker control command to trip and close the circuit breaker, the circuit breaker shall operate correctly per the control command.
- Read the circuit breaker position status from protection relay HMI after one control command, the circuit breaker position information shall be the same as the actual circuit breaker status.

Arc-flash detection system setup and testing

Setting up the arc-flash system

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, NOM-029-STPS-2011, or CSAZ462.
- The arc fault detection system is not a substitute for proper PPE when working on or near equipment being monitored by the system.
- Information on this product is offered as a tool for conducting arc-flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.
- Only qualified personnel is allowed to install and service this equipment. Read this entire set of instructions and check the technical characteristics of the device before performing such work.
- Perform wiring according to national standards (NEC) and any requirements specified by the customer.
- Observe any separately marked notes and warnings.
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on this equipment, disconnect all sources of electric power. Assume all circuits are live until they are completely de-energized, tested, and tagged. Pay particular attention to the design of the power system. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing relay to ensure that all power is off.
- The equipment must be properly grounded.
- Connect the device's protective ground to functional earth according to the connection diagrams presented in this document.
- Do not open the device. It contains no user-serviceable parts.
- Install all devices, doors and covers before turning on the power to this device.

Failure to follow these instructions will result in death or serious injury.

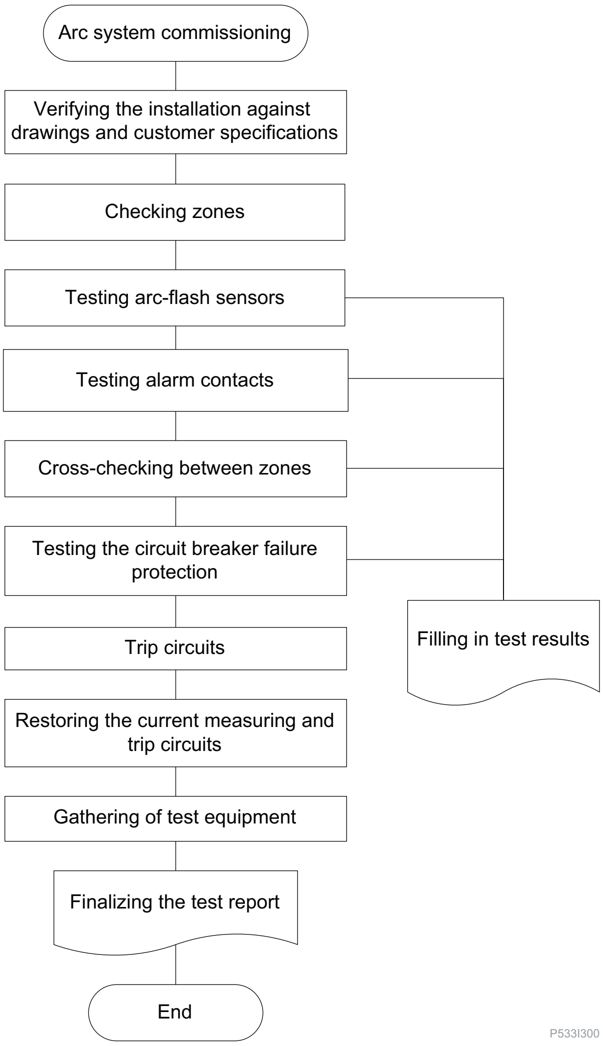
Before setting up the arc flash system:

- Mount and connect all components and sensors.
- Make sure that you understand the customer application.
- Identify the wiring connection of sensors to the device’s connectors.
- Identify the wiring connection to breaking devices.
- Power up the device.
- Verify LED indication as described with consideration of the customer application.

Commissioning and testing

This section contains the commissioning testing instructions. The figure below shows the testing sequence.

Figure 163 - Testing sequence



Checking zones

- Check the protected zones where sensors have been installed and compare them against the drawings.
- Consult the customer if the configuration does not match with the drawings.

Disconnecting trip circuits

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

Removing trip wires may cause loss of protection. Review system drawings and diagrams before disconnecting trip circuits.

Failure to follow these instructions will result in death or serious injury.

- Disconnect the trip signals to the circuit breakers that may disturb other parts of the system during the test.
- Also disconnect trip signals routed to other parts of the system, such as the breaker failure (ANSI 50BF) backup trip to upstream breakers and the transfer trip signals.
- Test the disconnected trip signals with a multimeter.

Test the arc-flash sensors

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, NOM-029-STPS-2011, or CSAZ462.
- The arc fault detection system is not a substitute for proper PPE when working on or near equipment being monitored by the system.
- Information on this product is offered as a tool for conducting arc-flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.
- Only qualified personnel is allowed to install and service this equipment. Read this entire set of instructions and check the technical characteristics of the device before performing such work.
- Perform wiring according to national standards (NEC) and any requirements specified by the customer.
- Observe any separately marked notes and warnings.
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on this equipment, disconnect all sources of electric power. Assume all circuits are live until they are completely de-energized, tested, and tagged. Pay particular attention to the design of the power system. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing relay to ensure that all power is off.
- The equipment must be properly grounded.
- Connect the device's protective ground to functional earth according to the connection diagrams presented in this document.
- Do not open the device. It contains no user-serviceable parts.
- Install all devices, doors and covers before turning on the power to this device.

Failure to follow these instructions will result in death or serious injury.

Testing the arc flash sensors with the light-only criteria operates the trip outputs of the device.

Testing the arc flash sensors with the light and current criteria, without an injected current, only generates an indication on PowerLogic P5 that protects the zone.

NOTE:

Testing the arc-flash sensors using a light source can trip the neighboring zones.

Because of their placement, some sensors cannot be tested without dismantling parts of the system. After completing the testing, reassemble the parts and validate the compliance with original mounting. Consult the equipment manufacturer before dismantling any parts.

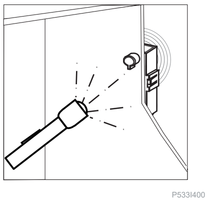
Testing the standard or pipe type sensors

Test the sensors with the PowerLogic P5 protection relay. Reset the PowerLogic P5 protection relay before the test.

NOTE:

Because of their placement, some sensors cannot be tested without dismantling parts of the system. After completing the testing, reassemble the parts and validate the compliance with original mounting. Consult the equipment manufacturer before dismantling any parts.

Figure 164 - Testing point sensors



1. Point a powerful light source such as a flashlight or camera flash unit to each arc-flash sensors until the sensor is activated.
2. Check the arc-flash sensor indication from the PowerLogic P5 protection relay.
3. Check the address of the activated arc-flash sensor from the PowerLogic P5 protection relay.
4. Compare the arc-flash sensor address information from the protection relay with that on the sensor location map.
5. Fill in the test result in the test report.
6. Reset the protection relay.
7. Repeat the procedure with the next arc-flash sensor.

Testing the supervision of arc-flash sensors

Test the sensors with PowerLogic P5 protection relay.

1. Disconnect one wire from the standard arc-flash sensor (or one end of the pipe type arc-flash sensor) to see that the sensor status supervision recognizes the fault in the arc-flash sensor.
2. Wait until the fault indication appears.
3. Check that the internal fault relay operates and that the event information is communicated to any external systems.
4. Fill in the test result in the test report.
5. Reconnect the arc-flash sensor and reset the system.
6. Repeat the procedure with the other arc-flash sensors.

Connecting a current injection device with/without time measurement

⚠CAUTION

CIRCUIT OVERLOAD

Do not open a loaded current measuring circuit before the secondary circuit of the current transformer is reliably short-circuited.

Failure to follow these instructions can result in injury or equipment damage.

1. Short circuit the secondary circuit of the current transformer and disconnect the PowerLogic P5 protection relay from the measuring circuit.
2. Connect a current injection device, one phase at a time, to the PowerLogic P5 protection relay of the current measuring circuit.
3. For a current injection device with time measurement, connect the injection device either to inject the current continuously or when triggered by the time measuring circuit:
    a. Use the digital input of the current injection device for the stop trigger in the time measurement circuit.
    b. Connect the trip output of the tested unit to the digital input of the current injection device for the stop trigger. For measuring the total operating time, use the NO contact of the circuit breaker, which indicates that status of circuit breaker is open, for the stop trigger.
    c. Connect the time measuring start signal output to the flashlight. Configure the time measuring start signal to either trigger only the flashlight or both the flashlight and the current injection.

       Preferably, the current injection should be triggered before the flashlight.
    d. Measure the operate time between the start trigger and stop trigger.

Testing the alarm contacts

Alarm signals generated by the arc-flash protection system (trip and self-supervision alarms) can be forwarded to higher-level switchgear supervision and control systems through the output contacts.

1. Activate an alarm by generating an arc fault trip or sensor status supervision alarm.
2. Check the alarm contact operation from the higher-lever system. The alarm signals can also be sent via communication.
3. Reset the protection relay.
4. Repeat the procedure with the next alarm contact.

Testing the pick-up setting of the arc-flash protection function

1. Check the pick-up setting of the current criteria by injecting a current to the PowerLogic P5 protection relay.
2. Increase the current until the overcurrent criterion picks up.
3. Reset the protection relay.
4. Compare the current settings with the results.

Testing the arc-flash protection function without the time measurement

1. Inject a current, two times greater than the pick-up current level, to the PowerLogic P5 protection relay. Inject a current in each phase, one phase at a time.
   Verify that the technical characteristics of the channels are not exceeded.

2. While injecting the current, apply light with a flashlight to at least one of the arc-flash sensors, one at a time.
3. Check that the arc-flash protection function activates.
4. Generate at least one trip with current for the PowerLogic P5 protection relay.
5. Reset the protection relay.

Testing the arc-flash protection function with the time measurement

1. Inject a current, two times greater than the pick-up current level, to the PowerLogic P5 protection relay. Inject current to all three phases.
   The current can be injected in two ways:
   - Continuous injection
   - Injection triggered by the time measurement start signal.

   Verify that the technical characteristics of the channels are not exceeded
2. Position a flashlight to each of the light sensors in sequence. Start the time measurement to trigger the flash.
3. Check that the arc-flash protection function operates.
4. Check the operation time from the time measuring device.
5. Generate at least one trip with current.
6. Reset the protection relay and repeat for other light sensors.

Testing the circuit-breaker failure protection

1. Inject a current above the overcurrent setting value to the PowerLogic P5 protection relay.
2. Point light to one of the light sensors in the protected zone with flash light. The light pulse has to be longer than the CBFP time setting. Thus, the light pulse from a camera flash is too short.
3. Check that the circuit breaker failure protection function operates.
4. Reset the protection relay.

   NOTE:

   Use a torch to test the CBFP because the light pulse from a flashlight is too short.

   Ensure that the light pulse is not too long. If the light pulse is longer than 3 seconds, the daylight blocking function generates an alarm.

Testing the selectivity of the arc-flash protection

1. Test the selectivity of the protection zones, one at a time, by pointing light to an arc-flash sensor in a protection zone.
2. Compare the operation against the protection plans.
3. Inject current and at the same time point light to one arc-flash sensor in the tested zone.
4. Compare the operation against the protection plans.
5. Repeat the procedure for the other zones.

Test report

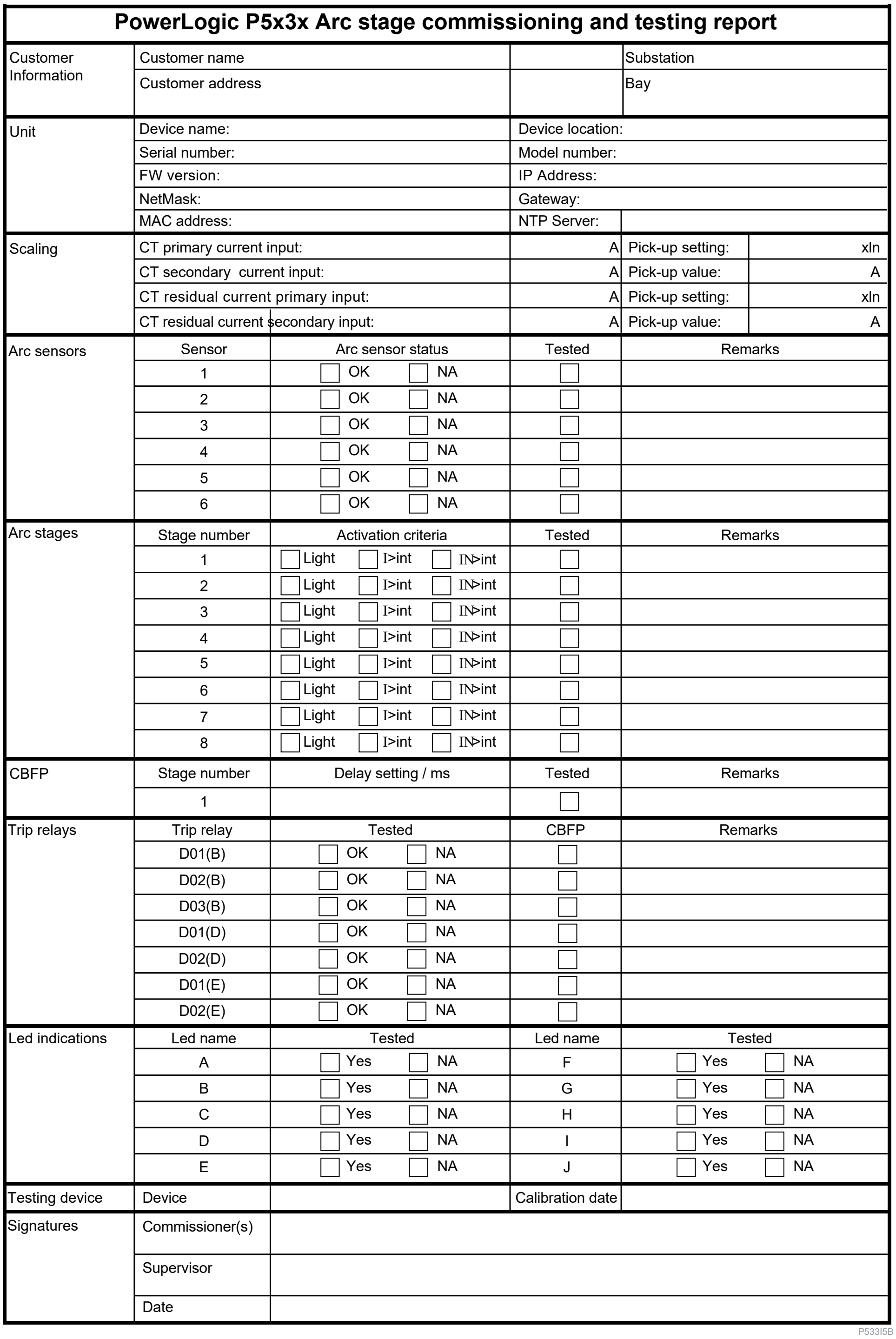
- Check the protected zones where sensors have been installed and compare them against the drawings.
- Consult the customer if the configuration does not match with the drawings.

Filling in the test report

Fill in all the required information about the system, the tested arc flash units and the test results.

Test report example

Figure 165 - Test report example



PowerLogic P5x3x Arc stage commissioning and testing report

Customer Information	Customer name		Substation		
	Customer address		Bay		
Unit	Device name:		Device location:		
	Serial number:		Model number:		
	FW version:		IP Address:		
	NetMask:		Gateway:		
	MAC address:		NTP Server:		
Scaling	CT primary current input:	A	Pick-up setting:	xIn	
	CT secondary current input:	A	Pick-up value:	A	
	CT residual current primary input:	A	Pick-up setting:	xIn	
	CT residual current secondary input:	A	Pick-up value:	A	
Arc sensors	Sensor	Arc sensor status	Tested	Remarks	
	1	☐ OK ☐ NA	☐		
	2	☐ OK ☐ NA	☐		
	3	☐ OK ☐ NA	☐		
	4	☐ OK ☐ NA	☐		
	5	☐ OK ☐ NA	☐		
	6	☐ OK ☐ NA	☐		
Arc stages	Stage number	Activation criteria	Tested	Remarks	
	1	☐ Light ☐ I>int ☐ IN>int	☐		
	2	☐ Light ☐ I>int ☐ IN>int	☐		
	3	☐ Light ☐ I>int ☐ IN>int	☐		
	4	☐ Light ☐ I>int ☐ IN>int	☐		
	5	☐ Light ☐ I>int ☐ IN>int	☐		
	6	☐ Light ☐ I>int ☐ IN>int	☐		
	7	☐ Light ☐ I>int ☐ IN>int	☐		
	8	☐ Light ☐ I>int ☐ IN>int	☐		
CBFP	Stage number	Delay setting / ms	Tested	Remarks	
	1		☐		
Trip relays	Trip relay	Tested	CBFP	Remarks	
	D01(B)	☐ OK ☐ NA	☐		
	D02(B)	☐ OK ☐ NA	☐		
	D03(B)	☐ OK ☐ NA	☐		
	D01(D)	☐ OK ☐ NA	☐		
	D02(D)	☐ OK ☐ NA	☐		
	D01(E)	☐ OK ☐ NA	☐		
	D02(E)	☐ OK ☐ NA	☐		
Led indications	Led name	Tested	Led name	Tested	
	A	☐ Yes ☐ NA	F	☐ Yes ☐ NA	
	B	☐ Yes ☐ NA	G	☐ Yes ☐ NA	
	C	☐ Yes ☐ NA	H	☐ Yes ☐ NA	
	D	☐ Yes ☐ NA	I	☐ Yes ☐ NA	
	E	☐ Yes ☐ NA	J	☐ Yes ☐ NA	
Testing device	Device		Calibration date		
Signatures	Commissioner(s)				
	Supervisor				
	Date				

P533I5B

InterRelay functional test

The InterRelay function provides test features for simple and efficient testing of signal transmission. The test features can be found in eSetup Easergy Pro in **DEVICE/TEST/InterRelay test**. The section **InterRelay test** lists the selectable test types, and the section **Send signal** is for the setting of test signals.

> **NOTE:** Functional test can only be executed when device is in *Test* or *Test block* mode, see Mode of use for testing purposes, page 283.

There are 2 test types for selection.

Loopback

In this mode, a user-settable bit pattern will be sent and the function checks that the received pattern is equal to the sent pattern. Only if the received signal pattern is equal to the sent pattern, a “Loopback test OK” signal will be raised, otherwise a “Loopback test NOK” signal.

> **NOTE:** In loopback mode, the tested relay shall be in test mode, and its address shall be set to *00*.

Manual

By this type of test, user can select any single of the digital sent signals and force sending it with a user defined value (0 or 1) for a user set definite duration time. All other digital signals in the frame are not affected. When user checked the box of **Execute manual test** of a signal, the test will be triggered and lasts for a user set duration, the value of received signal at the remote device can be read from local HMI or by eSetup Easergy Pro.

Line differential protection functional test

Different test conditions can be addressed as follows.

Stand-alone relay test

A PowerLogic P5L30 device without communication link to remote end device can be tested by looping the fiber optic send output back to the receive input using a short fiber optic wire and setting the communication address to *00*. With this configuration, the P5L30 line differential protection function is in ready state and accepts message frames from itself. The line differential function can now be tested by activating local test mode.

Inter-connected relay test

In this case, local end relay and remote end relays are connected through communication link and have matching addresses at local & remote relay (1A&1B or 2A&2B and so on). Without changing this configuration, the line differential function of each P5L30 can now be individually tested by activating local test mode.

Local test mode

For easy testing of the line differential characteristic a “local test” feature (often so-called “Loopback test”) is provided, which can be enabled in **DEVICE/TEST** menu.

> **NOTE:** Local test mode can only be enabled when the device is already in test mode!

In local test mode,

- The “LocTest” output at the tested P5L30 is set to TRUE (active) for indication.
- This “LocTest” signal is transmitted to the remote P5L30, which then indicates it as “RemTest active” and gets blocked (to prevent false operation).
- The line differential protection function automatically activates high stability operating mode, so that the maximum measured bias current is applied to all 3 phase elements. Upon exiting this local test mode, the user set operating mode gets active again.
- Differential and bias current calculation will not consider the current from remote P5L30. Currents received from remote P5L30 are processed with values “zero”, regardless the data received through communication link. This implies that also their values in **MEASUREMENTS** menu are displayed as *zero*.
- Direct and permissive intertrip signals are blocked:
  - no signal will be sent,
  - received intertrip signals will be forced to inactive/low state.

Loopback test procedure

The following description of the procedure to verify the parameters of the tripping characteristic is illustrated in Illustration of the local test procedure, page 203.

> **NOTE:** PowerLogic P5L30 line differential protection in local test mode processes received data with value zero, so the measured differential current will be equal to the injected current and the bias currents will be half of this value (Id = Itest, Ib = Itest/2).

1. Test of low set pick up value

   Infeed single phase current, starting from zero, until this phase element trips.

2. Test of characteristic within Slope 1

   Feed a certain current in one phase, for example: I_{A1} with a magnitude within [$I_{d.LS}$ and 2 * $I_{b.S2}$].

   This results in measured value $(I_d,I_b)_{A1} = (I_{A1}, ½ I_{A1})$, which is in the tripping area.

   Hence “L-diff trip A” signal gets active (logged in event list, but could also be configured to LED or digital output for monitoring purpose).

   Then, starting from zero, the current in another phase (for example phase B = I_B) is increased, until also “L-diff trip B” signal gets active. This shall happen at a current:

   I_{B1} = [$I_{d.LS}$ + ½ * s1 * (I_{A1} – $I_{d.LS}$)] +/- 5%

3. Test of characteristic within Slope 2

   This is same procedure as for test within Slope 1, just at higher currents.

   For example: I_{A2} with a magnitude higher than 2 * Ib_{S2}.

   Increase I_B from zero until “L-diff trip B” signal gets active.

   This shall happen at a current:

   I_{B2} = [$I_{d.LS}$ + s1 * ($I_{b.s2}$ – ½ * $I_{d.LS}$) + s2 * (½ * I_{A2} – $I_{b.s2}$)] +/- 5%

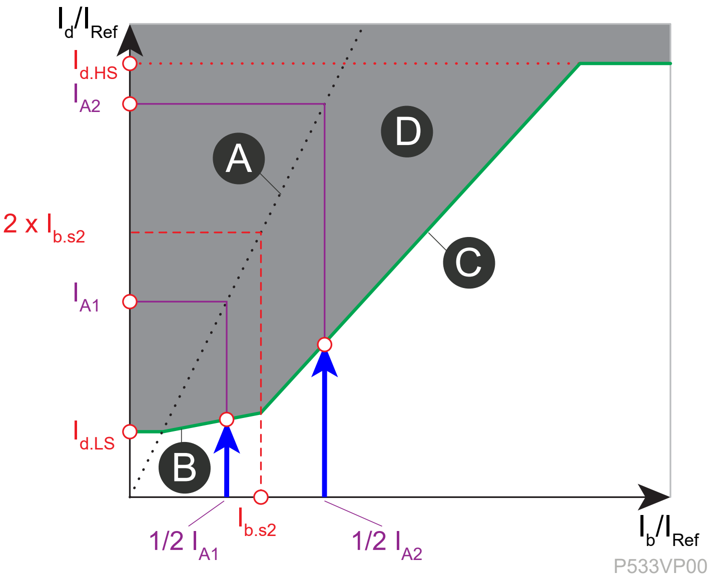
4. Test of unbiased high set pick up value

   This is theoretically same procedure as before, but with even higher currents. Respect thermal limits of CT inputs!

List of abbreviations:

- $I_{d.LS}$: Low set I_d
- $I_{b.S2}$: I_b for start of Slope 2
- s1: Slope 1
- s2: Slope 2

Figure 166 - Illustration of the local test procedure



A	Characteristic for single side fed fault = 200% slope	B	Slope 1
C	Slope 2	D	Trip

Analogue outputs test

The analogue outputs of CLIO modules can be tested through eSetup Easergy Pro in **DEVICE/TEST / Analogue outputs**. To set the test values, double click on the cells of the table in **Analogue outputs n** (n = 1 to 3), then check the **Execute test** box to trigger the test.

While executing the test, the DC output current will be forced to the set test value, but only up to 0.5 mA above the maximum value of the selected range. For example, for a range setting of 0-10 mA, setting the test current above 10.5 mA will only force an output of 10.5 mA.

As complementary information, the **Signal value** will be displayed, which represents the output of the test current in normal operation. Its value is determined by the ratio of the test value to the interval between the minimum and maximum of the assigned output signal range. For example, when Minimum = 0.0 A, Maximum = 100.0 A, and DC range = 0-10 mA, with a test value of 2 mA, the Signal value will be displayed as 20 A.

> **NOTE:** Functional test can only be executed when device is in *Test* or *Test block* mode, see Mode of use for testing purposes, page 283.

Final check

NOTICE

CIRCUIT OVERLOAD

- Remove all test or temporary shorting leads.
- If any external wiring was disconnected to perform the wiring verification tests, make sure that all connections are replaced according to the relevant external connection or scheme diagram.

Failure to follow these instructions can result in equipment damage.

The commissioning is now complete, but before putting the protection relay into normal operation, check the following items:

- Ensure that the protection relay is restored to service.
- Circuit breaker maintenance and current counters should be zero. These counters can be reset.
- Double check the application-specific settings, to help ensure that all the desired protection and control functions are enabled with the correct settings. Extract the final setting file from the protection relay.
- Check the Date and Time of the protection relay, to help ensure the date and time are exactly synchronized.
- Reset all event records, fault records, and disturbance records. Make sure that alarms and LEDs have been reset before leaving the protection relay.

The device is now ready for operation.

Cybersecurity

Cybersecurity overview

This chapter contains up-to-date information about cybersecurity of PowerLogic P5. Network administrators, system integrators and personnel that commission, maintain or dispose of a device should:

- Apply and maintain the device's security capabilities. See Device security capabilities, page 208 for details.
- Review assumptions about protected environments. See Protected environment assumptions, page 209 for details.
- Address potential risks and mitigation strategies. See Potential risks and compensating controls, page 210 for details.
- Follow recommendations to optimize cybersecurity.

To communicate a security topic affecting a Schneider Electric product or solution, go to https://www.se.com/ww/en/work/support/cybersecurity/vulnerability-policy.jsp.

The PowerLogic P5 device is delivered with auto-login feature. It will be disabled when the passwords for all three levels are changed from the default ones.

⚠WARNING

POTENTIAL COMPROMISE OF SYSTEM AVAILABILITY, INTEGRITY, AND CONFIDENTIALITY

- Change default passwords to help prevent unauthorized access to device settings and information.
- Disable unused ports/services and default accounts, where possible, to minimize pathways for malicious attacks.
- Place networked devices behind multiple layers of cyber defenses (such as firewalls, network segmentation, and network intrusion detection and protection).
- Use cybersecurity best practices (for example: least rights, separation of duties) to help prevent unauthorized exposure, loss, modification of data and logs, interruption of services, or unintended operation.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Security policy

NOTICE

LOSS OF ACCESS

- Setup a security policy and procedure to back up the security administrator user account.
- Do not share a single user account with multiple users. Set one user account associated to roles and rights per user.
- Do not excessively decrease "user parameters" values.

Failure to follow these instructions can result in loss of access to the protection relay.

Cybersecurity helps provide:

- Confidentiality (to help prevent unauthorized access)
- Integrity (to help prevent unauthorized modification)
- Availability/authentication (preventing the denial of service and assuring authorized access)
- Non-repudiation (preventing the denial of an action that took place)
- Traceability/detection (logging and monitoring)

For an efficient security, the instructions and procedures should structure the roles and responsibilities in terms of security within the organization; in other words, who is authorized to perform what and when. These should be known by the users.

The anti-intrusion and anti-physical access to any sensitive installation should be set up.

All the security rules implemented in the PowerLogic P5 protection relays are in complement of the points above.

In the PowerLogic P5 protection relays, the control of accessibility to the settings, parameters, configuration and logs is done with a user authentication after "Log in", with a name and password.

The PowerLogic P5 protection relay controls the access:

- through the local panel
- through eSetup Easergy Pro (front and rear connection)
- through the web HMI server
- through the EcoStruxure Power Device application

The Ethernet communication with the EcoStruxure Power Device application and eSetup Easergy Pro are encrypted.

The access through the communication protocols is not controlled by the PowerLogic P5 protection relay but by the SCADA system. The protocols do not include any specific secured commands.

NOTICE

CYBER SECURITY RISK OF INFORMATION DISCLOSURE, BEING TAMPERED WITH, OR DENIAL OF SERVICE

- Except for private GetSet protocol over the secured communication (SSH), the device can not transmit data encrypted with the following protocols: IEC 61850, DNP3 over Ethernet, Modbus slave over Ethernet, EtherNet/IP, IEC 60870-5-103 serial, IEC 60870-5-101 serial, DNP3 serial, Modbus slave serial, Modbus master serial, PTP and SNTP.
- Only personnel with authentication can access to your device network, if unauthorized personnel got the access, the transmitted information can be disclosed or subject to tampering.
- For transmitting data over an internal network, physically or logically segment the network. The access to the internal network needs to be restricted by using standard controls, such as firewalls, and other relevant features supported by your device, such as IP Table whitelisting.
- For transmitting data over an external network, encrypt protocol transmissions over all external connections using an encrypted tunnel, TLS wrapper or a similar solution.

Failure to follow these instructions can increase the risk of unauthorized access.

The access through the digital inputs is not controlled.

Any SCADA system, and any computer using eSetup Easergy Pro, CAE software and a central server, should have an updated anti-virus, anti-malware, anti-ransomware application activated during the use.

If a central server is used, a backup is recommended.

Even if PowerLogic P5 protection relay has an extension module with backup memory, it is recommended to archive any setting and files in a secured area.

A password policy should be implemented with:

- Change of the default passwords before the PowerLogic P5 protection relay is put into operation (see Password complexity, page 216).
- Periodic change of the passwords
- Revocation of the passwords of users who leave or do not need to use the device any more

Product defense-in-depth

Use a layered network approach with multiple security and defense controls in your IT and control system to minimize data protection gaps, reduce single-point of failure and create a strong cybersecurity posture. The more layers of security in your network, the harder it is to breach defenses, take digital assets or cause disruption.

Device security capabilities

This section describes the security capabilities available with your device.

Information confidentiality

These security capabilities help protect the confidentiality of information through secure protocols that employ cryptographic algorithms, key sizes and mechanisms used to help prevent unauthorized users from reading information in transit, i.e. SSH, SFTP and HTTPS.

Physical security

In order to help prevent unauthorized access, lock the shutter on the local panel of the PowerLogic P5 protection relay with a wired lead seal. See Lock the shutter and handle, page 57 for details.

Cybersecurity configuration

These security capabilities support the analysis of security events, help protect the device from unauthorized alteration and records configuration changes and user account events:

- Internal time synchronization.
- Time source integrity protection and the PowerLogic P5 protection relay configuration event logging.
- Timestamps, including date and time, match the PowerLogic P5 protection relay clock.
- SSH server hosts an internal SFTP site and stores files in the PowerLogic P5 protection relay’s flash memory, such as: COMTRADE records and firmware files.
- Embeds user information with changes.
- Offload information to syslog or a protected storage or retention location.

User accounts and rights

These security capabilities help enforce authorizations assigned to users, segregation of duties and least rights:

- User authentication is used to identify and authenticate software processes and devices managing accounts.
- User account lockouts configurable with number of unsuccessful login attempts.
- Password strength feedback using CAE.

Port hardening

The communication port of PowerLogic P5 protection relay can be disabled. Each logical port can be independently disabled. Port hardening configuration can be set from the local panel of PowerLogic P5 protection relay, from eSetup Easergy Pro, or from the web HMI, with the ENGINEER access right.

Firmware upgrades

This security capability helps protect the authenticity of the firmware running on the PowerLogic P5 protection relay and facilitates protected file transfer: digitally signed firmware is used to help protect the authenticity of the firmware running on the PowerLogic P5 protection relay and only allows firmware generated and signed by Schneider Electric.

Device backup creation and restore

This security capability helps PowerLogic P5 participate in system level backup operations by creating backups of the device state. In case of need, PowerLogic P5 can recover with help of those backups to a known good operational state. The protection, control and communication settings can be saved with eSetup Easergy Pro; the security configuration can be saved with CAE.

For how to create such backups and to use them to restore the protection relay please refer to the corresponding sections in eSetup Easergy Pro and CAE user manuals.

Security event logging

These security capabilities help provide a method to generate security-related reports and manage event log storage:

- Machine and human-readable reporting options for current device security settings.
- Audit event logs to identify:
  - The PowerLogic P5 protection relay configuration changes.
  - Energy management system events.
- PowerLogic P5 keeps the security logs with cyclic non-volatile memory, when the limit of the memory size is reached the oldest entries will be replaced by new ones.
- Time source integrity protection and event logged when changed.

Protected environment assumptions

- Cybersecurity governance – available and up-to-date guidance on governing the use of information and technology assets in your company.
- Perimeter security – installed devices, and devices that are not in service, are in an access-controlled or monitored location.
- Emergency power – the control system provides the capability to switch to and from an emergency power supply without affecting the existing security state or a documented degraded mode.
- Firmware upgrades – the PowerLogic P5 protection relay upgrades are implemented consistently to the current version of firmware.
- Controls against malware – detection, prevention and recovery controls to help protect against malware are implemented and combined with appropriate user awareness.

- Physical network segmentation – the control system provides the capability to:
    - Physically segment control system networks from non-control system networks.
    - Physically segment critical control system networks from non-critical control system networks.
- Logical isolation of critical networks – the control system provides the capability to logically and physically isolate critical control system networks from non-critical control system networks. For example, using VLANs.
- Independence from non-control system networks – the control system provides network services to control system networks, critical or non-critical, without a connection to non-control system networks.
- Encrypt protocol transmissions over all external connections using an encrypted tunnel, TLS wrapper or a similar solution.
- Zone boundary protection – the control system provides the capability to:
    - Manage connections through managed interfaces consisting of appropriate boundary protection devices, such as: proxies, gateways, routers, firewalls and encrypted tunnels.
    - Use an effective architecture, for example, firewalls protecting application gateways residing in a DMZ.
    - Control system boundary protections at any designated alternate processing sites should provide the same levels of protection as that of the primary site, for example, data centers.
- No public internet connectivity – access from the control system to the internet is not recommended. If a remote site connection is needed, for example, encrypt protocol transmissions.
- Resource availability and redundancy – ability to break the connections between different network segments or use duplicate devices in response to an incident.
- Manage communication loads – the control system provides the capability to manage communication loads to mitigate the effects of information flooding types of DoS (Denial of Service) events.
- Control system backup – available and up-to-date backups for recovery from a control system failure.

Potential risks and compensating controls

Address potential risks using these compensating controls:

Area	Issue	Risk	Compensating controls
User accounts	Default account settings are often the source of unauthorized access by malicious users.	If you do not change the default password, unauthorized access can occur.	Change the default password for all accounts to help reduce unauthorized access. See Passwords.
Secure protocols	IEC 61850, DNP3 over Ethernet, Modbus slave over Ethernet, EtherNet/IP, IEC 60870-5-103 serial, IEC 60870-5-101 serial, DNP3 serial, Modbus slave serial, Modbus master serial, IEEE 1588 and SNTP protocols are unsecure. The device does not have the capability to transmit data encrypted using these protocols.	If a malicious user gained access to your network, they could intercept communications.	For transmitting data over an internal network, physically or logically segment the network. For transmitting data over an external network, encrypt protocol transmissions over all external connections using an encrypted tunnel, TLS wrapper or a similar solution. See Protected environment assumptions, page 209.

Cybersecurity configuration

The PowerLogic P5 with firmware V01.500.101 or higher are delivered with Basic Cybersecurity level. The User can upgrade them to Advanced Cybersecurity level with a setting parameter available in the relay's local panel. Both levels can be described in the following way:

- **Basic Cybersecurity level**: Cyber Security Level 0 (CSL0)
  Most of cybersecurity rules are fixed by default configuration which cannot be customized. User accounts also fixed. Changing of password directly on device HMI. No security logs. Advanced features such as sending logs to Syslog server and centralized authentication mode are not provided.
- **Advanced Cybersecurity level**: Cyber Security Level 1 (CSL1)
  Customized cybersecurity rules option provided. Management of user accounts and update password[46] for all PowerLogic P5 devices in batch mode in a same local area network. Security logs provided, and the logs can be transmitted to Syslog server. Supports centralized authentication with Microsoft Active Directory as backend.

The Advanced Cybersecurity level of the protection relay holds certification for IEC 62443-4-1 for Secure Development Lifecycle and IEC 62443-4-2 Security Level 1 (SL1) for security features provided.

An overview of the differences between security features offered with Basic and Advanced levels is listed in the following table.

Security features	Basic CS level	Advanced CS level
Connect with Cybersecurity Admin Expert (CAE)[47]	-	■
Change/add/remove user account	-	■
Change password of user account	■[48]	■[46]
Generate security Logs	-	■
Backup security logs to Syslog server	-	■
Customize role privileges	-	■
Batch update user passwords of multiple PowerLogic P5	-	■
Communication ports hardening	■	■
Secure connection with eSetup Easergy Pro software	■	■
Discoverable by eSetup Easergy Pro	-	■
Centralized authentication	-	■
Web HMI via HTTPs	■	■
Cybersecurity reset without losing settings and records	■	■

The cybersecurity level used to be an order option. In the products delivered with firmware versions prior to V01.500.101 (earlier version V01.30x.yyy or V01.40x.yyy), the cybersecurity level was fixed. The character no. 17 in the model number informed about cybersecurity level available in the product:

P 5 x 2 0 - _ _ _ _ - _ _ _ _ _ - _ _ **A** _

P 5 x 3 0 - _ _ _ _ - _ _ _ _ _ - _ _ **B** _

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[46] In Advanced Cybersecurity level, changing password of user account can only be done on device HMI.

[47] CAE is a free engineering tool software which is used to manage cybersecurity rules for PowerLogic P5.

[48] In Basic Cybersecurity level, changing password of user account can only be done on device HMI.

Second last character of reference number	Security features		
	V01.30x.yyy and previous	V01.40x.yyy	V01.50x.yyy and next
A	CS Basic	CS Basic	N/A
B	CS Advanced	CS Advanced	
C	N/A	CS Basic + Advanced logic	
D		CS Advanced + Advanced logic	
E		N/A	Settable CS
F			Settable CS + Advanced logic

NOTE:

- From firmware version V01.500.101, only E or F options are available.
- In case of a firmware upgrade of a device with older firmware version to V01.50x.yyy, the options A and B will evolve to E. The options C and D will evolve to F.

To configure CS level:

1. With the local panel, enter the **Home menu/General** sub-menu/ **Cybersecurity/CS level config**, you can upgrade the level from *CS Basic* to *CS Advanced*.

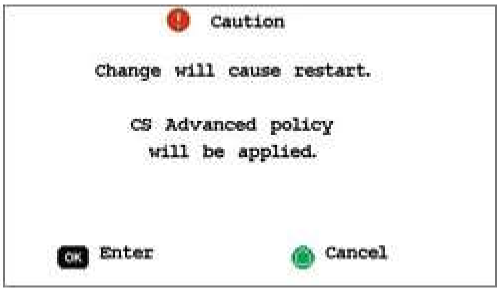
CS level config 4/4
CS level config
CS level config CS Basic

CS level config 4/4
Edit:CS level config
CS Basic
CS Advanced

The change is always possible from *CS Basic* to *CS Advanced* under condition of having right access level.

NOTE: After changing *CS Basic* to *CS Advanced* and pushing RBAC with CAE tool, it's not possible to downgrade the product back to *CS Basic*.

2. The pop-up page displays to inform this change, press **OK** key to confirm the restart operation.



Caution

Change will cause restart.

CS Advanced policy
will be applied.

After the restart, the new CS level configuration is valid.

HMI Auto-login

To facilitate the commissioning work by panel builder and system integrator, PowerLogic P5 is provided with an Auto-login feature when manufactured. This feature grants privilege of the role of INSTALLER for HMI access, without request of password. All roles and their rights are described in chapter of Roles and rights, page 214.

This feature is applicable for both Basic and Advanced CS levels.

The Auto-login feature will be disabled:

- For Basic CS level: when the passwords for all three levels are changed from the default ones. More details about the default passwords for all the levels, refer to Default settings, page 223.
- For Advanced CS level: when security rules are pushed to device by CAE software, the auto-login feature will be immediately disabled.

The following chapters will describe how the cybersecurity rules of PowerLogic P5 can be managed for Basic and Advanced CS levels. Before that, the roles and rights definitions must be described.

Roles and rights

PowerLogic P5 operations are protected by Role-Based Access Control (RBAC) concept. The roles are assigned with rights. The user accounts are then created upon those roles with granted rights which are associated with the corresponding roles. The following table provides an overview of the roles and their default rights. For Basic CS level the rights of role cannot be changed from default. For Advanced CS level the rights of role can be customized with CAE software.

Table 39 - List of roles for cybersecurity

Role	Description
VIEWER (Advanced CS level only)	Can view information except for security logs. Viewer cannot modify any settings and files.
OPERATOR	In addition of VIEWER's rights, OPERATOR can perform control actions and change setting groups.
ENGINEER	In addition of OPERATOR's rights, ENGINEER can make setting change, retrieve events, and fault records.
INSTALLER	In addition of ENGINEER's rights, INSTALLER can update the device firmware
SECAUD (Advanced CS level only)	Can read security logs.
SECADM (Advanced CS level only)	Can change security rules, this is the only role which can be used to work with CAE software.

All user accounts are password protected and granted up to 256 concurrent sessions.

The PowerLogic P5 default RBAC setting is compliant with IEC 62351-8 guidelines. With CAE it can be modified and extended depending on user requirements. The default RBAC setting is as the following table.

Table 40 - Roles vs. their access rights

	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD
Logs					■	■
Security			■	■	■	
Configuration change			■	■		
Control		■	■	■		
Clear statistics data		■	■	■		
Internal data	■	■	■	■		
Configuration read	■	■	■	■		
Settings read	■	■	■	■		
Control status read	■	■	■	■		
Read statistics data	■	■	■	■		
Read data	■	■	■	■		
Debug system				■		

Table 40 - Roles vs. their access rights (Continued)

	VIEWER	OPERATOR	ENGINEER	INSTALLER	SECADM	SECAUD
Debug application				■		
Secure communication	■	■	■	■		
Device cybersecurity data full access				■		
Backup memory copy				■		
Device user data file read		■		■		
Device user data file full access				■		
Device system data file full access				■		
Function key control		■	■	■		
Setting change			■	■		
Firmware update				■		
Firmware verify				■		
Zigbee sensors pairing				■		
Zigbee board firmware update				■		
EOS-BM100 firmware update				■		

Please find detailed explanation of the rights from following table.

Table 41 - List of rights

Right	Name of right in CAE[49]	Description
Logs	LOGS	Permission to retrieve security logs from PowerLogic P5 with CAE
Debug application	P5_RightApplicationDebug	Permission to execute firmware (application level) debug command (internal manufacturer user)
Backup memory copy	P5_RightBackupRootDirDefaultAccess	Permission to read, write, delete, transfer through SFTP, back up memory data in /backup/ directory of file system embedded in the device.
Configuration read	P5_RightConfigDft	Permission to read the configuration which need a reboot of the device, for example, scaling values like CT ratio or voltage connection mode.
Configuration change	P5_RightConfigMgt	Permission to modify the configuration, it means we can change any setting which need a reboot of the device, for example, scaling values like CT ratio or voltage connection mode.
Control status read	P5_RightCtrlObjDft	Permission to read the status of controllable objects such as status of switches, alarms, digital inputs/outputs, LED mode, etc.
Control	P5_RightCtrlObjMgt	Permission to change the status of controllable objects such as switches, alarms, digital inputs/outputs, LED mode, etc.
Device cybersecurity data full access	P5_RightCybSecRootDirDefaultAccess	Permission to read, write, delete, transfer through CAE, cybersecurity data in /cyb_sec/ directory of file system embedded in the device.
Read data	P5_RightDataDft	Permission to read all the data (i.e., measurements, fixed parameters (i.e. model number, ….), logs, …
Internal data	P5_RightDescMgt	Permission to read and write internal data (internal manufacturer user)
Firmware update	P5_RightFirmwareProgram	Permission to update firmware
Firmware verify	P5_RightFirmwareVerify	Permission to verify firmware authenticity and integrity before updating the firmware to the device
Function key 1-8 control	P5_RightFnkey01-07	Permission to operate with the function keys. There is one permission per function key Fx (x = 1 to 7)

---

[49] The name of right in CAE is needed when the rights will be assigned for new roles or to be customized for existing roles.

Table 41 - List of rights (Continued)

Right	Name of right in CAE[50]	Description
Secure communication	P5_RightSecureComm	Permission to connect eSetup Easergy Pro to PowerLogic P5
Settings read	P5_RightSettingDft	Permission to read any setting which do not need a reboot of the device, for example, protection threshold or operation time.
Settings change	P5_RightSettingMgt	Permission to modify any setting which does not need a reboot of the device, for example, protection or communication settings. Includes also logic and Mimic configuration in eSetup Easergy Pro, switching device mode (normal use or tests mode) and allowing test execution.
Read statistics data	P5_RightStatDft	Permission to read only statistics data like counters, demand, max, min., thermal capacity, …, etc.
Clear statistics data	P5_RightStatMgt	Permission to read and clear statistics data like counters, demand, max, min., thermal level, …, etc.
Debug system	P5_RightSystemDebug	Permission to execute firmware (low level) debug command (internal manufacturer user)
Device user data file read	P5_RightUserRootDirDefaultAccess	Permission to read through SFTP or eSetup Easergy Pro, user data in /usr/ directory of file system embedded in the device like disturbance records, …, etc.
Device user data file full access	P5_RightUserRootDirFullAccess	Permission to read, write, delete, transfer through SFTP or eSetup Easergy Pro, user data in /usr/ directory of file system embedded in the device like disturbance records, …, etc., except security logs.
Device system data file full access	P5_RightUserRootDirFullAccess	Permission to read, write, delete, transfer through SFTP, system data in /sys/ directory of file system embedded in the device (internal manufacturer user); permission to update, through eSetup Easergy Pro and the device firmware.
Security	SECURITY	Permission to change security settings including RBAC, password complexity, and timeout options…, etc.

Password complexity

The following rule of password complexity is available for both Basic CS level and Advanced CS level.

- Length of password must be 1 to 8 characters
- Passwords can be composed by the following ASCII [33 to 122] characters:
  - Latin capital letters from A to Z
  - Latin lowercase characters from a to z
  - Figures from 0 to 9
  - Non-alphabetic characters: [\ ] ^ _ ’ ! “ # $ %` & ‘ ( ) * + , - . / : ; < = > ? @

NOTE: Passwords cannot contain the user account name or parts (no more than two consecutive characters) of the user's full name. To help to secure the PowerLogic P5 protection relay, the password should be as long as possible, mixing lowercase and uppercase characters, figures and non-alphabetic characters.

It is possible to configure password with CAE according to NERC and IEEE 1686 standard recommendations.

Standard	Configuration
NERC	8 characters minimum with ASCII [33 to 122] characters. The lesser of three or more different types of characters (e.g., uppercase alphabetic, lowercase alphabetic, numeric from 0 to 9, non-alphabetic characters)
IEEE std1686	8 characters minimum with ASCII [33 to 122] characters 1 lowercase letter, 1 uppercase letter, 1 digit from 0 to 9 and 1 non-alphabetic character

---

[50] The name of right in CAE is needed when the rights will be assigned for new roles or to be customized for existing roles.

Password reset and factory reset

Starts from the firmware V02.501.101, the PowerLogic P5 protection relay supports password reset or factory reset. The solution depends on the cybersecurity level set to the device:

- For Basic Cybersecurity level, the reset will be only of the password, the settings will be kept.
- For Advanced Cybersecurity level, the reset will execute a factory reset of the device.

For Advanced Cybersecurity level, the reset can be disabled, however, the reset cannot be disabled for Basic Cybersecurity level. The available functions are summarized in the following table:

Type of reset	Basic CS level	Advanced CS level
Password reset	Yes	No
Factory reset	No	Yes
Reset can be disabled	No	Yes, INSTALLER rights is required. The default setting is "No".

Both password reset and factory reset are operated on local HMI of PowerLogic P5, under condition of having physical access to the device.

The cybersecurity level of the device is displayed at the upper right corner of the local HMI. B stands for the Basic Cybersecurity level, A stands for the Advanced Cybersecurity level.

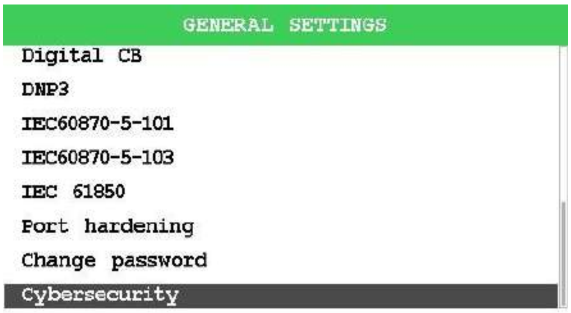
The applied solution is different with the firmware versions prior to V02.501.101, please consult related documentation or contact Schneider Electric Customer Care Centre.

Figure 167 - Padlock icons standing for the cybersecurity levels

Basic Cybersecurity level: password reset

When the PowerLogic P5 with Basic Cybersecurity level is in operation mode, the password reset can be made on the local HMI:

1. From the **main menu**, move the focus to **General**, then press the OK key to enter the submenu.
2. Select **Cybersecurity** option and press the OK key.



3. Then on the **Reset password to default** screen, press the OK key to activate the selection bar. Since the **Start password reset** is the only selection, press again the OK key, an option window will pop-out as shown below:

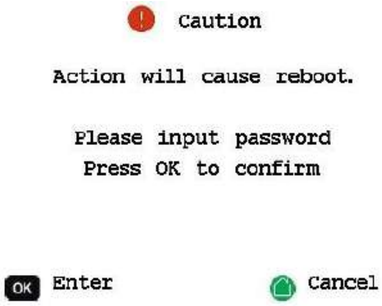
Reset password to default 1/4

Edit:Start password reset

-

On

4. Select **On** option and press the OK key.
   A message will appear to prompt a password input.



Caution

Action will cause reboot.

Please input password

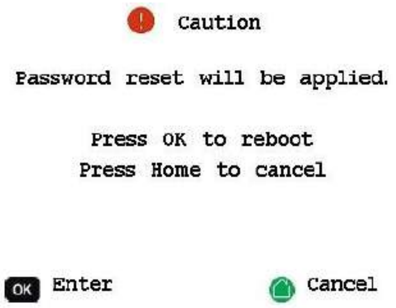
Press OK to confirm

5. Press the key in sequence ◁ △ ▷ ▽ ◁ △ ▷ ▽ and press the OK key.

   NOTE:

   - After inputting the password (◁ △ ▷ ▽ ◁ △ ▷ ▽), make sure press the OK key in five minutes. Otherwise the system will switch to the Mimic screen.
   - The PowerLogic P5 allows up to five attempts of password mistake. If you have reached the limitation, you will have to wait for four minutes.
   - It is recommended to short press each arrow, since there is no confirmation of the arrow pressing displayed on the screen, long pressing the arrow (more than 250 ms) can make an incorrect password input.

6. If the password is correct, a **Caution** message will be pop-outed as below. Press the OK key to reboot.

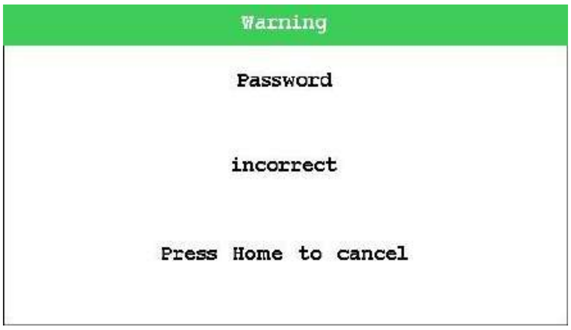


Caution

Password reset will be applied.

Press OK to reboot
Press Home to cancel

If the password is incorrect, a message will appear as shown below. Press the ⌂ key to cancel and input the correct password again.



Warning

Password

incorrect

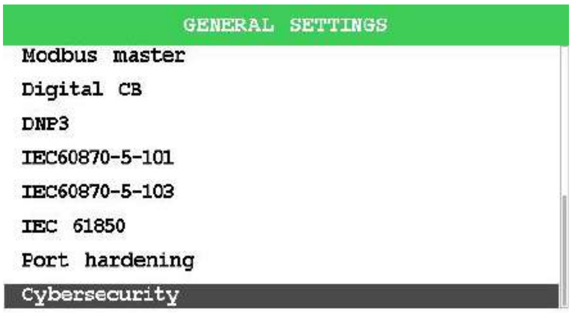
Press Home to cancel

Please wait until the reboot completes.

Advanced Cybersecurity level: factory reset

By default, **enable factory reset** setting is enabled. In case of the **enable factory reset** setting is enabled, and the PowerLogic P5 with Advanced Cybersecurity level is in operation mode, the factory reset can be made on the local HMI:

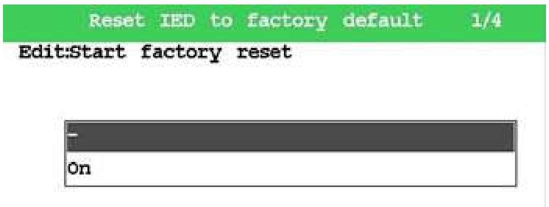
1. From the **main menu**, move the focus to **General**, then press the OK key to enter the submenu.
2. Select **Cybersecurity** option and press the OK key.



3. Then on the **Reset IED to factory default** screen, press the OK key to activate selection bar, select **Start factory reset** option.

Enable factory reset On
Start factory reset -

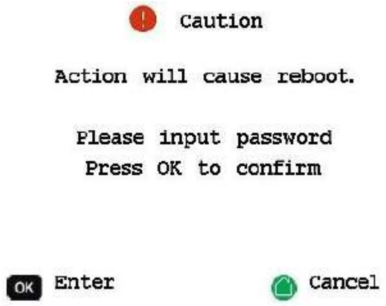
4. Press the OK key to enter the edit page.



Reset IED to factory default 1/4

Edit:Start factory reset

5. Select **On** option and press the OK key.
   A message will appear to prompt a password input.



Caution

Action will cause reboot.

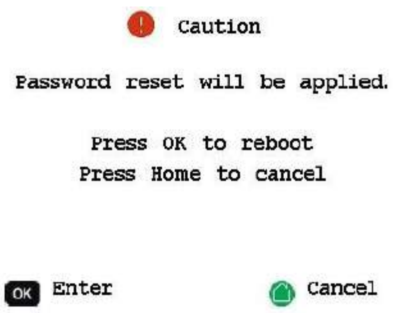
Please input password
Press OK to confirm

6. Press the key in sequence ◁ △ ▷ ▽ ◁ △ ▷ ▽ and press the OK key.

   NOTE:

   - After inputting the password (◁ △ ▷ ▽ ◁ △ ▷ ▽), make sure press the OK key in five minutes. Otherwise the system will switch to the Mimic screen.
   - The PowerLogic P5 allows up to five attempts of password mistake. If you have reached the limitation, you will have to wait for four minutes.
   - It is recommended to short press each arrow, since there is no confirmation of the arrow pressing displayed on the screen, long pressing the arrow (more than 250 ms) can make an incorrect password input.

7. If the password is correct, a message will appear as below. Press the OK key to reboot.

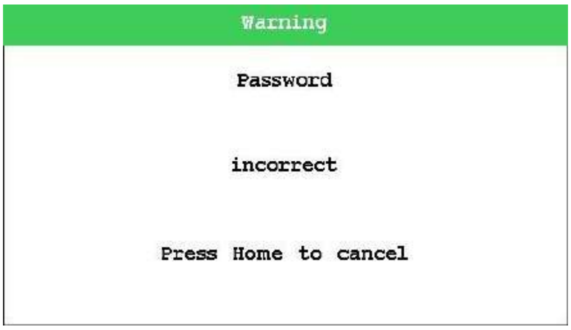


Caution

Password reset will be applied.

Press OK to reboot
Press Home to cancel

If the password is incorrect, a message will appear as below. Press the ⌂ key to cancel and input the correct password again.



Warning

Password

incorrect

Press Home to cancel

Please wait until the reboot completes. All the settings, passwords, logs and disturbance records will be reset to default values.

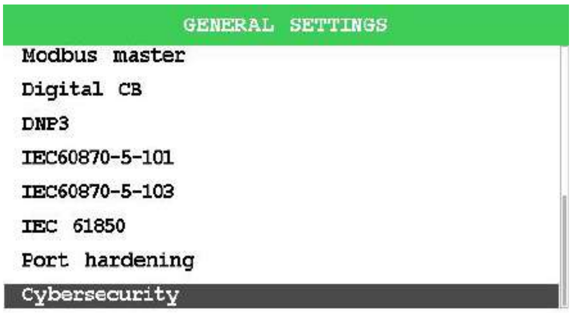
Advanced Cybersecurity level: disable the factory reset

Only the INSTALLER users are permitted to disable the factory reset by setting the **Enable factory reset** to *Off*.

> **NOTE:** Once the factory reset is disabled, in case of the user’s credentials lost, it will be impossible to perform a factory reset from PowerLogic P5 local HMI, please contact with Schneider Electric to get the technical support.

The operations to disable the factory reset are:

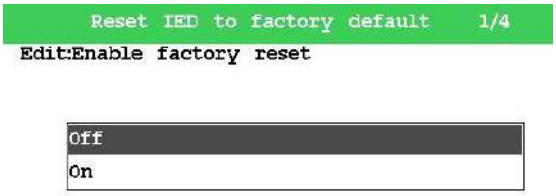
1. From the **main menu**, move the focus to **General**, then press the OK key to enter the submenu.
2. Select **Cybersecurity** option and press the OK key.



3. On **Reset IED to factory default** screen, press the OK key.

Enable factory reset On
Start factory reset -

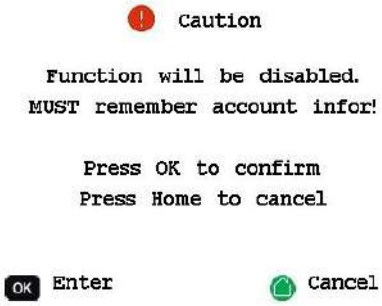
4. Press the OK key, then press the △ key to select **off**, press OK key after.



```
Reset IED to factory default    1/4
Edit:Enable factory reset

Off
On
```

A message will appear with warning that the factory reset function will be disabled and account information must be remembered.



```
Caution

Function will be disabled.
MUST remember account infor!

Press OK to confirm
Press Home to cancel

OK Enter            Cancel
```

5. Press the OK key to confirm.
Now the **Enable factory reset** setting is set to *Off*.

```
Reset IED to factory default    1/4
Enable factory reset
Enable factory reset              Off
Start factory reset                 -
```

Login and logout

Basic CS level comes with three fixed user accounts. Users cannot change name of those accounts. The available access interfaces for the three user accounts are as follows:

Table 42 - Accessible interfaces for user accounts of Basic CS level

User account	Role	Web HMI	Device HMI	Easergy Pro	SSH
OperatorLevel	OPERATOR	Y	Y	Y	Y
EngineerLevel	ENGINEER	Y	Y	Y	Y
InstallerLevel	INSTALLER	Y	Y	Y	Y

Advanced CS level allows user to manage user accounts and assign roles for them. The available access interfaces for roles of Advanced CS level are as follows:

Table 43 - Accessible interfaces for user accounts of Advanced CS level

Role	Web HMI	Device HMI	Easergy Pro	SSH	CAE
OPERATOR	Y	Y	Y	Y	N
ENGINEER	Y	Y	Y	Y	N
INSTALLER	Y	Y	Y	Y	N
SECAUD	Y	Y	N	N	Y (only for retrieving logs)
SECADM	N	N	N	N	Y

Login

- **Local HMI panel**: go to User Login menu from HMI main menu, then select account and enter password. Refer to Login and logout, page 262 for more information.
- **Easergy Pro software (via SSH)**: refer to Connecting to a single protection relay using USB cable, page 274 or Connecting to protection relays via Ethernet, page 274 for more information.
- **Web HMI (via HTTPS)**: Web HMI feature is disabled by default. Before use, it must be enabled in Communication menu by selecting the Ethernet port for HTTPS server. Refer to the communication user manual, search for “HTTPS server” for more information.
- **CAE (via HTTPS, only for Advanced CS level)** : only a Security Admin role (SECADM) can login to a CAE project.

Logout

For security reasons, it is recommended to logout after any operation on the PowerLogic P5 protection relay.

On the main menu screen, Login screen and Mimic screen, a padlock icon is presented at top-right corner of the title bar to signify that there is no user logged in to PowerLogic P5 protection relay. The padlock icon disappears when any user logs in.

Basic CS level setting

For Basic Cybersecurity level, the cybersecurity rules setting is straightforward:

1. The device is provided with three hardcoded account names and the names cannot be changed. Only the passwords can be changed.
2. Password change is available from the PowerLogic P5 HMI only.

Default settings

Basic Cybersecurity level comes with three fixed user accounts. CS rules are as follows:

Table 44 - Accessible interfaces for user accounts of Basic Cybersecurity level

User account	Role	Default password	Login session timeout (min)	Maximum login attempts	Password attempts timer (min)	User account locking duration (s)	Password complexity
OperatorLevel	OPERATOR	AAAA	15	5	3	240	Not required
EngineerLevel	ENGINEER	AAAA					
InstallerLevel	INSTALLER	AAAA					

The name of user account cannot be changed. The above table does not describe the rights of accounts. By default, the eSetup Easergy Pro and the P5 local HMI support maximum five consecutive failed login attempts. Once exceed the attempts, you have to wait for 240 seconds to unlock password attempts timer. The login will expire after 15 minutes of inactivity.

NOTE:

- It is strongly recommended to change default passwords of all accounts before PowerLogic P5 is put to operation.
- More information about the definition of user account parameters, refer to EcoStruxure™ Cybersecurity Admin Expert User Manual.

Changing password

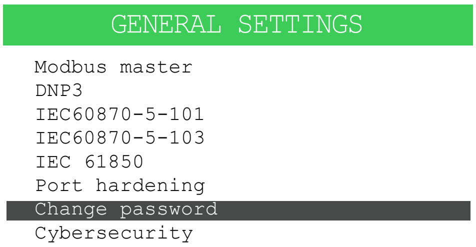
For Basic Cybersecurity level, the length of the password is 1 to 8 ASCII characters [33 to 122].

The scope of the rights of changing password for the three accounts are:

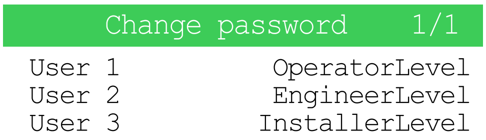
- InstallerLevel can change password for self, OperatorLevel and EngineerLevel.
- EngineerLevel can change password for self and OperatorLevel.
- OperatorLevel can change password only for self.

The password change is managed directly by the device local HMI as the following procedures:

1. Login to device by entering password. If the auto-login feature is still active, then the device is already logged in with InstallerLevel account.
2. Enter the **GENERAL SETTINGS** menu and select **Change password** option.

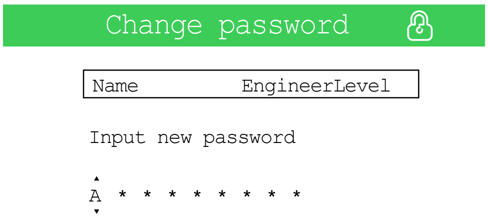


3. Select user.



User 1	OperatorLevel
User 2	EngineerLevel
User 3	InstallerLevel

4. Enter new password and then enter once again to confirm.

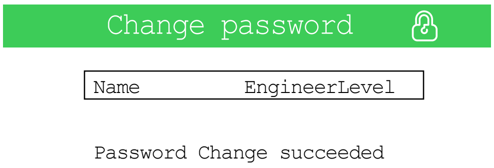


Name EngineerLevel

Input new password

A * * * * * * * *

5. A “Password Change succeeded” message will be displayed on screen.



Name EngineerLevel

Password Change succeeded

Special access control

Only for Basic CS level, PowerLogic P5 protection relay provides special access functions to further simplify commissioning with HMI and to enhance security:

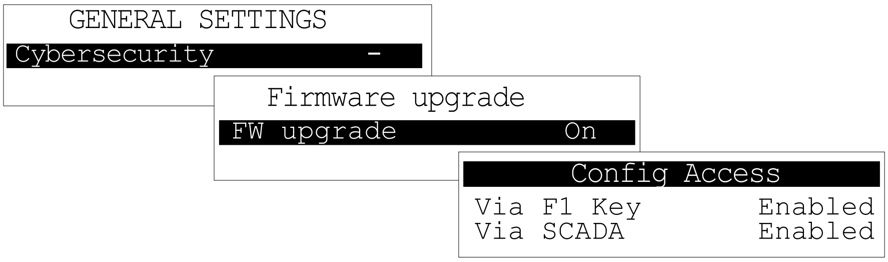
1. **Via F1 key** can be used to switch the protection relay temporarily into a mode in which the device is opened for setting change via local HMI without request of authentication.
2. **Via SCADA** can be used to switch the protection relay between local/remote modes. Therefore, once the device is set to local mode all remote setting change requests and control commands will be rejected.

PowerLogic P5 protection relay provides special access functions:

- **F1 key access control**: while “Via F1 key” disabled, F1 key works as normal function key. When “Via F1 key” is enabled. PowerLogic P5 can be switched between locked and unlocked states with F1 key. In locked state, all settings of the device become read-only, the front USB communication port is disabled, too. In unlocked state, settings of PowerLogic P5 become modifiable, settings can be modified via local panel HMI directly without username and password, front USB communication port also gets enabled. Please note that login is still required when using eSetup Easergy Pro and Web HMI in unlocked state. By setting PowerLogic P5 to unlocked state, it will bring convenience for users to configure the device during commissioning.
- **Communication SCADA access control**: the setting “Via SCADA” provides option to forbid any setting change and control command from SCADA communication protocols (Modbus, IEC61850, IEC103). If the setting is set to disabled, PowerLogic P5 rejects all SCADA protocol setting changes and control commands. However, this setting will not effect on local panel HMI, front USB communication port, eSetup Easergy Pro and Web HMI.

The settings “Via F1 Key” and “Via SCADA” can be configured from local panel HMI. This special access control is operational in Basic Cybersecurity level only.

Figure 168 - Config access Via F1 Key and Via SCADA shown on HMI



```
GENERAL SETTINGS
Cybersecurity              -

Firmware upgrade
FW upgrade               On

Config Access
Via F1 Key          Enabled
Via SCADA           Enabled
```

F1 key access control

PowerLogic P5 can be switched between lock/unlock states by F1 key.

NOTICE

IMPROPER EQUIPMENT OPERATION

If F1 key is configured as the quick switch of PowerLogic P5 lock/unlock, it will be not available for other functions.

Failure to follow these instructions can result in improper operation.

Table 45 - Via F1 Key configuration parameters

Via F1 Key			
	Disabled[51]	Enabled	
		Locked	Unlocked
Access via HMI	Read/Write	Read	Read/Write
Access via USB (Easergy Pro)	Read/Write	Cannot login	Read/Write
Access via rear comms (Easergy Pro)	Read/Write	Read	Read/Write
Access via rear comms (Web HMI)	Read/Write	Read	Read/Write

---

[51] When F1 key is disabled which means it is used as a normal function key, the read/write permission is decided by existing RBAC setting.

Communication SCADA access control

For communication SCADA (Modbus, IEC 61850, IEC 103), when “Via SCADA” is disabled, setting change or control command are disabled for PowerLogic P5, whether in locked or unlocked state, with or without communication board.

Table 46 - Via SCADA configuration parameters

Via SCADA		
	Disabled	Enabled
Access via rear comms SCADA (IEC 61850)	Read	Read/Write
Access via rear comms SCADA (Modbus)	Read	Read/Write
Access via rear comms SCADA (IEC 103)	Read	Read/Write

Auto log-out

While “Via F1 Key” is enabled, PowerLogic P5 will be switched to locked state automatically in below conditions, which is called “auto log-out”:

- if PowerLogic P5 is not connected with Easergy Pro, nor with WebHMI, and without any operation on HMI for 3 minutes;
- if PowerLogic P5 is disconnected from Easergy Pro for 3 minutes;
- if PowerLogic P5 is disconnected from WebHMI for 18 minutes.

Table 47 - Login requirements and auto log-out time out

Access	Login required	Auto log-out time out		
		If without operation	If log out	If disconnected without log out
via HMI	No	3 minutes	N/A	N/A
via rear comms (Easergy Pro)	Yes	Depends on “Automatic Disconnection” setting in Easergy Pro	3 minutes	3 minutes
via rear comms (Web HMI)	Yes	Never	3 minutes	18 minutes[52]

As long as connected with Easergy Pro or WebHMI, PowerLogic P5 will not be switched to locked state.

Advanced CS level setting

With Advanced CS level, all PowerLogic P5 security rules are managed with Cybersecurity Admin Expert (CAE) software.

Please be advised that CAE offers an independent user manual which describes its function in a higher detailed level, which can be downloaded from website of Schneider Electric in more detail.

The purpose of describing CAE software in this manual is to help PowerLogic P5 users start with the Advanced CS level configuration without having to read the complete CAE user manual. For this reason, only basic operations of the software will be described. For a thorough understanding of the CAE functions, please refer to CAE user manual.

---

52. It is proposed to click on “Logout” button at top right of WebHMI before closing the web browser, the auto log-out will be launched in 3 minutes.

Before configuring with CAE, PowerLogic P5 device of Advanced CS level is equipped with default security settings.

Default settings

The default Advanced Cybersecurity level users of PowerLogic P5 are:

Table 48 - Accessible interfaces for user accounts of Advanced Cybersecurity level

User account	Role	Default password	Login session timeout (min)	Maximum login attempts	Password attempts timer (min)	User account locking duration (s)	Password complexity
OperatorLevel	OPERATOR	AAAA	15	5	3	240	Not required
EngineerLevel	ENGINEER	AAAA					
InstallerLevel	INSTALLER	AAAA					
SecurityAdmin	SECADM	AAAAAAAA					

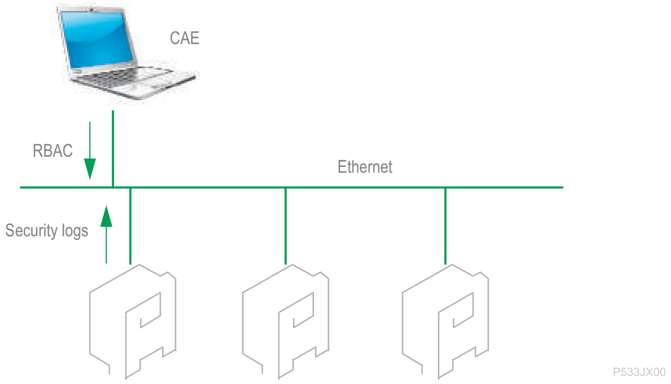
By default, the eSetup Easergy Pro and the P5 local HMI support maximum five consecutive failed login attempts. Once exceed the attempts, you have to wait for 240 seconds to unlock password attempts timer. The login will expire after 15 minutes of inactivity.

More information about the definition of user account parameters, refer to EcoStruxure™ Cybersecurity Admin Expert User Manual.

Introduction of CAE software

CAE allows users to centrally update usernames and passwords for all PowerLogic P5 devices in the same local area network without having to do it bay-by-bay. It can customize the rights of user roles and user accounts. More advanced features of CAE include configuring the Syslog server, extracting locally saved security logs from PowerLogic P5 devices, and centralized authentication over RADIUS/LDAP protocol with a Microsoft Active Directory as the back end.

NOTE: CAE projects can be only opened and edited by SECADM (Security Administrator) accounts.



System requirements

CAE is a software with no requirement of license nor cost. It can be downloaded for free from Schneider Electric's website.

CAE runs in Windows® 10 Professional version 32/64 bit.

Administrator's privilege is required to install CAE application components to Windows. After installed, non-administrator users will be also able to use the software.

To connect and manage PowerLogic P5 devices with CAE, the computer with CAE shall be in the same local area network with the devices.

CAE download and install

Go to https://www.se.com/ww/en/all-products and search for Cybersecurity Admin Expert to find the product page of CAE, click to enter product page.

Figure 169 - Product page of CAE

EcoStruxure™ **Cybersecurity Admin Expert** : Security Administration Tool

Product Range

Browse our products and documents for EcoStruxure™ **Cybersecurity Admin Expert** - Security Administration Tool

Click **See software** to choose package between x86 and x64 versions according to operating system of the computer to install CAE. The latest version of CAE at the time when this chapter was written is 2.2.1.2304.

NOTE: CAE only runs in Window 10. It will not run in Windows 7.

After downloading the installation package, unzip the package and run the **Cybersecurity Admin Expert Installer.exe** file to install. The files in folder ISSetupPrerequisites will be installed automatically.

Changing initial password

When launching CAE for the first time it will prompt for a username and password. The default username is *SecurityAdmin* with default password: AAAAAAAA. The username and password are both case sensitive.

Figure 170 - Initial password of CAE

SecurityAdmin

AAAAAAAA

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Account will be locked if password is entered incorrectly up to 5 times. If this is the only SECADM account of a project, a few minutes of waiting is obliged before any further attempts with the same account. Alternatively, the blocked account can be unblocked with another SECADM account immediately by using it to open the project. Once the project is opened, all blocks of SECADM accounts will be cancelled immediately.

After correctly entering the default username and password, CAE will ask for the default password of the SecurityAdmin account to be changed.

For security purposes, it is recommended to not use default passwords. Please change your default password.

Username: SecurityAdmin

Password: ●●

Confirm: ●●

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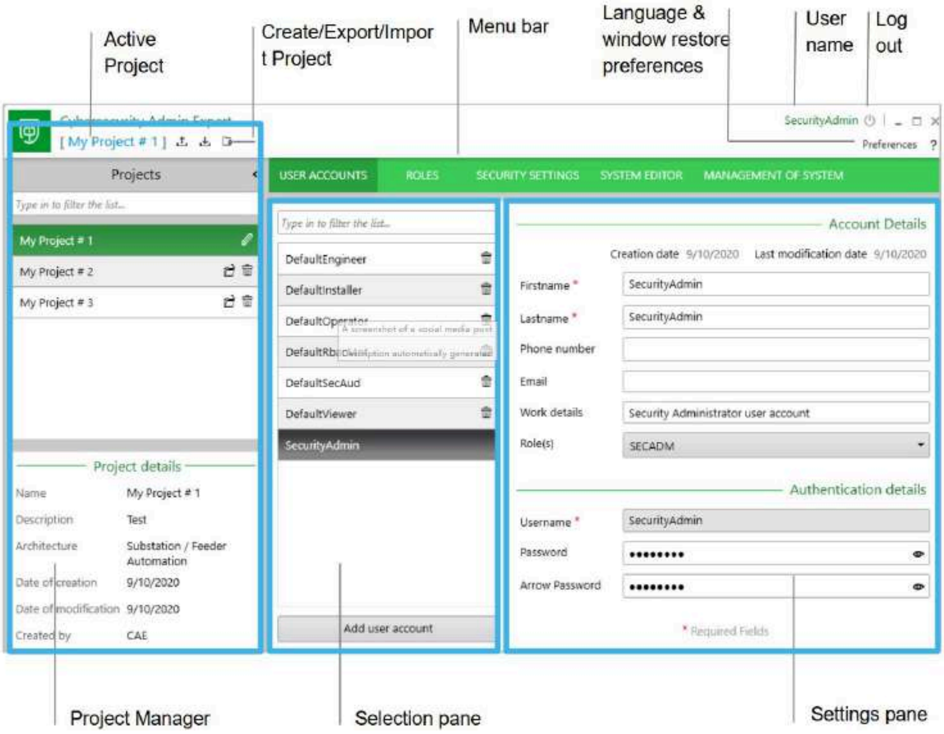
There is no password complexity requirement for a new project. When entering password input, you can click and hold the icon of eye to verify input.

CAE user interface overview

Cybersecurity Admin Expert (CAE) user interface window is composed of three main work areas:

1. Project Manager pane at left
2. Selection pane in the center
3. Settings pane at right



Project details

Name: My Project # 1

Description: Test

Architecture: Substation / Feeder Automation

Date of creation: 9/10/2020

Date of modification: 9/10/2020

Created by: CAE

Account Details

Creation date 9/10/2020 Last modification date 9/10/2020

Firstname *: SecurityAdmin

Lastname *: SecurityAdmin

Phone number:

Email:

Work details: Security Administrator user account

Role(s): SECADM

Authentication details

Username *: SecurityAdmin

Password: ••••••••

Arrow Password: ••••••••

* Required Fields

- **Menu Bar**: From the menu bar user can select required function. The organization of functions follows a typical configuration workflow, however, user can jump from one to another.
- **Preferences**: Click to choose language and activate/deactivate window restore preferences.
- **Username**: Logged in username is displayed in this area.
- **Log out**: To log out from the application, click on the power **on/off** icon.
- **Help**: click **?** icon then **Audit Logs** to see CAE application logs.
- **Create/Export/Import**: Use those buttons to create, export or import CAE security configuration project database.

Most of the CAE functions can be used without connection to PowerLogic P5 devices. Connection with devices in the same local area network is only required when using function of **MANAGEMENT OF SYSTEM** for pushing new CS rules to devices.

CAE functions are grouped in the following menu bars:

- **USER ACCOUNTS**: the functions for account edit such as create, rename, remove account, change password of account, and assign accounts to roles. Please note that one user account can be assigned to multiple roles. This user account will then have the rights of all corresponding roles combined.
- **ROLES**: edit PowerLogic P5 user roles and rights. User's rights are decided by the roles the user accounts are assigned to.
- **SECURITY SETTINGS**: set miscellaneous security-related features, such as session time out duration, password complexity requirement, Syslog server, account locking.
- **SYSTEM EDITOR**: list the discovered protection relays so that CAE can push new CS settings to the devices. Please note that PowerLogic P5 devices can be discovered automatically by CAE, since PowerLogic P5 supports DPWS and UDP. Therefore declaring of devices is optional. For devices that do not support UDP they must be added to the list otherwise CAE cannot find them.
- **MANAGEMENT OF SYSTEM**: discover PowerLogic P5 devices so that new CS settings can be pushed.

CAE recommended workflow

The CS rules of devices are managed with CAE by projects. Each project contains a set of roles and user accounts, with various security-related settings. The project can be worked offline, meaning there is no need to connect to PowerLogic P5 devices when changing the settings. When offline work is done, CAE can be connected to devices and push the project settings to them.

> **NOTE:** changing CS rules with CAE is a one-direction process. It means new settings can be pushed from CAE to PowerLogic P5, but existing CS settings cannot be pushed back to CAE.

The recommended workflow with CAE for PowerLogic P5 is as follows:

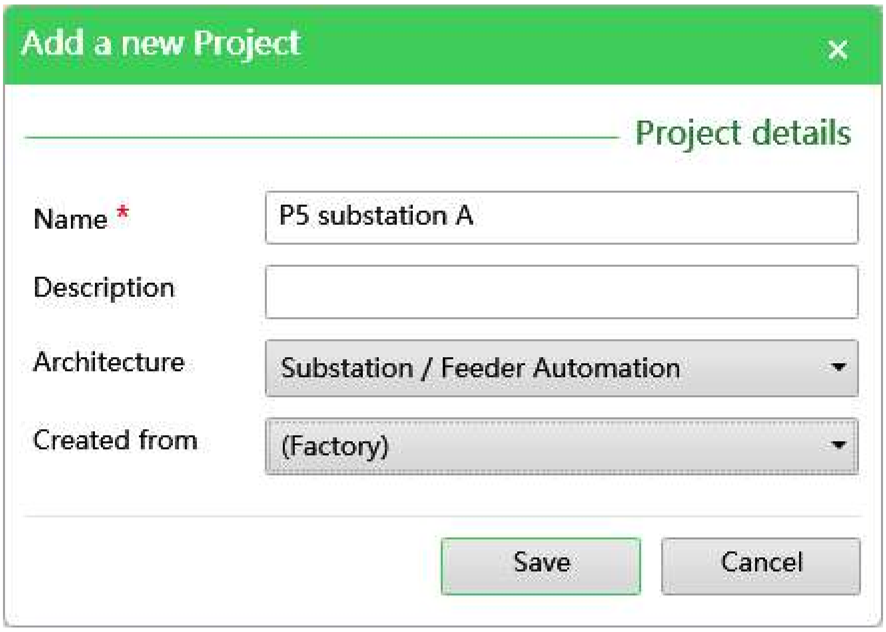
1. Manage the project: use the Project manager to open an existing CAE project or to create a new one.
2. Manage the user accounts: go to USER ACCOUNTS menu to create/remove/modify user accounts, assign roles to the accounts, and set passwords for accounts.
3. Manage the roles: go to ROLES menu to check whether the default rights of roles are in line with your organization cybersecurity policy. Rights can be changed for existing roles. New roles can be created. Existing roles can be removed.
4. Manage other security settings: go to SECURITY SETTINGS menu to set options including timeout, user account locking, password complexity, Syslog server, Security banners, and centralized authentication methods.

5. Define the devices: go to SYSTEM EDITOR to provide IP addresses of devices to CAE to let CAE connect with them. This step is optional for PowerLogic P5 because CAE can discover PowerLogic P5 devices automatically via DPWS and UDP.
6. Prepare the connection between computer with CAE and PowerLogic P5 device: CAE can connect with PowerLogic P5 through Ethernet and the front USB port. To connect through Ethernet connection make sure the computer with CAE is in the same local area network with PowerLogic P5 devices to be managed. Ensure quality of connection by USB cable if connect with front USB port. Use only one type of connection at a time.
7. Push new CS rules to PowerLogic P5: go to MANAGEMENT OF SYSTEM, use discover function to automatically find all PowerLogic P5 devices, and push new CS rules to them.

CAE menu: Projects

Click **Create a new project** button to create new project.

Example settings are as follows:



Name * P5 substation A

Description

Architecture Substation / Feeder Automation

Created from (Factory)

Selection in **Architecture** will impact the Security Settings menu which will be described in CAE menu: Security settings, page 234.

If the selection *Factory* is selected in **Created from** setting, the default CAE template will be used. Alternatively, it can be created from one of existing projects.

Click **Save** to save the project. Then double-click the new project in the project manager pane to switch to the project. CAE will ask for authentication upon opening the new project.

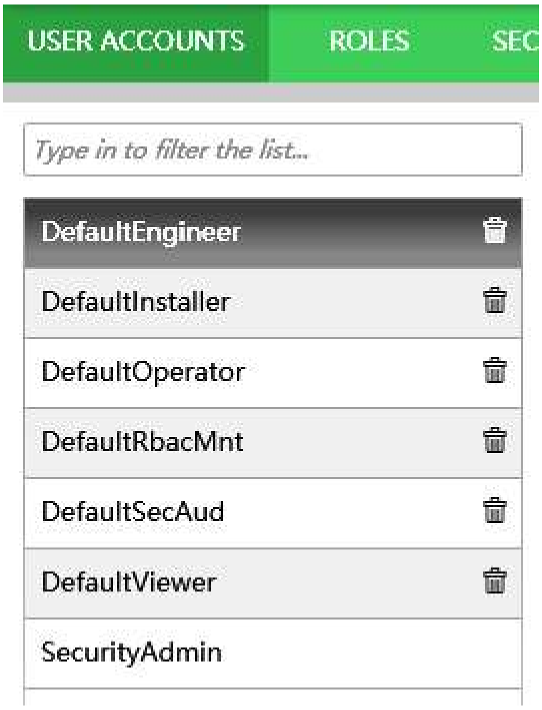
Use the account name *SecurityAdmin* and default password “AAAAAAAA” to login. CAE will then force changing of the initial password. There is no password complexity requirement for a new project.

After the password of SecurityAdmin has been changed, the project will be loaded with CAE default template settings if *Factory* is chosen to create the project from.

NOTE: CAE projects can only be opened by accounts of SECADM (Security Administrator) role.

CAE menu: User accounts

The default user accounts for any new project created from *Factory* template are as follows:



DefaultEngineer
DefaultInstaller
DefaultOperator
DefaultRbacMnt
DefaultSecAud
DefaultViewer
SecurityAdmin

It is advised to delete the “DefaultRbacMnt” account, because this role is not supported by default in PowerLogic P5’s roles template.

New created accounts can be assigned with roles. Each account can be assigned with multiple roles. It will then get the rights of all the assigned roles combined. The “Username” is the account name which will be used for authentication.

The default alphanumeric password for all user accounts is “AAAAAAAA”.

The arrow password facilitates operation of password input on the device HMI with arrow buttons.

Default passwords for all default accounts are as follows.

Table 49 - Default CAE alphanumeric and arrow passwords for PowerLogic P5

Account name	Role	Alphanumeric password	Arrow password
DefaultEngineer	ENGINEER	AAAAAAAA	↓←↑→↓←↑→ (then press OK key)
DefaultInstaller	INSTALLER		
DefaultOperator	OPERATOR		
DefaultSecAud	SECAUD		
DefaultViewer	VIEWER		
SecurityAdmin	SECADM		

If the arrow password is set in CAE, the PowerLogic P5 always prompts this authentication mode in the local HMI. If the feature is not required, please make sure to clear the arrow password for all the accounts as shown in below example.

Username * DefaultOperator
Password * ••••••••
Arrow Password Here must be cleared if arrow password is not wished for HMI login

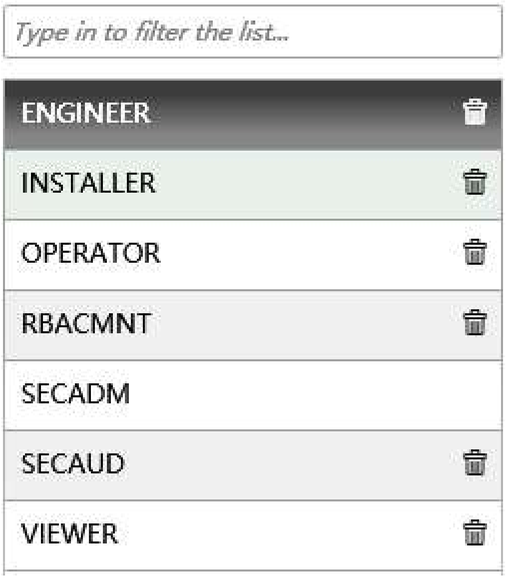
Alphanumeric password will always be asked for authentication requests from Easergy Pro and Web HMI.

NOTE:

1. It is strongly recommended to change the default passwords for all accounts before PowerLogic P5 is put to operation.
2. It is strongly recommended to create a 2nd user account assigned with SECADM role, so that in case of SecurityAdmin password lost, the 2nd SECADM account can be used to open the CAE project and recover passwords.
3. In case of managing multiple CAE projects in parallel, keep at least one SECADM account with the same password in all projects, so that to switch easily between CAE projects.
4. SecurityAdmin is the account with a hardcoded username for all CAE projects as well as for the devices. The username cannot be changed or deleted. Other roles cannot be assigned to this account (except SECADM).
5. Make sure to save changes for each account.

CAE menu: Roles

The default roles for CAE projects are as follows:



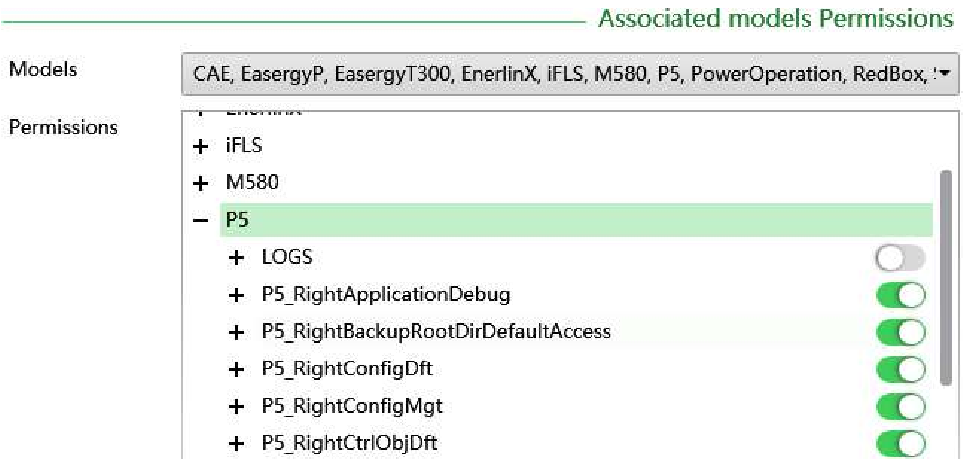
Type in to filter the list...

ENGINEER
INSTALLER
OPERATOR
RBACMNT
SECADM
SECAUD
VIEWER

It is recommended to remove the role RBACMNT unless it is absolutely needed.

The rights of existing roles can be modified in the **Role Details** fields. Please note that CAE is designed to manage CS rules for multiple Schneider Electric products. To modify rights of PowerLogic P5, please click on the **+** sign at left of **P5** and leave the other products.

NOTE: the setting **EasergyP** is not for PowerLogic P5.



Associated models Permissions

Models: CAE, EasergyP, EasergyT300, EnerlinX, iFLS, M580, P5, PowerOperation, RedBox,

Permissions:

- + iFLS
- + M580
- − P5
  - + LOGS
  - + P5_RightApplicationDebug
  - + P5_RightBackupRootDirDefaultAccess
  - + P5_RightConfigDft
  - + P5_RightConfigMgt
  - + P5_RightCtrlObjDft

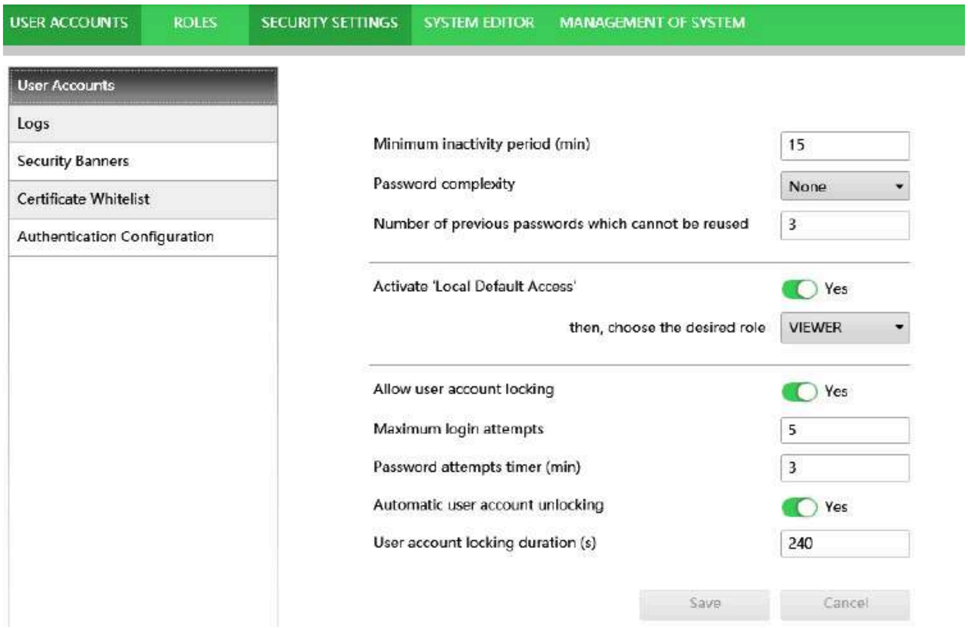
New roles can be added as needed.

CAE menu: Security settings

The functions in this menu make settings of various security parameters.

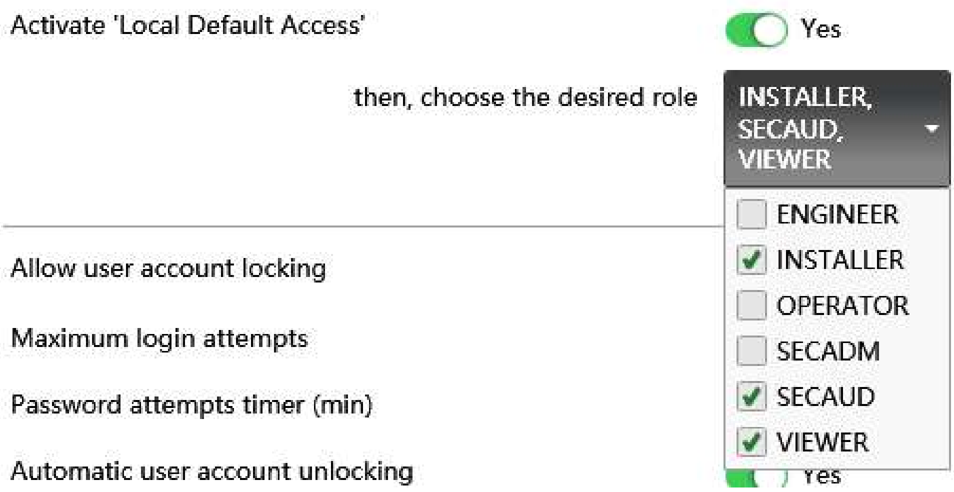
User Accounts

CAE is delivered with default security parameters as follows:



Minimum inactivity period (min): 15
Password complexity: None
Number of previous passwords which cannot be reused: 3
Activate 'Local Default Access': Yes
then, choose the desired role: VIEWER
Allow user account locking: Yes
Maximum login attempts: 5
Password attempts timer (min): 3
Automatic user account unlocking: Yes
User account locking duration (s): 240

To facilitate operation and setting via local HMI, **Activate 'Local Default Access'** can be set to *Yes* to automatically grant selected rights of the role. Anyone who can access to the PowerLogic P5 local HMI will have the rights of the roles assigned with *'Local Default Access'*. The default setting is VIEWER, but it can be extended to multiple ROLES if needed as follows:



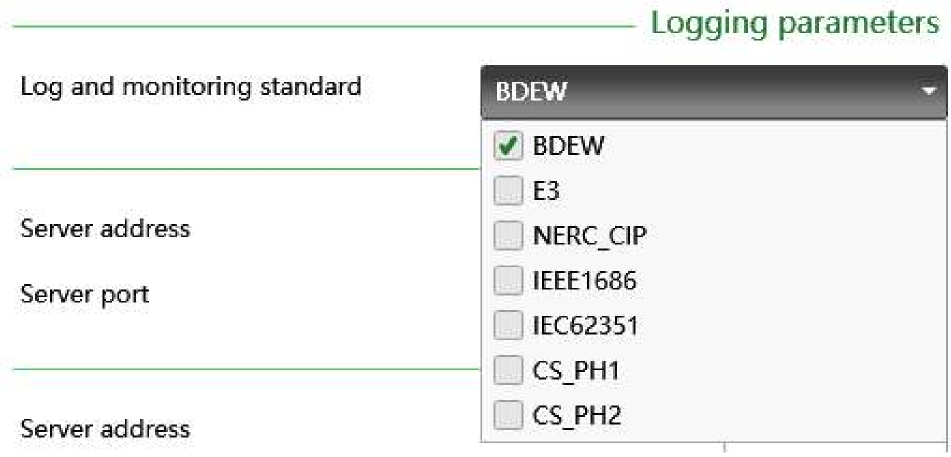
Activate 'Local Default Access': Yes
then, choose the desired role: INSTALLER, SECAUD, VIEWER
☐ ENGINEER
☑ INSTALLER
☐ OPERATOR
☐ SECADM
☑ SECAUD
☑ VIEWER

Please note that the *'Local Default Access'* option is only available for Substation / Feeder Automation architecture.

> **NOTE:** The setting of project architecture will also impact the following options:
>
> - **Allow user account locking**: can only be *YES* for Critical Power and Plant Automation.
> - **Automatic user account unlocking**: can be only *YES* for Critical Power and Plant Automation.

Logs

- **Logging parameters**: no standard logging parameters were enabled when PowerLogic P5 was released from factory. It will not generate any security log before being managed with CAE. During creation of a new CAE project the default standard enabled by CAE is BDEW. PowerLogic P5 also supports security logs according to IEEE 1686 standards. For type of logs and which will be generated for both standards refer to Security event logging, page 248.



Logging parameters

Log and monitoring standard: BDEW

☑ BDEW
☐ E3
☐ NERC_CIP
☐ IEEE1686
☐ IEC62351
☐ CS_PH1
☐ CS_PH2

- **Syslog parameters**: input remote Syslog server address and port in this section. PowerLogic P5 will send all the internally generated security logs to the server for backup after address and port defined.
- **SNMP parameters**: the options shall not be used since PowerLogic P5 does not support SNMP.

Security Banners

The security banners are warning messages displayed on the device HMI and Web HMI login interface for system use notification.

PowerLogic P5 will display *Authorized User Access Only* before authentication takes place in the device HMI and Web HMI. The displayed message can be customized in **Security banner medium** of CAE.

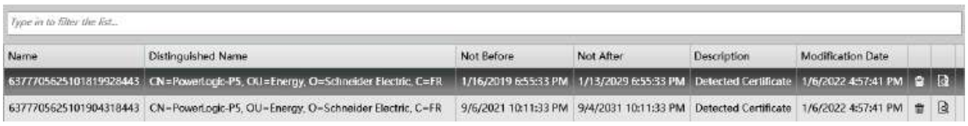
Security banner large:

Security banner medium: Your customized text here

Security banner small:

Certificate whitelist

PowerLogic P5 connects with CAE via HTTPs. PowerLogic P5 works as a server with device self-signed HTTPs certificate to help ensure the credentials and contents will not be transmitted in clear text.



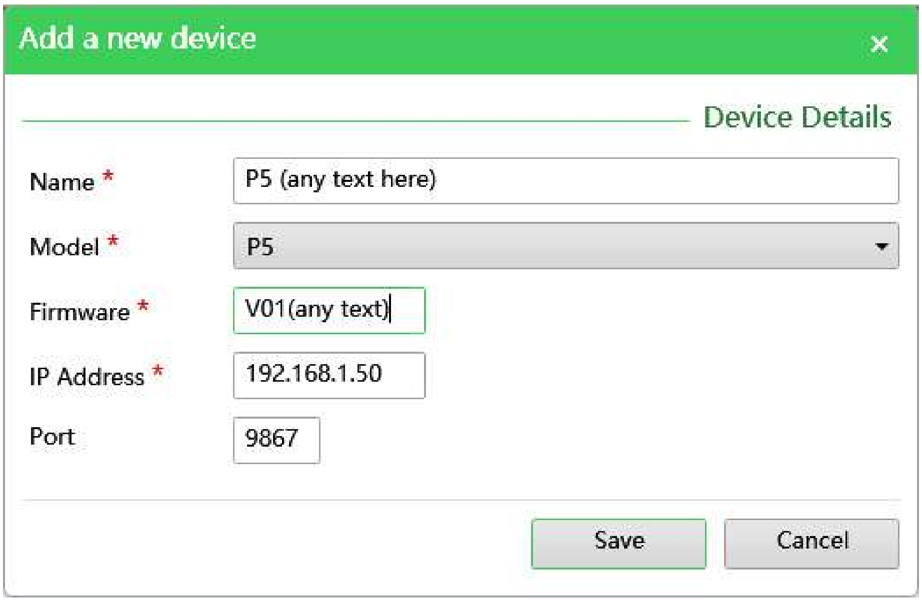
Name	Distinguished Name	Not Before	Not After	Description	Modification Date
6377705625101819928443	CN=PowerLogic-P5, OU=Energy, O=Schneider Electric, C=FR	1/16/2019 6:55:33 PM	1/13/2029 6:55:33 PM	Detected Certificate	1/6/2022 4:57:41 PM
6377705625101904318443	CN=PowerLogic-P5, OU=Energy, O=Schneider Electric, C=FR	9/6/2021 10:11:33 PM	9/4/2031 10:11:33 PM	Detected Certificate	1/6/2022 4:57:41 PM

During network discovery period, CAE discovers a new PowerLogic P5 device and makes connection. You will be prompted to add HTTPs certificate to the white list. Verify the validity of the certificate of the device. Select it, then click **Accept** to accept a new certificate of the device.

CAE menu: System editor

This function is optional for PowerLogic P5 because CAE can discover PowerLogic P5 devices in the same local area network automatically with Advanced CS level thanks to support of DPWS and UDP protocols.

NOTE: in rare occasions CAE may not discover all PowerLogic P5 devices in same network. In this case, declaring them will help CAE find them. Specifying the **Model** and **IP Address** is sufficient, leave the **Port** by default to *9867*. The remaining of information can be free text as follows:



Add a new device

Device Details

Name *: P5 (any text here)
Model *: P5
Firmware *: V01(any text)
IP Address *: 192.168.1.50
Port: 9867

After making the settings, CAE should be able to find the devices.

CAE menu: Management of system

After all Cybersecurity rules have been defined, the rules will be pushed to PowerLogic P5 devices.

Connecting to PowerLogic P5 with CAE

CAE can connect to PowerLogic P5 via Ethernet or front USB port. To make Ethernet connection, ensure the computer with CAE is on the same local area network as the PowerLogic P5 devices to be managed. To connect through front USB port, ensure the connection quality of the USB cable between computer and PowerLogic P5.

It is recommended to use the PING command to verify the connection between PowerLogic P5 and computer with CAE when using an Ethernet connection to PowerLogic P5.

Push the new CS rules to PowerLogic P5

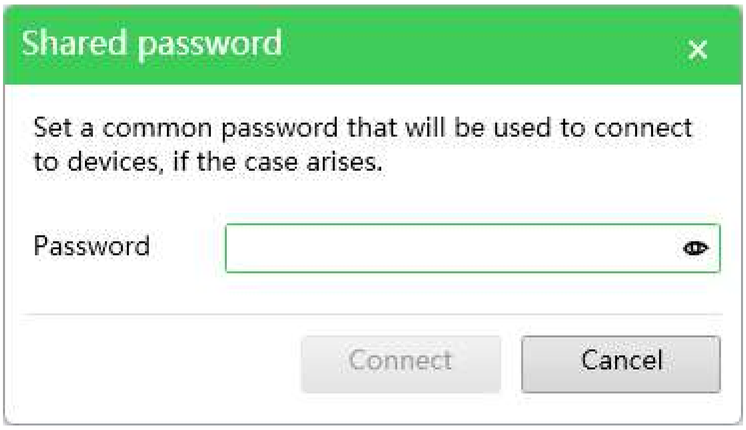
Click **Discover** button to find all PowerLogic P5 devices automatically in the same network as shown in image:

No SAM discovered

Last Security Configuration Version **8** was pushed on **1/11/2022 5:12:32 PM**

Status	Name	Type	Firmware	IP address	Security version	Version nam	
?	PowerLogic-P5	P5	V01.400.018	192.168.1.21 : 9867	8	Version 8	🗑
?	PowerLogic-P5	P5	V01.401.101	192.168.1.41 : 9867	8	Version 8	🗑

Click **Send security configuration** to push new CS rules to the devices.

> **NOTE:** for PowerLogic P5 devices that have already been managed by a CAE project, the passwords of SecurityAdmin in P5 devices and the CAE project must be the same. It means if the password of SecurityAdmin of PowerLogic P5 is “ABCD”, the password of SecurityAdmin account in the CAE project must be also “ABCD”. Otherwise the user will be prompted to provide SecurityAdmin’s password. In that case the password “ABCD” must be entered to enable connection with PowerLogic P5 devices. As in image below:
>
> 
>
>
> Set a common password that will be used to connect to devices, if the case arises.
>
> As an example, if password of SecurityAdmin is changed to “EFGH”, CAE will attempt to connect with PowerLogic P5 devices with existing password “ABCD”. If it succeeds the new password “EFGH” will be pushed to PowerLogic P5 devices.

Please note that the new password and new security settings will be pushed to PowerLogic P5 devices only by clicking **Send security configuration** button again.

Retrieving PowerLogic P5 device internal security logs

Right click on PowerLogic P5 in the list of discovered devices to retrieve security logs saved internally to device. The duration of operation takes about 30 seconds.

PowerLogic P5 stores security logs in a non-volatile memory. If the memory is full, the oldest log is replaced by the newest one.

Centralized authentication

PowerLogic P5 supports centralized authentication via RADIUS and LDAP protocols, so that its user account and privilege management can be merged into an existing authentication infrastructure of the customer network. This means that the existing RADIUS server or Active Directory server in the customer network can also manage the user account and privilege for PowerLogic P5. Users can use their existing username for other devices in their network, such as other protection relays, network switches, workstations on PowerLogic P5. Once the account settings are changed at the RADIUS or LDAP server, all PowerLogic P5 devices will take account of the changes for user authentication and authorization.

Solution overview

Depending on the existing authentication mechanism used in your network, and the firmware version of the PowerLogic P5, different solutions are available:

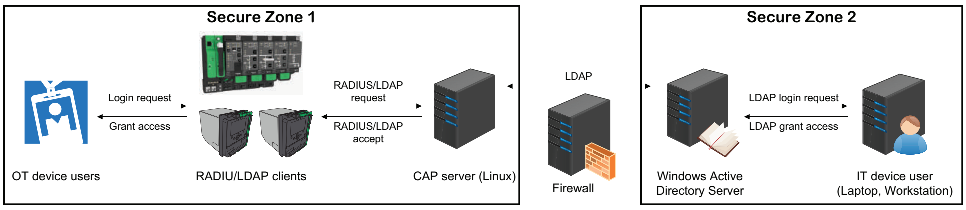
- If your existing authentication server is Microsoft Active Directory Server (referred to AD server hereinafter)
    - for the firmware version V01.500.101 and newer, you can connect to AD server directly, or with the Cybersecurity Application Platform (CAP) as a proxy. It is recommended to use the CAP as a proxy because it can simplify your firewall setup.
    - for the firmware version V01.402.201 and earlier, which only supports RADIUS, it is necessary to use the CAP as a proxy to connect to your AD server. This is because CAP can connect with the protection relay over RADIUS and connect with AD sever over LDAP.
- If your existing authentication server is RADIUS, the protection relay can be directly connected to the server
- We will use TekRADIUS as an example for connecting the protection relay and mapping the roles.

AD Server

If the existing authentication server is an AD server, it is recommended to use the CAP as a proxy to connect to the AD server. Using a CAP as a proxy can make firewall setup easier.

NOTE: The description of CAP in this document serves as a quick guide. For complete details on installing and using CAP, see the CAP documentation.

Figure 171 - Using the CAP as a proxy for connecting to the AD server

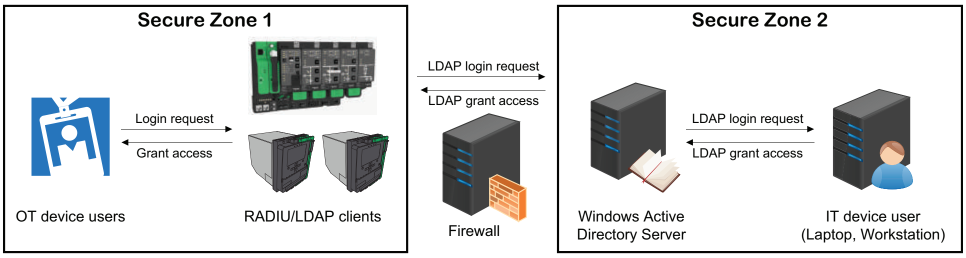


As shown above, the CAP server can be placed in Secure Zone 1 where PowerLogic P5 is located. Within the same zone there can be other devices such as RTUs, switches, and other protection relays. The firewall only needs to allow connection between the CAP server and the AD server, which makes the setup easier and more scalable.

NOTE: Secure Zone 1 is normally the most secure segment because it has OT devices which control the critical infrastructure devices such as circuit breakers and switches. Secure Zone 1 is more isolated than other network segments. Secure Zone 2 is the network used for information management services such as e-mail, file servers and Internet. Secure Zone 1 and 2 are isolated using firewalls and/or network diodes to ensure that the Secure Zone 1 is better secured.

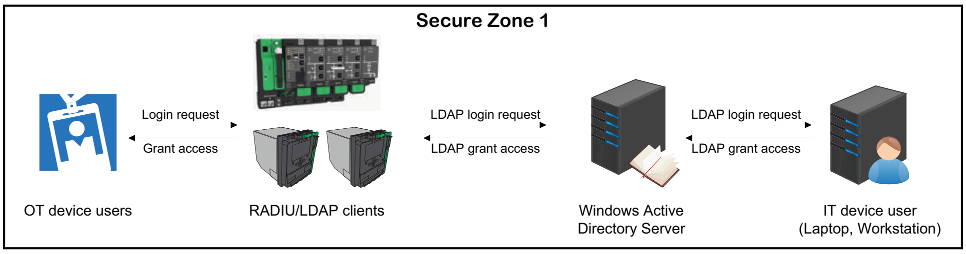
However, if using CAP is not wanted or possible, PowerLogic P5 can connect directly to the AD server with LDAP. In this case, the firewall needs to allow all PowerLogic P5 devices to connect to the AD server, as shown below.

Figure 172 - Direct connection between PowerLogic P5 and AD server, within two secure zones



Alternatively, if the AD server resides in the same Secure Zone with PowerLogic P5, there is no need to install the firewall, as shown below.

Figure 173 - Direct connection between PowerLogic P5 and AD server, within one secure zone



In the following sections, both connection methods between PowerLogic P5 and the AD server will be detailed, namely the indirect connection with CAP as the proxy, and the direct connection without CAP.

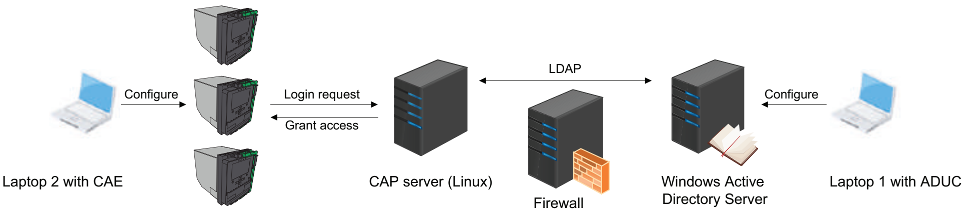
Again, it is recommended to use the CAP as the proxy if the AD server is not in the same Secure Zone as PowerLogic P5 as in Using the CAP as a proxy for connecting to the AD server, page 238.

The following items are required to carry out the configuration:

- A Microsoft Active Directory server. This is the central authentication server and the domain controller for your network. Windows Server 2019 was used when this document was written. Domain administrator privilege is required.
- A laptop with Active Directory Users and Computers (ADUC) installed. ADUC is the software to manage Active Directory objects, including users, computers, groups, organizational units (OU), and attributes. This laptop must be able to join the domain controlled by the above Windows server, for doing so the domain administrator privilege is required. This is “Laptop 1”.
- A laptop with CAE installed. With this laptop you can finish the PowerLogic P5 settings. Security Admin privilege to both the CAE project and to the PowerLogic P5 devices is required. There is no need for this laptop to join the above domain. This is “Laptop 2”. Note that you can also install CAE on your “Laptop 1” and to use only one laptop.
- A configured CAP server. For installation and configuration of the CAP server, see the CAP documentation. Administrative privilege to the CAP server is required.
- PowerLogic P5 devices in the Advanced CS mode.

When the above is all set as depicted in the following figure, the configuration can take place.

Figure 174 - Required devices and software for Indirect connection to AD server with CAP



The configuration consists of 2 or 3 steps, namely:

1. Configuration at the AD server end: this ensures that the user account is created and assigned to the user groups.
2. Configuration of the RADIUS server at the CAP end: it is only needed for older versions of PowerLogic P5. For newer versions it is not needed because LDAP can be used between PowerLogic P5 devices and the CAP.
3. Configuration at the PowerLogic P5 end: to map between user groups in the AD server and user roles in PowerLogic P5 devices.

We will use an example to walk you through.

In this example, a new user Alice WANG will be created in the AD sever. She belongs to the user group “Relay Engineer” in the domain controlled by that AD server. She should have the “ENGINEER” role privilege for the PowerLogic P5 devices.

Configuration at the AD server

In this step we will add a user and assign it to a user group in the AD server.

Use Laptop 1 to open the ADUC to connect to the AD server.

Create the user

Create a new user in the designated OU, here we use the OU “VALIDATION” as an example. The OU name “VALIDATION” and the domain “val.ctc.se.com” will be needed again in Assign user to group(s), page 241.

In ADUC (**Active Directory Users and Computers**), expand the domain *val.ctc.se.com*, right click on the OU *VALIDATION*, then click on **New/User** on the pop-up menu.

The new user is to be created with the detailed information as below:

- **First name**: Alice
- **Last name**: Wang
- **Full name**: AWang
- **User logon name**: Alice Wang
- **User logon name (pre-Windows 2000)**: Alice Wang

Note that the full name “AWang” is the username to be used for authentication at PowerLogic P5 end.

After the input of the above information, click on **Next >** button to next page.

> **NOTE:** If the user is newly created, do not check the *User must change password at next logon* option, as there is no mechanism at PowerLogic P5 to change the password. If it is required to force the user to change the initial password then they will need to log in with a PC and change the initial password before they can authenticate with PowerLogic P5.

Create the group

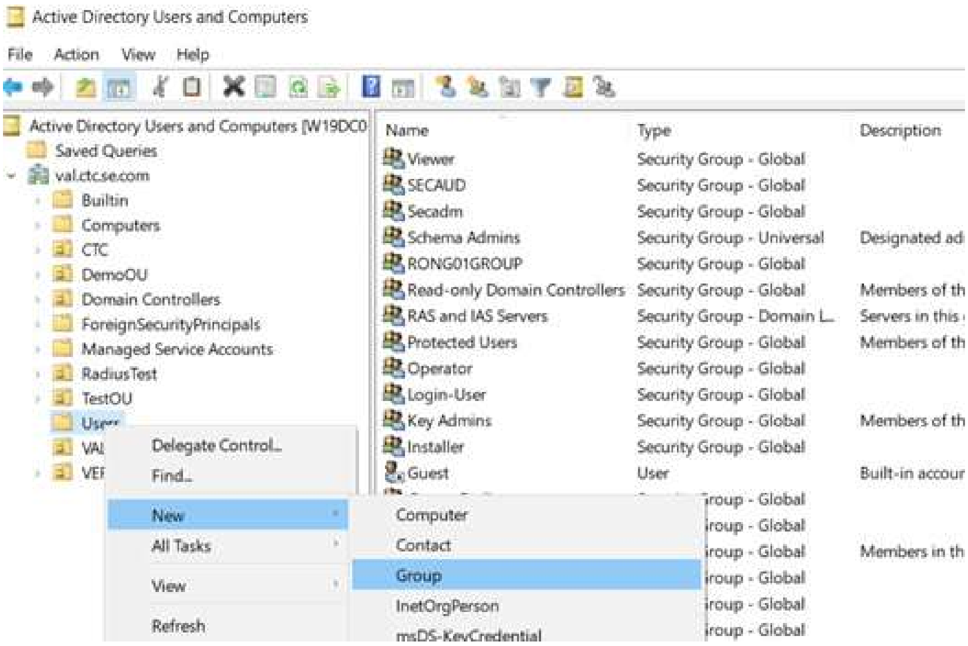
In ADUC, expand the domain *val.ctc.se.com*, right click on the Common Name (CN) *Users*, then click on **New/Group** on pop-up menu.

The new group is to be created with the detailed information as below:

- **Group name**: Relay Engineer
- **Group name (pre-Windows 2000)**: Relay Engineer
- **Group scope**: Global
- **Group type**: Security

Click **OK** button.

Figure 175 - Create the group in Users common name



Name	Type	Description
Viewer	Security Group - Global	
SECAUD	Security Group - Global	
Secadm	Security Group - Global	
Schema Admins	Security Group - Universal	Designated ad
RONG01GROUP	Security Group - Global	
Read-only Domain Controllers	Security Group - Global	Members of th
RAS and IAS Servers	Security Group - Domain L...	Servers in this
Protected Users	Security Group - Global	Members of th
Operator	Security Group - Global	
Login-User	Security Group - Global	
Key Admins	Security Group - Global	Members of th
Installer	Security Group - Global	
Guest	User	Built-in accour
	roup - Global	
	roup - Global	
	roup - Global	Members in th
	roup - Global	
	roup - Global	
	roup - Global	

Assign user to group(s)

Add the user “AWang” to the group “Relay Engineer” with the detailed information as below:

- **Select this object type**: Groups or Build-in security principals
- **From this location**: val.ctc.se.com
- **Enter the object names to select (examples)**: Relay Engineer

Click **OK** button.

If you want to assign the user to multiple groups, you can repeat the above step.

Configuration of the RADIUS server at CAP end

This step is only needed for older PowerLogic P5 versions which only have the RADIUS client. If your PowerLogic P5 version is V01.500.101 or later you can skip to the next section.

The setting at CAP end consists of two steps:

1. Mapping between AD groups and device roles
2. Setting the shared secret

Mapping between AD groups and device roles

Use the Laptop 1 to SSH into CAP with command:

ssh capuser@10.10.10.99 -p 4422

> **NOTE:** capuser is the only username for managing CAP when the installation is completed. CAP will ask you the password for capuser.

After successful login, enter the following command to enter the CAP setting:

cap-config

When the CAP setting menu is displayed, navigate to the following item:

- **Configuration/Configure RADIUS/AD proxy/Edit user configuration file**

If you want to map the “ENGINEER” role in PowerLogic P5 to the “Relay Engineer” group in AD server, do the following:

- In the editor, for the user group “Relay Engineer” in common name “Users”, and domain “val.ctc.se.com”, add the following lines
  - DEFAULT Ldap-Group == “CN=Relay Engineer,CN=Users,DC=val,DC=ctc,DC=se,DC=com”

    Reply-Message = “ENGINEER”

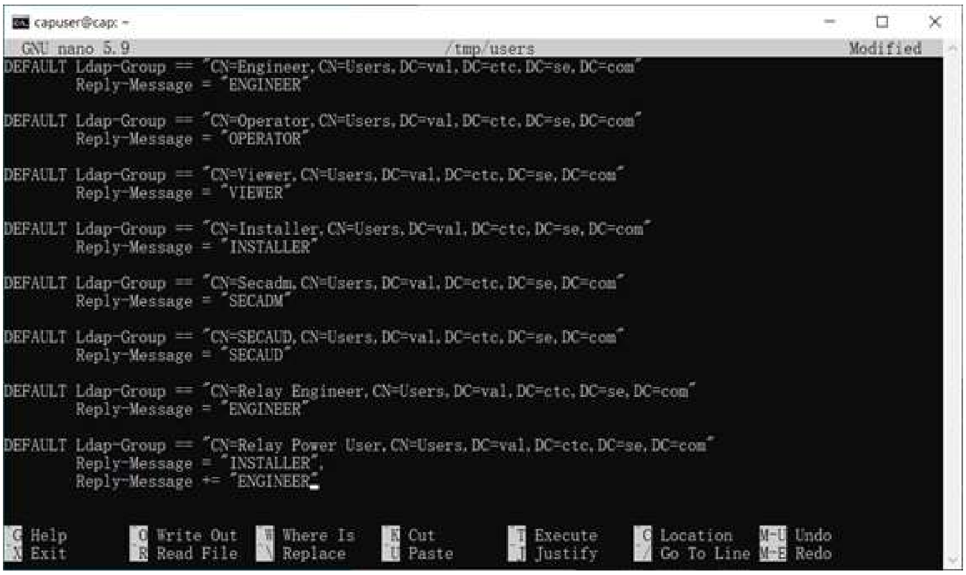
If you want to assign multiple roles in the PowerLogic P5 to one specific group in AD server, for example to map “INSTALLER” and “ENGINEER” roles to group “Relay Power User”, add the following lines:

- DEFAULT Ldap-Group == “CN=Relay Power User,CN=Users,DC=val,DC=ctc,DC=se,DC=com”

  Reply-Message = “INSTALLER”,

  Reply-Message += “ENGINEER”

Figure 176 - CAP server RADIUS configuration for mapping groups to roles



```
  GNU nano 5.9                        /tmp/users                        Modified
DEFAULT Ldap-Group == "CN=Engineer,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "ENGINEER"

DEFAULT Ldap-Group == "CN=Operator,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "OPERATOR"

DEFAULT Ldap-Group == "CN=Viewer,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "VIEWER"

DEFAULT Ldap-Group == "CN=Installer,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "INSTALLER"

DEFAULT Ldap-Group == "CN=Secadm,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "SECADM"

DEFAULT Ldap-Group == "CN=SECAUD,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "SECAUD"

DEFAULT Ldap-Group == "CN=Relay Engineer,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "ENGINEER"

DEFAULT Ldap-Group == "CN=Relay Power User,CN=Users,DC=val,DC=ctc,DC=se,DC=com"
        Reply-Message = "INSTALLER",
        Reply-Message += "ENGINEER"

^G Help      ^O Write Out ^W Where Is  ^K Cut       ^T Execute   ^C Location  M-U Undo
^X Exit      ^R Read File ^\ Replace   ^U Paste     ^J Justify   ^/ Go To Line M-E Redo
```

When the above modification is done, press **Ctrl + X**, then press **y** and **Enter** to confirm the modification and exit the nano editor with the changes saved.

The CAP will now restart the RADIUS service. To confirm the RADIUS service is successfully restarted, navigate to the following menu to check the logs:

- **Configuration/Configure RADIUS/AD proxy/Read logs**

The message “Ready to process requests” means that the RADIUS server has successfully restarted.

Setting the shared secret

The shared secret is a text string that serves as a password between the RADIUS client (PowerLogic P5) and the RADIUS server (CAP).

To set the shared secret, navigate to the following menu:

- **Configuration/Configure RADIUS/AD proxy/Edit clients configuration file**

Add the following lines to the file:

-
  ```
  client  ctc-val-test {
  ipaddr = 10.10.10.0/24
  secret = Test*#12
  }
  ```

The client name can be any text as you want, as an example we have used “ctc-val-test” here.

The ipaddr shall be the network segment in which the PowerLogic P5 devices are located, with 24 being the length of the subnet mask, the specified network segment is 10.10.10.0 to 10.10.10.255 in this case.

Configuration at the PowerLogic P5 end

Open the CAE software installed on Laptop 2, go to the menu **SECURITY SETTINGS/Authentication Configuration**.

LDAP setting

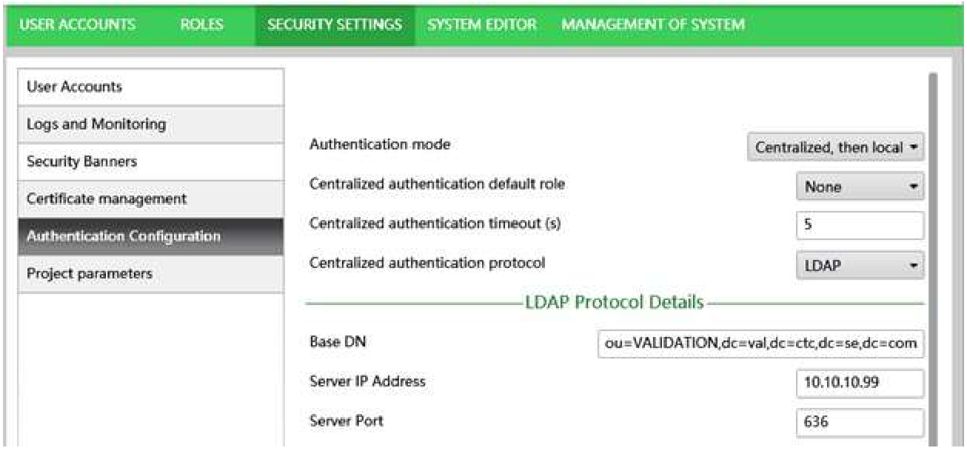
PowerLogic P5 versions later than V01.500.101 is equipped with an LDAP client thus it is recommended to use LDAP as it offers better security than RADIUS.

The LDAP protocol details for the setting are as following:

- In the section **LDAP Protocol Details**, for **Base DN**, for the OU *VALIDATION* and the domain *val.ctc.se.com* in this example, use value “ou=VALIDATION, dc=val,dc=ctc,dc=se,dc=com”.
- Value of input box **Server IP Address** and **Server Port**:
  - If you are using CAP as a proxy between PowerLogic P5 devices and the AD server, provide the proxy IP address and port number.
  - If PowerLogic P5 devices are connecting directly to the AD server, provide the AD server address and port number instead.

    NOTE: The port number depends on the type of protocol to be used. For detailed information about the port number and corresponding protocols please refer to the CAE and CAP documentation, and the setting of your AD server. PowerLogic P5 supports LDAP and LDAP + StartTLS protocols.

Figure 177 - LDAP setting in CAE



Authentication mode: Centralized, then local
Centralized authentication default role: None
Centralized authentication timeout (s): 5
Centralized authentication protocol: LDAP

LDAP Protocol Details

Base DN: ou=VALIDATION,dc=val,dc=ctc,dc=se,dc=com
Server IP Address: 10.10.10.99
Server Port: 636

- To grant the ”ENGINEER” role privilege to the “Relay Engineer”, click **Add a new group** button, input name *Relay Engineer* in the text box above the button, and check *ENGINEER* in the list of **Role(s)**, then click **Add a new group** button again.

Figure 178 - Map one role to one group

- To grant the ”ENGINEER” and “INSTALLER” roles privilege to the “Relay Power User”, click **Add a new group** button, input name *Relay Power User* in the text box above the button, and check *ENGINEER* and *INSTALLER* roles in the list of **Role(s)**, then click **Add a new group** button again.

Figure 179 - Map multiple roles to one group

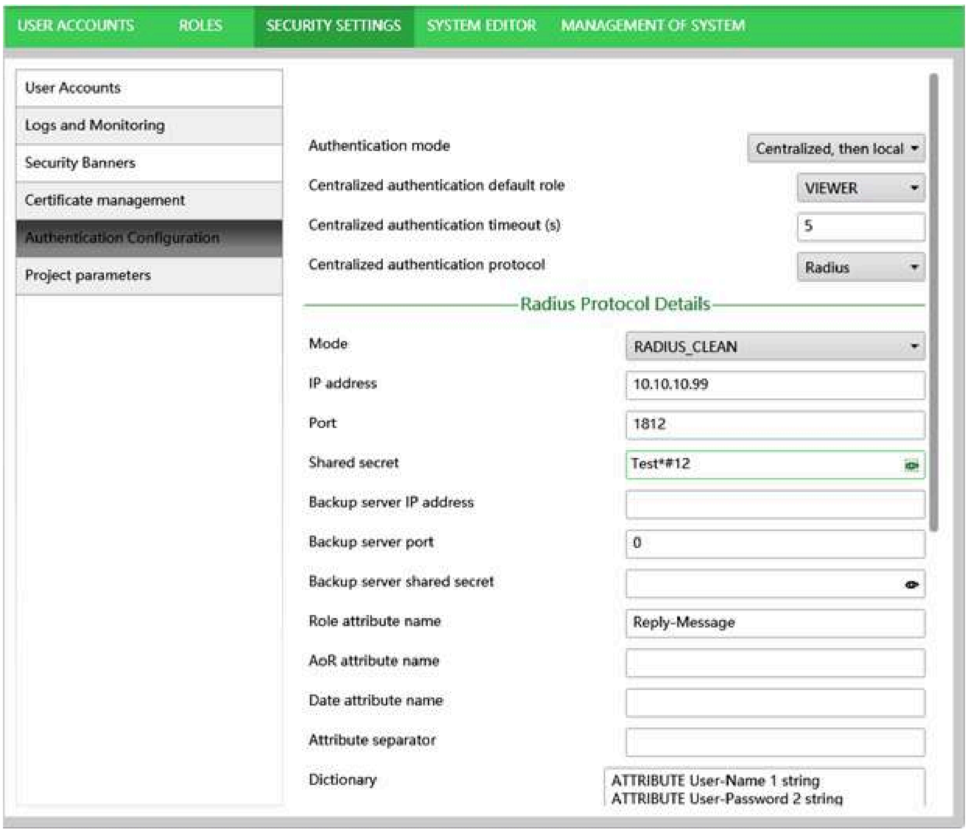
RADIUS setting

For older PowerLogic P5 versions, the only option is to connect to CAP over RADIUS.

Most of the settings can be left as defaults, except for the following in the section **LDAP Protocol Details**:

- **Shared secret**: it must be the same as set in the CAP server, which is “Test*#12” in this example.
- **Role attribute name**: it must be “Reply-Message”.
- **Mode** and **Port**: For details about the settings of Mode and Port, please refer to the CAE and CAP user documentation. PowerLogic P5 supports RADIUS_CLEAN and EAP_TTLS protocols.

Figure 180 - RADIUS setting in CAE for using CAP as proxy



Authentication mode: Centralized, then local

Centralized authentication default role: VIEWER

Centralized authentication timeout (s): 5

Centralized authentication protocol: Radius

Radius Protocol Details

Mode: RADIUS_CLEAN

IP address: 10.10.10.99

Port: 1812

Shared secret: Test*#12

Backup server IP address:

Backup server port: 0

Backup server shared secret:

Role attribute name: Reply-Message

AoR attribute name:

Date attribute name:

Attribute separator:

Dictionary: ATTRIBUTE User-Name 1 string
ATTRIBUTE User-Password 2 string

Congratulations! After completing the above steps, user Alice WANG can use her credentials set by the AD server for PowerLogic P5 authentication and obtain the role privileges in device mapped to her user group in AD server accordingly.

RADIUS as existing authentication server

PowerLogic P5 can use a RADIUS server directly as the authentication server — no AD server or CAP server is required. The RADIUS server can be in the same secure zone with the PowerLogic P5 devices, as shown in RADIUS server in the same secure zone with PowerLogic P5, page 245. Or the RADIUS sever can be in another secure zone, and the firewall is set to allow the RADIUS protocol between the PowerLogic P5 devices and the RADIUS server, as shown in RADIUS server in a different secure zone with PowerLogic P5, page 246

Figure 181 - RADIUS server in the same secure zone with PowerLogic P5

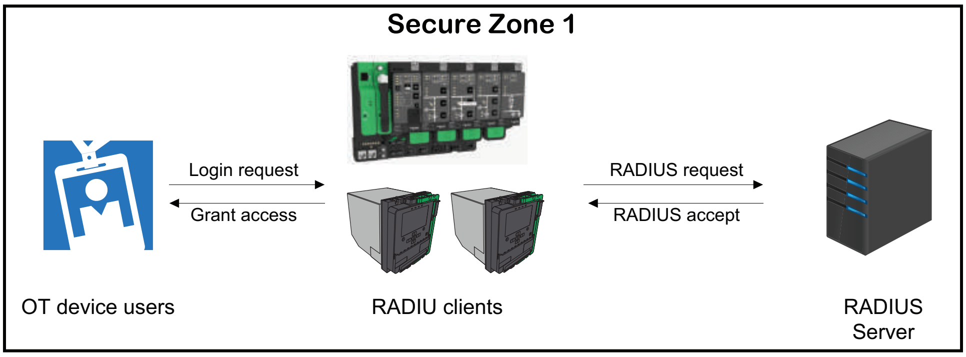
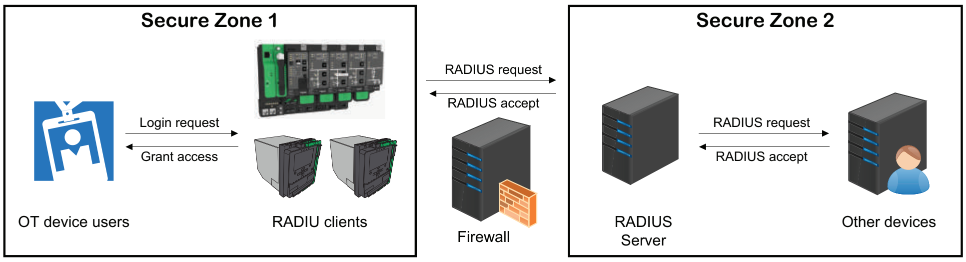


Figure 182 - RADIUS server in a different secure zone with PowerLogic P5



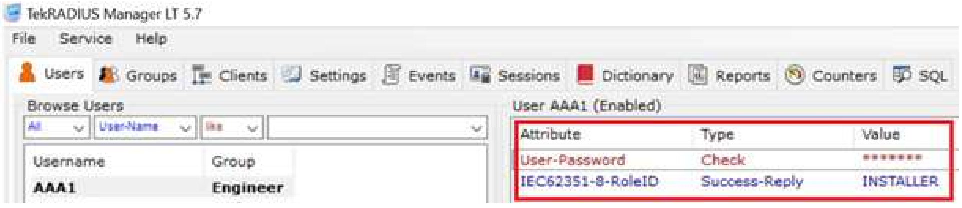
The configuration consists of 2 steps, namely:

1. Setting at the RADIUS server
2. Setting at the PowerLogic P5 end with CAE

Setting at the RADIUS sever

Using TekRADIUS as an example, the setting at the server end is as shown below.

Figure 183 - User role mapping in TekRADIUS server



Username	Group
AAA1	Engineer

User AAA1 (Enabled)

Attribute	Type	Value
User-Password	Check	*******
IEC62351-8-RoleID	Success-Reply	INSTALLER

On the left side you can find all the usernames and groups in the RADIUS server database. Note that the group “Engineer” here does not have any mapping relation with the roles in PowerLogic P5.

On the right side you can find the attributes for highlighted user. There are two attributes to be configured:

1. The first attribute specifies the password for user AAA1. The **Attribute** name shall be *User-Password*. The **Type** shall be *Check*. The **Value** contains the password.
2. To assign user AAA1 a role in PowerLogic P5, the 2nd attribute is needed. Its **Type** shall be *Success-Reply*. The **Attribute name** can be anything but must be the same as the Role attribute name setting in CAE. We use *IEC62351-8-RoleID* as an example. The role to be assigned to user AAA1 shall be entered in the Value field, which is *INSTALLER* in this example.

By providing the above two attributes, user AAA1 will get the INSTALLER role privilege in PowerLogic P5.

If you want to assign multiple roles to user AAA1, for example to assign “INSTALLER” and “ENGINEER” roles to AAA1, set the values of **Attribute** *IEC62351-8-RoleID* as *INSTALLER;ENGINEER* by repeating the sequence of operations above.

Figure 184 - Mapping multiple roles to TekRADIUS user

Username	Group
AAA1	Engineer

User AAA1 (Enabled)

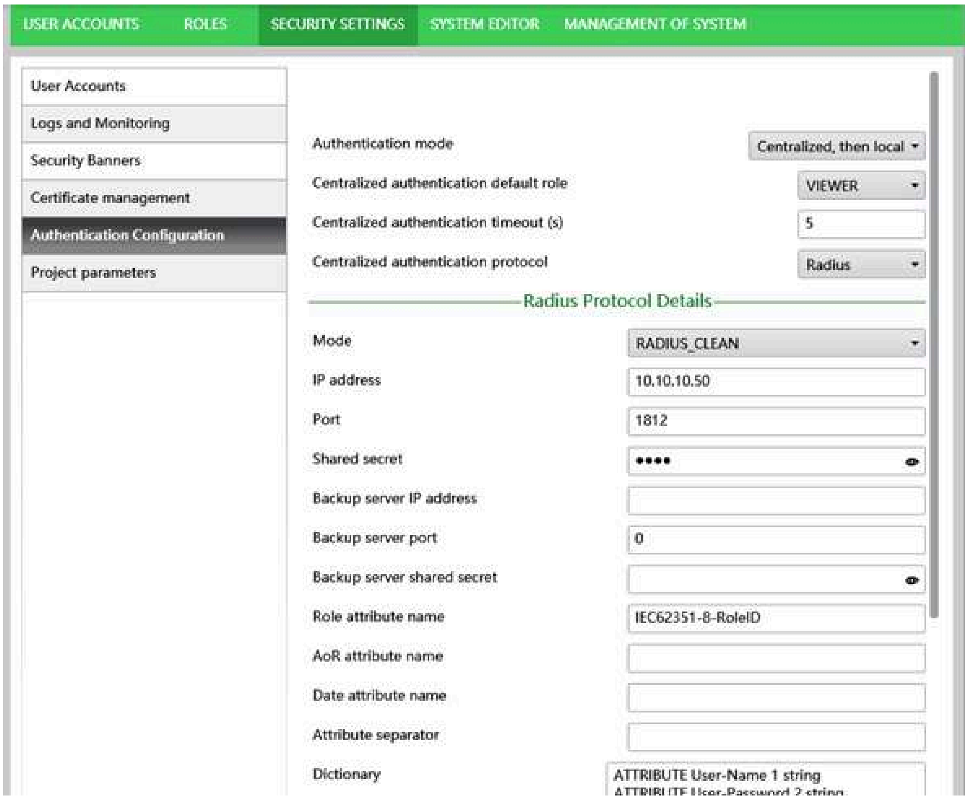
Attribute	Type	Value
IEC62351-8-roleDefinition	Check	*******
IEC62351-8-RoleID	Success-Reply	INSTALLER;ENGINEER

Setting at the PowerLogic P5 end with CAE

Open the CAE software, go to the menu **SECURITY SETTINGS/Authentication Configuration**. Choose *Radius* for **Centralized authentication protocol**. In the section of **Radius Protocol Details**, change the settings of the following items:

1. **Mode**, **IP address** and **Port number** of the TekRADIUS server: for details about the settings please refer to the CAE documentation and your RADIUS server setting. PowerLogic P5 supports RADIUS_CLEAN and EAP_TTLS
2. **Shared secret** needs to be the same as set in the TekRADIUS server.
3. **Role attribute name** must be the same as the TekRADIUS setting which is “IEC62351-8-RoleID” in this example

Figure 185 - CAE setting for RADIUS server



Authentication mode: Centralized, then local
Centralized authentication default role: VIEWER
Centralized authentication timeout (s): 5
Centralized authentication protocol: Radius

Radius Protocol Details

Mode: RADIUS_CLEAN
IP address: 10.10.10.50
Port: 1812
Shared secret: ••••
Backup server IP address:
Backup server port: 0
Backup server shared secret:
Role attribute name: IEC62351-8-RoleID
AoR attribute name:
Date attribute name:
Attribute separator:
Dictionary: ATTRIBUTE User-Name 1 string

Now the user AAA1 can authenticate to PowerLogic P5 with the credential set in the TekRADIUS server and obtain accordingly the role privileges as specified in the TekRADIUS server.

Port hardening

It is possible to disable PowerLogic P5 communication ports from the local panel, eSetup Easergy Pro, or web HMI with ENGINEER access right.

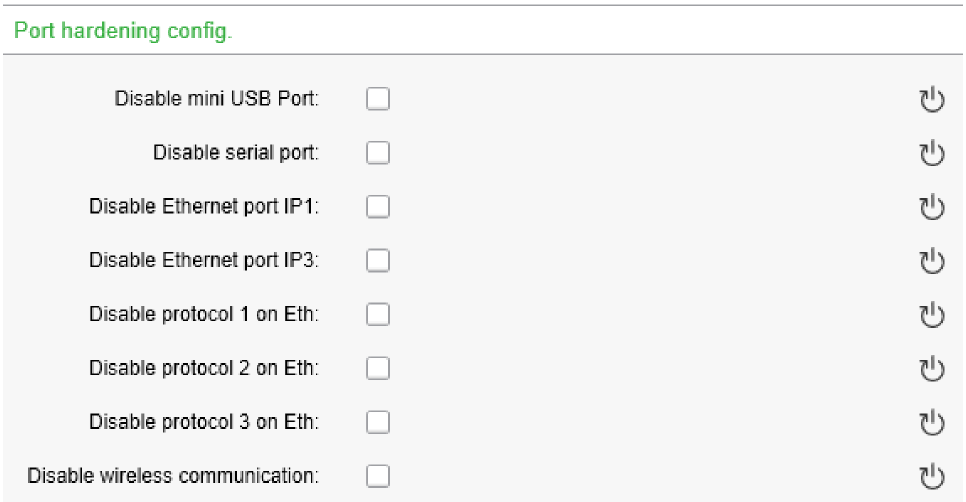
Physical ports which can be disabled:

- Front mini-USB port (for eSetup Easergy Pro connection)
- Rear serial port
- Rear Ethernet port

Wireless communication through Zigbee board can also be disabled.

The figure below shows the Port Hardening Configuration settings in eSetup Easergy Pro/**COMMUNICATION**/**Protocol Configuration**/**Port hardening config.**:

Figure 186 - Port hardening configuration settings in eSetup Easergy Pro



Port hardening config.

Disable mini USB Port: ☐

Disable serial port: ☐

Disable Ethernet port IP1: ☐

Disable Ethernet port IP3: ☐

Disable protocol 1 on Eth: ☐

Disable protocol 2 on Eth: ☐

Disable protocol 3 on Eth: ☐

Disable wireless communication: ☐

The port hardening can also be set from the local panel through the **Port hardening** configuration view of the **General** menu.

When the ports or the protocols on the Ethernet module are disabled or enabled, reboot of the PowerLogic P5 protection relay is needed.

> **NOTE:** In addition to port hardening configuration, and in order to help prevent access to the communication ports on the local panel, it is possible to replace put with install physical seal (See Lock the shutter and handle, page 57).
>
> **NOTE:** All the logical ports supported by PowerLogic P5 are disabled by default except SSH. The SSH is used for the secure communication with eSetup Easergy Pro.

It is possible to disable SSH protocol for the rear Ethernet ports. The setting can be made only from local panel by **General setting** / **Port hardening** / **Dis. Eth SSH**.

Security event logging

The function of security event log and back up remotely the logs to Syslog server is only available in Advanced CS level. The security logs are generated by PowerLogic P5 and saved locally with secured storage on FLASH memory. They are read-only and undeletable for any role. In the meantime the logs will be pushed to the Syslog server defined by CAE. Syslog server manages the logs according to customer security policy.

PowerLogic P5 does not enable by default any of logging standards listed in the table below . The logging standards can be selected in CAE according to requested logs.

Table 50 - Security logs list

Log ID	Description	BDEW	IEEE 1686–2013
CONNECTION_SUCCESS	Successful connection	■	■
CONNECTION_FAILURE	Unsuccessful connection (wrong credentials)	■	■
CONNECTION_FAILURE_AND_BLOCK	Unsuccessful connection (wrong credentials) triggering the blocking of the account	■	■
CONNECTION_FAILURE_ALREADY_BLOCKED	Unsuccessful authentication because the account is already blocked	■	■
DISCONNECTION	Disconnection triggered by user	■	■
DISCONNECTION_TIMEOUT	Disconnection triggered by timeout	■	■
FIRMWARE_UPDATE	Firmware update to IED	■	■
RBAC_UPDATE	Update of the RBAC setting in the IED		■
SEC_LOGS_RETRIEVAL	CAE extraction of security logs from IED		■
TIME_CHANGE	Time change from Easergy Pro, local HMI, Web HMI, protocol time synchronization		■
PORT_MANAGEMENT	Port hardening operations		■
SECURITY_UPDATE	Update of the Security policy database		■

Upgrades management

When the PowerLogic P5 protection relay firmware is upgraded – security configuration remains the same until changed, including usernames and passwords. It is recommended security configuration is reviewed after an upgrade to analyze rights for new or changed device features and revoke or apply them according to your company’s policies and standards.

Security functionality verification

When the Cybersecurity functionalities have been configured, it is recommended to verify that the following functions are working as intended:

- RBAC function is making sure that user cannot perform actions for which he does not have privilege.
- Security event logs (CS Advanced only) are properly generated in PowerLogic P5 locally and the remote Syslog server (if configured) keeps record of them.
- Disabled logical and physical ports can no longer be accessed.

It is recommended to repeat the above tests after firmware update or security policy update.

Use

Introduction

The local panel can be used for both entering all the data required for operation of the PowerLogic P5 protection relay and accessing the data for equipment management.

The following tasks can be handled from the local panel:

- Controlling switchgear units:
    - View equipment status on an animated mimic diagram
    - Local opening and closing of up to 6 devices controlled by PowerLogic P5
- Read out the list of enabled protections
- Readout and modification of settings
- Readout of live operating data including waveforms
- Read out logic status signals
- Readout of operating data logs and of monitoring signal logs
- Readout of event logs after overload situations, ground faults, or short circuits in the power system
- Read out the PowerLogic P5 protection relay's module versions
- Device resetting and triggering of additional control functions used in testing and commissioning
- Test the protection relay with dedicated IED modes (contact outputs forced or not)
- Entering a password according to different access rights for settings and operations (see Cybersecurity, page 205)

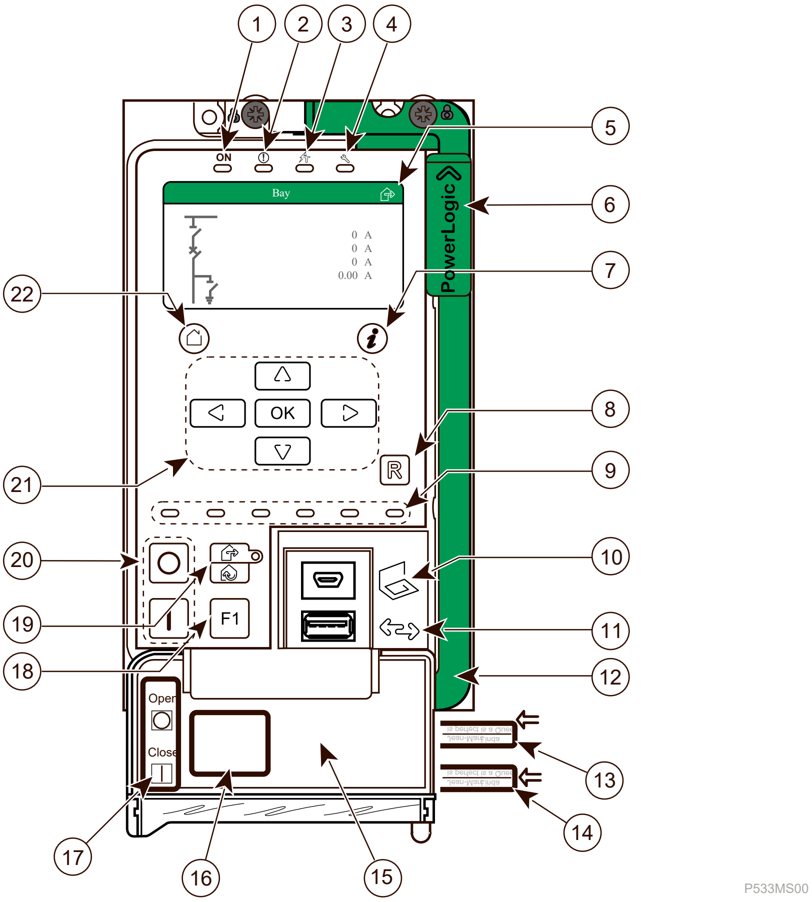
Control is also possible through the PC interface. This requires a suitable PC installed with a specific operating program called eSetup Easergy Pro (see eSetup Easergy Pro, page 271).

Local panel

Presentation

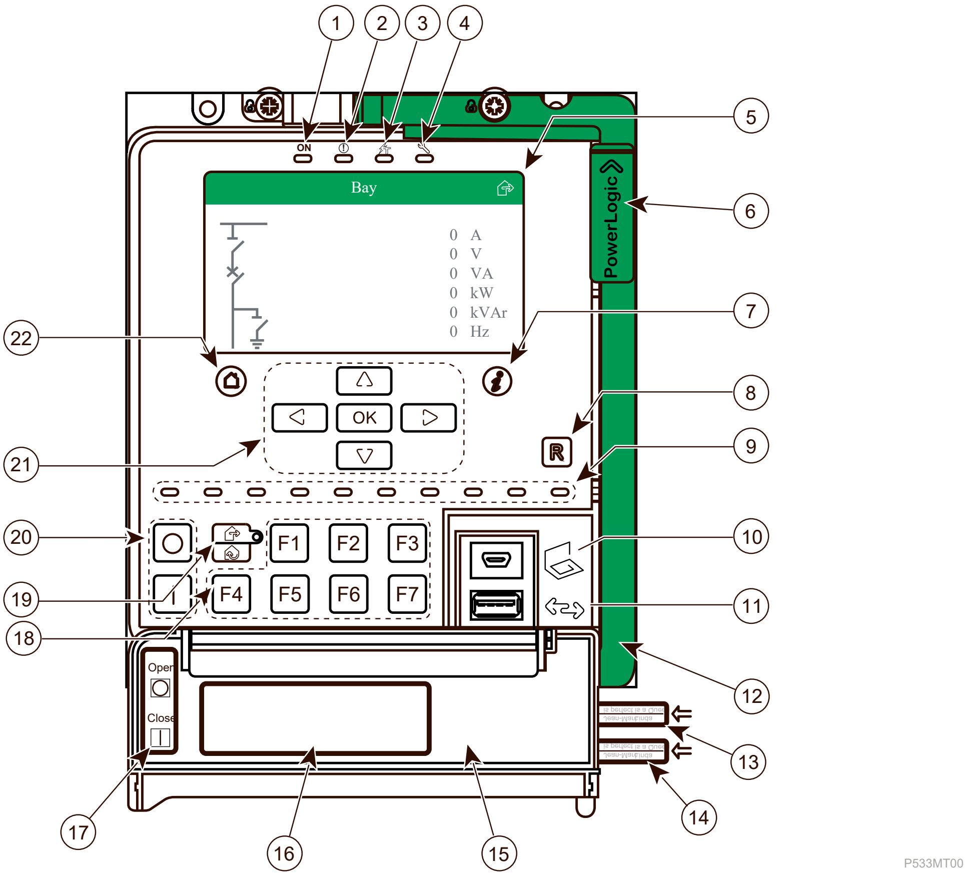
The PowerLogic P5 protection relay is equipped with a user friendly local panel.

Figure 187 - Local panel of PowerLogic P5x20



①	Power ON/OFF LED
②	Alarm LED
③	Trip LED
④	Maintenance/Test LED
⑤	Graphic 192 x 96 monochrome LCD screen
⑥	Handle lock (movable up and down)
⑦	Information key
⑧	Reset key
⑨	6 LEDs, user programmable
⑩	Mini-USB connector for connecting laptop (behind a plastic cover)
⑪	USB connector for data transfer (behind a plastic cover)
⑫	Handle
⑬	Label for protection relay name (inserted in the shutter)
⑭	LED identification label (inserted in the shutter)
⑮	Shutter
⑯	Label for programmable function key (stuck on the back of the shutter)
⑰	Label for CB (Circuit Breaker) open and CB close keys (stuck on the back of the shutter)
⑱	F1 function key
⑲	Remote Control/Local Control key
⑳	CB (Circuit Breaker) Open (upper) and CB Close (lower) keys
㉑	Navigation keypad and confirmation key
㉒	Home key

Figure 188 - Local panel of PowerLogic P5x30



① Power ON/OFF LED

② Alarm LED

③ Trip LED

④ Maintenance/Test LED

⑤ Graphic 480 x 272 color LCD screen

⑥ Handle lock (movable up and down)

⑦ Information key

⑧ Reset key

⑨ 10 LEDs, user programmable

⑩ Mini-USB connector for connecting laptop (behind a plastic cover)

⑪ USB connector for data transfer (behind a plastic cover)

⑫ Handle

⑬ Label for protection relay name (inserted in the shutter)

⑭ LED identification label (inserted in the shutter)

⑮ Shutter

⑯ Label for programmable function key (stuck on the back of the shutter)

⑰ Label for CB (Circuit Breaker) open and CB close keys (stuck on the back of the shutter)

⑱ F1 - F7 function keys

⑲ Remote Control/Local Control key

⑳ CB (Circuit Breaker) Open (upper) and CB Close (lower) keys

㉑ Navigation keypad and confirmation key

㉒ Home key

Push buttons

Symbol	Function
⌂	HOME/Cancel push-button for returning to the previous view. To return to the default screen of the LCD display, keep the button pressed for 3 seconds.
i	INFO push-button for viewing additional information.
R	Reset key to release latches and reset LED status.
F1	1 programmable function push-button for PowerLogic P5x20 (see Object control with function keys, page 563)
F1 to F7	7 programmable function push-buttons for PowerLogic P5x30 (see Object control with function keys, page 563)
OK	ENTER push-button for activating or confirming a function.
△	UP navigation push-button for moving up in the menu or increasing a numerical value.
▽	DOWN navigation push-button for moving down in the menu or decreasing a numerical value.
◁	LEFT navigation push-button for moving back across a menu or selecting a digit in a numerical value.
▷	RIGHT navigation push-button for moving forwards across a menu or selecting a digit in a numerical value.
I	Circuit breaker ON push-button (see Object control with I and O buttons, page 564)
O	Circuit breaker OFF push-button (see Object control with I and O buttons, page 564)
	This push button allows the user to set the PowerLogic P5 protection relay to remote control mode or local control mode.

NOTE: The programmable function push buttons, the Local/Remote control key and the control circuit breaker push buttons are protected by a shutter in normal operation. This shutter can be sealed (see Lock the shutter and handle, page 57).

LED indicators

Status indicators

This includes the 4 LEDs located on top of the LCD representing the different status of the PowerLogic P5 protection relay regarding power, alarm, trip, and operation mode (refer to item 1 to 4 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252) and the LED associated with the "Local/Remote" push button (refer to item 19 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252).

Table 51 - The states of the status indicators

Indicators	States		
	OFF	ON	Flash
ON	Power OFF	Power ON	-
❗	No alarm	-	Alarm
⚡	No trip	Trip	-
🔧	In service	Maintenance	Test/Test-block mode
➦	In local control mode	In remote control mode (steady green)	-

Configurable LEDs

These LEDs can be configured in three different colors: green, red and yellow, and be individually latched or unlatched (see LED matrix, page 554).

These LEDs are configured by default according to LED1 to LED6 on PowerLogic P5 x20, page 254 and LED1 to LED10 on PowerLogic P5 x30, page 254.

Table 52 - LED1 to LED6 on PowerLogic P5 x20

Color	LED 1	LED 2	LED 3	LED 4	LED 5	LED 6
PowerLogic P5U20						
Green	CB Open					
Yellow		Trip Circuit Supervision (TCS) Alarm			Therm Alarm	
Red	CB Closed		I Trip	IN Trip		
PowerLogic P5V20						
Green	CB Open					
Yellow		TCS Alarm				
Red	CB Closed		V Trip	VN Trip	f Trip	

Table 53 - LED1 to LED10 on PowerLogic P5 x30

Color	LED 1	LED 2	LED 3	LED 4	LED 5	LED 6	LED 7	LED 8	LED 9	LED 10
Green	CB Open									
Yellow		TCS Alarm			Therm Alarm					
Red	CB Closed		I Trip	IN Trip			V Trip	VN Trip	f Trip	

Customizing the local panel

The local panel of the PowerLogic P5 protection relay can be customized with four labels for:

- Configurable LEDs
- Configurable function keys

- Circuit breaker control push buttons
- Name of the protection relay or feeder

  NOTE: The PowerLogic P5 protection relay is delivered with:

  - A label of configurable LEDs with default configuration (English version; see LED1 to LED6 on PowerLogic P5 x20, page 254 and LED1 to LED10 on PowerLogic P5 x30, page 254)
  - A label in color for the circuit breaker control push buttons

The different labels can be defined with eSetup Easergy Pro in **DOCUMENTATION/Documentation view**.

The labels can be exported from the **Documentation view** to a pdf file by clicking the **Export PDF** button at bottom right, which then can be printed.

When the labels are printed and adjusted:

- Insert the label for the configurable LEDs in the shutter (see 14 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252)
- Stick the label for the programmable function push buttons on the back side of the shutter (see 16 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252)
- Stick the label for the circuit breaker control push buttons on the back side of the shutter (see 17 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252)
- Insert the label for the protection relay name in the shutter (see 13 in Local panel of PowerLogic P5x20, page 251 and Local panel of PowerLogic P5x30, page 252)

Introduction to the LCD display

PowerLogic P5 protection relay service cycle

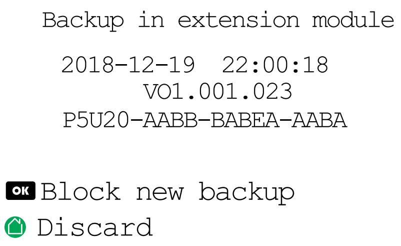
During the start-up of the PowerLogic P5 protection relay, a series of boot messages are displayed to guide the user through the whole process.

The start up process may be different dependent on whether the optional extension module is installed.

If there is no extension module installed, the protection relay enters into the operation mode and displays the default screen (for example the Mimic screen), which can be set through eSetup Easergy Pro in the **GENERAL** menu.

If the extension module is installed, the PowerLogic P5 protection relay checks whether the content of the extension module is a backup of its existing configuration and settings by comparing the version numbers.

Figure 189 - Message on handling the existing content in the extension module



```
Backup in extension module

  2018-12-19  22:00:18
        V01.001.023
  P5U20-AABB-BABEA-AABA

OK Block new backup
⌂ Discard
```

If it is, the PowerLogic P5 protection relay proceeds to the default screen; If it isn't, a message is displayed, prompting the user to either keep or discard the content of the extension module. If the user selects the “Block new backup” option, the content is kept, the PowerLogic P5 protection relay will block the backup operation; If the user selects the “Discard” option, the protection relay directly reconfigures from the extension module.

When the PowerLogic P5 protection relay is in operation mode, it is possible to switch to the main menu screen by pressing ⌂ key. Depending on the user role, the user can also change the device settings at any time.

If an event or alarm occurs during operation, a popup message is permanently displayed on the LCD screen until it is acknowledged using the R key.

If a fault occurs during operation, a popup alarm message is permanently displayed on the LCD screen, press i key to access the **Fault recorder** screen.

If there is an alarm message displayed and no action on the keypad for 5 minutes, the PowerLogic P5 protection relay will jump to the default screen and then display the alarm message again automatically.

If there is no alarm message displayed, the default screen is displayed automatically.

Menu structure

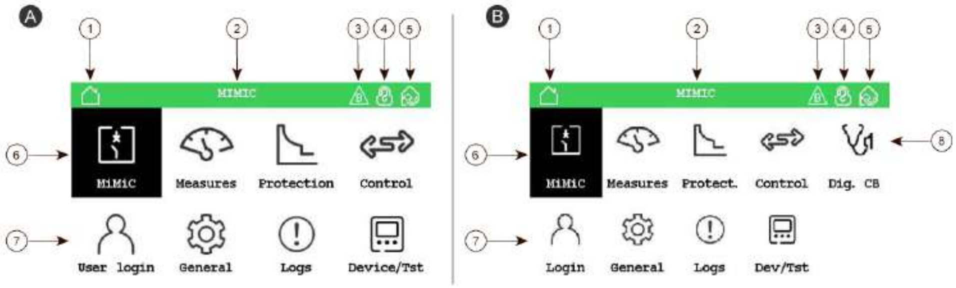
The PowerLogic P5 protection relay has two levels of menus: the main menu (home menu) and sub-menus.

> **NOTE:** The hierarchy and navigation of the menu structure are the same on PowerLogic P5x20 and PowerLogic P5x30, but due to a larger resolution, the PowerLogic P5x30 LCD color screens can display data and graphics in greater detail.

The PowerLogic P5 device is delivered with auto-login feature. It will be disabled when the passwords for all three levels are changed from the default ones. For the default passwords for all the levels, refer to Default settings, page 227.

Main menu (home menu)

Figure 190 - The main menu with menu item Mimic in focus



A	Main menu (Digital CB protocol is not configured)	B	Main menu (Digital CB protocol is configured)
1	Home menu icon	5	Remote/Local control icon
2	Full name of the menu item in focus	6	Menu item in focus
3	Cybersecurity level icon	7	Menu item not in focus
4	Padlock icon	8	Digital Circuit Breaker monitoring icon

The main menu screen has 2 widgets: the top title bar, and the main display area. The top title bar shows the following items:

- Menu name: full name of the menu item that is being selected (the names next to the menu icons use their short forms)
- Home icon: located on the left side of the top title bar, indicates that the current screen is the home screen of the LCD display
- Cybersecurity level icon: located on the right side of the top title bar. B stands for the Basic Cybersecurity level, A stands for the Advanced Cybersecurity level.
- Padlock icon (🔒): located on the right side of the top title bar, indicating that no user has logged in to the device; the icon disappears when any user has logged in.
- Remote/Local control icon: located on the right end of the top title bar, indicates the protection relay's current control mode

Figure 191 - The remote/local control icons

Remote mode

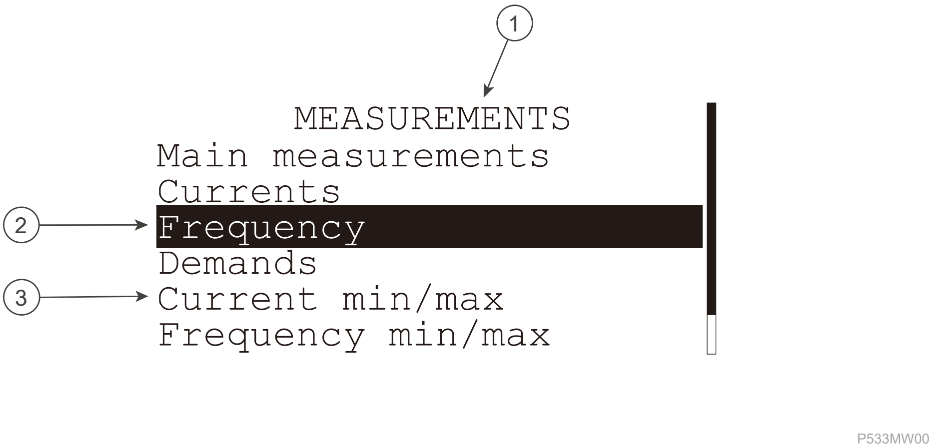
Local mode

The main display area lists all the menu items (sub-menus) of the PowerLogic P5 protection relay.

In the main menu, pressing the navigation keys on the local panel moves the focus onto a main menu item (sub-menu). The sub-menu title is displayed in the top title bar of the main menu screen. Pressing OK allows the user to enter the highlighted sub-menu.

Sub menus

Figure 192 - The Measurement sub-menu



1	Title of sub-menu	3	Menu item not in focus
2	Menu item in focus		

In the sub-menu, pressing △ or ▽ key moves the focus onto a sub-menu item and pressing OK selects the item and allows the user to enter the setting page of the item.

> **NOTE:** There could be more menu items than is able to be displayed in the view. The user needs to scroll to these items using the ▽ key.

Data/setting page

Some sub-menu items may have more than one data/setting pages, which is indicated by an arrow on either the left or right end, or by arrows on both ends of the title bar:

- Arrow on the right end
  Press the ▷ key scrolls the screen to the next data/setting page.
- Arrow on the left end
  Press the ◁ key scrolls the screen to the previous data/setting page.
- Arrows on both the left and right ends
  Press the ◁ or ▷ key scrolls the screen to the previous or next data/setting page, respectively.

Upon seeing the desired data/setting page, press OK to allow the user to enter the data/setting page, then press the △ or ▽ key moves the focus onto each parameter field.

> **NOTE:** There may be more parameters than the view can display. The user needs to scroll to these parameters using the ▽ key.

When an editable parameter is in focus, press OK to open the parameter setting view and enable the user to change the value or option by pressing the navigation arrow keys. When a non-editable parameter is in focus, press OK key to pop up a message indicating that the parameter is not editable. When the user is not fully authorized to edit the setting, press OK key to pop up a "Permission denied" message.

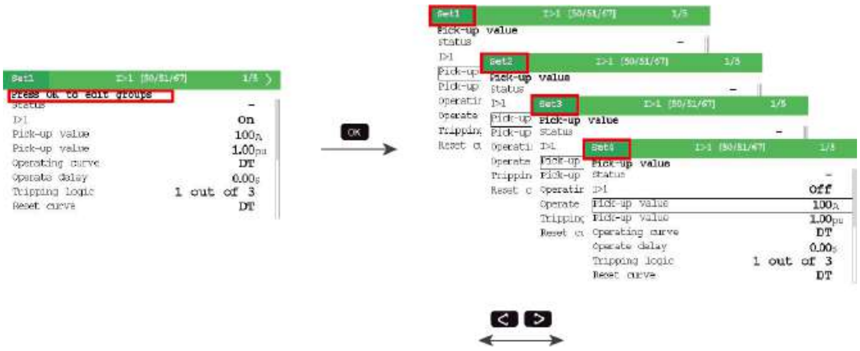
When changing the settings, use the navigation keys according to the following instructions to get the result quickly:

- For selecting options, use the △ and ▽ keys;
- For changing the value of integer numbers, use either the △ and ▽ keys, or the ◁ and ▷ keys;
- For changing the value of float numbers, first use the △ and ▽ keys to quickly approach the integer part of the number in steps of 1 and then use the ◁ and ▷ keys to adjust the decimal part in steps of 0.01.

In the protection menu, some protection stage items have a first setting page with more than one view. These views belong to different setting groups of the protection stage. In this case, upon selecting the menu item, an additional text line "Press OK to edit groups" is displayed at the top of the main display area to indicate that here the user can edit the settings of different setting groups.

Press the OK key to enter the group editing status. Press the ◁ and ▷ keys to scroll to the setting view for the desired setting group.

Figure 193 - Example of a data/setting page with 4 setting views



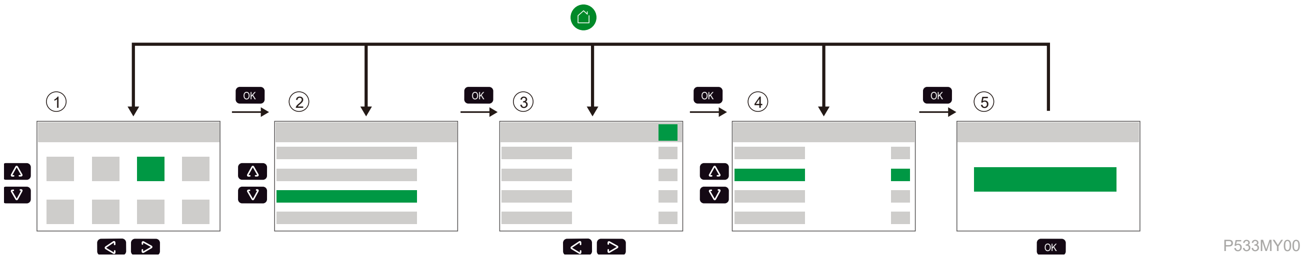
Set1 I>1 [50/51/67] 1/5 >
Press OK to edit groups
Status -
I>1 On
Pick-up value 100A
Pick-up value 1.00pu
Operating curve DT
Operate delay 0.00s
Tripping logic 1 out of 3
Reset curve DT

Set4 I>1 [50/51/67] 1/5
Pick-up value
Status -
I>1 Off
Pick-up value 100A
Pick-up value 1.00pu
Operating curve DT
Operate delay 0.00s
Tripping logic 1 out of 3
Reset curve DT

Moving in the menu structure

The following image describes the operation to navigate in the menu structure.

Figure 194 - Moving in the menu structure of the PowerLogic P5 protection relay



1	Main menu	4	Data/setting page (parameter selecting view)
2	Sub-menu	5	Parameter editing view
3	Data/setting page (page selecting view)	🟩	object in focus

Press ◁, ▷, △ and ▽ keys to move focus in menu.

Press OK key to enter the sub menu (2), the data/setting page selecting view (3), the parameter selecting view (4), or the parameter editing view (5), depending on where the user is situated in menu structure.

OK key is also used to confirm and finalize the editing in the parameter editing view.

Press ⌂ key once to return to previous view.

Keep pressing the ⌂ key for 3 seconds to display default screens.

Moving default screens and mimics

There are two ways to display default screens:

- keep pressing the ⌂ key for 3 seconds
- make no action on the keypad for 5 minutes.

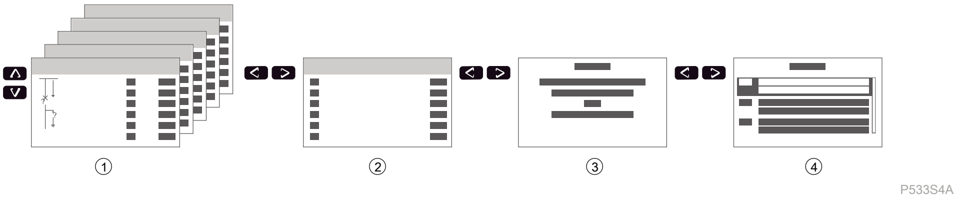
It is possible to scroll between visible mimics (per setting) and between default screens.

To scroll between mimics and other default screens, please press ◁ and ▷ keys to scroll between mimics and **Alarm list**.

In mimics of default screen, use △ and ▽ keys to scroll between **Mimic 1** and **Mimic 10**.

> **NOTE:** If **Mimic 2** to **Mimic 10** are set to invisible, press △ and ▽ keys will not scroll to other mimics from **Mimic 1**.

Regardless of which mimic is actually displayed, pressing ▷ key will scroll to **Main measurements** window. When pressing ◁ key in **Main measurements** window, **Mimic 1** will be displayed.



1	Mimics	2	Main measurements
3	Firmware version	4	Alarm list

Login and logout

NOTE: For more details about password management, see relevant sections in Cybersecurity, page 205.

Login

The user may need to log in before changing settings or accessing the data protected by password. The PowerLogic P5 device is delivered with auto-login feature. It will be disabled when the passwords for all three levels are changed from the default ones. For the default passwords for all three levels, refer to Default settings, page 227.

Except from the home screen or alarm popup screen, access the User Login screen by pressing the ℹ key on the local panel and press the OK key. This feature allows you to access the User Login screen from anywhere in the menu structure instead of returning to the Home page.

The following login procedure starts from the main menu.

1. Press the navigation keys and the OK key to enter the User Login menu from the main menu screen.

   The screen displays the Login view with the focus on the "Name" field.

2. Press OK to show the user list, which displays the three default user levels provided by the PowerLogic P5: Engineer Level, Operator Level and Installer Level.
3. Press △ or ▽ key to select a user name from the user list and then press the OK key to confirm your choice.
4. Enter the password by first pressing ◁ or ▷ key to select the code position, and then press△ or ▽ key to select different letter or digits and press the OK key to confirm.

   NOTE: After a correct password is entered, the LCD display returns to the home screen and the padlock icon disappears from the screen title bar, indicating that the user is now able to view/edit the settings, depending on the access right level of the user type.

Logout

By default, the user is automatically logged out if there is no action on the keypad for 3 minutes.
The user can also logout manually by first going to the User Login screen from the local panel and then pressing the OK key.

NOTE: Except from the home screen or alarm popup screen, access the User Login screen by pressing the ℹ key on the local panel and press the OK key. This feature allows you to access the User Login screen from anywhere in the menu structure instead of returning to the Home page.

Adjusting the LCD contrast (for PowerLogic P5x20)

The LCD contrast of the PowerLogic P5x20 protection relay can be adjusted according to the following steps:

1. On the local panel, select the **Device/Test** menu icon and then press the OK key to enter sub-menu.
2. Press ▽ key to select **Contrast of LCD**.
3. Press OK key twice to enter the setting page of LCD contrast.

4. The setting range of contrast is 1 to 15. To increase contrast, press △ or ▷, to decrease, press ▽ or ◁. After setting, press OK key to confirm. The contrast of LCD will be changed after confirmed.
5. Press ⌂ key to go back previous view, or keep press the key for 3 seconds to go back to default screen.

   NOTE: The LCD contrast can alternatively be adjusted by pressing the key and then pressing the △ and ▽ key. The contrast changes incrementally with every step but the screen does not display the values.

Changing language

The interface language can be changed on the local panel according to the following steps:

1. Press the navigation keys to select the **General settings** menu from the main menu screen, then press OK key to enter. The screen displays the **General settings** menu with the focus on the "Language" option.
2. Press the OK key to enter the Language setting page.
3. Press the OK key to focus on the setting item.
4. Press the OK key again to bring up the language list.
5. Press the △ or ▽ key to select the desired language and then press the OK key to confirm the selection.

   NOTE: The interface language can alternatively be changed through eSetup Easergy Pro in the **GENERAL** menu/**System info** sub-menu.

Changing the parameters

⚠WARNING

UNINTENDED EQUIPMENT OPERATION

Make sure that the reboot of the protection relay has no impact on people and equipment.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

After changing some settings, the protection relay needs to reboot. During this time, the device is not operational.

Parameters can be changed on the setting pages of certain sub-menus:

1. In the main menu, enter the menu item that relates to the function you need to access.
   Refer to Main menu (home menu), page 256 for how to access the menu items.
2. In the sub-menu, select the sub-menu item that includes the parameter you want to change.
   Refer to Sub menus, page 257 for how to access the sub-menu items.
3. With the related sub-menu item selected, press ◁ or ▷ key to scroll to the specific setting page on which you can find the parameter and then press OK to enter the setting page.
4. Press the △ or ▽ key to move the focus onto the parameter field and then press the OK key to start editing the parameter.

5. Use the navigation keys to change the value of the parameter and then press the OK key to confirm your change.
   Refer to Data/setting page, page 259 for how to use the navigation keys tactically.
6. Press the ⌂ key once to go back to the previous view in the menu, or press it for 3 seconds to return to the default screen.

Manage the alarm messages

Handling the pop-up alarm message

When an alarm message box pops up on the LCD screen, the user can acknowledge the message and close the message box by pressing the R key. Alternatively, if there is more than one alarm, the user can press the key R for about 2 seconds to bring up a dialog box where the user can opt to delete all the alarm messages.

Changing the alarm settings and viewing the alarm list

Alarm settings and list can be accessed from the Logs function group in the main menu.

The following procedure describes how to change the alarm settings and view the alarm list:

1. From the main menu, use navigation keys to select **Logs** function group, click OK key to enter sub-menu. Refer to Main menu (home menu), page 256 for how to access the menu items.
2. In the **Logs** sub-menu, select the option **Alarm logs** to enter the **Alarms** setting page.

   Refer to Sub menus, page 257 for how to access the sub-menu items.
3. Press OK key to enable selection in setting page, use △ or ▽ key to move the focus onto the parameter field and then press OK to edit setting of parameters.

   The setting page includes the following parameters:
   - **Counter**: number of alarms (from 0 to 200)
   - **Order**: scroll order (New - Old)
   - **Fault value**: fault value scaling (Primary or PU)
   - **Alarm screen**: enable alarm pop-up messages (On or Off)
   - **Event synchro.**: displaying event time not in sync (On or Off)
   - **Clear alarms**: edit DI to clear all alarms
4. Press △ or ▽ key to change the settings of the parameters and then press OK to confirm change.
5. Press the ⌂ key once to go back to the previous view in the menu, or press it for about 3 seconds to return the default screen.

   NOTE: For viewing the alarm list, press ▷ key once to go to the **Alarm list** page after Step 2.

Matrix operations

The matrix mapping operation can be performed on the local panel of the PowerLogic P5 protection relay, in the eSetup Easergy Pro software tool, or through the web HMI.

The following procedure describes the mapping operation on the local panel of the PowerLogic P5 protection relay. The operation is much easier in eSetup Easergy Pro and the web HMI due to their intuitive interfaces.

1. Select the Control function from the main menu, press OK to enter the sub-menu.
2. Press △ or ▽ key to scroll to the menu item (e.g. DI) that needs matrix mapping operation.
3. Press ◁ or ▷ key to scroll to the matrix mapping page and start the mapping operation.

   NOTE: The local panel LCD screen only shows the first line of mapping relations already existing in the configuration. If no mapping relation is available for the first line of the matrix, the screen only shows the digital input or internal signal on the left side of the screen.
4. Press △ or ▽ key to scroll to the digital input or internal signal type and then press OK to confirm. The first crossing point on the matrix line starts to blink.
5. Press ◁ or ▷ key to scroll to the crossing point for which you want to set the mapping status.

   NOTE: Some crossing points may not be visible in the screen but the user can view all the crossing points by pressing ▷ key.
6. Press ◁ or ▷ key to select the mapping status (enabled or disabled; connected or unconnected; latched or unlatched, depending on which matrix mapping operation is being performed) and then press OK to confirm.

   The screen shows the current line of mapping relations, leaving the empty crossing points invisible on the screen.
7. Press ◁ key to leave the matrix setting page and then ⌂ key to return to the preview level in the menu structure.

Controlling objects

The local panel provides buttons for directly controlling objects like circuit breaker and ground switch. The user do not need to go through the menu to find out the options for closing/opening the objects.

Controlling an object with Selective Control enabled

To enable the Selective control feature, navigate to the **Control** menu/**Control objects** sub-menu of the local HMI, or to the **GENERAL** menu/**Local panel conf** sub-menu of the eSetup Easergy Pro.

When Selective Control is enabled, the control operation will include a confirmation step (select before operate).

1. Press ○ on the local panel to open a circuit breaker or stop a motor, or press I on the local panel to close a circuit breaker or start a motor.
2. Press the same key (○ or I) again to confirm your operation, or press ⌂ on the local panel to cancel the previous operation.

Controlling an object with Direct Control enabled

To enable the Direct control feature, navigate to the **Control** menu/**Control objects** sub-menu of the local HMI, or to the **GENERAL** menu/**Local panel conf** sub-menu of the eSetup Easergy Pro (refer to Controlling an object with Selective Control enabled, page 267 and Local panel configuration, page 560 respectively).

When Direct Control is enabled, the control operation is done without confirmation.

1. Press ○ on the local panel to open a circuit breaker or stop a motor, or press I on the local panel to close a circuit breaker or start a motor.
2. The object in control acts according to your control operation.

Specific language file change

The PowerLogic P5 protection relay can be ordered in English version only or in English with another local language (see).

The selection of the language can be done with eSetup Easergy Pro or directly on the local panel of the PowerLogic P5 protection relay (see Changing language, page 263).

Other languages can be uploaded to the PowerLogic P5 protection relay through eSetup Easergy Pro, using the Update language option from the 🛠 (Tools) drop down list in the tool bar.

NOTE: The language files use the .bin extension.

For detailed list of languages, contact Schneider Electric.

Transferring data to USB memory stick

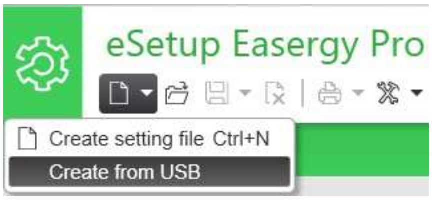
The PowerLogic P5 protection relay supports data transfer to a USB memory stick plugged into the USB 3.0 type A port located under the flap of the local panel.

Files of the following formats in the protection relay can be transferred:

File format	Description
manifest.mnfs	IED information and integrated check data
/DR/*.dat, *.cfg	Disturbance records
events.csv	IED sequence of events (maximum 2000 events)
Setting.xml	IED setting file in XML format

The settings stored in Setting.xml can be opened by eSetup Easergy Pro: click on the black triangle at right of the file button of the tool bar, select **Create from USB** to open the Setting.xml.

Figure 195 - Open Setting.xml by eSetup Easergy Pro



The features of the USB data transfer function are as follows:

- Hot-plugging is supported and the USB key status is automatically detected by the device.
- Files are copied to a sub-folder of the folder “P5bak” of the USB disk. The name of the sub-folder is composed of 3 parts: the date and time, the serial number S/N, and the model number.

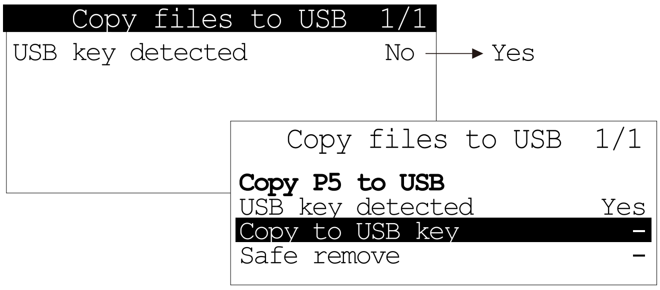
  The sub-folder is created automatically before transferring the data.
- Each file transferred is accompanied by a CRC32 check to help ensure the integrity.
- Software and hardware information is stored in the manifest file.
- Data transfer process takes about 2 to 10 minutes.
- The USB key used must be in FAT32 format and with write caching disabled.
- USB 3.0 or above is recommended for use on the device.

NOTE: The USB data transfer function transfers only disturbance record files to USB key, the digital format setting file, event, alarm files can be transferred only by eSetup Easergy Pro.

The data is transferred to the USB key according to the following steps:

1. Use navigation keys to select and press OK key to enter **Device/Test** sub menu. Select **USB key** and press OK key to enter the view of **Copy files to USB**. Insert USB Key to the USB port in front of local panel.

   The **USB key detected** status will be changed from “No” to “Yes” automatically.

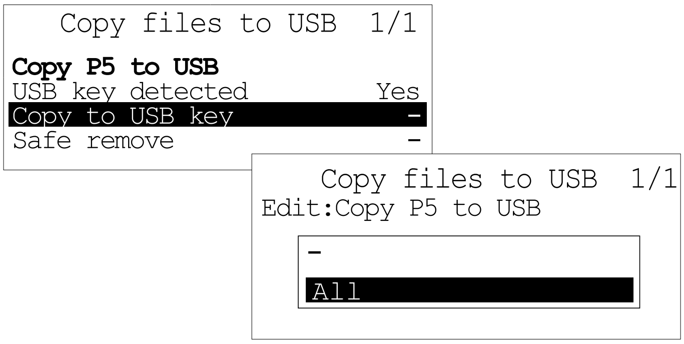


```
Copy files to USB  1/1
USB key detected        No → Yes
```

```
Copy files to USB  1/1
Copy P5 to USB
USB key detected       Yes
Copy to USB key          -
Safe remove              -
```

P533OK00

2. Press OK key to enable selection. Select **Copy to USB key** and then select **All** to copy all the files from the protection relay to USB key.

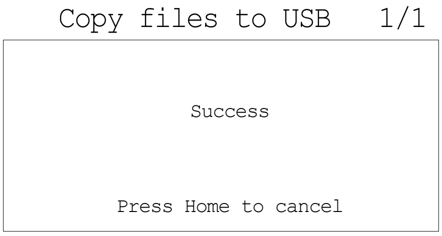


```
Copy files to USB  1/1
Copy P5 to USB
USB key detected       Yes
Copy to USB key          -
Safe remove              -
```

```
Copy files to USB  1/1
Edit:Copy P5 to USB
  -
  All
```

P533OJ00

3. A progress bar will be displayed on the screen for a short while. After finished copy, a “Success” message will be displayed. Please press ⌂ key to close this message.



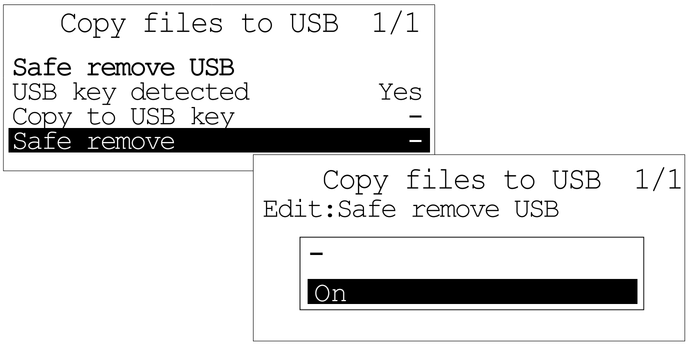
```
Copy files to USB  1/1

       Success

 Press Home to cancel
```

P533O900

4. To remove USB key, please select **Safe remove**, then select **On** and press OK key.



```
   Copy files to USB  1/1
Safe remove USB
USB key detected        Yes
Copy to USB key           -
Safe remove               -
```

```
   Copy files to USB  1/1
Edit:Safe remove USB
   -
   On
```

P533S000

eSetup Easergy Pro

Overview

⚠WARNING

UNINTENDED EQUIPMENT OPERATION

Make sure that the reboot of the protection relay has no impact on people and equipment.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

After changing some settings, the protection relay needs to reboot. During this time, the device is not operational.

eSetup Easergy Pro is a setting and operating software tool for configuring PowerLogic P5 devices, local operation and customization functions.

The eSetup Easergy Pro software is supplied directly through the Schneider Electric website www.se.com, along with the eSetup Easergy Pro program for recovering disturbance recording files, and all the PowerLogic P5 documentation in PDF format.

Figure 196 - eSetup Easergy Pro menu bar and tool bar

The eSetup Easergy Pro software has a graphical interface where the protection relay settings and parameters are grouped under nine menu tabs:

- General
- Measurements
- Control
- Protection
- Matrix
- Logs
- Communication
- Device/Test
- Documentation
- Digital CB (optional)

The contents of the tabs depend on the device type and the selected application mode. Refer to the User Manual of eSetup Easergy Pro for detailed information on the setting views of each menu.

The eSetup Easergy Pro stores the device configuration in a setting file. The configuration of one physical device is saved in one setting file. The configurations can be printed out and saved for later use.

When starting to work with eSetup Easergy Pro, there are three options:

- Create a new setting file without connecting to a protection relay
- Open an existing (previously saved) setting file without connecting to a protection relay
- Connect to a relay and read the settings from the protection relay .

eSetup Easergy Pro can be connected to a single relay via the mini-USB port in the protection relay's local panel or to a group of protection relays through Ethernet.

Operation modes

The eSetup Easergy Pro software can be used in three operation modes:

- Disconnected mode
- Single unit connecting mode
- Network connecting mode

Using eSetup Easergy Pro in disconnected mode

The disconnected mode allows you to prepare parameters and settings files for PowerLogic P5 prior to commissioning.

The parameter and protection setting files prepared in disconnected mode will be downloaded later to the PowerLogic P5 protection relays in connected mode.

In this mode, the user can create a setting file from scratch, or open a previously saved setting file as a basis for creating configuration for a protection relay of the same type. Refer to the User Manual of eSetup Easergy Pro for more information.

Using eSetup Easergy Pro to connect with a single PowerLogic P5

The single connection mode is used during commissioning of a PowerLogic P5 protection relay:

- To upload, download and modify PowerLogic P5 parameters and settings.

  Refer to the User Manual of eSetup Easergy Pro for more information on uploading (writing)/downloading (reading) setting files to/from the connected protection relays.

NOTICE

UNINTENDED EQUIPMENT OPERATION AND NUISANCE TRIPPING

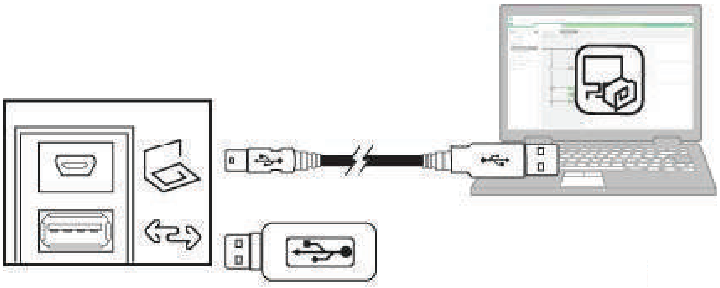
After writing new settings, configurations or firmware to a protection relay, perform a test to verify that the protection relay operates correctly with the new settings.

Failure to follow these instructions can result in unwanted shutdown of the electrical installation.

- To have all the measurements and supporting data available for commissioning.

The PC fitted with the eSetup Easergy Pro software is connected to the mini-USB port in the local panel of the PowerLogic P5 using a USB cord (reference 59700).

Figure 197 - Connecting a PC to the PowerLogic P5 using a USB cable



Using eSetup Easergy Pro connected to an PowerLogic P5 network

The network connection mode is used during operation:

- To manage the protection system.
- To check the status of the power supply.
- To diagnose any incident occurring on the power supply.

The PC fitted with the eSetup Easergy Pro software is connected to a group of PowerLogic P5 units via a communication network (connection via serial link or Ethernet).

The connection window allows configuration of the PowerLogic P5 network, and provides access to the parameter and protection setting files of the PowerLogic P5 units on the network.

Setting up the connection

Installing the USB driver

If it is the first time you connect the PowerLogic P5 protection relay to a PC running eSetup Easergy Pro, you need to install the USB driver on the PC.

The steps for installing the driver are as follows:

1. Connect the USB cable (reference 59700) to the front port of the PowerLogic P5 protection relay and the PC (see Connecting a PC to the PowerLogic P5 using a USB cable, page 272), after that look for a new COM port under COM & LPT in the Device Manager window of the PC.

If you are unsure which is the right port, detach the USB cable and insert it again when you are in this menu.

2. Right-click on the port and select Update Driver Software from the contextual menu.

3. Select the option Browse my computer for driver software and locate the driver in the P5 driver_files folder under the eSetup Easergy Pro directory.

Would you like to install this device software?

4. Click the Install button in the prompt window to start installing the driver.

Windows has successfully updated your driver software

Windows has finished installing the driver software for this device

Schneider Electric USB Remote NDIS Device

5. If the driver has been installed successfully, the connection now appears under Network adapters in the Device Manager window each time you connect the PC to a PowerLogic P5 protection relay.

Connecting to a single protection relay using USB cable

1. Install the USB driver from the eSetup Easergy Pro file package for the first time connecting the PowerLogic P5 protection relay to a PC running eSetup Easergy Pro (see Installing the USB driver, page 273).
2. Connect the USB cable (reference 59700) between the PC running eSetup Easergy Pro and the local port of the PowerLogic P5 protection relay, with the mini-USB type B connector of the cable plugged into the protection relay and the type A connector to the PC (see Connecting a PC to the PowerLogic P5 using a USB cable, page 272).
3. On the eSetup Easergy Pro toolbar, click the **ON** connection button. The Login pop-up window opens.
4. Select the right PowerLogic P5 USB serial port name.
5. Click **Connect**.
   A new window showing the relay information opens.
6. Enter the user name and password to login.
   eSetup Easergy Pro's main view opens.

NOTE: If you connect for the first time to a device on which the default users and passwords are used, refer to Cybersecurity, page 205.

Connecting to protection relays via Ethernet

You can connect to a single protection relay or multiple protection relays via Ethernet.

1. On the eSetup Easergy Pro toolbar, click the **ON** connection button. The Login pop-up window opens.
2. Click **ETHERNET**.
3. Select the right IP address from the drop-down menu.
   - For the protection relay's IP address, see the protection relay local panel menu **BUS/ETHERNET PORT**.
   - To save the defined connection settings, click the disk icon.
4. Click **Connect**. A new window showing the protection relay information opens.
5. Enter the user name and password to login. eSetup Easergy Pro's main view opens.

Web HMI

Overview

The Web HMI is used for operation and settings of PowerLogic P5 through web browser.

The Web HMI can be accessed through the following browsers:

Operation system	Certificate state	Mozilla Firefox® [53]	Google Chrome® [54]	Microsoft Edge® [55]
Windows 7	without pre-installed certification	■	-	-
	pre-installed certification	■	-	-
Windows 10	without pre-installed certification	■	-	-
	pre-installed certification	■	■	■

The compatibility of browsers and PowerLogic P5 firmware versions are listed as below:

Firmware versions of PowerLogic P5	Mozilla Firefox®	Google Chrome®	Microsoft Edge®
Versions earlier than V02.501	Compatible	Not compatible	Not compatible
Versions later than V02.501 (included)	Compatible	Compatible	Compatible

NOTE: Firefox is recommended for the compatibility with PowerLogic P5.

Enable the HTTPS server

Before connecting the PowerLogic P5 with Web HMI, you must enable the HTTPS server of it. The setting is made by eSetup Easergy Pro, in **COMMUNICATION/ Protocol configuration/Enable HTTPS server**, enable the Enable HTTPS server check box if it was not enabled. Then select the IP address you wish to use from the **IP address selection**.

Device reboot reminder

NOTE: Attention to the reminder message of device reboot.
Some setting changes require a reboot of the PowerLogic P5 protection relay. This is reminded by a message appearing on the HMI screen when you change such settings through the HMI.

Find the IP address of your PowerLogic P5 device

The IP address of the PowerLogic P5 device can be found through eSetup Easergy Pro or through the local HMI.

- From eSetup Easergy Pro: the IP addresses are displayed in **COMMUNICATION/Protocol configuration** section.
- From local HMI: you can find the addresses in **General/Ethernet port** menu.

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[53] Mozilla Firefox® is a registered trademark of the Mozilla Foundation.
[54] Google Chrome® is a registered trademark of Google Corporation.
[55] Microsoft Edge® is a registered trademark of Microsoft Corporation.

Troubleshooting of Web HMI connection

Ensure the connection between your laptop and the PowerLogic P5, set the IP address and the subnet mask of your laptop to ensure a successful Ethernet communication with the PowerLogic P5 device.

Table 54 - Web HMI connection troubleshooting

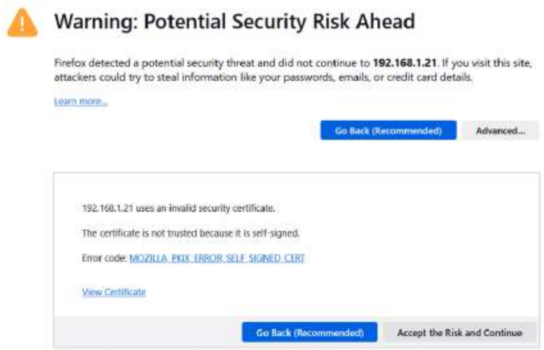
Connection issue	Possible causes	Actions
Unable to connect	The connection may be blocked by the firewall	Make sure your browser is permitted to access the web or temporarily deactivate the firewall during the Web HMI connection.
Unable to find the device	The address setting and subnet mask are not correctly set.	Set the IP address and the subnet mask of your laptop to ensure a success Ethernet communication with PowerLogic P5 device.

Mozilla Firefox

Warning: Potential Security Risk Ahead

Firefox detected a potential security threat and did not continue to **192.168.1.21**. If you visit this site, attackers could try to steal information like your passwords, emails, or credit card details.

1. We take the default IP address as example. Input "https://192.168.1.21" to the address bar, the message will be displayed as in the left image.



Warning: Potential Security Risk Ahead

Firefox detected a potential security threat and did not continue to **192.168.1.21**. If you visit this site, attackers could try to steal information like your passwords, emails, or credit card details.

192.168.1.21 uses an invalid security certificate.

The certificate is not trusted because it is self-signed.

Error code: MOZILLA_PKIX_ERROR_SELF_SIGNED_CERT

2. Click on **Advanced** button to extend the information zone below, if you want to check the certificate, click on **View Certificate**.

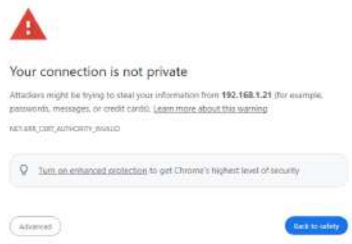
3. In the tab **Warning: Potential Security Risk Ahead**, click on the **Accept the Risk and Continue** button to continue to the login page.

4. The login page of Web HMI will be displayed as shown in the image.

5. Input username and password, then click on **Login** button to login.

   NOTE: The default settings of username and password can be found in Default settings, page 223 or Default settings, page 227, depends on the cybersecurity level of the device.

Google Chrome



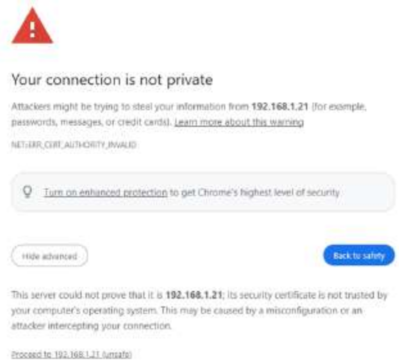
Your connection is not private

Attackers might be trying to steal your information from **192.168.1.21** (for example, passwords, messages, or credit cards). Learn more about this warning

NET::ERR_CERT_AUTHORITY_INVALID

Turn on enhanced protection to get Chrome's highest level of security

1. We take the default IP address as example. Input "https://192.168.1.21" to the address bar, the message will be displayed as in the left image.



Your connection is not private

Attackers might be trying to steal your information from **192.168.1.21** (for example, passwords, messages, or credit cards). Learn more about this warning

NET::ERR_CERT_AUTHORITY_INVALID

Turn on enhanced protection to get Chrome's highest level of security

This server could not prove that it is **192.168.1.21**; its security certificate is not trusted by your computer's operating system. This may be caused by a misconfiguration or an attacker intercepting your connection.

Proceed to 192.168.1.21 (unsafe)

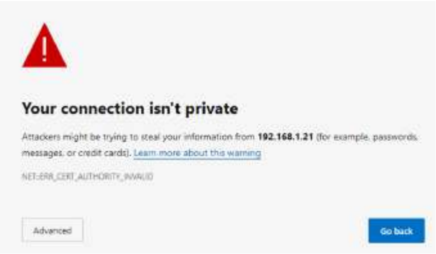
2. Click on **Advanced** button to extend the information zone below, click on the link **Proceed to 192.168.1.21 (unsafe)**.

3. The login page of Web HMI will be displayed as shown in the image.

4. Input username and password, then click on **Login** button to login.

NOTE: The default settings of username and password can be found in Default settings, page 223 or Default settings, page 227, depends on the cybersecurity level of the device.

Microsoft Edge



Your connection isn't private

Attackers might be trying to steal your information from **192.168.1.21** (for example, passwords, messages, or credit cards). Learn more about this warning

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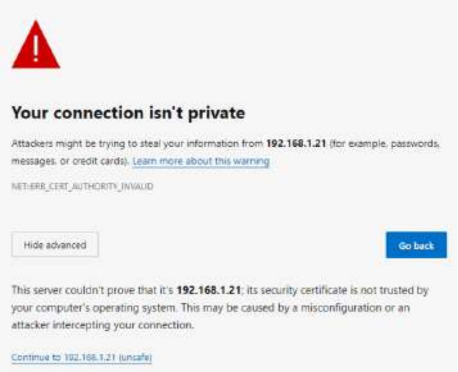
1. We take the default IP address as example. Input "https://192.168.1.21" to the address bar, the message will be displayed as in the left image.



Your connection isn't private

Attackers might be trying to steal your information from **192.168.1.21** (for example, passwords, messages, or credit cards). Learn more about this warning

NET::ERR_CERT_AUTHORITY_INVALID

This server couldn't prove that it's **192.168.1.21**; its security certificate is not trusted by your computer's operating system. This may be caused by a misconfiguration or an attacker intercepting your connection.

Continue to 192.168.1.21 (unsafe)

2. Click on **Advanced** button to extend the information zone below, click on the link **Continue to 192.168.1.21 (unsafe)**.

3. The login page of Web HMI will be displayed as shown in the image.

4. Input username and password, then click on **Login** button to login.

NOTE: The default settings of username and password can be found in Default settings, page 223 or Default settings, page 227, depends on the cybersecurity level of the device.

The EcoStruxure Power Device application

The EcoStruxure Power Device application is used to facilitate and simplify the operations and maintenance of the PowerLogic P5 protection relay, directly with a smart phone a few meters from the cubicle.

The EcoStruxure Power Device application can be connected to the PowerLogic P5 protection relay using a Wi-Fi router.

The EcoStruxure Power Device application provides easy access to device status, control and monitoring of the circuit breaker, measurements, settings, events and other functions through the mirror HMI or a simplified view.

- Mirror HMI:

  Duplicates the device display in the EcoStruxure Power Device application to perform actions more easily.
- Simplified view:

  The EcoStruxure Power Device application gives you an organized view of all the device’s functionalities for easier access to data.

Connecting to protection relays via Ethernet

You can connect to a single protection relay or multiple protection relays via Ethernet.

Preparations before launching the EcoStruxure Power Device application

1. Equip the PowerLogic P5 protection relay with Ethernet modules (slot M or L).
2. Connect the PowerLogic P5 protection relay to a Wi-Fi router with RJ45 cable.
3. Configure the Wi-Fi network of the smart phone (IP address of the smart phone should be in the same network segment as the PowerLogic P5 protection relay).

Connecting to protection relays

1. Launch the EcoStruxure Power Device application.
2. Sign in with the account and password created at the Schneider Electric server.
3. Connect the new product via scanning QR code or selecting the PowerLogic P5 protection relay in the product list.
4. Enter the IP address of the PowerLogic P5 protection relay and click **Connect**.
5. Enter the username and password of the PowerLogic P5 protection relay.
6. A new window showing the PowerLogic P5 protection relay information opens.

Protection functions

General features of protection stages

Enable/disable protection functions

The different stages of the protection function can be enabled/disabled individually.

If a protection function stage is disabled, it is not shown in the **PROTECTION** menu in the local panel.

To enable or disable a protection function stage:

- With eSetup Easergy Pro or Web HMI, enter the **PROTECTION** menu/**Valid protection stages** sub-menu or directly go to each protection stage view in the same menu.
- With the local panel, enter the **Home** menu/**PROTECTION** sub-menu/**List of protection enabled** menu item/**Enabled Stages** menu item.

  The **Enabled Stages** menu item allows to enable or disable the protection stage(s) of a protection function. If a protection stage is enabled here, it appears in the **PROTECTION** menu as a menu option.

For the motor protection, there is a dedicated **Motor status** view (**PROTECTION** menu/**Motor status** sub-menu) where it is possible to enable or disable the following protection functions:

- Thermal overload protection for machine (ANSI code 49M)
- Motor start-up supervision (ANSI code 48)
- Motor restart inhibition (ANSI code 66)
- Locked rotor (ANSI code 51LR)
- Motor Anti-backspin (ABS) protection
- Motor speed detection
- Emergency restart

NOTE: The **Motor status** view is comprised of settings (e.g. nominal motor start current) common to these functions.

Setting groups

Setting groups are controlled by using controlling inputs like digital inputs, function keys, virtual inputs, HMI or custom logic.

When none of the assigned inputs are active, the active setting group is defined by parameter Setting group control in the **PROTECTION** menu/**Valid protection stages** sub-menu via eSetup Easergy Pro.

When one controlling input activates, the corresponding setting group is activated as well. If multiple inputs are active at the same time, the active setting group follows the definition by 'Setting group priority'.

By using virtual I/O the active setting group can be controlled using the local panel display, any communication protocol, or in-built programmable logic functions.

When a controlling input is configured, the **Setting group** parameter in the same menu is not operational.

Setting group changes are applied simultaneously to all protection functions.

Example of setting groups

Any digital input can be used to control setting groups but in this example DI1, DI2, DI3 and DI4 are chosen to control setting groups 1 to 4. This setting is done with the parameter 'Setting group x DI control' where x refers to the desired setting group.

'Setting group priority' is used to give a condition to a situation where two or more digital inputs, controlling setting groups, are active at the same time. 'Setting group priority' could have values: "1 to 4" or "4 to 1".

Assuming that DI2 and DI3 are active at the same time and 'Setting group priority' is set to "1 to 4" , setting group 2 becomes active. If 'Setting group priority' is reversed, that is, "4 to 1", the setting group 3 becomes active.

When a setting is selected by a digital input and this one is not activated, the 'Setting group' will not take effect.

Protection stage status

The status of a protection stage is one of the following:

- **Ok = '-'**

  The stage is idle and is measuring the analogue quantity for the protection. No power system fault detected.
- **Blocked**

  The stage is blocked for some reason (for example, through block matrix).
- **Start**

  The stage detected a fault (i.e. pick up value reached) and is counting the operation delay.
- **Trip**

  The stage has tripped and the fault is still on.

Directional operation

A global CT polarity setting is available in the **GENERAL** menu/**Scaling** submenu. These phase and neutral CT polarity settings affect:

- up to version v01.4xx.yyy only the ground differential protection function REF.

  NOTE: All other measurements and directional protection elements are not affected from this setting and still operate on measured current(s) and voltage(s) as per function description.
- from version v01.5xx.yyy additionally all measurements and directional protection elements (directional phase and neutral overcurrent, directional power, Wattmetric E/F, ...).

Mode of use for testing purposes

A **Mode of use** parameter is provided to set the PowerLogic P5 in *Test* or *Test block* mode.

- The *Test* mode is provided for checking correct condition, operation and – if connected – external wiring of output relays without stimulation of any data processing in PowerLogic P5 by secondary injection of voltage or current signals. For more details refer to Check the digital outputs, page 172 and Digital outputs, page 175.

- In *Test block* mode the output relay's operation is blocked. This mode allows secondary injection tests of functions without any output operation, thereby avoiding signaling that could disturb the normal operation of the switchgear or inadvertently trip the circuit breaker (CB).

In both modes, InterRelay (InterRelay functional test, page 201) and analog output signals can be tested (Analogue outputs test, page 203).

Also update of VO data is affected from the mode of use:

- In *Test* mode the value of LN.Mod will be test and the LN.DO.q.Test bit will be set.
- In *Test block* mode the value of LN.Mod will be test/blocked and the LN.DO.q.Test bit will be set.

NOTE: When tests are completed PowerLogic P5 must be set back to normal mode.

The **Mode of use** can be configured in the **GENERAL** menu/**System info** sub-menu.

Start and trip signals

Signals per function

Every protection stage outputs two internal digital signals: start and trip, some even phase-selectively. The start signal is issued when a fault is detected, triggering the set operate delay timer. The trip signal is issued after the configured operate delay elapses, unless the fault disappears, and the start signal resets before the delay ends.

Each protection function stage has a counter associated with the start and trip signals, which can be cleared individually.

Fix Global trip signal

Trip signals of the short-circuit protection stages are OR-combined in fixed way to form the “Global trip” signal. It is provided with a Global trip timer which allows for assigning a settable dwell time delay (0.0 to 10.0 s) to the protection trip output. This minimum global trip command time parameter can be configured in the **CONTROL / Global trip timer** menu.

Using the output matrix, users can connect the internal start and trip signals to the digital outputs and indicators (see Output matrix, page 553).

Configurable General start and trip signals

In some applications, not all enabled protection functions are used to trip the circuit breaker. For instance, the start or trip signal of a phase overcurrent protection stage might be used to send a “high load current” alarm to the operation system to initiate re-dispatch actions. This approach can lead to a problem where most protection trip signals force the “global trip,” thereby prohibiting the use of the global trip in output configuration for the overcurrent stage.

One solution for user-defined general signals is to set them up using programmable logic, which involves an application-specific OR combination of start or trip signals, along with a logic timer element for the minimum trip command time. However, these signals lack standardized correspondence with existing dedicated signals in communication protocols, particularly LN PTRC in IEC 61850.

A better solution is available with general signals, user-configurable through a dedicated matrix. Trip signals from all available protection functions, as well as further binary signals (DI, VI, InterRelay input signals which may represent trip signals), can be individually linked into one or both general trip signals.

Additionally, the “Global trip” signal is linked into “General trip 1” by default for backward compatibility.

While only the trip signals from protection functions can be linked to general trip signals, automatically related phase-selective, neutral, and general start signals are determined. Directional information is also considered to provide proper PTRC modeling in IEC 61850. However, at the IED level, only general forward and reverse direction signals are accessible. The basic principle is shown in Configuration of general trip signals, page 286.

As the main purpose of general trip signals is to form the trip commands, they are equipped with minimum pulse timers, settable in **CONTROL / Global trip timer**.

Definition of start signals:

- If the protection element provides phase-selective start signals, these are linked into corresponding phase-selective “General starting 1 A (B, C)” signals. Examples: I>n, V>n, V<n, and so on (with n = stage instance).
- If the protection element provides a neutral start signal, it is linked into the “General starting 1 N” signal. Examples: IN>n, REF, Watt EF>n, and so on.
- If the protection element provides a general start signal only, it is linked into all three phase-selective “General starting 1 A (B, C)” signals. Examples: I2>n, I<, f<n, and so on.
- If the protection element provides no start signal, none of the phase-selective nor the neutral start signals are triggered. Examples: SOTF, CBFn, 49F, and so on.

These individual starting signals are OR-combined in the matrix to form general start signals per phase and neutral start signals. From these signals then the “General start” signal is determined.

Definition of direction signals:

- If the protection element provides phase-selective direction signals, these are linked into corresponding phase-selective directional signals. Example: I>n
- If the protection element provides a neutral direction signal, it is linked into the neutral direction signal. Examples: IN>n, Watt EF>n
- If the protection element provides no direction signal, no further consideration is needed.

These individual “attributes” of direction information are combined in the matrix to form directional signals per phase and a neutral direction signal. Noteworthy, these are not BOOLEAN signals, but enumerations with up to four values (unknown | forward | reverse | both). For instance, in a borderline (test) case, I>1 might determine “phase A forward,” while I>2 determines “phase A reverse,” therefore “Direction 1, A” would be “both”. If no direction is determined (for example, for phases B and C for an A-N fault), then the general signals are “unknown.”

From these detailed general direction information, two “general direction” signals were derived per table below to make them available on IED level.

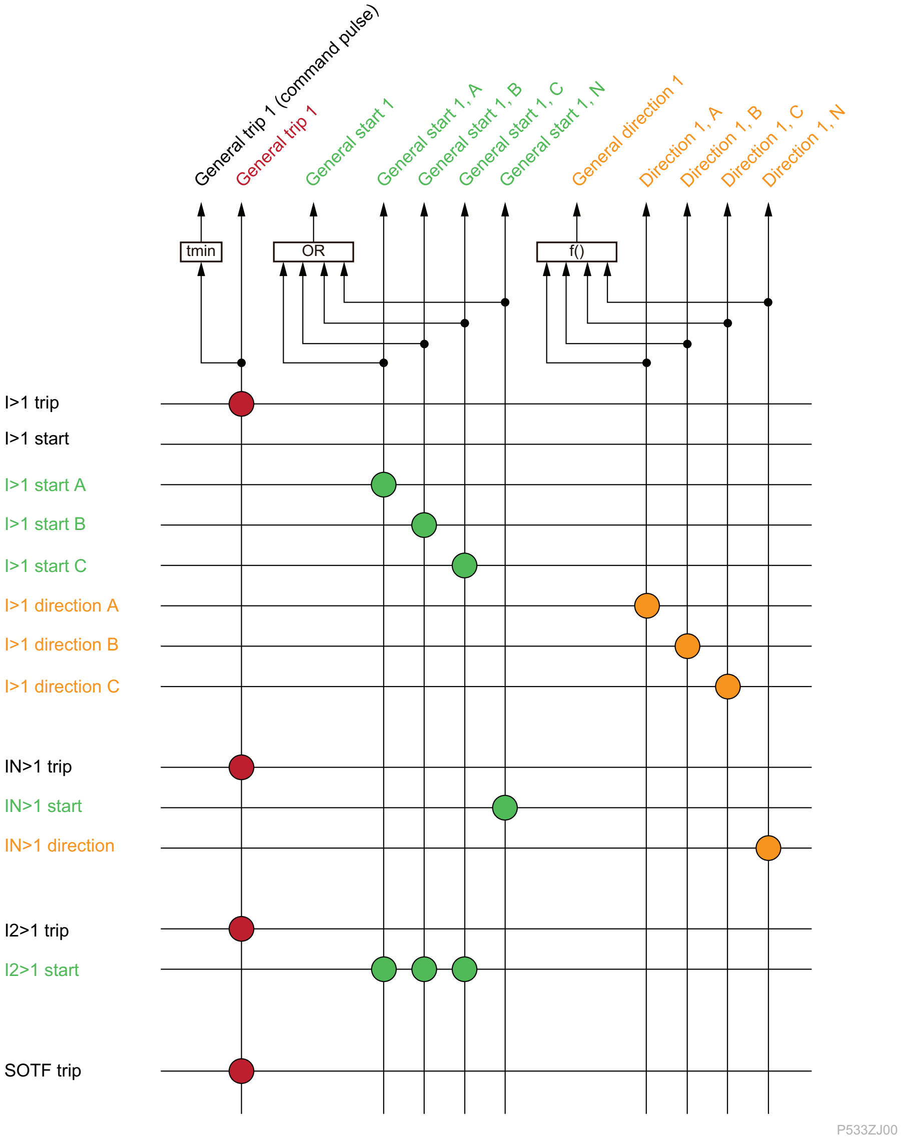
Table 55 - Definition of General direction signals

General direction n	=> General direction n forward	General direction n reverse
unknown	FALSE	FALSE
forward	TRUE	FALSE
reverse	FALSE	TRUE
both	TRUE	TRUE

Where: n = 1 or 2.

All mentioned signals are available as inputs to other matrices and to programmable logic. They can also be transferred by communication protocols, namely in IEC 61850 LN PTRC instances, but also in legacy protocols, such as IEC 60870-5-103.

Figure 198 - Configuration of general trip signals



Start and trip counters

Each protection function stage has a counter associated to the start and trip signals, they can be cleared individually.

Blocking

Any protection function, except arc-flash protection (see Arc-flash (ANSI 50ARC), page 402), can be blocked with internal and external signals through the block matrix. Internal signals are for example:

- logic outputs
- start signals from other stages
- trip signals from other stages

External signals are for example:

- digital inputs
- virtual inputs

Some protection stages are also inbuilt of blocking functions. For example, phase overcurrent protection with input of inrush detection.

Depending on the timing when the block input arrives at the protection function, the state of the protection will also be different:

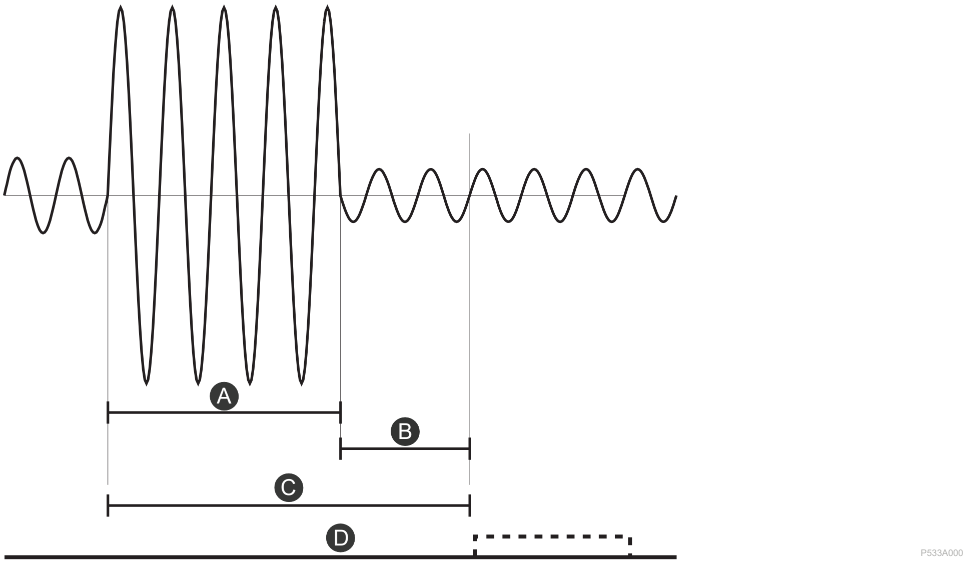
- If the protection is not started, the blocking input from block matrix will inhibit start, the protection will not trip in case of a fault condition.
- If the protection is started but not tripped, the blocking input from block matrix will freeze the delay counting until the blocking condition is off or the start resets, that is, the fault condition disappears.
- If the stage has already tripped, the blocking input from block matrix will reset both start and trip. The protection internal timer also resets to zero.

See Block matrix, page 555 for more information.

Overshoot time

Overshoot time is the time the protection relay needs to notice that a fault has been cleared during the operate time. This characteristic is important when grading the operate time settings between relays.

Figure 199 - Definition for overshoot time



A	Fault time	B	Overshoot time (≤ 50 ms)
C	Operate time configuration, have to be greater than the sum of fault time and overshoot time.	D	Trip contacts

For example, when there is a heavy fault in an outgoing feeder, it will start both the incoming and outgoing feeder relay. However, the fault must be cleared by the outgoing feeder protection relay and the incoming feeder relay must not trip. Although the operating delay setting of the incoming feeder is more than that of the outgoing feeder, the incoming feeder might still trip if the operate time difference is not big enough. The difference must be more than the overshoot time of the incoming feeder relay plus the operate time of the outgoing feeder circuit breaker.

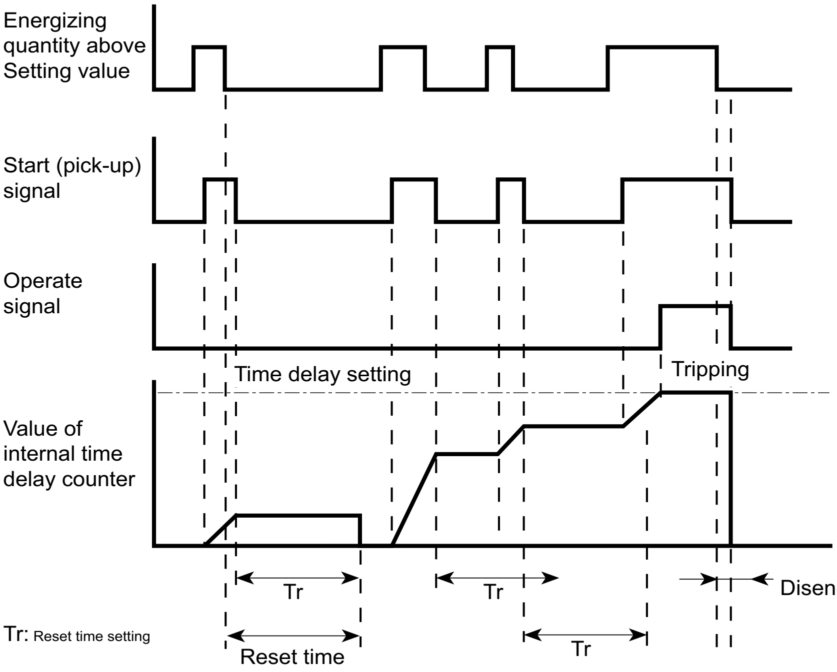
Definition for overshoot time, page 287 shows an overvoltage fault seen by the incoming feeder when the outgoing feeder clears the fault. If the operation delay setting would be slightly shorter or if the fault duration would be slightly longer than in the figure, an unselective trip might happen (the dashed pulse in the figure). In devices, the overshoot time is less than 50 ms.

Disengaging time and reset time

The disengaging time is the time between the moment when the fault conditions disappear and the moment the tripping contact relay opens. It is an instantaneous time.

Disengaging time and adjustable reset time according to IEC 60255-151 standard, page 288 shows an example of reset time, that is, release delay when the PowerLogic P5 protection relay is clearing an overcurrent fault. When the PowerLogic P5 protection relay's trip contacts are closed, the circuit breaker starts to open. After the circuit breaker contacts are open, the fault current still flows through an arc between the opened contacts. The current is finally cut off when the arc extinguishes at the next zero crossing of the current. This is the start moment of the reset delay. After the reset time delay the trip contact and start contact are opened unless latching is configured. The precise reset time depends on the fault size; after a significant fault, the reset time is longer. The reset time also depends on the specific protection stage. The maximum reset time for each stage is specified under the characteristics of every protection function.

Figure 200 - Disengaging time and adjustable reset time according to IEC 60255-151 standard



The adjustable reset time is a definite or inverse time hold used mainly to detect restriking faults (DT) or allow coordination with electromechanical protection relays (Inverse). It can be used also for coordination with electromechanical relays.

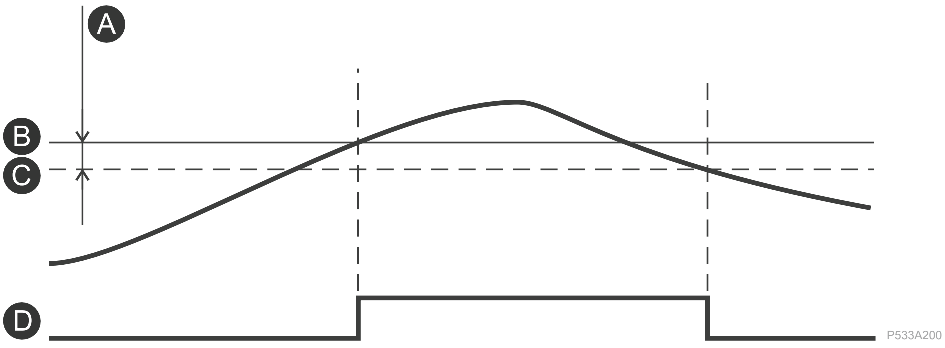
It is implemented in the following protection functions:

- Non-directional/directional phase overcurrent protection (ANSI 50/51/67)
- Non-directional/directional ground fault overcurrent protection (ANSI 50N/51N/67N)
- Negative sequence overcurrent (ANSI 46)

Hysteresis and reset ratio

When comparing a measured value against a start value, some amount of hysteresis is needed to avoid oscillation near equilibrium situation. With zero hysteresis, any noise in the measured signal or any noise in the measurement itself would cause unwanted oscillation between fault-on and fault-off situations.

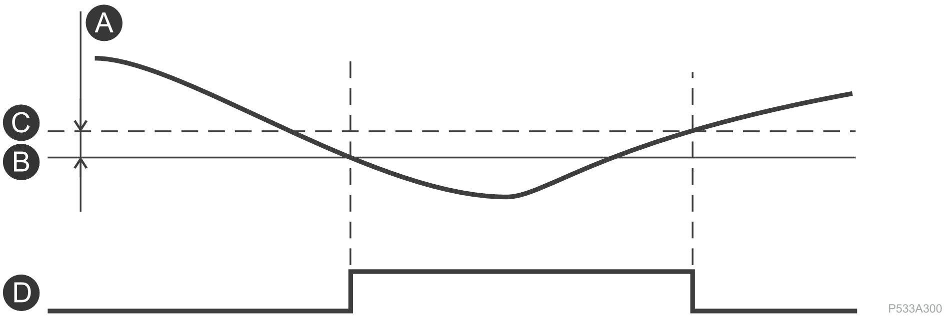
Figure 201 - Example of behavior of an over-protection with hysteresis



A	Hysteresis	B	Start level
C	Reset level	D	Start

The reset ratio is the ratio between the reset level and the start level. To avoid any chattering of the protection for low settings of thresholds, a reset ratio can be claimed with a minimum value of hysteresis. For example: <93% with a minimum of hysteresis of 0.005 Inom.

Figure 202 - Example of behavior of an under-protection with hysteresis



A	Hysteresis	B	Start level
C	Reset level	D	Start

Time grading for logic selectivity

When a fault occurs, the protection scheme only needs to trip circuit breakers whose operation is required to isolate the fault.

This selective tripping is also called discrimination or protection coordination and is typically achieved by time grading. Protection systems in successive zones are arranged to operate in times that are graded through the sequence of equipment so that upon the occurrence of a fault, although there are a number of protections that devices respond to, only those relevant to the faulty zone complete the tripping function.

The different operation time characteristics of control outputs have to be considered:

- the signaling of the raising edge (“make”) with high speed output is at least 5 ms faster than with conventional hinged-armature relay output;
- the signaling of the falling edge (“break”) with high speed output is at maximum 15 ms slower than with conventional hinged-armature relay output.

The recommended discrimination time between two PowerLogic P5 protection relays in an MV network is 200 ms considering a CB opening time of 60 ms.

Accuracy claims

All accuracy claims on operation and reset thresholds and times are based on tests performed according to related functional standard of the IEC 60255-1xx series.

Unless explicitly stated (or required per standard) the tests were executed under reference conditions:

- quasi-stationary semisolid signals at nominal frequency fnom (frequency protection excepted)
- total harmonic distortion ≤ 2 %
- ambient temperature 20°C (68°F)
- nominal auxiliary voltage

Deviations are claimed relative to the setting under such reference conditions, where required also with an additional absolute value (usually relevant at very small/ low set thresholds only).

Recorded values on the last eight faults

There are detailed information available on the last eight faults for each of the protection stages. The recorded values are specific for protection stages and could contain information like time stamp, fault value, elapsed delay, fault current, fault voltage, phase angle and setting group.

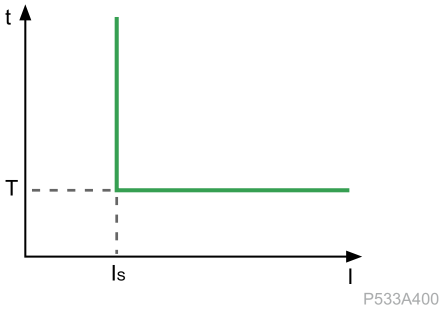
Dependent time and definite time operation

Description

Definite time protection

The tripping time is constant and gets triggered from the protection function starting.

Figure 203 - Definite time protection



Dependent time operation

The dependent time operation is the Inverse Definite Minimum Time (IDMT) type of operation in accordance with standards IEC 60255-151, BS 142 and IEEE C-37.112. The dependent time operation is available for several protection functions:

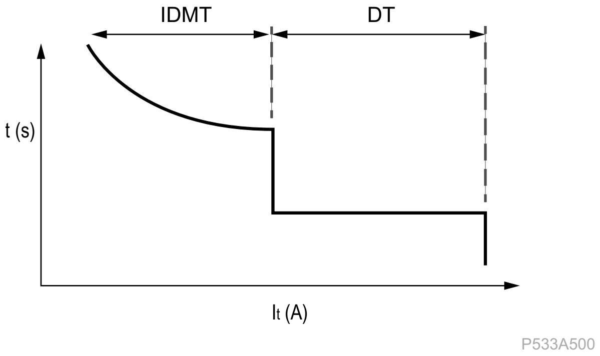
- Overcurrent protection (directional or not),
- Ground fault protection (directional or not),
- Over/under voltage protection

The operate time in the dependent time mode (IDMT) is dependent on the magnitude of the fault. The bigger the fault, the faster the stage issues a trip signal and vice versa. The trip time calculation resets if the injected quantity drops below the start level.

The operate time in Definite Time (DT) mode is defined regardless of the fault signal. It is activated as soon as the pickup value is reached.

The operate time in the definite time mode is fixed by the operate delay setting. The timer starts when the protection stage starts and counts until the set time has elapsed. After that, the stage issues a trip command. If the fault is cleared before the definite time has elapsed, then the protection stage resets.

Figure 204 - Dependent time and definite time operation curves



Stage-specific dependent delay

Some protection functions have their own specific type of dependent delay. Details of these dedicated dependent delays are described with the appropriate protection function.

Operation modes

There are two operation modes to use the dependent time characteristics:

- Standard delays

  Using standard delay characteristics by selecting the **Operating curve** parameter in dedicated protection function. See Standard dependent operation delay, page 293.
- Fully programmable dependent delay characteristics

  Building the characteristics by setting 16 [current, time] points. The relay interpolates the values between given points with second degree polynomials. This mode is activated by the setting curve family to "PrgN", where N = 1, 2, 3, corresponding to the three different programmable curves available. Each programmed curve can be used independently by any number of protection stages. See Programmable dependent time curves, page 296.

Local panel graph

PowerLogic P5 protection relay shows a graph of the currently used dependent delay on the local panel display. The up and down keys can be used for zooming. Also the delays at 20 x I_{set}, 4 x I_{set}, 2 x I_{set} and 1.05 x I_{set} are shown.

Limitations

Once a ratio of measured value to pickup value (G/Gs) greater than G_D is reached, the tripping time is bounded on the lower end. Different values G_D apply to the different curves.

Curve	G_D
IEC SI	30
IEC VI	30
IEC EI	20
IEC LTI	30
UK RECT	15
RI	36
IEEE MI	76
IEEE VI	76
IEEE EI	76
NI CO8	76
STI CO2	76
LTI CO5	76
MI CO7	76
VI CO9	76
EI CO11	76
IEC UTI	76
FR STI	76
BPN	76

ANSI NI	76
ANSI STI	76
ANSI LTI	76

Standard dependent operation delay

The standard dependent operation delay curves follow the equation below:

$$t(s) = TDM \times \left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - p} + c \right]$$

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where:

- t(s) is the operate time in seconds.
- G is the measured value.
- G_S is the start value.
- TDM is Time Dial Multiplier.

Table 56 - IDMT operating characteristics

Description **according to IEC60255-151 standard**	**k**	**c**	**α**	**p**	
Data attribute **according to IEC 61850-7-3 standard**	**setParA**	**setParB**	**setParC**	**setParD**	**SetCharact**
IEC Standard Inverse (IEC/A)	0.14	0	0.02	1	9
IEC Very Inverse (IEC/B)	13.5	0	1	1	10
IEC Extremely Inverse (IEC/C)	80	0	2	1	12
IEC Long Time Inverse	120	0	1	1	14
IEC Ultra Time Inverse	315.2	0	2.1	1	17
Rectifier Inverse	45900	0	5.6	1	18
RI	-4.2373	0	-1	1.43644	19
FR Short Time Inverse	0.05	0	0.04	1	20
BPN (EDF)	1000	0.655	2	1	21
IEEE Moderately Inverse (IEC/D)	0.0515	0.114	0.02	1	4
IEEE Very Inverse (IEC/E)	19.61	0.491	2	1	2
IEEE Extremely Inverse (IEC/F)	28.2	0.1217	2	1	1
Short-Time Inverse (CO2)	0.1052	0.0262	0.8	1	22
Long-Time Inverse (CO5)	4.842	1.967	1.1	1	23

Table 56 - IDMT operating characteristics (Continued)

Description **according to IEC60255-151 standard**	**k**	**c**	**α**	**p**	
Data attribute **according to IEC 61850-7-3 standard**	**setParA**	**setParB**	**setParC**	**setParD**	**SetCharact**
Moderately Inverse (CO7)	0.0094	0.0366	0.02	1	24
Inverse (CO8)	5.95	0.18	2	1	25
Very Inverse (CO9)	4.12	0.0958	2	1	26
Extremely Inverse (CO11)	5.57	0.028	2	1	27
ANSI Normally Inverse	8.9341	0.17966	2.0938	1	29
ANSI Short Time Inverse	0.2663	0.03393	1.2969	1	30
ANSI Long Time Inverse	5.6143	2.18592	1	1	31

NOTE:

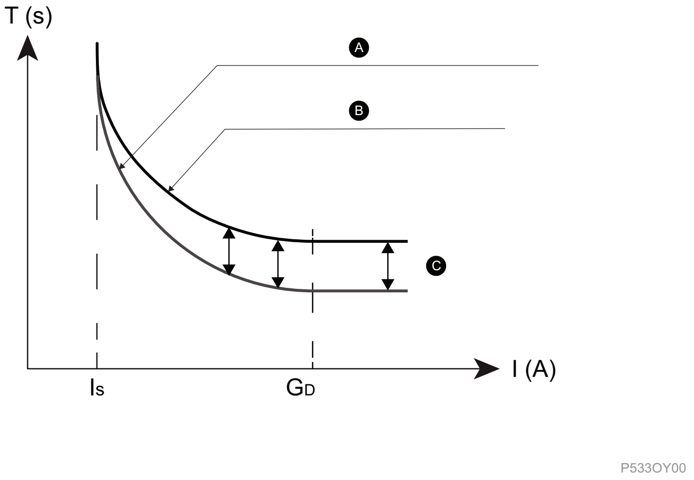
- SetCharact is for DT curve: 5.
- The effective operate value is greater than G_S.

Operating curve selection

The operating curve of the overcurrent protection can be selected to DT, standard dependent operate delay, and programmable dependent operate delay.

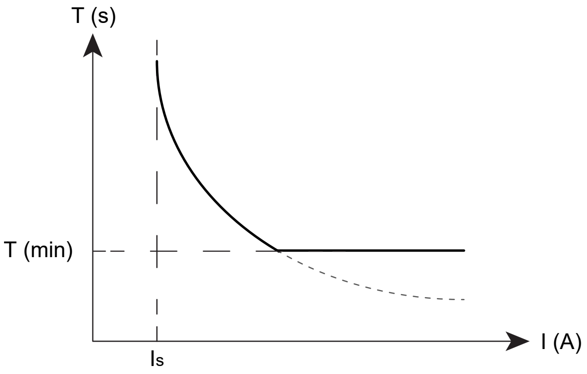
When the “Operating Curve” is set to IDMT curve, the settings “DT adder” and “Minimum operate time” will show up. “DT adder” defines the additional time delay plus the IDMT timer (see DT adder setting impact on IDMT operating curve, page 294). “Minimum operate time” defines the minimum operating time for IDMT curves to help ensure the IDMT stage will not trip faster than the DT stage when the fault current is very large (see Minimum operate time setting impact on IDMT operating curve, page 295).

Figure 205 - DT adder setting impact on IDMT operating curve



A	IDMT curve without DT adder	B	IDMT curve with DT adder
C	DT adder		

Figure 206 - Minimum operate time setting impact on IDMT operating curve



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Standard dependent reset delay

After the IDMT time elapses, the operation timer is reset when the start signal goes low, according to the following equation:

$$t_{reset}(I) = TDM \times \left[\frac{tr}{1 - \left(\frac{G}{G_s} \right)^{p}} \right]$$

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The reset time characteristic is defined by a setting in the protection stage. The allowed settings are dependent on the operate curve as shown in the table.

Table 57 - IDMT reset time

Operating curve	Reset curve		
	IDMT		DT
	tr(s)	P	
DT	-	-	Yes
IEC Standard Inverse (IEC/A)	8.2	6.45	Yes
IEC Very Inverse (IEC/B)	50.92	2.4	Yes
IEC Extremely Inverse (IEC/C)	44.1	3.03	Yes
IEC Long Time Inverse)	40.62	0.4	Yes
IEC Ultra Time Inverse	-	-	Yes
Rectifier Inverse	-	-	Yes
RI	-	-	Yes
FR Short Time Inverse	-	-	Yes
BPN (EDF)	-	-	Yes
IEEE Moderately Inverse (IEC/D)	4.85	2	Yes
IEEE Very Inverse (IEC/E)	21.6	2	Yes
IEEE Extremely Inverse (IEC/F)	29.1	2	Yes

Table 57 - IDMT reset time (Continued)

Operating curve	Reset curve		
	IDMT		DT
	tr(s)	P	
Short-Time Inverse (CO2)	0.1052	2	Yes
Long-Time Inverse (CO5)	4.842	2	Yes
Moderately Inverse (CO7)	0.0094	2	Yes
Inverse (CO8)	5.95	2	Yes
Very Inverse (CO9)	4.12	2	Yes
Extremely Inverse (CO11)	5.57	2	Yes
ANSI Normally Inverse	9	2	Yes
ANSI Short Time Inverse	0.5	2	Yes
ANSI Long Time Inverse	15.75	2	Yes

The TDM (inverse time coefficient) of the IDMT reset curve is the one defined for the operating curve.

For all operating curves not listed in the table above, the reset curve is of DT type.

Programmable dependent time curves

Programming dependent time curves requires eSetup Easergy Pro setting tool and rebooting the unit.

The [current, time] curve points are programmed using eSetup Easergy Pro PC program. There are some rules for defining the curve points:

- the configuration must begin from the top line
- the line order must be as follows: the smallest current (longest operate time) on the top and the largest current (shortest operate time) on the bottom
- all unused lines (on the bottom) should be filled with I/I_{start} = 1 and operate time = 0.00 s

Here is an example configuration of curve points:

Table 58 - Example configuration of curve points

Point	Current I/I_{start}	Operate delay
1	1.00	10.00 s
2	2.00	6.50 s
3	5.00	4.00 s
4	10.00	3.00 s
5	20.00	2.00 s
6	40.00	1.00 s
7	1.00	0.00 s
8	1.00	0.00 s
9	1.00	0.00 s
10	1.00	0.00 s
11	1.00	0.00 s
12	1.00	0.00 s
13	1.00	0.00 s
14	1.00	0.00 s

Table 58 - Example configuration of curve points (Continued)

Point	Current I/I_{start}	Operate delay
15	1.00	0.00 s
16	1.00	0.00 s

Cold load pick-up

Description

Cold load pick-up

The cold load pickup function detects that a cold load condition exists and provides an information to optionally change the selected current protection settings for defined duration of time after energization of the load.

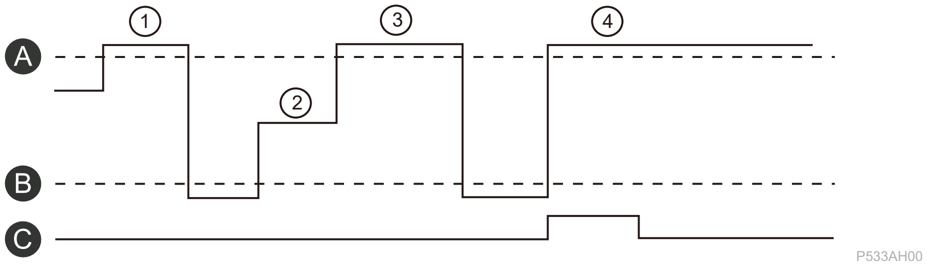
A situation is regarded as cold load when all the three phase currents have been below a given idle value for longer than the cold time setting and then at least one of the currents exceeds a given pick-up level within 80 ms. In such a case, the cold load detection signal is activated and will keep active for "CLPU time delay" for a given time. This signal is available for the output matrix and blocking matrix.

Application for cold load detection

Right after closing a circuit breaker, a given amount of overload can be allowed for a given limited time to take care of situations where a load has been de-energized for an extended period of time and is then re-energized. This applies particularly to applications such as motor loads (e.g., compressor motor inside air conditioning loads) or thermostatically controlled heating of water where the load current is much greater for a cold load than when it is operating normally. So, the cold load pickup function can improve the profiling of overcurrent protection settings to dynamic load situations caused by load de-energization.

Example

Figure 207 - Functionality of cold load current feature



A	Pick-up value	B	Idle state
C	Cold load		

1. No activation because the current has not been under the set Idle current.
2. Current dropped under the Idle current level but now it stays between the Idle current and the pick-up current for over 80 ms.
3. No activation because the phase two lasted longer than 80 ms.
4. Now we have a cold load activation which lasts as long as the “CLPU time delay” was set or as long as the current stays above the pick-up setting.

Characteristics

Table 59 - Settings and characteristics of cold load pick-up function

Settings/characteristics (description/label)	Value
Idle current/Idle current	
Range	0.01...0.50 pu[56]
Resolution	0.01 pu[56]
Pickup current/Pickup	
Range	0.30...10.00 pu[56]
Resolution	0.01 pu[56]
CLPU dead time/Dead time	
Setting range	0.10...14400.00 s
Resolution	0.01 s
CLPU time delay/Max time	
Setting range	0.01...300.00 s
Resolution	0.01 s
Accuracy	1% or ±20 ms

---

[56] Nominal CT Rating

Selective Overcurrent Logic (SOL)

Description

The Selective Overcurrent Logic (SOL) function, can considerably reduce the tripping time of the circuit breakers closest to the source, compared to a pure time discrimination, and may be used for logic discrimination in closed ring networks also using directional protection.

SOL function is applied to the non-directional/directional phase overcurrent protection (ANSI 50/51/67), non-directional/directional ground fault overcurrent protection (ANSI 50N/51N/50G/51G/67N), definite time and IDMT.

With PowerLogic P5 protection relays, the discrimination can be done in two different ways:

- Logic overcurrent stages protection functions that send SOL signals (downstream protection) and that may be prevented from tripping by the reception of SOL signals (upstream protection).
- Time-based overcurrent stages: protection stages that may delayed by SOL signals (upstream protection). They are used as backup for the logic overcurrent stages.

When a fault occurs:

- Any downstream protection can activate the SOL function through the output matrix, so that the SOL function can send a SOL signal to the upstream protections.
- At the reception of the SOL signal by the upstream protection, the latter changes its operating delay from operate delay to SOL operate delay. When the upstream protection is using IDMT delay, SOL will also have impact on the curve settings.

Operation

To implement the SOL function, downstream and upstream protection should be set as follows:

Set the downstream protection to send the SOL1 trip signal to upstream relay:

1. Check the **Enable for SOL** box in the **Selective overcurrent logic** view of **PROTECTION** menu in eSetup Easergy Pro.
2. Select from the drop-down list of **SOL signal number**.
3. Set the value of **CB trip clearing time**.
4. Switch to **MATRIX** menu/**Output matrix** submenu, configure the PowerLogic P5 output matrix:

   Connect the start signals of the different protections involved in the logic discrimination to the SOLx Start (x = 1 or 2) signal, then connect the SOLx send (x = 1 or 2) signal to a dedicated contact relay or GOOSE output.

Set the upstream protection to receive the SOLx trip signal:

1. Configure the PowerLogic P5 output matrix:

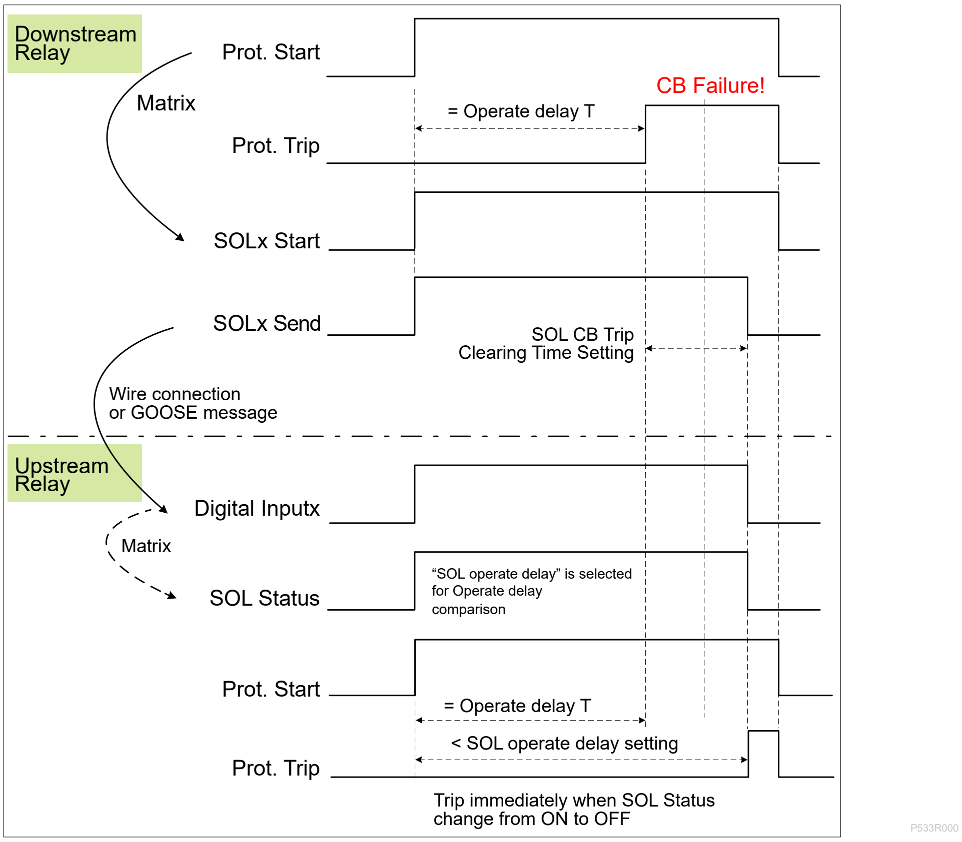
   Connect the dedicated logic input (DI or GOOSE input signal), linked with the downstream SOLx send signal, to the SOLx input signal.
2. Switch to **PROTECTION** menu, select specific protection function in the left column, set the SOL status to the value "SOLx"
3. Set the **SOL operate delay** to a value higher than the value of the setting **Operate delay**.

Up to two output signals can be provided by the SOL function.

The value of the setting **SOL operate delay** should be greater than the value of the setting **Operate delay** in the overcurrent protection plus the value of the setting **CB trip clearing time** in the SOL function. The setting **SOL operate delay** can make sure the downstream protection tripping with selectivity. The setting **CB trip clearing time** is used to set the release time of the SOLx send signal for the downstream protection.

If a fault occurs at downstream, the downstream protection issues a trip command to isolate the fault according to the value of the setting **Operate delay**. Then a global trip signal is activated by the trip signal. At the same time, a timer with the value of the setting **CB trip clearing time** is triggered by the global trip signal and starts timing. If the downstream protection successfully isolates the fault, the SOL signal is released and all the P5 relays of the upstream protection will be reset. If the downstream protection cannot clear the fault due to a circuit breaker fail, when the tripping duration time of the downstream protection exceeds the value of the setting **CB trip clearing time**, consequently upstream protection nearest to the downstream protection will switch the value of the setting **SOL operate delay** to the value of the setting **Operate delay** due to no reception of the SOL signal. Then the protection will trip immediately.

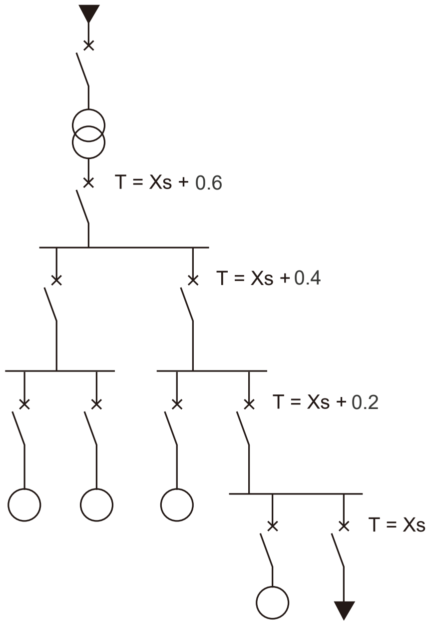
The SOL operate delay of the upstream protection usually takes into account the breaking device operating time and the protection reset time.



NOTE: Normally Prot.Start/Prot.Trip means the start/trip signal of overcurrent protection or ground fault protection (50/51/67/50N/51N/50G/51G/67N). SOL operation delay setting should be greater than “Operation delay T + SOL CB Trip Clearing Time Setting”.

Example 1

Figure 208 - Example 1: Radial distribution with use of time-based discrimination

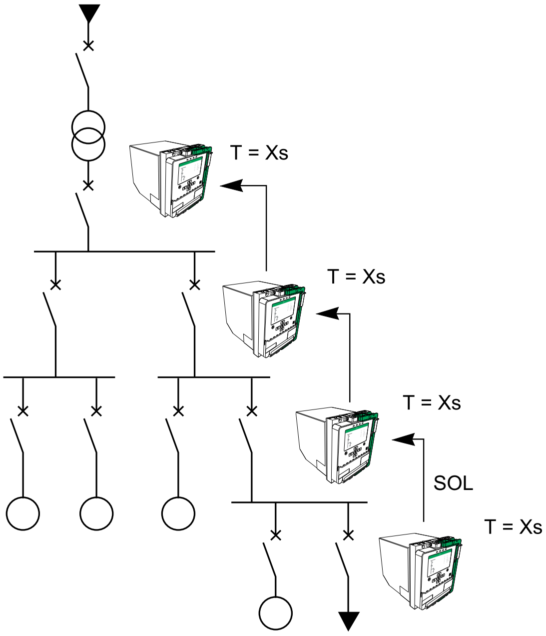


T: operate delay setting in protection function

The upstream protection units are typically delayed by 0.2 s to give the downstream protection units time to trip. When there are many levels of discrimination, the protection tripping time at the source is long. In this example, if the protection tripping time for the protection unit furthest downstream is Xs = 0.2 s, the protection tripping time at the source is T = Xs + 0.6 s = 0.8 s.

Example 2

Figure 209 - Example 2: Radial distribution with use of logic discrimination

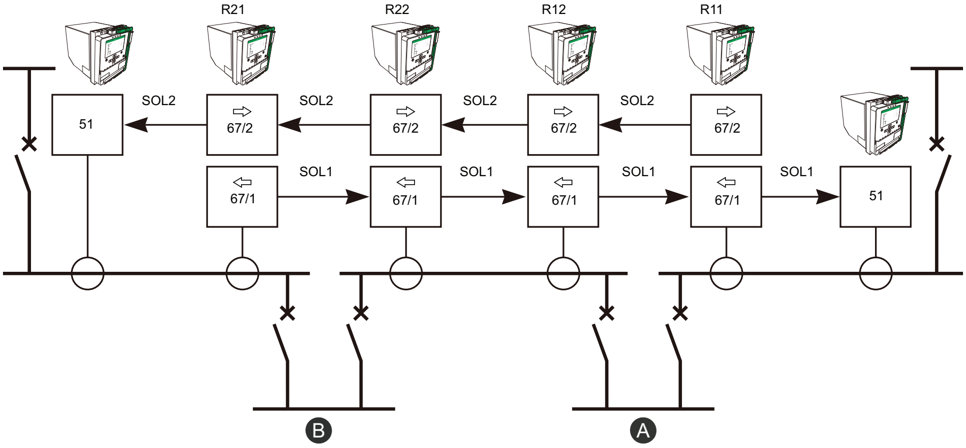


T: operate delay setting in protection function

When a fault appears, the protection units that detect it inhibit the upstream protection units by switching to the SOL operate delay setting. The protection unit furthest downstream trips since it is not blocked by another protection unit. The delays are to be set in accordance with the device to be protected.

Closed ring network application

The SOL function can support the closed ring network which includes two substations application, each of which comprises two PowerLogic P5 relays, marked R11, R12 and R21, R22. Each of the PowerLogic P5 relay configures different directional overcurrent units (stages).



A	Substation 1
B	Substation 2

Starting at one end of the ring, the detection direction of PowerLogic P5 unit 1 and 2 of the directional protection functions should be alternated between line and busbars.

Characteristics

Settings and characteristics	Values
Enable for SOL/SOL	
Options[57]	Disabled; Enabled
SOL1Start	
Options[57]	-; Trip
SOL2Start	
Options[57]	-; Trip
SOL signal number/SOL op number	
Range	1, 2
CB trip clearing time/CB trip time	
Setting range	0.00...1.00 s
Resolution	0.01 s

---

[57] Configured via Output Matrix

Incomer fault locator (ANSI 21FL)

Description

The PowerLogic P5 protection relay can locate a short-circuit in a radial operated network.

The fault location is given in reactance (ohms) and kilometers or miles. The fault value can then be exported, for example, with an event to a Distribution Management System (DMS). The system can then localize the fault. If a DMS is not available, the distance to the fault is displayed as kilometers, and as a reactance value. However, the distance value is valid only if the line reactance is set correctly. Furthermore, the line should be homogenous, that is, the wire type of the line should be the same for the whole length. If there are several wire types on the same line, an average line reactance value can be used to get an approximate distance value to the fault. Names and reactance values for widely used overhead wires are:

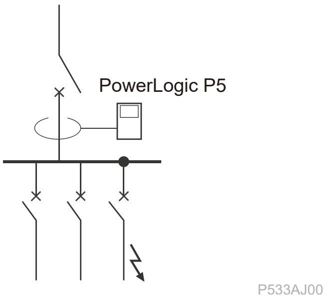
- Sparrow: 0.408 ohms/km or 0.656 ohms/mile
- Raven: 0.378 ohms/km or 0.608 ohms/mile

  NOTE: The fault locator is normally used in the incoming bay of the substation. Therefore, the fault location is obtained for the whole network with just one PowerLogic P5 protection relay, by compensating the effect of the healthy feeders.

The incomer short circuit fault locator operates if:

- The PowerLogic P5 protection relay is located in the incoming feeder.
- The CTs and VTs are connected such that the fault is seen in the forwards direction. Any fault seen in the reverse direction will not produce a fault location result.

Figure 210 - Example of fault on feeder detected by the incomer fault detector



The algorithm functions in the following order:

1. The needed measurements (phase currents and phase to phase voltages) are continuously available.
2. The fault distance calculation can be triggered in two ways:
   - By opening a feeder circuit breaker due to a fault and sudden increase in phase currents (Enable incomer fault locator + Triggering digital input).
   - Another option is to use only the sudden increase in the phase currents (Enable incomer fault locator).
3. Phase currents and voltages are registered in three stages: before the fault, during the fault and after the faulty feeder circuit breaker was opened.
4. The fault distance quantities are calculated.
5. Two phases with the biggest fault current are selected.
6. The load currents are compensated.
7. The faulty line length reactance is calculated.

$$Z_{AB} = \frac{\vec{V_A} - \vec{V_B}}{\vec{I_A} - \vec{I_B} - \vec{I_{pre\text{-}fault}}}$$

A533AK00

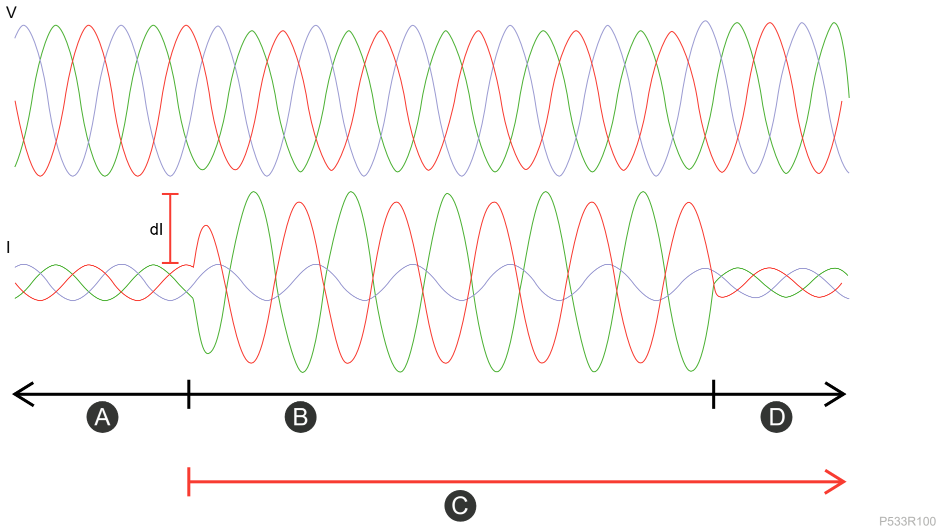
VA	Phase A to ground voltage
VB	Phase B to ground voltage
IA	Phase A current
IB	Phase B current
$I_{pre\text{-}fault}$	Pre-fault load current

The reference current setting is used to start the calculation of the fault locator based on the pre-fault current magnitude. The calculation can be triggered by a digital or logic input.

Example

An application example where the fault location algorithm is used at the incomer side is presented below. The settings of the Incomer fault locator function is configured in the **PROTECTION** menu/**Incomer fault locator** sub-menu.

Figure 211 - Illustration of the fault location algorithm used at the incomer side



A	Pre-fault time more than 2 s	B	In order to calculate the fault location, the fault current must be present for at least 0.08 s and last no longer than 1 s
C	When the digital input is used together with the current change, the input signal has to be activated at least 0.5 s after the fault occurs	D	Post-fault only few cycles

Characteristics

Table 60 - Setting parameters of incomer fault locator

Parameter	Value	Unit	Default	Description
Triggering digital input (Trig DI)	Selection of one digital input (DI), one virtual input (VI), one virtual output (VO), or one function key (Fx)	-	-	Trigger mode (= triggering based on sudden increase of phase current, otherwise sudden increase of phase current + DIx/VIx)
Line reactance/ unit (Xline)	0.010...10.000	Ohm	0.389	Per unit (positive-sequence) reactance of the line. This value is only used to convert the fault reactance to the distance per set unit (kilometers or miles).
Current change to trig (dI)	0.10...8.00	pu	0.5	Trig current (sudden increase of phase current)
Blocked before next trig	10...600	s	70	Blocks function for this time after trigger. This is used for blocking calculation during auto-reclosing sequences.
Xmax limit	0.5...500.0	Ohm	500.0	Limit for maximum reactance. If the reactance value is above the set limit, the calculation result is not shown.
Unit	Editable for user	-	km	-
Event	Disabled; Enabled	-	Enabled	Event mask
Accept zero pre-fault current	Disabled; Enabled	-	Disabled	-

Table 61 - Measured and recorded values of incomer short circuit fault locator

	Parameter	Unit	Description
Measured values/ recorded values	Distance fault	km	Distance to fault
	XFlt	Ohm	Fault reactance
	Date	-	Fault date
	Time	hh:mm:ss: mss	Fault time
	Cntr	-	Number of faults
	Pre	A	Current before fault (= load current)
	Fault	A	Fault current
	Post	A	Current after fault
	V drop	%	Voltage drop during the fault
	Duration	s	Fault duration
	Type	-	Fault type (1-2, 2-3, 1-3, 1-2-3)

Feeder fault locator (ANSI 21FL)

Description

The PowerLogic P5 protection relay can locate a short-circuit fault and a ground fault on the feeder itself in a radially operated network. The fault location function (ANSI code 21FL) is given as a reactance (ohms) and converted to kilometers or miles. The fault value can then be exported, for example, with an event to a Distribution Management System (DMS). The system can then localize the fault. If a DMS is not available, the distance to the fault is displayed as kilometers/miles and as a reactance value.

However, the distance value is valid only if the line reactance is set correctly.

Furthermore, the line should be homogenous, that is, the wire type of the line should be the same for the whole length. If there are several wire types on the same line, an average line reactance value can be used to get an approximate distance value to the fault. Names and reactance values for widely used overhead wires are:

- Sparrow: 0.408 ohms/km or 0.656 ohms/mile
- Raven: 0.378 ohms/km or 0.608 ohms/mile

When the feeder fault locator is calculating short-circuit impedance, the following formula is used:

$$\vec{Z}_{AB} = \frac{\vec{V}_A - \vec{V}_B}{\vec{I}_A - \vec{I}_B}$$

A533AN00

VA	Phase A to ground voltage
VB	Phase B to ground voltage
IA	Phase A current
IB	Phase B current

When the feeder fault locator is calculating ground fault impedance, the following is used (e.g. for phase A):

$$\vec{Z}_A = \frac{\vec{V}_A}{\vec{I}_A + k \text{ x } \vec{I}_{N.calc}}$$

A533AP00

VA	Phase A to ground voltage
IA	Phase A current
k	Ground factor k, needs to be set by user
IN.calc	Neutral current, calculated from phase currents

$$\overrightarrow{IN}_{.calc} = \vec{I}_A + \vec{I}_B + \vec{I}_C$$

P533AR00

The ground factor k is calculated with the following formula:

$k = (Z_{NL} - Z_{1L}) / (3 \text{ x } Z_{1L})$

where:

Z_{NL} = Zero sequence line impedance

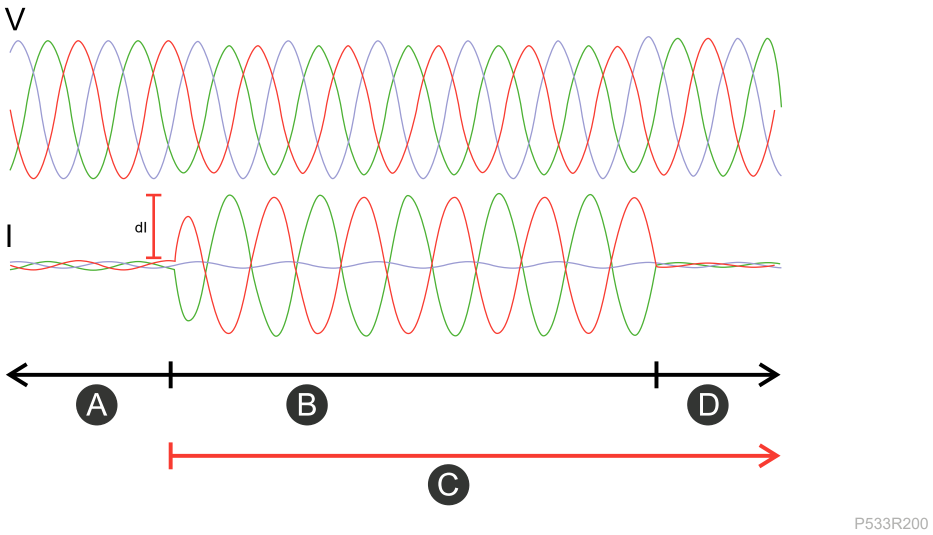
Z_{1L} = Positive sequence line impedance

Fault reactance calculation is triggered if the start value is exceeded or both “Start setting” and “Triggering digital input” terms are fulfilled. When used, “Triggering digital input” can be either digital or virtual input.

Example

An application example where the fault location algorithm is used at the feeder side is presented below. The settings of the feeder fault locator function is configured in the **PROTECTION** menu/**Feeder fault locator** sub-menu.

Figure 212 - Illustration of the fault location algorithm used at the feeder side



A	Pre-fault time more than 2 s	B	In order to calculate the fault location the fault current must be present for at least 0.08 s and last no longer than 1 s
C	When the digital input is used together with the current change, the input signal has to be activated at least 0.5 s after the fault occurs	D	Post-fault only few cycles

Characteristics

Table 62 - Settings and characteristics of the feeder fault locator function (ANSI 21FL)

Parameter	Value	Unit	Default	Description
Pick-up value	0.10...5.00	pu[58]	1.2	Current limit for triggering.
Triggering digital input	Selection of one digital input (DI), one virtual input (VI), one virtual output (VO), or one function key (Fx)	-	-	Trigger mode (= triggering based on sudden increase of phase current, otherwise sudden increase of phase current + DIx/VIx/VOx/Fx)
Line reactance/ unit (Xline)	0.010...10.000	Ohm	0.491	Per unit positive-sequence reactance of the line. This value is only used to convert the fault reactance to the distance per set unit (kilometers or miles).
Earth factor	0.000...10.000	-	0.678	Calculated earth factor from line specifications.

---

[58] Inom = phase CT primary nominal

Table 62 - Settings and characteristics of the feeder fault locator function (ANSI 21FL) (Continued)

Parameter	Value	Unit	Default	Description
Earth factor angle	-60... +60	°	10	Angle of calculated earth factor from line specifications.
Unit	km	-	km	Unit of distance
Event enabling	Off; On	-	On	Event mask

Table 63 - Measured and recorded values of feeder fault locator

	Parameter	Unit	Description
Measured values/ recorded values	Distance	km	Distance to the fault
	Xfault	Ohm	Fault reactance
	Cntr	-	Number of faults
	Type	-	Fault type: IA-N, IB-N, IC-N; IA, IB-N; IB, IC-N; IA, IC-N; IA-IB; IB-IC; IA-IC IA-B-C; IA, B, C-N

Neutral admittance (ANSI 21YN)

Description

The neutral admittance protection function can be applied in high resistance grounded, ungrounded or compensated power system to detect ground fault with increased sensitivity. Two stages of the neutral admittance protection are available in the PowerLogic P5 protection relay, each stage has three elements: over-admittance (21YN-1 or 21YN-2), over-conductance (GN > 1 or GN > 2) and over-susceptance (BN > 1 or BN > 2).

The neutral admittance Y_n is calculated based on the neutral current IN and the neutral voltage VN:

$$Y_n = G_n + jB_n = IN / -VN = 3IN / -3VN$$

The source of the neutral current is settable from the sensitive ground fault CT, CSH core balance CT, standard ground fault CT, or the sum of three phase currents.

The neutral admittance protection is blocked if the following conditions are met:

- The neutral current is based on the sum of three phase currents
- The CTS supervision function detects a CT failure
- The CTS output signal is configured to block neutral admittance protection through the blocking matrix

The source of the neutral voltage is from the direct measurement when the Voltage mode is “+VN”, otherwise the source of the neutral voltage is from the sum of three phase voltages. The neutral admittance protection is only active when the neutral voltage VN is above the setting threshold.

The neutral admittance protection is also blocked if the following conditions are met:

- The neutral voltage is based on the sum of three phase voltages
- The VTS supervision function detects a VT failure
- The VTS output signal is configured to block neutral admittance protection through the blocking matrix

The settings of the admittance protection are based on the percentage of the rated neutral admittance. The formula for calculating the rated neutral admittance are listed in the table below.

Table 64 - Calculation of the rated neutral admittance

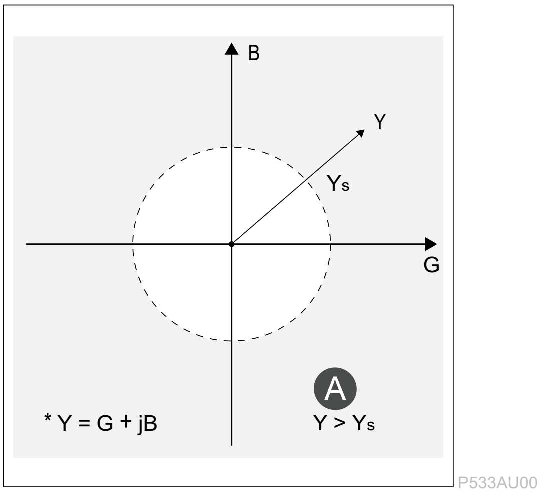
IN source	VN source	Rated neutral admittance (Y_n)
Sensitive ground fault CT	VN	Sensitive IN CT primary / (√3*VN primary)
Sensitive ground fault CT	(VA + VB + VC)	Sensitive IN CT primary / (√3*VT primary)
CSH core balance CT	VN	Nominal IN.CSH / (√3*VN primary)
CSH core balance CT	(VA + VB + VC)	Nominal IN.CSH / (√3*VT primary)
Standard ground fault CT	VN	Ground fault CT primary / (√3*VN primary)
Standard ground fault CT	(VA + VB + VC)	Ground fault CT primary / (√3*VT primary)
(IA + IB + IC)	VN	CT primary / (√3*VN primary)
(IA + IB + IC)	(VA + VB + VC)	CT primary / (√3*VT primary)

Operation

Operation of admittance protection

The admittance protection is non-directional. Hence, provided the magnitude of admittance exceeds the set value 21YN-1, the protection relay will operate.

Figure 213 - Admittance protection operation with non-directional characteristic

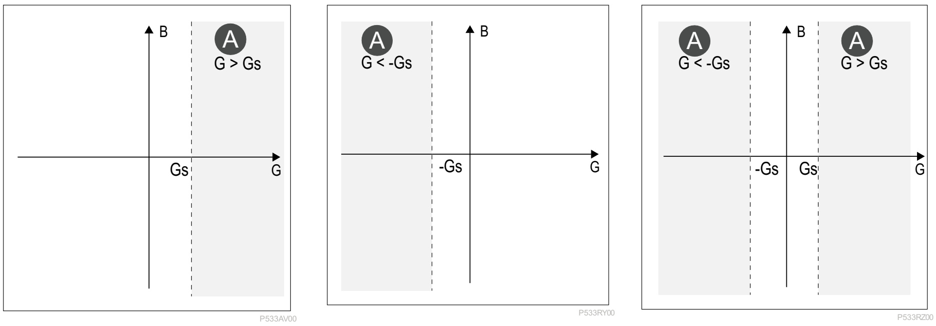


A	Operate zone

Operation of conductance protection

The conductance protection may be set to non-directional, forward or reverse. Hence, provided the magnitude and the directional criteria are met for conductance, the PowerLogic P5 protection relay will operate. The correction angle causes rotation of the directional boundary for conductance through the set correction angle.

Figure 214 - Conductance protection operation characteristic



Conductance: Forward Conductance: Reverse Conductance: Non-directional

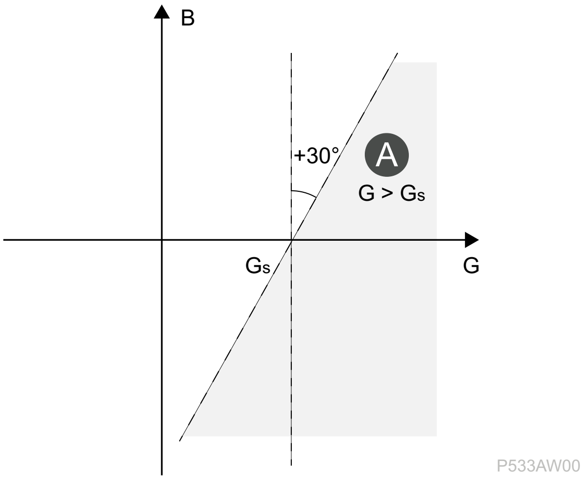
A	Operate zone

NOTE:

Center of the characteristic area for forward direction occurs when IN is in phase with -VN.

Assuming that the direction of the G axis is 0°. If the correction angle is set to +30°, this rotates the boundary from 90°...270° to 60°...240°.

Figure 215 - Conductance protection operation characteristic with +30° correction angle

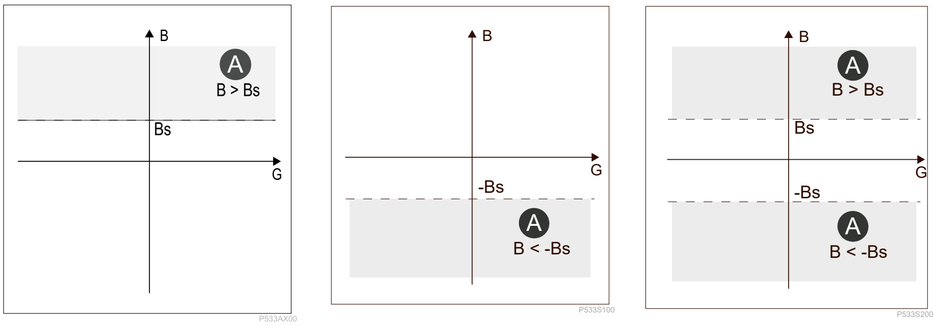


A	Operate zone

Operation of susceptance protection

The susceptance protection may be set to non-directional, forward or reverse. Hence, provided the magnitude and the directional criteria are met for susceptance, the PowerLogic P5 protection relay will operate. The correction angle causes rotation of the directional boundary for susceptance through the set correction angle.

Figure 216 - Susceptance protection operation characteristic



Susceptance: Forward Susceptance: Reverse Susceptance: Non-directional

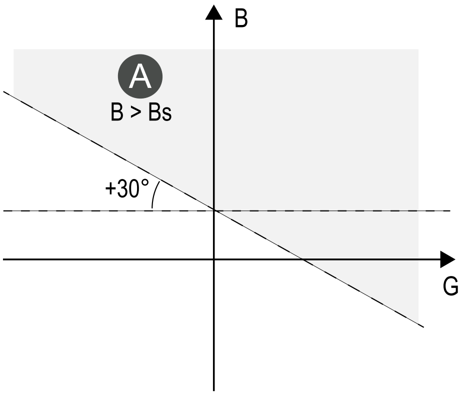
A	Operate zone

NOTE:

Center of characteristic area for forward direction occurs when IN leads -VN by 90°.

Assuming that the direction of the G axis indicates 0°. If the correction angle is set to +30°, this rotates the boundary from 0°...180° to 330°...150°.

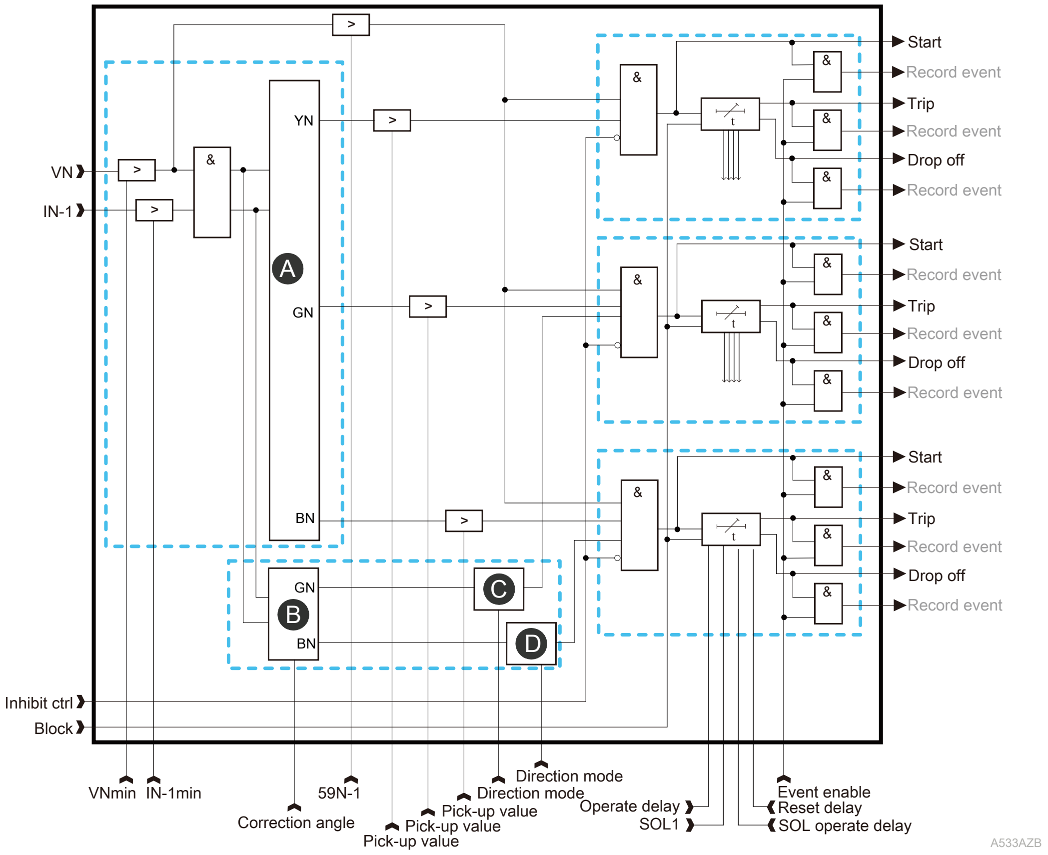
Figure 217 - Susceptance protection operation characteristic with +30° correction angle



A	Operate zone

Block diagram

Figure 218 - Block diagram of the neutral admittance protection



A	Admittance Calculation	B	Direction Determination
C	GN Mode = Non dir or GN Mode = GN dir	D	BN Mode = Non dir or BN Mode = BN dir

Characteristics

Table 65 - Settings and characteristics of the neutral admittance protection

Settings/ characteristics (description/label)	Values
Enable All YN>/All YN>[59]	
Options	Off/On
VN pick-up value/VN>	
Setting range	0.005...0.800 pu[60] for measured values 0.020...0.800 pu[60] for calculated values
Resolution	0.001
Accuracy	±5%
Reset ratio	95% ± 2%
VN minimum	
Value	0.004 pu[60] (fixed) for measured values 0.019 pu[60] (fixed) for calculated values
IN minimum	
Value	0.1 A primary (fixed), for current measured by CSH core balance CT (2A) 1 A primary (fixed), for current measured by CSH core balance CT (20A) 0.005 pu[61] (fixed) for current measured by sensitive ground fault CT 0.02 pu[61] (fixed) for current measured by standard ground fault CT 0.005 pu[61] (fixed) for current measured by standard ground fault CT (for CSH30 use) 0.05 pu[61] (fixed) for calculated ground fault current value
Enable 21YN-1/GN>1/BN>1[62]	
Options	Off/On
Pick-up value/21YN-1	
Setting range	(1%...200%) IN/VN[63] for current measured by sensitive ground fault CTs (5%...1000%) IN/VN[63] for current measured by standard ground fault CTs (5%...1000%) IN/VN[63] for current measured by standard ground fault CTs (for CSH30 use) (25%...5000%) IN/VN[63] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Resolution	1% IN/VN[63] for current measured by sensitive ground fault CTs 5% IN/VN[63] for current measured by standard ground fault CTs 25% IN/VN[63] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Accuracy	±5%
Reset ratio	90% ± 5%
Pick-up value/GN>1	
Setting range	(1%...100%) IN/VN[63] for current measured by sensitive ground fault CTs (5%...500%) IN/VN[63] for current measured by standard ground fault CTs (5%...500%) IN/VN[63] for current measured by standard ground fault CTs (for CSH30 use) (25%...2500%) IN/VN[63] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Resolution	1% IN/VN[63] for current measured by sensitive ground fault CTs 5% IN/VN[63] for current measured by standard ground fault CTs 25% IN/VN[63] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Accuracy	±5%
Reset ratio	90% ± 5%

---

[59] General protection stage on/off control
[60] Vnom = VT primary nominal (PP)
[61] Inom
[62] This setting does not take effect if the general protection stage control is set to Off. See the previous footnote.
[63] YN.nom

Table 65 - Settings and characteristics of the neutral admittance protection (Continued)

Settings/ characteristics (description/label)	Values
Pick-up value/BN>1	
Setting range	(1%...100%) IN/VN[64] for current measured by sensitive ground fault CTs (5%...500%) IN/VN[64] for current measured by standard ground fault CTs (5%...500%) IN/VN[64] for current measured by standard ground fault CTs (for CSH30 use) (25%...2500%) IN/VN[64] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Resolution	1% IN/VN[64] for current measured by sensitive ground fault CTs 5% IN/VN[64] for current measured by standard ground fault CTs 25% IN/VN[64] for current measured by 2A CSH, 20A CSH, and for current value that is calculated
Accuracy	±5%
Reset ratio	90% ± 5%
Direction mode/Direction mode	
Options	Non-dir; Forward; Reverse
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±5% or ±50 ms
SOL1/SOL1	
Options	Disable/Enable
SOL operate delay/SOL operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±5% or ±20 ms
Reset delay/Reset delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	±5% or ±20 ms
Input for inhibit control/Inhibit control	
Options	Digital inputs and virtual inputs for selection
Characteristic time	
Start time	≤ 65 ms at 2 21YN-1 100 ms at maximum
Overshoot time	≤ 40 ms at 2 21YN-1
Setting group/SetGrp	
Number	4

---

[64] YN.nom

Transformer Overfluxing Protection (ANSI 24)

Description

Overview

This Transformer Overfluxing Protection (ANSI 24) function is applied for P5T30.

The transformer overfluxing protection detects an inadmissibly high induction in the iron core of transformers which may have been caused by a voltage increase and/or a frequency decrease.

Flux density of transformer $B = K \times U / f$

Where: K is a coefficient depending on iron core material and dimensions.

The degree of overexcitation can be expressed by the overexcitation multiple (the ratio based on nominal excitation Bn):

$$n = \frac{B}{B_n} = \frac{V/f}{V_n/f_n}$$

P533TJ00

Where:

- n: the overexcitation ratio.
- B, B_n: actual and nominal values of flux density of transformer cores.
- V, V_n: actual and nominal voltage of transformer windings, phase to phase voltage.
- f, f_n: actual and nominal frequency.

According to the overexcitation ratio, one three-stage overfluxing (V/f) element protects the transformer against overexcitation:

- One alarm stage with DT delay (V/f Alarm)
- One trip stage with DT or IDMT delay (V/f>1)
- One trip stage with DT delay (V/f>2)

The element measures the ratio of voltage to frequency and operates when this ratio exceeds the setting. When the flux level drops below the reset value (set pickup value minus hysteresis), the reset timer starts.

Conditions

The element is valid only when the VT measures VP or VPP. Otherwise, the element is invisible on the HMI screen and in Easergy Pro.

Whether the VT measures VP or VPP, the voltage used in overfluxing element is VPP.

The element is operational only when the measured frequency is 45Hz to 55Hz for fnom = 50 Hz; 54Hz to 66Hz for fnom = 60 Hz.

The overfluxing element is equipped with a definite-time reset time for inverse-time trip characteristic.

Function decomposition

V/f Alarm stage (DT)

The definite-time alarm stage is used to indicate unhealthy conditions before damage of the transformer. The “V/f Alarm” signal is issued when the overexcitation multiple is greater than the setting of pick-up value of the operate delay.

The “V/f Alarm” signal can be issued only when “Enable for V/f Alarm” is on.

V/f>1 Trip stage (DT/IDMT)

V/f>1 trip stage can be set to operate with a definite time (DT) or inverse time delay (IDMT), as per set “Operating curve”. This stage can be used to provide the protection trip output.

The “V/f>1 Start” and “V/f>1 Trip” signals can be issued only when “Enable for V/f>1” is on.

Definite-time delay

When the overexcitation multiple is greater than the setting of pick-up value, “V/f>1 Start” signal will be issued. The “V/f>1 Trip” signal will be issued in case of the “V/f>1 Start” signal is active for the operate delay.

Inverse-time delay

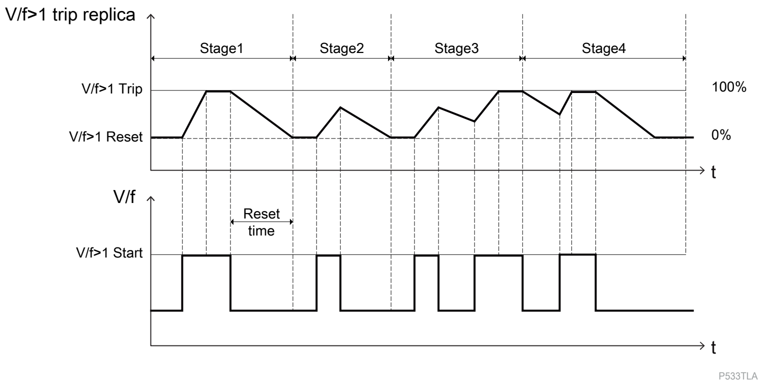
When the overexcitation multiple is greater than the setting of pick-up value, “V/f>1 Start” signal will be issued. There are three delay curves for selection of inverse time delay (IDMT) setting: Prg1, Prg2, Prg3. Each curve is composed by 16 operation values and delays. For overfluxing, the value of “Gs” is always 1.00. The “V/f>1 Trip” signal will be issued according to the operation values of selected curve.

Definite-time reset delay

Overfluxing is a thermal heating based function, therefore the reset timer starts whenever the flux level drops below reset value (= pick-up – hysteresis). The accumulated heat is linearly decreased from the present value down to zero over the course of the reset time. It will restart from half the previously accumulated level, if that level was 100%.

The following figure explains the reset characteristic. It will take the set reset time for the replica to reset completely to zero after the thermal replica reached 100% of V/f>1 Trip level. If the thermal replica has not reached 100% of V/f>1 Trip, the reset time will be reduced proportionally. For example, if the reset time setting is 100 s and the thermal replica reached only 50% of V/f>1 Trip level when V/Hz resets, the reset time will be 50 s, as shown in Stage 2. If another V/Hz excursion appears before replica reaches 0, the V/Hz time delay takes the remaining time left into consideration, as shown in Stage 3.

Figure 219 - Example of Reset characteristic



This implies that the V/f>1 trip replica is limited to 100% and kept at 100%, even if the V/f>1 Start condition persists (for example, broken trip circuit). Likewise, the V/f>1 trip replica never can drop below 0% level.

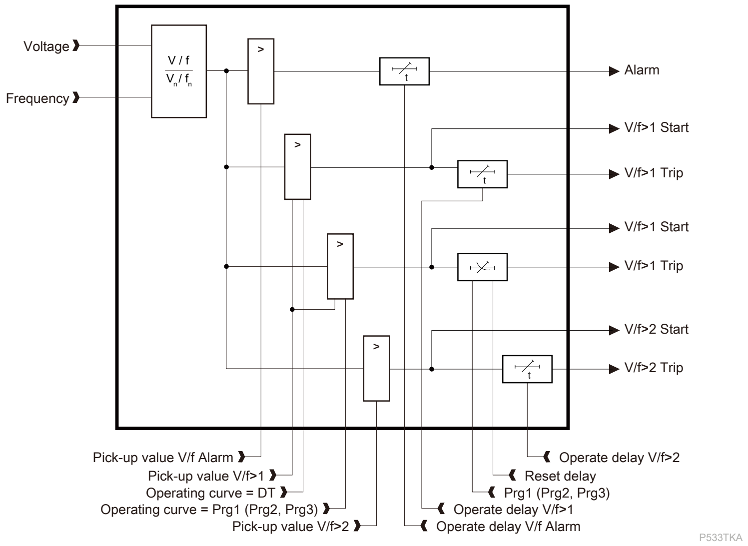
V/f>2 Trip Stage(DT)

The V/f>2 is a definite-time trip stage. The “V/f>2 Start” signal will be issued when the overexcitation multiple is greater than the setting of pick-up value. The “V/f>2 Trip” signal will be issued when the “V/f>2 Start” signal is active for the operate delay.

The “V/f>2 Start” and “V/f>2 Trip” signals can be issued only when “Enable for V/f>1” is on.

Block diagram

Figure 220 - Block diagram of the Transformer Overfluxing Protection (ANSI 24)



Characteristics

Table 66 - Settings and characteristics of the transformer overfluxing protection

Settings/characteristics (description/label)	Value
V/f>1 alarm stage	
Pick-up value	1.00...1.60
Accuracy of pick-up value	±2%
Operate delay	0...10000 s
V/f>1 trip stage	
Enable	On/Off
Pick-up value	1.05...1.60
Accuracy of pick-up value	±2%
Operate curve	DT, Prg1, Prg2, Prg3

Table 66 - Settings and characteristics of the transformer overfluxing protection (Continued)

Settings/characteristics (description/label)	Value
Definite-time delay	
Operate delay[65]	0...10000 s
Accuracy of definite-time delay	±1% or ±100 ms
Inverse-time delay	
Reset delay[66]	0...10000 s
Accuracy of inverse-time delay	±5% or ±100 ms
Accuracy of reset-time delay	±1% or ±100 ms
V/f>2 trip stage	
Enable	On/Off
Pick-up value	1.05...1.60
Accuracy of pick-up value	±2%
Operate delay	0...10000 s
Characteristics	
Starting resetting ratio	95% ±2%

---

[65] Setting for the operate delay of the definite-time trip stage.
[66] Setting for the reset time defines the decreasing rate at the inverse-time characteristic.

Synchro-check (ANSI 25)

Description

The synchro-check function (ANSI code 25) checks the synchronization of the electrical networks on either side of a circuit breaker to avoid closing a breaker when phases are not aligned. This helps ensure that circuit breaker contacts have the minimum wear when closing and avoids excessive disturbance on the network.

The PowerLogic P5 protection relay includes a function that checks synchronism when the circuit breaker is open. The function monitors voltage amplitude, frequency and phase angle difference between two voltages.

The synchro-check function operates in different conditions according to three synchronization modes: Sync, Async and Off.

In case that the synchro-check function is set to Sync mode, the conditions to operate are defined as below:

- The phase angle difference is less than 2°;[67]
- The frequency difference is less than the frequency difference setting;
- The magnitude difference is less than the voltage difference setting.

In case that the synchro-check function is set to Async mode, the conditions to operate are defined as when the phase angle difference, the frequency difference, and the magnitude difference are respectively below their setting values.

- The phase angle difference is less than the phase angle difference setting;
- The frequency difference is less than the frequency difference setting;
- The magnitude difference is less than the voltage difference setting.

In case that the synchro-check function is set to Off, the circuit breaker cannot be closed when the voltage is present on both sides.

The synchro-check function is available when one of the following analogue measurement modules and a suitable measuring mode is in use:

- VPP/VPPy
- 3VP/VPPy
- 3VP/VPy
- 2VPP+VN+VPPy

NOTE: The voltage used for synchro-check is the phase to phase voltage. Where only phase to neutral is available the equivalent phase to phase voltage will be calculated.

The synchro-check function operates for a power system frequency between 46 Hz and 64 Hz.

The following signals of the stage are available in the output matrix and in the logic editor:

- “Request” signal

  This signal is active when a request has been received but the breaker is not yet closed.
- “OK” signal

  This signal is active when the synchronizing conditions are met, or the voltage check criterion is met. See section "Voltage checking" below.

---

[67] The values of phase angle difference [˚] are:

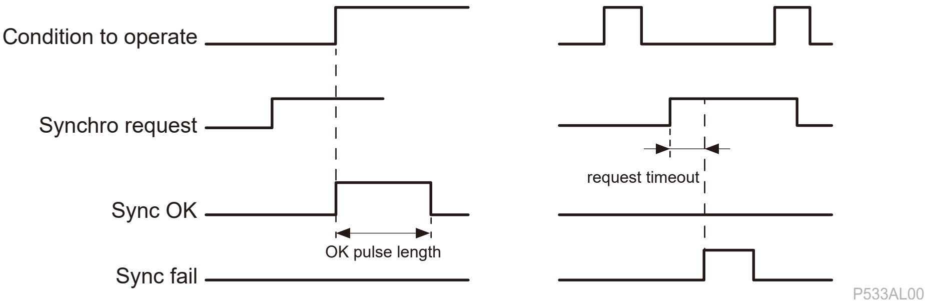
- less than 0.1 ˚ when the frequency difference [Hz] is less than or equal to 0.003 Hz (3 mHz),
- less than 0.5 ˚ when the frequency difference [Hz] is greater than 0.003 Hz (3 mHz) and less than or equal to 0.3 Hz,
- less than 0.83 ˚ when the frequency difference [Hz] is greater than 0.3 Hz.

The setting of phase angle difference is used as the reset threshold of synchro-check OK, the recommended setting value of **Phase angle difference [˚]** is *2* ˚.

- "Fail" signal

  This signal is activated, if the function fails to close the breaker within the request timeout setting. See The principle of the synchro-check function, page 321.

Figure 221 - The principle of the synchro-check function



NOTE: The CB close time setting can be used to anticipate the closing of the CB and meet all the conditions to operate.

Voltage checking

When one of the two voltage is absent, coupling may be authorized according to one of the seven checking modes.

- VAB and VABy absent (DD)
- VAB absent and VABy present (DL)
- VAB present and VABy absent (LD)
- VAB absent regardless of VABy state (present or absent) (DD/DL)
- VABy absent regardless of VAB state (present or absent) (DD/LD)
- One voltage is present while the other one is absent (DL/LD)
- At least one voltage is absent (DD/DL/LD)

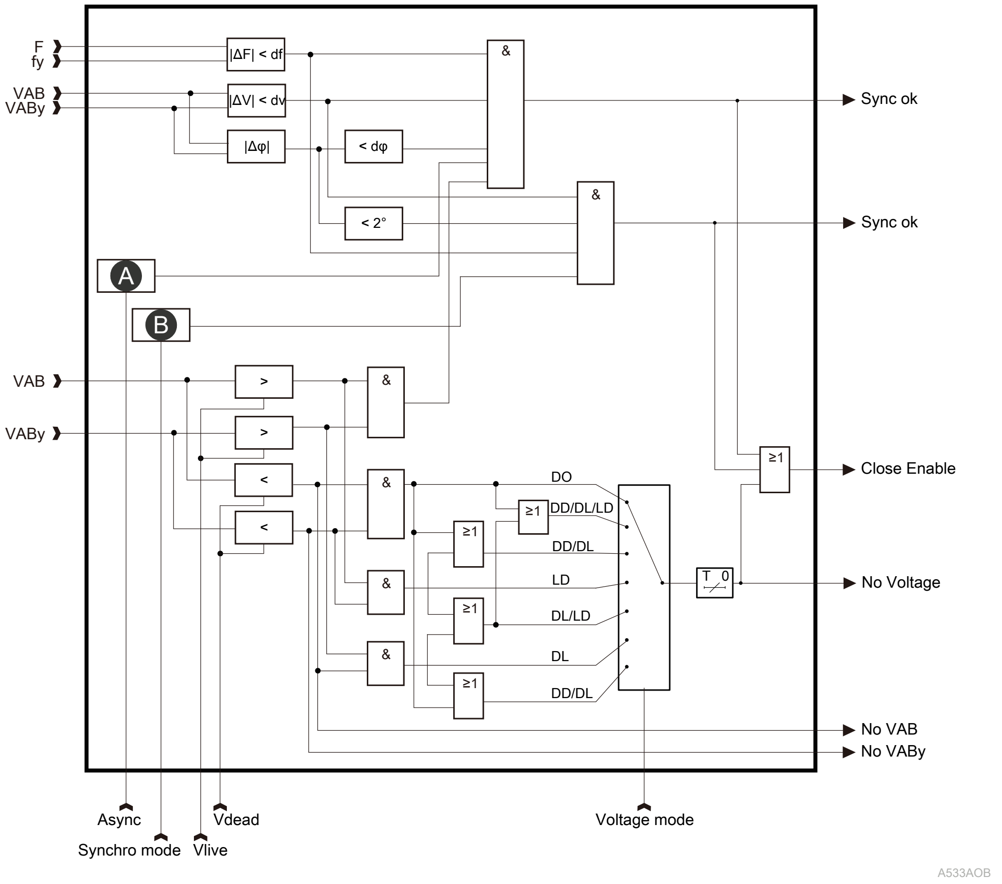
The presence of each voltage is detected by comparing the voltage to the Vlive limit setting. The absence of each voltage is detected by comparing the voltage to Vdead limit setting.

Synchro-check enable and bypass

In the application when circuit breaker closing should be guaranteed by synchro-check result, a parameter to define the circuit breaker should be configured, otherwise synchro-check result will not impact on the close operation, this parameter can be found under **Protection** menu/**Sync-check** sub-menu/**CB object 1**. Sometimes there are also the request to bypass sync-check result, this is also available in PowerLogic P5, which can be realized via the "Bypass" parameter under Protection menu/Sync-check sub-menu.

Block diagram

Figure 222 - Block diagram of the synchro-check protection function (ANSI 25)



A	Async	B	Sync

Characteristics

Table 67 - Setting and characteristics of the synchro-check function (ANSI 25)

Settings/characteristics (description/label)	Values
Synchronization mode/Synchro mode	
Options	Off; Async; Sync
Voltage check mode/Voltage mode	
Options	DD; DL; LD; DD/DL; DD/LD; DL/LD; DD/DL/LD
CB close time/CB close time	
Setting range	0.04...0.60 s
Resolution	0.01 s
Vdead limit setting/Vdead	
Setting range	0.01...1.20 pu[68]
Resolution	0.01 pu[68]

---

[68] VT Primary nominal

Table 67 - Setting and characteristics of the synchro-check function (ANSI 25) (Continued)

Settings/characteristics (description/label)	Values
Accuracy	±0.03 pu[69] or 3% of the setting
Vlive limit setting/Vlive	
Setting range	0.10...1.30 pu[69]
Resolution	0.01 pu[69]
Accuracy	0.03 pu[69]
Frequency difference/Frequency diff	
Setting range	0.01...1.00 Hz
Resolution	0.01 Hz
Accuracy	±20 mHz
Hysteresis	< 10 mHz
Voltage difference/Voltage diff	
Setting range	0.01...0.60 pu[70]
Resolution	0.01 pu[70]
Accuracy	±0.03 pu[70]
Reset ratio	97% ± 2%
Phase angle difference/Angle diff	
Setting range	2°...90°
Resolution	1°
Accuracy	±2° when Δf < 0.2 Hz; else ±5°
Request timeout/Request time	
Setting range	0.1...600.0 s
Resolution	0.1 s
Accuracy	±1% or ±20 ms
Stage operation range	
Frequency range	46...64 Hz
Setting groups/SetGrp	
Number	4

---

[69] VT Primary nominal
[70] Vnom

Undervoltage (ANSI 27)

Description

The Undervoltage protection function (ANSI code 27) is used to detect voltage dips or sense abnormally low voltages to trip or trig load shedding or load transfer. The function provides the selection of three phase to phase voltages or three phase to ground voltages for comparison with the voltage threshold. Each phase can start or trip independently. If the fault situation remains on longer than the operate time setting, a trip signal is issued.

This function operates with either the definite time delay or inverse time delay or programmable curves. These 3 options could be set in Operating curve parameter by eSetup Easergy Pro. The inverse time delay characteristic follows the equation below:

$$t(G) = \frac{T}{1-(\frac{G}{G_S})}$$

P533OR00

where:

- t(G) is the theoretical operate time in seconds with constant value of G.
- T is the time delay setting (theoretical operate time for G = 0).
- G is the measured value of the characteristic quantity.
- G_S is the setting value.

The [voltage, time] curve points are programmed using eSetup Easergy Pro. There are some rules for defining the curve points:

- the configuration must begin from the top line
- the line order must be as follows: the smallest voltage (shortest operate time) on the top and the largest voltage (longest operate time) on the bottom
- all unused lines (on the bottom) should be filled with G/G_S= 1.00 and operate time = 0.00 s

Here is an example configuration of curve points:

Table 68 - Example configuration of curve points

Point	Voltage (pu)	Operate delay(s)
1	0.10	0.00 s
2	0.10	0.10 s
3	0.70	0.10 s
4	0.70	0.50 s
5	0.90	1.00 s
6	1.00	0.00 s
7	1.00	0.00 s
8	1.00	0.00 s
9	1.00	0.00 s
10	1.00	0.00 s
11	1.00	0.00 s
12	1.00	0.00 s
13	1.00	0.00 s
14	1.00	0.00 s
15	1.00	0.00 s
16	1.00	0.00 s

Reset delay

The V< stage has a settable reset delay that enables the detection of intermittent faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets after the release delay has elapsed. If the fault appears again before the release delay time has elapsed, the delay counter continues from the previous value. This means that the function eventually trips if faults are occurring often enough.

Blocking during voltage transformer fuse failure

At all the protection stages, the undervoltage function can be blocked with any internal or external signal using the block matrix. The blocking signal can also be a signal from the custom logic (refer to Logic functions, page 566).

The VTS fast alarm output can be used to block undervoltage protection function as internal signals. Refer to Voltage transformer supervision (ANSI 60), page 652.

This function can also be blocked when circuit breaker is opened and the setting “CB open blocking” is ON.

Operate mode

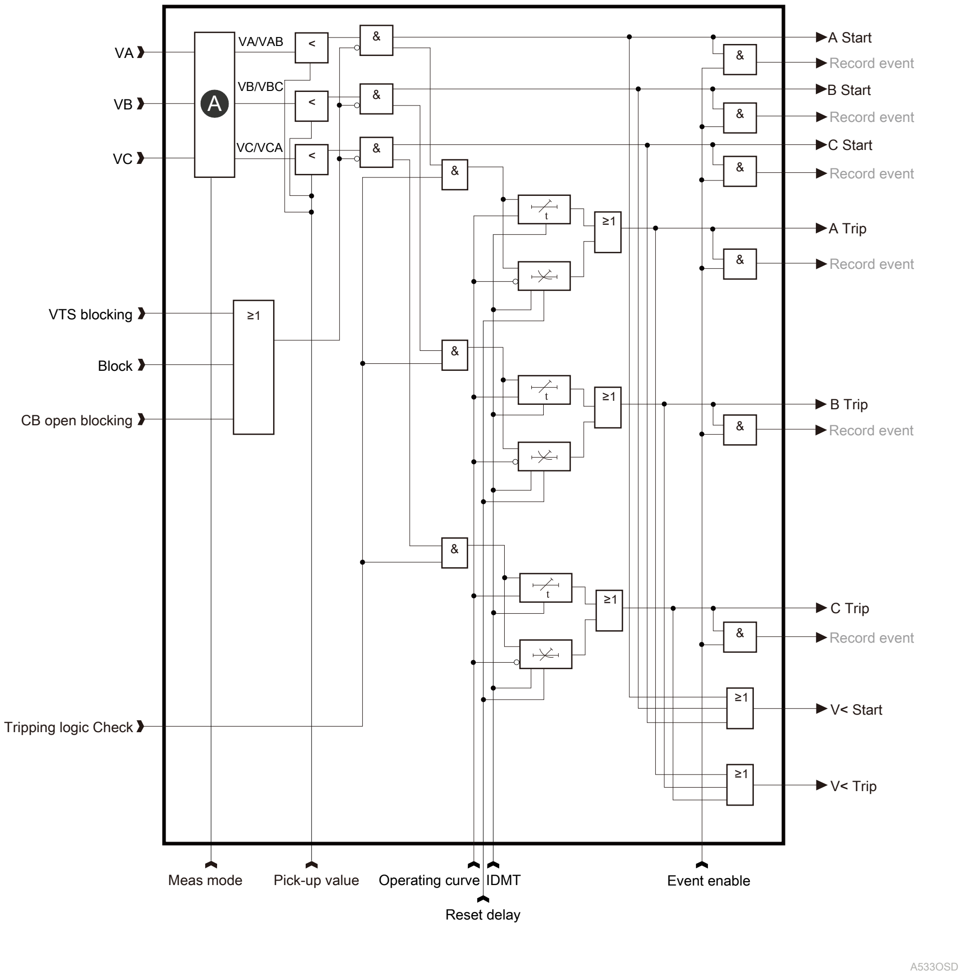
The setting "Tripping logic" is available to configure the operate mode. When "Tripping logic" is "Any phase", the general trip signal "V< trip" is raised when any phase operates. When "Tripping logic" is "Three phases", the signal "V< trip" is raised only when all three phases operate.

Three independent stages

There are three separately adjustable stages: 27-1, 27-2 and 27-3. All these stages have the same settings and performance.

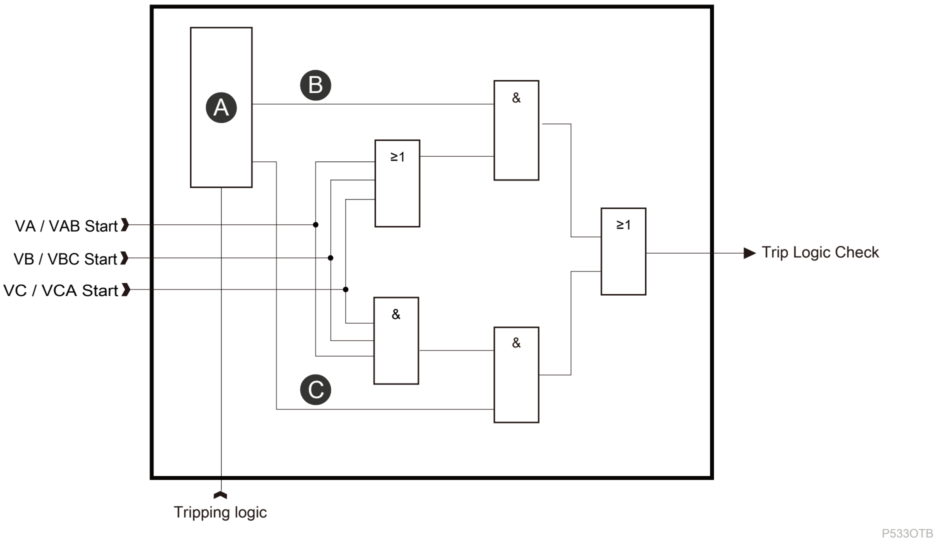
Block diagram

Figure 223 - Block diagram of the Undervoltage protection function (ANSI 27)



A Select setting

Figure 224 - Block diagram of the Tripping Logic



A Select setting B “Any ph”

C “Three ph”

Once Trip logic check passed, which means general trip happens, the general trip resets only if all three phase are reset, no matter which trip logic is selected.

Characteristics

Table 69 - Settings and characteristics of the Undervoltage protection (ANSI 27)

Settings/characteristics (description/label)	Values
Enable V</V<	
Options	Off/On
Pick-up value/Pick-up value	
Setting range	0.020...1.200 pu[71]
Resolution	0.001 pu[71]
Accuracy	±2% or ±0.0005 pu[71]
CB open blocking/CB open blocking	
Options	Off/On
Measurement mode/Meas mode	
Options	Phase-phase; Phase-ground
Operating curve/Operating curve	
Options	DT; IDMT; Prg1-3
Tripping logic/Tripping logic	
Options	Any phase; Three phases
Operate delay/Operate delay	
Setting range	0.00...600.00 s
Resolution	0.01 s
Accuracy	DT: ±1% or ±10 ms
	IDMT: ±5% or ±20 ms
Reset delay/Reset delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	±5% or ±30 ms
Hysteresis/Hysteresis	
Setting range	1.0%...5.0%
Resolution	1.0%
Accuracy	±2%
Characteristic times	
Start time	< 40 ms (35 ms with high speed)
Disengaging time	< 60 ms (75 ms with high speed)
Overshoot time	< 30 ms
Setting group/SetGrp	
Number	4

---

[71] Vnom = VT primary nominal (PP) or Vnom/√3 = VT primary nominal (PN) depending on measurement mode parameter setting.

Positive sequence undervoltage (ANSI 27P)

Description

This is a protection function (ANSI code 27P) for motors against faulty operations due to insufficient or unbalanced power system voltage. There are special self-blocking features for starting up and shutting down a motor.

This undervoltage protection function calculates the positive sequence of the fundamental frequency component V1.

By using the positive sequence, all three phases are supervised, with one value, and if the motor looses the connection to the network (loss of mains), the undervoltage situation is detected even if the frequency decreases significantly from nominal frequency.

Whenever the positive sequence voltage V1 drops below the start setting of a particular stage, this stage activates and a start signal is issued. If the fault situation remains on longer than the time defined in the operate time setting, a trip signal is issued.

Blocking during VT fuse failure

Like all the protection stages, the positive sequence undervoltage function can be blocked with any internal or external signal using the block matrix, for example, if the secondary voltage of one of the measuring transformers disappears because of a fuse failure. The blocking signal can also be a signal from the user's logic.

Self-blocking at low voltage

The protection is blocked when the biggest of the three phase to phase voltages is below the low voltage block limit setting (refer to Positive sequence undervoltage state and block limit, page 329).

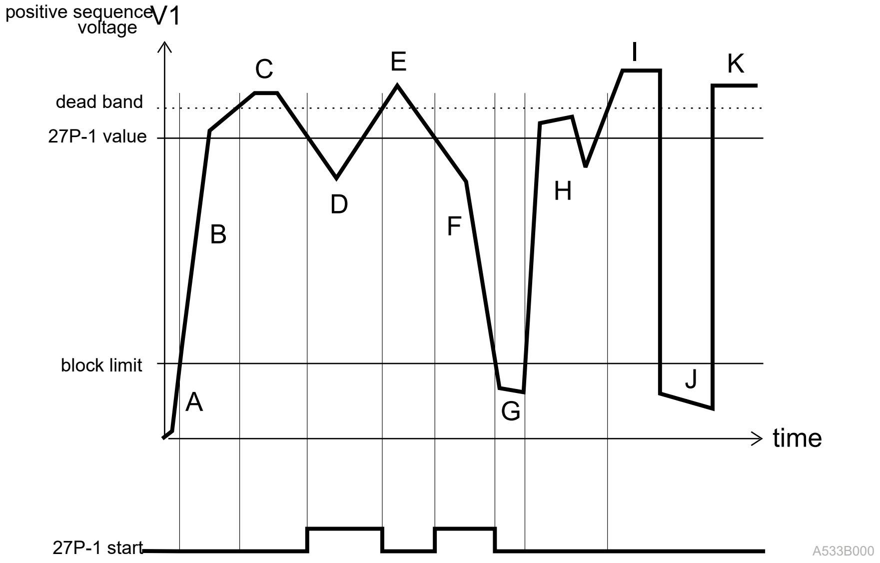
Block according to circuit breaker position

The positive sequence undervoltage protection is blocked when the circuit breaker is open or in undefined status.

Two independent stages

There are two separately adjustable stages: 27P-1 and 27P-2. Both stages can be configured for definite time (DT) operate characteristic.

Figure 225 - Positive sequence undervoltage state and block limit



A The maximum phase to phase voltage is below the block limit. This is not regarded as an undervoltage situation.

B The maximum phase to phase voltage is above the block limit but below the start level. However, this is not regarded as an undervoltage situation because the voltage has never been above the start level since being below the block limit.

C The voltage is OK because it is above the pick-up value.

D This is an undervoltage situation.

E The voltage is OK.

F This is an undervoltage situation.

G The maximum phase to phase voltage is below the block limit and this is not regarded as an undervoltage situation.

H Same as B.

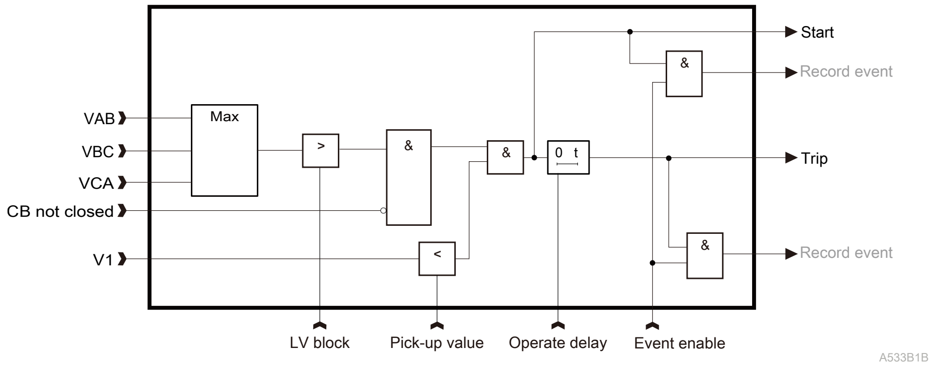
I The voltage is OK.

J Same as G.

K The voltage is OK.

Block diagram

Figure 226 - Block diagram for the positive sequence undervoltage protection



Characteristic

Table 70 - Settings and characteristics of the positive sequence undervoltage protection stages 27P-1 and 27P-2

Settings/characteristics (description/label)	Value
Pick-up value/Pick-up value	
Setting range	0.20...1.20 pu[72]
Resolution	0.01 pu[72]
Accuracy	±1%
Reset ratio	105%
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±30 ms
Under voltage blocking/LV block[73]	
Setting range	0.02...1.00 pu[72]
Reset value	1.05 pick-up value
Resolution	0.01 pu[72]
Accuracy	±2%
Characteristic times	
Start time	< 70 ms (65 ms with high speed)
Disengaging time	< 85 ms (100 ms with high speed)
Overshoot time	< 50 ms
Setting group/SetGrp	
Number	4

---

[72] Vnom/√3

[73] Common settings for setting group 1, 2, 3, 4.

Directional power (ANSI 32)

Description

Directional power protection function (ANSI code 32) can be used, for example, to disconnect a motor in case the supply voltage is lost and thus help prevent power generation by the motor. It can also be used to detect loss of load of a motor.

Directional power protection function is sensitive to active power. If the fault situation stays on longer than the delay setting, a trip signal is issued.

Figure 227 - Example of loss of load

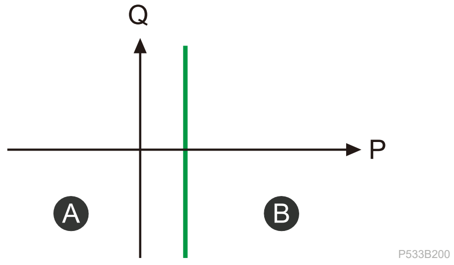
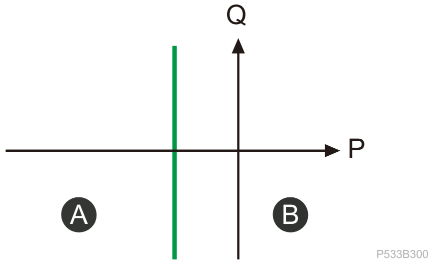


Figure 228 - Example of a motor working as a generator



A	Reverse zone	B	Forward zone

The start setting range is from -200% to +200% of the nominal apparent power S_{NOM}. The nominal apparent power is determined by the configured voltage and current transformer values according to equation below.

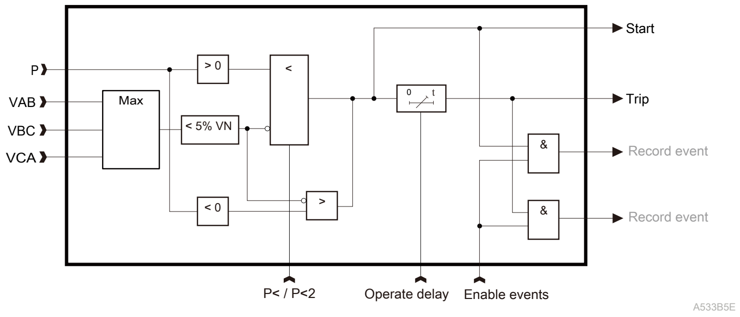
$$S_n = \sqrt{3}\ Vnom\ x\ Inom$$

A533B400

There are two identical stages available with independent setting parameters. Each stage is deactivated if the maximum line voltage drops below 5% of the nominal voltage value.

Block diagram

Figure 229 - Block diagram of the directional power protection



Characteristics

Table 71 - Settings and characteristics of the directional power protection

Settings/characteristics (description/label)	Value
Pick-up value/Pick-up value	
Setting range	-200.0%...+200.0% Sn[74]
Resolution	0.5%
Accuracy	±3% or ±0.5% Sn
Reset ratio	105% ± 3% if P > 0; 95% ± 3% if P < 0
Minimum hysteresis	2.5 W secondary
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.1 s
Accuracy	±1% or ± 150 ms
Characteristic times	
Start time	< 250 ms
Disengaging time	< 500 ms
Setting group/SetGrp	
Number	4

---

[74] Snom = √3 x Vnom x Inom

Wattmetric ground fault (32N)

Description

The wattmetric ground fault protection function (ANSI code 32N) is a directional function designed for compensated neutral power systems (namely Petersen-coil grounded) in which the resistive part of the neutral current is large enough (typically greater than 5 A).

The settings of the wattmetric ground fault protection are based on the fundamental component of the neutral current and of the neutral voltage. The protection operates also with a detection of restriking faults.

The protection calculates the active and reactive neutral powers as follows:

$PN = IN \times VN \times \cos\varphi_N$

$QN = IN \times VN \times \sin\varphi_N$

where

$$IN = \vec{I}_A + \vec{I}_B + \vec{I}_C$$

A533B600

$$VN = \vec{V}_A + \vec{V}_B + \vec{V}_C$$

A533B700

The Pick-up value setting of neutral power setting in percentage of PN.

> **NOTE:** Connect the VN signal according to the connection diagram to achieve correct polarization.

The wattmetric ground fault protection provides 2 operating zones, separated by a non-detection zone:

- Forward fault zone

  The forward zone is intended to issue a signal or trip command during a fault at the downstream side of the protection.

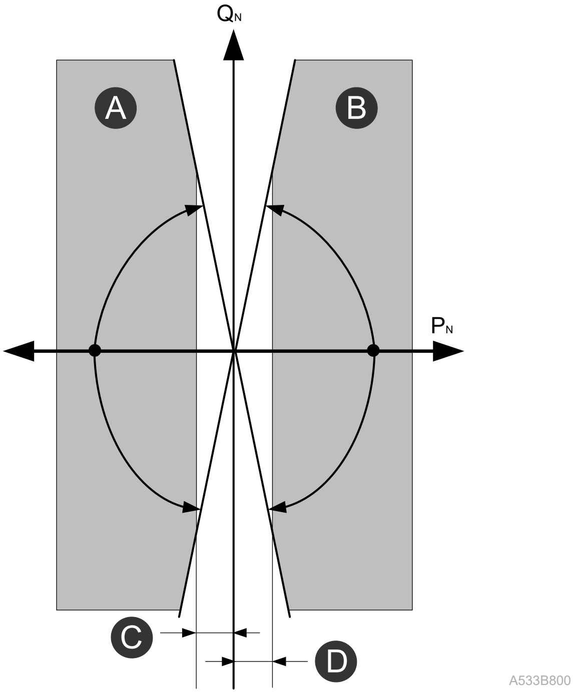
- Backward fault zone

  The backward zone is intended to issue a signal during a fault at the upstream side of the protection.

The two zone area are defined by a pickup sector setting.

If the direction mode is set to Reverse, the wattmetric ground fault protection operates in upstream fault zone.

Figure 230 - Operating zones of the wattmetric ground fault protection



A	Forward zone	B	Reverse zone
C	Pick-up value	D	Pick-up value

The protection is deactivated if the neutral voltage is lower than VN pick-up value setting.

Table 72 - The primary values corresponding to different pick-up values

		P_0.prim.nom = Iprim.nom x Vprim. nom			Stage: Sw> = I_r x V_r x cosϕ				
CT	VT	Iprim. nom	Vprim. nom	P_0.prim. nom kW	8 kW	20 kW	40 kW	80 kW	120 kW
50/1	20000/100	50	20000	1732	0.46%	1.15%	2.31%	4.62%	6.93%
100/1	20000/100	100	20000	3464	0.23%	0.58%	1.15%	2.31%	3.46%
200/1	20000/100	200	20000	6928	0.12%	0.29%	0.58%	1.15%	1.73%
300/1	20000/100	300	20000	10392	0.08%	0.19%	0.38%	0.77%	1.15%
400/1	20000/100	400	20000	13856	0.06%	0.14%	0.29%	0.58%	0.87%
600/1	20000/100	600	20000	20785	0.04%	0.10%	0.19%	0.38%	0.58%
50/5	20000/100	50	20000	1732	0.46%	1.15%	2.31%	4.62%	6.93%
100/5	20000/100	100	20000	3464	0.23%	0.58%	1.15%	2.31%	3.46%
200/5	20000/100	200	20000	6928	0.12%	0.29%	0.58%	1.15%	1.73%
300/5	20000/100	300	20000	10392	0.08%	0.19%	0.38%	0.77%	1.15%
400/5	20000/100	400	20000	13856	0.06%	0.14%	0.29%	0.58%	0.87%
600/5	20000/100	600	20000	20785	0.04%	0.10%	0.19%	0.38%	0.58%

Four memory modes

The detection of current faults is controlled by a memory hold time that extends the transient pick-up information enabling the operation of the definite time delay even if the faults are rapidly extinguished (< 1.5 ms) and restrike rapidly and periodically.

The wattmetric protection can be used in different modes:

- Fault memory based on voltage

  The detection of current faults is controlled by the presence of neutral voltage that extends the transient pick-up information enabling the operation of the definite time delay even if the faults are rapidly extinguished and restrike rapidly and periodically. The level of the neutral voltage is settable.
- Fault memory based on the time memory

  The detection of current faults is controlled by a memory hold time that extends the transient pick-up information enabling the operation of the definite time delay even if the faults are rapidly extinguished and restrike rapidly and periodically. The memory time is settable (Memory time).
- Both criteria

  The protection operates with both, memory time and memory neutral voltage.
- Without memory criteria

  When the fault is detected, the start signal is raised after confirmation. Neither memory time nor neutral voltage memory is taken into account.

Operation

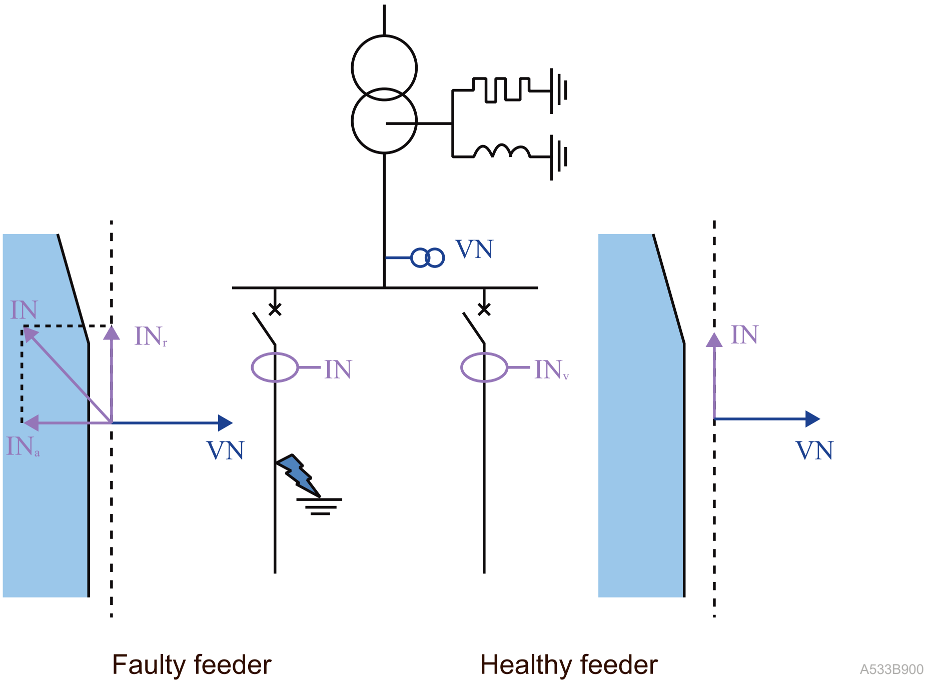
With a Petersen coil system, the current in a faulty feeder is usually inductive and in a healthy feeder, capacitive.

For the forward output, a confirmation is applied on the start signal, because the wattmetric is based on active power and when a restriking fault occurs with a Petersen coil system, the following phenomenon needs to be considered:

For the backward output, the wattmetric protection is able to detect the capacitive current circulation in healthy feeders, to see that the fault is on upstream side:

- In steady state, this capacitive current has a phase-shift of 90° with the neutral voltage. So this capacitive current is not detected because it is outside the backward characteristic, symmetrical to forward area.
- During the transient, the capacitive current goes first in the backward area, before to go outside with at the end a phase-shift of 90°. This transient signal is not used to detect a backward fault with capacitive current, but mainly to block other protection functions of healthy feeders. This can be the case when a HV/MV transformer supplies two incomers at the same time (see Faulty feeder vs. healthy feeder, page 336).

Figure 231 - Faulty feeder vs. healthy feeder

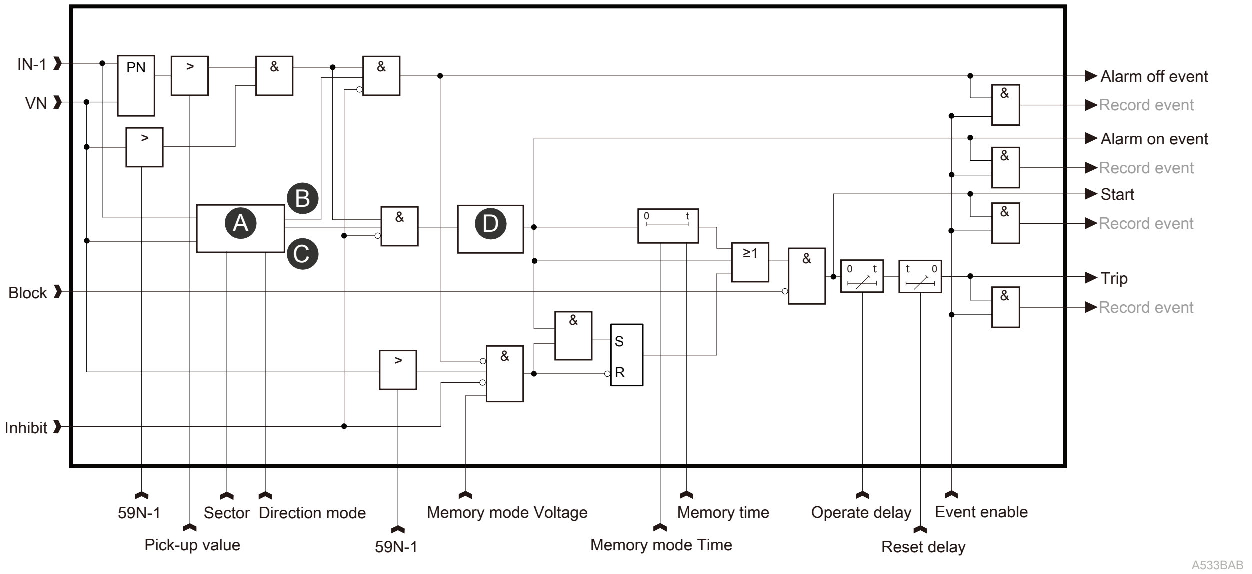


Tripping direction

The normal operate area, in PowerLogic P5 protection relay could be set to forward or reverse area, because sometimes it is not possible to modify CT or VT connections when there is a mistake in the wirings. In that case, to avoid a modification of wirings, you can set the operate area to forward (default setting) or reverse. So if you change the operate area, the confirmation must be applied to the operate area (which could be forward or reverse).

Block diagram

Figure 232 - Block diagram of the wattmetric ground fault protection function (ANSI 32N)



A	-Sector < φ0 < +Sector 180 - Sector < φ0 < 180 + Sector	B	Backward
C	Forward	D	Confirmation

Characteristics

Table 73 - Settings and characteristics of the wattmetric ground fault protection

Settings/characteristics (description/label)	Value
IN input/IN input	
Options	IN.meas, IN.calc, IN.sens for model with ground fault CT (1/5A CT, 1A CT and CSH30) IN.calc, IN.CSH for model with CSH
Direction mode/Direction mode	
Options	Forward; Reverse
Inhibit control/Inhibit control	
Options	Selection of one digital input (DI) or one virtual input (VI)
Timer instant delay ctrl./Timer Inst control	
Options	Selection of one digital input (DI) or one virtual input (VI)
Pick-up value/Pick-up value	
Setting range	0.001...0.2 Pn_0[75] for IN.calc 0.001...2 Pn_0[75] for IN.sens 0.1...20 Pn_0[75] for IN.CSH measured with CSH 2A 0.01...2 Pn_0[75] for IN.CSH measured with CSH 20A
Resolution	0.1%
Accuracy	±10%

---

[75] PN.nom = INx VN x cosφN

Table 73 - Settings and characteristics of the wattmetric ground fault protection (Continued)

Settings/characteristics (description/label)	Value
Reset ratio	90% ± 3%
VN pick-up value/VN>	
Setting range	0.020...0.800 pu[76]
Resolution	0.001 pu[76]
Accuracy	±0.050 pu[76]
Reset ratio	95% ± 3%
Pick-up sector size/Sector	
Setting range	0°...90°
Resolution	1°
Accuracy	±1° with IN and VN measured ±3° with IN and VN calculated
Hysteresis	1° with IN measured 3° with IN calculated
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
SOL status/SOL status	
Options	Off, SOL1, SOL2
SOL operate delay/SOL operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Memory mode/Memory mode	
Options	None; Voltage; Time; Both
Memory time/Memory time	
Setting range	0.05...10.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Reset delay/Reset delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Characteristic times	
Start time	< 50 ms (45 ms with high speed) for power at 2 IN pick-up value × VN pick-up value < 55 ms (50 ms with high speed) for power at 1.2 IN pick-up value × VN pick-up value < 60 ms (55 ms with high speed) for power at 1.05 IN pick-up value × VN pick-up value
Overshoot time	< 40 ms for power at 2 IN pick-up value × VN pick-up value
Disengaging time	< 60 ms (75 ms with high speed)

---

[76] Vnom = VT primary nominal (PP)

Table 73 - Settings and characteristics of the wattmetric ground fault protection (Continued)

Settings/characteristics (description/label)	Value
Setting group/SetGrp	
Number	4

Phase undercurrent (ANSI 37)

Description

The phase undercurrent protection (ANSI code 37) measures fundamental component of phase currents. By detecting motor loss of load, it’s typically used to protect pumps against loss of prime. This protection protects rather the devices driven by motor than the motor itself, for example a submersible pump (where the flowing liquid inherently cools the pump) or conveyor belt.

Phase undercurrent protection can be configured for definite time characteristic only.

To differentiate normal operation of circuit breaker and undercurrent conditions, a low current setting is available to block this protection function.

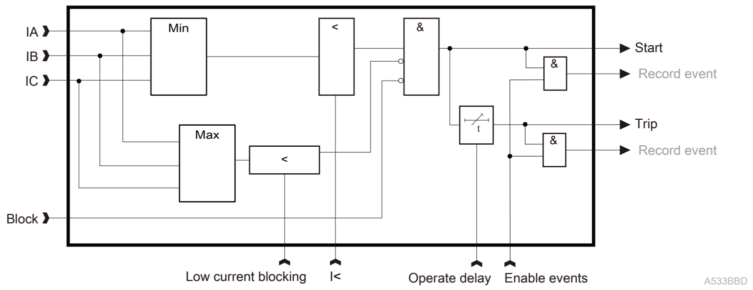
Low-current self-blocking

The value of low-current self-blocking could be different in each setting groups. To avoid unwanted tripping, phase undercurrent protection shall be blocked when maximum of phase currents drops under the setting.

Phase undercurrent protection will automatically become inactivated if its pickup threshold is set equal to or lower than this undercurrent blocking limit.

Block diagram

Figure 233 - Block diagram of the phase undercurrent protection function (ANSI 37)



Characteristics

Table 74 - Settings and characteristics of the phase undercurrent protection function (ANSI 37)

Settings/characteristics (description/label)	Value
Pick-up value/Pick-up value	
Setting range	0.05...1.00 pu[77]
Resolution	0.01 pu[77]
Accuracy	±2% or ±0.005 Inom
Reset ratio	105% ± 2%
I< block limit/I< block limit	
Value	0.02...0.50 pu[77]
Operate delay/Operate delay	
Setting range	0.0...300.0 s
Resolution	0.1 s
Accuracy	±1% or ±20 ms
Characteristic times	
Start time	< 60 ms (55 ms with high speed)
Disengaging time	< 65 ms (80 ms with high speed)
Setting group/SetGrp	
Number	4

---

[77] Inom

Temperature monitoring (ANSI 38)

Description

The temperature monitoring function (ANSI code 38) is used to detect abnormal heat rise by measuring the temperature inside equipment fitted with sensors:

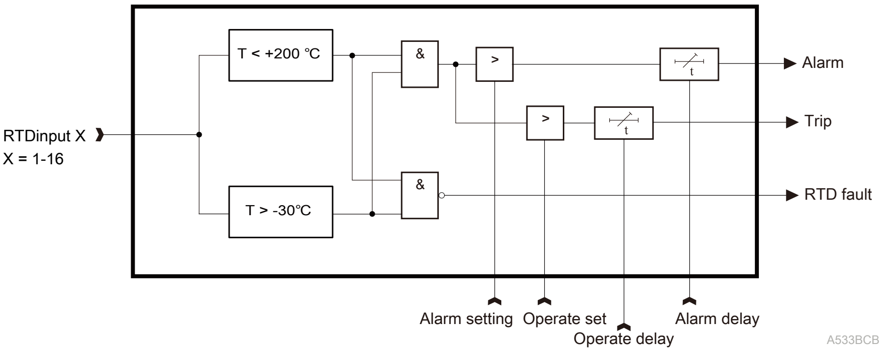
- transformer: protection of primary and secondary windings
- motor and generator: protection of stator windings and bearings. This protection function is associated with an RTD of the Pt100 platinum (100 Ω at 0°C or 32°F) or nickel (Ni100 or Ni120) type, in accordance with the IEC 60751 and DIN 43760 standards.
- it picks up when the monitored temperature is greater than the set point (Ts)
- it has two independent set points:
  - alarm set point
  - tripping set point, the trip signal of temperature monitoring is not a part of the global trip.
- when the protection function is activated, it detects whether the RTD is shorted or disconnected:
  - RTD shorting is detected if the measured temperature is less than -30°C or -22°F (measurement displayed as "——")
  - RTD disconnection is detected if the measured temperature is greater than +200°C or +392°F (measurement displayed as "–//–").

  If an RTD fault is detected, the associated threshold is inhibited and the start and trip signals are forced to reset state.

  The "RTD fault" item is also made available in the control matrix and an alarm message is generated specifying the number of the MET148-2 module for the faulty RTD.

Block diagram

Figure 234 - Block diagram of the temperature monitoring function (ANSI 38)



Characteristics

Table 75 - Setting and characteristics of the temperature monitoring function (ANSI 38)

Settings/characteristics (description/label)	Value
Alarm and trip set points/T°1>1, T°1>2	
Setting range	0°C...180°C (32°F...356°F)
Unit	°C
Accuracy	±1°C (±1.8°F)
Resolution	1°C (1.8°F)
Pick up/drop out	3°C (37.4°F)
Alarm delay/AlmDly	
Setting range	0.00...600.00 s
Accuracy	1% ± 20 ms
Operate delay/OperDly	
Setting range	0.00...600.00 s
Accuracy	1% ± 20 ms
Characteristic times	
Start time	< 3 s
Setting group/SetGrp	
Number	1

Negative sequence overcurrent (ANSI 46)

Description

The negative sequence overcurrent protection function (ANSI code 46) gives greater sensitivity to detect phase to phase faults at the end of long lines, where phase overcurrent elements may not operate.

For rotating machines, the negative sequence overcurrent protection provides protection against a temperature rise caused by an unbalanced power supply, phase inversion, loss of phase, and unbalanced phase current.

The negative sequence current is calculated from the measured phase currents according to the following formula (for standard phase rotation A - B - C):

$$\vec{I}_2 = \frac{1}{3}\left(\vec{I}_A + a^2\vec{I}_B + a\vec{I}_C\right)$$

A533BD00

with

$$a = e^{j\frac{2\pi}{3}}$$

P533BE00

The negative sequence overcurrent protection function operates with inverse or definite tripping time characteristic.

There are two separately adjustable stages available in PowerLogic P5, both providing the same settings and performance.

With transformer differential protection P5T30 each stage can be individually linked to the measured phase currents of one end.

If phase swapping feature is used, then this is considered in the calculation of the negative sequence current.

Back-up mode

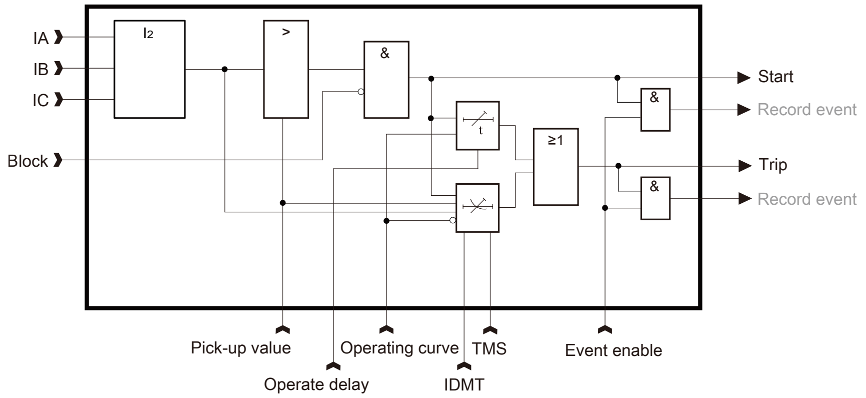
The back-up mode is for PowerLogic P5L30 only.

The negative sequence overcurrent protection, the non-directional/directional phase overcurrent protection and the non-directional/directional ground fault overcurrent protection can be set as backup protections of the line differential protection in case the line differential protection is permanently blocked. By default, the overcurrent stages are active. Once the back-up mode is enabled, the overcurrent protections will be active only if the line differential protection is blocked, and when the line differential protection is not blocked or disabled, the overcurrent protections will be inactive again.

To enable/disable the back-up mode, check/uncheck the **Back-up mode** in eSetup Easergy Pro/ **PROTECTION**/**Negative sequence overcurrent 46** and **Phase overcurrent 50/51/67** and **Ground fault overcurrent 50N/51N/67N**.

Block diagram

Figure 235 - Block diagram of the negative sequence overcurrent protection function (ANSI 46)



A533BFD

Characteristics

Table 76 - Settings and characteristics of the negative sequence overcurrent protection

Settings/characteristics (description/label)	Value
Pick-up value/Pick-up value	
Setting range	0.02...5.00 pu[78]
Resolution	0.01 pu[78]
Accuracy	±3% or ±0.005 pu[78]
Reset ratio	95% ± 2%
CT input selection[79]	
Setting range	CT-1, CT-2
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Accuracy	±1% or ±20 ms
Operating curve/Operating curve	
Option	DT; IEC: SI, VI, EI, LTI, UTI; IEEE: MI, VI, EI ANSI: NI, STI, LTI Others: UK_Rectifier, FR_STI, RI, STI_CO2, LTI_CO5, MI_CO7, NI_CO8, VI_CO9, EI_CO11, BPN Prg1-3
Accuracy	±5% or ±30 ms (for IDMT)
TDM/TDM	
Setting range	0.020...20.000
Resolution	0.001
DT adder/DT adder	
Setting range	0.00...1.00 s
Resolution	0.01 s
Minimum operate delay/Min operate delay	
Setting range	0.00...10.00 s
Resolution	0.01 s
Reset curve/Reset curve	
Options	DT; IDMT; Prg1-3
Reset delay/Reset delay	
Setting range	0.03...100.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Back-up mode	
Enable back-up mode	Off/On
Characteristic times	
Start time	< 50 ms (45 ms with high speed) for currents at 2 x Pick-up value < 55 ms (50 ms with high speed) for P5T30, for currents at 2 x Pick-up value

---

[78] I_{nom}
[79] Available for P5T30 only.

Table 76 - Settings and characteristics of the negative sequence overcurrent protection (Continued)

Settings/characteristics (description/label)	Value
	< 60 ms (55 ms with high speed) for currents at 1.2 x Pick-up value < 65 ms (60 ms with high speed) for currents at 1.05 x Pick-up value
Disengaging time	< 75 ms (90 ms with high speed)
Setting group/SetGrp	
Number	4

Unbalance overcurrent, broken conductor (ANSI 46BC)

Description

The purpose of the unbalance overcurrent, broken conductor protection function (ANSI code 46BC) is to detect unbalanced load conditions, for example a broken conductor of a loaded overhead line in a medium voltage radial network.

Different fault conditions may apply:

- Broken conductor in contact with the ground at the source side
- Broken conductor in contact with the ground at the load side
- Open circuit (conductor not in contact with the ground) caused by broken conductor, blown fuse, circuit breaker pole failure, etc.

This function can also be used for motor protection in order to detect blown fuse or phase reverse connection.

The PowerLogic P5 provides two stages of unbalance overcurrent, broken conductor protection. Each stage can be enabled or disabled independently.

The function is inactive if only 2 phase current sensors are connected (2 CT mode with setting **Number of connected phase CT** = *A/C* in the **GENERAL** menu/ **Scaling** sub-menu).

The operation of the unbalanced load function is based on the negative phase sequence component I_2 related to the positive phase sequence component I_1. These are calculated from the phase currents using the method of symmetrical components. The function requires that the measuring inputs are connected correctly. The unbalance protection has definite time operation characteristic.

The positive and negative sequence currents I_1 and I_2 are defined as follows (for standard phase rotation A - B - C):

$$\vec{I_1} = \frac{1}{3}(\vec{I_A} + a\vec{I_B} + a^2\vec{I_C})$$

A533BG00

Related Topics:

$$\vec{I_2} = \frac{1}{3}(\vec{I_A} + a^2\vec{I_B} + a\vec{I_C})$$

A533BH00

with phasor rotating constant:

$$a = e^{j\frac{2\pi}{3}}$$

P533BE00

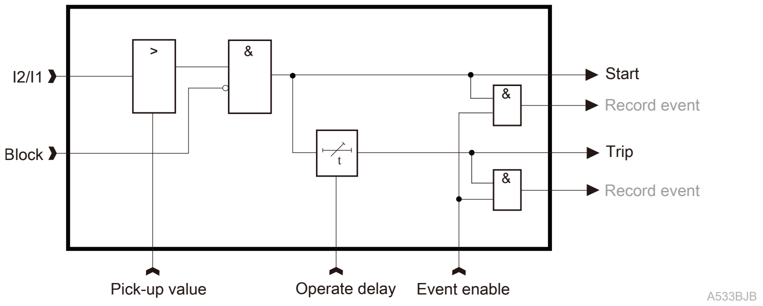
> **NOTE:** The broken conductor function is inhibited if the positive sequence current I_1 is less than 5% of the nominal current.

With transformer differential protection P5T30 each stage can be individually linked to the measured phase currents of one end.

If phase swapping feature is used, then this is considered in the calculation of the sequence currents.

Block diagram

Figure 236 - Block diagram of the unbalance overcurrent broken conductor protection function (ANSI 46BC)



Characteristics

Table 77 - Settings and characteristics of the unbalance overcurrent broken conductor protection

Settings/characteristics	Value
Pick-up value/Pick-up value	
Setting range	2%...70%
Resolution	1%
Accuracy	±3%
CT input selection[80]	
Setting range	CT-1, CT-2
Reset ratio	
Value	95%
Accuracy	±2% or ±2 mA secondary
Operate delay/Operate delay	
Setting range	0.00...300.0 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Characteristic times	
Start time	< 50 ms (45 ms with high speed) for currents at 2 x Pick-up value < 60 ms (55 ms with high speed) for currents at 1.2 x Pick-up value < 75 ms (70 ms with high speed), for currents at 1.05 x Pick-up value < 105 ms (100 ms with high speed) for P5T30, for currents at 1.05 x Pick-up value
Disengaging time	< 75 ms (90 ms with high speed)
Setting group/SetGrp	
Number	4

---

[80] Available for P5T30 only.

Negative sequence overvoltage (ANSI 47)

Description

To protect a rotating machine from being energized with a reverse voltage sequence or to help prevent overheating of the motor due to a broken conductor condition, negative sequence overvoltage protection (ANSI code 47) can be applied. This protection monitors the voltage phase sequence detecting a reverse rotation or voltage unbalance due to a missing (asymmetrical) phase. The detection of these conditions can then be used to trip the machine and help prevent damage to both the motor and the mechanically coupled process.

The PowerLogic P5 protection relay provides two stages of negative sequence overvoltage protection. Each stage can be enabled or disabled independently. The negative sequence voltage is derived from the three phase voltages. If the VT connection is configured as “VPP/VPPy”, the negative sequence voltage cannot be derived, and the negative sequence overvoltage protection is disabled.

If the negative sequence voltage input exceeds the voltage setting, this function starts instantaneously, and it operates with the definite time delay or inverse time delay characteristic that has been selected. The inverse time delay characteristic follows the equation below:

$$t = \frac{T}{\frac{V}{G_S} - 1}$$

P533BK00

where:

t is the theoretical operate time in seconds.

T is the operate delay setting (theoretical operate time for V = 2 × G_S).

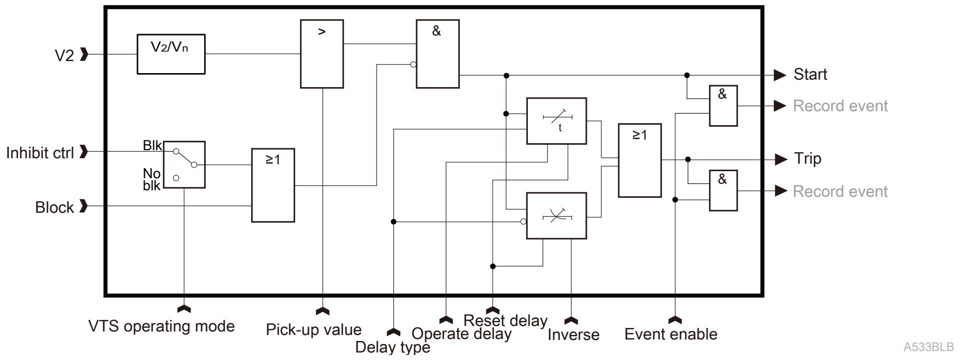
V is the calculated value of negative sequence voltage.

G_S is the pick-up setting value of the negative sequence overvoltage protection.

The V stage has a settable reset delay that enables the detection of intermittent faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets after the release delay has elapsed. If the fault appears again before the release delay time has elapsed, the delay counter continues from the previous value. This means that the function eventually trips if faults are occurring often enough. This function is blocked by VTS operation if the setting "VTS operating mode" is set to "Blocking".

Block diagram

Figure 237 - Block diagram of the negative sequence overvoltage protection (ANSI 47)



A533BLB

Characteristics

Table 78 - Settings and characteristics of the negative sequence overvoltage protection function

Settings/characteristics (description/label)	**Values**
VTS operating mode/VTS operating mode	
Options	No action; Blocking
Pick-up value/Pick-up value	
Setting range	0.01...1.00 pu[81]
Resolution	0.01 pu[81]
Accuracy	±2% or ±0.05 V secondary
Reset ratio	98% ± 1% fixed
Minimum hysteresis	120 mV secondary
Operating curve/Delay type	
Options	DT; IDMT(the characteristic follows the equation provided in Description, page 350)
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	DT: ±2% or ±20 ms; IDMT: ±5% or ±20 ms
Reset delay/Reset delay	
Setting range	0.03...300 s
Resolution	0.01 s
Accuracy	±2% or ±20 ms
Characteristic times	
Start time	< 55 ms (50 ms with high speed) for voltage from 0.9 Pick-up value to 1.1 Pick-up value
Overshoot time	< 40 ms for voltage from 0.9 Pick-up value to 1.1 Pick-up value
Setting group/SetGrp	
Number	4

---

[81] Vnom = VT primary nominal (PP) / √3

Thermal overload protection for feeder (ANSI 49F)

Description

The Thermal Overload protection function for Feeder (ANSI code 49F) can be applied to minimize damage to overhead lines and underground cables when operating at temperatures in excess of the designed maximum withstand (deterioration of the insulation, sagging conductors etc.).

The PowerLogic P5 protection relays that are designed for feeder protection incorporate a current based thermal replica, using phase current to reproduce the heating and cooling of the feeder conductors. In this case, the PowerLogic P5 protection relay automatically uses the highest phase current as input information for the thermal model. The current measurement is based on 3 phase RMS currents, that takes into account harmonic rank up to 15. The mathematical model used to compute the thermal level of the feeder conductors is based on the thermal model defined in the IEC 60255-149 standard.

The thermal replica can optionally take account of ambient temperature, preferably when an ambient temperature sensor is available. However, where an ambient temperature sensor is not available, the user may enter a default value for ambient temperature which is different to the value defined in the feeder conductors data sheet (e.g. to take account of summer and winter ambient temperature values).

The Thermal Overload for Feeder protection can be used in two different setting modes:

- Current based setting mode
- Temperature based setting mode

The following sections explain the two setting modes.

Also with transformer differential protection P5T30 one such thermal overload element is provided which can be linked to the measured phase currents of one end as per application requirements.

Current based setting mode

This setting mode is active when "Temperature based mode" is set to "Current". In this setting mode, the thermal level H(t) is computed according to the thermal model defined in the IEC 60255-149.

The thermal level H(t) is computed according to the following equation:

$$H(t) = H(t - \Delta t) + \left(\frac{I_{eq}(t)}{k \times I_b}\right)^2 \times \frac{\Delta t}{\tau} - H(t - \Delta t) \times \frac{\Delta t}{\tau}$$

P533BM00

where:

- H(t) is the thermal level computed at time t ("Thermal level").
- H(t - Δt) is the thermal level computed at time t - Δt.
- $I_{eq}(t)$ is the equivalent heating phase current at time t computed from the maximum of the 3 phase RMS currents.
- I_b is "Base current" or "Feeder basic current".
- k is the "k" factor applied to the basic current to define the maximum continuous current.
- τ is the time constant of the feeder ("Time constant" or "Time constant τ"), where τ is assumed to be much greater than Δt.

"$[I_{eq}(t) / (k \text{ x } I_b)]^2$x Δt / τ" expresses the heat transfer due to the phase current $I_{eq}(t)$ and "H(t - Δt) x Δt / τ" expresses the natural cooling of the feeder conductors.

The thermal overload protection operates when the thermal level is greater than 100%. This thermal level of 100% can be reached with a permanent current above the basic current value I_b multiplied by the k factor.

With a continuous load current "I_{eq}", the thermal level "H" is equal to:

$$H\ (I_{eq}) = (\frac{I_{eq}}{k \times I_b})^2$$

P533BN00

The table below indicates the thermal level with different values of continuous load current:

I_{eq} / (k x I_b) ratio	Thermal Level (%)
1	100% (operation)
0.9	81%
0.8	64%
0.7	49%
0.6	36%
0.5	25%
0.4	16%
0.3	9%

Generally, the base current $I_b$is set to the feeder thermal rated current, and overload factor k should be set to take into account the short-term overload capability. The default overload factor k is 1.15.

A thermal alarm ("49F alarm" output) is provided which operates when the thermal level is greater than or equal to the "Thermal alarm value" setting (expressed in %) and is usually set to be lower than 100%, the operate level. This threshold, expressed in %, is available only in the current based setting mode.

The thermal level in % is accessible as an output measurement.

When thermal overload is managed in the several setting groups, the thermal level is kept after the setting group change (no thermal level reset), and the thermal level is computed according to the new settings.

Temperature based setting mode

This setting mode is active when "Operating mode" setting is set to "Ambient". In this setting mode, the protected object temperature computation is based on the previous thermal level H(t) calculation (see previous section "Current based setting mode") with an additional reference to the maximum operating temperature of the feeder conductors, the maximum ambient temperature and the working temperature, defined by setting.

In this mode, the thermal level H(t) is computed with the following formula, derived from the equation of thermal level H(t) calculation:

$$H(t) = H(t - \Delta t) + F_a \times (\frac{I_{eq}(t)}{k \times I_b})^2 \times \frac{\Delta t}{\tau} - H(t - \Delta t) \times \frac{\Delta t}{\tau}$$

P533BQ00

Where common values are identical to the thermal level H(t) calculation formula, and the additional "F_a" ambient temperature factor is defined with the following equation:

$$F_a = \frac{T_{max} - T_{nom}}{T_{max} - T_a}$$

P533BR00

where:

- T_{max} is the maximum temperature of the equipment ("Max object temperature").

- T_{nom} is the limit of the ambient temperature designed for the feeder conductors to operate at rated loads without causing thermal degradation of insulation ("Nominal ambient temperature", typically equal to 40°C).
- T_a is the real time ambient temperature of the feeder conductors measured with the RTD number 8. When no temperature sensor is available or the sensor is faulty, or the temperature measurement exceed "Max object temperature" setting or lower than the "Min ambient temperature", the value of "Default ambient temperature" will be used for this temperature.

The ambient temperature of the feeder conductors is computed with the following formula:

$$T_{object} = H(t) \times (T_{max} - T_a) + T_a$$

P533BS00

Where H(t), T_{max} and T_a are defined according to the previous equations.

The thermal overload protection operates when the computed temperature "T_{object}" is above or equals the maximum temperature T_{max}.

A temperature alarm is provided ("49F T> alarm" output). This output operates when the temperature level is greater than or equal to the alarm temperature setting(expressed in °C).

The ambient temperature (T_a) and object temperature (T_{object}) are accessible as output measurements in °C (T_a = "Ambient temperature" output and T_{object} = "Object temperature" output). The default value of the ambient temperature is equal to the "Default ambient temperature" setting.

Additional features

The thermal level computation expressed in % is always available with the feeder thermal level output. The current thermal level is saved in a non volatile memory when the PowerLogic P5 protection relay is powered off. If the current thermal level is above 90%, a value of 90% is memorized to help prevent possible nuisance tripping on supply restoration.

A measurement output where the estimated time to trip is provided, based on the hypothesis that the load current present remains constant until thermal overload operation occurs.

A time remaining alarm ("49F rsv alarm" output) is provided. It operates when the calculated remaining time is less than or equal to the "Reserve time thermal alarm" setting.

There is a digital input (“Feeder thermal level reset” signal) to reset the thermal level value, when the digital input is asserted, the value of thermal level is set to Zero.

It is possible to block the protection function using the block matrix.

Typical values of time constant in minutes:

Applications	Time constant (min)
Dry-type transformers	40 (rating < 400 kVA) 60...90 (rating 400...800 kVA)
Air-core reactors	40
Capacitor banks	10
Overhead lines	10 (Cu: cross section greater than or equal to 100 mm^2 (0.15 in^2); or Al: 150 mm^2 (0.23 in^2))
Busbars	60

Time to trip calculation

For a continuous current higher than the current threshold (k x I_b), the operate time of the thermal overload protection can be computed with the following equation:

$$t = \tau \times L_n \times \left(\frac{F_a \times H(I_{eq}) - H_0}{F_a \times H(I_{eq}) - 100\%}\right)$$

P533BO00

where:

- τ is the time constant for the protected equipment.
- Ln( ) is natural logarithm function.
- F_a is the ongoing temperature compensation. In current based setting mode, $F_a = 1$.
- $H(I_{eq})$ is the thermal level calculated with the continuous load current (I_{eq}) and the base current setting (I_b).
- H_0 is the current thermal state corresponding to the last calculation.

In the same way, for a continuous current higher than the current threshold (k x I_b), the time for the alarm to operate is:

$$t = \tau \times L_n \times \left(\frac{F_a \times H(I_{eq}) - H_0}{F_a \times H(I_{eq}) - H_{alarm}}\right)$$

P533BT00

where:

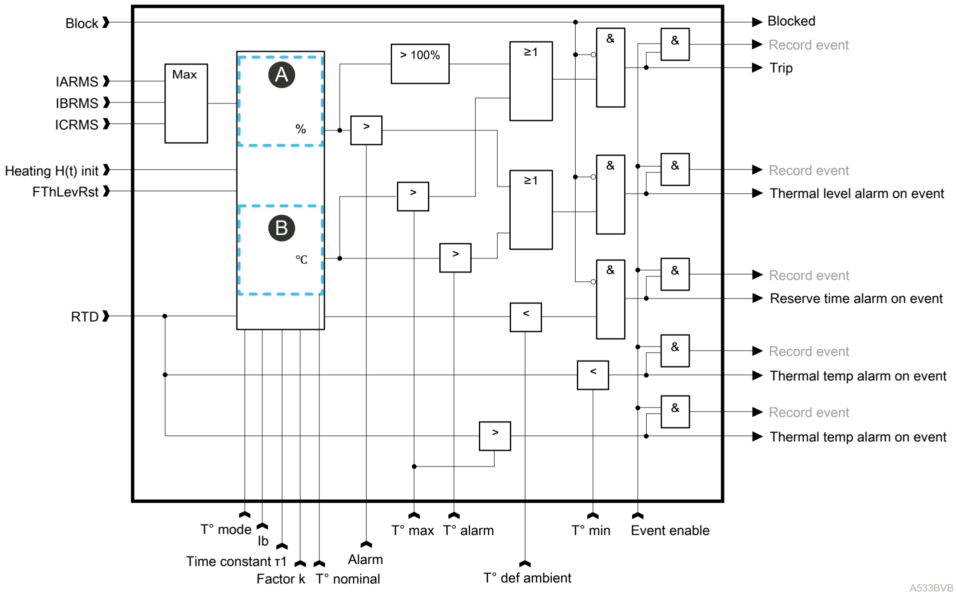
H_{alarm} is "Alarm" (alarm temperature setting, in %). In temperature based setting mode, the alarm temperature setting is expressed in °C. The corresponding thermal level in % (H_{alarm}) is defined by the following equation:

$$H_{alarm} = \frac{T_{alm} - T_a}{T_{max} - T_a} \times 100\%$$

P533BU00

Block diagram

Figure 238 - Block diagram of the thermal overload protection function (ANSI 49F)



A	Current based mode calculation zone	B	Temperature based mode calculation

Characteristics

Table 79 - Settings and characteristics of the thermal overload protection stage 49F

Settings/characteristics (description/label)	Values
Base current setting/I_b	
Setting range	0.1...4.0 pu[82]
Resolution	0.01 pu[82]
CT input selection[83]	
Setting range	CT-1, CT-2
Overload factor k/Factor k	
Setting range	0.1...1.5
Resolution	0.01
Time constant/Time constant τ1	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Thermal alarm value/Alarm	
Setting range	50%...100% of thermal level
Resolution	1%
Reserve time thermal alarm/Reserve value	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Operating mode/T°mode	
Options	Current; Ambient
Nominal ambient temperature/T°nominal	
Setting range	-40... +300 °C (-40... +572 °F)
Resolution	1 °C (1.8 °F)
Max object temperature/T°max	
Setting range	-40 - +300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Alarm temperature/T°alm	
Setting range	0... +300 °C (32...+572 °F)
Resolution	1 °C (1.8 °F)
Min ambient temperature/T°min	
Setting range	-40... 300 °C (-40... +572 °F)
Resolution	1 °C (1.8 °F)
Default ambient temperature/T def ambient	
Setting range	-40...300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Thermal level init value/ Heating H(t) init	
Setting range	0%...90%
Resolution	0.1%

---

[82] I_{nom}

[83] Available for P5T30 only.

Table 79 - Settings and characteristics of the thermal overload protection stage 49F (Continued)

Settings/characteristics (description/label)	Values
Characteristics	
Tripping time accuracy	±5% or ±500 ms (with the applicable factor according to IEC 60255-149)
Setting group/SetGrp	
Number	4

Motor status

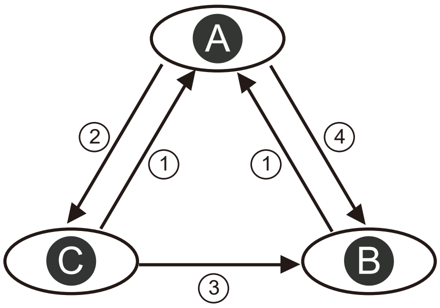
Description

There are three possible status for a motor: stopped, starting or running.

The PowerLogic P5 detects motor start by CB position, motor current, or both CB position and motor current using “Motor start detection mode”.

- CB Position: The CB position changes from open to closed.
- Current: Three phase currents have been less than 5% Inom(phase CT primary nominal). Then any of the three phase currents increases and exceeds the motor start detection current.
- CB Position and Current: Any of the three phase currents exceeds the motor start detection current in 90 ms after CB position changes from open to close.

Figure 239 - Motor status



P533BW00

A	Stopped	B	Running
C	Starting		

Criterion for motor in starting state

1. As soon as the motor start is detected, the motor changes from “Stopped” state to “Starting” state.②

   NOTE: Motor start counter counts the number of successful starts, not including the emergency restart.

Criterion for motor in stopped state

1. If the motor start criterion is “CB Position”, the motor is in “Stopped” state when CB is open. ①
2. If the motor start criterion is “Current” or “CB & Current”, the motor is in “Stopped” state when three phase currents are all less than 5% Inom (phase CT primary nominal). ①

Criterion for motor in running state

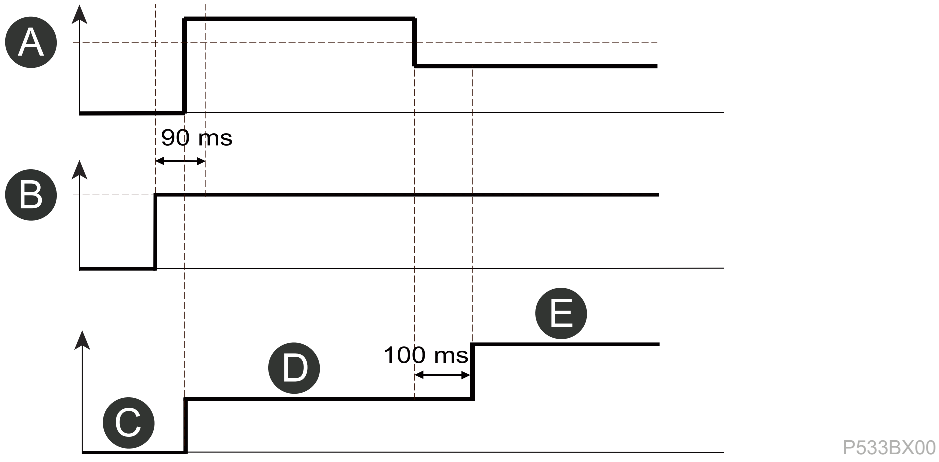
1. When the motor is in “Starting” state and three phase currents drop below the motor start detection current for 100 ms, the motor state changes to “Running”. ③

2. If the motor start is not detected successfully and the criteria for motor in “Stopped” state are not satisfied, the relay will consider the motor is in “Running” state.

   For example: if the motor start detection mode is “CB & Current” and all three phase currents do not exceed the motor start detection current within 90 ms after CB is closed, the motor start is not detected. Motor state changes from “Stopped” state to “Running” after the 90 ms timing window. ④

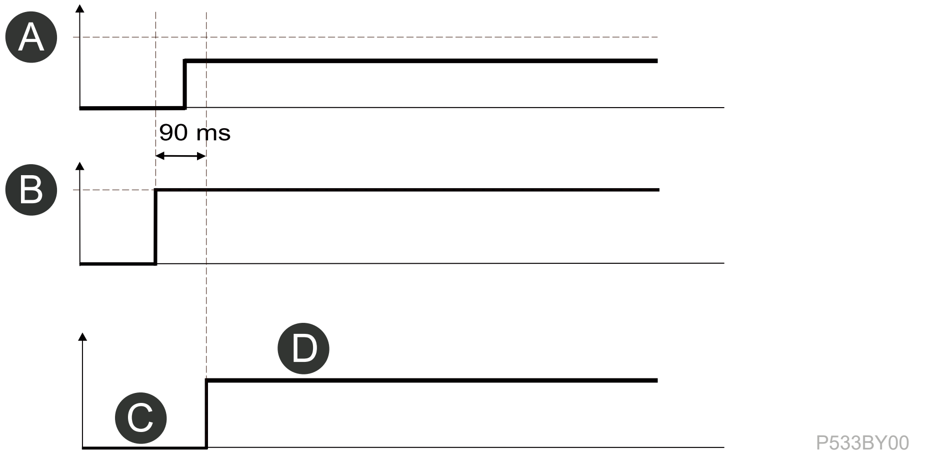
Typical diagrams for the detection of successful direct-on-line start and soft start are shown in the following diagrams, with the use of the “CB & Current” mode.

Figure 240 - Successful DOL start



A	Motor start detection current	B	CB Closed
C	Motor stopped	D	Motor starting
E	Motor running		

Figure 241 - Successful soft start



A	Motor start detection current	B	CB Closed
C	Motor stopped	D	Motor running

If the corresponding condition is satisfied in two consecutive executions, the motor status is changed.

General settings

Settings (description/label)	**Value**
Nom motor start current/Imot nom start	
Setting range	1.50...10.00 pu[84]
Resolution	0.01 pu[84]
Motor start detection current/I_{start}>	
Setting range	0.10...10.00 pu[84]
Resolution	0.01 pu[84]
Reset ratio	95% ± 2%
Minimum hysteresis	5 mA secondary
Motor start detection mode/StrDetMod	
Options	CB Position; Current; CB & Current

---

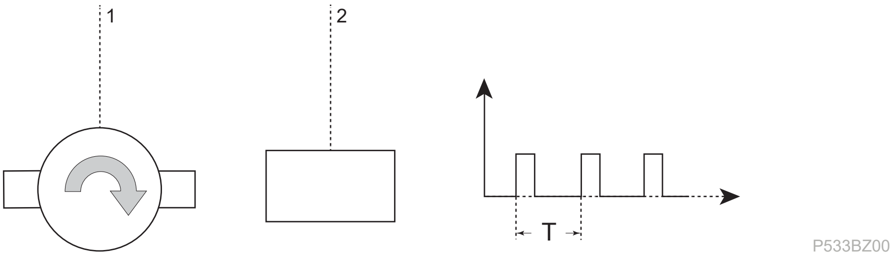
[84] I_{nom}

Motor speed detection

Description

Motor rotation speed (Ω) can be measured based on cams mounted on a rotor with a proximity sensor. The output from the proximity sensor is a train of electrical pulses, where each pulse corresponds to the detection of an individual cam. Hence, if a given application has R number of cams mounted 360º/R apart on a rotor, the number of cams R is equal to the number of pulses per rotation of the rotor shaft. The time interval T (in seconds) between consecutive pulses can be used to calculate the revolutions per minutes (rpm), using: $\Omega = 60 / (R \times T)$.

Figure 242 - Proximity sensor



1 Rotor with 2 cams

2 Proximity sensor

Table 80 - Characteristics of proximity sensor

Characteristics	Values
Pass-band (in Hz)	> 2 Ω_{NOM} x R/60 Ω_{NOM} is rated motor rotation speed.
Output	24...250 V DC, 3 mA minimum
Leakage current in open status	< 0.5 mA
Voltage dip in closed status	< 4 V (with 24 V power supply)
Pulse duration	0 status > 120 µs 1 status > 200 µs

The proximity detector output pulses are at a voltage level which is compatible with the logic inputs (24...240 V DC), which means that a logic input must be mapped to a given proximity detector to perform the speed measurement. The 12I4O module contains a specific digital input (DI1) to detect the motor speed. It can recognize the high voltage signal as status 1 with > 200 us pulse width and the low voltage signal as status 0 with > 120 us pulse width.

PowerLogic P5 protection relay can only use one speed detection input. If several 12I4O modules (such as Slot C, Slot D, Slot E) are fitted in the PowerLogic P5 protection relay, the user can select the dedicated digital input from any of the 12I4O modules for motor speed detection. If there is no 12I4O module fitted in the relay, the motor speed detection and motor overspeed / underspeed protection will be invisible.

NOTICE

UNINTENDED EQUIPMENT OPERATION

If the counting input DI1 on 12I4O is selected for motor speed detection, this input cannot be used by any other protection functions.

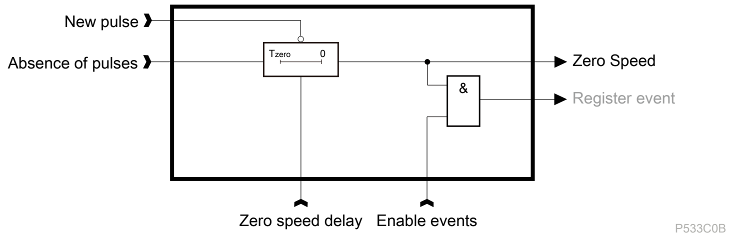
Failure to follow this instruction can result in equipment damage.

When the motor speed detection function is Enabled and one specific digital input is selected as motor speed input, the settings, such as “Delay”, “On Event”, “OFF Event” and “Debounce” settings in “Control/digital inputs” are automatically noneffective for this selected digital input.

This function provides an output signal “Zero speed”. If the PowerLogic P5 protection relay does not detect the pulse from the proximity sensor for motor speed measurement for a settable duration, the zero speed output signal is ON.

Block diagram

Figure 243 - Block diagram of zero speed detection



Characteristics

Table 81 - Settings and characteristics of motor speed detection protection

Settings/characteristics (description/label)	Values
Motor speed input/Speed input	
Options	Selection of DI for motor speed • PowerLogic P5U20 12I4O DI1 on Slot C • PowerLogic P5M30 12I4O DI1 on Slot C, D, E This selection is dependent on the hardware configuration of the device.
Rated motor speed Ω_{NOM}/Ω_{NOM}	
Setting range	100...3600 rpm
Resolution	1 rpm
Pulse per rotation/R	
Setting range	1...900 (with limitation Ω_{NOM} x R / 60 ≤ 1500)
Resolution	1
Zero speed confirm time/Zero speed delay	
Setting range	1...300 s
Resolution	1 s
Accuracy	±2% or ±150 ms
Motor speed measurement	
Range	0...7200 rpm
Resolution	1 rpm
Accuracy	±1 rpm
Refresh interval	1 s
Measurement time	100 ms
Setting group/SetGrp	
Number	1

Motor start time supervision (ANSI 48)

Description

The motor start time supervision protection function (ANSI code 48) helps to protect the motor against prolonged direct-on-line (DOL) starts caused by, for example, a stalled rotor, too high inertia of the load or too low voltage.

During the motor starting, the current exceeds the motor full load current and motor thermal stress increases quickly. So motor overheating is possible if the duration of the motor starting exceeds the set period.

This function is sensitive to the fundamental frequency component of the phase currents.

The motor start time supervision protection 48 measures the fundamental frequency component of the phase currents.

The 48 stage can be configured for definite operate time or dependent operate time characteristic. For a weak voltage supply, the dependent characteristic is useful allowing more start time when a voltage drop decreases the start current and increases the start time. Equation 7.7 defines the dependent operate time. Example of an dependent operation time of the motor start time supervision protection function, page 364 shows an example of the dependent characteristic. If the measured current is less than the specified start current I_{start}, the operate time is longer than the specified start time T_{start}.

$$T = \left(\frac{I_{nomMotSt}}{I}\right)^2 \times T_{start}$$

P533C100 Equation 7.7

Where:

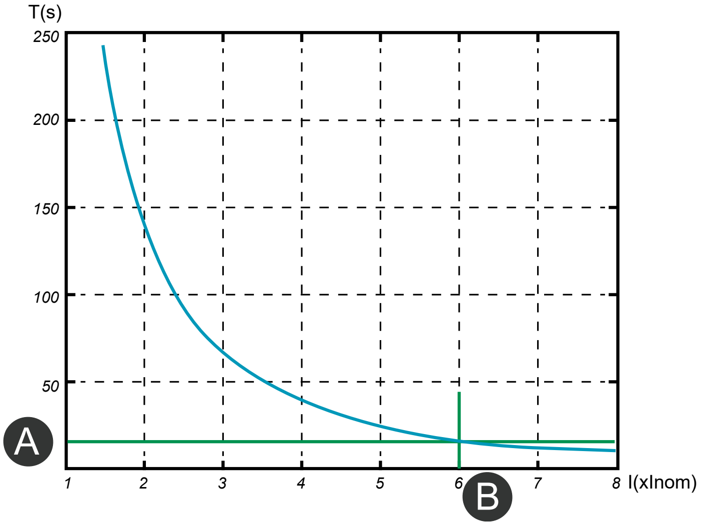
T = Dependent operate time

$I_{nomMotSt}$ = Nominal motor start current

I = Maximum of IA, IB, IC

T_{start} = Motor start time

Figure 244 - Example of an dependent operation time of the motor start time supervision protection function



A533C200

A	T_{start} = 15 s, maximum allowed start time.	B	I_{start} = 6 x Inom, rated start current.

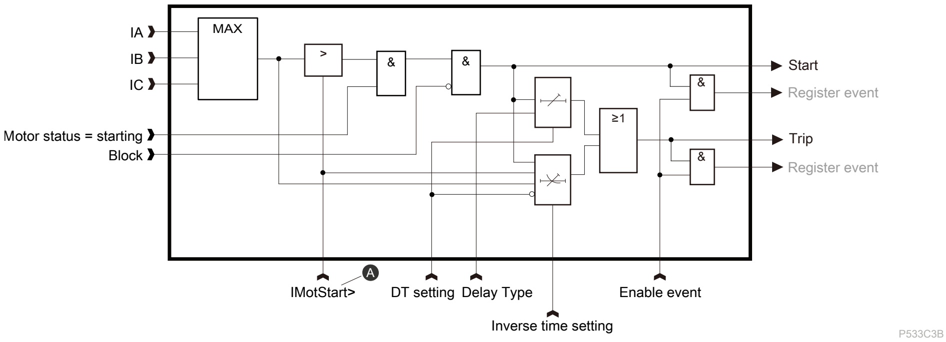
NOTE:

The pick-up current setting I_{start}> is the start detection level of the start current. While the motor status is starting and the current exceeds the pick-up setting I_{start}>, the motor start-up supervision stage starts to count the operate time.

When current drops below the setting I_{start}>, the motor start-up supervision stage releases. Motor start-up supervision is active only during the starting of the motor.

Block diagram

Figure 245 - Block diagram of the motor start time supervision function (ANSI 48)



A	IMotStr is set in motor status function as motor start detection current.

Characteristics

Table 82 - Settings and characteristics of the motor start time supervision protection stage 48-1

Settings/characteristics (description/label)	Value
Operating curve/Delay type	
Options	DT (definite time); INV (inverse time)
Motor start time/Motor start operate time delay	
Setting range	1.0...300.0 s
Resolution	0.1 s
Accuracy	±1% or ±20 ms (DT) ±5% or ±20 ms (INV)
Characteristic times	
Start time	< 70 ms (65 ms with high speed)
Disengaging time	< 85 ms (100 ms with high speed)
Setting groups/SetGrp	
Number	1

NOTE: For motor start detection current and nominal start current settings, see Motor status, page 358.

Thermal overload protection for machine (ANSI 49M)

Description

The Thermal Overload protection function for machine (ANSI code 49M) can be applied to help prevent damage on the stator and rotor against overloading conditions due to balanced and unbalanced currents.

- The PowerLogic P5 protection relays designed for protecting machines incorporate a current based thermal replica, using phase current to reproduce the heating and cooling of the equipment to be protected. In this case, the PowerLogic P5 protection relay automatically uses the highest phase current as input information for the thermal model. The current measurement is based on 3 phase RMS currents, that takes into account harmonic rank up to 15. The mathematical model used to compute the thermal level of the protected equipment is based on the thermal model defined in the IEC 60255-149 standard.
- The thermal replica takes into account the overheating generated by the negative sequence current in the motor, with a weighting defined by a settable coefficient, depending on the motor characteristics.
- The thermal replica provides the capability to set two heating time constants, one for starting sequence or the phase current is greater than the motor start threshold (e.g. locked stator in running state) and one for normal running, in addition to the cooling time constant applied when the motor is stopped. The selection of the time constants are decided according to the motor state input from the motor status function. Besides, the time constant τ_2 is also decided by the max phase current which is greater than the motor start value. Indication of the time constant τ_1 and time constant τ_2 active is provided by means of digital outputs.
- The thermal replica can optionally take account of ambient temperature, preferably when an ambient temperature sensor is available. However, where an ambient temperature sensor is not available, the user may enter a default value for ambient temperature which is different to the value defined in the protected equipment data sheet (for example, to take account of summer and winter ambient temperature values).

NOTE: The motor thermal level in thermal overload (ANSI code 49M) function can be reset by Modbus communication.

The Thermal Overload for machine protection can be used in two different setting modes:

- Current based setting mode
- Temperature based setting mode

The following sections explain the two setting modes.

Current based setting mode

This setting mode is active when "Operating mode" is set to "Current". In this setting mode, the thermal level H(t) is computed according to the thermal model defined in the IEC 60255-149.

According to the user settings, in general, the thermal level is computed by three different ways according to the three different motor states:

- Running state
- Starting state
- Stopped state

Motor in running state

When the motor is running, the thermal level H(t) is computed according to the following equation:

$$H(t) = H(t - \Delta t) + (\frac{I_{eq}(t)}{k \times I_b})^2 \times \frac{\Delta t}{\tau_1} - H(t - \Delta t) \times \frac{\Delta t}{\tau_1}$$

P533C400

where:

- H(t) is the thermal level computed at time t.
- H(t - Δt) is the thermal level computed at time t - Δt.
- $$I_{eq} = \sqrt{max\ (IA,IB,IC)^2 + q \times (I2)^2}$$

  P533C500

  where:

  - IA, IB, IC are the RMS phase currents.
  - q is a user setting to define the unbalance factor ("Unbalance factor" or "Factor q").

    For an asynchronous motor, q is determined as follows:

    $$q = 2 \times \frac{T_{LR} / I_{LR}^2}{S_n} - 1$$

    P533C600

    I_{LR} is the motor locked rotor current/ starting current in pu value.

    T_{LR} is the motor locked rotor torque in pu value.

    S_n is rated slip.

    NOTE: In 2 CT mode it is recommended to set q = 0.
  - I2 is the negative sequence current.

    NOTE: The actual measured equivalent current is displayed as I% load = I_{eq} / (k x I_b) in the function.
- I_b is the "Base current" or "Machine nominal current".
- k is the “Max. permissive current factor” or the "k" factor applied to the basic current to define the maximum continuous current.
- τ_1 is the heating thermal time constant of the motor ("Heating time constant 1" or "Time constant τ_1"), where τ_1 is assumed to be much greater than Δt.

In the equation above the term "$[I_{eq}(t) / (k \times I_b)]^2 \times \Delta t / \tau_1$" expresses the heat transfer due to the phase current $I_{eq}(t)$, and the term "H(t - Δt) x Δt / τ_1" expresses the natural cooling of the devices (in the running state).

The digital output Motor TC1 active is asserted in this state.

Motor in starting state

When the motor is starting, the user can set a different time constant, to take into account the heating effect on rotor windings during the starting sequence. In that state, the thermal level H(t) is computed according to the same equation than above, where the time constant τ_1 is replaced by the time constant τ_2.

$$H(t) = H(t - \Delta t) + (\frac{I_{eq}(t)}{k \times I_b})^2 \times \frac{\Delta t}{\tau_2} - H(t - \Delta t) \times \frac{\Delta t}{\tau_2}$$

P533C700

Where τ_2 is the heating time constant during starting sequence or the phase currents is greater than the motor start threshold ("Heating time constant 2" or "Time constant τ_2").

The digital output Motor TC2 active is asserted in this state.

Motor in stopped state

When the motor is stopped, the cooling effect is dominant since there is no heating contribution, so a cooling time constant must be taken into account in the stopped state. In that state, the thermal level H(t) is computed according to the following equation:

$$H(t) = H(t - \Delta t) - H(t - \Delta t) \times \frac{\Delta t}{\tau_3}$$

P533C800

Where τ_3 is the cooling thermal time constant of the protected equipment ("Cooling time constant" or "Time constant τ_3").

The digital outputs Motor TC1 active and Motor TC2 active are reset in this state.

The thermal overload protection operates when the thermal level is greater than 100%. This thermal level of 100% can be reached with a permanent current above the basic current value ("Base current" or "I_b") multiplied by the k factor (Max. permissive current factor).

With a continuous load current "I_{eq}", the thermal level "H" is equal to:

$$H(I_{eq}) = \left(\frac{I_{eq}}{k \times I_b}\right)^2$$

P533BN00

The table below indicates the thermal level with different values of continuous load current:

I_{eq} / (k x I_b) ratio	Thermal Level (%)
1	100% (operation)
0.9	81%
0.8	64%
0.7	49%
0.6	36%
0.5	25%
0.4	16%
0.3	9%

Generally, the base current I_b is set to the motor rated current, and overload factor k should be set to take into account the motor overload capability. For motors with the service factor as 1.0 and thermal class F/B, the overload factor k is 1.15.

An thermal alarm ("49M alarm" output) is provided which operates when the thermal level is greater than or equal to the "Thermal alarm value" setting (expressed in %) and is usually set to be lower than 100%, the operate level. This signal can be used to lock the CB reclosing until thermal state is back under the alarm level.

The thermal level in % is accessible as an output measurement.

When thermal overload is managed in the several setting groups, the thermal level is kept after the setting group change (no thermal level reset), and the thermal level is computed according to the new settings.

Temperature based setting mode

This setting mode is active when "Operating mode" setting is set to "Ambient". In this setting mode, the protected equipment temperature computation is based on the previous thermal level H(t) calculation (see previous section Current based setting mode, page 366) with an additional reference to the maximum operating temperature of the equipment, the nominal ambient temperature and the working ambient temperature, defined by setting.

In this mode, the thermal level H(t) is computed with the following formula, derived from the equation of thermal level H(t) calculation:

$$H(t) = H(t - \Delta t) + F_a \times \left(\frac{I_{eq}(t)}{k \times I_b}\right)^2 \times \frac{\Delta t}{\tau} - H(t - \Delta t) \times \frac{\Delta t}{\tau}$$

P533BQ00

Where common values are identical to the thermal level H(t) calculation formula, and the additional "F_a" ambient temperature factor is defined with the following equation:

$$F_a = \frac{T_{max} - T_{nom}}{T_{max} - T_a}$$

P533BR00

where:

- T_{max} is the maximum temperature of the equipment ("Max object temperature" setting).
- T_{nom} is the limit of the ambient temperature designed for the protected equipment to operate at rated loads without causing thermal degradation of insulation ("Nominal ambient temperature" setting, typically equal to 40 °C).
- T_a is the real time ambient temperature of the protected equipment measured with the RTD number 8.

The ambient temperature of the protected equipment is computed with the following formula:

$$T_{object} = H(t) \times (T_{max} - T_a) + T_a$$

P533BS00

Where H(t), T_{max} and T_a are defined according to the previous equations.

The thermal overload protection operates when the computed temperature "T_{object}" is above or equals the maximum temperature T_{max}.

A temperature alarm is provided ("49M T> alarm" output). This output operates when the temperature level is greater than or equal to the alarm temperature setting(expressed in °C).

The ambient temperature (T_a) and machine temperature (T_{object}) are accessible as output measurements in °C (T_a = "Ambient temperature" output and T_{object} = "Machine temperature" output).

Additional features

The thermal level computation expressed in % is always available with the motor thermal level output. The current thermal level is saved in a non volatile memory when the PowerLogic P5 protection relay is powered off. If the current thermal level is above 90%, a value of 90% is memorized to help prevent possible nuisance tripping on supply restoration.

A measurement output about the remaining time to trip ("Estimated time to trip") is provided, based on the hypothesis that the load current present remains constant until thermal overload operation occurs.

A time remaining alarm ("49M rsv alarm" output) is provided. It operates when the calculated remaining time is less than or equal to the "Reserve time thermal alarm" time setting.

A remote command can be used to reset the thermal level (e.g. after commissioning tests). This reset can be also performed from the local panel.

It is possible to block the protection function using the block matrix.

After each motor start sequence, the function is able to compute the thermal level consumed by the latest start. This measurement is accessible with the measurement output "Motor start thermal level/Motor start H(t)". When the thermal level calculation is above (100% - Motor start H(t)), the output signal "Block motor start" is asserted to inhibit CB Closing from taking place. The output time measurement output "Time left for motor start" provides the remaining time until the motor can be started.

There is a digital input (“MThLevRst” signal) to reset the thermal level value, when the digital input is asserted, the value of Thermal level H(t) shall be set to Zero.

Conditions (defined by settings)	**Impact on thermal level computation**
Stopped state	$I_{eq}(t) = 0$ Cooling time constant τ_3 is used
I > MotStrVal setting or starting state	Heating time constant 1 τ_2 is used
Running state and I < MotStrVal	Heating time constant 1 τ_1 is used

Time to trip calculation

For a continuous current higher than the current threshold (k x I_b), the operate time of the thermal overload protection can be computed with the following equation:

$$t = \tau \times L_n \times \left(\frac{F_a \times H(I_{eq}) - H_0}{F_a \times H(I_{eq}) - 100\%} \right)$$

P533BO00

where:

- τ is the heating time constant for the protected equipment.
  - When the motor is in starting state, the heating time constant 2 is used;
  - When the motor is in running state, the heating time constant 1 is used;
- L_n( ) is natural logarithm function.
- F_a is the ongoing temperature compensation. In current based setting mode, $F_a = 1$.
- $H(I_{eq})$ is the thermal level calculated with the continuous load current and the base current.
- H_0 is the current thermal state corresponding to the last calculation.

In the same way, for a continuous current higher than the current threshold (k x I_b), the time for the alarm to operate is:

$$t = \tau \times L_n \times \left(\frac{F_a \times H(I_{eq}) - H_0}{F_a \times H(I_{eq}) - H_{alarm}} \right)$$

P533BT00

where:

H_{alarm} is "Alarm", the alarm threshold setting in % of thermal level. In temperature based setting mode, the threshold alarm threshold is expressed in °C with "T_{alm}" setting. The corresponding thermal level in % (H_{alarm}) is defined by the following equation:

$$H_{alarm} = \frac{T_{alm} - T_a}{T_{max} - T_a} \times 100\%$$

P533BU00

Time left for motor start

The thermal level of last motor start state need firstly be calculated through following equation:

$$H_{start} = F_a \times \left(\frac{I_{start}}{k \times I_b} \right)^2 \times \frac{t_{start}}{\tau_{start}}$$

P533Q100

where:

- F_a is ambient temperature factor calculated by:

  $$F_a = \frac{T_{max} - T_{nom}}{T_{max} - T_a}$$

  P533BR00

  If it is current only mode, then $F_a = 1$.

- I_{start} is the start current detected during last motor start.
- I_b is the basic current of the machine (setting).
- k is the factor (setting) applied to the basic current to define the maximum continuous current.
- t_{start} is the time duration of motor starting state.
- τ_2 is the heating time constant 2.

When the thermal level H(t) is above (100% - H_{start}), time left for motor start is defined with the following equation:

$$t = \tau_{cooling} \times L_n\left(\frac{H(t)}{100\% - H_{start}}\right)$$

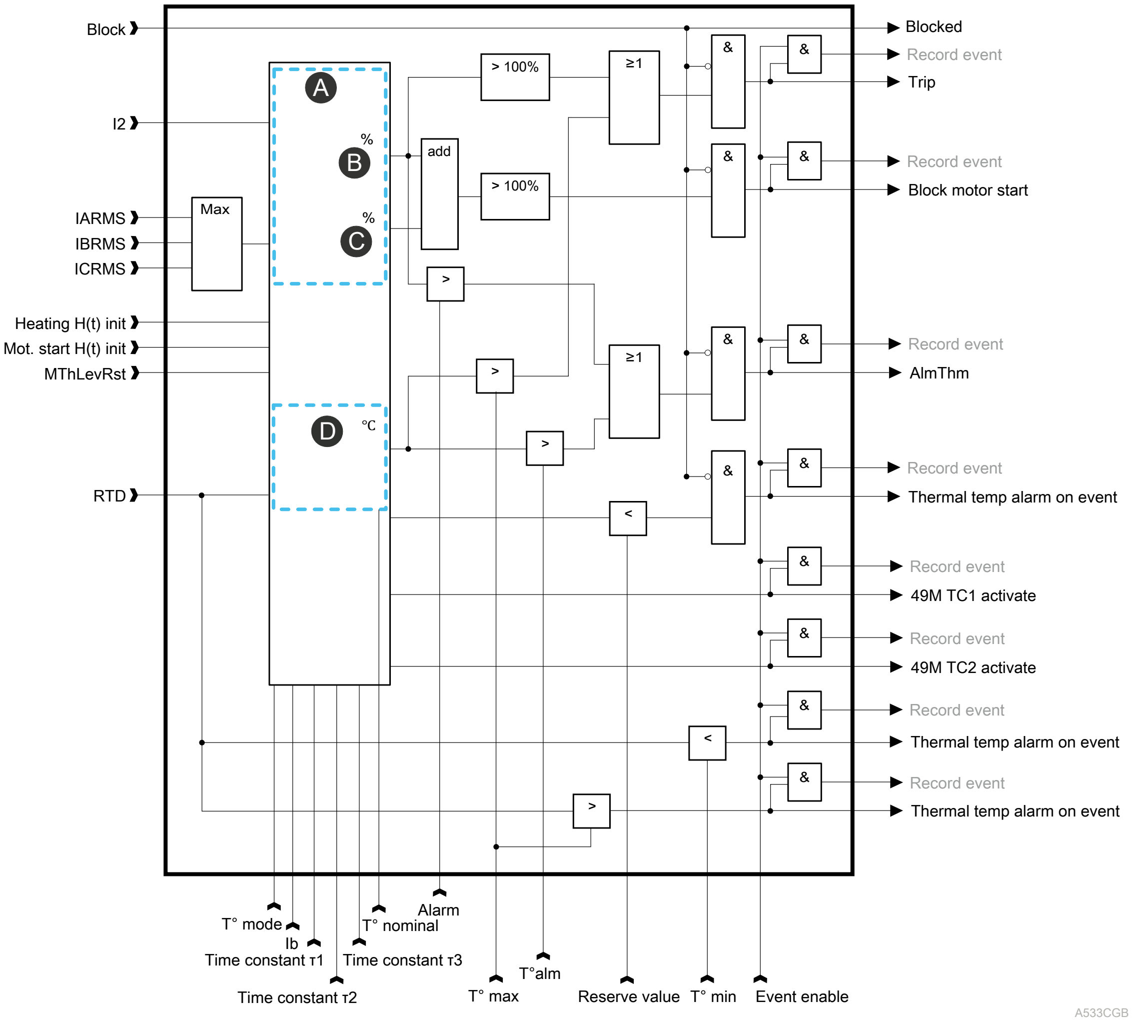
P533Q200

where:

- H(t) is the thermal level calculated at the moment.
- τ_3 is the cooling time constant when motor is stopped.

Block diagram

Figure 246 - Block diagram of thermal overload protection function (ANSI 49M)



A	Current based mode calculation	B	Therm level
C	Motor str level	D	Temperature based mode calculation

Characteristics

Table 83 - Settings and characteristics of the thermal overload protection stage 49M

Settings/characteristics (description/label)	Values
Base current/I_b	
Setting range	0.1...4.0 pu[85]
Resolution	0.01 pu[85]
Overload factor k/Factor k	
Setting range	0.10...1.50
Resolution	0.01
Heating time constant 1/Time constant Ţ1	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Heating time constant 2/Time constant Ţ2	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Cooling time constant/Time constant Ţ3	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Unbalance factor/Unbalance factor	
Setting range	0.0...10.0
Resolution	0.1
Thermal alarm value/Alarm	
Setting range	50%...100% of thermal level
Resolution	1%
Reserve time thermal alarm/Reserve value	
Setting range	1.0...1000.0 min
Resolution	0.1 min
Operating mode/T°mode	
Options	Current; Ambient
Nominal ambient temperature/T° nominal	
Setting range	-40...+300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Max object temperature/T° max	
Setting range	-40...+300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Alarm temperature/T° alm	
Setting range	0...+300 °C (32...+572 °F)
Resolution	1 °C (1.8 °F)

---

[85] I_{nom}

Table 83 - Settings and characteristics of the thermal overload protection stage 49M (Continued)

Settings/characteristics (description/label)	Values
Min ambient temperature/T° min	
Setting range	-40...300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Default ambient temperature/T° dft ambient	
Setting range	-40...300 °C (-40...+572 °F)
Resolution	1 °C (1.8 °F)
Characteristics	
Tripping time accuracy	±5% or ±500 ms (with the applicable factor according to IEC 60255-149)
Setting group/SetGrp	
Number	4

NOTE: To test the thermal overload protection more easily and faster, it is possible to set a thermal level init. value and a motor start thermal level init. value from 0% to 90%. After test, it is possible to reset the values to 0%.

Locked rotor (ANSI 51LR)

Description

The locked rotor protection function (ANSI code 51LR) stage 51LR measures the fundamental frequency component of the phase currents and calculates the maximum of the measured three phase currents.

The locked rotor stage protects the motor when too heavy load or a mechanical failure of the motor causes rotor jam during the motor running condition.

The stage's start setting is relative to the motor's nominal starting current. The nominal starting current can be configured in the **Motor status** view of the **Protection** menu in eSetup Easergy Pro.

The locked rotor stage can be configured for definite time or inverse time operation characteristic. *Equation 7.8* defines the dependent operate time.

$$T = \left(\frac{I_{motNomSt}}{I}\right)^2 T_{start}$$

P533FN00 Equation 7.8

T = Dependent operate time

$I_{motNomSt}$ = Nominal motor start current

I = Maximum of IA, IB, IC (to be unique with 48 function)

T_{start} = Operation delay

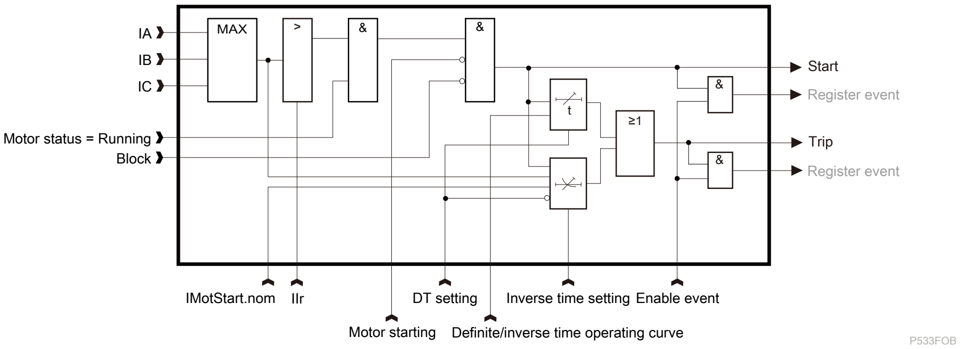
When the measured maximum phase current I exceeds the defined start setting, the locked rotor protection stage starts operation delay calculation. When the calculated delay exceeds the operation delay in DT or INV delay mode, the protection operates.

The stage releases when the maximum phase current I drops below the start setting.

The stage operation is automatically blocked when the motor status is “starting”.

Block diagram

Figure 247 - Block diagram of the locked rotor protection stage 51LR



Characteristics

Table 84 - Settings and characteristics of the locked rotor protection stage 51LR-1

Settings/characteristics (description/label)	Values
Pick-up value/I_{lr}>	
Setting range	10%...100% IMotStart.nom[86]
Resolution	0.1%[86]
Accuracy	±3%[86]
Reset ratio	97% ± 2%
Operating curve/Delay type	
Options	DT (definite time); INV (inverse time)
Operate delay/Operate delay	
Setting range	1.0...300 s
Resolution	0.1 s
Accuracy	±1% or ±20 ms (DT) ±5% or ±20 ms (INV)
Characteristic times	
Start time	< 60 ms (55 ms with high speed) for currents at 2 x I_{lr} < 70 ms (65 ms with high speed) maximum
Disengaging time	< 85 ms (100 ms with high speed)
Setting group/SetGrp	
Number	1

---

[86] IMotStr.nom is set in motor status function.

Motor restart inhibition (ANSI 66)

Description

Any motor has a restriction on the number of starts within a defined period to avoid the over temperature of the motor, mainly inside the rotor. A settable time interval between two consecutive starts is also necessary to allow the motor to cool down following the previous start. The motor restart inhibition function (ANSI code 66) includes two elements “number of starts limitation” and “minimum time between starts”.

To enable the motor restart inhibition function (ANSI code 66), as well as other protection functions (ANSI 48, ANSI 49M, ANSI 51LR), which are all related with motor, the “Motor status” detection function shall be enabled. Since the motor restart inhibition function uses the “Thermal Level” input to differentiate between motor cold start and hot start, the motor thermal overload protection (ANSI 49M) must also be enabled.

Number of starts limitation

Depending on the initial motor thermal level, there are two types of motor start.

- Cold start

  The initial thermal state is not greater than setting “Hot status limit”.

- Hot start

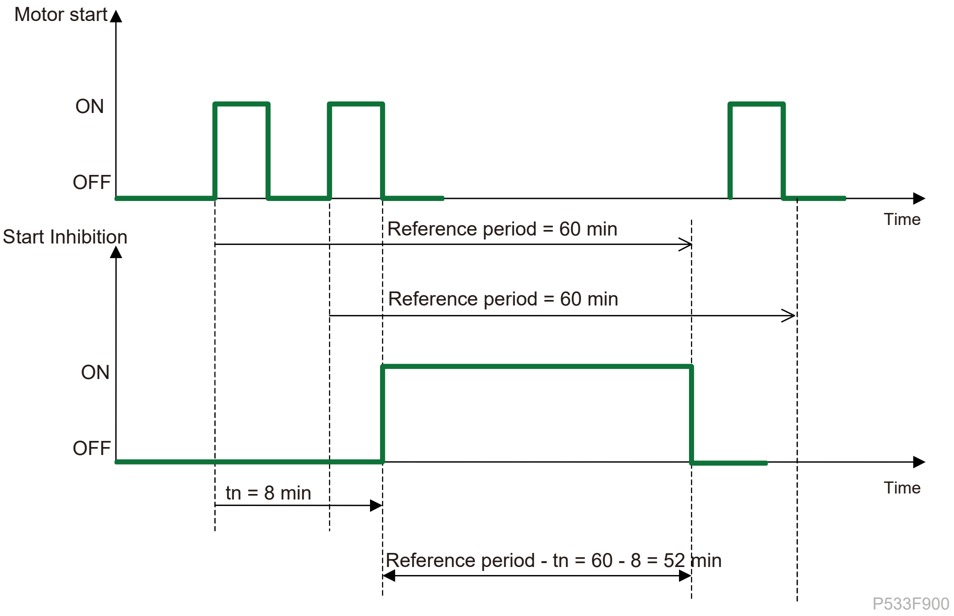
  The initial thermal state is greater than setting “Hot status limit”.

Once the motor start is detected (refer to Motor status section for details), the PowerLogic P5 protection relay initiates a monitor timer defined by the setting “Reference period”, and the cold start counter or hot start counter is incremented by one. Each motor start has one corresponding monitor timer. When the monitor timer expires, the motor start related with that monitor timer will be removed from the cold or hot start counter (decremented by one). When the motor is stopped, the PowerLogic P5 protection relay will compare the cold and hot start counters with the settings “Max motor cold starts” and “Max motor hot starts”, respectively. If either of these two counters reaches the related setting, the motor restart is inhibited (“N> motor start inhibition” = True) until the concerned monitor timer expires and the cold or hot start counter is below the setting.

Example:

The maximum number of motor cold starts is 2 and maximum number of motor hot starts is 1. Two cold starts are detected. When the 2nd motor stop is detected, the cold start counter reaches the setting. So, motor restart is inhibited until the first monitor timer expires.

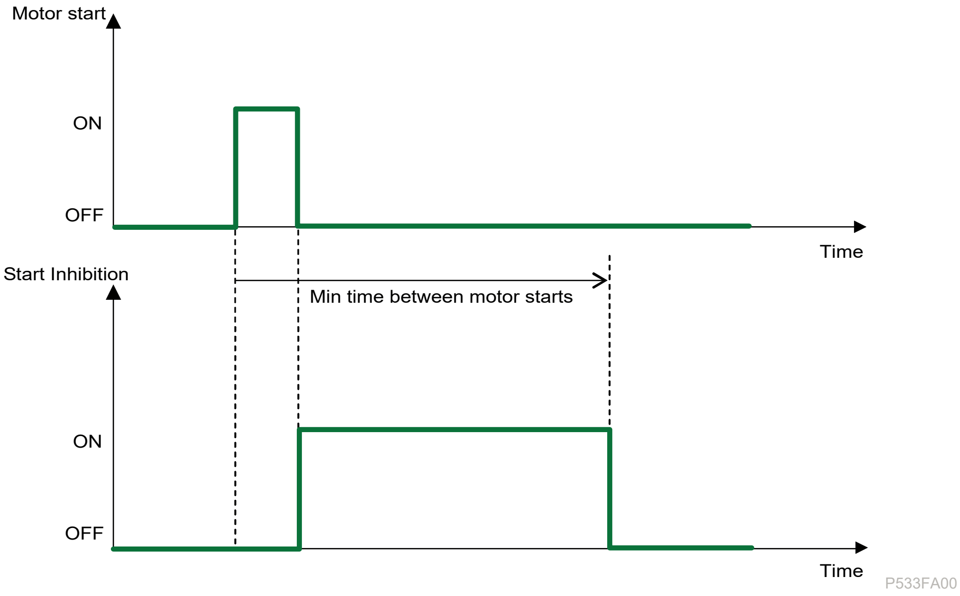
Figure 248 - Motor restart inhibition example 1



Minimum time between starts

Once the motor start is detected (refer to Motor status section for details), the PowerLogic P5 protection relay initiates another monitor timer defined by setting “Min time between motor starts”. When the motor is stopped (CB is open or current is less than 5% Inom depending on the motor start detection mode), and the monitor timer of the last motor start has not expired, the PowerLogic P5 will also inhibit the restart until the monitor timer expires.

Figure 249 - Motor restart inhibition example 2



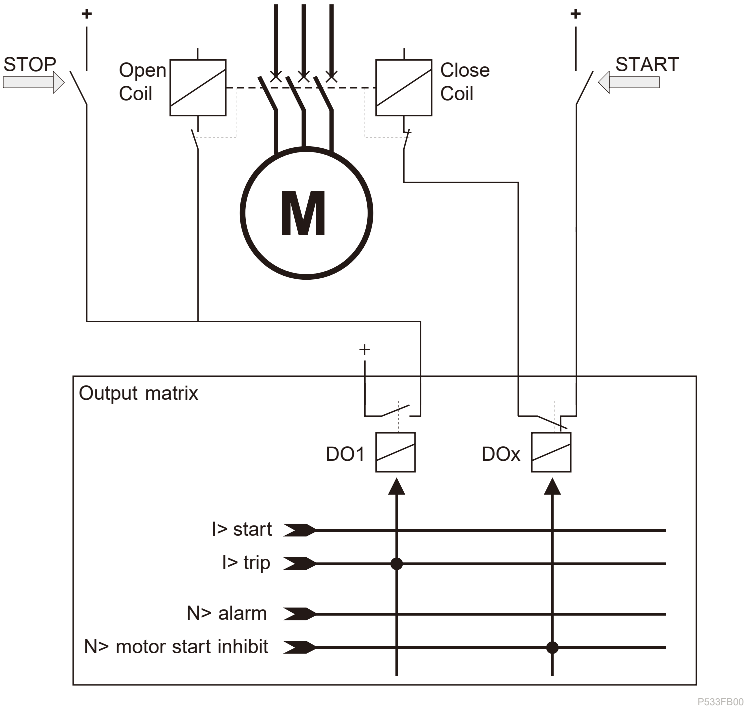
So, the motor restart inhibition function is active if any one of the following conditions is satisfied:

- Blocking due to number of starts limitation
- Blocking due to minimum time between 2 starts

Motor connection example

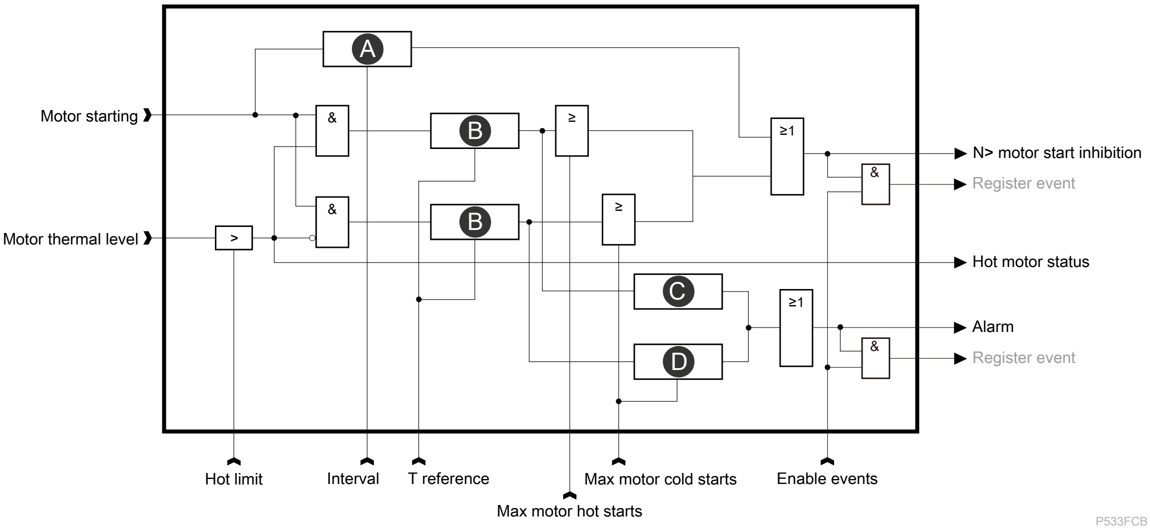
Motor restart inhibition application example, page 378 shows an application for preventing too frequent motor starts using the 66-1 stage. The close coil wire has been connected through the normally closed (NC) contact of the signal relay , which is controlled with the N> start inhibit signal. Whenever the N> motor start inhibit signal becomes active, it prevents the circuit breaker from closing.

Figure 250 - Motor restart inhibition application example



Block diagram

Figure 251 - Block diagram of the motor restart inhibition function (ANSI 66)



A	Min. time between motor starts	B	Count num. during reference period
C	≥ Hot starts/t -1	D	≥ Cold starts/t -1

Characteristics

Table 85 - Settings and characteristics of the motor restart inhibition function (ANSI 66)

Settings/characteristics (description/label)	Values
Reference period/T reference	
Setting range	10.0...120.0 min
Resolution	0.1 min
Hot status limit/Hot limit	
Setting range	0%...100.0% H(t)[87]
Resolution	0.1% H(t)[87]
Max motor/Hot starts	
Setting range	1...20
Resolution	1
Max motor/Cold starts	
Setting range	1...20
Resolution	1
Min time between motor starts/Interval	
Setting range	0.0...100.0 min
Resolution	0.1 min
Def. motor start elap. time/Time by default	
Options	0 min; 120 min
Setting groups/SetGrp	
Number	1

---

[87] Motor thermal level

Motor overspeed (ANSI 12)

Description

Based on the direct measurement of motor speed, the motor overspeed protection function (ANSI code 12) detects racing when the motor is driven by the load, or a loss of synchronization for synchronous motors, or for process monitoring.

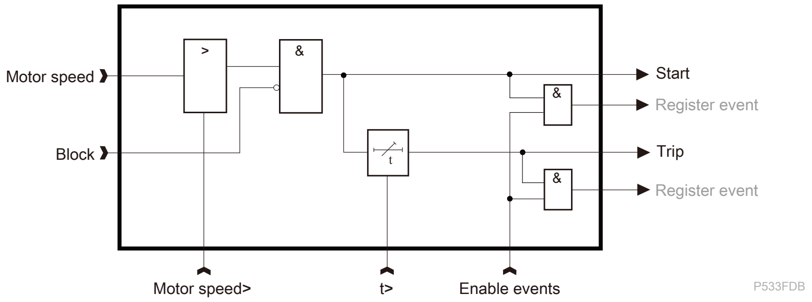
Motor overspeed protection is only available when motor speed detection function is Enabled.

The PowerLogic P5 protection relay provides two stages of motor overspeed protection. Whenever the motor speed reaches the pick-up value of a particular stage, this stage starts and a start signal is issued. If the fault remains active longer than the operating delay setting, a trip signal is issued.

If there is no 12I4O module fitted in the relay, the motor overspeed protection will be invisible.

Block diagram

Figure 252 - Block diagram of the motor overspeed stages Motor overspeed 12-1 and 12-2



Characteristics

Table 86 - Settings and characteristics of the motor overspeed protection function (ANSI 12)

Settings/characteristics (description/label)	Values (stage Motor overspeed 12-1)	Values (stage Motor overspeed 12-2)
Pick-up value		
Setting range	100%...160% Ω_{NOM}	
Resolution	1% Ω_{NOM}	
Accuracy	±2%	
Reset ratio	95% ± 2%	
Operate delay		
Setting range	1...300 s	
Resolution	1 s	
Accuracy	±1% or ±25 ms	
Characteristic times		
Start time	< 250 ms + 2 x (60000 ms/ (Ω x R))	
Disengaging time	< 250 ms + 2 x (60000 ms/ (Ω x R))	

Table 86 - Settings and characteristics of the motor overspeed protection function (ANSI 12) (Continued)

Settings/characteristics (description/label)	Values (stage Motor overspeed 12-1)	Values (stage Motor overspeed 12-2)
Setting group/SetGrp		
Number	1	

Motor underspeed (ANSI 14)

Description

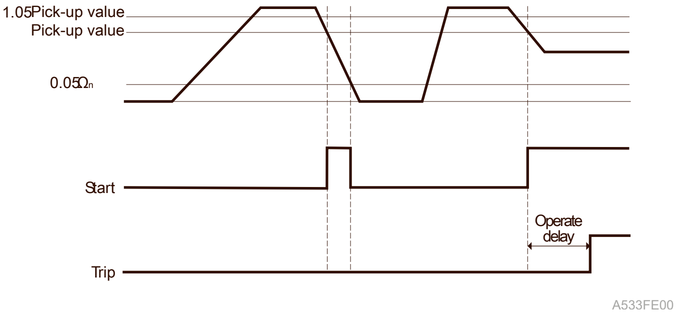
Based on the direct measurement of motor speed, the motor underspeed protection function (ANSI code 14) detects the slow-downs of motor speed after motor starting, possibly resulting from the mechanical overloads or locked rotor.

Motor speed protection is only available when motor speed detection function is Enabled.

The motor underspeed protection is active after the motor speed has successful achieved the speed pick-up value. As shown in figure below, the underspeed protection function picks up if the speed measured drops below the speed pick-up value after having first exceeded the set point by 5%. The underspeed protection is blocked when the motor speed drops below 5% of Ω_{NOM} rated motor speed to avoid unwanted tripping when the motor is switched off. If the underspeed protection starts longer than the operating delay setting, a trip signal is issued.

If there is no 12I4O module fitted in the relay, the motor underspeed protection will be invisible.

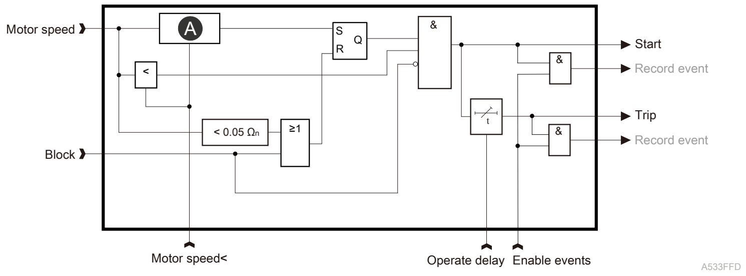
Figure 253 - Motor underspeed start and trip conditions



The PowerLogic P5 protection relay provides two stages of motor underspeed protection.

Block diagram

Figure 254 - Block diagram of the motor underspeed stages 14-1 and 14-2



A	> 1.05 Pick-up value

Characteristics

Table 87 - Settings and characteristics of the motor underspeed protection function (ANSI 14)

Settings/characteristics (description/label)	Values (stage 14-1)	Values (stage 14-2)
Pick-up value/,		
Setting range	10%...100% Ω_{NOM}	
Resolution	1% Ω_{NOM}	
Accuracy	±2%	
Reset ratio	105% ± 2%	
Low motor speed self-blocking		
Value	5% Ω_{NOM}, fixed	
Accuracy	±2% x (5% Ω_{NOM})	
Time delay/Operate delay		
Setting range	1...300 s	
Resolution	1 s	
Accuracy	±1% or ±25 ms	
Characteristic times		
Start time	< 250 ms + 2 x (60000 ms / (Ω x R))	
Disengaging time	< 250 ms + 2 x (60000 ms / (Ω x R))	
Setting group		
Number	1	

Motor Anti-backspin (ABS) protection

Description

For a motor with high inertia, once the CB/Contactor supplying power to the motor is switched off, the rotor may continue to turn for a considerable length of time. In that case, the motor terminal voltage is out of phase and the motor re-starting operation may result in serious damage. In some other applications for example when a motor is on a down-hole pump, after the motor stops, the liquid may fall back down the pipe and spin the rotor backwards. It would be very undesirable to start the motor at this time. In these circumstances the motor anti-backspin function is used to detect when the rotor has completely stopped, to allow restarting of the motor.

Three criteria can be used to detect whether rotor has completely stopped.

- Speed measured mode

  "Zero Speed" signal from motor speed detection function is ON. If there is no 12I4O module fitted in the relay, the speed measured mode will be invisible.
- External zero speed mode

  "Zero Speed DI" digital input is ON when a rotation detection sensor is available.
- Motor status

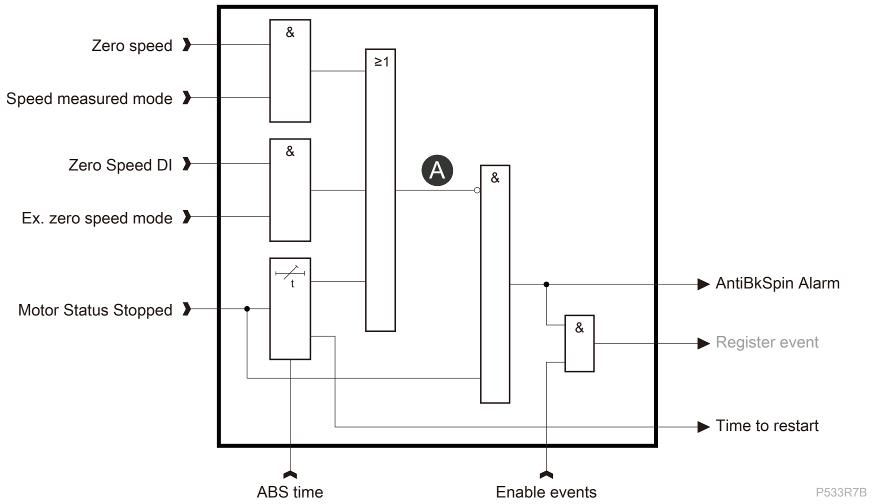
  Motor "Stopped" input from motor status function is ON and the delay timer expired.

When the "Zero Speed" input and the "Zero Speed DI" digital input are not available or disabled, this protection function simply provide a "Restart Delay" feature after the motor is stopped.

Only when "Motor Status" function is Enabled, "Motor Anti-backspin" protection can be activated. The output signal "AntiBkSpin Alarm" is ON when the motor status turns to be "Stopped" and the internal signal "ABSAllowRestart" is not satisfied. The "ABSAllowRestart" signal indicates if the rotor has completely stopped. The timer "Time to restart" is based on the setting "ABS Time" to indicate the left time before the motor restart is allowed. If the zero speed is detected, the timer "Time to restart" will be reset and the motor restart is allowed immediately.

Block diagram

Figure 255 - Block diagram of Motor Anti-backspin (ABS)



A	ABSAllowRestart

Characteristics

Table 88 - Settings and characteristics of Motor Anti-backspin (ABS) protection

Settings/characteristics (description/label)	Values
Measured zero speed mode/Speed measured mode	
Options	Enable; disable
Zero speed external mode/Ex. zero speed mode	
Options	Enable; disable
Zero speed input DI/Zero speed DI	
Options	Selection of one digital input (DIx)
Anti-backspin time/ABS time	
Setting range	1...7200 s
Resolution	1 s
Accuracy	±1% or ±25 ms
Setting group	
Number	1

Emergency restart

Description

It may be necessary to restart a hot motor when the system is in emergency. An emergency restart can be enabled through digital input/HMI/remote communication, then it removes all motor start inhibit. For a successful emergency restart, the emergency restart input should keep asserted during the whole motor starting period.

An operation counter is provided to record the number of emergency restarts. Emergency restart counter can be cleared via a command in HMI or remote communication.

When emergency restart is triggered, motor thermal overload protection (49M) responds to it

- When the motor is stopped, the signal “Block motor start” is reset and the motor thermal level is limited to **100% - Motor start thermal level** if the thermal level is higher than **100% - Motor start thermal level**.
- When the motor is starting, the thermal level is limited to 90%.
  Before the completion of motor starting, if the emergency restart is Off, the motor thermal level can increase to more than 90% during starting.
- When the motor is running, it has no impact on the motor thermal level.

When emergency restart is triggered, motor restart inhibition (66) protection responds to it

- When the motor is stopped, the signal “N> motor start inhibition” is reset and the value of emergency restart counter is incremented by 1.
- When the motor is starting, the detected motor start will neither impact the number of cold starts and hot starts nor trigger the timer of “Minimum time between motor starts”.
  If the emergency restart condition changes from On to Off prior to the completion of the motor starting, this motor starting is considered as a normal start.

  NOTE: The emergency restart will not impact the motor start counter and the minimum time between two starts.
- When the motor is running, it has no impact on motor restart inhibition (66).

When emergency restart is triggered, motor anti-back spin (ABS) protection responds to it

- When the motor is stopped, ABS works on timer between a stop and a start, then the signal “AntiBkSpin” is reset **(Measured zero speed mode** is OFF and **Zero speed external mode** is OFF).

  NOTE: The emergency restart will only impact ABS timer, it will not impact **Measured zero speed mode** and **Zero speed external mode.**
- When the motor is starting or running, it has no impact on ABS function.

Characteristics

Table 89 - Settings and characteristics of Emergency restart protection

Settings/characteristics (description/label)	Values
EMRE input/EMRE input	
Options	DIx; VIx; Fx

Inrush detection (ANSI 68H2)

Description

Second harmonic inrush blocking detects high transient current flows that usually occur when transformers are energized at no-load or the voltage is restored to the transformer after a brief voltage dip/interruption. It helps prevent tripping for this normal operation condition.

There are two ways to enable inrush blocking of protection functions:

- Within individual phase and neutral OC protection stages, check the **Inrush blocking** in any or all setting group(s).
- By using the Block Matrix, map the “inrush detection” signal to individual protection functions. This configuration is valid for all setting groups.

During transformer inrush conditions, the second harmonic level may not be the same for all phases. So PowerLogic P5 protection relay calculates the ratio between the second harmonic component and the fundamental frequency component for each phase. When the ratio of the second harmonic component of any phase is higher than the ratio setting, after a fixed delay (20 ms), the inrush detection signal will be activated and the inrush current will be discriminated.

There are two operating modes for inrush detection which is configured via the "Inrush operating mode" setting. When it is in the "Phase block" mode, after inrush current is detected, it will block the related overcurrent function only in that phase (or phases); when it is in the "Cross block" mode, if any phase inrush current is detected, it will block the related overcurrent function in all 3 phases.

To avoid maloperation, the inrush detection is only active if the phase current is greater than a fixed minimum current of 10% Inom. Otherwise, the output of the inrush detection is reset. As additional constraint, a maximum threshold current is settable. Currents above this threshold will bypass any inrush blocking. This threshold is set based on the transformer reactance. This reactance will limit any inrush current, therefore currents greater than this are treated as short circuits.

Conversely, to secure proper operation during evolving faults or for faults fed from sources with high amount of harmonics, any established overcurrent protection starting will block the inrush blocking function.

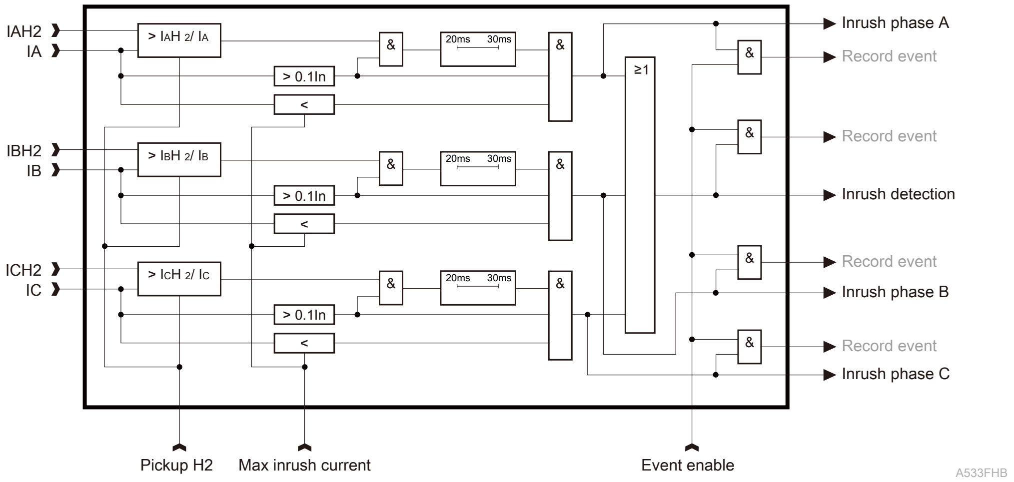
A fixed reset delay (30 ms) of the "inrush detection" signal is implemented to avoid signal chattering and potential maloperation because of too fast unblocking the protection stages, especially at the end of the inrush condition.

The inrush blocking signal requires the presence of second harmonic current for 1 period (20 ms). Similarly the reset of this condition requires the absence of second harmonic component for 30 ms.

In transformer differential protection application P5T30 two stages of this inrush blocking function are available with common functionality. Each stage evaluates the currents from one end and determines inrush condition and its inrush blocking signals accordingly for its end. This allows selective use of these signals in the block matrix, namely to have a common link to one end from which currents are measured in the OC stage and in the inrush blocking function.

Block diagram

Figure 256 - Block diagram of inrush blocking



IX.H2	Second harmonic component of phase current
IX.fund	fundamental component of phase current

Characteristics

Table 90 - Settings and characteristics of the inrush blocking function

Settings/characteristics (description/label)	Values
Pick-up value/Pick-up H2	
Setting range	10%...35%
Resolution	1%
Accuracy	±1%
Hysteresis	1%
CT input selection[88]	
Setting range	CT-1 is fixed for stage 1, CT-2 is fixed for stage 2.
Max inrush current/CurBlkVal	
Setting range	1.00...20.00 pu[89]
Resolution	0.01 pu[89]
Accuracy	±3% or ±0.005 pu[89]
Inrush operating mode	Phase block; Cross block
Characteristic times	
Start time	< 40 ms
Setting group	
Number	1

---

[88] Available for P5T30 only.
[89] I_n = phase CT primary nominal

Switch On To Fault (ANSI 50HS)

Description

The switch-on-to-fault (SOTF) protection function (ANSI code 50HS) offers protection when the circuit breaker (CB) is closed on a faulty line. In this case a fast trip is required and instantaneous trip is inherently selective. Overcurrent-based protection does not clear the fault until the intended time delay has elapsed. SOTF gives a trip signal without additional time delay if the CB is closed and a fault is detected within a set time window after closing the CB.

Some faults may be caused by conditions not removed from the feeder after a reclosing cycle or a manual close, or due to grounding clamps left on after maintenance work.

The manual closing order from the circuit breaker may be initiated from one of several sources:

- Local close switch via digital inputs
- CB close command from local panel or eSetup Easergy Pro
- Remote communication

Operation

Switch-on-to-fault function operates within the SOTF active operation time, page 390 and Switch-on-to-fault function does not operate after the SOTF active operation time elapses, page 391 illustrate the operation of the SOTF function:

1. Switch-onto-fault gets not activated if the CB has not been in open position before the fault. Open CB detection is noticed from the highest phase current value which has to be under a fixed low threshold (0.02 x I_{nom}). Opening of the CB can be detected also with digital inputs (Dead line detection input = DI1 – DIx, Fx, VI1 – VIx). In this case, digital input which is connected to 52a need to be configured to this "Dead line detection input". The default detection method is based on the current threshold, so the dead line detection input parameter has value "–".
2. Dead line detection delay defines how long the CB has to be open so that the SOTF function gets active. If the set detection delay time is not elapsed when the highest phase current value (maximum of IA, IB, IC) rises over the start setting, the SOTF does not operate.
3. If the highest phase current value of IA, IB, IC goes successfully under the low limit and rises to a value between the low limit and the start value, then if the highest phase current value rises over the start setting value before the SOTF active operation time expires, the SOTF trips. If this SOTF active operation time is exceeded, the SOTF does not trip even if the start setting value is exceeded.

Figure 257 - Switch-on-to-fault function operates within the SOTF active operation time

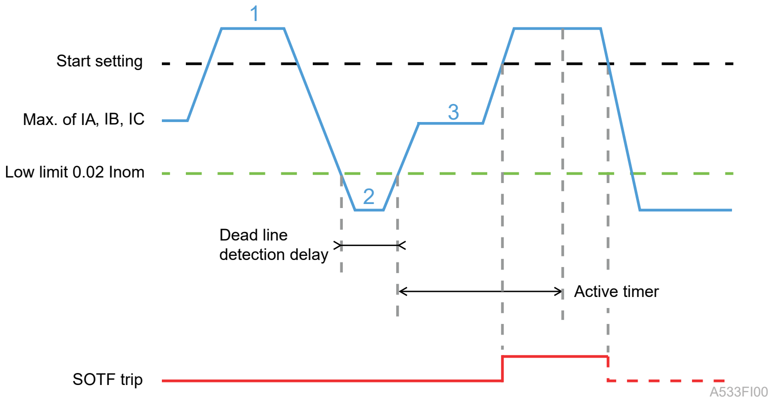
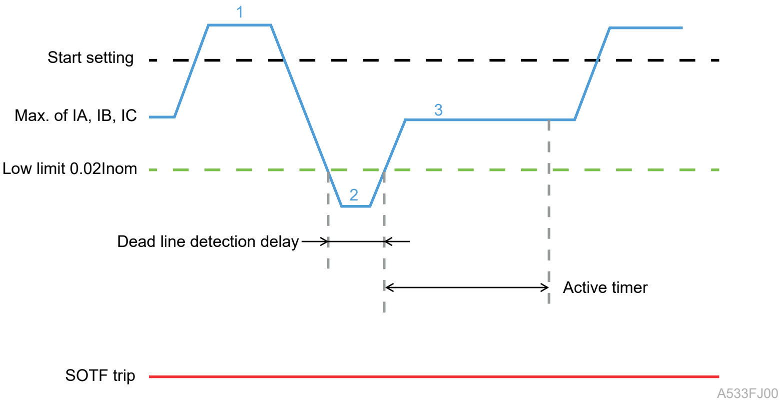
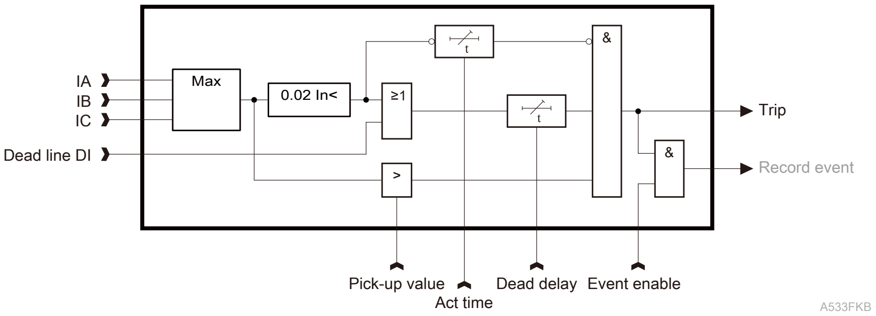


Figure 258 - Switch-on-to-fault function does not operate after the SOTF active operation time elapses



Block diagram

Figure 259 - Block diagram of the Switch On To Fault protection function (ANSI 50HS)



Characteristics

Table 91 - Settings and characteristics of the switch-on-to-fault protection function (ANSI 50HS)

Settings/characteristics (description/label)	Values
Pick-up value/SOTF	
Setting range	1.00...40.00 pu[90]
Resolution	0.01 pu[90]
Accuracy	±3%
Reset ratio	97% ±1%
Dead line detection delay/Dead delay	
Setting range	0.00...60.00 s
Resolution	0.01 s
SOTF active after CB closure/Act time	
Setting range	0.10...60.00 s
Resolution	0.01 s
Dead line detection input	

---

[90] phase CT primary nominal

Table 91 - Settings and characteristics of the switch-on-to-fault protection function (ANSI 50HS) (Continued)

Settings/characteristics (description/label)	Values
Options	Selection of one digital input (DI), one virtual input (VI), or one function key.
Characteristic times	
Start time	< 30 ms (25 ms with high speed) when $I/I_{set} > 2$
Disengaging time	< 60 ms (75 ms with high speed)
Setting group	
Number	1

Non-directional/directional phase overcurrent protection (ANSI 50/51/67)

Description

The overcurrent protection function is used against short circuit faults and overloads. It provides three-phase and six-stage non-directional/directional overcurrent protection. All the six overcurrent stages can be selected to be either non-directional, forward or reverse. Further more, phase segregated start and trip signals are available for each overcurrent stage. All the six stages have the same settings and performance. Typical applications are:

- Short-circuit protection of two parallel cables or overhead lines in a radial network.
- Short-circuit protection of a looped network with a single feeding point.
- Short-circuit protection of a two-way feeder, which usually supplies loads but is used in special cases as an incoming feeder.

All 6 overcurrent stages are also available with transformer differential protection P5T30 as back-up protection. Each stage can be individually linked to the measured phase currents of one end. As no voltage measurement is available, these stages can operate in non-directional mode only, and also no voltage-controlled adjustment of operate threshold and time is available.

Phase directional element

The directional element get polarized by the quadrature phase-phase voltages, as shown in the table below:

Phase of protection	Operate current	Polarizing voltage phase rotation ABC	Polarizing voltage phase rotation ACB
A Phase	IA	VBC = VB - VC	VCB = VC - VB
B Phase	IB	VCA = VC - VA	VAC = VA - VC
C Phase	IC	VAB = VA - VB	VBA = VB - VA

The directional check is performed based on the following criteria:

Forward directional	-90° < (angle(I) - angle(V) - RCA) < 90°
Reverse directional	-90° > (angle(I) - angle(V) - RCA) > 90°

Where RCA = 90° - feeder impedance angle

Under system fault conditions, the fault current vector will lag its nominal phase voltage by an angle dependent upon the system X/R ratio. Therefore, the relay should operate with the maximum sensitivity for currents lying in this region. This is achieved by means of the Relay Characteristic Angle (RCA) setting. It defines the angle by which the current applied to the relay must be displaced from the voltage applied to the relay to obtain the maximum relay sensitivity. This is the "Characteristic angle" setting in the overcurrent menu. On the P5 relay, it is possible to set characteristic angles anywhere in the range –95° to +95°.

For a close-up three-phase fault, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, the relay will store the pre-fault voltage information and continues to apply it to the directional overcurrent elements for a time period of 5 s under the circumstance. This feature ensures that either instantaneous or time delayed directional phase overcurrent elements will be allowed to operate, even with a three-phase voltage collapse. This function uses memorized voltages for calculation if the polarization voltages drop below the minimum voltage threshold (0.015 pu[91]), in case of close-up three-phase fault. These memorized voltages will be used until at least one polarization voltage

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[91] Vnom = VT primary nominal (PP) or Vnom/√3 = VT primary nominal (PN) depending on P5 voltage mode

is going above the minimum voltage threshold (0.015 pu[92]), or during a maximum time period of 5 s. If the input voltage loss continues longer than 5 s the directional overcurrent is blocked.

VTS blocking

Voltage Transformer Supervision (VTS) blocking only affects the directional overcurrent protection. When the “Direction mode” is selected as “Forward” or “Reverse”, the setting "VTS blocking" will show up. When "VTS blocking" is set to "Non-directional", the directional element will be ignored, and the directional overcurrent protection will be switched to non-directional protection under VT failure condition. When "VTS blocking " is set to "Blocked", the directional overcurrent protection will be blocked under VT failure condition.

Dynamic setting element

Dynamic mode allows the overcurrent protection settings dynamically adjusted during the transient period. It can be applied to cooperate between the Cold Load Pick-up, and also to realize voltage-controlled overcurrent.

When "Dynamic Mode" is ON and the digital input signal " DynamicInput" in Output Matrix is ON:

1. It will switch to the "Dynamic threshold" setting for fault detection.
2. For DT operating curve, it will switch to the "Dynamic operate delay" setting.
3. For IDMT, it will switch to the "Dynamic TDM" setting.

For Cold Load Pickup application, an output signal "CLP Operation" to indicate cold load energized condition will be available. In Output Matrix, "CLP Operation" will be linked to "DynamicInput" to realize this functionality.

Selective overcurrent logic

Selective overcurrent logic can be activated when the setting "SOL status" is set to "SOL1" or "SOL2" and the related digital input signal "SOLInputx" in Output Matrix is ON. For DT operating curve, it will switch to the setting "SOL operate delay" for logic discrimination. For IDMT curve, it will switch to the "SOL TDM" setting for logic discrimination.

The CLP and SOL functions have dynamic impacts on the overcurrent settings of timer and start value. The associated inputs could be activated at the same time. In this case, SOL takes precedence over CLP.

Inrush blocking

The user can block the overcurrent function by selecting the setting "Inrush blocking" of each stage. The purpose is to make the overcurrent function inoperative during the transformer energization, otherwise a large primary current flow for a transient period will cause an unwanted trip.

It is highly possible that inrush blocking is determined later than the trip of instantaneous OC stage. Therefore, when the "Inrush blocking" setting is enabled in overcurrent stage, an additional delay (25 ms fixed) gets applied to wait for potential inrush blocking signal before start is ON.

To secure proper protection operation during evolving faults or for faults fed from sources with high amount of harmonics, a confirmed starting from any overcurrent protection stage will remove the inrush blocking from all overcurrent stages. This needs to be considered in the setup of inrush blocking: all OC stages, with operate threshold below the expected maximum inrush current have to be subjected to inrush blocking. Alternatively, use of the blocking matrix could be considered.

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[92] Vnom = VT primary nominal (PP) or Vnom/√3 = VT primary nominal (PN) depending on P5 voltage mode

For further details please also refer to the related application note.

Operating curve selection

The operating curve of the overcurrent protection can be selected to DT, standard dependent operate delay, and programmable dependent operate delay. When the “Operating Curve” is set to IDMT curve, the settings “DT adder” and “Minimum operate time” will show up. “DT adder” defines the additional time delay plus the IDMT timer. “Minimum operate time” defines the minimum operating time for IDMT curves to help ensure the IDMT stage will not trip faster than the DT stage when the fault current is very large. For more information, refer to Operating curve selection, page 294.

Tripping logic

When the “Tripping logic” is set to "1 out of 3" and any phase starts, the output of the "Trip Logic Check" is TRUE. That means tripping can be allowed at any started phase. When the “Tripping logic” is set to "2 out of 3" and any two phases start, the output of the "Trip Logic Check" is TRUE. That means tripping can be allowed at the two started phases. The tripping logic is shown in following diagram.

Six independent stages

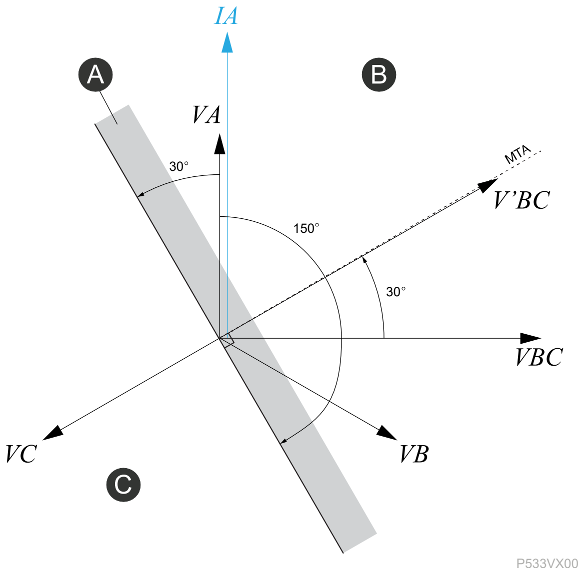
There are six separately adjustable stages: 50/51/67-1, 50/51/67-2, 50/51/67-3, 50/51/67-4, 50/51/67-5, and 50/51/67-6. All the six stages have the same settings and performance. All the stages have definite operate time (DT) and dependent operate time (IDMT).

Directional operation

Three modes are available: Non-directional, Forward and Reverse. In the Non-directional mode, the stage is acting just like an ordinary overcurrent protection function stage.

An example of directional overcurrent characteristic with set characteristic angle of 30° (RCA) for a phase A fault is shown as below.

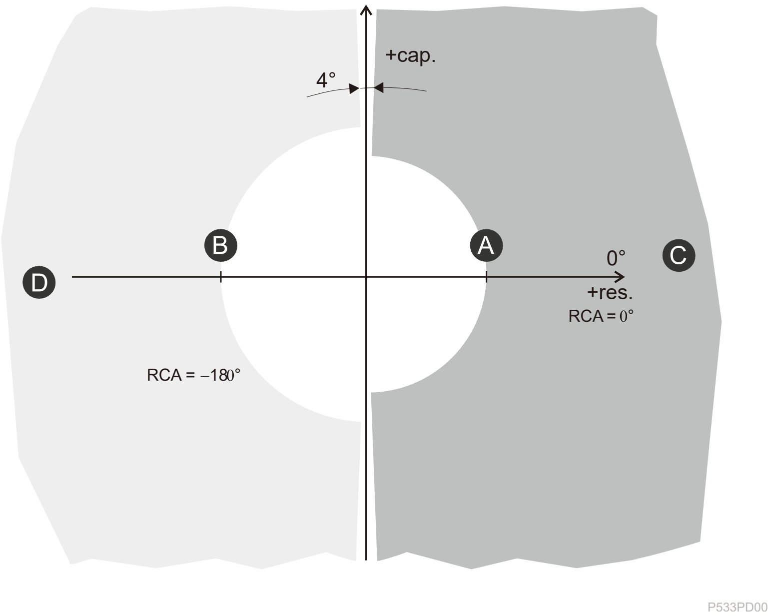
Figure 260 - Example of the directional overcurrent function characteristic



A	Set relay characteristic angle (RCA)	B	Forward direction
C	Reverse direction		

An example of bi-directional operation characteristic using 2 overcurrent stages is shown as below. The RCA of the two stages are 0° and -180°.

Figure 261 - Bi-directional application with two stages



A	Directional overcurrent stage1 pickup value setting	B	Directional overcurrent stage2 pickup value setting
C	Directional overcurrent stage1 trip area	D	Directional overcurrent stage2 trip area

Tripping logic

When the setting "Tripping logic" is set to "1 out of 3", any of the three phase currents exceeds the setting value and, in directional mode (Forward or Reverse), the direction is located in the trip area, this stage starts and issues a start signal. If the fault situation is present longer than the operate time setting, a trip signal is issued.

Voltage-controlled overcurrent

Voltage-controlled overcurrent protection can be used as system back-up protection or as transformer back-up protection. Normally voltage-controlled overcurrent protection is preferred for the applications where a generator is directly connected to a busbar without a step-up transformer. It is recommended as well to use this solution to increase the sensitiveness of overcurrent back-up transformer protection. P5 relays provide a dynamic setting mode for each overcurrent protection stage, so that overcurrent pick-up setting and operate delay setting will be replaced by dynamic threshold and dynamic operate delay settings. So the overcurrent protection adjusts the current setting according to the detected undervoltage condition. The information about application and setting examples can be found in the Application Book.

High Impedance Busbar Differential Protection

The PowerLogic P5 overcurrent elements **I>** can be used for high impedance busbar protection based on the high impedance differential protection principle, offering stability for any type of fault occurring outside the protected zone and satisfactory operation speed for faults within the zone. For this application instantaneous operation is commonly applied, which can be obtained in a simple way by selecting definite time delay characteristic with minimum time delay setting. The information about application, calculations, setting examples and recommendations for resistors can be found in the Application Book.

Back-up mode

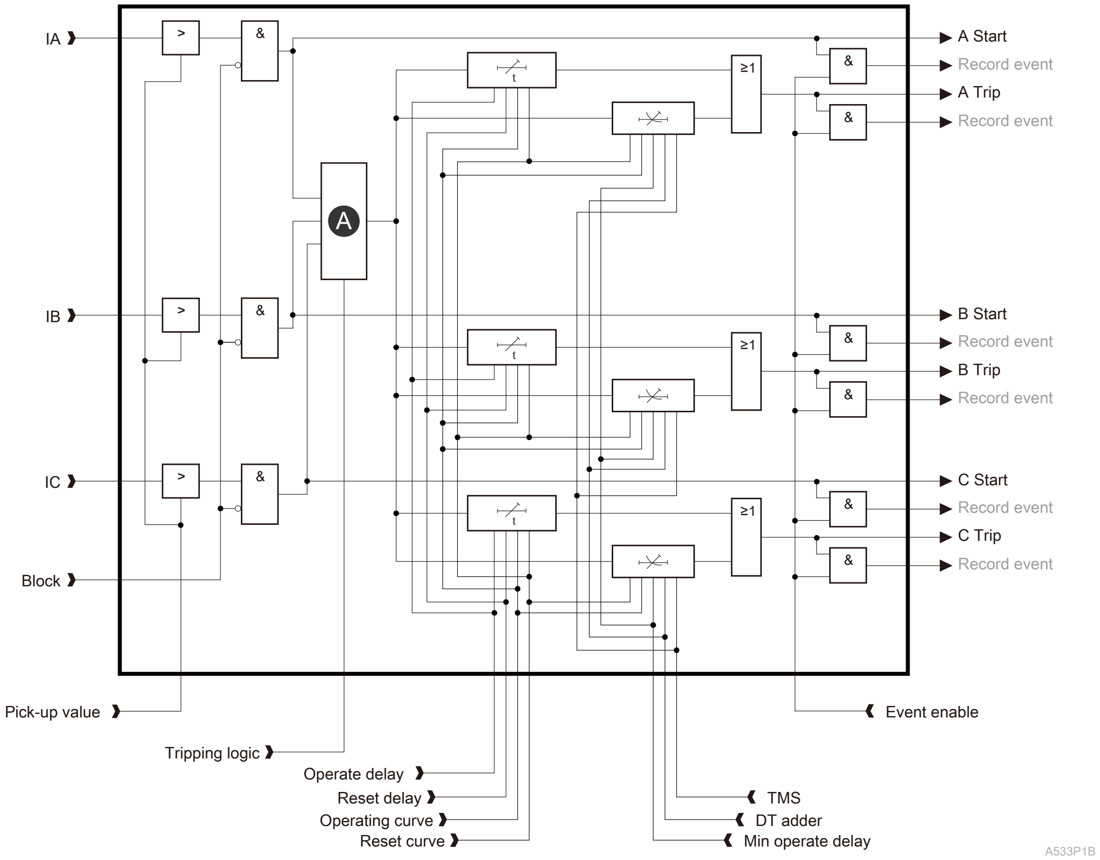
The back-up mode is for PowerLogic P5L30 only.

The negative sequence overcurrent protection, the non-directional/directional phase overcurrent protection and the non-directional/directional ground fault overcurrent protection can be set as backup protections of the line differential protection in case the line differential protection is permanently blocked. By default, the overcurrent stages are active. Once the back-up mode is enabled, the overcurrent protections will be active only if the line differential protection is blocked, and when the line differential protection is not blocked or disabled, the overcurrent protections will be inactive again.

To enable/disable the back-up mode, check/uncheck the **Back-up mode** in eSetup Easergy Pro/ **PROTECTION**/**Negative sequence overcurrent 46** and **Phase overcurrent 50/51/67** and **Ground fault overcurrent 50N/51N/67N**.

Block diagram

Figure 262 - Block diagram of non-directional overcurrent protection function

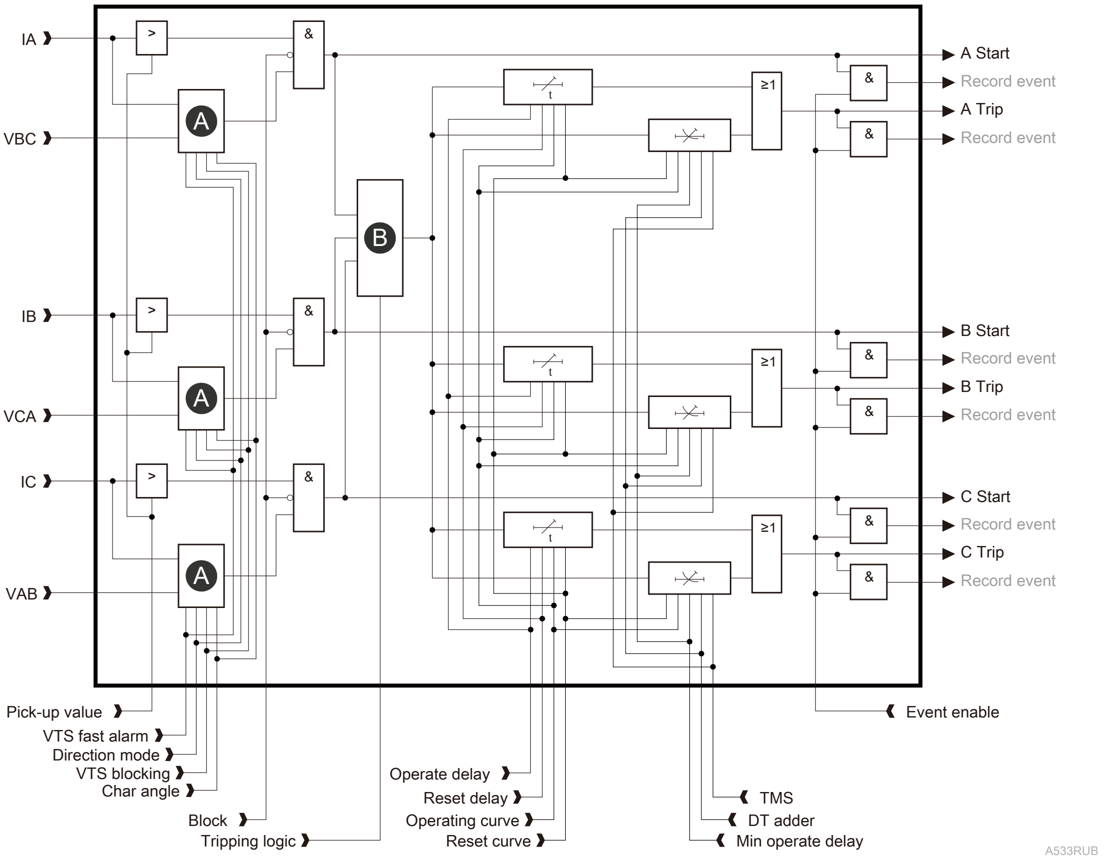


A	Tripping logic

NOTE:

- Block input can be signals configured via Block matrix, due to inrush condition detected.
- Pick-up value can be value from "Pick-up value" setting, "Dynamic threshold" setting depending on the configuration.
- Operate delay can be the value from "Operate delay" setting, "SOL operate delay" setting or "Dynamic operate delay" setting depending on the configuration.
- TDM value can be the value from "TDM" setting, "SOL TDM" setting or "Dynamic TDM" setting depending on the configuration.

Figure 263 - Block diagram of directional overcurrent protection function



A	Direction check logic, for Forward direction, it should follow the equation: -90° < (angle(I) - angle(U) - RCA) < 90°, and for Reverse direction, it should follow the equation: -90° > (angle(I) - angle(U) - RCA) > 90°	B	Tripping logic

NOTE:

- Block input can be signals configured via Block matrix, due to inrush condition detected.
- Pick-up value can be value from "Pick-up value" setting, "Dynamic threshold" setting depending on the configuration.
- Operate delay can be the value from "Operate delay" setting, "SOL operate delay" setting or "Dynamic operate delay" setting depending on the configuration.
- TDM value can be the value from "TDM" setting, "SOL TDM" setting or "Dynamic TDM" setting depending on the configuration.
- VAB/VBC/VCA can be the calculated phase to phase voltage, or memory value for close-up three-phase fault.

Characteristics

Table 92 - Setting and characteristics of the non-directional/directional phase overcurrent protection (6 stages have the same settings)

Setting/characteristics (description/label)	Values
Pick-up value/50/51/67-1	
Setting range	0.05...40.00 pu[93] (DT) 0.05...5.00 pu[93] (IDMT)
Resolution	0.01 pu[93]
Accuracy	±2% or ±0.005 pu[93]
Reset ratio	95% ± 2%
Transient overreach	< 5% for X/R up to 120
CT input selection[94]	
Setting range	CT-1, CT-2
Back-up mode/Back-up mode[95]	
Options	Off/On
Operating Curve	
Options	DT; IEC: SI, VI, EI, LTI, UTI; IEEE: MI, VI, EI ANSI: NI, STI, LTI Others: UK_Rectifier, FR_STI, RI, STI_CO2, LTI_CO5, MI_CO7, NI_CO8, VI_CO9, EI_CO11, BPN Prg1-3
Accuracy	±5% or ±20 ms (for IDMT)
Operate delay/Operate delay	
Setting range	0.00...600.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
TDM/TDM	
Setting range	0.020...20.000
Resolution	0.001
DT adder/DT adder	

---

[93] Inom
[94] Available for P5T30 only.
[95] Available for P5L30 only.

Table 92 - Setting and characteristics of the non-directional/directional phase overcurrent protection (6 stages have the same settings) (Continued)

Setting/characteristics (description/label)	Values
Setting range	0.00...1.00 s
Resolution	0.01 s
Minimum operate delay/Min operate delay	
Setting range	0.00...10.00 s
Resolution	0.01 s
Direction mode/Direction mode	
Options	Non-directional; Forward; Reverse
Characteristic angle/Char angle	
Setting range	-95° - +95°
Resolution	1°
Accuracy	±2°
VTS blocking	
Options	Blocked; Non-directional
Tripping logic/Tripping Logic	
Setting range	1 out of 3; 2 out of 3
Reset curve/Reset curve	
Options	DT; IDMT; Prg1-3
Reset delay/Reset delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	±1% or ±30 ms
Inrush blocking/Inrush blocking	
Options	Off/On
SOL status/SOL status	
Options	Off; SOL1; SOL2
SOL operate delay/SOL operate delay	
Setting range	0.00...600.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
SOL TDM/SOL TDM	
Setting range	0.020...20.000
Resolution	0.001
Dynamic mode/Dynamic mode	
Options	Off/On
Dynamic threshold/Dyn pick-up value	
Setting range	0.05...40.00 pu[96] (DT) 0.05...5.00 pu[96] (IDMT)
Resolution	0.01 pu[96]
Accuracy	±2% or ±0.005 In
Dynamic operate delay/Dynamic op delay	

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[96] Inom

Table 92 - Setting and characteristics of the non-directional/directional phase overcurrent protection (6 stages have the same settings) (Continued)

Setting/characteristics (description/label)	Values
Setting range	0.00...600.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
Dynamic TDM/Dynamic TDM	
Setting range	0.020...20.000
Resolution	0.001
Back-up mode	
Enable back-up mode	Off/On
Voltage memory time	
Value	5 s fixed
Angle memory	
Value	5 s fixed
Minimum voltage for the direction determination	
Value	0.015 pu[97]
Characteristic times	
Start time	< 30 ms (25 ms with high speed) for currents at 2 x Is pick-up value (non-directional) < 35 ms (30 ms with high speed) for currents at 1,2 x Is pick-up value (non-directional)
	< 40 ms (35 ms with high speed) for currents at 1,2 x Is pick-up value (directional)
Disengaging time	< 55 ms (70 ms with high speed)
Overshoot time	< 30 ms
Setting group	
Number	4

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[97] Vnom

Arc-flash (ANSI 50ARC)

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION, OR ARC FLASH

Information on this product is offered as a tool for conducting arc flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.

Failure to follow these instructions will result in death or serious injury.

Description

The arc-flash protection function (ANSI code 50ARC) is a high speed protection function able to detect arcing events in a few millisecond, to minimize equipment damages.

The arc-flash protection contains 8 arc stages that can be used to trip the circuit breakers. Arc stages are activated with overcurrent and light signals (or light signals only). The allocation of light or "light + current confirmation" signal to arc stages is defined in arc-flash protection matrix: current, light and output matrix. The matrix are programmed via the dedicated arc-flash matrix menus. Available matrix signals depend on the model number (see).

Available signal inputs for arc-flash protection depend on the PowerLogic P5 protection relay's configuration with 3 or 6 light inputs.

For PowerLogic P5x30 protection relay, arc sensor x (where x is the sensor number) alarm signal is used to indicate the health status of the arc sensor. These state signals are available in LED matrix, Output matrix, Block matrix and Object block matrix. All the signals are in Boolean type:

- when the arc sensor alarm signal is activated, it means the arc sensor is not in health state, such as: disconnection, short circuit, open circuit, not installed correctly, etc.
- when the arc sensor alarm signal is not activated, it means the arc sensor is in health state.

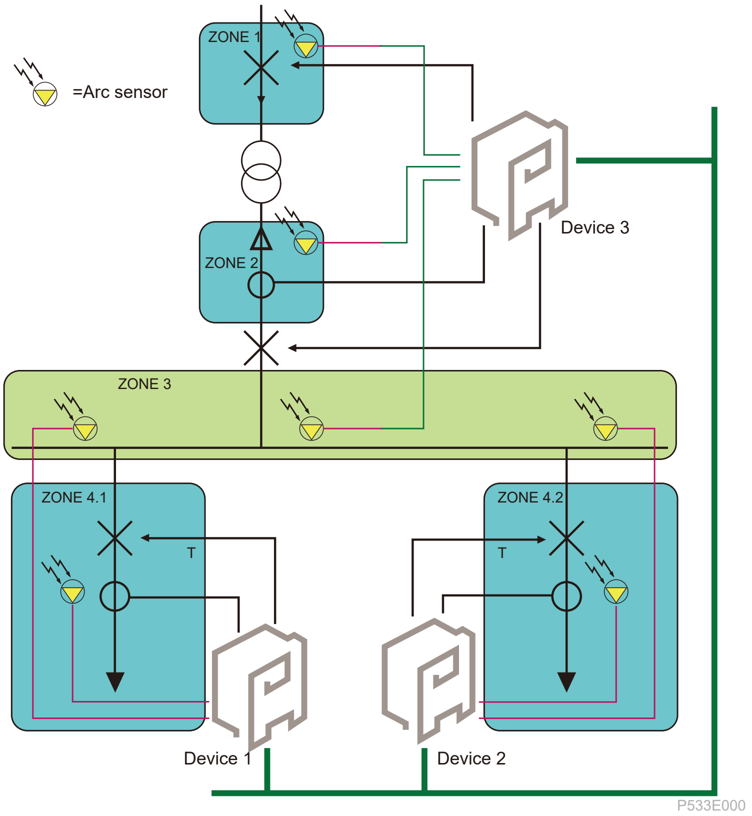
In transformer differential protection application P5T30 the current inputs of the arc-flash protection can be assigned to one of the 2 ends.

With 3 to 6 arc-flash input options, the PowerLogic P5x30 protection relay allows to build a multi-zone arc-flash protection system.

Information like arc detection or current detection can be exchanged across the system using two communication ways:

- GOOSE messages using the IEC 61850 protocol (preferred solution)
- Virtual outputs

Figure 264 - Application example of the arc-flash protection function



In this application example, the arc-flash sensor for zone 4.1 is connected to Device 1. If the arc-flash sensor detects the fault and simultaneously Device 3 sends a current signal, the zone 4.1 is isolated by the outgoing feeder breaker.

The arc-flash sensor for zone 4.2 is connected to the Device 2 and operates the same way.

The arc-flash sensors for zone 3 are connected to Device 1, 2 or 3. If a sensor detects the fault in zone 3, the light-only signal is transferred to Device 3 which also detects overcurrent and then trips the main circuit breaker.

An eventual arc-flash fault in zone 1 or 2 does not necessarily activate the current element in Device 3. However, arc detection can be achieved by using the light-only principle. If an arc-flash occurs in cable termination, zone 1 or zone 2, the fault is cleared by the upstream circuit breaker.

Each arc-flash protection stage provides:

- One arc detection function, which can be connected either to one of the available arc sensors (for local detection) or to a digital input or GOOSE information (for remote detection).
- One current detection function, which can be connected either to phase or ground fault high-speed overcurrent (for local detection) or to a digital input or GOOSE information (for remote detection).
- One trip input to other relays

  The trip signal of arc-flash protection is not a part of the global trip. In this case it is convenient to use Goose which provides a fast signal to the other relay.

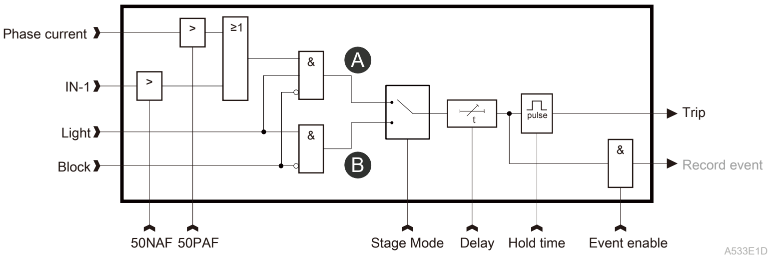
Ground fault current can be only measured and detected, according to the PowerLogic P5 protection relay, from:

- 1/5A neutral CT input
- CSH/CSH30 neutral current input

Each stage of the arc-flash protection can be blocked individually by a control inputs such as digital input, virtual inputs and function keys.

Block diagram

Figure 265 - Block diagram of the arc-flash protection function



A	Light + Current	B	Light

Operation

Before configuring the arc flash protection, the arc sensors need to be installed through eSetup Easergy Pro.

The installation process is as follows:

1. In eSetup Easergy Pro, select **PROTECTION** menu/**ARC protection** sub-menu.
2. Under **Settings** view, click the “Install arc sensors” drop-down list and select Install.
3. Wait until the Installation state shows Ready.

   The installation of the sensors is now done.

The installed sensors and the sensor status can be viewed at the bottom of the ARC protection view.

This is an online process only. The installation process is only applicable when eSetup Easergy Pro is connected to aPowerLogic P5 protection relay. The offline configuration does not have this menu visible.

The arc-flash protection is implemented by configuration in the following three matrix (see **Matrix** menu in eSetup Easergy Pro):

- Arc matrix - current
- Arc matrix - light
- Arc matrix - output

The event configuration for the protection is done in the **Event enabling - ARC** view of the **Log** menu in eSetup Easergy Pro.

NOTE: When an arc-flash sensor is disconnected, an alarm message is automatically generated and displayed on the local panel.

Arc matrix – current

In the Arc matrix – current setting view, the available current signals (left column) are linked to the appropriate arc stages (1...8).

Figure 266 - View of Arc matrix – current

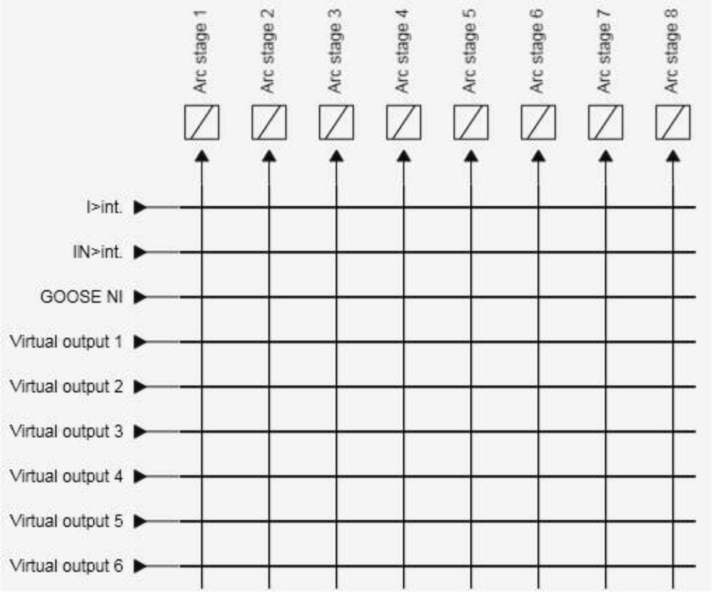


Table 93 - Arc matrix – current parameter group

Item	Range	Description
I>int.	On, Off	Phase IA, IB, IC internal overcurrent signal
67NI	On, Off	Ground fault overcurrent signal
GOOSE NI	On, Off	Goose network input (IEC 61850)
Virtual output 1...20	On, Off	Virtual output
Arc stage 1...8	On, Off	Arc protection stage 1 to 8

Arc matrix – light

In the **Arc matrix – light** setting view, the available arc light signals (left column) are linked to the appropriate arc stages (1...8).

Figure 267 - View of Arc matrix – light

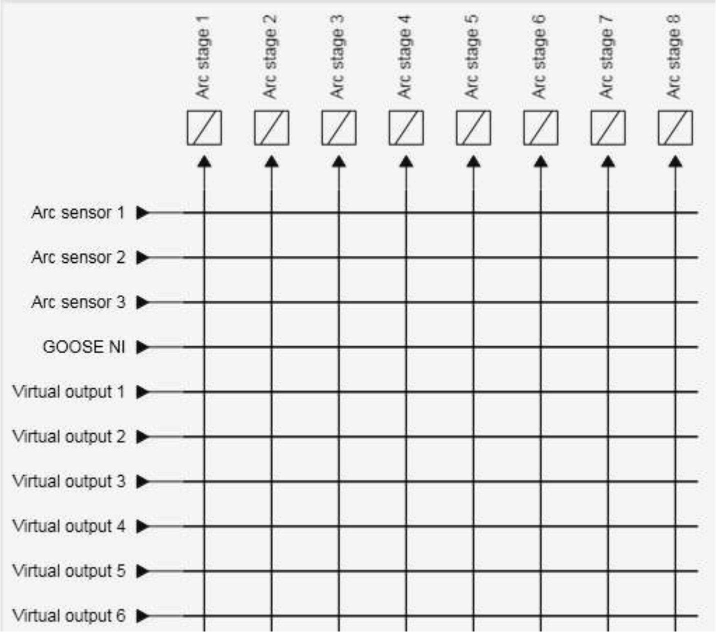


Table 94 - Arc matrix – light parameter group

Item	Range	Description
Arc sensor 1...6	On, Off	Internal arc-flash sensor 1 to 3 or 1 to 6, according to the configuration
GOOSE NI	On, Off	Goose network input
Virtual output 1...20		Virtual output
Arc stage 1...8	On, Off	Arc protection stage 1 to 8

Arc matrix – output

In the **Arc matrix – output** setting view, the used Arc stages (1...8) are connected to the required outputs. Possible latched function per output is also determined in this view. The available outputs depend on the model number.

> **NOTE:** Arc matrix is the only way to configure arc stage signals to the output relay in PowerLogic P5, it is not configurable via standard Output matrix. But the configured signals will be reflected in the Output matrix.

Figure 268 - View of Arc matrix – output

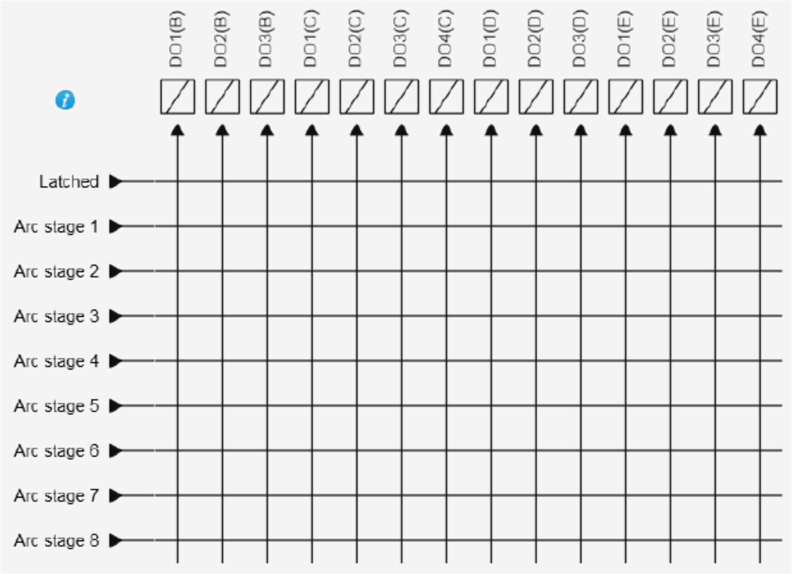


Table 95 - Arc matrix – output parameter group Setting Range

Setting	Range	Description
Latched	On, Off	Output latch
Arc stage 1...8	On, Off	Arc protection stage 1 to 8
Digital output	On, Off	DO1 to DO3 (slot B) or DO1 to DO4 (slots C, D, E) according to the PowerLogic P5 configuration

Event enabling matrix

This matrix is used to generate events when the current elements, light signals from the arc sensors, and the arc stages are activated or drop off.

Characteristics

⚠⚠ DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

Do not use the arc operation delay for primary trip.

Failure to follow these instructions will result in death or serious injury.

The arc operation delay is intended, with the separate arc stage, for the circuit breaker failure scheme only.

Table 96 - Setting and characteristics of the arc-flash protection function (ANSI 50ARC)

Setting/characteristics (description/label)	Values	
Stage Mode/Mode		
Options	Light; Light and I	
I>int. pick-up value/I>int		
Setting range	0.50...8.00 pu[98]	
Resolution	0.01pu[98]	
Accuracy	±2.5%	
CT input selection[99]		
Setting range	CT-1, CT-2	
IN>int. pick-up value/IN>int.		
Setting range	0.10...5.00 pu[98]	
Resolution	0.01pu[98]	
Accuracy	±2.5%	
DI to block stage		
Options	Selection of one digital input (DI), one virtual input (VI), or one function key (Fx).	
Operate delay/Delay		
Setting range	0...255 ms	
Accuracy	±1% or 20 ms	
Min. hold time (1~8)/Hold time		
Setting range	20...2500 ms	
Resolution	1 ms	
Accuracy	±1% or 20 ms	
Characteristic time		
Tripping time [100]		
Light only	2 ms minimum	4 ms maximum
Light + I> (earth fault) at 2xI>	5 ms minimum	11 ms maximum
Light + I> (phase fault) at 2xI>	4 ms minimum	7 ms maximum
Light by Goose + I> (earth fault)	5 ms minimum	11 ms maximum
Light by Goose + I> (phase fault)	4 ms minimum	10 ms maximum

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[98] I_{nom}

[99] Available for P5T30 only.

[100] With high speed high break contact relay (PowerLogic P5x30) only.

Table 96 - Setting and characteristics of the arc-flash protection function (ANSI 50ARC) (Continued)

Setting/characteristics (description/label)	Values	
Light + I> by Goose (earth fault)	7 ms minimum	16 ms maximum
Light + I> by Goose (phase fault)	5 ms minimum	12 ms maximum

Circuit breaker failure (ANSI 50BF)

Description

If a circuit breaker fails to open, following a tripping order (mainly detected by the non-extinction of the fault current), the circuit breaker failure protection function (ANSI code 50BF) sends a tripping order to the upstream or adjacent breakers.

With transformer differential protection P5T30 two CBF elements are available with a fix link to the measured currents of one end (CBF-1 to end 1, CBF-2 to end 2).

The circuit breaker failure protection has three types of inputs to operate:

- Current protection
- Non-current protection like frequency protections or voltage protections
- External trip

The circuit breaker failure protection incorporates two timers, CB Fail 1 Timer and CB Fail 2 Timer, allowing configuration for these scenarios:

- Simple CB failure protection, where only CB Fail 1 Timer is enabled. For any protection trip, the CB Fail 1 Timer is started, and normally reset when the circuit breaker opens to isolate the fault. If breaker opening is not detected, CB Fail 1 Timer times out and closes an output contact assigned to breaker fail (using the output matrix). This contact is used to backtrip upstream switchgear, generally tripping all infeeds connected to the same busbar section.
- A re-tripping scheme, plus delayed back-tripping. Here, CB Fail 1 Timer is used to route a trip to a second trip circuit of the same circuit breaker. This requires duplicated circuit breaker trip coils, and is known as re-tripping. Should re-tripping fail to open the circuit breaker, a back-trip may be issued following an additional time delay. The back-trip uses CB Fail 2 Timer, which is also started at the instant of the initial protection element trip.

CB failure protection elements CB Fail 1 Timer and CB Fail 2 Timer can be configured to operate for trips triggered by protection elements within the protection relay or via an external protection trip. The latter is achieved by allocating one of the digital inputs to External Trip selected with the "DI for external trip signal" parameter.

Resetting of the CB failure protection is possible from a breaker open indication (from the pole dead logic) or from a protection reset. In these cases, resetting is only allowed provided the undercurrent elements have also reset. The resetting options are summarized in this table:

Table 97 - CB fail timer reset mechanisms

Initiation	CB fail timer reset
Current based protection (linked to CBF_ITrp in Output matrix)	[IA<] & [IB<] & [IC<] & [IN<] according to PowerLogic P5 model
IN.sens based protection (fixed to IN>x (x = 1...6),when the IN>x input is set to IN.sens)	[IN.sens<] according to PowerLogic P5 model
Non-current based protection (linked to CBF_nITrp in Output matrix)	Three options are available: • Current protection reset only • Pole dead • Reset of the non-current protection
External protection (from DI selected in CBF settings)	Three options are available. • Current protection reset only • Pole dead • Reset when external trip signal disappears

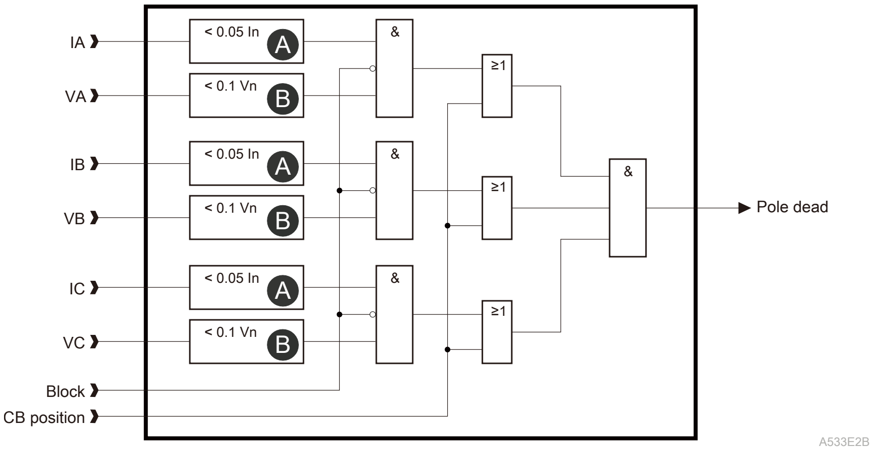
Pole dead logic

The pole dead logic can be used to give an indication if one or more phases of the line are dead. A pole dead condition is determined by either monitoring the status of the circuit breaker auxiliary contacts or by measuring the line currents and voltages. If a "CB Open" signal is given the protection relay will automatically initiate a pole dead condition regardless of the current and voltage measurement. Similarly, if both the line current and voltage fall below a pre-set threshold the protection relay will also initiate a pole dead condition.

This is necessary so that a pole dead indication is still given even when an upstream circuit breaker is opened. The undervoltage (V<) and undercurrent (I<) thresholds have the following, fixed, pickup and drop-off levels as shown in Pole dead logic, page 410.

If the VT fails a signal is taken from the VTS logic to block the pole dead indications that would be generated by the under-voltage and under-current thresholds. However, the VTS logic will not block the pole dead indications if they are initiated by a "CB Open" signal. The object for used CB is directly set in the **Objects** view of the **Control** menu in eSetup Easergy Pro.

Figure 269 - Pole dead logic



A	Drop off 0.055 In
B	Drop off 0.3 Vn

NOTE: For PowerLogic P5U20 and P5T30, undervoltage detection logic is ignored. For PowerLogic P5V20, only CB position is used to check pole dead, undercurrent and undervoltage logic are disabled.

Matrix use

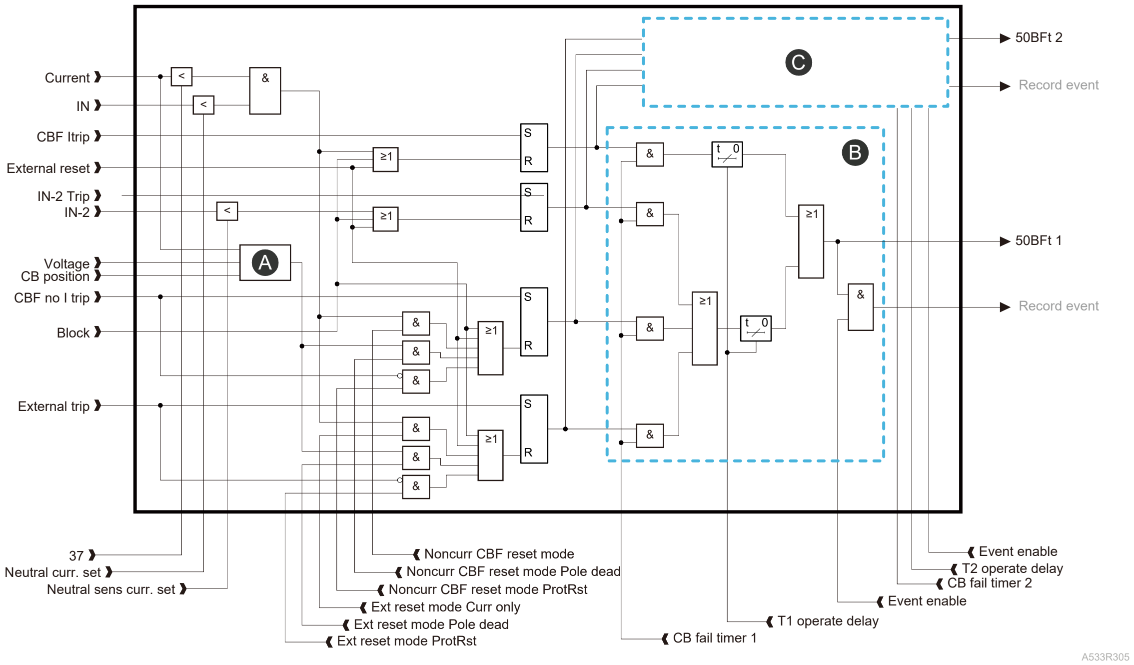
This function can be blocked by the blocking matrix.

To activate the circuit breaker failure function with current protection trip or with non-current protection trip, it is required to connect the relevant signals in Output matrix. These are the CBF_ITrp signal or CBF_nITrp signal respectively.

The digital inputs used for the external trip signal as well as for external reset signal are directly set in the breaker failure function.

Block diagram

Figure 270 - Block diagram of the circuit breaker failure protection function



A	Pole Dead Detection	B	CBF 1
C	CBF 2 (same diagram as CBF 1)		

NOTE: The IN-2 trip is the signal of IN> protection trip when the input of IN> is set to IN-2.

Characteristics

Table 98 - Settings and characteristics of the breaker failure protection function (ANSI 50BF)

Settings/characteristics (description/label)	Values
I< current set/I<	
Setting range	0.02...4.00 pu
Resolution	0.01 pu
CT input selection[101]	
Setting range	CT-1 is fixed for stage 1, CT-2 is fixed for stage 2.
IN< current set/IN<	
Setting range	0.020...4.000 pu[102] for IN.meas; 0.020...4.000 pu[102] for IN.meas with use of CSH30; 0.050...4.000 pu[102] for IN.CSH.
Resolution	0.001
IN.sens< current set/IN.sens<	
Setting range	0.002...0.800 pu[102] for sensitive ground fault
Resolution	0.001 pu[102]

---

[101] Available for P5T30 only.
[102] Inom for IN.calc; IN.nom for IN.meas; IN.CSH.nom for IN.CSH

Table 98 - Settings and characteristics of the breaker failure protection function (ANSI 50BF) (Continued)

Settings/characteristics (description/label)	Values
Timer1 operate delay/T1 operate delay	
Setting range	0.00...50.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Timer2 operate delay/T2 operate delay	
Setting range	0.00...50.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Noncurrent CBF reset mode	
Options	I<only; PoleDead; ProtRst
Ext. CBF reset mode	
Options	I<only; PoleDead; ProtRst
DI for external trip signal	
Options	Selection of one digital input DI, one virtual input VI, or one function key
DI for external reset signal	
Options	Selection of one digital input DI, one virtual input VI, or one function key
Characteristic times	
Reset time[103]	< 30 ms for any trip initiate, reset by I<; < 30 ms for any trip initiate, reset by IN<; < 50 ms for non-current protection initiate, reset by Pole Dead[104]
Setting group	
Number	1

---

[103] Does not take into account any contact relay

[104] Considering by default, 10 ms of debounce time filter on digital inputs.

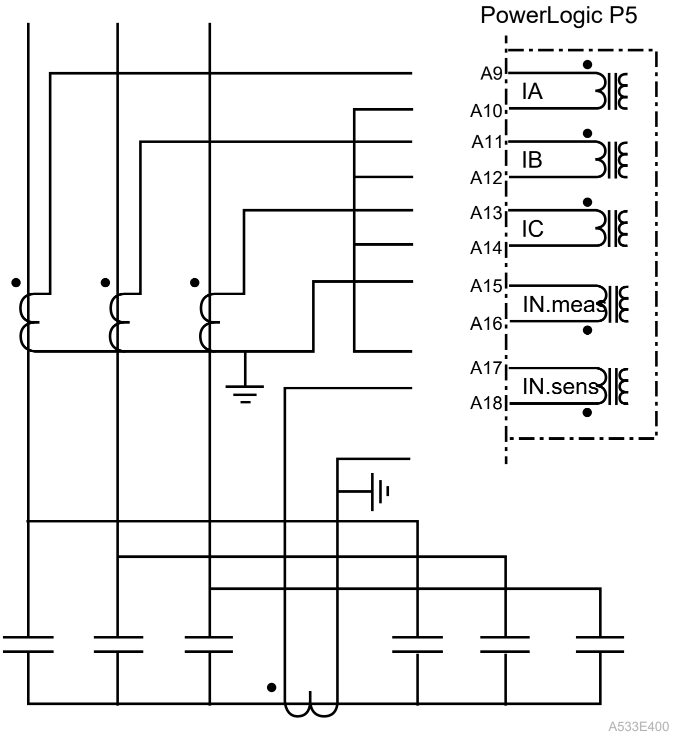
Capacitor bank unbalance (ANSI 51C)

Description

The capacitor bank unbalance protection function (ANSI code 51C) detects unbalance current flowing between the neutral points of a double-wye connected capacitor, filter and reactor bank. The typical connection for capacitor bank unbalance protection is shown in Typical capacitor bank protection application with the PowerLogic P5 protection relay, page 413. The unbalance current is measured with a dedicated current transformer (Standard neutral CT, or CSH core balance CT) between two wye-points of the bank.

Under healthy conditions any standing unbalance current caused by small differences in each side of the banks is limited and it can be compensated as described in the following section. When there are failures within one capacitor unit, the unbalance current will increase, depending on the number of failed capacitor elements.

Figure 271 - Typical capacitor bank protection application with the PowerLogic P5 protection relay



Normally, stage 1 is applied as the trip stage and stage 2 is applied as the alarm stage. As well as current input IN , the phase current IA is used to polarize the capacitor bank unbalance current for the standing unbalance current compensation and the faulty phase location.

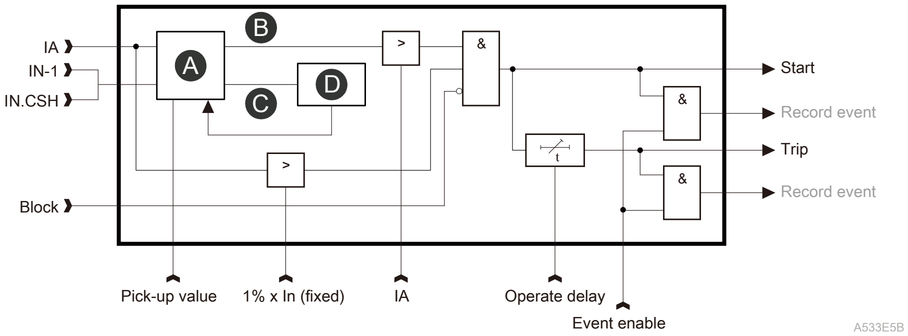
Compensation method

The unbalance current under normal conditions can be compensated to get better protection sensitivity. There are two compensation modes, Normal mode and Location mode. Stage 1 can only select Normal mode. Stage 2 can select Normal mode or Location mode.

Normal mode

The compensation is performed manually during commissioning. Using eSetup Easergy Pro (**PROTECTION** menu/**Capacitor unbalance 51C-1** sub-menu/**51C-1 unbalance** view) or relay HMI, the relay can get the standing unbalance current vector (here, IA is the angle reference) and record the magnitude and angle. For flexible compensation purpose, the magnitude of the standing unbalance current to be compensated is user settable under Normal Mode (setting SetBal), while the angle of the standing unbalance current is not settable, fixed as the recorded angle during commissioning.

Figure 272 - Capacitor unbalance protection with Normal compensation method



A	Compensation value: IN.compensate = IN - IN.cmp	B	Mag(IN.compensate)
C	Angle(IN) - Angle(IA)	D	Recorded IN angle

Location mode

As in the Normal mode, the initial standing unbalance current vector (magnitude, angle referred to IA) can be recorded during commissioning. The magnitude of the standing unbalance current to be compensated is not user settable, but the automatic compensation feature is provided. In Location Mode the branch of each faulty element can be estimated and thus improve the fault finding and maintainability of the capacitor bank.

Sensitive Setting

The stage 51C-2 Pick up value should be set based on the calculated unbalance current change of one faulty element. The calculation can use the following formula:

$$3I_N = \frac{\frac{V_{P\text{-}N}}{(2\cdot\pi\cdot f\cdot C_1)^{-1}} - \frac{V_{P\text{-}N}}{(2\cdot\pi\cdot f\cdot C_2)^{-1}}}{3}$$

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C1 = Capacitor unit capacitance (µF)

C2 = Capacitor unit capacitance, after one element fails (µF)

The entered setting should be smaller than the calculated value. As a rule of thumb 90% of the calculated unbalance current under one capacitor element faulty is recommend as the current setting.

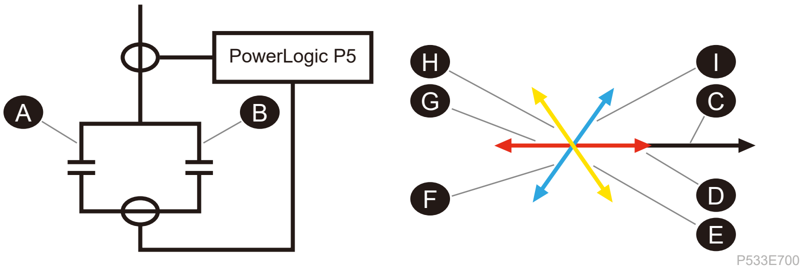
Counter Calculation

If there is an element failure in the bank, the relay checks the phase angle of the unbalance current (referred to IA). Based on this angle, the protection relay can detect the location of the faulty element and increase the corresponding counter with the calculated faulty elements number. For a double-wye connected capacitor bank, there are a total of six counters to indicate six options for the location of the faulty element, as shown in How a failure in different branches of the bank affects the IN measurement, page 415.

The current setting is based on the unbalance current with one faulty capacitor element, and the setting Max Allowed Faults is provided to specify how many faulty capacitor elements are allowed without the relay operating. The faulty element number can be calculated as follows:

N = compensated IN magnitude / IN setting

Figure 273 - How a failure in different branches of the bank affects the IN measurement



A	Branch 1	F	Phase 2 fault in branch 1
B	Branch 2	G	Phase 1 fault in branch 2
C	IA as reference	H	Phase 3 fault in branch 1
D	Phase 1 fault in branch 1	I	Phase 2 fault in branch 2
E	Phase 3 fault in branch 2		

Automatic Compensation

The operation time setting for stage 51C-2 specifies how long the relay must wait until it is certain that there is a faulty element in the bank. After this time has elapsed, the corresponding counter will contain the number of faults. If none of the six counters reach the setting Max Allowed Faults, the stage 51C-2 makes a new compensation automatically and the compensated unbalance current for this stage is now zero. The 51C-2 stage will reset and be sensitive to a new faulty element. Note the counters are not reset by this action and will continue to accumulate any further faulty elements. As shown in Automatic compensation under location mode, page 416, the current vector A is the initial recorded standing unbalance current and the current vector B is the unbalance current with the faulty capacitor elements. The new compensation current is “vector B – vector A”. If one of the six counters reach the setting Max Allowed Faults, stage 51C-2 will operate and the compensation current vector is recovered to the initial recorded standing unbalance current vector A.

Note, the automatic compensation does not affect the measured unbalance current of stage 51C-1.

Figure 274 - Automatic compensation under location mode

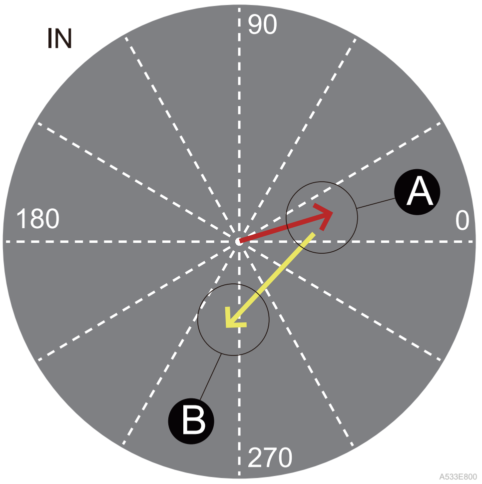
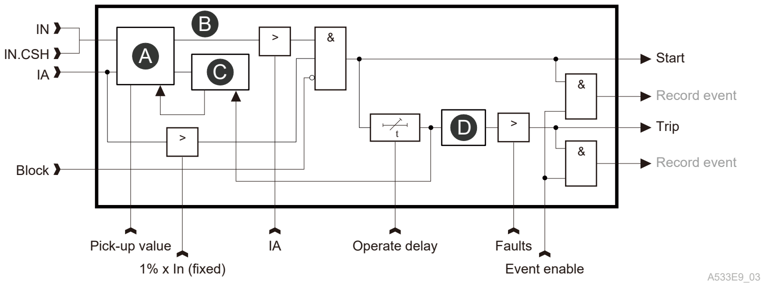


Figure 275 - Capacitor unbalance protection with Location compensation mode



A	Compensation value: IN.compensate = IN - IN.cmp	B	Mag(IN.compensate)
C	Recorded IN	D	Counter calculation

Characteristics

Table 99 - Settings and characteristics of the capacitor bank unbalance protection stage (ANSI 51C)

Settings/characteristics (description/label)	Values
IN input/Input	
Options	IN.CSH , IN.calc, IN.meas
Pick-up setting/Pick-up setting	
Setting range	0.02...20.00 pu[105] for IN.meas; 0.02...10.00 pu[105] for IN.meas with use of CSH30; 0.05...20.00 pu[105] for IN.CSH.
Resolution	0.01 pu
Accuracy	±3% or ±0.002 pu for IN.meas; ±3% or ±0.002 pu for IN.meas with use of CSH30; ±3% or ±0.005 pu for IN.CSH;
Reset ratio	95% ± 3%
Transient overreach	< 10% with X/R up to 120
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
Compensation Mode	
Options	Off; Normal; Location
Compensation Current (only available under Normal Compensation Mode)	
Setting range	0.010...3.000 pu[105]
Resolution	0.001 pu
Max Allowed Faults (only available under Location Compensation Mode)	
Setting range	0...10
Characteristic times	
Start time	< 40 ms (35 ms with high speed)
Overshoot time	< 40 ms
Disengaging time	< 95 ms (110 ms with high speed)
Setting group	
Number	4

---

[105] PU is the per unit value based on Inom = phase CT primary nominal (IN.calc) or IN.nom = standard neutral CT primary nominal (IN.meas) or IN.CSH.nom = CSH CT primary nominal (IN.CSH) or IN.sens.nom = sensitive neutral CT primary nominal (IN.sens)

Overvoltage (ANSI 59)

Description

The Overvoltage protection function (ANSI code 59) is used to detect system voltages that are too high or to check that there is sufficient voltage to authorize a source transfer.

The Overvoltage function provides the selection of phase to phase voltage or phase to ground voltage. Whenever any of these voltages exceeds the pickup value setting of a particular stage, this stage starts and a start signal is issued. If the fault situation remains on longer than the operate time setting, a trip signal is issued.

This function operates with either the definite time delay or inverse time delay characteristic or programmable curves. The inverse time delay characteristic follows the equation below:

$$t(G) = \frac{T}{(\frac{G}{G_S}) - 1}$$

P533OU00

where:

- t(G) is the theoretical operate time in seconds with constant value of G.
- T is the time delay setting (theoretical operate time for G = 2Gs).
- G is the measured value of the characteristic quantity.
- Gs is the setting value.

Reset delay

The reset delay of V> stage is configurable, it enables the detection of intermittent faults. The time counter of the protection function does not reset immediately after the fault is cleared, but resets after the release delay has elapsed. If the fault appears again before the release delay time has elapsed, the delay counter continues from the previous value. This means that the function eventually trips if faults are occurring often enough.

There are three delay types for select: DT, IDMT, or Prg 1-3. For the detail of Prg 1-3, please refer to Programmable dependent time curves, page 296.

Operate mode

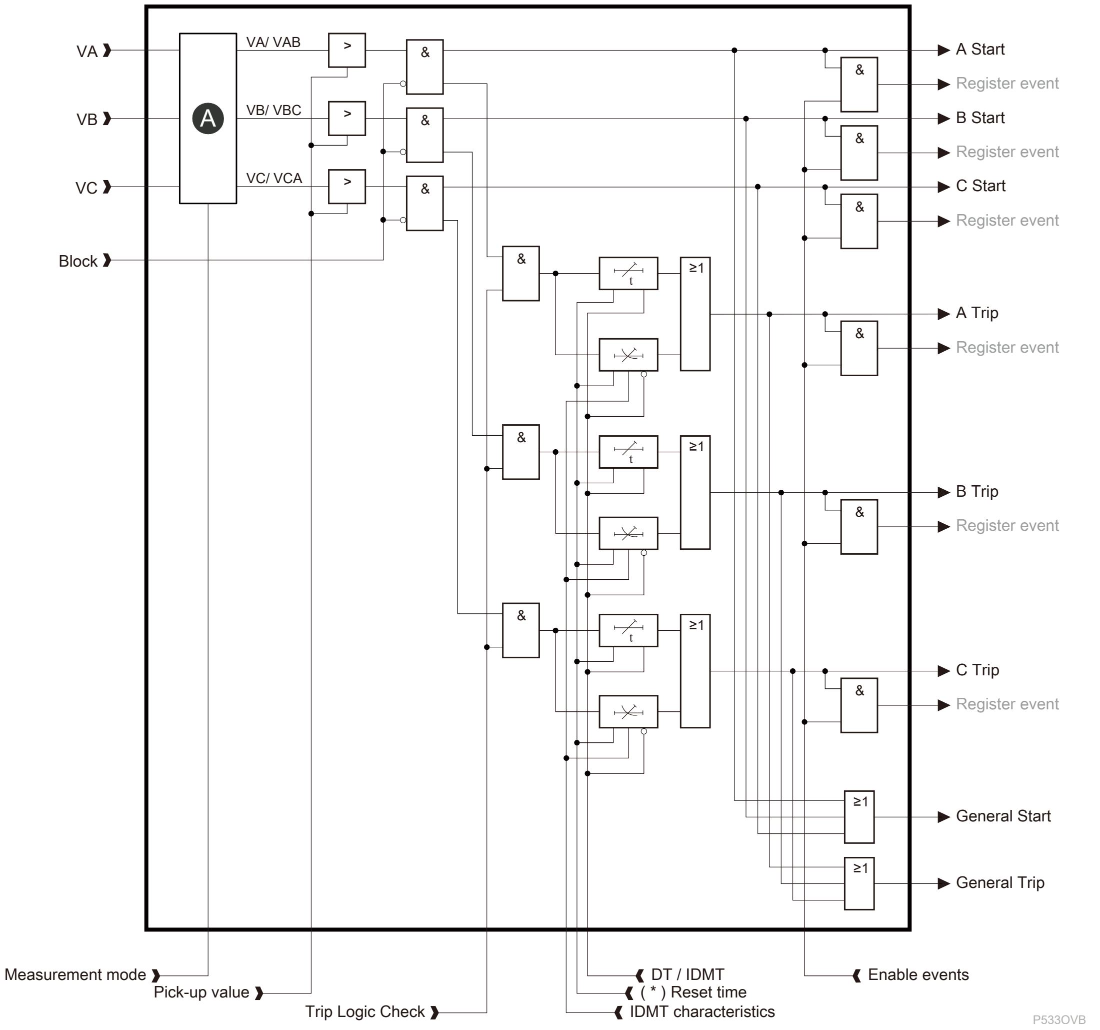
The setting "Tripping logic" is available to configure the operate mode. When "Tripping logic" is "Any phase", the general trip signal "V> trip" is raised when any phase operates. When "Tripping logic" is "Three phases", the signal "V> trip" is raised only when all three phases operate.

Three independent stages

There are three separately adjustable stages. All these stages have the same settings and performance.

Block diagram

Figure 276 - Block diagram of the Overvoltage protection function (ANSI 59)



A	Select setting

For the block diagram of the Tripping Logic, refer to Block diagram of the Tripping Logic, page 326.

Characteristics

Table 100 - Settings and characteristics of the Overvoltage protection (ANSI 59)

Settings/characteristics (description/label)	Values
Enable V>	
Options	Off/On
Pick-up value/V>	
Setting range	0.020...1.500 pu[106]

---

[106] Vnom = VT primary nominal (PP) or Vnom/√3 = VT primary nominal (PN) depending on measurement mode parameter setting

Table 100 - Settings and characteristics of the Overvoltage protection (ANSI 59) (Continued)

Settings/characteristics (description/label)	Values
Resolution	0.001 pu[107]
Accuracy	±2% or ±0.05 V secondary
Measurement mode/MeasMode	
Options	Phase-Phase; Phase-Ground
Delay type/Type	
Options	DT; IDMT; Prg 1-3
Tripping logic/Triplogic	
Options	Any Phase; Three Phases
Operate delay/Operate delay	
Setting range	0.00...600.00 s
Resolution	0.01 s
Accuracy	DT: ±1% or ±10 ms
	IDMT: ±5% or ±20 ms
Reset time/Reset time	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	DT: ±5% or ±30 ms
Hysteresis	
Setting range	1.0%...5.0%
Resolution	1.0%
Characteristic times	
Start time	< 40 ms (35 ms with high speed)
Overshoot time	< 40 ms
Disengaging time	< 55 ms (70 ms with high speed)
Setting group/SetGrp	
Number	4

---

[107] Vnom = VT primary nominal (PP) Vnom/√3 = VT primary nominal (PN)

Neutral overvoltage (ANSI 59N)

Description

The neutral overvoltage protection function (ANSI code 59N) is used as non-selective backup for ground faults and also for selective ground fault protection for motors having a unit transformer between the motor and the busbar.

This function is sensitive to the fundamental frequency component of the neutral displacement voltage. The attenuation of the third harmonic is more than 60 dB because third harmonics are present between the neutral point and ground even when there is no ground fault.

Whenever the neutral voltage VN exceeds the start setting of a particular stage, this stage issues a start signal. If the fault situation is present longer than the operate time setting, a trip signal is issued.

Measuring the neutral overvoltage

The neutral displacement voltage is either measured with a single voltage transformer between the motor's neutral point and ground or calculated from the measured phase to neutral voltages according to the selected voltage measurement mode (see Voltages, page 525):

- When the voltage measurement mode contains "+VN": The neutral displacement voltage is measured with voltage transformer(s), for example using a broken delta connection such as 3VP+VN, 2VPP+VN and 2VPP+VN+VPPy, the measured neutral voltage exists. In this scenario, user can select:
    - in secondary volts,

$$VN_{sec.meas}\,[V]$$

    - as per unit value,

$$VN\,[p.u.] = \frac{VN_{sec.meas}\,[V] \cdot VN_{prim.nom}\,[V]}{\sqrt{3} \cdot VN_{sec.nom}\,[V] \cdot V_{prim.nom}\,[V]}$$

    - in primary kilovolts,

$$VN_{prim.meas}\,[kV] = \frac{VN_{sec.meas}\,[V]}{VN_{sec.nom}\,[V]} \times VN_{prim.nom}\,[kV]$$

- When the voltage measurement mode is 3VP: The neutral displacement voltage is calculated from the phase voltages and therefore no separate neutral displacement voltage transformer is needed. The calculated neutral voltage exists:
    - in secondary volts,

$$VN_{sec.calc}\,[V] = (VA_{sec.meas} + VB_{sec.meas} + VC_{sec.meas})\,[V]$$

    - as per unit value,

$$VN\,[p.u.] = \frac{VN_{sec.calc}\,[V]}{\sqrt{3} \cdot V_{sec.nom}\,[V]}$$

    - in primary kilovolts,

$$VN\,[kV] = \frac{VN_{sec.calc}\,[V]}{V_{sec.nom}\,[V]} \times V_{prim.nom}\,[kV]$$

- When the “Voltage measurement mode” is VPP/VPPy, the neutral voltage displacement feature is not applicable, as the calculated neutral voltage is not reliable.

Three independent stages

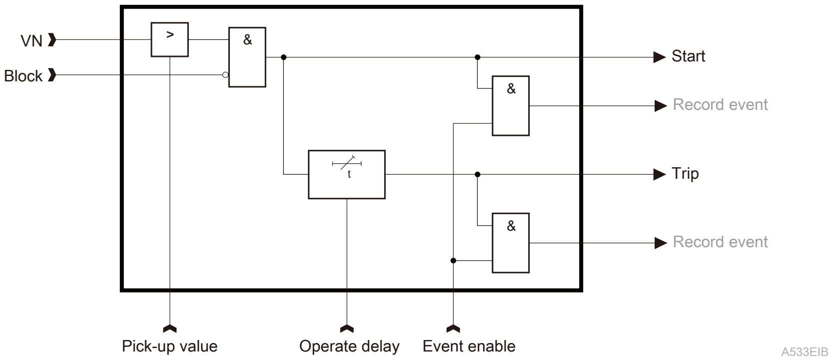
There are three separately adjustable stages: 59N-1, 59N-2 and 59N-3. All stages operate with definite time (DT) operation characteristics.

Block diagram

The neutral overvoltage protection function (ANSI code 59N) is used as non-selective backup for ground faults also for selective ground fault protection for motors having a unit transformer between the motor and the busbar.

This function is sensitive to the fundamental frequency component of the neutral voltage. Whenever the selected neutral voltage value, measured or calculated, exceeds the pick-up setting of a particular stage, this stage starts and issues a start signal. If the fault situation is present longer than the operate time delay setting, a trip signal is issued.

Figure 277 - Block diagram of the neutral voltage displacement protection function



Characteristics

Visibility of VT setting sections and VN setting sections depends on the fitted VTs (and the selected measurement mode). The setting range will be updated as required in the table below.

Table 101 - Settings and characteristics of the neutral overvoltage protection function

Settings/characteristics (description/label)	Values
Pick-up value	
Setting range	0.02...1.50 pu[108]
Resolution	0.01 pu[108]
Accuracy	±2% or ± 0.005 pu[108]
Reset ratio	97% ± 2%
Operate delay	
Setting range	0.00...300.00 s

---

[108] √3 x Vnom

Table 101 - Settings and characteristics of the neutral overvoltage protection function (Continued)

Settings/characteristics (description/label)	Values
Resolution	0.01 s
Accuracy	±1% or ±10 ms
Reset time	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±30 ms
Characteristic times	
Start time	< 50 ms (45 ms with high speed)
Overshoot time	< 40 ms
Disengaging time	< 55 ms (70 ms with high speed)
Setting groups	
Number	4
Evaluation VN	
Options	Measured/Calculated

Capacitor overvoltage (ANSI 59C)

Description

This capacitor overvoltage protection function (ANSI code 59C) calculates the voltages of a three-phase Y-connected capacitor bank using the measured currents of the capacitors and the capacitor reactance. No voltage measurements are needed. Especially in filter applications, there are harmonics and, depending on the phase angles, the harmonics can increase the peak voltage. This protection function calculates the worst-case overvoltage in per-unit values according to IEC 60871-1 standard. Harmonics up to 15th are taken into account.

$$V_c = \frac{X_c}{V_{cLN}} \sum_{n=1}^{15} \frac{I_h}{n}$$

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where

$$X_c = \frac{1}{2 \cdot \pi \cdot f \cdot C_{set}}$$

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V_c = Amplitude of a pure fundamental frequency sine wave voltage, whose peak value is equal to the maximum possible peak value of the actual voltage (including harmonics) over a Y-coupled capacitor.

X_c = Reactance of the capacitor at the measured frequency

V_{cLN} = Nominal voltage of the capacitance C.

n = Order number of harmonic. n = 1 for the fundamental frequency component. n = 2 for 2nd harmonic etc.

I_h = nth harmonic of the measured phase current. h = 1 - 15.

f = Measured system frequency.

C_{set} = Single phase capacitance between phase and starpoint.

The above equation gives the maximum possible voltage, while the actual voltage depends on the phase angles of the involved harmonics. The protection is sensitive to the highest voltage of the three phase to neutral voltages. Whenever this value exceeds the start setting of a particular stage, this stage starts and issues a start signal. If the fault situation is present longer than the definite operation delay setting, a trip signal is issued.

Reactive power of the capacitor bank

The rated reactive power per phase-ground capacitor is calculated as follows:

$$Q_n = 2 \cdot \pi \cdot f_n \cdot V_{cLN}^2 \cdot C_{set}$$

A533EL00

Q_n = Rated reactive power of the three-phase capacitor bank

f_n = Rated frequency. 50 Hz or 60 Hz.

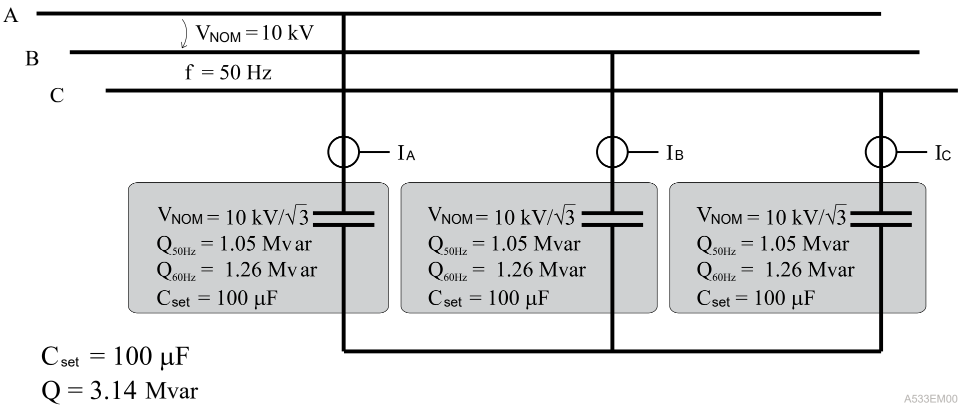
V_{cLN} = Nominal voltage of the capacitance C.

C_{set} = Single phase capacitance between phase and starpoint.

Three separate capacitors connected in wye (III Y)

In this configuration, the capacitor bank is built of three single-phase sections without internal interconnections between the sections. The three sections are externally connected to a wye (Y). The single-phase to starpoint capacitance is used as the setting value.

Figure 278 - Example of wye (III Y) connected capacitor bank

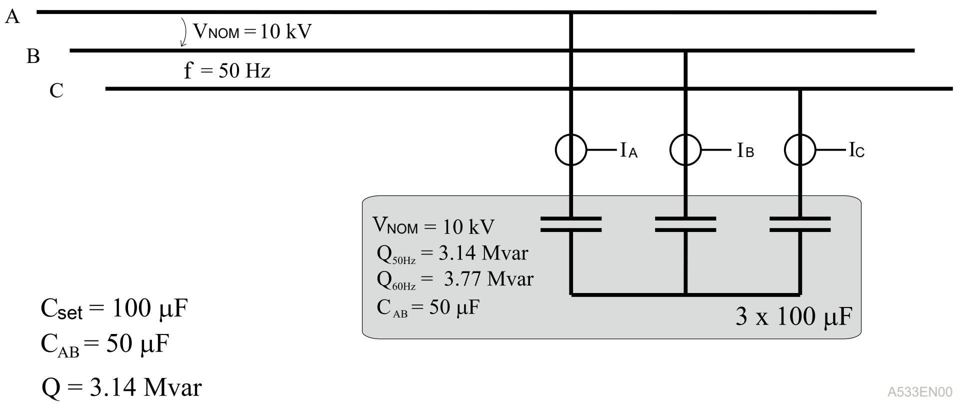


Three phase capacitor connected internally in wye (Y)

In this configuration, the capacitor bank consists of a three-phase capacitor connected internally to a wye (Y).

The single-phase to starpoint capacitance is used as the setting value, which can be calculated from the capacitance C_{AB} between phases A and B (as given on the nameplate): $C_{set} = 2C_{AB}$

Figure 279 - Three-phase capacitor bank connected internally in wye (Y)



Capacitance between phases A and B is 50 µF and the equivalent phase to neutral capacitance is 100 µF whose value is also used as the setting value.

Overvoltage and reactive power calculation example

The capacitor bank is built of three separate 100 µF capacitors connected in wye (Y). The rated voltage of the capacitors is 8 kV; the measured frequency is 50.04 Hz and the rated frequency is 50 Hz.

The measured fundamental frequency current of phase A is: IA = 181 A; the measured relative 2nd harmonic is: 2% = 3.62 A; the measured relative 3rd harmonic is: 7% = 12.67 A; the measured relative 5th harmonic is: 5% = 9.05 A.

According to equation $C_{set} = C_{nameplate}$, the phase to starpoint capacitance is: C_{set} = 100 µF

The rated power is: Q_n = 2011 kvar

$$Q_n = 2 \cdot \pi \cdot f_n \cdot V_{cLN}^2 \cdot C_{set}$$

A533EL00

The reactance is: X_c = 1 / (2π x 50.04 x 100 x 10 - 6) = 31.806 Ω

$$X_c = \frac{1}{2\cdot\pi\cdot f\cdot C_{set}}$$

P533EK00

The pure fundamental voltage V_c having a peak value equal to the highest possible voltage with similar harmonic content as the measured reactive capacitor currents is: Vcp1 = 31.806 x (181 / 1 + 3.62 / 2 + 12.67 / 3 + 9.05 / 5) = 6006 V

and in per-unit values: Vcp1 = 6006/8000 = 0.75

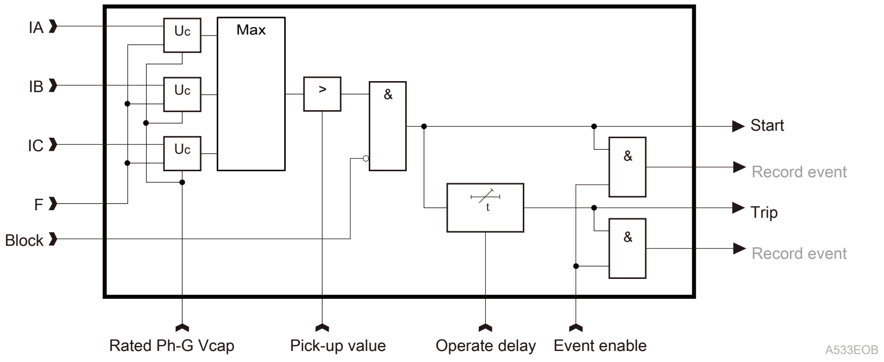
$$V_c = \frac{X_c}{V_{cLN}} \sum_{n=1}^{15} \frac{I_h}{n}$$

A533EJ00

The same calculation is executed for phases B and C. The highest of the three values is compared to the start setting.

Block diagram

Figure 280 - Block diagram of the capacitor overvoltage protection function (ANSI 59C)



Characteristics

Table 102 - Settings and characteristics of the capacitor overvoltage protection 59C

Settings/characteristics (description/label)	Values
Pick-up value/V_c>	
Setting range	0.10...2.50 xV_cLN[109]
Resolution	0.01
Accuracy	±3%
Reset ratio	97% ± 2%
L-N capacitance of one phase/C	
Setting range	1.00...650.00 µF
Resolution	0.01 µF
Rated L-N voltage V_cLN/V_cLN	
Setting range	100...260000 V
Resolution	1 V
Operate delay/t> (DT)	
Setting range	0...30.0 s

---

[109] Phase to ground voltage rating of capacitor

Table 102 - Settings and characteristics of the capacitor overvoltage protection 59C (Continued)

Settings/characteristics (description/label)	Values
Resolution	0.5 s
Accuracy	< 1.5 s
Characteristic times	
Start time	< 1.5 s
Disengaging time	< 1.5 s
Setting group	
Number	4

Non-directional/directional ground fault overcurrent (ANSI 50N/51N/67N)

Description

The ground fault overcurrent protection function (ANSI codes 50N/51N) with optional neutral voltage polarization (ANSI code 67N) provides selective and sensitive detection and operation on ground faults in power networks or equipment like motors or transformers (for example the tank protection).

It can be adapted for all types of network grounding and used in applications with varying network structure and feeder length.

According to the model of the PowerLogic P5 protection relay, the neutral current can be directly measured or calculated from the three phase currents.

The protection basically operates on fundamental component or on RMS value of the neutral current.

When using fundamental component, it is not sensitive to the third harmonic. It can be set up in directional mode by using neutral voltage. Direction decision is mainly based by measuring the angle between neutral current and neutral voltage and comparing it to the characteristic that can be set according to the system grounding. For directional mode, whenever the magnitude of neutral current IN and neutral voltage VN and the phase angle between IN and VN fulfils the start criteria, the stage starts and issues a start signal. If the fault situation is present longer than the operate delay setting, a trip signal is issued.

All 6 neutral overcurrent stages are also available with transformer differential protection P5T30 as back-up protection. Each stage can be individually linked to the measured neutral current or the calculated sum of the three phase currents of one end. If neutral voltage measurement from one end is available (depending on VT configuration), the stages linked to that end can operate in directional mode, too. Stages linked to the other end can operate in non-directional way only.

Input signal selection

The **IN input** can be *IN.calc*, *IN.meas*, *IN.sens* or *IN.CSH* based on the configuration of CT input on slot A:

- *IN.calc* is available for the PowerLogic P5 models with CT input or LPCT input.
- *IN.meas* is available for the PowerLogic P5 models with standard neutral current input. It is proposed for the solidly grounded networks.
- *IN.sens* is available for the PowerLogic P5 models with neutral current input. It is proposed for the insulated grounding networks or ungrounded networks with core-balance CT (other than CSH).
- *IN.CSH* is available for the PowerLogic P5 models with CSH core-balance CT input.

For the characteristics of different types of **IN input**, refer to Characteristics for measuring neutral current, page 523.

NOTE: In addition of the above configurations, in eSetup Easergy Pro/ **GENERAL/Scaling**, if the selection of **Number connected phase CTs** is *A/C*, the selection *IN.calc* will become unavailable.

Measurement mode

Ground fault current protection can use either fundamental component or RMS (root mean square) value of the selected neutral current.

This selection depends on the application needs. In most cases fundamental current is used. The RMS value provides a more robust operation for distorted fault currents with significant amount of higher harmonics.

The RMS calculation is based on the samples with the formula:

$$I_{RMS} = \sqrt{\frac{1}{n}\sum_{k=1}^{n} i_k^2}$$

P533WJ00

Where: n = 48 is the number of samples per period.

The (optional) determination of fault direction is always based on the fundamental vectors of neutral current and voltage.

> **NOTE:** Different to the method evaluating fundamental signal only, the RMS method also processes transient DC components in the measurement current, which may inevitably occur during switching operations. When using the sensitive measurement input IN.sens, this can lead to unwanted starting at very small pick-up values (< 0.003 IN.nom). Therefore, setting such small values is not recommended.

Polarization

The neutral displacement voltage used for polarization is either directly measured by neutral voltage channel of the PowerLogic P5 protection relay or, alternatively, internally calculated from the three phase voltages. Their availability depends on the selected voltage measurement mode.

- 3VP, 3VP/VPPy and 3VP/VPy:

  Only internally calculated neutral voltage is available and can be used.
- 3VP+VN, 2VPP+VN, and 2VPP+VN+VPPy:

  Both, measured and calculated neutral voltages are available and one of them can be selected.
- VPP/VPPy

  No neutral voltage is available. Ground fault overcurrent protection can be set up in non-directional way only.

The reference for the set VN pick-up value depends on the selected signal:

- with measured neutral voltage it is the neutral VT primary nominal voltage;
- with calculated neutral voltage it is the phase VT primary nominal voltage.

Operating curve selection

The operating curve of the ground fault overcurrent protection can be selected to DT, standard dependent operate delay, and programmable dependent operate delay. When the “Operating Curve” is set to IDMT curve, the settings “DT adder” and “Minimum operate time” will show up. “DT adder” defines the additional time delay plus the IDMT timer. “Minimum operate time” defines the minimum operating time for IDMT curves to help ensure the IDMT stage will not trip faster than the DT stage when the fault current is very large. For more information, refer to Operating curve selection, page 294.

Inrush blocking

The user can block the overcurrent function by selecting the setting "Inrush blocking" of each stage. The purpose is to make the earth overcurrent function inoperative during the transformer energization, otherwise a large primary current flow for a transient period will cause an unwanted trip. For more information, refer to Inrush blocking, page 394.

Selective overcurrent logic

The SOL function have dynamic impacts on the ground fault overcurrent settings of timer and start value. For more information on activating the SOL function, refer to Selective overcurrent logic, page 394.

Dynamic setting element

Dynamic mode allows the ground fault overcurrent protection settings dynamically adjusted during the transient period. It can be applied to cooperate between the Cold Load Pick-up, and also to realize voltage-controlled overcurrent. For more information, refer to Dynamic setting element, page 394.

Modes for different network types

The available modes are:

- ResCap

  This feature can be used with compensated networks when the Petersen coil is temporarily switched off. This mode consists of two sub modes, Res and Cap. A digital signal can be used to dynamically switch between these two submodes. When the digital input is active (DI = 1), Cap mode is in use and when the digital input is inactive (DI = 0), Res mode is in use.

  - Res

    The stage is sensitive to the resistive component of the selected IN signal. This mode is used with compensated networks (resonant grounding) and networks grounded with a high resistance (resistive grounding). Compensation is usually done with a Petersen coil between the neutral point of the main transformer and ground. In this context, high resistance means that the maximum ground fault current is limited to a certain value, e.g. to the rated phase current. The trip area is a half plane as drawn in Operation characteristic of the directional ground fault protection in Res or Cap mode, page 431. The base angle is usually set to zero degrees.

  - Cap

    The stage is sensitive to the capacitive component of the selected IN signal. This mode is used with ungrounded (isolated) networks. The trip area is a half plane as drawn in Operation characteristic of the directional ground fault protection in Res or Cap mode, page 431. The base angle is usually set to zero degrees.

- Sector

  This mode is used with networks grounded with a small resistance. In this context, "small" means that a fault current may be more than the rated phase currents. The trip area has a shape of a sector as drawn in Two examples of operation characteristic of the directional ground fault stages in Sector mode, page 431. The angle offset is usually set to zero degrees or slightly on the lagging inductive side (negative angle).

- NoDir

  This mode makes the stage equal to the non-directional stage 50N/51N-1. The phase angle and VN amplitude setting are discarded. Only the amplitude of the selected IN input matters.

Figure 281 - Operation characteristic of the directional ground fault protection in Res or Cap mode

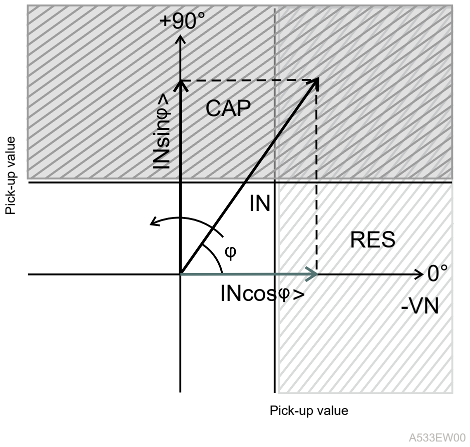
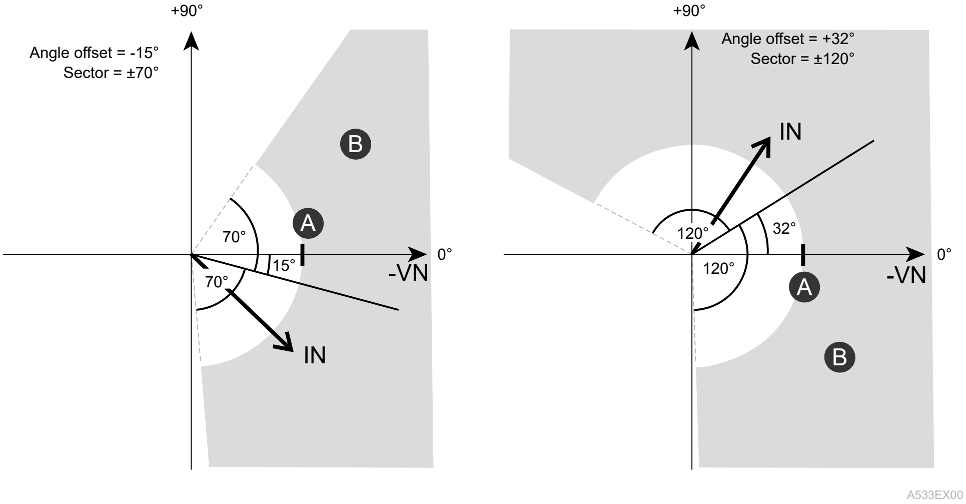


Figure 282 - Two examples of operation characteristic of the directional ground fault stages in Sector mode



A	IN pick-up setting	B	Trip area

The drawn IN phasor in both figures is inside the trip area. The angle offset and half sector size are user’s parameters.

Intermittent ground fault detection

Short ground faults make the protection start but do not cause a trip. A short fault means one cycle or more. For transient intermittent ground faults shorter than 1 ms in compensated networks, there is a dedicated protection stage 67NI-1. When starting happens frequently, such intermittent faults can be cleared using the intermittent time setting.

When a new start happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage trips.

Faulty phase detection during ground fault

Phase recognition

A neutral voltage displacement has been detected.

A faulted phase or phases are detected in the two-stage system.

1. Use delta principle to detect the faulty phase/phases.
2. Configuration of the faulty phase with neutral current angle comparison to the suspected faulted phase.

For an ideal, grounded network, when there is a forward ground fault in phase A, its current increases, creating a calculated or measured zero sequence current with a phase angle of 0 degrees. If there is a reverse ground fault in phase A, its current decreases creating a calculated or measured zero sequence current with a phase angle of 180 degrees.

When there is a forward ground fault in phase B, its current increases creating a calculated or measured zero sequence current with a phase angle of -120 degrees. If there is a reverse ground fault in phase B, its current decreases creating a calculated or measured zero sequence current with a phase angle of 60 degrees. When there is a forward ground fault in phase C, its current increases creating a calculated or measured zero sequence current with a phase angle of 120 degrees. If there is a reverse ground fault in phase C its current degreases creating a calculated or measured zero sequence current with a phase angle of -60 degrees.

For a compensated network, the stability of the protection depends on the network compensation degree. So for compensated networks, this feature can be turned off to avoid confusion.

For high-impedance grounded networks, there is a drop-down menu in all setting groups to choose between RES/CAP. RES is the default and it is for grounded networks. When CAP is chosen, the IN angle is corrected to an inductive direction of 90 degrees.

Possible outcomes and conditions for those detections

- FWD IA

  Phase A increases above the set limit and two other phases remain inside the set (delta) limit. IN current angle is +/- 60 degrees from phase A’s phase angle.
- FWD IB

  Phase B increases above the set limit and two other phases remain inside the set (delta) limit. IN current angle is +/- 60 degrees from phase B’s phase angle.
- FWD IC

  Phase C increases above the set limit and two other phases remain inside the set (delta) limit. IN current angle is +/- 60 degrees from phase C’s phase angle.
- FWD IA - IB

  Phase A and B increase above the set limit and phase C remains inside the set (delta) limit. IN current angle is between phase A’s and phase B’s phase angles.
- FWD IB - IC

  Phase B and C increase above the set limit and phase A remains inside the set (delta) limit. IN current angle is between phase B’s and phase C’s phase angles.
- FWD IC - IA

  Phase C and A increase above the set limit and phase B remains inside the set (delta) limit. IN current angle is between phase C’s and phase A’s phase angles.
- FWD IA - IB - IC

  All three phase currents increase above the set delta limit.

- REV 1 (any one phase)

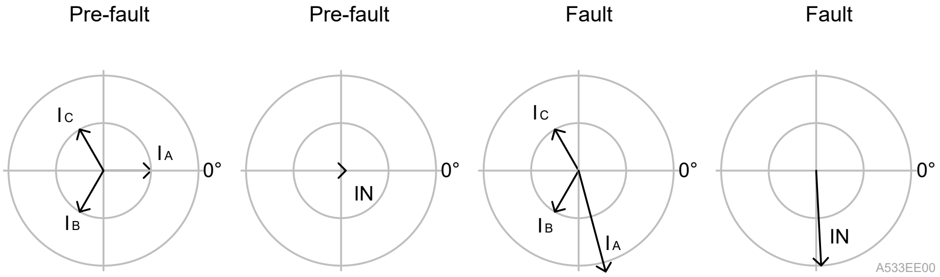
  One phase decreases below the set delta limit and other two phases remain inside the delta limit.
- REV 2 (any two phases)

  Two phases decrease below the set delta limit and third phase remains inside the delta limit.
- REV 3 (all three phases)

  All three phase currents decrease below the set delta limit.

Different simulated fault scenarios

Figure 283 - Phase A forward



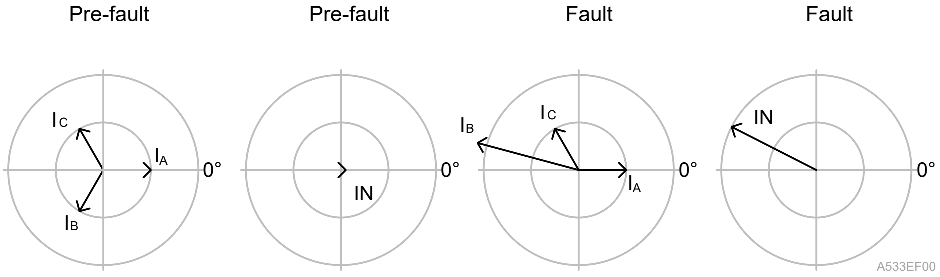
Healthy conditions
A, B, C, 100A

Healthy conditions
IN, 0A

Phase A e/f
IA, 384A<-75°

Phase A e/f
IN, 187A<-87°

Figure 284 - Phase B forward



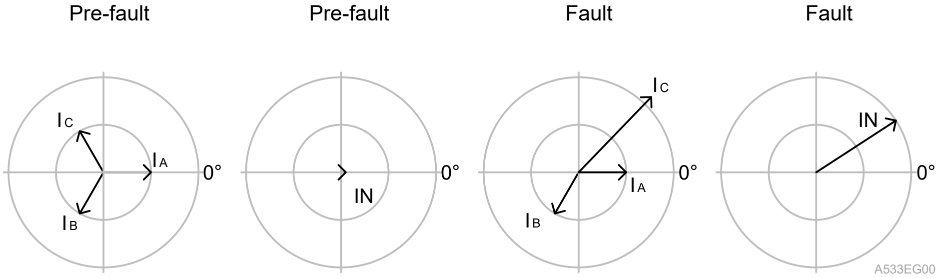
Healthy conditions
A, B, C, 100A

Healthy conditions
IN, 0A

Phase B e/f
IB, 384A<-165°

Phase B e/f
IN, 187A<-153°

Figure 285 - Phase C forward



Healthy conditions
A, B, C, 100A

Healthy conditions
IN, 0A

Phase C e/f
IC, 384A<-46°

Phase C e/f
IN, 187A<-33°

Fault recording

When a faulty phase is recognized, it is recorded in the ground fault current protection fault log (also in the event list and alarm screen). This faulted phase and direction recording function have a tick box in eSetup Easergy Pro for enabling/disabling in the protection stage settings.

Six independent stages

There are six separately adjustable stages: 50N/51N/67N-1, 50N/51N/67N-2, 50N/51N/67N-3, 50N/51N/67N-4, 50N/51N/67N-5 and 50N/51N/67N-6.

All the stages can be configured for definite operation time (DT) or dependent operation time.

NOTE: The PowerLogic P5 protection relay shows a scalable graph of the configured delay on the local panel display.

High-impedance restricted earth fault protection

The high impedance protection principle can be applied as differential protection for machines, power transformers and busbar installations. It is offering stability for any type of fault occurring outside the protected zone and satisfactory operation speed for faults within the zone. The PowerLogic P5 protection relays can realize this application. Both the standard neutral overcurrent element and the very sensitive neutral overcurrent element can be used for high-impedance restricted earth fault (REF) protection. The information about application, setting examples and recommendations for resistors can be found in the Application Book.

Back-up mode

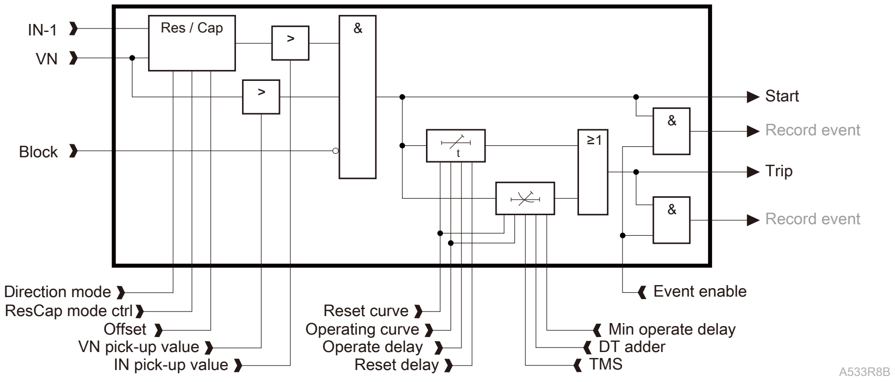
The back-up mode is for PowerLogic P5L30 only.

The negative sequence overcurrent protection, the non-directional/directional phase overcurrent protection and the non-directional/directional ground fault overcurrent protection can be set as backup protections of the line differential protection in case the line differential protection is permanently blocked. By default, the overcurrent stages are active. Once the back-up mode is enabled, the overcurrent protections will be active only if the line differential protection is blocked, and when the line differential protection is not blocked or disabled, the overcurrent protections will be inactive again.

To enable/disable the back-up mode, check/uncheck the **Back-up mode** in eSetup Easergy Pro/ **PROTECTION**/**Negative sequence overcurrent 46** and **Phase overcurrent 50/51/67** and **Ground fault overcurrent 50N/51N/67N**.

Block diagram

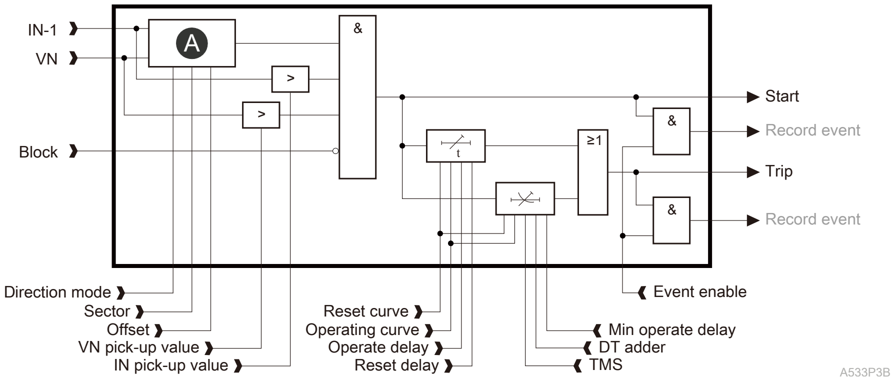
Figure 286 - Block diagram of the non-directional/directional ground fault overcurrent protection function operating in ResCap mode (ANSI 50N/51N/67N)



NOTE:

- The **IN input** can be *IN.calc, IN.meas, IN.sens* based on the configuration.
- The **VN** can be directly measured from an open delta VT or calculated from three phase VTs.
- **Block** input can be signals configured via Block Matrix, due to inrush condition detected, or blocked under the VTS condition based on the configuration and operating condition.
- **IN pick-up value** is either the setting **IN pick-up value** or the **Dynamic threshold** depending on the configuration and operating condition.
- **Operate delay** is either the setting **Operate delay**, the **SOL operate delay** or the **Dynamic operate delay** setting depending on the configuration and operating condition.
- **TDM** value is either the setting **TDM**, the **SOL TDM** or the **Dynamic TDM** setting depending on the configuration and operating condition.
- **Res / Cap**: when working as Res mode, the operate characteristic follows the equation: IN* cos (Angle (IN) - Angle(-VN) - Angle offset) > IN pick-up value. when working as Cap mode, the operate characteristic follows the equation: IN* sin (Angle (IN) - Angle(-VN) - Angle offset) > IN pick-up value.

Figure 287 - Block diagram of the non-directional/directional ground fault overcurrent protection function operating in Sector mode (ANSI 50N/51N/67N)

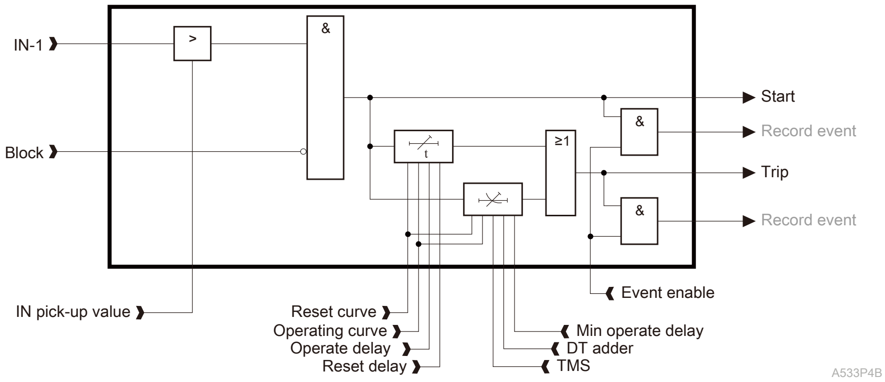


A	Directional check The operate characteristic should follow the equation: | Angle (IN) - Angle(-VN) - Angle offset | < Sector

NOTE:

- The **IN input** can be *IN.calc, IN.meas, IN.sens* based on the configuration.
- **Block** input can be signals configured via Block Matrix, due to inrush condition detected, or blocked under the VTS condition based on the configuration and operating condition.
- **IN pick-up value** is either the setting **IN pick-up value** or the **Dynamic threshold** depending on the configuration and operating condition.
- **Operate delay** is either the setting **Operate delay**, the **SOL operate delay** or the **Dynamic operate delay** setting depending on the configuration and operating condition.
- **TDM** value is either the setting **TDM**, the **SOL TDM** or the **Dynamic TDM** setting depending on the configuration and operating condition.

Figure 288 - Block diagram of the non-directional/directional ground fault overcurrent protection function operating in Non-dir mode (ANSI 50N/51N/67N)



NOTE:

- The **IN input** can be *IN.calc, IN.meas, IN.sens* based on the configuration.
- **Block** input can be signals configured via Block Matrix, due to inrush condition detected, or blocked under the VTS condition based on the configuration and operating condition.
- **IN pick-up value** is either the setting **IN pick-up value** or the **Dynamic threshold** depending on the configuration and operating condition.
- **Operate delay** is either the setting **Operate delay**, the **SOL operate delay** or the **Dynamic operate delay** setting depending on the configuration and operating condition.
- **TDM** value is either the setting **TDM**, the **SOL TDM** or the **Dynamic TDM** setting depending on the configuration and operating condition.

Characteristics

Table 103 - Setting and characteristics of the non-directional/directional ground fault overcurrent protection function (ANSI 50N/51N/67N)

Setting/characteristics (description/label)	Values
IN Pick-up value/IN>	
Setting range	For delay type DT: 0.050...40.000 pu[110] for IN.calc; 0.020...20.000 pu[110] for IN.meas; 0.002...1.000 pu[110] for IN.sens;

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[110] Inom for IN.calc; IN.nom for IN.meas; IN.sens.nom for IN.sens.meas; IN.CSH.nom for IN.CSH

Table 103 - Setting and characteristics of the non-directional/directional ground fault overcurrent protection function (ANSI 50N/51N/67N) (Continued)

Setting/characteristics (description/label)	Values
	0.020...20.000 pu[111] for IN.measwith use of CSH30; 0.050...20.000 pu[111] for IN.CSH. For delay type IDMT: 0.050...5.000 pu[111] for IN.calc; 0.020...5.000 pu[111] for IN.meas; 0.002...1.000 pu[111] for IN.sens; 0.020...5.000 pu[111] for IN.meas with use of CSH30; 0.050...5.000 pu[111] for IN.CSH.
Resolution	0.001 pu[111]
Accuracy	±2% or ±0.005 pu[111] for IN.calc; ±2% or ±0.002 pu[111] for IN.meas; ±2% or ±0.0005 pu[111] for IN.sens; ±2% or ±0.002 pu[111] for IN.meas with use of CSH30; ±2% or ±0.005 pu[111] for IN.CSH.
Reset ratio	95% ±2% or ±2mA
Transient overreach	< 5% for X/R up to 120
EFCT input selection[112]	
Setting range	EFCT-1, EFCT-2
Measurement mode/IN meas mode	
Options	FFT, RMS
Back-up mode/Back-up mode[113]	
Options	On/Off
VN Pick-up value/VN Pick-up value	
Setting range	0.01...1.00 pu[114]
Resolution	0.01 pu[114]
Accuracy	±2% or ±0.005 pu[114]
IN input/Input	
Options	IN.calc, IN, IN.sens, IN.CSH
VN input mode	
Options	Measured, Calculated
Operating Curve	
Options	DT; IEC: SI, VI, EI, LTI, UTI; IEEE: MI, VI, EI ANSI: NI, STI, LTI Others: UK_Rectifier, FR_STI, RI, STI_CO2, LTI_CO5, MI_CO7, NI_CO8, VI_CO9, EI_CO11, BPN Prg1-3
Accuracy	±5% or ±20 ms (for IDMT)
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01
Accuracy	±1% or ±10 ms
TDM/TDM	

---

[111] Inom for IN.calc; IN.nom for IN.meas; IN.sens.nom for IN.sens.meas; IN.CSH.nom for IN.CSH
[112] Available for P5T30 only.
[113] Available for P5L30 only.
[114] √3 x Vnom

Table 103 - Setting and characteristics of the non-directional/directional ground fault overcurrent protection function (ANSI 50N/51N/67N) (Continued)

Setting/characteristics (description/label)	Values
Setting range	0.020...20.000
Resolution	0.001
DT adder/DT adder	
Setting range	0.00...1.00 s
Resolution	0.01 s
Minimum operate delay/Min operate delay	
Setting range	0.00...10.00 s
Resolution	0.01 s
Direction mode/Direction mode	
Options	ResCap, Sector, Non_Dir
Char ctrl. in ResCap mode/ChCtrl	
Options	Res, Cap, DI, VI
Angle offset/Offset	
Setting range	-180°...+179°
Resolution	1°
Accuracy	±2°
Reset ratio (angle)	2°
Pick up sector size	
Sector size	10°...170°
VTS blocking	
Options	Blocked, Non-directional
Reset curve/Reset curve	
Options	DT; IDMT; Prg1-3
Reset delay/Reset delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	±1% or ±30 ms
SOL use by INDir>	
Options	Off; SOL1; SOL2
SOL operate delay/SOL operate delay	
Setting range	0.00...300.0 s
Resolution	0.1s
Accuracy	±1% or ±10 ms
SOL TDM/SOL TDM	
Setting range	0.020...20.000
Resolution	0.001
Dynamic mode/Dynamic mode	
Options	Off/On
Dynamic threshold/Dyn pick-up value	

Table 103 - Setting and characteristics of the non-directional/directional ground fault overcurrent protection function (ANSI 50N/51N/67N) (Continued)

Setting/characteristics (description/label)	Values
Setting range	For delay type DT: 0.050...40.000 pu[115] for IN.calc; 0.020...20.000 pu[115] for IN.meas; 0.002...10.000 pu[115] for IN.sens; 0.020...20.000 pu[115] for IN.meas with use of CSH30; 0.050...20.000 pu[115] for IN.CSH. For delay type IDMT: 0.050...5.000 pu[115] for IN.calc; 0.020...5.000 pu[115] for IN.meas; 0.002...1.000 pu[115] for IN.sens; 0.020...5.000 pu[115] for IN.meas with use of CSH30; 0.050...5.000 pu[115] for IN.CSH.
Resolution	0.001 pu[115]
Accuracy	±2% or ±0.005 pu[115] for IN.calc; ±2% or ±0.002 pu[115] for IN.meas; ±2% or ±0.0005 pu[115] for IN.sens; ±2% or ±0.002 pu[115] for IN.meas with use of CSH30; ±2% or ±0.005 pu[115] for IN.CSH.
Dynamic operate delay/Dynamic op delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
Dynamic TDM/Dynamic TDM	
Setting range	0.020...20.000
Resolution	0.001
Back-up mode	
Enable back-up mode	Off/On
Characteristic times	
Start time	< 30 ms (25 ms with high speed) for currents at 2 x Is pick-up value (non-directional) < 40 ms (35 ms with high speed) for currents at 1,2 x Is pick-up value (non-directional)
	< 45 ms (40 ms with high speed) for currents at 2 x Is pick-up value (directional) < 50 ms (45 ms with high speed) for currents at 1,2 x Is pick-up value (directional)
Disengaging time	< 65 ms (80 ms, only for high speed high break digital outputs)
Overshoot time	< 40 ms for currents at 2 x Is
Setting group	
Number	4

---

[115] Inom for IN.calc; IN.nom for IN.meas; IN.sens.nom for IN.sens.meas; IN.CSH.nom for IN.CSH

Restricted ground fault protection (ANSI 64)

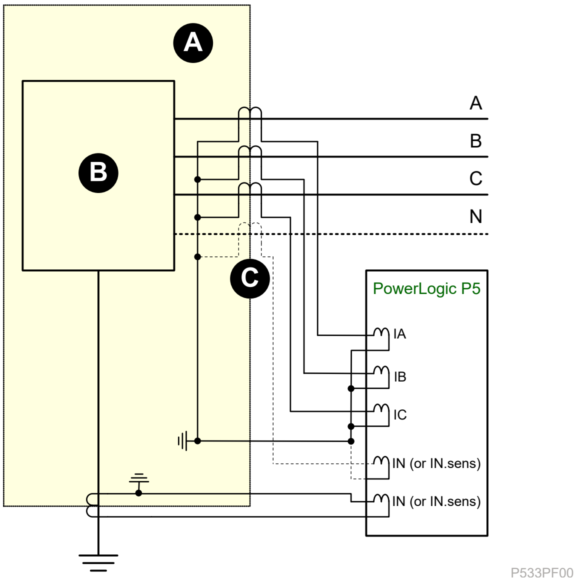
Description

Ground faults occurring on a transformer winding or terminal may be of limited magnitude, either due to the impedance present in the earth path or by the percentage of transformer winding that is involved in the fault. It is common to apply standby earth fault protection fed from a single CT in the transformer earth connection, this provides time-delayed protection for a transformer winding or terminal fault. In general, particularly as the size of the transformer increases, it becomes unacceptable to rely on time-delayed protection to clear winding or terminal faults as this would lead to an increased amount of damage to the transformer. A common requirement is therefore to provide instantaneous phase and earth fault protection. Applying differential protection across the transformer may fulfill these requirements. However, an earth fault occurring on the LV winding, particularly if it is of a limited level, may not be detected by the differential relay, as it is only measuring the corresponding HV current. Therefore, instantaneous protection that is restricted to operating for transformer earth faults only is applied. This is referred to as restricted ground differential protection.

When applying differential protection such as REF, some suitable means must be employed to give the protection stability under external fault conditions, thus ensuring that relay operation occurs for faults inside the protected zone only. For this, two methods are commonly used:

- The low impedance REF (biased REF) technique operates by measuring the level of current flowing through the protected object (through phase, neutral and ground connections) and altering the relay sensitivity according to the level of currents. The dedicated 64REF protection function is such a biased differential function.
- The high impedance REF technique ensures that the relay circuit is of sufficiently high impedance such that the differential voltage that may occur under external fault conditions is less than that required to drive set current through the relay. Such protection scheme can be set up with P5 neutral overcurrent elements, as detailed in related application note.

Figure 289 - Basic biased REF scheme



A	Zone of protection	B	Protected object
C	Optional (5CT application)		

The restricted ground differential protection principle has several advantages. It is very selective because the protection zone is limited between the current transformers that are used for the restricted ground differential protection. Because of its selectivity, the restricted ground differential protection requires no additional time delay for protection coordination. Therefore, the restricted ground differential protection is especially suitable for the protection of transformers and rotating machines against internal ground faults. Because of the differential protection principle, it is also very sensitive which makes it suitable for detecting faults located near the neutral point of transformers and rotating machines.

The low-impedance restricted ground differential protection function is sensitive to the fundamental frequency component of the measured currents.

With transformer differential protection P5T30 two REF elements are available with a fix link to the measured currents of one end (REF-1 to end 1, REF-2 to end 2).

Wording

REF is also referred to as Balanced Earth Fault (BEF) Protection, where this terminology is usually used when the protection is applied to a delta winding. Also in some areas the use of "Ground" instead of "Earth" is preferred.

5CT Application

For protection of 4 wire systems (including the dashed connections in Basic biased REF scheme, page 440) the "5CT application" feature in REF has to be enabled. In all other REF applications this feature shall remain disabled.

This feature is not available with P5T30.

CT polarity

Low impedance restricted ground differential protection function measures phase and neutral currents, as sketched in Basic biased REF scheme, page 440. When calculating differential and bias currents, the sign of the measured currents must be considered. Accordingly, settings are provided to adjust actual wiring to the function needs. For the CT orientation and polarity, please refer to CT and LPCT typical application, page 73 and Scaling settings, page 513.

Amplitude matching

Neutral CTs can have smaller current ratio than phase CTs, reflecting different expected fault currents for phase and ground faults as a result from power system grounding impedances. In order to calculate correct differential and bias currents, such differences in CT ratio must be considered.

For this purpose, restricted ground differential protection function automatically scales all currents to a common reference, which is the phase CT primary current. This scaling uses matching factors which are calculated from the ratio of the neutral and phase CTs.

- Standard earth fault current amplitude matching factor:

  IN CT scaling factor = Neutral CT ratio / Phase CT ratio
- Sensitive earth fault current amplitude matching factor:

  IN.sens scaling CT factor = Sensitive neutral CT ratio / Phase CT ratio

  Where:
  - Phase CT ratio = IP CT primary / IP CT secondary
  - Neutral CT ratio = IN CT primary / IN CT secondary
  - Sensitive neutral CT ratio = IN.sens CT prim. / IN.sens CT sec.

Permissible ranges of the matching factors are within 0.01 and 10. If this condition is not satisfied, the low impedance restricted ground differential protection will be blocked.

Example: Phase CT ratio is 1000A: 1A; Neutral CT ratio is 500A: 5A; Then reference current is 1000A = phase CT primary nominal current and IN scaling factor is 500:5 / 1000:1 = 0.1.

Measurements

Protection function calculates differential and bias currents. The continuously updated values of these measurements are displayed on device HMI and are available for communication both to local operating tool as well as to remote SCADA systems for monitoring during normal operation or check during commissioning.

The differential current is always calculated as vectorial sum of all currents, for example:

- In 4 CT application: Id = | IA + IB + IC + I'G |
- In 5 CT application: Id = | IA + IB + IC + I'G + I’N |

Where:

- IA, IB, IC are the phase currents.
- I'G is the amplitude matched current flowing through the wye point to ground (measured through standard or sensitive neutral CT acc. to selected IG input).
- I’N is the amplitude matched current from the neutral wire CT in "5CT application" (measured through remaining neutral CT, not set as IG input).

The bias current calculation depends on selected operating mode.

Phase comparison

Under condition of an external fault causes the CT saturation, there will be significant differential current, the intensity will be equal to the current of the saturated CT. The measured differential current may be identified as an internal fault which may initiate an unwanted trip. To help to reduce the risk of tripping, bias differential protection uses the phase comparison logic to identify if the detected fault is internal or external.

The logic remains active as long as the restricted ground differential protection is active. There is no setting for this logic, a Block Low output signal indicates the phase comparison block status:

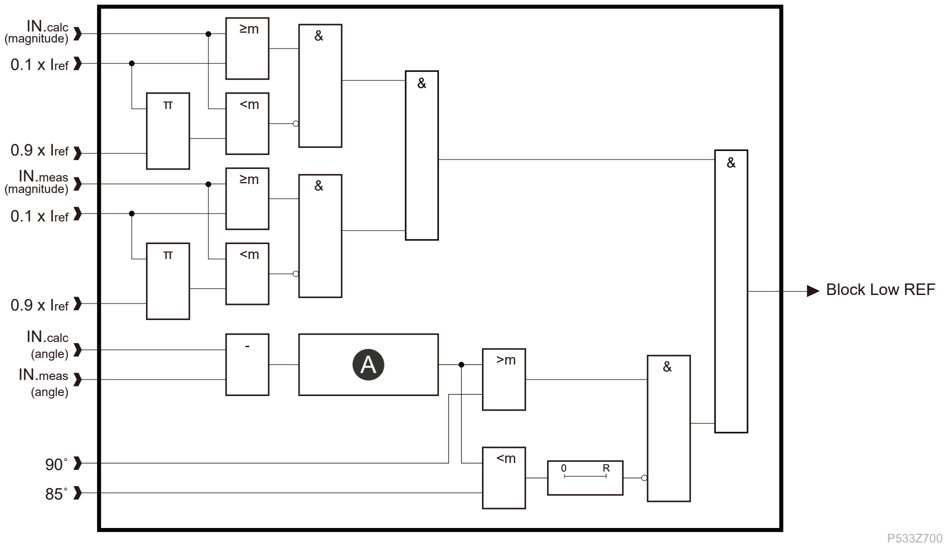
- If the current measured by any CT is lower than 0.1 x Iref, there will be no block to bias differential protection.
- If the currents measured by both CTs are greater than 0.1 x Iref, and the phase angle difference between the two CTs is within [-90, 90] degrees, the detected fault will be identified as internal fault, which will not block the bias differential protection.
- If the currents measured by both CTs are greater than 0.1 x Iref, and the phase angle difference between the two CTs is not within [-90, 90] degrees, the detected fault will be identified as external fault, the bias differential protection will be blocked.

The characteristic of the phase comparison is as below:

Characteristic	Values
Hysteresis of current magnitude	90%
Hysteresis of angle difference	5°
Counter for external fault block output	Without
Reset counter from external fault to internal fault	15 ms

The following diagram is the phase compare logic diagram for Low :

Figure 290 - Low phase comparison logic diagram



A	If AngDiff (angle difference) < 0 AngDiff = - AnfDiff; If AngDiff >180 AngDiff = 360 — AngDiff		
π	Multiplier	-	Subtraction

Operating modes

There are two operating modes selectable:

- Sum(IP) bias = Biased by sum of phase currents
- Max(IP) bias = Biased by maximum phase current

The difference between both is the definition of the restraining current and their tripping characteristic.

Biased by sum of phase currents

In this operating mode, bias current is calculated as follows:

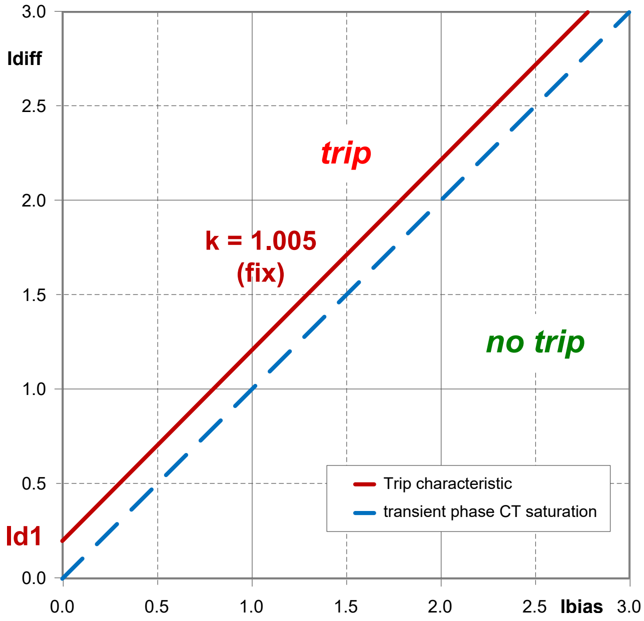
- In 4 CT application: Ib = | IA + IB + IC | = | Σ(IP) |
- In 5 CT application: Ib = | IA + IB + IC |

Where:

- IA, IB, IC are the phase currents.

The related differential characteristic is shown in REF tripping characteristic in operating mode "Sum(IP) bias", page 444 as the solid red line.

Figure 291 - REF tripping characteristic in operating mode "Sum(IP) bias"



The characteristic has a fixed slope of 1.005, beginning at the "Low set Id1". The characteristics equation is: Id = Id1 + 1.005 x Ib.

The dashed blue line indicates the values of apparent differential and bias currents (Id, Ib) in case of transient saturation of a phase CT during an external phase fault. As per definition above for calculating differential and bias currents, this characteristic is always below the tripping characteristic, hence in stable region.

The slope provides slight increase of stability margin (slight increase of required differential current for tripping) with increasing sum of phase currents.

> **NOTE:** Low impedance REF biased by sum of phase currents is only applicable where the protected object (e.g. transformer winding) has a neutral point earthing which is fitted with a CT, because it needs measured ground current to operate. So this mode cannot be applied for balanced earth fault protection or delta windings. Its main advantage is an inherent stability against transient phase CT saturation.

Biased by maximum phase current

In this operating mode, bias current is calculated as follows:

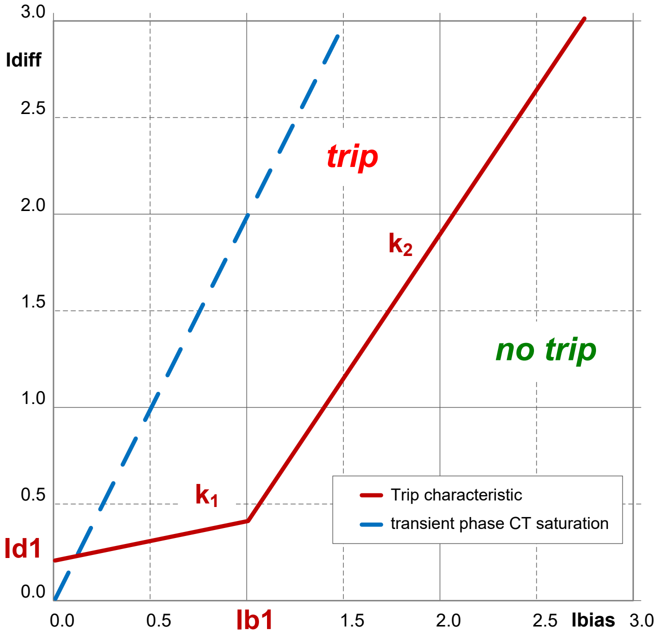
- In 4 CT application: Ib = 0.5 x (Max{| IA |, | IB |, | IC | } + | I'G |)
- In 5 CT application: Ib = 0.5 x (Max{| IA |, | IB |, | IC | } + | I’N |+ | I'G |)

Where:

- IA, IB, IC are the phase currents.
- I'G is the amplitude matched current flowing through the wye point to ground (measured through standard or sensitive neutral CT acc. to selected "IG input").
- I’N is the amplitude matched current from the neutral wire CT in "5CT application" (measured through standard or sensitive neutral CT not selected as "IG input").

A dual slope characteristic is required with this operating mode, as shown in REF Tripping characteristic in operating mode "Max(IP) bias”, page 445 as solid red line.

Figure 292 - REF Tripping characteristic in operating mode "Max(IP) bias”



Also this characteristic starts at "Low set Id1", has a first section with "slope k1" for bias currents up to "Bias current Ib1" setting and then a second section with higher "slope k2" for increased stability at high bias current levels.

The characteristics equations for the two ranges are:

- For Ib ≤ Ib1: Id = Id1 + k1 x Ib
- For Ib > Ib1: Id = Id1 + k1 x Ib + (k2 - k1) x (Ib – Ib1)

The dashed blue line in the figure indicates the values of apparent differential and bias currents (Id, Ib) in case of transient saturation of a phase CT (or likewise a single phase current infeed test).

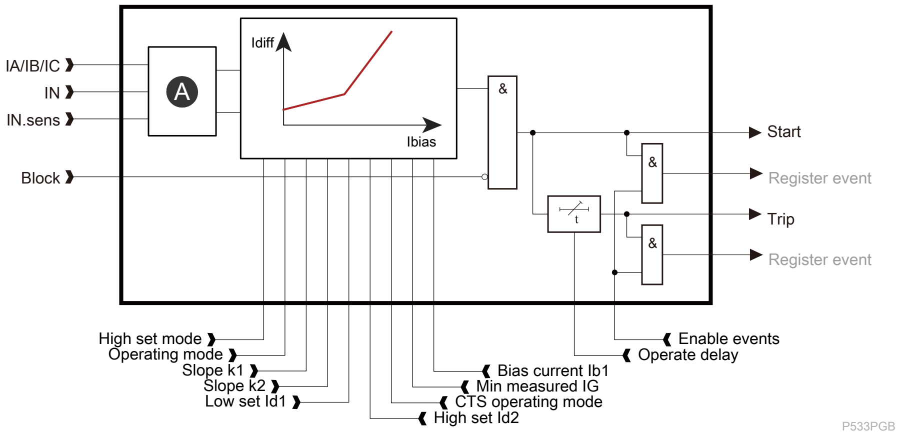
In order to reduce the risk of false tripping caused from phase CT saturation only, this operating mode is accomplished with a check for minimum ground current. A trip is released only if the measured current exceeds the set threshold “Min measured IG”.

NOTE:

- It is recommended that this threshold is set below Id1, otherwise it introduces a further restriction in the tripping characteristic. If this constraint is intentionally not required, it could be disabled by setting the threshold to 0 pu.
- This mode has the advantage of being universally applicable to all kinds of protected objects with or without neutral point earthing, i.e. including balanced earth fault protection for unearthed wye or delta windings. Unless minimum wye point current constraint is set up, this bias definition also allows the user to apply tripping test simply by shorting a phase current (for simulation of neutral current) without the need of current injection equipment.

Block diagram

Figure 293 - Low impedance REF function structure overview



A REF calculation

High-set unrestrained differential operation

Within low impedance REF protection function an unrestrained operation can be enabled by selecting "High set mode". If this feature is enabled and the differential current exceeds the “High set Id2”, REF will trip regardless the actual bias current.

Current Transformer Supervision (CTS)

REF operation in presence of a CTS alarm is settable as follows:

- Indication: CTS alarm has no impact on REF operation. It is an indication only.
- Blocking: REF is blocked while the CTS alarm is present, to avoid any maloperation.
- Restraining: REF trip characteristic is shifted vertically while the CTS alarm is present, by activating the dedicated setting "CTS low set Id1" instead of normal "Low set Id1". That way bias is increased, yet REF remains operational for faults with high current level.

Characteristics

Table 104 - Settings and characteristics of the low impedance restricted earth fault protection function (ANSI 64REF)

Settings/characteristics (description/label)	Values
Phase current input selection[116]	
Stage 1	Fixed to CT-1
Stage 2	Fixed to CT-2
Inhibit REF/Inhibit REF	
Option	DI/VI/Function key
IG input/IG input	
Option	IN.meas/IN.sens
5 CT application/5 CT application	
Option	Enable/Disable
Phase CT polarity/Phase CT polarity[117]	
Option	Standard/Opposite
Neutral CT polarity/Neutral CT polarity[117]	
Option	Standard/Opposite
Sensitive neutral CT polarity/Sensitive neutral CT polarity[117]	
Option	Standard/Opposite
Operating mode/Operating mode	
Option	Sum(IP) bias/Max(IP) bias
Min measured IG/Min measured IG	
Setting range	0.00...1.00 pu[118]
Resolution	0.01 pu[118]
Slope k1/Slope k1	
Setting range	0...100%
Resolution	1%
Slope k2/Slope k2	
Setting range	10...200%
Resolution	1%
Bias current Ib1/Bias current Ib1	
Setting range	0.10...1.50 pu[118]
Resolution	0.01 pu[118]
Low set Id1/Low set Id1	
Setting range	0.10...1.00 pu[118]
Resolution	0.01 pu[118]
Accuracy	±3% or ± 0.005 I_{ref}
Operate delay/Operate delay	
Setting range	0.00...1.00 s
Resolution	0.01 s

---

[116] Available for P5T30 only.
[117] These settings can be found in the GENERAL menu/Scaling sub-menu.
[118] Inom

Table 104 - Settings and characteristics of the low impedance restricted earth fault protection function (ANSI 64REF) (Continued)

Settings/characteristics (description/label)	Values
Accuracy	±1% or ±10 ms
High set mode/High set mode	
Option	Enable/Disable
High set Id2/High set Id2	
Setting range	2.00...30.00 pu[119]
Resolution	0.01 pu[119]
CTS operating mode/CTS operating mode	
Option	Indication/Blocking/Restraining
CTS low set Id1/CTS low set Id1	
Setting range	0.00...1.00 pu[119]
Resolution	0.01 pu[119]
Accuracy	±3% or ± 0.005 I_{ref}
Characteristic times	
Start time	< 40 ms (35 ms with high speed) for currents at 2 x pick-up value
Accuracy	±3% or ±0.005 pu
Disengaging time	< 100 ms
Reset ratio	95% ± 2%
Setting group	
Number	4

---

[119] Inom

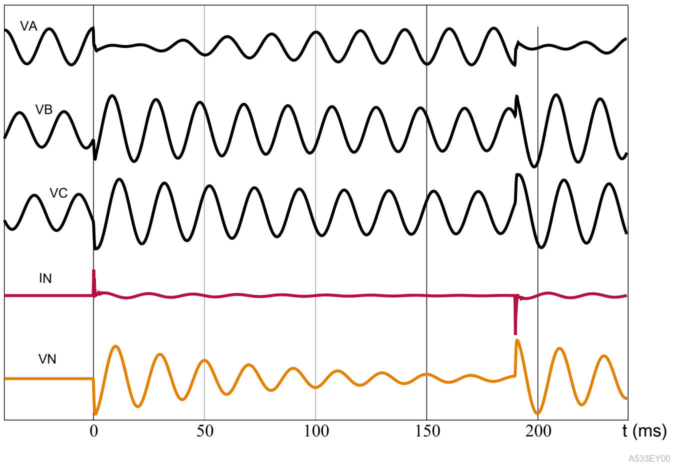
Transient intermittent ground fault (ANSI 67NI)

Description

The directional transient intermittent ground fault protection function (ANSI code 67NI) is used to detect short transient intermittent faults in compensated cable networks. The transient faults are self-extinguished at the zero crossing of the transient part of the fault current I_{Fault} and the fault duration is typically just 0.1 - 1 ms. Such short intermittent faults cannot be correctly recognized by conventional directional ground fault function using the fundamental frequency components of IN and VN only.

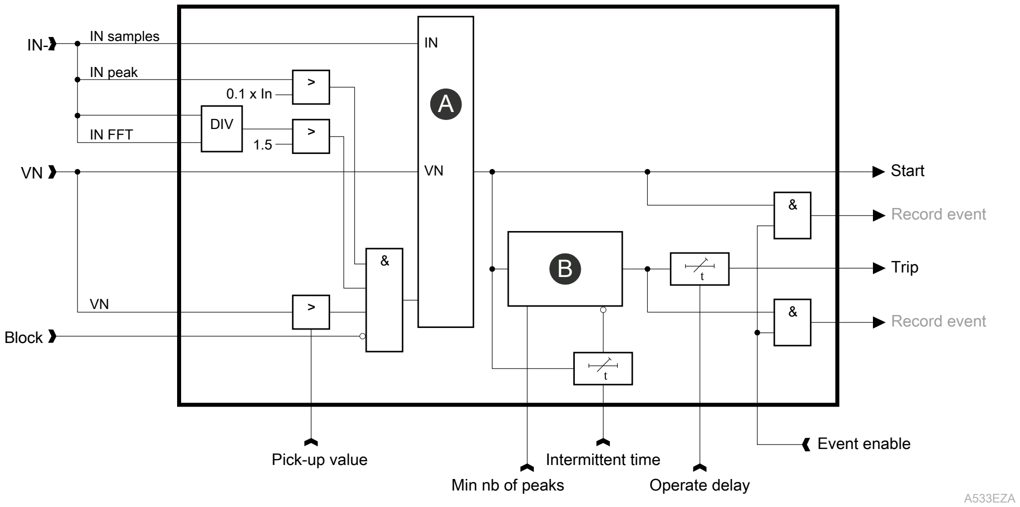
Although a single transient fault usually self extinguishes within less than 1 ms, in most cases a new fault happens when the line to neutral voltage of the faulty phase has recovered.

Figure 294 - Typical line to neutral voltages, ground fault current of the faulty feeder and the neutral displacement voltage during two transient ground faults in phase A (the network is compensated)



Block diagram

Figure 295 - Block diagram of the directional transient intermittent ground fault stage 67NI



A	Transient algorithm	B	Counter

Operation

Direction calculation

The function is sensitive to the instantaneous sampled values of the ground fault overcurrent and neutral voltage displacement voltage. The sample of the neutral voltage can be from a direct VN measurement with a voltage transformer, or can be calculated from the three phase voltages.

NOTE: Connect the VN signal according to the connection diagram to achieve correct polarization.

Co-ordination with the conventional directional ground fault protection based on fundamental frequency signals

The transient intermittent ground fault current stage 67NI should always be used together with the conventional directional ground fault overcurrent protection stages 50N/51N/67N-1, 50N/51N/67N-2. The transient stage 67NI may in worst case detect the start of a steady ground fault in wrong direction but does not trip because the peak value of a steady state sine wave IN signal must also exceed the corresponding base frequency component's peak value to allow 67NI to trip. The operate time of the transient stage 67NI should be lower than the settings of any directional ground fault overcurrent stage to avoid any unnecessary trip from the 50N/51N/67N-1 and 50N/51N/67N-2 stages .The start signal of the 67NI stage can be also used to block 50N/51N/67N-1, 50N/51N/67N-2 stages of all parallel feeders.

Auto reclosing

The start signal of any 50N/51N/67N-1 stage initiating auto reclosing (AR) can be used to block the 67NI stage to avoid the 67NI stage with a long intermittent setting to interfere with the AR cycle.

Usually the 67NI stage itself is not used to initiate any AR. For transient faults, the AR does not help because the fault phenomena itself already includes a repetitive unsuccessful self-extinguishing.

Operate time, peak amount counter and intermittent time coordination

The protection function has three independently settable parameters: operation delay, required number of peaks and intermittent time. All characteristics need to be satisfied before the stage issues a trip signal. There is also a settable reset delay so that the stage does not release before the circuit breaker has operated. If, for example, the number of peaks is set to 2, the operation delay is set to 160 ms and the intermittent time to 200 ms, then the function starts the operation delay from the first peak. If the second peak occurs after 80 ms, the peak amount criteria is satisfied. After 160 ms the delay time elapses, all operate criteria are satisfied and the stage trips.

If the second peak does not occur before the operational delay elapses, the stage is released after the intermittent time has elapsed. But if the second peak occurs after the operate time has elapsed but still within the intermittent time, then a trip is issued instantly.

If the intermittent time elapses before the operation delay elapses, the stage is reset.

There are a couple of limitations to avoid completely incorrect settings. Peaks cannot occur more often than twice per period, so there are about 10 ms in between (at 50 Hz nominal frequency). Therefore if the peak amount is set to 10, then the operation delay setting does not accept a value smaller than 100 ms. Vice versa, if the operation delay is set to 40 ms, then it is not possible to set a peak amount greater than 4. This prohibits settings that can be never satisfied.

Figure 296 - Peak amount condition is satisfied and operate time elapses within intermittent time setting. Stage issues a trip.

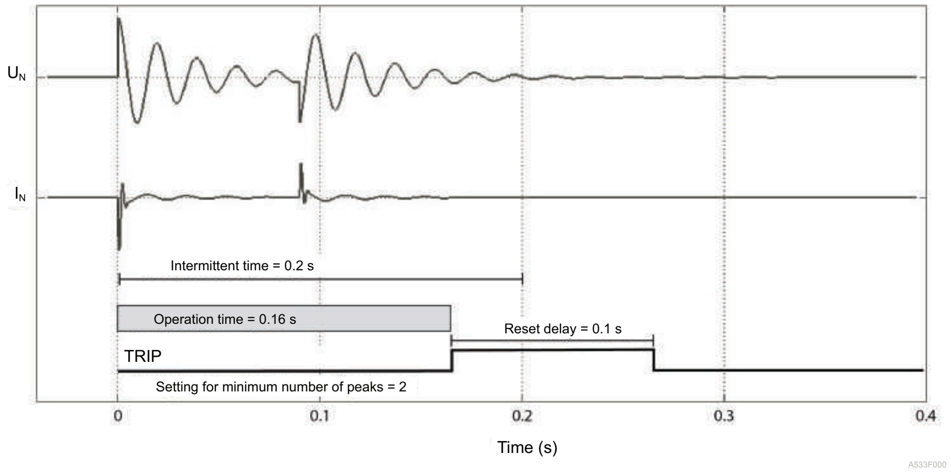


Figure 297 - Peak amount condition is not satisfied when operation delay elapses but last required peak occurs during intermittent time. Stage then issues instant trip.

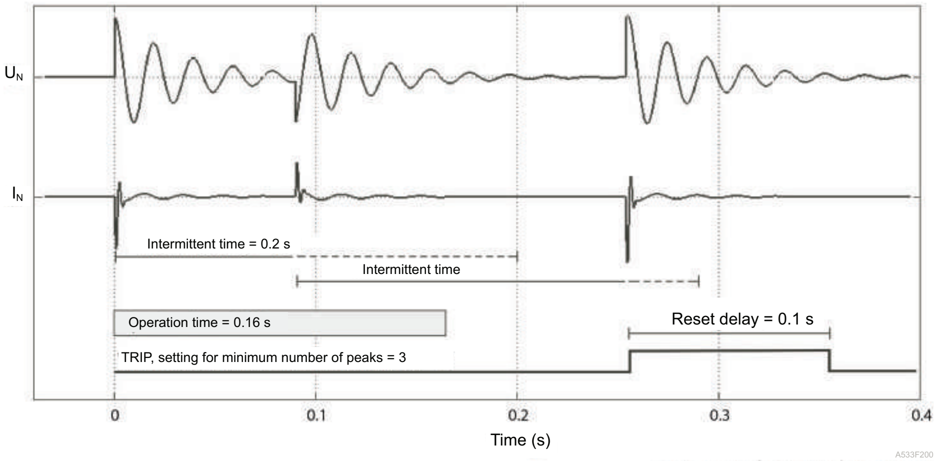
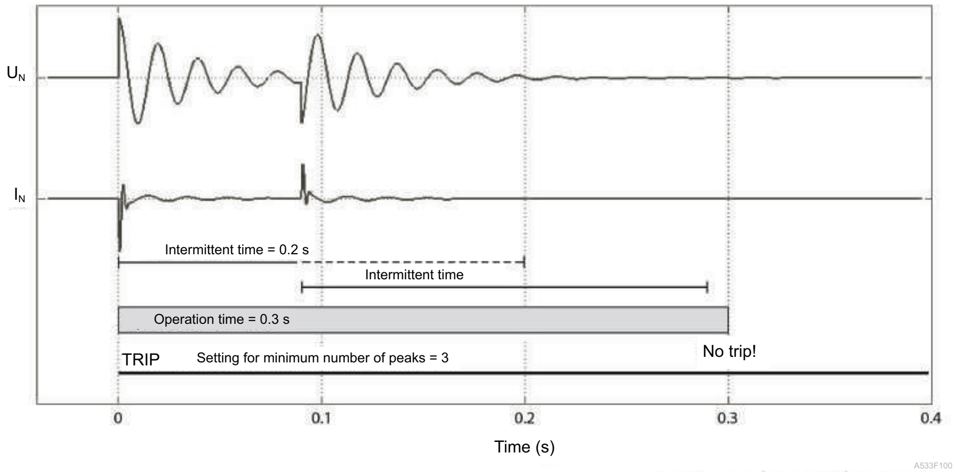


Figure 298 - Peak amount condition is satisfied but intermittent time elapses before operate time. Stage is reset.



Characteristics

Table 105 - Settings and characteristics of the transient intermittent ground fault protection stage 67NI

Settings/characteristics (description/label)	**Values**
IN input	
Options	IN peak, IN.CSH peak , IN.sens peak
Direction mode/Mode	
Options	Forward; Reverse
IN peak value/INPeak	
Value	0.1 pu[120] (fixed)
VN Pick-up/VN>	
Setting range	0.01...0.60 pu[121]
Resolution	1% pu[121]
Accuracy	±3%
Reset ratio	97% ± 2%
Min number of peaks/MinPeaks	
Setting range	1...20
Resolution	1
Operate delay/t>	
Setting range	0.00...300.00 s
Resolution	0.02 s
Accuracy	±1% or ±20 ms
Reset delay/Rst delay	
Setting range	0.06...300.00 s
Resolution	0.01 s
Intermittent time/Intmt time[122]	
Setting range	0.01...300.00 s
Resolution	0.01 s
Characteristic times	
Start time	< 50 ms (45 ms with high speed) maximum
Disengaging time	< 65 ms
Setting group	
Number	4

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[120] Inom for IN.calc; IN.nom for IN.meas; IN.sens.nom for IN.sens.meas; IN.CSH.nom for IN.CSH

[121] √3 x VT primary nominal (PN)

[122] Common setting for setting group 1, 2, 3, 4.

5th harmonic (H5) detection (ANSI 68H5)

Description

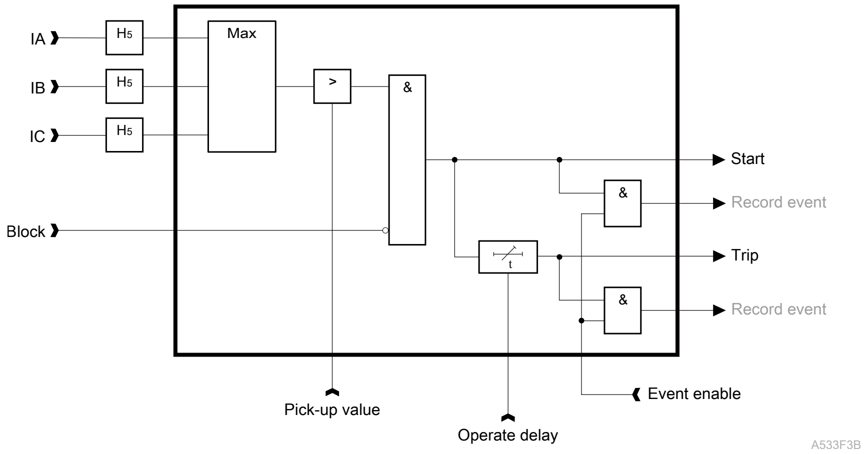
Overexciting a transformer creates odd harmonics. The fifth harmonic component can be used to detect overexcitation. This stage can also be used to block some other function stages.

The ratio between the fifth harmonic component and the fundamental frequency component is measured on all the phase currents. When the ratio in any phase exceeds the setting value, the stage activates a start signal. After a settable delay, the stage operates and activates a trip signal.

It is recommended to set the trip delay to longer than 60 ms, to block properly the protection stages.

Block diagram

Figure 299 - Block diagram of the 5th harmonic detection stage 68H5



Characteristics

Table 106 - Setting and characteristics of the 5th harmonic detection stage 68H5

Setting/characteristics (description/label)	Values
Pick-up value/Pick-up value	
Setting range	10%...100%
Resolution	1%
Accuracy	±1% or ±0.005 Inom
Reset ratio	97% ± 1%
Operate delay/Operate delay	
Setting range	0.00...300.00 s
Resolution	0.01 s
Accuracy	±1% or 30 ms
Characteristic times	
Start time	< 55 ms (50 ms with high speed)
Disengaging time	< 70 ms (85 ms with high speed)

Table 106 - Setting and characteristics of the 5th harmonic detection stage 68H5 (Continued)

Setting/characteristics (description/label)	Values
Setting group	
Number	1

Auto-recloser function (ANSI 79)

Description

Depending on the application, a high percentage of faults on the electrical network are transient, such as those caused by lightning or insulator flashovers. The Auto-Recloser (AR) function is designed to automatically restore power to a feeder or overhead line after a protection trip has occurred, using a trip/close sequence (auto-reclosing cycle). This minimizes network downtime in the event of a transient fault. In most fault incidents, if the faulty line is immediately tripped, reclosure of the circuit breaker (CB) will successfully reenergize the line (for example, Closed/Open/Closed cycle). However, since permanent faults can also occur, an AR scheme must be designed to handle these cases by leaving the CB in the open state after a defined number of auto-reclosing cycles (for example, Closed/Open/Closed/Open cycle).

Although the basic principle of AR is straightforward, configuring the timers and parameters requires attention to detail.

> **NOTE:** With the PowerLogic P5 version V02.502 the auto-recloser function has been redesigned to meet IEC 61850 modelling and to provide additional features. This needs to be considered when converting existing schemes set up with previous firmware versions to the new solution. It is therefore recommended to study this description before deciding on changed and new settings and options.

Operation

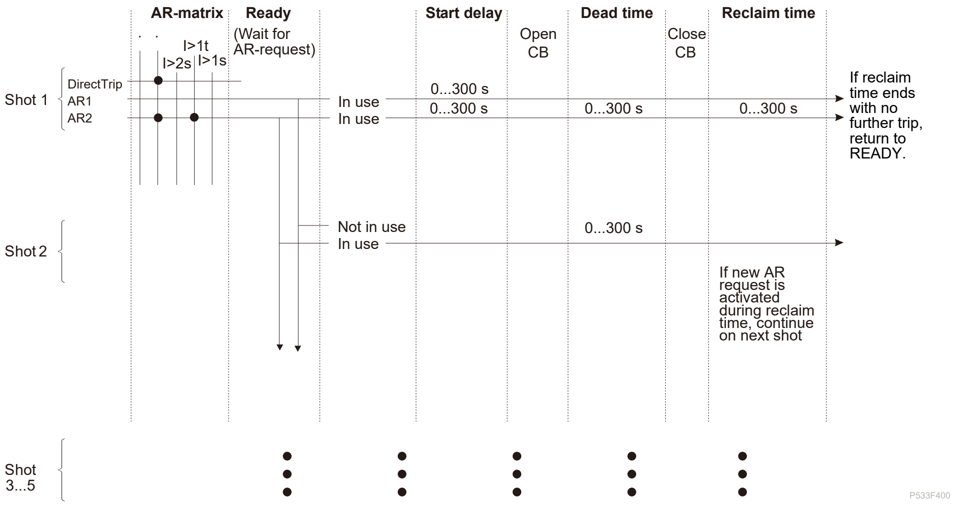
The AR function provides a sequence of up to five configurable shots. Each shot is triggered by protection start or trip signals (internal or external trip), as configured in the auto-recloser matrix by AR lines. The four AR lines (AR1 to AR4) in a shot are prioritized by their numbers, with AR1 having the highest priority. A common configuration for AR lines in a shot is to have the instantaneous overcurrent stage initiate AR1, the time-delayed overcurrent stage initiate AR2, and the earth/ground fault protection initiate AR3 and AR4.

The AR function itself will trip after a "start time." Once the CB is open, AR controls the timing ("dead time") and execution of the reclosing. One cycle of tripping and reclosing is called an AR shot. Typically, the first shot is made with a short dead time, just long enough to securely de-ionize the air of an arcing fault on the overhead line, to minimize supply interruption. If more than one shot is applied, longer dead times are used for consecutive shots.

The sequence chart in Auto-reclose shot triggers and timers, page 456 explains the relationship between the initialization signals of the Auto-recloser shots and the sequence (cycles) of AR operations. So-called AR lines can be enabled or disabled independently for each shot, and a shot is enabled only if at least one AR line within it is enabled. A total of 4 configurable AR lines are available.

Enabled shots will operate according to their priorities, with the shot of the smallest number having the highest priority and the largest number having the lowest priority. For example, if shot 1 is not enabled or is blocked, AR will start with shot 2.

Figure 300 - Auto-reclose shot triggers and timers



In Auto-reclose shot triggers and timers, page 456 shot 1 is enabled, so AR starts with it. The AR line with the smallest index that gets triggered initiates the start delay timer of the shot. For instance, if AR1 and AR3 are triggered, AR1's start time is used. If AR3 is triggered first, the shot will use AR3's start time. If AR1 then becomes active, the start timer will switch to AR1's start time. Once the start time ends, further shot timing exclusively uses the timer settings of the triggered AR line with the highest priority.

At the end of the start time, the AR issues its trip signal if the circuit breaker (CB) is still closed, meaning no trip has been issued from another protection function or relay in the meantime. The CB open operation must be completed within a given time limit; a too slow operation will abort further execution of the AR.

After the CB is open, the dead time timer starts. Each AR line within the shot is provided with its individual timers, and the times of the AR line that initialized the shot are used throughout the shot.

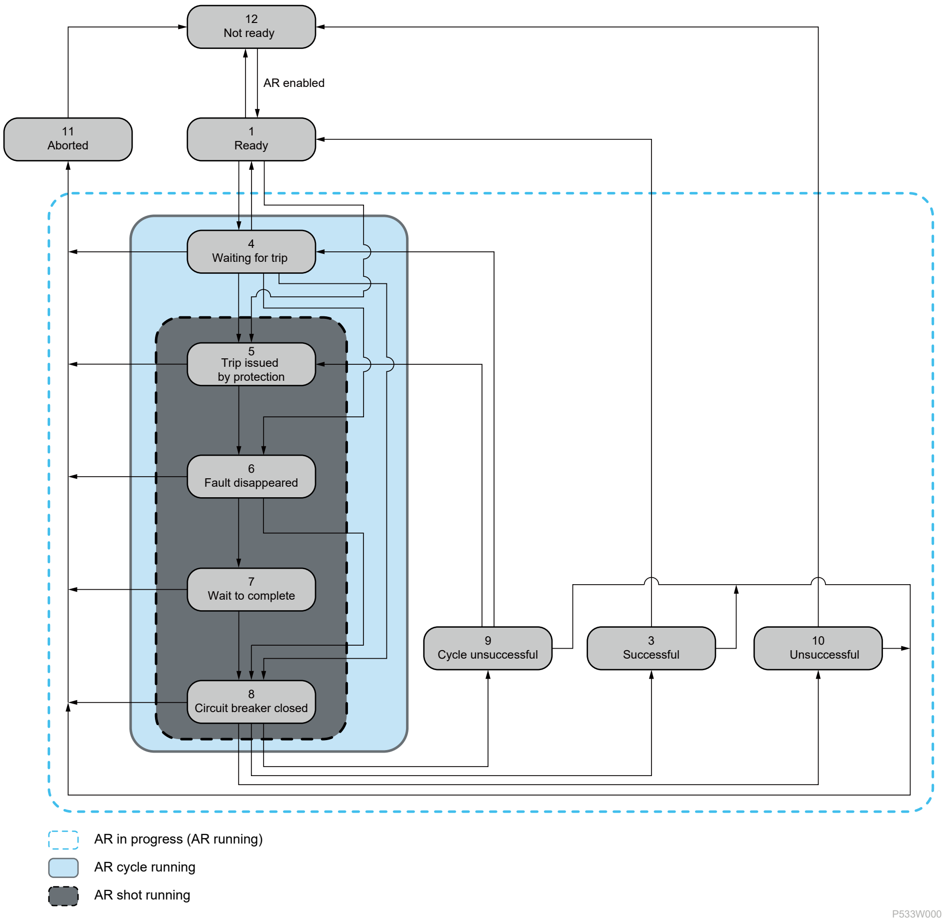
When the dead time elapses, the reclose request will be sent to the CB control function, which will issue the close command, subject to optional sync check and mandatory permission check according to the Object block matrix. The duration of this re-close is also subject to a time limit check. The reclaim time starts only if the CB re-closure is completed in due time. If the reclaim time elapses with no further starting or tripping, the AR sequence is successfully executed, and the AR function returns to the READY state, waiting for a new AR request in shot 1. If a further protection start or trip occurs, the next available shot is triggered; otherwise, the AR cycle is unsuccessful, and the AR function moves to the NOT READY state.

This sequence is described as a state machine in AR states and transitions, page 457, with 11 unambiguous states in line with IEC 61850-7-500.

It is recommended to configure protection stage start signals to initiate the AR function. A trip signal from the protection stage can be used as a backup. If AR does not issue the open command, the protection trip signal will still operate the CB. The delay setting of the protection stage should be longer than the AR start delay, the CB operation time, and the protection reset time.

An AR cycle is aborted at any time by a manual CB open or close control command.

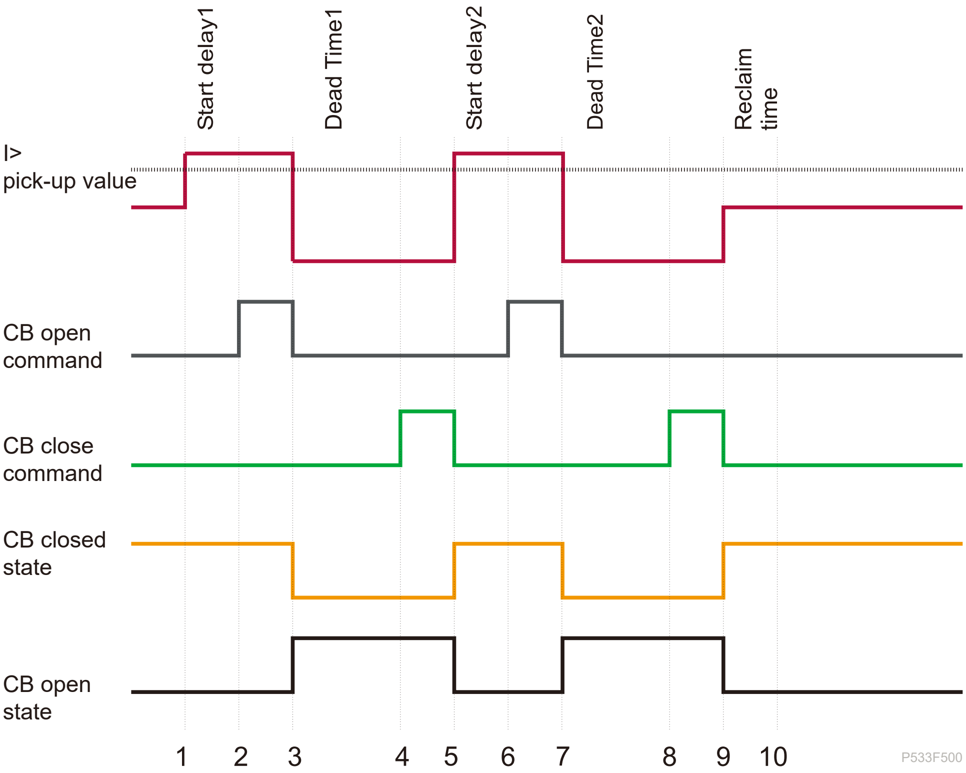
Figure 301 - AR states and transitions



Example of an Auto-recloser cycle

The figure below shows an example of an AR cycle with two shots where 2nd shot is successful.

Figure 302 - Example sequence of AR with two shots



1. The current exceeds the overcurrent protection pick-up threshold; the overcurrent protection start signal is linked to AR1, which triggers shot 1.
2. The start delay for shot 1 elapses, and the AR trips.
3. The circuit breaker is in the open status, and the dead time for shot 1 starts.
4. The dead time for shot 1 elapses; a CB re-close request is raised, and the control issues the CB close command.
5. The CB closes. The fault current flows again, triggering the start delay for shot 2.
6. The start delay for shot 2 elapses, and the AR trips.
7. The CB is in the open status, and the dead time for shot 2 starts.
8. The dead time for shot 2 elapses; a CB re-close request is raised, and the control issues the CB close command.
9. The CB closes. No fault current is present (no protection start condition is present); the reclaim time for shot 2 starts.
10. After the reclaim time elapses, the AR sequence ends successfully. The AR function is ready again, waiting for the next AR request.

Settings

Auto reclosing can be enabled or disabled by:

- Setting "Enable for Auto Reclosing" on the HMI. (**Protect / PROTECTION / List of protection enabled / Enable for AR**)
- A binary input signal (DI, VI, VO, F-Button).
- Command through a communication protocol (including the eSetup Easergy Pro tool).

All three methods have equal priority; the last enable or disable operation remains valid until the next change. The "Enable for Auto Reclosing" setting allows configuration by the HMI and also displays the current enabled/disabled status.

AR enable delay at CB close

Auto-recloser function readiness is subject to several conditions (like CB drive is ready to execute sequential open and close). Once all conditions are given, AR gets only READY if the CB is in closed state for this enable delay. This timer may be used to prevent starting an AR cycle with an SOTF condition (see Switch On To Fault (ANSI 50HS), page 390 for detail).

CB maximum open time, CB maximum close time

The CB open and close operation times are critical in terms of deciding whether to continue AR or not. Therefore these CB times are monitored and if they exceed the set limits, the AR will be ABORTED.

Extend reclaim time with DI

Extension (prolongation) of the (last) reclaim time is required in some applications.

With this setting any binary input signal (DI, VI or VO) can be selected to trigger such extension. Extension will be active as long as the input signal is true. Upon reset of this input the CB must further remain in closed position for the set reclaim time before AR cycle is finished successfully.

AR info for mimic display

To enable or disable the display of Auto-Recloser (AR) progress during execution.

AR counters

AR function provides counters of:

- Start of shot 1 to shot 5 starts from AR1 to AR4 triggers
- Total number of AR cycles started
- Number of successful AR cycles
- Number of unsuccessful AR cycles
- Number of aborted AR cycles

The description texts in eSetup Easergy Pro tool (up to 32 characters) and on the local HMI (up to 16 characters) are editable with eSetup Easergy Pro / **PROTECTION / AR counter texts**.

Reclose check condition

There are 4 selectable modes of synchro-check for permitting the re-close request:

- None: no voltage or synchro-check will be executed in this mode.
- Voltage check: the auto-reclose will be allowed for either LD[123] or DL condition, it means either line or bus is not energized.
- Async check: the auto-reclose will be allowed if the async check passed.
- Sync check: the auto-reclose will be allowed if the sync check passed.

---

[123] See Voltage checking, page 321 for detail.

Start delay

This is the time between the triggering of a shot from an AR line trigger until issuing the AR trip. If all AR line triggers reset before this timer elapses, AR will also reset and return to READY state.

Dead time

The dead time of a shot starts when CB is opened. It controls the time to send the reclose request by the time setting. A CB re-close request will be sent when this timer elapses.

Reclaim time

During the reclaim time the closed state of the CB is monitored. If the CB stays closed throughout the reclaim time, AR cycle was successful and AR returns to READY state.

If a further protection start/trip or CB open is observed during the reclaim time, the AR cycle was unsuccessful. Either a next shot is started, or AR is ABORTED.

Auto-recloser matrix

Auto-recloser function is provided with a dedicated matrix for easy conditioning common signals of AR:

- Direct final trip:

  If this condition gets activated at any time during execution of an AR cycle, the AR will immediately trip and transit to ABORTED state.
- AR1 to AR4:

  These are forming the conditions to trigger AR shots and selection of shot timers. Their use can be enabled or disabled individually per shot.
- Block AR:

  This provides flexible selection of conditions which will dynamically block AR function. If this condition gets activated at any time during execution of an AR cycle, AR transits to ABORTED state.
- Block shot n (n = 1 to 5):

  Upon activation individual shot will be blocked.

  > **NOTE:** Activation of Block shot n gets only effective, if the shot is not in execution.

Output signals

Table 107 - Output signals of Auto-recloser

AR signal	Description
Enable for AR	Enable the Auto-recloser.
AR ready	The AR is in READY state. The AR can transit from AR NOT READY to AR READY only under the listed conditions: 1. The AR function is enabled. 2. At least one AR shot is enabled, with at least one of its ARn (n = 1 to 4) triggers not being blocked.

Table 107 - Output signals of Auto-recloser (Continued)

AR signal	Description
	3. AR is not blocked by a user defined input signal (through AR matrix). This includes no presence of user-defined AR lockout condition. 4. No general start or trip signal is present. 5. CB drive is ready to execute an O-C-O switching sequence (at beginning). 6. The CB is in healthy condition. 7. The CB is in closed position. This condition is mandatory because of AR link with CB – object control.
AR not ready	The AR is in NOT READY state.
AR blocked	Blocking conditions for AR are configured in Auto-recloser matrix: 1. The signal 'Block AR' is active. 2. All 'Block shot n' (n = 1 to 5) are active.
AR running	This signal gets active when AR leaves READY state by getting triggered from an ARn (n = 1 to 4) in first enabled shot until the end of the last AR cycle. AR then returns to either (NOT) READY or ABORTED state.
AR trip	AR trips after actual shot start time has elapsed.
AR shot n active (n = 1...5)	The shot n is in execution with its dead and reclaim timers.
AR direct final trip	The signal 'Direct final trip' is active, which is configured in Auto-recloser matrix.
ARn final trip (n = 1…4)	If the fault is still present after all enabled shots are executed, the ARn final trip signal will be raised, where n is the index number of the executed ARn line of the last shot.
AR successful	This signal is issued for 100 ms when AR was successful.
AR unsuccessful	This signal is issued for 100 ms when AR was unsuccessful.

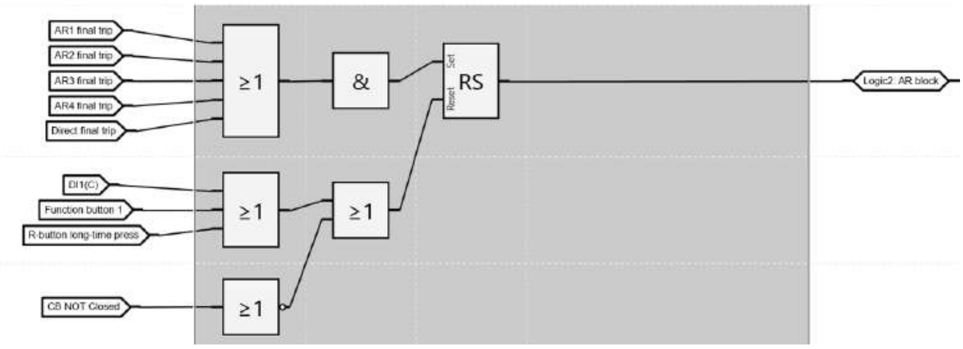
Lockout functions

AR lockout

The Auto-Recloser (AR) function can be locked out using programmable logic. The reasons for lockout, which are the inputs to the programmable logic, are user-selectable. By default, the AR final trip signals force a lockout. Using an RS flip-flop the output signal is latched. It is labeled as "AR lockout."

This output can be used as an input signal for the Output matrix, LED matrix, and Block matrix, or it can be linked to "Block AR" in the Auto-Recloser matrix. The reset condition is user-definable and can reflect either user interaction (such as "R-button press") or a system condition (such as "CB closed").

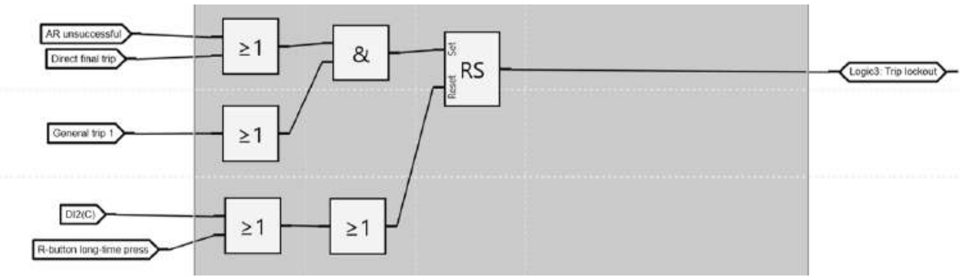
Figure 303 - AR lockout configuration in programmable logic



Trip lockout

The Lockout relay (ANSI 86) function may conflict with the AR function if the trip signal is permanently latched by the Lockout function. To address this, the trip lockout function also needs to be configured in programmable logic, using adequate AR status information. The figure below shows a typical solution.

Figure 304 - Trip lockout configuration in programmable logic when using AR



Characteristics

Table 108 - Setting and characteristics of the auto-recloser protection function (ANSI 79)

Setting/characteristics (description/label)	Values
Enable for AR/Auto-reclosing	
Options	On; Off
DI for AR enabling/DI for AR enabling	
Options	Selection of: • one digital input (DI) • one virtual input (VI) • one virtual output (VO) • or one function key
AR enable delay at CB close/Enable delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
CB maximum open time/Open time	
Setting range	0.02...1.00 s
Resolution	0.01 s
CB maximum close time/Close time	

Table 108 - Setting and characteristics of the auto-recloser protection function (ANSI 79) (Continued)

Setting/characteristics (description/label)	Values
Setting range	0.02...1.00 s
Resolution	0.01 s
DI to extend reclaim time/Ext. reclaim	
Options	Selection of: • one digital input (DI) • one virtual input (VI) • one virtual output (VO) • or one function key
AR info for mimic display/ShowInfo	
Options	On; Off
Enable for AR lines/Enable	
Options	On; Off
Start delay/Start delay	
Setting range	0.00...10.00 s
Resolution	0.01 s
Dead time/Dead time	
Setting range	0.01...1,200.00 s
Resolution	0.01 s
Reclaim time/Reclaim time	
Setting range	0.02...3,000.00 s
Resolution	0.01 s
Reclose check condition/Reclose check condition	
Options	None; Voltage; Async; Sync

Overfrequency (ANSI 81O)

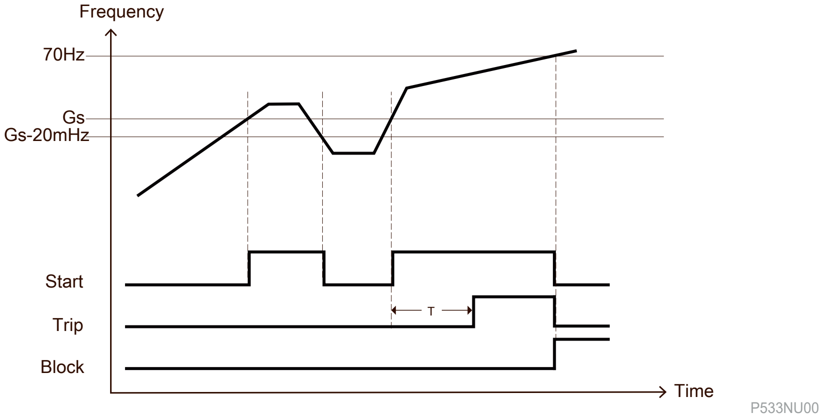
Description

Frequency deviations result from an imbalance between power generation and power loads. An over frequency condition happens when the power generation exceeds the power loads, which maybe is due to a sudden removal of load due to tripping of an outgoing feeder. The sustained over frequency condition may damage the power generators. Normally the governor system would respond quickly and restore normal frequency. Over frequency protection is required as a back-up for generator overspeed. Also, over frequency protection is also applied in load restoration schemes to detect that the power system frequency has recovered sufficiently to allow load which had previously been shed to be reconnected.

So, the over frequency protection function (ANSI code 81O) is used for load restoration, and as a backup protection for overspeeding.

Whenever the frequency reaches the pick-up value of a particular stage, this stage starts, and a start signal is issued. If the fault remains on longer than the operating delay setting, a trip signal is issued.

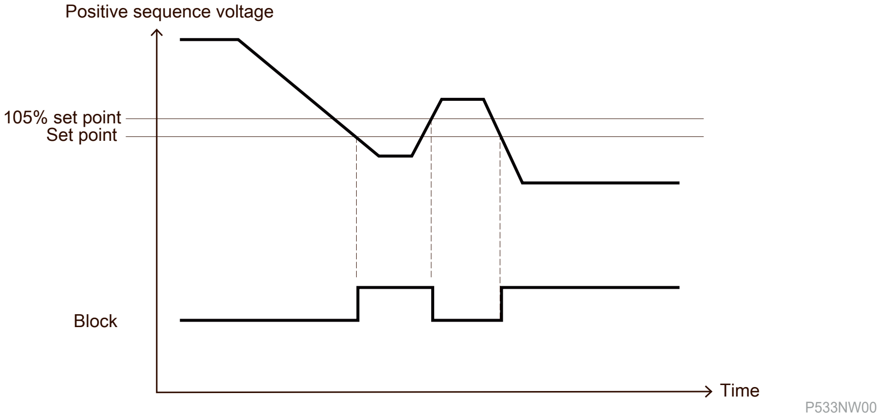
Figure 305 - Status change of overfrequency protection (Gs: frequency setting)



Self blocking at low voltage

The protection is blocked when the positive sequence voltage is lower than the setting threshold. This feature is common to all the groups and stages of ANSI 81O, ANSI 81U and ANSI 81R functions, yet with individual threshold settings.

Figure 306 - Low voltage block logic

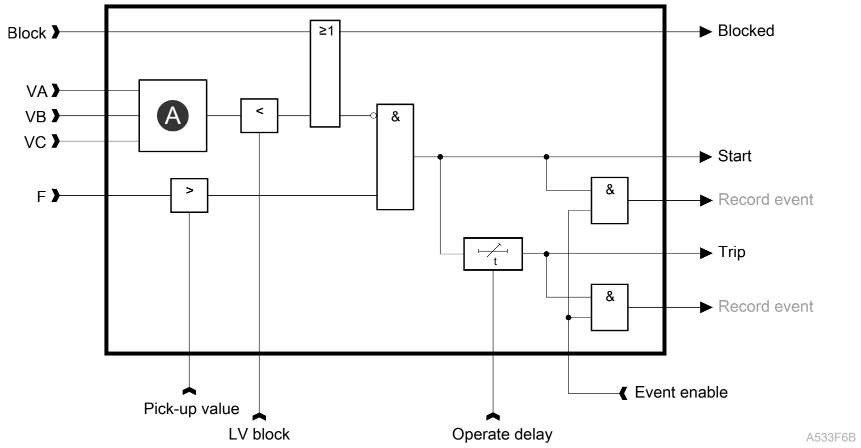


Two independent stages

There are two separately adjustable stages: 81O-1 and 81O-2. All the stages have definite operate time (DT).

Block diagram

Figure 307 - Block diagram of the overfrequency protection (ANSI 81O)



A	Positive Sequency voltage

Characteristics

Table 109 - Setting and characteristics of the overfrequency protection stages 81O-1 and 81O-2

Setting/characteristics (description/label)	Values
Pick-up value/f>	
Frequency protection operation range	35...70 Hz
Setting range	40.00...65.00 Hz
Resolution	0.01 Hz
Accuracy	±0.01 Hz
Hysteresis	0.02 Hz ± 0.005 mHz
Operate delay/t>	
Setting range	0.00...7200.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
Low voltage blocking/LV block	
Setting range	0.10...1.00 pu[124]
Resolution	1%
Accuracy	±5% or ±0.5V (secondary)
Reset ratio	105%
Characteristic times	
Start time	< 110 ms (105 ms with high speed), typically 80 ms

---

[124] Vnom/√3 = VT primary nominal (PN)

Table 109 - Setting and characteristics of the overfrequency protection stages 81O-1 and 81O-2 (Continued)

Setting/characteristics (description/label)	Values
Disengaging time	< 120 ms (135 ms with high speed)
Overshoot time	< 70 ms
Voltage measurement range	
Minimum value	Vmin = 0.30 pu
Maximum value	Vmax = 2.20 pu
Setting group	
Number	4

Underfrequency (ANSI 81U)

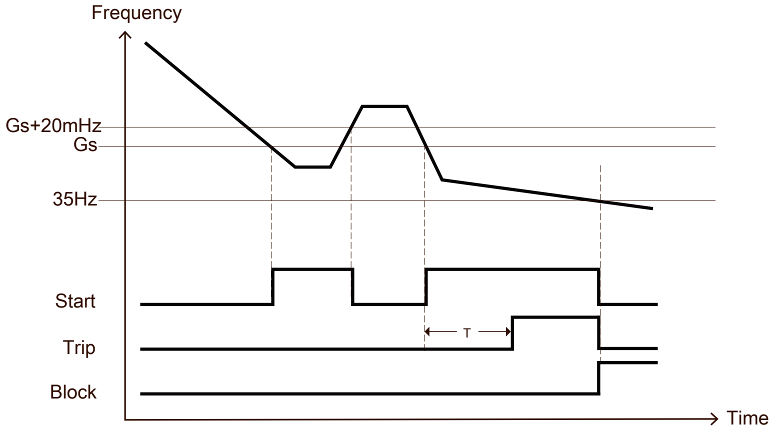
Description

Frequency deviations result from an imbalance between power generation and power loads. An under frequency condition happens when the power load exceeds the available power generation. This happens when an interconnected system splits, and the load left connected to one of the subsystems is in excess of the capacity of the generators. Sustained under frequency has implications on the stability of the power system, whereby any subsequent disturbance may damage equipment and even lead to blackouts. It is therefore usual to provide protection for under frequency conditions and the related load-shedding scheme shall be deployed to restore the normal frequency.

So, the under frequency protection function (ANSI code 81U) is used for detection of an abnormally low frequency compared to the rated frequency to monitor power supply quality. The protection may be used for overall tripping or load shedding.

Whenever the frequency reaches the pick-up value of a particular stage, this stage starts, and a start signal is issued. If the fault remains on longer than the operating delay setting, a trip signal is issued.

Figure 308 - Status change of underfrequency protection (Gs: frequency setting)



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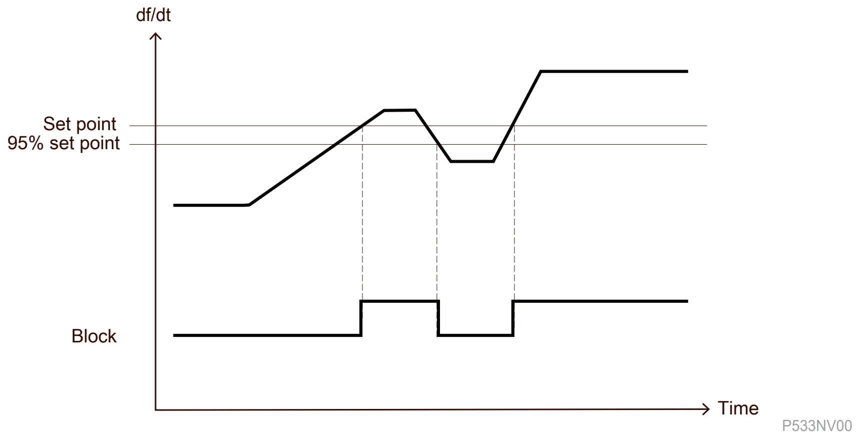
Self blocking at low voltage

The protection is blocked when the positive sequence voltage is lower than the setting threshold. This feature is common to all the groups and stages of ANSI 81O, ANSI 81U and ANSI 81R functions, yet with individual threshold settings. See Low voltage block logic, page 464.

Large df/dt block

The protection is blocked when the rate of change of frequency df/dt is larger than the setting threshold. The measured df/dt here shall not depend on any setting in ROCOF protection function.

Figure 309 - Large df/dt block logic

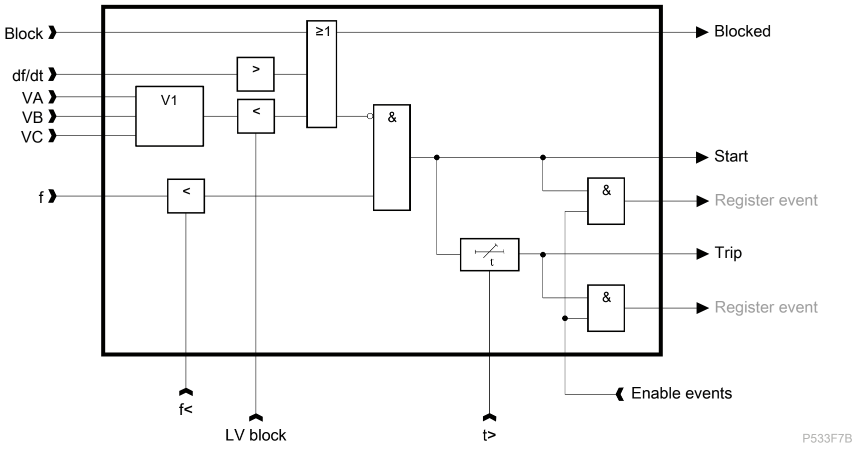


Eight independent stages

There are eight separately adjustable stages: 81U-1, 81U-2...81U-8. All the stages have definite operate time (DT).

Block diagram

Figure 310 - Block diagram of the underfrequency protection function (ANSI 81U)



Characteristics

Table 110 - Setting and characteristics of the underfrequency protection stages 81U-1, 81U-2...81U-8

Setting/characteristics (description/label)	Values
Pick-up value/f<	
Frequency protection operation range	35...70 Hz
Setting range	40.00...65.00 Hz
Resolution	0.01 Hz
Accuracy	±0.01 Hz
Hysteresis	0.02 Hz ± 0.005 Hz

Table 110 - Setting and characteristics of the underfrequency protection stages 81U-1, 81U-2...81U-8 (Continued)

Setting/characteristics (description/label)	Values
Operate delay/Operate delay	
Setting range	0.00...7200.00 s
Resolution	0.01 s
Accuracy	±1% or ±10 ms
df/dt blocking	
Setting range	0.10...20.00 Hz/s
Resolution	0.01 s
Accuracy	±5% or 0.050 Hz/s
Hysteresis	5% or 0.05 Hz/s
Low voltage blocking/LV block	
Setting range	0.10...1.00 pu[125]
Resolution	1%
Accuracy	±5% or ±0.5V (secondary)
Reset ratio	105%
Characteristic times	
Start time	< 110 ms (105 ms with high speed), typically 80 ms
Disengaging time	< 100 ms (115 ms with high speed)
Overshoot time	< 70 ms
The voltage measured range	
Minimum value	Umin = 30 V
Maximum value	Umax = 220 V
Setting group	
Number	4

---

[125] Vnom/√3 = VT primary nominal (PN)

Rate of change of frequency (ANSI 81R/81FR)

Description

Frequency deviations result from the imbalance between the power generation and power loads. The Rate of Change of Frequency (RoCoF) is depending on the system inertia, severity of electric power unbalance, system damping constant and various other parameters. Sometimes the significant electric power deficiency in the separated subsystem (islanding condition) could cause a large frequency decay in a short time. If corrective measures (such as load shedding) are not taken quickly, the frequency may drop below the minimum system operating level and cause a widespread network collapse.

Compared with the underfrequency protection (ANSI 81U), the protection based on RoCoF can forecast a severe frequency decay and trigger fast corrective measures before the frequency drops to below the minimum system operating level.

So, the RoCoF protection function is normally used along with underfrequency protection in order to trigger load shedding where the frequency drops too fast. It can also be used to detect loss of mains where local generation is suddenly disconnected from the power system. The calculation of the rate of change of frequency is based on the positive sequence voltage.

The RoCoF protection in PowerLogic P5 can operate as independent rate of change of frequency protection, as frequency supervised rate of change of frequency protection or as regular under/over frequency protection. The selection is made with Operating mode and Direction mode settings which are independent for each one of 9 stages.

- If Direction mode is “Negative” and Operating mode is "f+RoCoF", it is underfrequency supervised RoCoF protection
- If Direction mode is “Positive” and Operating mode is "f+RoCoF", it is overfrequency supervised RoCoF protection
- If Direction mode is “Either”, it is RoCoF protection
- If Direction mode is “Negative” and Operating mode is "Frequency", it is underfrequency protection
- If Direction mode is “Positive” and Operating mode is "Frequency", it is overfrequency protection

RoCoF stage can be used as underfrequency protection by applying "Frequency" mode.

NOTE: If set direction mode to “Either”, please set operating mode to “f +RoCof” firstly, to avoid dependency confusion.

Self blocking at low voltage

The protection is blocked when the positive sequence voltage is lower than the set undervoltage blocking threshold.

Self blocking at frequency out of range

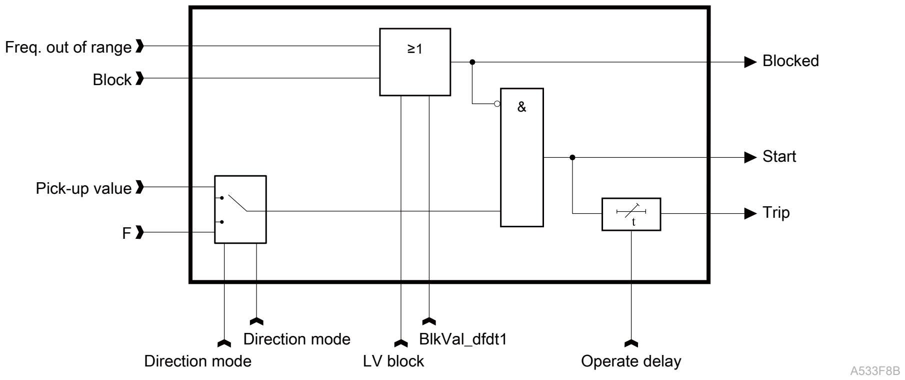
The protection is blocked when the measured frequency is out of the range 35...70 Hz.

df/dt blocking

The protection is blocked when the measured rate of change of frequency df/dt is bigger than the set df/dt blocking limit. To ensure the RoCoF is safely blocked, a short time delay such as 50 ms is suggested.

Block diagram

Figure 311 - RoCoF function structure overview



Characteristics

Table 111 - Setting and characteristics of the rate of change of frequency protection stages

Settings/characteristics (description/label)	Values
Direction mode/Direction mode	
Options	Negative; Positive; Either
Operating mode/OpMod	
Options	f+RoCoF; Frequency
Pick-up value/Pick-up value	
Settable df/dt window ΔT	0.05...1.00 s, default 50 ms, step 5 ms
Setting range	0.1...10.0 Hz/s
Resolution	0.1 Hz/s
Accuracy	< 0.05 Hz/s if df/dt < 5 Hz/s; ±2% if df/dt ≥ 5 Hz/s;
Hysteresis	5% or 0.05 Hz/s
Undervoltage blocking/LV block [126]	
Setting range	0.10...1.00 pu[127]
Resolution	1%
Accuracy	Static voltage ±5% or ± 0.5 V (secondary)
Reset ratio	105%
df/dt blocking/BlkVal_dfdt	
Setting range	0.10...20.00 Hz/s
Resolution	0.01 Hz/s
Accuracy	±5% or 50 mHz/s for ΔT = 50 ms and up to 10 Hz/s
Hysteresis	5% or 0.05 Hz/s
Operate delay/Operate delay	
Setting range	0.00...100.00 s
Resolution	0.01 s

---

126. Common setting for setting group 1, 2, 3, 4.
127. Vnom/√3 = VT primary nominal (PN)

Table 111 - Setting and characteristics of the rate of change of frequency protection stages (Continued)

Settings/characteristics (description/label)	Values
Accuracy	±1% or ±10 ms
Frequency threshold	
Setting range	40.00...65.00 Hz, Step 0.01 Hz
Accuracy	± 10 mHz
Hysteresis	Gs + 20 mHz[128]
Characteristic times	
Start time	< 135 ms at 2 Gs[128] for df/dt > 0.1 Hz/s for ΔT = 50 ms < 170 ms at 2 Gs[128] for df/dt = 0.1 Hz/s for ΔT = 50 ms
Disengaging time	< 180 ms for 2 Gs[128] to 0 and ΔT = 50 ms
Setting group	
Number	4

---

[128] Gs: frequency setting

Lockout relay (ANSI 86)

Description

The ANSI 86 function, traditionally performed by lockout relays, may be ensured by PowerLogic P5 protection relay using latching of output signals. The latched Global trip signal is used to inhibit any close order, until the cause of tripping disappears and is acknowledged by the user.

In basic application, the Global trip signal or likewise any of the General trip signals needs to be linked in latched mode to a changeover contact (for example, DO2 on slot B) in output matrix. Its NC contact (for example, terminals 12-13 for DO2 on slot B) has to be rooted into the close command circuit to interrupt it, as long as the DO is energized.

In applications, where auto-reclosing is used with trip lockout at unsuccessful termination of the AR sequence, programmable logic scheme needs to be set up as described in Trip lockout, page 462.

Latch function

This feature can be programmed for outputs in the **MATRIX** menu/**Output matrix** sub-menu of the eSetup Easergy Pro. Any protection stage start or trip, digital input, logic output, alarm and GOOSE signal connected to the following outputs can be latched when required:

- Output contacts DOs
- LEDs on the local panel
- Virtual outputs VO1- VO20

NOTE: The latched signal is identified with a dot and circle in the matrix signal line crossing.

The latch can be released by the following methods:

- from the local panel with the R key.
- from the eSetup Easergy Pro.
- from a user configurable DI.

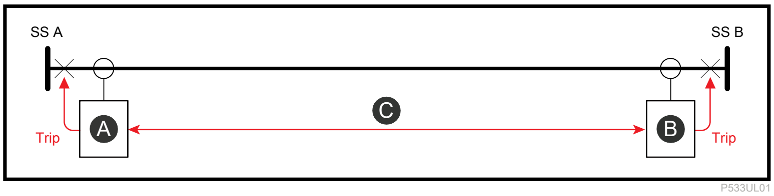
See Releasing latches, page 558 for more detailed information.

Protection communication

Introduction

The digital protection communication is an effective replacement to the traditional hardwired exchange of digital information between 2 protection relays inside substations or in different substations. It allows optimization of the communication related requirements of speed, security and dependability, while minimizing the amount of wiring between relays and providing comprehensive monitoring and status reporting of the communication link.

Figure 312 - Protection communication between 2 P5 relays



A	Protection relay A	B	Protection relay B
C	Protection communication, transfer of digital data (start, trip, direction,...)		

Configurations

Address

The setting of address is made by eSetup Easergy Pro in **GENERAL/Optical fiber communication**, in section **Configuration**, selection of **Address**.

For two relays to communicate with one another either the universal address 00 or an address pair in the same group can be set. One relay shall be assigned with address A and the other with address B. For example, if the group 1 addresses are to be used, then one relay shall be set to address *1A* and the other relay shall be set to address *1B*.

A relay with address *1A* will only accept messages from a relay with address *1B*, and vice versa. That way a set up with inadvertently false communication addresses can be easily detected.

For all these address groups patterns are chosen to provide optimum noise immunity against bit corruption. There is no preference as to which address group is better than the other.

Baud rate

The baud rate for communication between two relays is settable by eSetup Easergy Pro in **GENERAL/Optical fiber communication**, in section **Configuration**, selection of **Baud rate**.

There are three selectable values for P5F30, P5T30, P5M30: 56/64/115.2 kBit/s. There are two selectable values for P5L30: 115.2 kBit/s and 2 MBit/s.

> **NOTE:** 115.2 kBit/s cannot be used on long distances with 40km single-mode SFP (reference REL51043).

Communication monitoring

Alarms

Communication between the two relays is continuously monitored. Different type of alarms will be raised if no message is received within due time or if too many faulty messages are received within a defined time window.

Link failure alarm

This alarm is raised if no valid message is received within a user set **Comm link fail time**.

Depending on user setting the alarm will be either automatically reset when the internal communication flag is reset, or only upon acknowledgement by user.

Communication failure alarm

This alarm means any of the set frame sync timers elapses and hence for any received signal the fallback mode gets active.

When receiving a next fully valid message, it will reset automatically, hence when all received signals were successfully updated with the information received from such valid message.

Communication error alarm

This alarm will be issued if too many faulty messages are received either within a given time window or based on a given number of received telegrams. If the percentage of received erroneous telegrams (based on the total number of telegrams received) exceeds a user set **Comm error alarm level**, the related Communication error alarm will be raised.

Communication statistics

To aid the bit error evaluation of the communication link, InterRelay communication statistics are kept by the relay. The statistics records the number of errored messages detected and the number of valid messages received for the communications channel. The number of errored messages detected complies with ITU-T G.821.

The stored statistics data are:

- Valid messages: number of messages received which were OK/accepted.
- Errored messages: number of messages received but rejected.
- Errored seconds: number of seconds containing 1 or more errored messages. This is not updated for severely errored seconds.
- Lost messages: number of messages lost.
- Severely errored seconds: number of seconds containing ≥ 30% errored messages.
- Elapsed time since reset: the number of seconds since the communications error statistics were last reset.

The error statistics are automatically cleared on power-up. They can be cleared by eSetup Easergy Pro in **GENERAL**/**Optical fiber communication**:

- In **Statistics** section, after clicking the **Clear** button or buttons, the settings shall be written to the relay by clicking the **Write** button.
- In **Configuration** section, by clicking the **Reset** button besides the **Statistics reset command**, the settings will be written automatically.

Characteristics

Table 112 - Settings and characteristics of Protection communication

Settings/characteristics (description/label)	Values
Address	00, 1A, 1B … 20A, 20B
Baud rate	For P5F30, P5T30, P5M30: 56 kBit/s, 64 kBit/s, 115.2 kBit/s
	For P5L30: 115.2 kBit/s, 2 MBit/s
Comm link fail time	0.1…600.0 s
Comm error alarm level	1%…100%
Comm link fail self-reset	Disabled/Enabled
Comm error self-reset	Disabled/Enabled
Settings with line differential protection P5L30 only	
Delay tolerance time	200 ... 10000 µs
Propagation delay state	Disabled/Enabled
Maximum propagation delay	1...50 ms

InterRelay (ANSI 85)

Introduction

The InterRelay application is an effective replacement to the traditional hardwired exchange of digital information between 2 protection relays by using a serial communication link. It allows optimization of the communication related requirements of speed, security and dependability, while minimizing the amount of wiring between relays and providing comprehensive monitoring and status reporting of the communication link.

The InterRelay application is available for P5L, P5F, P5M and P5T only. The typical use cases are inter-substation communications for direct intertripping or permissive tripping, distance signaling, remote CB status indication, CBF backtrip, DEF signalling, load shedding and restoration. In some cases, the InterRelay signals may also be used in interlocking.

NOTE: The maximum length of Fiber Optic (FO) depends on the fitted FSP transceiver, see Slot L: Protection communication module with SDLC (references REL51053 and REL51043), page 100 for more details.

InterRelay communication

The InterRelay communication is enabled/disabled and configured by eSetup Easergy Pro in **PROTECTION/InterRelay communication**, 16 digital signals are transmitted within the message frame.

The meaning of these signals is freely user configurable, in the same way as for example output or LED configurations, it means configuration is done in matrix style (see next section). As typical examples, any start/trip/status signal of protection functions, switchgear open/close condition, or (timed) logic outputs are available through the configuration matrix.

Two modes of fallback are selectable in case a communication failure is detected: either keeping last valid value (*Latching*) or forcing default value (*Default*). This fallback mode gets active if the set **Frame sync time** elapses. This timer is re-triggered upon receiving a valid message. Because of different types of signals and related application needs, this timer is individually settable for each signal.

Matrix

The InterRelay signals can be programmed in different matrix of PowerLogic P5:

- The InterRelay send signals (IROut 1…16) can be connected to any protection stages outputs, digital and virtual inputs etc.
- InterRelay received signals (IRIn 1…16) can be connected in all other matrices:
  - LED matrix: for the use of activating the Alarm LED, the trip LED, and the configurable LEDs on the local panel of PowerLogic P5
  - Blocking matrix: for the use of blocking any protection.
  - Object block matrix: for the use of blocking open/close operation of the controllable objects.
  - Auto-recloser matrix: to trigger final trip or an AR cycle.
  - General signals matrix: to link them into one of the general trip signals.

For the detail of matrix, please refer to Matrix, page 552.

Characteristics

Table 113 - Settings and characteristics of InterRelay function (ANSI 85)

Settings/characteristics (description/label)	Values
Received signals IRn (n=1...16) related features	
Frame sync time	0.01…1.50 s
Fallback mode	Default/Latched
Default value	0/1
InterRelay test settings	
Loopback test mode	Yes/No
Test pattern	Any pattern of 16 digital signals with values 0 or 1.
Send signal value	0/1
Execute single signal test	Yes/No
Communication	
Refer to Protection communication, page 474.	

Line differential protection (ANSI 87L)

Description

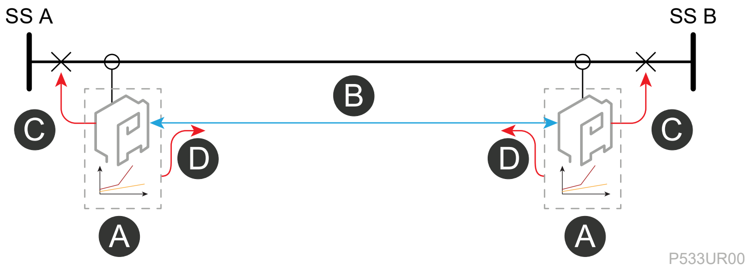
General

The PowerLogic P5L30 line differential protection is based on a high-speed, phase segregated comparison of currents flowing at both ends of overhead lines or underground cables. The current measurements need to be exchanged between both line ends by use of a communication channel and must be time-aligned for proper comparison.

It operates with absolute selectivity, using a biased trip characteristic to prevent maloperation under adverse conditions (CT saturation during high through-flowing currents, neglected capacitive charging currents, angle error of current measurements, in-zone transformer with tap changer, and so on).

Based on the primary current comparison principle, the local and remote primary currents are permanently compared. In normal operation conditions or during external faults without CT saturation, the primary currents at both ends are practically the same, so the comparison result is almost zero. For faults on the protected line this comparison results in current differences which cause the protection trip. The zone of protection is precisely defined by the location of the current transformers.

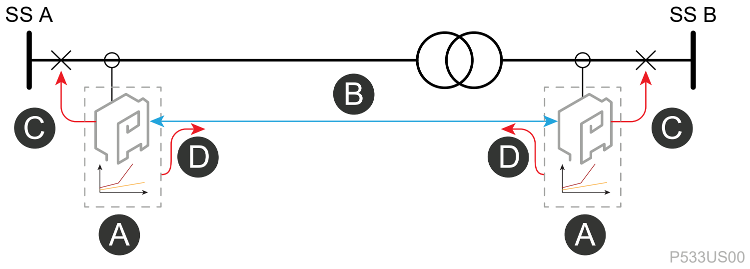
Figure 313 - Current differential protection principle



A	PowerLogic P5	B	Protection communication
C	Trip	D	Measured current values, transfer trip, and other digital data

In some applications, a power transformer is in the line differential protection zone. For example, the industrial power infeed, with no HV-side CB for cost saving reasons. Additional settings for the power transformer (vector group, voltage ratio, grounding), adequate ranges for CT ratios, and related supplementary features (inrush detection, high-set unrestrained operation, overfluxing protection) are therefore also included in the line differential protection.

Figure 314 - Current differential protection scheme including power transformer in protected zone



A	PowerLogic P5	B	Protection communication
C	Trip	D	Measured current values, transfer trip, and other digital data

The differential and bias currents are added by default to the selection of disturbance recorder channels. For changing channels selection refer toDisturbance recording parameters (measurements and monitored values), page 589.

Current measurement and preprocessing

CT polarity

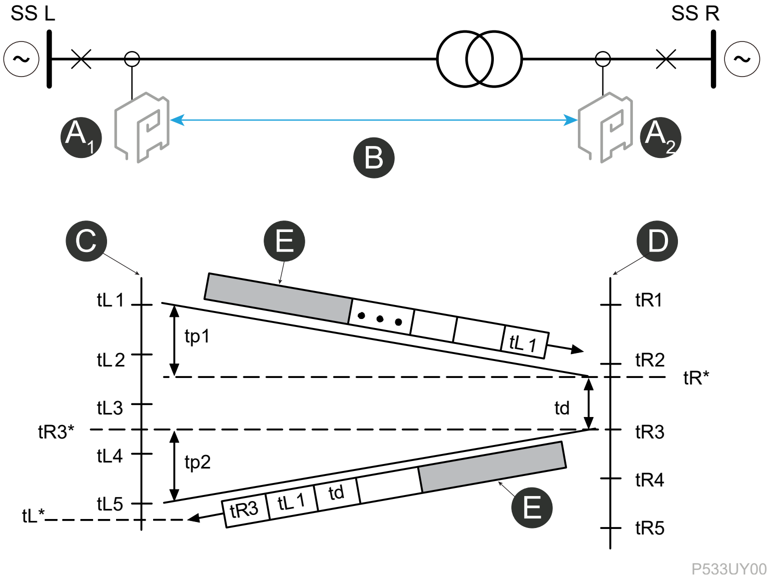
Differential protection function measures phase currents through different sets of CTs, which could be connected in standard way (common point toward protected object side) or in opposite way. This affects the sign of the measured current. Accordingly, settings are provided to adjust actual wiring to the function needs. For the CT orientation and polarity, please refer to Scaling settings, page 513.

Time alignment

To calculate differential current between line ends it is necessary that the current samples from each end are taken at the same moment in time. PowerLogic P5L30 achieves this by the continuous calculation of the propagation delay between line ends.

As shown in the followed figure, consider two PowerLogic P5L30 relays at the end L and the end R being placed at the two ends of the line. Relay at the end L samples its current signals at time tL1, tL2..., and relay at the end R at time tR1, tR2...

Figure 315 - Propagation delay measurement



A_1, A_2	PowerLogic P5L30 at end L (A_1) and end R (A_2)	B	Protection communication
C	Measure sampling time:	D	Propagation delay time:
	tR3* = (tL – tp2)		tp1 = tp2 = ½ (tL* - tL1 – td)
E	Current vectors		

Where:

- tL1, tL2, etc.: sampling instants of relay L.
- tR1, tR2, etc.: sampling instants of relay R.
- tp1: propagation delay time from relay L to R.
- tp2: propagation delay time from relay R to L.
- td: time between the arrival of message tL1 at relay R and dispatch of message tR3.
- tL*: arrival time of message tR3 at relay L.
- tR*: arrival time of message tL1 at relay R.
- tR3*: calculated sampling time of tR3 by relay L.

  NOTE: The sampling instants at the two ends will not, in general, be coincidental or of a fixed relationship, due to slight drifts in sampling frequencies.

Assume that at time tL1, relay L sends a data message to relay R. The message contains a time tag, tL1, together with other timing and status information and the current vector values calculated at tL1. The message arrives at end R after a channel propagation delay time, tp1. Relay R registers the arrival time of the message as tR*.

Since relays L and R are identical, relay R also sends out data messages to end L. Assume relay R sends out a data message at tR3. The message therefore contains the time tag tR3. It also returns the time tag from latest received message from relay L (namely tL1) and the delay time, td, between the arrival time of the received message, tR*, and the sampling time, tR3, it means td = (tR3 - tR*).

The message arrives at end L after a channel propagation delay time, tp2. Its arrival time is registered by relay L as tL*. From the returned time tag, tL1, relay L can measure the total elapsed time as (tL* - tL1). This equals the sum of the propagation delay times tp1, tp2 and the delay time td at end R.

Therefore,

(tL* - tL1) = (td + tp1 + tp2)

The relay assumes that the transmit and receive channels follow the same path and so have the same propagation delay time. This time can therefore be calculated as:

tp1 = tp2 = ½(tL* - tL1 - td)

As the propagation delay time has now been deduced, the sampling instant of the received data from relay R (tR3*) can be calculated. As shown in the above figure, the sampling time tR3* is measured by relay L as:

tR3* = (tL* - tp2)

In the above figure, tR3* is between tL3 and tL4. To calculate the differential and bias currents, the vector samples at each line end must correspond to the same point in time. It is necessary therefore to time align the received tR3* data to tL3 and tL4. This can be achieved by rotating the received current vector by an angle corresponding to the time difference between tR3* and tL3 (and tL4). For example a time difference of 1 ms would require a vector rotation of 1/20 * 360° = 18° for a 50 Hz system.

The propagation delay is measured for each received message and displayed as part of the protection communication statistics. It is continuously monitored, and abnormalities are signaled by following alarms:

Comm delay change

This alarm will be raised if the variation (the difference of consecutive propagation delays) exceeds the setting **Delay tolerance time**. As a stable transmission time is key for proper alignment of currents from both ends, correct calculation of differential and bias currents cannot be achieved in a secure manner under such time variations. Therefore, line differential protection gets temporarily blocked until a stable propagation time is detected again.

Comm delay exceeded

This alarm is raised if the propagation delay exceeds the setting **Maximum propagation delay**. If the transmission time exceeds this limit, the validity of the current vector alignment is at stake, as compared currents are measured at very different times during the course of the fault. Line differential protection gets blocked as long as the propagation delay exceeds this limit.

Magnitude alignment - CT ratio correction

For correct operation of the differential element, it is important that under load and through fault conditions, the currents compared by the differential element of the relay balance. There are many cases where CT ratios at each end of the differential protection are different.

For a healthy line, the sum of currents flowing in and out balance each other. That is true for primary currents, but as they are measured through secondary currents, CTs potentially different transformation ratios need to be considered. Ratio correction factors are therefore provided. With these the measured currents get scaled to a settable reference current.

- For a plain line protection application, this reference current must be set to the same value at both ends. It is recommended to use the average value of the CTs primary currents.

  Example:

  - CT(end L): 400/1 A
  - CT(end R): 200/1 A
  - set I_{ref} = 300 A at both relays.
- For a line differential protection with in-zone transformer this reference current has to be set to different values at both ends, in accordance with the transformer (nominal) ratio.

  It is recommended to set the reference currents equal to the transformer nominal currents.

  Example: 10 MVA, 33/11 kV transformer with a nominal power of $S_{n.tr}$ = 10 MVA

  - $I_{ref}(33\text{ kV}) = I_{n.tr}(33\text{ kV}) = S_{n.tr} / (\sqrt{3} * 33\text{ kV}) = 175\text{ A}$
  - $I_{ref}(11\text{ kV}) = I_{n.tr}(11\text{ kV}) = S_{n.tr} / (\sqrt{3} * 11\text{ kV}) = 525\text{ A}$

    So, for a 200/1 A CT on 33 kV end the CT correction factor on that end will be 200/175 = 1.142.

    And for a 800/1 A CT on 11 kV end the CT correction factor on that end will be 800/525 = 1.523.

The current correction factors are calculated as the quotient of the primary CT value and the set reference current on each end:

$k_{corr} = I_{n.CT.pr} / I_{ref}$

- For proper quality of numerical data processing, the correction factor values are restricted to the following range:

  $0.500 \leq k \leq 10.000$

The measured phase currents at each end will be scaled to the reference current by multiplication with the correction factors:

$I_{P.corr} = k_{corr} * I_{P.meas}$

Where: P= A,B,C

These scaled currents will be transmitted to the remote end relay, together with the time information to allow for time alignment. In this way, both relays will have comparable values.

Differential protection calculation

From these scaled currents the phase differential protection calculates two currents per phase:

- differential current: absolute value of the vector sum of local and remote currents.

  $I_{d.P} = | \underline{I}_{P.corr.local} + \underline{I}_{P.corr.remote} |$
- bias current: absolute value of the vector difference of local and remote current, divided by 2

  $I_{b.P} = (| \underline{I}_{P.corr.local} - \underline{I}_{P.corr.remote} |) / 2$

Where: P = A, B, C.

With this definition the currents during normal load condition will be:

- differential current = zero;
- bias current = load current.

By default, current differential protection operates in a phase-segregated way, it means differential and bias current for each phase ($I_{d.A}$,$I_{b.A}$), ($I_{d.B}$,$I_{b.B}$) and ($I_{d.C}$,$I_{b.C}$) are independently compared against the set characteristic.

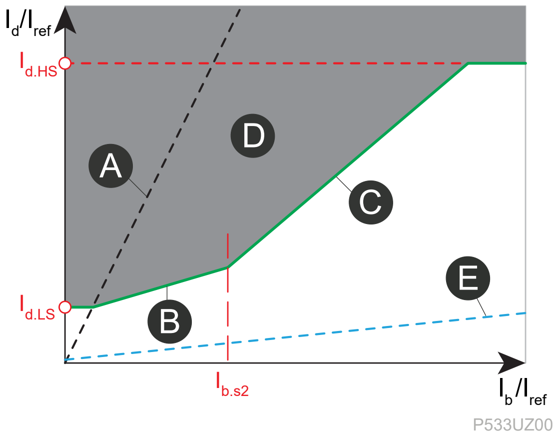
As an alternative, the restraint mode can be set to higher stability. Then the maximum bias current from all 3 phases is applied to all 3 differential protection elements, it means ($I_{d.A}$,$I_{b.A}$), ($I_{d.B}$,$I_{b.B}$) .and ($I_{d.C}$,$I_{b.C}$) are compared against the characteristic with $I_{.b.max}$ = max($I_{b.A}$, $I_{b.B}$, $I_{b.C}$).

NOTE: Even when selecting this higher stability mode, the measured bias current per phase is still shown in **Fault log**.

Trip characteristic

Basic operation condition of differential protection is the difference between the currents entering and leaving a protected zone. The protection operates when this difference exceeds a set threshold. Yet, as current differences can also result from various errors, differential protection adopts a biasing technique to prevent maloperation. This method effectively raises the differential current trip level in proportion to the value of through flowing current. The operating characteristics of the PowerLogic P5L30 phase differential element is shown in the image below.

Figure 316 - Biased tripping characteristic



A	Characteristic for single side fed fault = 200% slope	B	Slope 1
C	Slope 2	D	Trip
E	Angle error influence		

This triple-slope characteristic is determined by four settings:

- $I_{d.LS}$: The basic differential current setting which determines the minimum pick-up level of the relay.

  [default = 0.2 pu]
- s1 (Slope 1): The lower percentage bias setting used when the bias current is below $I_{b.s2}$. This provides stability for small CT mismatches, whilst ensuring good sensitivity to resistive faults under heavy load conditions.

  [default = 30%]
- $I_{b.s2}$: A bias current threshold setting, above which the higher percentage bias slope s2 is used.

  [default = 2 pu]
- s2 (Slope 2): The higher percentage bias slope setting used to improve relay stability under heavy through-flowing fault current conditions with potential CT saturation errors.

  [default = 70%]

The tripping criteria can be formulated as:

1. **For $I_b \leq 0.5 * I_{d.LS}$:** $I_d > I_{d.LS}$
2. **For $0.5 * I_{d.LS} < I_b \leq I_{b.s2}$:** $I_d > s1 * I_b + I_{d.LS} * (1 - 0.5 * s1)$
3. **For $I_b > I_{b.s2}$:** $I_d > s2 * I_b + I_{d.LS} * (1 - 0.5 * s1) + I_{b.s2} * (s1 - s2)$

A further high set unrestrained element $I_{d.HS}$ can be enabled to provide high-speed operation in the event of CT saturation. Its use is recommended for applications with in-zone current limiting elements, namely in-zone power transformers.

The differential protection can be delayed for a settable definite time, which should only be used if there are further in-zone protection zones, for example, fused tapped feeders connected to the protected line.

Current release

The phase differential protection function is provided with an optional current release with a settable current threshold I>.

The current release function supervises all three phase currents. If enabled, the smallest of the three phase currents will be determined. The phase differential protection will be activated only if this smallest phase currents is higher than the set threshold. If the current value of all phase currents is below the configured threshold, phase differential protection will be forced to inactive state.

This current release function is active only if the phase differential protection is not in a starting state. When the phase differential function is active and in starting condition, the current supervision will not be executed any more.

Angle error supervision

In the design of time alignment of measurements, the propagation time for the differential protection communication in both ways is assumed to be equal. If that condition is not met, a differential current will be measured. As an example, an asymmetric propagation time of 333 μs will result in a ratio of differential current to through-flowing load current of about 10%. For various values of load currents, this will result in differential currents on an angle error slope at about 6°.

In order to detect such adverse condition, an angle error supervision is implemented (light blue characteristic in the image Biased tripping characteristic, page 483). If the calculated differential current is above that characteristic for a set time, a dedicated alarm signal will be issued.

Intertripping

Below two types of intertrip signals are transmitted in each message frame.

Direct intertrip (DIT)

When a trip is issued by the differential element of a relay , in addition to tripping the local breaker, the function will send a differential intertrip signal to the remote relay. To enhance security, receipt of such direct intertrip signal is accepted only if being in 2 consecutive message frames.

By default, it is linked to the CB trip output DO1(B) in the “Output” matrix. This will ensure tripping of remote end of the protected line, even for marginal fault conditions so that the differential protection on one end just does not pick up.

This DIT transfer and internal execution remains in service, even if the local differential protection is out of service. Therefore, a valid received DIT signal is still executed and can operate the digital outputs as per the configuration in the Output matrix.

This intertrip signal source is limited to the line differential protection function only. It is not available to transfer any trip from other protection functions. For such more general direct intertrip applications any of the available InterRelay signals can be used, or with the below permissive intertrip.

Permissive intertrip (PIT)

The differential protection function further provides a permissive intertrip signal and functionality. This PIT signal is sent by default in case of a trip signal from the differential protection, but further trip signals from other protection functions can be configured in the “Output” matrix.

Upon receiving such PIT signal from the remote terminal, the differential protection function applies one of the following checks:

- None: The received PIT signal forces an unconditional local PIT trip signal (with reference to line differential same functions as DIT).
- Local: When receiving the PIT signal, a trip is issued if a local measured current is above the set threshold “PIT current”.
- Remote: When receiving the PIT signal, a trip is issued if the remote current (received from remote PowerLogic P5L30) is above set threshold “PIT current”.

If such permissive condition is fulfilled, the line differential protection will issue the permissive trip signal.

CT supervision (differential CTS)

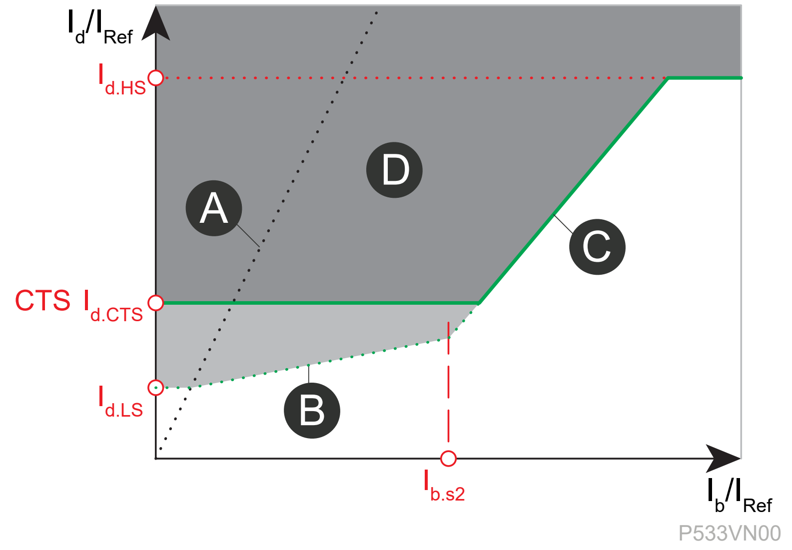
In general, the current transformer supervision feature is used to detect failure of one or more of the phase current inputs to the relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the AC current circuits risks dangerous CT secondary voltages being generated.

Separate CTS functions supervising the phase currents at local end as well the differential currents are provided to alarm about such failure condition. As a precondition, the differential CTS function will not be active if none of the three phases present an undercurrent condition Ix < 0.1 Inom (x = A, B, C). Furthermore, they allow two modes of interaction with line differential protection function:

- Indication: CTS alarms have no effect on differential protection
- Blocking: The differential protection is blocked while CTS condition is present.
- Restraining: The minimum differential protection pick-up value is “shifted” vertically to a higher threshold (CTS $I_{d.LS}$) while CTS condition is present.

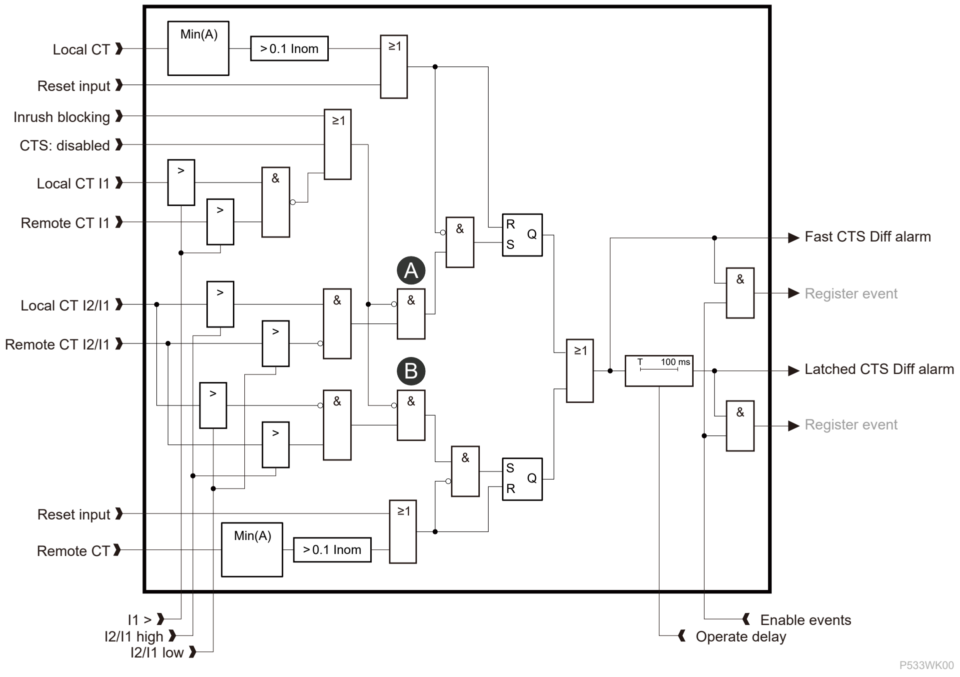
CTS condition signal is transmitted to the remote end device, to apply blocking or restraining there too, to prevent false operation.

Figure 317 - Differential tripping characteristic with CTS restraining



A	Characteristic for single side fed fault = 200% slope	B	Slope 1
C	Slope 2	D	Trip

Figure 318 - CTS DIFF operate logic



A	Local CT	B	Remote CT

Compensation modes

So-called compensation modes can be enabled in line differential protection function to address specific items of the protected line. One of the 3 options below could be selected:

- None
- Capacitive charging currents
- In-zone power transformers

The details are given in the following sections.

NOTE: It is mandatory that the same compensation mode is set at both ends.

Capacitive charging current compensation

The charging current of a line or cable can be seen as differential current. If this current is of a sufficiently high magnitude, as is the case for cables and long lines, then a relay maloperation could occur. Two issues are apparent with a charging current: the first being inrush during line energization and the second being steady state charging current.

Inrush charging current is predominately high order harmonics (9th and 11th for example). The Fourier filtering used by the PowerLogic P5L30 relays will remove these frequency components and hence provide stability.

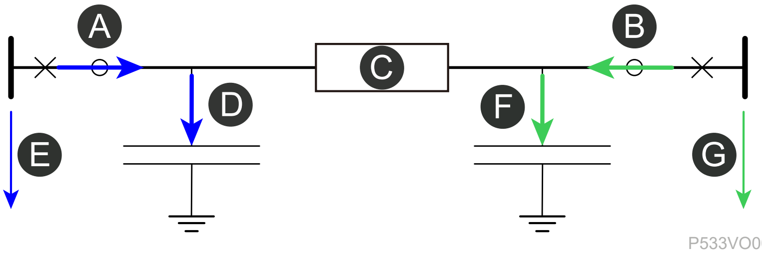
Steady state charging current is nominally at fundamental frequency and hence may cause relay maloperation.

As a basic mean, such differential current can be considered by adequate rise of the tripping characteristic ($I_{d.LS}$ and slope 1).

The best available option will be the capacitive charging current compensation. This feature derives the charging currents from the measured line voltages and subtract them from the measured currents before further calculating the differential and bias currents.

NOTE: If no measured voltage is available, the capacitive charging current compensation operates as if nominal voltage would be measured.

Figure 319 - Capacitive charging current



A	IL: Left end line current	B	IR: Right end line current
C	ZLine: Line impedance	D	Icap.L: Left end charging current
E	VL: Left end voltage	F	Icap.R: Right end charging current
G	VR: Right end voltage		

The capacitive charging current level, related to the nominal voltage level of the protected line, is usually given in per unit value, typically in A/km. This value multiplied by the line length gives the line capacitive charging current $I_{cap.line}$ which is to be set when activating this compensation feature.

From that the capacitive charging current at each end is calculated per phase as ratio of actual measured phase voltage (V_P) to nominal voltage (V_n):

$I_{P.cap} = ½ * I_{cap.line} * (\sqrt{3}\ V_P / V_n)$

Where: P = A,B,C.

NOTE: The same capacitive charging current has to be set on both relays.

This capacitive charging current then is considered (actually subtracted) in the differential and bias current calculation.

Transformers in-zone application

In applying the well established principles of differential protection to transformers, a variety of considerations have to be taken into account. These include compensation for any phase shift across the transformer, possible unbalance of signals from current transformers either side of windings, and the effects of the variety of grounding and winding arrangements. In addition to these factors, which can be compensated for by correct application of the relay, the effects of normal system conditions on relay operation must also be considered. The differential element must restrain for system conditions which could result in maloperation of the relay, such as high levels of magnetizing current during inrush conditions.

Basic details of features of the transformer and related settings are already described in Transformer differential protection (ANSI 87T), page 496. Therefore, this section provides just the list of provided features and the description of particularities.

Obviously, in such application the transformer compensation mode setting in the line differential protection function has to be enabled on both ends.

CT ratio correction

When setting the reference currents of line differential protection, the nominal transformer ratio needs to be considered, it means nominal currents are inverse proportional to the nominal voltages, as detailed in Magnitude alignment - CT ratio correction, page 482.

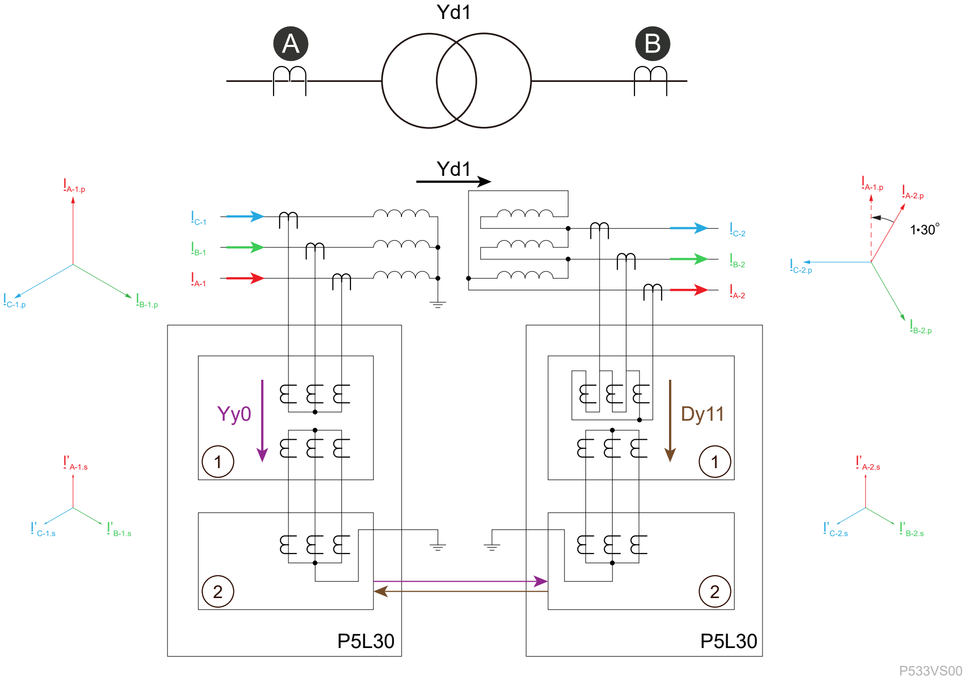
It’s recommended to set the reference currents of the line differential relays equal to the transformer nominal current.

The HV and LV current transformer primary ratings should be selected to match the transformer winding rated currents, so that the CT correction factors are as close as possible to 1. Numerical data processing accuracy imposes the need that they must be in a range of 0.5 to 10.0. Otherwise, differential protection gets blocked.

Vector group compensation and zero-sequence current filtering

Selection of the phase angle compensation settings will be dependent on the phase shift (described by the vector group) of the power transformer. This phase correction is applied to each relay. A traditional way to compensate the phase shift was the use of interposing CTs (ICTs). Modern differential relays like PowerLogic P5L30 replicate such ICTs in software. This has the advantage of being able to cater for line CTs connected in either star as well as being able to cater for zero sequence current filtering. A typical application for an Yd1 power transformer is sketched in the image below:

Figure 320 - Example of transformer vector group compensation



A	CT-1	B	CT-2
1	ICT	2	Line DIFF

To aid selection of the correct setting on the relay menu, most commonly used transformer configurations and the selection of related vector group settings are shown in the following table. Also, in the bottom lines (yellow marked) the generic rule is given.

As shown in the table, a delta winding is introduced with the Y side software ICT. This provides the required zero sequence trap, as would have been the case if the vector correction factor had been provided using an external ICT.

Whenever an in-zone grounding connection is provided, a zero-sequence trap should always be provided. For instance, if a YNyn power transformer is in the protected zone, there will be some difference between HV and LV zero sequence magnetizing current of the transformer. This is normally small, but to avoid any problem with any application the above rule for zero sequence traps shall be applied with grounded windings.

Table 114 - Selection of vector group settings

Transformer connection	Transformer phase shift	Vectorial compensation (ICT) and vector group (vg) vector group and enabling I0–filtering are relay settings)					
		HV			LV		
		ICT	vg	I0–filt.	ICT	vg	I0–filt.
Dy1	-30°	Yy0 (0°)	0	no	Yd11 (+30°)	11	no
Dyn1				no			yes
Yd1		Yd1 (-30°)	1	no	Yy0 (0°)	0	no
YNd1				yes			no
Dy5	-150°	Yy0 (0°)	0	no	Yd7 (+150°)	7	no
Dyn5				no			yes
Yd5		Yd5 (-150°)	5	no	Yy0 (0°)	0	no
YNd5				yes			no
Dy7	+150°	Yy0 (0°)	0	no	Yd5 (-150°)	5	no
Dyn7				no			yes

Table 114 - Selection of vector group settings (Continued)

Yd7		Yd7 (+150°)	7	no	Yy0 (0°)	0	no
YNd7				yes			no
Dy11	+30°	Yy0 (0°)	0	no	Yd1 (-30°)	1	no
Dyn11				no			yes
Yd11		Yd11 (+30°)	11	no	Yy0 (0°)	0	no
YNd11				yes			no
Yy0	0°	Yy0 (0°)	0	no	Yy0 (0°)	0	no
YNy0		Ydy0 (0°)		yes	Yy0 (0°)		no
Yyn0		Yy0 (0°)		no	Ydy0 (0°)		yes
YNyn0		Ydy0 (0°)		yes	Ydy0 (0°)		yes
Dy vg	φ = vg * (-30°)	Yy0 (0°)	0	no	Yd (12 - vg)	12 - vg	no
Dyn vg				no			yes
Yd vg		Yd vg	vg	no	Yy0 (0°)	0	no
YNd vg				yes			no

Where:

- vg = vector group = [0 … 11]
- Dy or Yd configurations have odd vector group numbers only
- Dd or Yy configurations have even vector group numbers only (only Yy0 in this table)

NOTE: This table applies for systems with clockwise phase rotation (A-B-C) only. In systems with anti-clockwise phase rotation (A-C-B) the complementary vector group (vg' = 12 - vg) has to be used instead of the vector group (vg) given on the transformer nameplate (and used in above table).

High set differential current element

The optional high set differential protection element should be enabled for in-zone transformer applications. This is provided to ensure rapid clearance for heavy internal faults with saturated CTs. Because high set is not restrained the setting must be set such that it will not operate for the largest through-flowing currents expected. It is basically limited by the transformer reactance, commonly indicated as relative short-circuit voltage Vsc. The maximum through fault current for infinite source at one end with nominal voltage will be then its inverse multiple of transformer nominal current, namely Itr.n / Vsc. For example, for Vsc = 10% the maximum through fault current is 10 times transformer nominal current. A safety margin of at least 20% should be added to this current value to cater for permissible higher system voltages and inaccuracies. Also, the difference between transformer nominal currents and set reference currents has to be considered.

Inrush detection

When energizing a transformer from one end a magnetizing inrush current flows into the energized winding. This current is not represented at the remote end. Therefore, inrush current detection and prevention from false tripping has to be considered.

As the maximum inrush current depends on the transformer size, a settable differential current limit (typically set above 120% of maximum expected inrush current) is provided to discriminate between such inrush condition and fault condition. If actual measured differential current exceeds that limit “Inrush current limit”, then inrush detection is disregarded.

As inrush takes place at one end only, the status of inrush detection per phase and the measured maximum inrush current are sent through the communication link to the remote device to prevent false differential operation there, too.

Two methods are provided to avoid trips on inrush current.

Inrush restraining mode

The phase differential protection uses a settable multiple of the maximum second harmonic current value to add it to the bias current.

$Ib_{.add} = H2_{mult} * IH2_{max}$

Where:

- $Ib_{.add}$: current added to the bias current of each phase on both ends
- $H2_{mult}$: settable multiplier
- $IH2_{max}$: highest 2nd harmonic current = max ($IH2_A$, $IH2_B$, $IH2_C$)

The 2^nd^ harmonic currents are calculated with Fourier filtering technique and the rms value of the highest current is sent through the communication link to the remote device.

NOTE: When this inrush restrain function is enabled, it must be ensured that this function is enabled at both ends to avoid possible maloperation.

Inrush blocking mode

In this mode, the ratio of 2nd harmonic to fundamental current (IH2/IH1) is measured in each phase. Inrush decision is made if this ratio exceeds a set threshold.

Blocking can be set to be either phase selective or cross blocking operation. In the latter all 3 phase differential elements get blocked, if in at least one phase an inrush decision is made.

Overfluxing detection

If the transformer is energized with a voltage in excess of its nominal voltage, saturation effects occur which in turn cause higher magnetizing currents. Without stabilization, these could lead to differential protection tripping. The fact that the current of the protected object under saturation conditions has a high proportion of 5th harmonic serves as the basis of stabilization.

Overfluxing detection is provided as an option, based on the phase segregated differential currents. The ratio of the 5th harmonic to fundamental component of the differential current is evaluated, while the fundamental current is within a range of 0.1…4.0 I_{ref}. If this ratio is bigger than the set threshold, overflux blocking gets activated and blocks the differential protection function. As per setting, this is either phase selective or cross-blocking.

Further considerations

Back-up overcurrent protection

In case of line differential protection is blocked for any reason (most likely the loss of communication link), local back up overcurrent protection stage(s) can be automatically activated. For that purpose, a dedicated setting is provided in the phase and neutral overcurrent protection stages of the PowerLogic P5L30 relays. Refer to Negative sequence overcurrent (ANSI 46), page 344, Non-directional/ directional phase overcurrent protection (ANSI 50/51/67), page 393 and Non-directional/directional ground fault overcurrent (ANSI 50N/51N/67N), page 428 for detail.

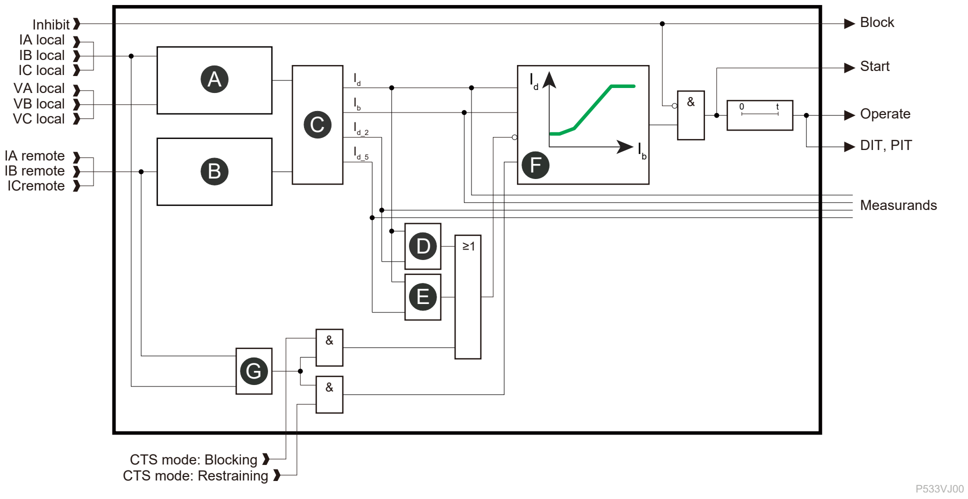
To enable the back-up overcurrent protection, check **Back-up mode** in eSetup Easergy Pro/**PROTECTION**/**Negative sequence overcurrent 46** and **Phase overcurrent 50/51/67** and **Ground fault overcurrent 50N/51N/67N**.

In-zone “Teed” Loads

Many rural feeders have small fuse protected loads tapped off the line within the zone of protection. In most cases the load is small enough to be ignored when setting the $I_{d.LS}$ threshold. The problem, however, is when a fault occurs downstream of the fuse. The current differential protection would assume the fault was on the feeder, instead of at the load, and may trip before the fuse has a chance to blow. This could cause considerable and unnecessary disruption to rest of the system. To prevent this from occurring the operating time of the current differential element can be time delayed to grade with the fuse.

Block diagram

Figure 321 - Line differential protection function structure overview



A	Local end current and voltage: - Polarity alignment - Time alignment - Magnitude alignment - Optional: Phase sequence alignment - Optional: Vector group correction - Optional: Zero-sequence current filtering - Optional: Captive charging current compensation	B	Remote end current (aligned vector data through communication link)
C	DIFF calculation	D	Inrush detection
E	Overfluxing detection	F	Biased characteristic
G	Differential CTS		

Characteristics

Table 115 - Settings and characteristics of line differential protection function (ANSI 87L)

Settings/characteristics (description/label)	Values
Enable line differential protection	
Enable for L-Diff	Off/On
Low set I_d	
Setting range	0.10 ... 3.00 pu
Resolution	0.01 pu
Slope 1	
Setting range	10% ... 150%
Resolution	1%
I_b for start of slope 2	
Setting range	1.00 ... 30.00 pu
Resolution	0.01 pu
Slope 2	
Setting range	30% ... 150%
Resolution	1%
High set mode	
Enable High set mode	Off/On
High set I_d	
Setting range	1.00 ... 30.00 pu
Resolution	0.01 pu
Restraint mode	
Setting range	Phase selective/Higher stability
Operate delay	
Setting range	0.00...100.00 s
Resolution	0.01 s
Accuracy	1% or ±10 ms
Current release status	
Enable of current release	Disabled/Enabled
I> release	
Setting range	0.02 ... 1.00 pu
Accuracy	±2% or ±0.005 pu
Angle supervision	
Angle supervision slope	1% ... 30%
Angle supervision time	0.10 ... 30.00 s
CTS operating mode	
Setting range	Indication/Blocking/Restraining
CTS low set Id	
Setting range	0.10 ... 30.00 pu
Resolution	0.01 pu
PIT time	

Table 115 - Settings and characteristics of line differential protection function (ANSI 87L) (Continued)

Settings/characteristics (description/label)	Values
Setting range	0.000 ... 2.000 s
Resolution	0.001 s
PIT current selection	
Setting range	Disabled/Remote/Local
PIT current	
Setting range	0.10 ... 20.00 pu
Resolution	0.01 pu
Compensation mode	
Setting range	None/Cap. charging/Transformer
Capacitive charging current	
Setting range	0 ... 1000 A
Resolution	1 A
Vector group	
Setting range	1 ... 11
Zero-sequence current filtering	
Options	Disabled/Enabled
Inrush restraint mode	
Options	Disabled/Restraining/Blocking
2nd harmonic multiplier	
Setting range	0.1 ... 20.0
Resolution	0.1
Inrush blocking ratio	
Setting range	5% ... 50%
Resolution	1%
Accuracy	2%
Inrush cross block	
Enable Inrush cross block	Disabled/Enabled
Max inrush	
Setting range	1.00 ... 30.00 pu
Resolution	0.01 pu
Overflux blocking	
Enable Overflux blocking	Disabled/Enabled
Overflux blocking ratio	
Setting range	5% ... 100%
Resolution	1%
Accuracy	2%
Overflux cross block	
Enable Overflux cross block	Disabled/Enabled
Scaling	
Reference current (Iref)	10...10000 A
CT correction factor	0.1 ... 2.00 x CT prim

Table 115 - Settings and characteristics of line differential protection function (ANSI 87L) (Continued)

Settings/characteristics (description/label)	**Values**
Linear range	40 x Iref
References	
Communication	Refer to Protection communication, page 474.
Characteristics[129]	
Basic characteristic accuracy	±5% or ±0.01 pu
Reset ratio	95% ± 2%
Start time	< 40 ms (35 ms with high speed) for differential currents at 2 x Low set I_d
Disengaging time	< 60 ms (75 ms with high speed)
Setting group/SetGrp	
Number	4

---

[129] Claimed values are valid for power system frequencies within nominal frequency +/- 2 Hz.

Transformer differential protection (ANSI 87T)

Description

General

The PowerLogic P5T30 transformer differential protection is a high-speed, two-ended, phase segregated, transformer differential protection for distribution applications in the industry and utility segments, with absolute selectivity for power transformers, motors, generators, shunt reactors and similar equipment. For full application flexibility of this protection function, CT arrangement uses generic naming "CT-1" and "CT-2". In a standard transformer differential application CT-1 end is the high voltage (HV) end, and CT-2 end is the low voltage (LV) end.

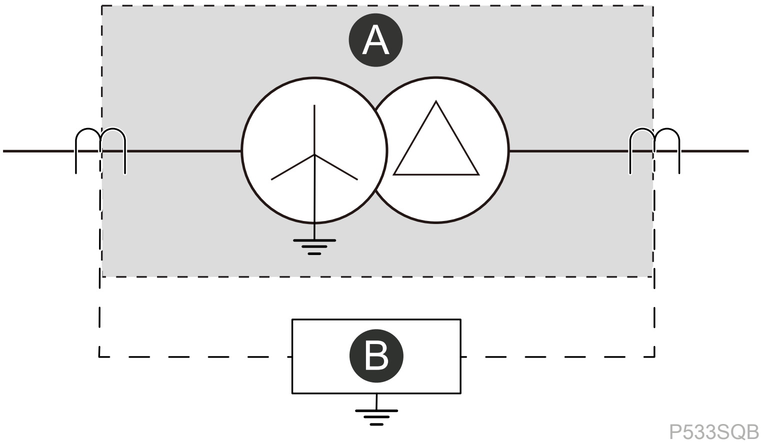
Based on the primary current comparison principle, the current values from both ends are continuously compared. In normal operation conditions or during external faults without CT saturation, the primary currents at both ends are practically the same, so the comparison result is practically zero (actually, the magnetizing current and thermal copper losses take less than 1% of transformer nominal current). For faults inside the protected transformer (inside the protected object) the comparison will result in values higher than the operation value, so the protection will trip. The zone of protection is precisely defined by the location of current transformers in the substations.

As the differential protection function measures the currents through the CTs, errors introduced from the CTs (namely transformation error and transient saturation) are considered. Same with uncertainties regarding the transformation ratio of the primary transformer.

This is basically done by calculating differential and restraining current and comparing these values against a triple-slope tripping characteristic.

The trip is usually instantaneous, or with a time delay for more complex protection schemes where other protection functions are embedded in the differential protection zone.

Figure 322 - Protected zone of current differential protection



A	Protected zone	B	Differential relay

The 16 disturbance recording channels are added by default when enabling this protection. If you want to edit the channels or add new channel, refer to Disturbance recording parameters (measurements and monitored values), page 589.

Current measurement and preprocessing

CT polarity

Differential protection function measures phase currents through different sets of CTs, which could be connected in standard way (common point toward protected object side) or in opposite way. This affects the sign of the measured current. Accordingly, settings are provided to adjust actual wiring to the function needs. For the CT orientation and polarity, please refer to CT and LPCT typical application, page 73 and Scaling settings, page 513.

Phase swapping

Hydro pump storage applications use motor/generators, where reversing the operating mode is done by swapping 2 phases either on HV or LV side. If such a reversing switch is inside the protected zone, the protection scheme is able to get aligned. Accordingly, settings are provided for this phase swapping feature. Please refer to Scaling settings, page 513.

Activation of phase swapping is controlled through a dedicated digital input signal (Phase swap activation input = DI1 – DIx, Fx, VI1 – VIx).

Amplitude matching

Protection is based on comparison of the primary phase currents. In a transformer protection application, these will be naturally different with a ratio inverse to the nominal voltages of the windings.

These currents are measured through CTs with a different transformation ratio, more or less according to the nominal currents of the power transformer.

For example, a 110kV/22kV power transformer with 60 MVA rated power has a nominal current on HV side of 315 A and on LV side of 1575 A. Accordingly CTs on HV side could be 400:1 A and on LV side 2000:1 A.
PowerLogic P5 takes into account such different nominal currents and ratios in the data processing and provides amplitude matching settings to adjust the function accordingly: all currents are scaled to reference currents, calculated based on a common reference power S_{ref} and the nominal voltages of each end. For protection of transformers, motors, shunt reactors etc., this reference power is usually the rated or nominal power of the protected object.

The reference currents are calculated from the set reference power S_{ref},

- End-1 (HV) reference current: $I_{ref-1} = S_{ref} / \sqrt{3} \cdot V_{rated,end-1}$
- End-2 (LV) reference current: $I_{ref-2} = S_{ref} / \sqrt{3} \cdot V_{rated,end-2}$

With these reference currents and the primary nominal currents of the CTs the amplitude matching factors are calculated:

- CT-1 amplitude matching factor: $k_{amp,1} = I_{CT-1,primary} / I_{ref-1}$
- CT-2 amplitude matching factor: $k_{amp,2} = I_{CT-2,primary} / I_{ref-2}$

These matching factors are displayed at the P5.

If the value of a factor is outside the range from 0.1 to 32.0, the differential protection function is blocked.

The measured phase currents from each end are scaled with these factors per following equations:

- HV end phase currents: $\underline{I}_{amp,p,2} = k_{amp,1} \cdot I_{p,CT-1}$
- LV end phase currents: $\underline{I}_{amp,p,2} = k_{amp,2} \cdot I_{p,CT-2}$

where:

- amp = amplitude-matched
- p = phase A, B or C

Vector group correction

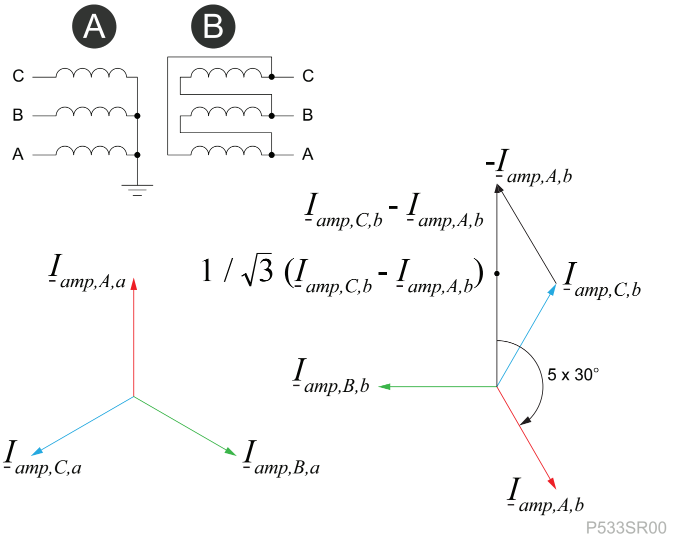
The transformer HV windings are indicated by capital letters and the LV windings by lower case letters. The numbers refer to positions on a clock face and indicate the phase displacement of balanced 3-phase LV line currents with respect to balanced 3-phase HV line currents. The HV side is taken as reference and it is the 12 o’clock position.

Therefore, each hour represents a 30° shift; for example, 1 represents a 30° lag and 11 represents a 30° lead (LV with respect to HV). An additional N, YNd1 (lower case for LV, d) indicates a neutral to earth connection on the high voltage winding of the power transformer.

By studying the relative phase shifts that can be obtained, it can be seen that star-star windings allow even vector group configurations and star-delta/delta-star windings allow odd group configurations.

According to the set vector group the LV side currents for differential comparison are calculated from different phases to align with the primary connection, as sketched in the following figure.

Figure 323 - Example of phase shift for a YNd5 transformer



A	Winding a
B	Winding b

Zero-sequence current filtering

The figure below shows the need for zero-sequence current filtering for differential protection across a transformer. It mimics the distribution of primary zero-sequence current in the protection scheme. The power transformer delta winding acts as a “trap” to zero-sequence current. This current is therefore only seen on the star connection side of the power transformer and hence as differential current by the protection scheme.

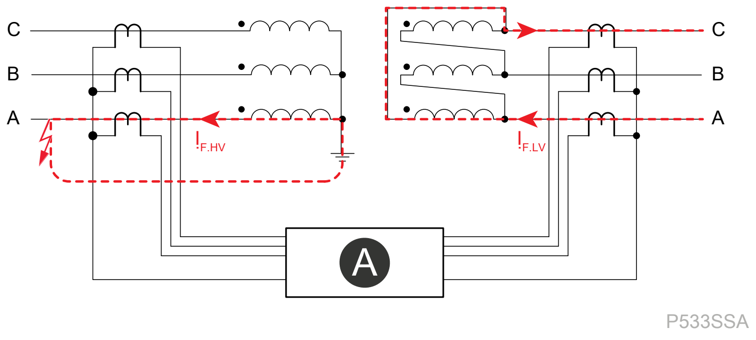
If the zero-sequence current filtering is enabled, one third of measured zero-sequence current is subtracted from each phase current. Otherwise, if disabled, one third of measured zero-sequence current is added to each phase current to increase the differential protection sensitivity for internal ground faults on non-grounded ends.

Accordingly, the following calculations are executed per end:

1. Determination of zero-sequence current:
    - $\underline{I}_{zero,x} = (\underline{I}_{A,x} + \underline{I}_{B,x} + \underline{I}_{C,x}) / 3$
2. Determination of filtered phase currents:
    - If zero-sequence current filtering is enabled:
        - $\underline{I}_{p,zero.x} = \underline{I}_{p,x} - \underline{I}_{zero,x}$
    - Otherwise:
        - $\underline{I}_{p,zero.x} = \underline{I}_{p,x} + \underline{I}_{zero,x}$

where x = end 1 (HV) or 2 (LV), p = A, B, C

Figure 324 - Need for zero-sequence current filtering



A	DIFF

	HV end (CT-1)	LV end (CT-2)
Setting	Zero-sequence current filtering CT-1 = Yes	Zero-sequence current filtering CT-2 = No
Calculated currents per end and measuring system:		
	$\underline{I}_{zero,HV} = (\underline{I}_{A,HV} + \underline{I}_{B,HV} + \underline{I}_{C,HV}) / 3 = \underline{I}_{F,HV} / 3$	$\underline{I}_{zero,LV} = (\underline{I}_{A,LV} + \underline{I}_{B,LV} + \underline{I}_{C,LV}) / 3 = 0$
ms1 (A)	$\underline{I}_{ms1,zero,HV} = \underline{I}_{A,HV} - \underline{I}_{zero,HV} = 2/3 \cdot \underline{I}_{F,HV}$	$\underline{I}_{ms1,zero,LV} = \underline{I}_{C,LV} - \underline{I}_{A,LV} + \underline{I}_{zero,LV} = 2 \cdot \underline{I}_{F,LV}$
ms2 (B)	$\underline{I}_{ms2,zero,HV} = \underline{I}_{B,HV} - \underline{I}_{zero,HV} = - 1/3 \cdot \underline{I}_{F,HV}$	$\underline{I}_{ms2,zero,LV} = \underline{I}_{B,LV} - \underline{I}_{C,LV} + \underline{I}_{zero,LV} = - 1 \cdot \underline{I}_{F,LV}$
ms3 (C)	$\underline{I}_{ms3,zero,HV} = \underline{I}_{C,HV} - \underline{I}_{zero,HV} = - 1/3 \cdot \underline{I}_{F,HV}$	$\underline{I}_{ms3,zero,LV} = \underline{I}_{A,LV} - \underline{I}_{B,LV} + \underline{I}_{zero,LV} = - 1 \cdot \underline{I}_{F,LV}$

The following table lists all the mathematical phasor operations. It shows that for all odd-numbered vector group characteristics the zero-sequence current on the low-voltage side is basically always filtered out, whereas for even-numbered vector group characteristics the zero-sequence current on the low-voltage side is basically never filtered out automatically. The latter is also true for the high-voltage side since in that case no mathematical phasor operations are performed. Vector group matching and zero-sequence current filtering must therefore always be viewed in combination.

Table 116 - Numerical processing depending on vector group and zero-sequence current filtering

Vector group	With zero-sequence current filtering	Without zero-sequence current filtering
Mathematical operations on the HV side		
	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p,z} - \underline{I}_{amp,zero.z}$	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p,z}$
Mathematical operations on the LV side for even-numbered vector group characteristics		
0	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p,z} - \underline{I}_{amp,zero.z}$	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p,z}$
2	$\underline{I}_{vec,ms,z} = -\ (\underline{I}_{amp,p+1,z} - \underline{I}_{amp,zero.z})$	$\underline{I}_{vec,ms,z} = - \underline{I}_{amp,p+1,z}$
4	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p-1,z} - \underline{I}_{amp,zero.z}$	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p-1,z}$
6	$\underline{I}_{vec,ms,z} = -\ (\underline{I}_{amp,p,z} - \underline{I}_{amp,zero.z})$	$\underline{I}_{vec,ms,z} = - \underline{I}_{amp,p,z}$
8	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p+1,z} - \underline{I}_{amp,zero.z}$	$\underline{I}_{vec,ms,z} = \underline{I}_{amp,p+1,z}$
10	$\underline{I}_{vec,ms,z} = -\ (\underline{I}_{amp,p-1,z} - \underline{I}_{amp,zero.z})$	$\underline{I}_{vec,ms,z} = - \underline{I}_{amp,p-1,z}$
Mathematical operations on the LV side for odd-numbered vector group characteristics		
1	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p,z} - \underline{I}_{amp,p+1,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p,z} - \underline{I}_{amp,p+1,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$
3	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p-1,z} - \underline{I}_{amp,p+1,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p-1,z} - \underline{I}_{amp,p+1,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$
5	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p-1,z} - \underline{I}_{amp,p,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p-1,z} - \underline{I}_{amp,p,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$
7	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p+1,z} - \underline{I}_{amp,x,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p+1,z} - \underline{I}_{amp,p,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$
9	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p+1,z} - \underline{I}_{amp,p-1,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p+1,z} - \underline{I}_{amp,p-1,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$
11	$\underline{I}_{vec,ms,z} = (\underline{I}_{amp,p,z} - \underline{I}_{amp,p-1,z}) / \sqrt{3}$	$\underline{I}_{vec,ms,z} = [(\underline{I}_{amp,p,z} - \underline{I}_{amp,p-1,z}) / \sqrt{3}] + \underline{I}_{amp,zero.z}$

Where the indices in the equations have the following meanings:

- amp: amplitude-matched
- vec: amplitude- and vector group-matched
- p: phase A, B or C
- p+1: cyclically trailing phase
- p-1: cyclically leading phase
- ms: measuring system 1, 2 or 3
- z: end 1(HV) or 2(LV)

A reverse phase rotation (A-C-B) setting and phase swapping condition are taken automatically into account in the calculation of these amplitude- and vector group-matched phase currents from both ends.

Differential protection

Differential protection calculations

The differential protection is based on calculation of differential and restraint (or bias) current, both calculated from amplitude matched, vector group compensated and zero-sequence current filtered currents as detailed in Numerical processing depending on vector group and zero-sequence current filtering, page 500.

The differential current is sum of HV and LV side current values (per phase), it is calculated with:

$$I_d = | \underline{I}_{vec,end1} + \underline{I}_{vec,end2} |$$

The bias current is the difference of HV and LV side current values (per phase), scaled to be comparable with the load current in normal operation.

It is calculated in one of the following ways according to the selected method:

- Sum of absolute values divided by 2:

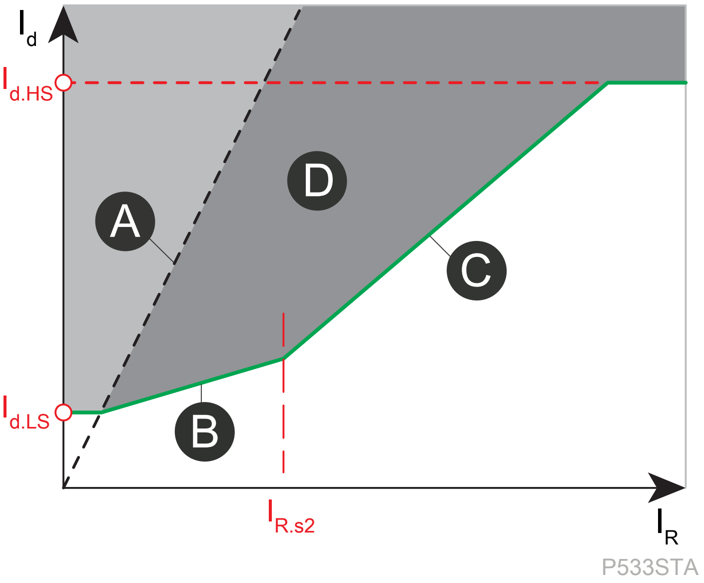
  $I_R = (| \underline{I}_{vec,end1} | + | \underline{I}_{vec,end2} |) / 2$
- Absolute value of phasor difference divided by 2:

  $I_R = | \underline{I}_{vec,end1} - \underline{I}_{vec,end2} | / 2$

Differential characteristic

With high current flowing through the protected object, for example during external fault conditions, a differential current might be apparent. The reason can be due to different ratio errors and/or magnetizing/saturation characteristics of the CTs. Therefore, the current differential protection gets provided with a biased tripping characteristic, as shown in following figure:

Figure 325 - Biased tripping characteristic



A	Characteristic for single side fed fault = 200% slope	B	Slope 1
C	Slope 2	D	Trip area

Whatever method is used, the calculated value pair of differential and restraining current (I_d and I_R) is compared against this characteristic with three sections (green characteristic in above figure). The first section is a horizontal line at set pick-up threshold $I_{d.LS}$ up to the intersection with the line for single side infeed, with value considering basic inaccuracies (transformer magnetizing current, …). The first slope (slope 1) ensures sensitivity to internal faults, while providing increasing restraint to for example compensate effect of false amplitude matching due to non-compensated tap changer. The second slope provides stability against measuring errors like CT saturation.

The high set unrestrained differential current level $I_{d.HS}$ defines the characteristic boundary. Differential currents which are higher than this value indicate internal faults (external faults are limited for example by transformer reactance) and require the fastest fault clearance. Therefore, differential protection will operate without consideration of the restraint current.

The differential operating current is calculated using the following characteristic equations:

For $I_R < I_{d.LS} / 2$	$I_d > I_{d.LS}$
For $I_{d.LS} / 2 \le I_R \le I_{R.S2}$	$I_d >$ Slope 1 x $(I_R - I_{d.LS} / 2) + I_{d.LS}$
For $I_R > I_{R.S2}$	$I_d >$ Slope 2 x $(I_R - I_{R.S2}) +$ Slope 1 x $(I_{R.S2} - I_{d.LS} / 2) + I_{d.Ls}$

High-set differential operation

The transformer differential function provides a setting “EnableHS” for unrestrained operation.

When the setting “EnableHS” is set to *On*, the start and trip decision is made regardless of the amount of measured restraining current if the measured differential current exceeds the high-set threshold $I_{d.HS}$.

When the setting “EnableHS” is set to *Off*, the high-set (unrestrained) differential operation is disabled.

Operate time delay

The transformer differential function provides a setting for time delayed trip, to allow time grading of overlapping differential protection zones. The default setting is instantaneous, meaning with no intentional time delay. In that case, start and trip signals are issued at the same time.

Supplementary features

Inrush detection

Any sudden change of magnetizing voltage will cause a magnetizing inrush. This most commonly occurs when energizing a transformer (initial inrush), but it occurs also upon voltage recovery after primary system failure (recovery inrush) or voltage drop when energizing a parallel transformer (sympathetic inrush).

This magnetizing inrush current usually flows into one transformer winding only and is not represented at the other transformer end, hence is seen as differential current from the protection. Therefore, inrush current detection and prevention from false tripping is an inherent part of the differential protection function.

Inrush condition is determined by evaluating the ratio of the 2nd harmonic to fundamental current component, based on the phase segregated differential currents. This signal analysis is executed only if the differential current is within reasonable limits:

- the fundamental of the differential current is higher than a fixed minimum current of 0.1 I_{ref}
- the differential current is smaller than a set threshold, set above the expected maximum inrush current

Further complementary conditions are checked prior to accepting an inrush condition:

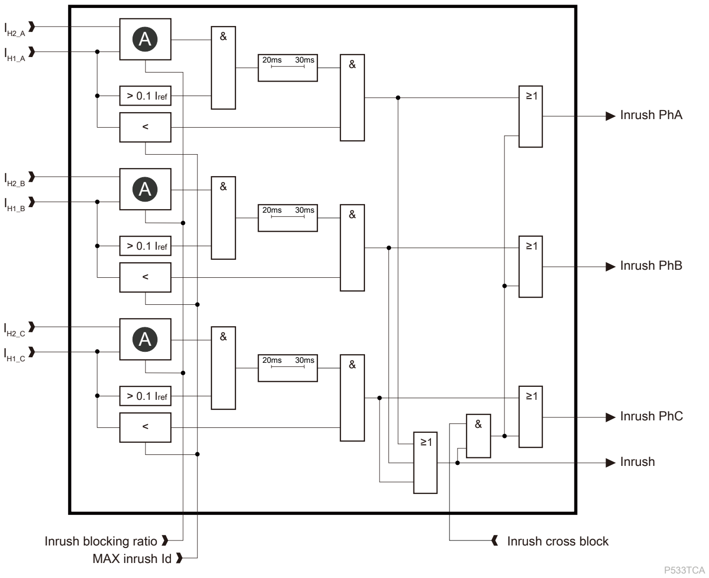
- the differential current waveform must show gaps with gap angle greater than 60 degrees (namely, periods of few milliseconds with no current flow, as they are present with real inrush currents)
- the inrush waveform has to be detected in at least 2 phases (there is no three-phase transformer energization condition, where only one phase shows an inrush waveform).

If inrush detection is enabled and an inrush condition is determined, then differential protection will be blocked.

The differential protection blocking is settable to be either phase-selective or cross-blocking.

NOTE: In the matrix, the differential inrush signals of matrix (T-Diff inrush, T-Diff inrush A, T-Diff inrush B, T-Diff inrush C) are not the interenal inrush blocking signals introduced in this section. The T-Diff inrush, T-Diff inrush A, T-Diff inrush B, T-Diff inrush C are identified by the value of H2/H1 in differential currents, the gap angle is not included in the matrix signals. It is proposed to set Operate delay = 40 ms if you want to block the transformer differential protection with the above 4 differential inrush signals of matrix. The logic of the differential inrush signals of matrix are defined as shown in the following diagram:

Figure 326 - Differential current H2 / H1 structure overview



A	H2 / H1 > pick-up H2

Overfluxing detection

If the transformer is energized with a voltage in excess of its nominal voltage, saturation effects occur which in turn cause higher magnetizing currents. Without stabilization, these could lead to differential protection tripping. The fact that the current of the protected object under saturation conditions has a high proportion of 5th harmonic serves as the basis of stabilization.

Overfluxing detection is provided as an option, based on the phase segregated differential currents. The ratio of the 5th harmonic to fundamental component of the differential current is evaluated, while the fundamental current is within a range of 0.1…4.0 I_{ref}. If this ratio is bigger than the set threshold, overflux blocking gets activated and blocks the differential protection function. As per setting, this is either phase selective or cross-blocking.

The structure overview is much similar to the figure above.

CT saturation detection

During external faults CTs may saturate, either because of very high fault currents, or because of slowly decaying DC offset of primary current. Appropriate measures are implemented to detect such conditions to prevent false differential tripping. Yet vice versa, a fast reset of this blocking feature is also provided for fast differential protection tripping in case of consecutive faults inside the protection zone.

CT supervision (CTS 1, CTS 2, differential CTS)

Generally, current transformer supervision is used to detect failure of the phase current inputs to protection relay of one or more phases. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the AC current circuits risks dangerous CT secondary voltages being generated.

Differential CTS will operate if the following 4 conditions present simultaneously:

- At least one of the three phases presents an undercurrent condition Ix < 0.1 Inom (x = A, B, C).
- the ratio of negative to positive sequence current I_2/I_1 on one end exceeds a high set threshold (I_2/I_1 high)
- the ratio I_2/I_1 on the other end remains below a low set threshold (I_2/I_1 low)
- the positive sequence currents I_1 on both ends exceed a set threshold I_1>

When CTS operates, it will raise its fast CTS alarm output instantaneously, while a latched CTS alarm output is issued after a set delay has expired.

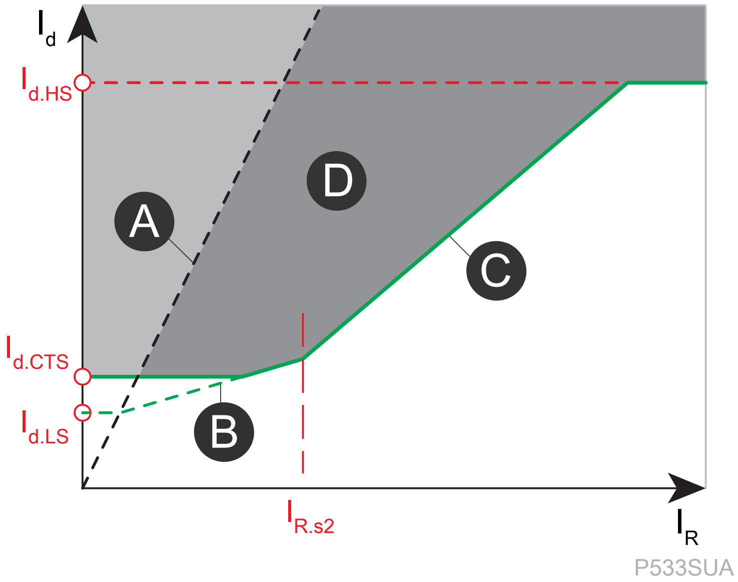
As a mutual constraint, differential CTS gets blocked and its output reset if (and as long as) any inrush or overflux blocking signal is present.

Differential CTS is provided with three modes of interaction with differential protection function:

- **Indication only:** no impact of CTS alarm on differential protection operation.
- **Restraining:** the minimum differential protection pick-up value is “shifted” vertically to a set $I_{d.CTS}$ while CTS alarm is present, as shown below.
- **Blocking:** differential protection is blocked while CTS alarm is present.

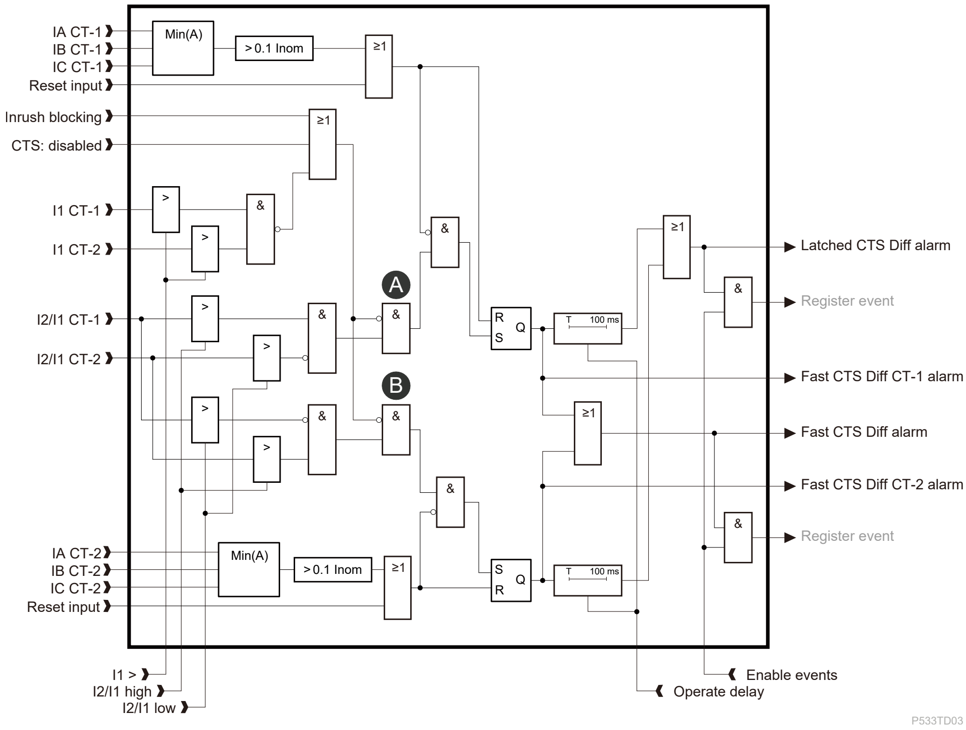
Refer to Current transformer supervision (ANSI 60), page 649 for detail of CTS 1 and CTS 2.

Figure 327 - Biased tripping characteristic with CTS restraint



A	Characteristic for single side fed fault = 200% slope	B	Slope 1
C	Slope 2	D	Trip area

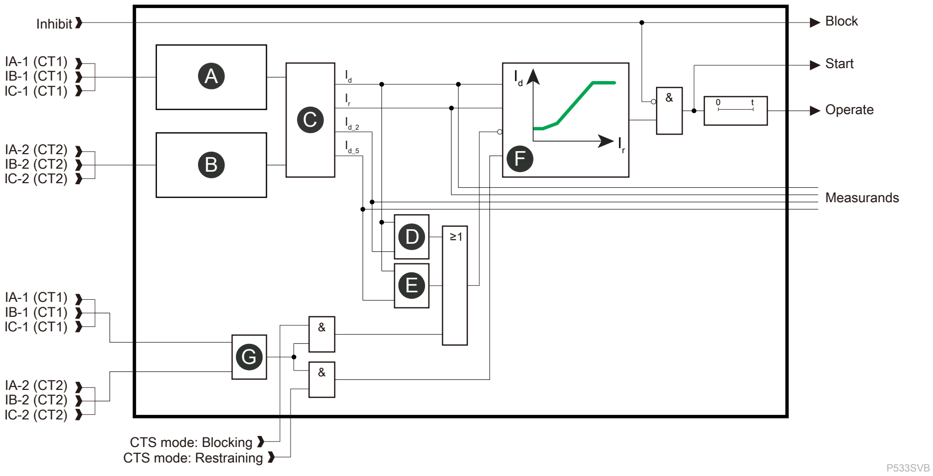
Figure 328 - CTS DIFF operate logic



A	CT-1	B	CT-2

Block diagram

Figure 329 - Transformer differential protection function structure overview



A End 1 (CT-1) current:
- Polarity adjustment
- Phase swapping
- Ratio correction
- Zero-sequence current filtering

B End 2 (CT-2) current:
- Polarity adjustment
- Phase swapping
- Ratio correction
- Vector group correction
- Zero-sequence current filtering

C	DIFF calculation	D	Inrush detection
E	Overfluxing detection	F	Biased characteristic
G	Differential CTS		

Characteristics

Table 117 - Settings and characteristics of transformer differential protection function (ANSI 87T)

Settings/characteristics (description/label)	Values
Reference power	
Setting range	0.1...1000.0 MVA
CT-1 end rated voltage	
Setting range	0.1...500.0 kV
CT-2 end rated voltage	
Setting range	0.1...500.0 kV
Phase CT-1 polarity	
Setting range	Standard/Opposite
Phase CT-2 polarity	
Setting range	Standard/Opposite
CT-1 Phase swap	
Setting range	No swap; A-B; B-C; C-A
CT-2 Phase swap	
Setting range	No swap; A-B; B-C; C-A
Enable for T-Diff	
Enable T-Diff	On/Off
Vector group	
Setting range	0…11
Zero-seq. current filtering CT-1, Zero-seq. current filtering CT-2	
Enable Zero-seq. current filtering CT-1 Enable Zero-seq. current filtering CT-2	On/Off
Low set I_d	
Setting range	0.10… 3.00 I_{ref}
Resolution	0.01 I_{ref}
Accuracy	±3% or ± 0.005 I_{ref}
Reset ratio	95% ± 2%
Slope 1	
Setting range	10%…150%
Resolution	1%
I_b for start of slope 2	
Setting range	1.00…30.00 I_{ref}
Resolution	0.01 I_{ref}
Slope 2	
Setting range	30%…150%
Resolution	1%
High set mode	
Enable High set mode	On/Off
High set I_d	
Setting range	1.00…30.00 I_{ref}

Table 117 - Settings and characteristics of transformer differential protection function (ANSI 87T) (Continued)

Settings/characteristics (description/label)	Values
Resolution	0.01 I_{ref}
Accuracy	±3% or ± 0.005 I_{ref}
Reset ratio	95% ± 2%
Bias calculation mode	
Setting range	Diff. of phasors; Sum of abs. val.
Operate delay	
Setting range	0.00…100.00 s
Resolution	0.01 s
Accuracy	±1% or ± 20 ms
Inrush blocking	
Enable Inrush blocking	On/Off
Inrush blocking ratio	
Setting range	5%…50%
Resolution	1%
Inrush cross block	
Enable Inrush cross block	On/Off
Max inrush current	
Setting range	2.50…30.00 I_{ref}
Resolution	0.01 I_{ref}
Overflux blocking	
Enable Overflux blocking	On/Off
Overflux blocking ratio	
Setting range	5%…100%
Resolution	1%
Overflux cross block	
Enable Overflux cross block	On/Off
CTS operating mode	
Setting range	Indication; Blocking; Restraining
CTS low set I_d	
Setting range	0.10…3.00 I_{ref}
Resolution	0.01 I_{ref}
Accuracy	±3% or ± 0.005 I_{ref}
Reset ratio	95% ± 2%
Characteristics	
Start time	< 50 ms (40 ms with high speed) for differential currents at 2 x Low set I_d < 35 ms (30 ms with high speed) for differential currents at 4 x Low set I_d
Disengaging time	< 50 ms
Setting group/SetGrp	
Number	4

Programmable stages (ANSI 99)

Description

For special applications dedicated protection and monitoring stages can be set up by selecting the signal to be supervised and the comparison mode. This is not to be confused with programmable IDMT curves. Programmable stages trigger an event from a selection of signals and select the type, level and timing to suit the application.

The following parameters are available:

Priority:

If operate times less than 80 ms are needed, select 10 ms. For operate times shorter than 1 s, 20 ms is recommended. For longer operation times and THD signals, 100 ms is recommended.

Input value A:

The selected supervised signal in compare conditions ">" and "<". The available signals are shown in Available signals to be supervised by the programmable stages, page 509

Input value B:

The selected supervised signal in "Diff" and "AbsDiff" mode. This selection becomes available once "Diff" or "AbsDiff" is chosen as compare condition. Available signals for selection depends on the selected input value A.

Timebase for input value A (B):

The timebase of the selected supervised signal can be set to "Instant", "200 ms", "1 min", or "demand". When the timebase "demand" is selected, the demand time window is set in the **Demand values** view of the **Measurements** menu.

Compare condition:

- > ('over...')

  Comparison of input A against exceeding the set pick-up value.
- < ('under...')

  Comparison of input A against dropping below the set pick-up value.
- Diff

  Calculated value of input A minus input B is compared against exceeding the set pick-up value, if the sign of the difference value is positive.
- AbsDiff

  Calculated absolute value of input A minus input B is compared against exceeding the set pick-up value.

Pick-up value :

Limit of the stage. The available setting range and the unit depend on the selected signal.

Operate delay:

Definite time operate delay.

Hysteresis:

Hysteresis (dead band) of the comparator function as percentage of the set threshold.

No Compare limit for mode < :

Only used in compare condition under (‘<’). This is the minimum limit to start the comparison. Signal values below this limit are disregarded. This feature prevents the programmable stage to operate on small values that could be caused by noise or signal interferences.

NOTE: The 'No Compare limit for mode <' value can only be set successfully when it is smaller than the start values in all 4 setting groups. An attempt to set it higher than the start value in any setting group is rejected, even if the setting group is not active.

Available signals

Table 118 - Available signals to be supervised by the programmable stages

Signals	Description
IA, IB, IC	Phase currents
IN	Neutral current
IN.sens	Sensitive neutral current
IN.CSH	Neutral current measured with CSH
VAB, VBC, VCA	Phase to phase voltages
VA, VB, VC	Phase to neutral voltages
VN.meas	Measured neutral voltage
VN.calc	Neutral voltage calculated from 3 phase voltages
f	Frequency
IN.calc	Neutral current calculated from 3 phase currents
I_1	Positive sequence current
I_2	Negative sequence current
I_2/I_1	Ratio of negative to positive sequence current
V_1	Positive sequence voltage
V_2	Negative sequence voltage
V_2/V_1	Ratio of negative to positive sequence voltage
VPN average	Average phase to neutral voltage
VPP average	Average phase to phase voltage
IA THD	Total harmonic distortion of current IA
IB THD	Total harmonic distortion of current IB
IC THD	Total harmonic distortion of current IC
VA THD	Total harmonic distortion of voltage VA
VB THD	Total harmonic distortion of voltage VB
VC THD	Total harmonic distortion of voltage VC
IA_{RMS}	RMS value of current IA
IB_{RMS}	RMS value of current IB
IC_{RMS}	RMS value of current IC
IN_{rms}	RMS value of neutral current IN.meas from standard CT input
$IN.sens_{rms}$	RMS value of neutral current IN.sens from sensitive CT input
$IN.CSH_{rms}$	RMS value of neutral current IN.CSH from core-balance CSH input

Eight independent stages

The PowerLogic P5 protection relay has eight independent programmable stages. Each programmable stage can be enabled or disabled according to the application.

Analogue inputs and outputs

Description

The analogue input/output signals of PowerLogic P5 can be used for exchanging measured values from/to transducers through the CLIO module.

They can be accommodated to a variety of transducer types and measurement ranges. The supported ranges on the device are:

- 0 to 1 mA
- 0 to 10 mA
- 0 to 20 mA
- 4 to 20 mA

NOTICE

RISK OF CONNECTED EXTERNAL DEVICE DAMAGE

- Disable the analog output channel before changing the DC range setting of the channel.
- Before enabling the analog output channel, check consistency of output range setting with input range of the connected external device.

Failure to follow these instructions can result in equipment damage.

Analogue DC current signals proportional to speed, pressure, vibration and so on could be fed into PowerLogic P5 to forward them through communication protocols to a control system, but also to monitor them against settable limits.

Output signals could be selected from PowerLogic P5 measurements, such as current, voltage, power, and so on with settable range limits for appropriate scaling.

The mA current input signals are converted into assigned physical signals with a linear relationship, as shown in Linear relationship between DC current and assigned physical signal, page 511. Description and unit of the analogue input signals are editable. Also, their minimum and maximum values can be set, which are equivalent to the minimum and maximum mA current of the selected range.

For example, entering a motor speed of 0-2000 rpm through 4-20 mA transducer requires following settings:

- Description = Motor speed
- Minimum = 0
- Maximum = 2000
- Unit = rpm
- DC range = 4-20 mA (AI.min = 4 mA, AI.max = 20 mA)

  NOTE: The range of AI.Min and AI.Max values is constrained between -10,000.0 and +10,000.0 to allow the converted value to be displayed on the mimic.

Analogue output signals are converted in opposite way. For example, providing measured active power within 0…100 kW to a 0-20 mA transducer requires following settings:

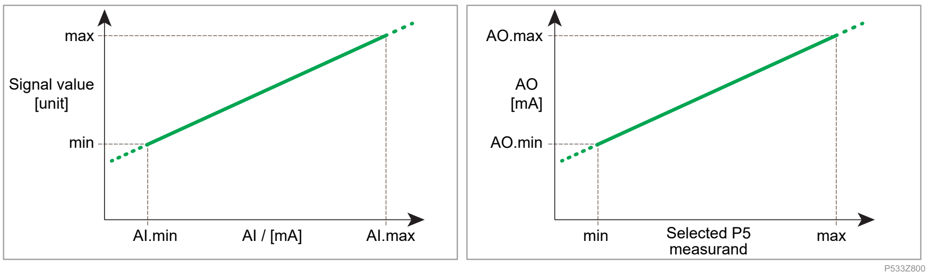
- Selection = P
- Minimum = 0
- Maximum = 100
- DC range = 0-20 mA (AO.Min = 0 mA, AO.Max = 20 mA)

For both, analogue input and output conversion, a negative slope could be set with a maximum value smaller than the minimum value. The only constraint is that the minimum and maximum must not be set to the same value. When changing the linear characteristic from a positive slope to a negative slope (for example, changing from Minimum = 0, Maximum = 100 to Minimum = 100, Maximum = 0), the writing process may be unsuccessful. This occurs because the new minimum value will be considered equal to the existing maximum value setting, and vice versa. Solution is to

1. Change the new minimum and maximum values to something different from the existing values.
2. Write the new values to the system.
3. Change the minimum and maximum values to the desired values.
4. Write the desired values to the system again.

   NOTE: It is recommended to disable the analog output channel before changing its output range from a higher to a smaller range (for example from 4-20 mA to 0-1 mA) to avoid temporarily too high current output to the transducer.

Figure 330 - Linear relationship between DC current and assigned physical signal



The analogue input signals are monitored. So-called 'Warning' and 'Alarm' stages allow indication and operation upon abnormal input signal levels, where commonly a warning is just used for indication of a signal slightly out of normal range, while an alarm is seen as a more severe violation and may even force automatic control (like switching off a motor in case of too low speed). The 2 stages can be configured independently, which means an 'Alarm' can be raised without a 'Warning' before. The threshold settings are made in percentage of the signal range, therefore independent from the selected current range. Each stage:

- Can be enabled or disabled individually.
- Has a settable operate direction:
  - 'Under' means to raise a warning or alarm when the input value falls below the set threshold.
  - 'Over' means to raise a warning or alarm when the input current rises above the set threshold.
- Has its own time delay setting.

Complementary monitoring of the input current is provided. All inputs are monitored against negative currents (value below -0.5 mA) or currents greater than the maximum value of the selected DC range, with a tolerance of 0.5 mA. For example, when using the 0-10 mA range, the Monitor alarm is raised for currents below -0.5 mA or above 10.5 mA. When using the 4-20 mA range, a further user-defined undercurrent monitoring stage can be enabled with a pick-up value within 0.5 and 3.5 mA.

The output signals of these monitoring stages are available as input signals in the programmable logic and all matrices. The only exception is the General signals matrix, which has just AI Alarm signals as input.

Characteristics

Table 119 - Settings and characteristics of analogue inputs and outputs

Settings/characteristics (description/label)	Values
Analogue inputs AIn(m) (module n=1…3, input m=1…4) related features	
DC range	0-1 mA, 0-10 mA, 0-20 mA, 4-20 mA
Minimum	-10 000.0…10 000.0
Maximum	-10 000.0…10 000.0
Monitor set	0.5…3.5 mA
Warning pick-up	0…100%
Warning delay	0.0…1 000.0 s
Warning direction	Over/Under
Alarm pick-up	0…100%
Alarm delay	0.0…1 000.0 s
Alarm direction	Over/Under
Analogue outputs AOn(m) (module n=1…3, output m=1…4) related features	
DC range	0-1 mA, 0-10 mA, 0-20 mA, 4-20 mA
Selection	Acc. to list (currents, voltages, power, and so on.)
Minimum	-500 000.00…500 000.00
Maximum	-500 000.00…500 000.00
Accuracy	±5% or ±0.1 mA
Updating cycle	100 ms

Measurement functions

Primary, secondary and per unit scaling

All measurement values are shown as primary values although the PowerLogic P5 protection relay is connected with its analogue voltage and current inputs to secondary signals. Some measurement values are shown as relative values in per unit or percent. Almost all pick-up setting values are using relative scaling.

The scaling is done using the rated values of VTs and CTs, or LPVTs and LPCTs depending on the selected model order option.

Scaling settings

The scaling settings define the characteristics of measurement transformers connected to the PowerLogic P5 protection relay and determine the correct adaptation and performance of the metering and protection functions.

They are accessed through:

- eSetup Easergy Pro or web HMI **Scaling** view in **General** menu
- on local panel in the **CT- VT** view of the **General** menu

The scaling parameters are listed in List of scaling parameters, page 513.

Table 120 - List of scaling parameters

Scaling parameters	Description	Selection[130]	Value
Iprim.nom	Rated primary phase current of CT	CT	10 A to 20 kA
	Nominal current	LPCT	K x I_{pr} (automatically calculated)
Isec.nom	Rated secondary phase current of CT	CT	1 A or 5 A
Ipr	LPCT rated current corresponding to 22.5 mV at the secondary	LPCT	10 A to 5 kA
Phase CT polarity	Orientation of phase CT connection	CT, LPCT	Standard/Opposite
IN CT polarity	Orientation of standard neutral CT connection	Standard neutral current CT	Standard/Opposite
IN.sens CT polarity	Orientation of sensitive neutral CT connection	Sensitive neutral current CT	Standard/Opposite
CSH CT polarity	Orientation of CSH connection	CSH core balance CT	Standard/Opposite
K	Current factor	LPCT	0.25 - 0.50 - 1.00 - 1.25 - 1.33 - 2.00 - 2.50 - 3.20 - 4.00 - 5.00 - 6.30 - 6.66 - 10 - 16 - 20 - 25 - 31.5
Number of connected phase CT	Number of CT	CT	IA/IB/IC, or IA/IC
IN.prim.nom	Rated primary neutral current of CT	Calculated	10 A to 20 kA (see $I_{prim.nom}$)
		CSH core balance CT according to the input selected	2 A or 20 A
		Standard or sensitive neutral current CT	1 A to 20 kA
IN.sec.nom	Rated secondary neutral current of CT	Calculated	1 A or 5 A (see $I_{sec.nom}$)
		CSH core balance CT	-

---

[130] Depending on the model number option.

Table 120 - List of scaling parameters (Continued)

Scaling parameters	Description	Selection[131]	Value
		Standard neutral current CT	1 A, 2 A, 5A
IN.sens.prim.nom	Rated primary neutral current of CT	Sensitive neutral current CT primary	1 A to 20 kA
IN.sens.sec.nom	Rated secondary neutral current of CT	Sensitive neutral current CT secondary	1 A fixed
VT type[131]	VT type		LPVT (fixed)
Vprim.nom	Rated primary voltage of transformer	VT	100 V to 500 kV
	Nominal voltage	LPVT	75 V to 500 kV
Vsec.nom	Rated secondary voltage of transformer	VT	25 V to 250 V
Vpr	LPVT rated voltage corresponding to 3,25/√3 mV at the secondary	LPVT	50 to 500,000 V
K	Voltage factor	LPVT	0.25 to 1.5
VAMagCor[132]	VA magnitude correction	LPVT	0.9000 to 1.1000
VAAngCor[132]	VA Angle correction	LPVT	-5.0000 to 5.0000
VBMagCor[132]	VB magnitude correction	LPVT	0.9000 to 1.1000
VBAngCor[132]	VB Angle correction	LPVT	-5.0000 to 5.0000
VCMagCor[132]	VC magnitude correction	LPVT	0.9000 to 1.1000
VCAngCor[132]	VC Angle correction	LPVT	-5.0000 to 5.0000
VAyMagCor[132]	VAy magnitude correction	LPVT	0.9000 to 1.1000
VAyAngCor[132]	VAy Angle correction	LPVT	-5.0000 to 5.0000
VByMagCor[132]	VBy magnitude correction	LPVT	0.9000 to 1.1000
VByAngCor[132]	VBy Angle correction	LPVT	-5.0000 to 5.0000
VN.prim.nom	Rated primary neutral voltage of transformer	VT	Same setting as the rated primary voltage of transformer
		LPVT	Same setting as the rated primary voltage of transformer
VN.sec.nom	Rated secondary neutral voltage of transformer	VT	25 V to 240 V
Phase rotation	Phase sequence selection		A - B - C or A - C - B
Voltage measurement mode	Usage of voltage inputs for phase voltage, neutral voltage or other additional voltage	VT	3VP, 3VP+VN, 3VP/VPy, 3VP/VPPy, 2VPP +VN+VPPy, 2VPP + VN, VPP/VPPy
		LPVT	3VP, 3VP+VN, 3VP/VPy, 3VP/VPPy
fn	Nominal frequency of power system		50 Hz or 60 Hz
Power direction	Direction of the power flow		Outgoing or Incoming

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[131] Depending on the model number option.

[131] Only available for LPVT board

[132] When LPVT is installed in the system, a magnitude correction factor and an angle correction factor will be used to compensate the accuracy. If the LPVT is a resistor divided type, it is recommended to set magnitude to 1 and angle correction factors to 0, but if it is a capacitor divided type, then these correction factor settings should be configured according to the nameplate of the LPVT sensor.

Current values

Primary and secondary values

Table 121 - Primary and secondary scaling

	Current (CT) Neutral current calculated	Neutral current (CT)	Current (LPCT) Neutral current calculated (LPCT)
Secondary -> Primary	$I_{prim}=I_{sec} \cdot \frac{I_{prim.nom}}{I_{sec.nom}}$	$IN_{.prim} = IN_{.sec} \cdot \frac{IN_{.prim.nom}}{IN_{.sec.nom}}$	$I_{prim}= \frac{V_{sec}}{k \cdot 22.5\ mV} \cdot I_{pr}$
Primary -> Secondary	$I_{sec} = I_{prim} \cdot \frac{I_{sec.nom}}{I_{prim.nom}}$	$IN_{.sec} = IN_{.prim} \cdot \frac{IN_{.sec.nom}}{IN_{.prim.nom}}$	$V_{sec} = \frac{I_{prim}}{I_{pr}} \cdot k \cdot 22.5\ mV$

For neutral current measured by CSH core balance CTs, only primary values are considered. CTprim is equal at 2A or 20A according to the connection on the protection relay.

Examples

1. **Secondary to primary (CT)**

   CT = 500 A / 5 A

   If the current on PowerLogic P5 input is 4 A, then the corresponding primary current is Iprim = 4 x 500 / 5 = 400 A.

2. **Secondary to primary (LPCT)**

   LPCT = 100 A / 22.5 mV

   If the voltage on the LPCT input is 30 mV, then the corresponding primary current is Iprim = 30 / 22.5 x 100 = 136 A, whatever is K.

   With K = 0.25, V_{sec} corresponds to 136 / (100 x 0.25) = 5.44 I_{nom}.

3. **Primary to secondary (CT)**

   CT = 500 A / 5 A

   If PowerLogic P5 displays Iprim = 100 A, then the injected current is

   I_{sec} = 100 x 5 / 500 = 1 A.

4. **Primary to secondary (LPCT)**

   LPCT = 100 A / 22.5 mV

   If PowerLogic P5 displays Iprim = 640 A, then the injected current is

   V_{sec} = 640 / 100 x 22.5 = 144 mV, whatever is K.

   With K = 3.2, V_{sec} corresponds to 640 / (100 x 3.2) = 2 I_{nom}.

Per unit [pu] values

Table 122 - Per unit [pu] scaling

	Phase current (CT) scaling	Phase current (LPCT) scaling	Neutral current scaling	Neutral current (CSH) scaling
Physical -> Per unit	$I_{pu} = \frac{I_{sec}}{I_{sec.nom}}$	$I_{pu} = V_{sec} / (k \cdot 22.5)$	$I_{pu} = \frac{I_{sec}}{I_{sec.nom}}$	-
	$I_{pu} = \frac{I_{prim}}{I_{prim.nom}}$	$I_{pu} = \frac{I_{prim}}{I_{pr} \cdot k}$	$I_{pu} = \frac{I_{prim}}{I_{prim.nom}}$	$I_{pu} = \frac{I_{prim}}{I_{prim.nom}}$
Per unit -> physical	$I_{sec} = I_{pu} \cdot I_{sec.nom}$	$I_{sec} = I_{pu} \cdot k \cdot 22.5$	$I_{sec} = I_{pu} \cdot I_{sec.nom}$	-
	$I_{prim} = I_{pu} \cdot I_{prim.nom}$	$I_{prim} = I_{pu} \cdot k \cdot I_{pr}$	$I_{prim} = I_{pu} \cdot I_{prim.nom}$	$I_{prim} = I_{pu} \cdot I_{prim.nom}$

Examples

1. **Secondary to per unit for phase current (CT)**

   CT = 750 A / 5 A

   If the current injected is 7 A, then the per unit current is

   I_{pu} = 7 / 5 = 1.4 pu

2. **Per unit to secondary for phase current (CT)**

   CT = 750 A / 5 A

   If the protection setting is 2.0 pu, then the corresponding secondary current is I_{sec} = 2 x 5 = 10 A.

3. **Secondary to per unit for phase current (LPCT)**

   LPCT = 100 A / 22.5 mV with K = 3.2

   If the PowerLogic P5 protection relay displays Iprim = 640 A, then the injected voltage is

   V_{sec} corresponds to 640 / (100 x 3.2) = 2 I_{nom}.

4. **Primary to per unit for phase current (LPCT)**

   LPCT rated current = 100 A with LPCT Current factor k = 2 (45 mV at the secondary)

   If the primary current is 150 A (33.75 mV at the secondary), then the per unit current (voltage) is I_{pu} = 150/200 = 33.75/45 = 0.75 I_{nom}.

5. **Per unit to primary and secondary current (LPCT)**

   LPCT rated current = 100 A with LPCT Current factor = 10

   If protection setting is 1.5 I_{nom}, the corresponding secondary voltage is

   V_{sec} = 1.5 x 10 x 22.5 = 337.5 mV,

   and the corresponding primary current is

   Iprim = 1.5 x 100 x 10 = 1.5 kA.

6. **Secondary to per unit for neutral current (CT)**

   Ground fault CT = 750 A / 1 A

   If for standard and sensitive neutral inputs the current is 30 mA, then the per unit current is

   I_{pu} = 0.03 / 1 = 0.03.

7. **Per unit to secondary for neutral current (CT)**

   Ground fault CT = 50 A / 1 A

   If for standard and sensitive neutral inputs the protection setting is 0.1 pu, then the corresponding I_{sec} = 0.1 x 1 = 100 mA.

Calculation scenarios for CSH30

Scenario 1: The second value of standard ground fault CT is 1 A and fixed to 2 A CSH channel and 2 turns in CSH CT primary.

Parameters: IN.prim = 1000 A, IN.sec = 1 A, Turns = 2, IN.CSH.nom = 2 A, standard CT is connected to 2 A CSH channel

Table 123 - Calculation scenario 1

Earth fault current in primary (A)	Standard IN CT secondary value (A)	Standard IN CT secondary value (pu)	CSH CT primary value (A)	CSH CT primary value (pu)
500	0.5	0.5	0.5	0.25
1000	1.0	1.0	1.0	0.5
2000	2.0	2.0	2.0	1.0

Scenario 2: The second value of standard ground fault CT is 5 A and fixed to 20 A CSH channel and 4 turns in CSH CT primary.

Parameters: IN.prim = 1000 A, IN.sec = 5 A, Turns = 4, IN.CSH.nom = 20 A, standard CT is connected to 20 A CSH channel

Table 124 - Calculation scenario 2

Earth fault current in primary (A)	Standard IN CT secondary value (A)	Standard IN CT secondary value (pu)	CSH CT primary value (A)	CSH CT primary value (pu)
500	2.5	0.5	2.5	0.125
1000	5.0	1.0	5.0	0.25
2000	10.0	2.0	10.0	0.5

Voltage values

Rated phase and neutral voltage inputs

Voltage transformer scaling is always based on the phase to phase voltages in all voltage measurements modes.

The rated phase and neutral voltage inputs are defined as below:

Table 125 - Voltage rating (VT)

VT connection	VT ratio		Value for 1 pu or 100%				
	primary	secondary	PP	PN	V1	V2	VN
3VP	Vprim. nom/√3	Vsec.nom/ √3	Vprim. nom	Vprim. nom/√3	Vprim. nom/√3	Vprim. nom/√3	√3 x Vprim. nom
1VPP	Vprim. nom	Vsec.nom	Vprim. nom	-	-	-	-
2VPP	Vprim. nom	Vsec.nom	Vprim. nom	Vprim. nom/√3	Vprim. nom/√3	Vprim. nom/√3	-

Table 125 - Voltage rating (VT) (Continued)

VT connection	VT ratio		Value for 1 pu or 100%				
Broken delta	VN.prim.nom/√3	VN.sec.nom/√3	-	-	-	-	√3 x Vprim.nom
VPy	Vprim.nom/√3	Vprim.nom/√3	-	Vprim.nom/√3	-	-	-
VPPy	Vprim.nom	Vprim.nom	Vprim.nom	-	-	-	-

NOTE: V1 and V2 are respectively the positive and the negative sequence voltages. VN is the neutral voltage (zero-sequence voltage x3).

Table 126 - Voltage rating (LPVT)

Connection	LPVT primary	LPVT secondary	LPVT nominal voltage	Value for 1 pu or 100%				
				PP	PN	V1	V2	VN
3VP	Vprim.nom/√3	3.25V/√3	Vprim.nom/√3	Vprim.nom	Vprim.nom/√3	Vprim.nom/√3	Vprim.nom/√3	Vprim.nom/√3
Broken delta[133]	VN.prim.nom/√3	VN.sec.nom/√3	-	-	-	-	-	√3 x Vprim.nom
VPPy	Vprim.nom.y	3.25V/√3	Vprim.nom.y/√3	Vprim.nom.y	-	-	-	-

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[133] possible only with VT + LPVT adapter

Primary and secondary scaling of phase to phase voltages

Table 127 - Primary and secondary scaling of phase to phase voltages

	Phase to phase voltage measurement (PP) with VT	Phase to neutral measurement (PN) with VT	Phase to neutral voltage measurement with LPVT
Secondary –> Primary	$V_{prim} = V_{sec} \cdot \frac{V_{prim.nom}}{V_{sec.nom}}$	$V_{prim} = \sqrt{3} \cdot V_{sec} \cdot \frac{V_{prim.nom}}{V_{sec.nom}}$	$V_{prim} = 3.25 \frac{V_{prim.nom}}{V_{sec.nom}}$
Primary –> Secondary	$V_{sec} = V_{prim} \cdot \frac{V_{sec.nom}}{V_{prim.nom}}$	$V_{sec} = \frac{V_{prim}}{\sqrt{3}} \cdot \frac{V_{sec.nom}}{V_{prim.nom}}$	$V_{sec} = \frac{V_{prim}}{V_{prim.nom}} \cdot \frac{3.25}{\sqrt{3}}$

Examples

1. **Secondary to primary**

   Phase to phase voltage measurement mode (VT)

   VT = 12000 V / 110 V

   If voltage connected to the PowerLogic P5 input V_A, V_B or V_C = 100 V, then primary voltage is Vprim = 100 x 12000 / 110 = 10909 V.

   Phase to neutral voltage measurement mode (VT)

   VT = 12000 V / 110 V

   If the three phase symmetric voltage magnitude is 60 V, then the primary voltage is Vprim = √3 x 60 x 12000 / 110 = 11336 V.

2. **Primary to secondary**

   Phase to phase voltage measurement mode (VT)

   VT = 12000 V / 110 V

   If the PowerLogic P5 protection relay displays Vprim = 10910 V, then the secondary voltage is Vsec = 10910 x 110 / 12000 = 100 V.

   Phase to neutral voltage measurement mode (VT)

   VT = 12000 V / 110 V

   If the PowerLogic P5 protection relay displays VAB = VBC = VCA = 10910 V for a symmetric voltage system, then the secondary voltages at V_A, V_B and V_C are

   Vsec = 10910 / √3 x 110 / 12000 = 57.7 V.

3. **Phase to neutral voltage measurement mode (LPVT)**

   LPVT = 20 kV / 3.25 V with k = 0.5

   If the PowerLogic P5 protection relay displays VAB = VBC = VCA = 11 kV for a symmetric voltage system, then the secondary voltages V_A, V_B, and V_C are

   Vsec = 11000 / 20000 x 3.25 / √3 = 1.032 V.

Per unit [pu] scaling of phase to phase voltages

One per unit = 1 pu = 1 x Vnom = 100%, where Vnom = rated voltage of the VT.

Table 128 - Per unit [pu] scaling of phase to phase voltages

	Phase to phase voltage measurement (PP) with VT	Phase to neutral voltage measurement (PN) with VT	Phase to neutral voltage measurement with LPVT
Physical –> per unit	$V_{pu} = \frac{V_{sec}}{V_{sec.nom}} = \frac{V_{prim}}{V_{prim.nom}}$	$V_{pu} = \sqrt{3} \cdot \frac{V_{sec}}{V_{sec.nom}} = \sqrt{3} \cdot \frac{V_{prim}}{V_{prim.nom}}$	$V_{pu} = \frac{V_{prim}}{k \cdot V_{pr}}$
			$V_{pu} = \frac{V_{sec}}{k \cdot 3.25} \cdot \sqrt{3}$
Per unit –> physical	$V_{sec} = V_{pu} \cdot V_{sec.nom}$	$V_{sec} = V_{pu} \cdot \frac{V_{sec.nom}}{\sqrt{3}}$	$V_{sec} = \frac{V_{pu} \cdot k \cdot 3.25}{\sqrt{3}}$
	$V_{prim} = V_{pu} \cdot V_{prim.nom}$	$V_{prim} = V_{pu} \cdot \frac{V_{prim.nom}}{\sqrt{3}}$	$V_{prim} = V_{pu} \cdot k \cdot V_{pr}$

Examples

1. **Secondary to per unit**

   Phase to phase voltage measurement mode

   VT = 12000 V / 110 V

   If the voltage input of V_A or V_B is 100 V, then the per unit voltage is

   Vpu = 100 / 110 = 0.91 pu.

   Phase to neutral voltage measurement mode

   VT = 12000 V / 110 V

   If the three symmetric phase to neutral injected to the voltage inputs are 63.5 V, then the per unit voltage is pu = √3 x 63.5 / 110 = 1.00 pu.

2. **Per unit to secondary**

   Phase to phase voltage measurement mode

   VT = 12000 V /110 V

   If the PowerLogic P5 protection relay displays 1.00 pu, then the secondary voltage is Vsec = 1.00 x 110 = 110 V.

   Phase to neutral voltage measurement mode

   VT = 12000 V / 110 V

   If the PowerLogic P5 protection relay displays 0.8 pu, then the three symmetric phase to neutral voltages injected to the inputs are

   Vsec = 0.8 x 110 / √3 = 50.8 V.

3. **Per unit to secondary for voltage measurement with LPVT**

   LPVT = 20 kV / 3.25 V with k = 0.8

   If the phase to neutral voltage displayed is 0.5 x Vnom, the secondary value injected to the PowerLogic P5 protection relay is 0.5 x 0.8 x 3.25 / √3 = 0.75 V.

Per unit [pu] scaling of neutral voltage

Table 129 - Per unit [pu] scaling of neutral voltage

	Neutral voltage measured	Neutral voltage calculated with VT	Neutral voltage calculated with LPVT
Physical -> per unit	$VN_{pu} = \frac{VN_{sec} \cdot VN_{prim.nom}}{\sqrt{3} \cdot VN_{sec.nom} \cdot V_{prim.nom}}$	$VN_{pu} = \frac{\left\lvert \overline{V}_A + \overline{V}_B + \overline{V}_C \right\rvert_{sec}}{\sqrt{3} \cdot V_{sec.nom}}$	$VN_{pu} = \frac{\left\lvert \overline{V}_A + \overline{V}_B + \overline{V}_C \right\rvert_{sec}}{k \cdot 3.25}$
	$VN_{pu} = \frac{VN_{prim}}{\sqrt{3} \cdot V_{prim.nom}}$	$VN_{pu} = \frac{\left\lvert \overline{V}_A + \overline{V}_B + \overline{V}_C \right\rvert_{prim}}{\sqrt{3} \cdot V_{prim.nom}}$	$VN_{pu} = \frac{\left\lvert V_A + V_B + V_C \right\rvert_{prim}}{k \cdot V_{prim}}$
Per unit -> physical	$VN_{sec} = \frac{VN_{pu} \cdot VN_{sec.nom}}{\sqrt{3} \cdot VN_{prim.nom} \cdot V_{prim.nom}}$	$\left\lvert \bar{V}_A + \bar{V}_B + \bar{V}_C \right\rvert_{sec} = VN_{pu} \cdot \sqrt{3} \cdot V_{sec.nom}$	$\left\lvert \bar{V}_A + \bar{V}_B + \bar{V}_C \right\rvert_{sec} = VN_{pu} \cdot \sqrt{3} \cdot k \cdot 3.25\, V$
	$VN_{prim} = \sqrt{3} \cdot VN_{pu} \cdot V_{prim.nom}$	$\left\lvert \bar{V}_A + \bar{V}_B + \bar{V}_C \right\rvert_{prim} = VN_{pu} \cdot \sqrt{3} \cdot V_{prim.nom}$	$\left\lvert V_A + V_B + V_C \right\rvert_{prim} = VN_{pu} \cdot \sqrt{3} \cdot V_{prim.nom}$

Examples

1. **Secondary to per unit**

   Neutral voltage measured (VT)

   VN.sec.nom = 110 V (configuration value corresponding to VN measured when starpoint fully displaced); VN.prim.nom = Vnom / √3 = 20 kV / √3.

   If the voltage fed into the relay's voltage input V4 is 44 V, then the per unit neutral voltage value is Vpu = (44 / 110) x (20 kV / √3) = 0.40 / 3 = 0.13 pu = 13.3%.

   Neutral voltage calculated (VT)

   VT ratio = 20 kV / 110 V

   If the voltage fed into the relay's voltage input V1 is 38.1 V, while V2 = V3 = 0, then the per unit neutral voltage value is

   Vpu = (38.1 + 0 + 0) / (√3 x 110) = 0.20 pu = 20%.

   Neutral voltage calculated (LPVT)

   LPVT ratio = 20 kV / (k x 3.25 V) with k = 1.5

   If the voltage fed into the relay's voltage LPVT input V1 is 2 V, while V2 = V3 = 0, then the per unit neutral voltage value is Vpu = (2 + 0 + 0) / (k x 3.25 x √3) = 0.24 pu = 24%.

2. **Per unit to secondary**

   Neutral voltage measured (VT)

   VN.sec.nom = Vsec.nom = 110 V (configuration value corresponding to VN measured when starpoint fully displaced); VN.prim.nom = Vnom / √3 = 20 kV / √3.

   If the relay measures VN.pu = 0.20 pu, then the secondary voltage at voltage input V4 is VN.sec = 0.20 x (110 V / (20 kV / √3)) x (√3 x 20 kV) = 22 x 3 = 66 V.

   Neutral voltage calculated (VT)

   VT ratio = 20 kV /110 V

   If the relay measures VN.pu = 0.20 pu and if voltage at inputs V2 = V3 = 0, then the secondary voltage at V1 is Vsec = 0.2 x √3 x 110 V = 38.1 V.

   Neutral voltage calculated (LPVT)

   LPVT ratio = 20 kV / (k x 3.25 V) with k = 1.5

   If the relay measures VN.pu = 0.30 pu and if voltage at LPVTs V1 = V3 = 0, then the secondary voltage at V2 is Vsec = 0.3 x 1.5 x 3.25 / √3 = 0.84 V.

Reading of measurements

All measurement values can be read out via:

- Local panel: Measurements menu (⏲) and on the Mimic screen if they were configured with eSetup Easergy Pro
- eSetup Easergy Pro: **Measurements** menu
- Communication interface (if the used protocol provide this)
- EcoStruxure Power Device application

The refresh interval, on automatic cyclic updates, is less than 1 second typically.

Phase currents

PowerLogic P5 measures the fundamental and RMS values of phase current inputs using 1A CTs, 5A CTs, or LPCTs:

Table 130 - Measurements of fundamental and RMS values of phase current

Value	Description
Fundamental value	
IA	Fundamental value of phase 1 current IA
IB	Fundamental value of phase 2 current IB
IC	Fundamental value of phase 3 current IC
RMS value	
IA_{rms}	RMS value of phase 1 current IA
IB_{rms}	RMS value of phase 2 current IB
IC_{rms}	RMS value of phase 3 current IC

The RMS current measurement takes into account harmonics up to the 15th. The calculation is done as follows:

$$I_{RMS} = \sqrt{I_{f1}^2 + I_{f2}^2 + \ldots + I_{f15}^2}$$

P533Z100

Table 131 - Characteristics for measuring phase current

Signal	Measurement range	Unit	Resolution	Accuracy
Magnitude				
CT	0.005...60.000 Inom	A	1 A	±1% for range 1.2...1.5 Inom ±0.5% for range 0.8...1.2 Inom ±1% for range 0.3...0.8 Inom ±2% for range 0.1...0.3 Inom
LPCT	0.05...45.00 Inom	A	1 A	±1% for range 1.2...1.5 Inom ±0.5% for range 0.8...1.2 Inom ±1% for range 0.3...0.8 Inom ±2% for range 0.1...0.3 Inom
Phase angle[134]				
	-180°...+180°		0.1°	0.5° with I > 0.1Inom[135]

Neutral current

The neutral current is calculated by the vector sum of the 3 phase currents or directly measured with a conventional CT or CSH core balance CT. Where the neutral current is directly measured, the PowerLogic P5 protection relay uses either the connected standard neutral input (IN) or alternatively the sensitive neutral input (IN.sens).

Table 132 - Characteristics for measuring neutral current

Signal	Measurement range	Unit	Resolution	Accuracy
IN.calc (IN calculated from 3 phase currents)	0.005...60.000 Inom	A	0.01 A	±3% for range 1.2...1.5 Inom ±1.5% for range 0.8...1.2 Inom ±3% for range 0.3...0.8 Inom ±6% for range 0.1...0.3 Inom
IN.meas (IN measured with standard CT)	0.005...30.000 IN.nom	A	0.01 A	±0.5% for IN > 0.05 IN.nom ±1% for range 0.02...0.05 IN.nom ±2% for IN < 0.02 IN.nom
IN.meas (CSH30) (IN measured with standard neutral CT and CSH30 interposing ring CT)	0.010...30.000 IN.nom	A	0.01 A	±2% or 0.001 IN.nom
IN.sens (IN measured with sensitive neutral CT)	0.002...4.000 IN.sens.nom	A	0.001 A	±2% for IN < 0.002 IN.sens.nom ±1% for IN > 0.002 IN.sens.nom
IN.CSH (IN measured with CSH core-balance CT)	0.005...42.000 IN.CSH.nom	A	0.01 A	±2% or 0.001 IN.nom

Positive and negative sequence currents

The positive and negative sequence currents are calculated as the vector sum of the 3 phase currents, subject to phase rotating constant.

For standard phase rotation (A – B – C) they are:

$$\vec{I}_1 = \frac{1}{3}\left(\vec{I}_A + a\,\vec{I}_B + a^2\vec{I}_C\right)$$

A533BGA

$$\vec{I}_2 = \frac{1}{3}\left(\vec{I}_A + a^2\vec{I}_B + a\,\vec{I}_C\right)$$

A533BHA

with phasor rotating constant:

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[134] Phase angle can only be detected when current is over 100 mA.

[135] Nominal CT Rating

$$a = e^{j\frac{2\pi}{3}}$$

P533BEB

Table 133 - Characteristics for measuring positive and negative sequence currents

Signal	Measurement range	Unit	Resolution	Accuracy
I1	0.01...60.00 Inom	A	1 A	±3% for range 1.2...1.5 Inom ±1.5% for range 0.8...1.2 Inom ±3% for range 0.3...0.8 Inom ±6% for range 0.1...0.3 Inom
I2	0.01...60.00 Inom	A	1 A	±3% for range 1.2...1.5 Inom ±1.5% for range 0.8...1.2 Inom ±3% for range 0.3...0.8 Inom ±6% for range 0.1...0.3 Inom

Frequency

PowerLogic P5 protection relay determines the frequency based on the samples of an available voltage or current signal. The frequency determination will be automatically adapted to the availability and quality of the related signal inputs:

- Based on positive sequence voltage V1 or
- Based on any single phase to phase voltage or phase to neutral voltage or
- Based on currents when the voltage is not measured or below 15%Vnom.

The frequency is not measured if:

- The maximum of three phase to phase or phase to neutral voltages or positive sequence voltage V1 is less than 15% Vnom
- The maximum of three currents or positive sequence current (I1) is less than 10%Inom.

The following table provides an overview of the characteristics for frequency measurement:

Table 134 - Characteristics for frequency measurement

Characteristics	Range
Measurement range	10...72 Hz
Units	Hz
Resolution	0.001 Hz
Accuracy	± 0.01 Hz

Voltages

The PowerLogic P5 measures the fundamental and RMS values of phase to phase voltages and phase to neutral voltages.

Table 135 - Measurements of phase to phase and phase to neutral voltages

Value	Description
VA	Fundamental value of the phase to neutral voltage on phase A
VB	Fundamental value of the phase to neutral voltage on phase B
VC	Fundamental value of the phase to neutral voltage on phase C
VAB	Fundamental value of the phase to phase voltage between phase A and phase B
VBC	Fundamental value of the phase to phase voltage between phase B and phase C
VCA	Fundamental value of the phase to phase voltage between phase C and phase A
VA_{rms}	RMS value of the phase to neutral voltage on phase A
VB_{rms}	RMS value of the phase to neutral voltage on phase B
VC_{rms}	RMS value of the phase to neutral voltage on phase C
VAB_{rms}	RMS value of the phase to phase voltage between phase A and phase B
VBC_{rms}	RMS value of the phase to phase voltage between phase B and phase C
VCA_{rms}	RMS value of the phase to phase voltage between phase C and phase A

These voltages are measured with the three analogue voltage inputs VA, VB and VC.

A 4th analogue voltage input V_4 is used to measure an additional phase to phase voltage or phase to neutral voltage, which is usually used as a reference voltage for the synchronization checking function.

V_y : fundamental value of the additional phase to phase voltage

V_{yrms} : RMS value of the additional phase to phase voltage calculated as follows:

$$V_{RMS} = \sqrt{V_{f1}^2 + V_{f2}^2 + \ldots + V_{f15}^2}$$

P533Z200

For phase to phase (2VPP) connections, which can be applied for cost reasons in isolated or compensated power systems, the three phase to phase voltages are directly measured and the phase to neutral voltages are calculated taking into account the neutral voltage measurement (VN) when it is measured. Otherwise, the calculation considers a balanced power system.

For phase to neutral (3VP) connections, the three phase to neutral voltages are directly measured and the three phase to phase voltages are calculated.

Table 136 - The voltage modes and the corresponding measurements and calculated values

Voltage mode	Sensors	Voltages measured	Voltages calculated	Additional voltages
3VP	VT, LPVT	VA, VB, VC	VAB, VBC, VCA	
3VP+VN	VT	VA, VB, VC	VAB, VBC, VCA	
3VP/VPy	VT, LPVT	VA, VB, VC, VA_y[136]	VAB, VBC, VCA, VAB_y	VA'
3VP/VPPy	VT, LPVT	VA, VB, VC, VAB_y[136]	VAB, VBC, VCA	VAB'
2VPP+VN	VT	VAB, VBC	VCA, VA, VB, VC	

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[136] Used for synchro-check function.

Table 136 - The voltage modes and the corresponding measurements and calculated values (Continued)

Voltage mode	Sensors	Voltages measured	Voltages calculated	Additional voltages
2VPP+VN+VPPy	VT	VAB, VBC, VAB_y[137]	VA, VB, VC	VAB'
VPP/VPPy	VT	VAB, VAB_y[137]	VA, VB, VC, VBC, VCA[138]	VAB'

Depending on the phase rotation, the phase to phase values are defined according to A-B-C network: phase to neutral and phase to phase voltages, page 526 and A-C-B network: phase to neutral and phase to phase voltages, page 526:

- For voltage between phases A and B:

  $$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$$

  A533Z300

- For voltage between phases B and C:

  $$\vec{V}_{BC} = \vec{V}_B - \vec{V}_C$$

  A533Z400

- For voltage between phases C and A:

  $$\vec{V}_{CA} = \vec{V}_C - \vec{V}_A$$

  A533Z500

Figure 331 - A-B-C network: phase to neutral and phase to phase voltages

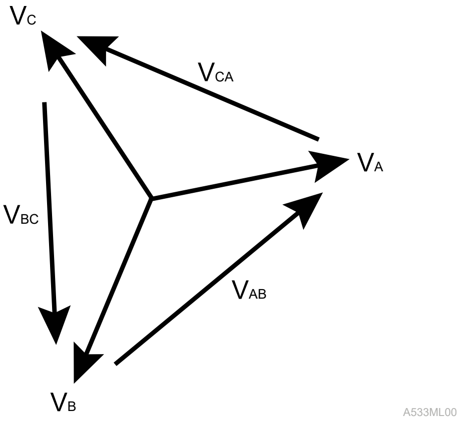
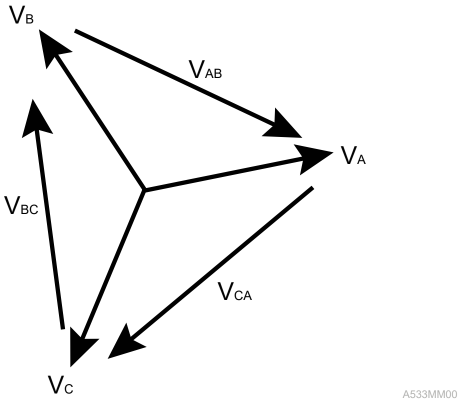


Figure 332 - A-C-B network: phase to neutral and phase to phase voltages



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[137] Used for synchro-check function.
[138] Considering a balanced power system.

Table 137 - Characteristics for measuring voltage

Characteristics	Measurement range	Accuracy	Unit	Resolution
Magnitude	Conventional VT: 0.01...1.50 Vnom[139]	±5% for range 1%...10% Vnom[139] ±2% for range 10%...20% Vnom[139] ±1% for range 20%...50% Vnom[139] ±0.5% at 50% Vnom[139] and above	V	1 V
	100 V adapter (EMS59572): 0...240 V secondary			
	400 V adapter (EMS59574): 0...400 V secondary	±5% for range 1%...10% Vnom[139] ±2% for range above 10% Vnom[139]		
Phase angle	-180°...+180°	0.5° with V > 0.1 Vnom[139] and I > 0.1 Inom	°	0.1°

Neutral voltage

The PowerLogic P5 protection relay measures the fundamental value of a neutral voltage VN by an open wye/delta voltage transformer. If such a VT is not available, the protection relay is able to calculate VN by taking the internal sum of the three phase to neutral voltages:

$$\vec{V}_N = \vec{V}_A + \vec{V}_B + \vec{V}_C$$

If the calculation method is used, the measurement can only be considered as valid if the power system is balanced.

The following table provides an overview of the measuring options:

Table 138 - Neutral voltage measuring options

Voltage mode	Sensors	Measured/Calculated
3VP	VT, LPVT	VN.calc calculated[140]
3VP+VN	VT	VN.meas measured
3VP/VPPy	VT, LPVT	VN.calc calculated[140]
3VP/VPy	VT, LPVT	VN.calc calculated
2VPP+VN	VT	VN.meas measured
2VPP+VN+VPPy	VT	VN.meas measured
VPP/VPPy	VT	VN not available

The following table lists the characteristics for measuring neutral voltage:

Table 139 - Characteristics for measuring neutral voltage

Measurement range	Accuracy	Unit	Resolution
Conventional VT: 0.01...1.50 Vnom[139]	±5% for range 1...10 V secondary ±2% for range 10...20 V secondary ±1% for range 20...50 V secondary ±0.5% for at 50 V secondary and above	V	1 V
100 V adapter (EMS59572): 0...240 V secondary			
400 V adapter (EMS59574): 0...400 V secondary	±5% for range 1...10 V secondary ±2% for range at 10 V secondary and above		

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[139] VT Primary nominal

[140] Considering a balanced power system

Positive and negative sequence voltages

The positive and negative sequence voltages are calculated as the vector sum of the 3 phase voltages, subject to phase rotating constant.

For standard phase rotation (A – B – C) they are:

$$\vec{V}_1 = \frac{1}{3}\left(\vec{V}_A + a\vec{V}_B + a^2\vec{V}_C\right)$$

A533AQ00

$$\vec{V}_2 = \frac{1}{3}\left(\vec{V}_A + a^2\vec{V}_B + a\vec{V}_C\right)$$

A533VR00

with phasor rotating constant:

$$a = e^{j\frac{2\pi}{3}}$$

P533BE00

Table 140 - Characteristics for measuring positive and negative sequence voltages

Signal	Measurement range	Unit	Resolution	Accuracy
V1	0.01...1.50 Vnom	V	1 V	±15% for range 1%...10% Vnom[141] ±6% for range 10%...20% Vnom[141] ±3% for range 20%...50% Vnom[141] ±1.5% at 50% Vnom[141] and above
V2	0.01...1.50 Vnom	V	1 V	±15% for range 1%...10% Vnom[141] ±6% for range 10%...20% Vnom[141] ±3% for range 20%...50% Vnom[141] ±1.5% at 50% Vnom[141] and above

Power and power factor

Active, reactive, apparent power

The PowerLogic P5 protection relay calculates the active, reactive and apparent power values of the power system based on the fundamental or RMS values of the primary three phase currents and voltages.

All power values are determined separately for each phase based on the fundamental or RMS values of related phase current and voltage signal depending on the availability.

Three phase power values can be calculated using phase to neutral voltages and phase currents as follows :

- Active power = 3·V·I·cosφ
- Reactive power = 3·V·I·sinφ
- Apparent power = 3·V·I

According to the transformers used, power calculations are based on the 2 or 3 wattmeter method.

The 2 wattmeter method is only accurate when there is no neutral current (i.e. balanced power system is), but it is not applicable if the neutral is distributed.

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[141] VT Primary nominal

The 3 wattmeter method gives an accurate calculation of 3-phase as well as per phase powers in all cases, regardless of whether or not the neutral is distributed.

Table 141 - Power calculation

Voltage measurement mode	Voltage transformer	Voltages used	Currents used (acc. to connected phase CTs)	P, Q, S calculation method	Power per phase (Px, Qx, Sx with x = A,B, C)
3VP 3VP/ VPy 3VP/VPPy 3VP+VN	VT, LPVT	VA, VB, VC	IA, IB, IC	3 wattmeter	Available
			IA, IC	2 wattmeter	Not available
2VPP+ VN 2VPP+ VN + VPPy	VT	VAB,VCB,VN	IA, IB, IC	3 wattmeter	Available
			IA, IC	2 wattmeter	Not available
VPP/VPPy	VT	VAB	IA, IB, IC	3 wattmeter	Available
			IA, IC	2 wattmeter	Not available

Power calculation

The power values are calculated in detail as follows:

- By 3 wattmeter method:

$$P = \vec{V}_A \vec{I}_A \cos(\vec{V}_A \vec{I}_A) + \vec{V}_B \vec{I}_B \cos(\vec{V}_B \vec{I}_B) + \vec{V}_C \vec{I}_C \cos(\vec{V}_C \vec{I}_C)$$

$$Q = \vec{V}_A \vec{I}_A \sin(\vec{V}_A \vec{I}_A) + \vec{V}_B \vec{I}_B \sin(\vec{V}_B \vec{I}_B) + \vec{V}_C \vec{I}_C \sin(\vec{V}_C \vec{I}_C)$$

- By 2 wattmeter method:

$$P = \vec{V}_{AB} \vec{I}_A \cos(\vec{V}_{AB} \vec{I}_A) + \vec{V}_{CB} \vec{I}_C \cos(\vec{V}_{CB} \vec{I}_C)$$

$$Q = \vec{V}_{AB} \vec{I}_A \sin(\vec{V}_{AB} \vec{I}_A) + \vec{V}_{CB} \vec{I}_C \sin(\vec{V}_{CB} \vec{I}_C)$$

> **NOTE:** If just one phase to phase voltage is measured (voltage measurement mode “VPP/VPPy”), then a symmetric 3-phase voltage system is assumed to calculate the non-measured voltages.

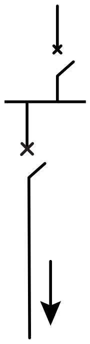
-

$$S = \sqrt{P^2 + Q^2}$$

P533ZA00

According to standard practice, it is considered that[142]:

- For the **Power direction** = *Outgoing*:
  - Power supplied from the busbar to the consumer is positive.
  - Power supplied to the busbar from a consumer is negative.



P533MO00

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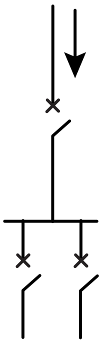
[142] Choice to be set in the **Scaling** view of the **GENERAL** menu.

- For the **Power direction** = *Incoming*:
  - Power supplied from the busbar to the consumer is positive.
  - Power supplied to the busbar from a consumer is negative.



P533MN00

Cosφ and power factor

PowerLogic P5 protection relay calculates:

- cosφ, tanφ, the angle φ and power factor values of the power system.
- cosφ and power factor values of the phase, depending on their availability of phase current and voltages.

cosφ, tanφ and the angle φ express the phase displacement between the phase currents and phase to neutral voltages.

The power factor is defined by:

$$Cos\varphi = P \Big/ \sqrt{P^2 + Q^2}$$

P533ZB00

The + and - signs of cosφ give the direction of power flow.

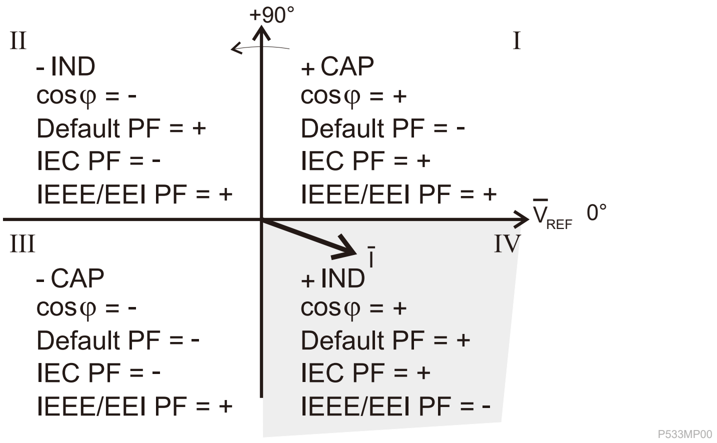
The IND (inductive) and CAP (capacitive) indications of the power factor give type of load.

Power and current direction

The PowerLogic P5 supports three available options of power factor: the *P5 default*, the *IEC*, and the *IEEE/EEI*. The figure below shows the concept of three-phase current direction and sign of cosφ and power factor PF (the absolute value is equal to cosφ, the sign 'IND' indicates inductive, which means lagging current, while 'CAP' indicates capacitive, which means the leading current).

> **NOTE:** The data in following figures and tables are based on outgoing power direction setting (default). For incoming power direction, the inversion of the sign of current and accordingly the different calculated value for the power is considered in the measurements.

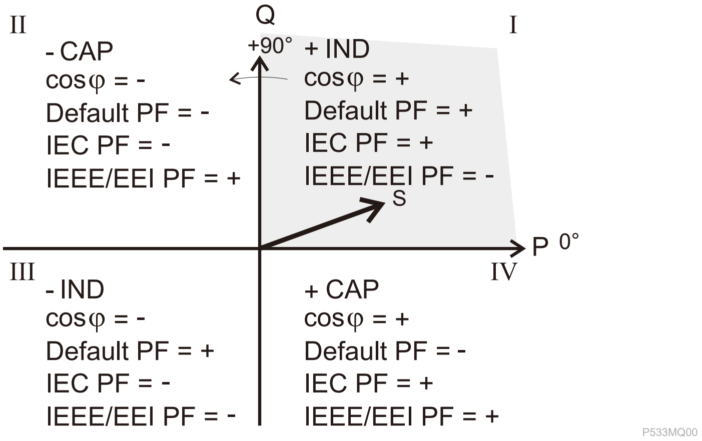
Figure 333 - Quadrants of voltage/current phasor plane



I:	Forward capacitive power current is leading
II:	Reverse inductive power current is leading
III:	Reverse capacitive power current is lagging
IV:	Forward inductive power current is lagging

This figure below shows the same concepts on a PQ-power plane.

Figure 334 - Quadrants of power plane



I:	Forward inductive power current is lagging
II:	Reverse capacitive power current is lagging
III:	Reverse inductive power current is leading
IV:	Forward capacitive power current is leading

Table 142 - Power quadrants

Power quadrant	Current related to voltage	Power direction	Cosφ	Default PF	IEC PF	IEEE/EEI PF
+ inductive	Lagging	Forward	+	+	+	-
+ capacitive	Leading	Forward	+	-	+	+
- inductive	Leading	Reverse	-	+	-	-
- capacitive	Lagging	Reverse	-	-	-	+

Characteristics

The following tables summarize the characteristics for power measuring:

Table 143 - Characteristics for power measuring (part 1)

Characteristics	Active power	Reactive power	Apparent power
Units	kW	kvar	kVA
Resolution	0.1 kW	0.1 kvar	0.1 kVA
Accuracy	±1% Snom typically[143]	±1% Snom typically[143]	±1% Snom typically[143]

Table 144 - Characteristics for power measuring (part 2)

Characteristics	Power factor	Cosφ	Tanφ	Angle φ
Measurement range	0 to 1 IND/CAP	-1 to +1	-99.999 to +99.999	-180° to +180°
Resolution	0.01	0.01	0.001	0.01
Accuracy	0.01[144]	0.01[144]		

---

[143] Snom= √3 Vprim.nom Iprim.nom
[144] For measurements at Inom, Vnom, cosφ > 0.8.

Active and reactive energy

The PowerLogic P5 protection relay measures the following active and reactive energy values, calculated on basis of the three voltages and phase currents IA, IB and IC measured according to the related current flow, subject to the power direction setting:

- E+: the accumulated active energy exported
- E-: the accumulated active energy imported
- Eq+: the accumulated reactive energy exported
- Eq-: the accumulated reactive energy imported

It is based on fundamental values or RMS values. The choice is done with the **Energy calculation mode** parameter.

The resolution of each energy counter can be defined by setting from 1 K unit to 1 M unit, by setting the number of decimal places of the value calculated.

When the apparent energy counter reaches 1 TVAh, the active and reactive energy counters reset to zero. To monitor the energy consumption on a feeder, a dedicated energy counter can be set up over a defined time window of between 10 minutes and 24 hours.

All the energy counter settings can be done:

- with eSetup Easergy Pro in the **Energy** view of the **Measurements** menu
- on local panel in the **Measurement** menu

The accumulated energy values are maintained when the PowerLogic P5 protection relay is powered off.

Table 145 - Characteristics of active and reactive energy measuring

Characteristics	Active energy	Reactive energy
Measurement range	999999.999 MWh	999999.999 MVArh
Units	MWh	MVArh
Resolution (self-adaptable)	0.001...1 MWh	0.001...1 MVArh
Accuracy	± 1% typical[145]	

---

[145] At In, Vnp, cosφ > 0.8

Harmonics and Total Harmonic Distortion (THD)

The total harmonic distortion (THD) is calculated as a percentage of all the currents and voltages measured in relation to the base value of the fundamental frequency.

The device calculates the value from the 2nd to the 15th harmonic of each phase current and voltage signal separately and as total value.

The harmonic distortion is calculated as follows:

$$THD = \frac{\sqrt{\sum_{i=2}^{15} h_i^2}}{h_1}$$

P533ZC00

where

h_1 = Fundamental value

h_2 - h_{15} = Harmonics

Example

h_1 = 100A, h_3 = 10 A, h_7 = 3 A, h_{11} = 8 A

$$THD = \frac{\sqrt{10^2 + 3^2 + 8^2}}{100} = 13.15\%$$

P533ZD00

For reference, the RMS value is

$$RMS = \sqrt{100^2 + 10^2 + 3^2 + 8^2} = 100.9\ A$$

P533ZE00

Demand values

The PowerLogic P5 protection relay calculates average demand values of phase currents IA, IB, IC and power values S, P and Q. They are calculated over an adjustable demand time in a range from 10 to 60 minutes.

The parameters used to configure or control the demand values in the **MEASUREMENTS** menu/**Demand values** sub-menu of eSetup Easergy Pro are the following:

Table 146 - Demand value parameters

Parameter	Unit	Description
Demand time	min	Demand time (averaging time)
Fundamental frequency values		
IAda	A	Demand of phase current IA
IBda	A	Demand of phase current IB
ICda	A	Demand of phase current IC
Pda	kW	Demand of active power P
PFda	-	Demand of power factor PF
Qda	kvar	Demand of reactive power Q
Sda	kVA	Demand of apparent power S
RMS values		
IARMSda	A	Demand of RMS phase current IA
IBRMSda	A	Demand of RMS phase current IB
ICRMSda	A	Demand of RMS phase current IC
Prmsda	kW	Demand of RMS active power P
Qrmsda	kvar	Demand of RMS reactive power Q
Srmsda	kVA	Demand of RMS apparent power S

Table 147 - Resetting to zero

Characteristics	Range
Demand time	10...60 min
Currents	see Phase currents, page 522
Powers	see Power and power factor, page 528

Minimum and maximum values

Minimum and maximum values for many measurements are available through the user interfaces (HMI, eSetup Easergy Pro, Web HMI or communications protocols). Each record of minimum or maximum value includes a time stamp. This time stamp is reset either when a clear command (ClrMax) is applied or by a product restart.

The available values are listed in the following table:

Table 148 - Available minimum and maximum values

Min & Max measurement	Description
IA, IB, IC	Phase current, fundamental frequency value
IA_{RMS}, IB_{RMS}, IC_{RMS}	Phase current, RMS value

Table 148 - Available minimum and maximum values (Continued)

Min & Max measurement	Description
IN, IN'	Ground fault overcurrent, fundamental value
VA, VB, VC	Voltages, fundamental frequency values
VA_{RMS}, VB_{RMS}, VC_{RMS}	Phase to neutral voltages, RMS value
VAB, VBC, VCA	Phase to phase voltage
VAB_{RMS}, VBC_{RMS}, VCA_{RMS}	Phase to phase voltage, RMS value
VN	Neutral voltage
f	Frequency
P, Q, S	Active, reactive, apparent power
PF	Power factor

The clearing parameter "ClrMax" is a common reset for all min. and max. values.

Table 149 - Parameters

Parameter	Value	Description	Note
ClrMax	-; Clear	Reset all minimum and maximum values	Settable[146]

A ClrMax command can be initiated as below:

- with "Clear min & max" parameter in the **Measurements** menu in eSetup Easergy Pro
- with "Clear min & max" parameter in the **Measurements** menu in the Web HMI
- from the local panel with the "Clr Max" parameter
- With a suitably configured DI
- with virtual inputs / outputs according to the setting of the "DI to clear min & max" parameter

In addition any action that results in a restart of the PowerLogic P5 protection relay will also clear the min/max values. This includes power cycling and certain configuration updates.

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[146] An editable parameter (password needed).

Average current

The PowerLogic P5 protection relay calculates the average of the three phase currents IA + IB + IC over a period of time defined by the “Average current window” setting, in the **3_Phase Average current** view of the **Measurements** menu in eSetup Easergy Pro.

Table 150 - 3_Phase Average current

Parameter	Value	Description
Average current window	1 s; 1 min; Demand Time	Time for calculating the average current

If the “Average current window” is set to “Demand Time”, the setting value will depend on the “Demand time” setting, which is configured in the **Demand values** view of the **Measurements** menu.

Table 151 - Demand values

Parameter	Range	Description
Demand time	10...60 min	Demand time (averaging time)

The average current is refreshed each second when the “ Average current window” is set to “1 s”, and it is refreshed each minute when the “Average current window” is set to “1 min” or “Demand Time”.

The average current is available in eSetup Easergy Pro and all communication interfaces.

Voltage sags and swells

The PowerLogic P5 protection platform provides many power quality functions that can be used to evaluate, monitor and alarm on the current power system quality. Two of the most important power quality functions are the voltage sag and swell monitoring.

The PowerLogic P5 protection relay provides separate monitoring logs for sags and swells. The voltage log is triggered if any voltage input either goes under the sag limit (V<) or exceeds the swell limit (V>). There are four registers for both sags and swells in the fault log. Each register will have start time, phase information, duration, minimum, average and maximum voltage values of each sag and swell event. Furthermore, there are total number of sags and swells counters as well as total timers for sags and swells.

The voltage sags and swells monitoring function can be read and set:

- on local panel, through **Measures** menu, under **"Voltages"** sub-menu, in the view of **Voltage sag & swell**
- with eSetup Easergy Pro, under the **Measurements** menu, in the view of **Voltage sag & swell**

Measurement mode

There are 3 selections in drop menu: *Ph-Ph*, *Ph-G* and *Default*, stand for different types of measured voltage.

- Ph-Ph: phase to phase voltage
- Ph-G: phase to ground voltage
- Default: use the setting of “Voltage mode” from system setting.

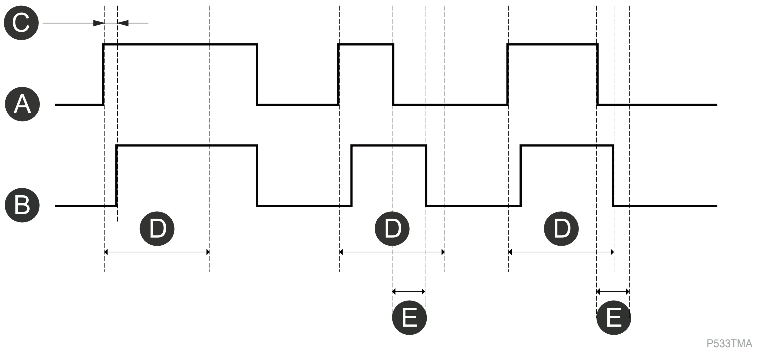
SSW maximum time and SSW gap time

These 2 settings define how to end the Voltage swell signal.

As shown in following chart:

- When Voltage > “Voltage swell limit” is fulfilled, Voltage swell signal will be activated after a delay time. SSW maximum timer starts.
- In case of Voltage > “Voltage swell limit” is continued, Voltage swell signal will also be activated in continue.
- When Voltage > “Voltage swell limit” ends, SSW gap timer starts. Voltage swell signal will be ended either SSW maximum timer or SSW gap timer reaches the set value.

Figure 335 - Example of SSW maximum time and SSW gap time



A	Voltage > “Voltage swell limit”	B	Voltage swell signal
C	Delay time	D	SSW maximum time
E	SSW gap time		

Table 152 - Setting and characteristics of voltage sags and swells monitoring

Setting/characteristics	Values
Measurement mode	
Options	Default (same as the scaling setting); Ph-Ph; Ph-G
Voltage sag limit	
Setting range	10%...120% U_{NOM}[147]
Resolution	1% U_{NOM}[147]
Accuracy	±0.5 V or 3% of the set value
Reset ratio	103%
Voltage swell limit	
Setting range	10%...150% U_{NOM}[147]
Resolution	1% U_{NOM}[147]
Accuracy	±0.5 V or 3% of the set value
Reset ratio	97%
DT delay time	
Setting range	0.06...1.00 s
Resolution	0.02 s
Accuracy	±1% or ±30 ms
Low voltage blocking	
Setting range	0...50% U_{NOM}[147]
Resolution	1% U_{NOM}[147]
Accuracy	±5% of the set value
Maximum time	
Setting range	10...1000 s
Resolution	1 s
Gap time	
Setting range	0.00...5.00 s
Resolution	0.01 s
Characteristic time	
Disengaging time	< 60 ms

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[147] VT Primary nominal

Temperature

Operation

This function gives the temperature value measured by Resistance Temperature Detectors (RTDs):

- Platinum Pt100 (100 Ω at 0°C or 32°F) in accordance with the IEC 60751 and DIN 43760 standards
- Nickel 100 Ω or 120 Ω (at 0°C or 32°F).

Each RTD channel gives one measurement: tx = RTD x temperature.

The function also indicates RTD faults:

- RTD disconnected (t > 205°C or t > 401°F)
- RTD shorted (t < -35°C or t < -31°F).

In the event of a fault, the display of the value is inhibited.

The associated monitoring function generates a maintenance alarm.

Readout

The measurements may be accessed through:

- **RTD** view of the **Measures** menu on the local panel of the PowerLogic P5 protection relay
- **Temperature** view of the **MEASUREMENTS** menu in eSetup Easergy Pro
- The communication link

Characteristics

Table 153 - Characteristics of temperature measuring

Characteristics	Values
Range	-30...+200°C (-22...+392°F)
Resolution	1°C (1°F)
Accuracy	±1°C for +20...+140°C (±1.8°F for +68...+284°F); ±2°C for -30...+20°C (±3.6°F for -22...+68°F); ±2°C for +140...+200°C (±3.6°F for +284...+392°F)
Refresh interval	5 seconds (typical)

Accuracy derating according to wiring (connection in 3-wire mode)

The deviation Δt is proportional to the length of the connector and inversely proportional to the connector cross-section:

$$\Delta t\,(^{\circ}\mathrm{C}) = 2 \times \frac{L\,(km)}{S\,(mm^2)}$$

P533ZF00

- ±2.1°C/km for a cross-section of 0.93 mm² (AWG 18)
- ±1°C/km for a cross-section of 1.92 mm² (AWG 14)

Analogue inputs and outputs

The values of the analogue inputs and analogue output signals are displayed in eSetup Easergy Pro and on local HMI. They can also be sent by CAN communication protocol.

In eSetup Easergy Pro, the values are in **MEASUREMENTS / Analogue I/O**.

Analogue I/O n DC currents and **Analogue I/O n signal values** (n = 1...3) will be displayed in groups, one group per connected CLIO module.

In Analogue I/O n DC currents group, first of all the connection status of the CLIO module is displayed. There are 2 statuses only. With proper wiring, setup and power supply *Link on* is indicated, otherwise *Link off*.

Then the direct current values of the inputs and outputs are shown. Values out of range or from not enabled analogue I/O channels are indicated with “-“.

Analogue I/O n signal values are the scaled values of the analogue input signals and the actual measured values of PowerLogic P5 which are assigned to the analogue outputs.

In local HMI of PowerLogic P5, the above displays can be found in **Measures / Analogue I/O n**, n = 1...3.

For the installation and configuration of the CLIO modules, please refer to CLIO module (REL70071), page 141.

Control functions

Digital outputs

Description

Digital outputs are available for control and signalling purposes.

The number of available outputs depends on the number and type of board options ordered.

The following digital output contact relays are available:

- **Slot B**

  The digital output DO1 is normally opened (NO) contact (and high speed high break contact for P5x30 only) used for control. The digital output DO2 (Change Over contact) is usually used for control.

  The digital output DO3 (Normal Open) is usually used for control.

  The digital output DO4 (change over contact) is dedicated to the watchdog (signalling).

  Both the tripping DO2 relay and the watchdog relay have normally open (NO) or normally closed (NC) contacts. Refer to Selecting the trip command and examples of use, page 580.

- **Slot C, D, E (6I4O option)**

  The digital outputs DO1 to DO4 (Normal Open single pole single throw) are for signalling only.

  Slot C, D, E (5I5O option)

  The digital outputs DO1 and DO2 (Change Over contact single pole double throw) are usually used for control.

  The digital outputs DO3 (Normal Open single pole single throw) are for control.

  The digital outputs DO4 and DO5 are normally opened (NO) contact and high speed high break contact used for control.

  Slot C, D, E (12I4O option)

  The digital outputs DO1 to DO4 are independently controlled normally open signalling contacts with DO1 & DO2 and DO3 & DO4 having a common connection point.

- **Slot D, E (Arc-flash option)**

  The digital output DO1 (Normal Open) is usually used for control.

  The digital output DO2 (Change Over contact single pole double throw) is usually used for control.

  The digital output DO3 (Normal Open single pole single throw) is usually used for signalling.

  The contacts are (SPST) normal open (NO) type, except signal relay DO2 and DO4 (watchdog) which has a changeover contact (SPDT).

  The digital outputs can be set in Normal Open or Normal Close position with eSetup Easergy Pro and Web HMI in the **Relays polarity** view of the **Control** menu.

The status of the digital outputs can be read:

- with eSetup Easergy Pro in the **Relays** view of the **Device/Test** menu
- by the local panel in the **digital output Slot x** view under the menu option **DO** of the **Device/Test** sub-menu
- EcoStruxure Power Device application
- Web HMI

Label and description texts can be edited with eSetup Easergy Pro or the Web HMI in **Names for output relays** view according to the demand. Labels are the short parameter names used on the local panel display and descriptions are the longer names used by eSetup Easergy Pro (the **Names of the output relays** view in the **Control** menu).

Any internal signal can be connected to the output relays using the output matrix. An output relay can be configured as latched or non-latched. (see **Output Matrix** view in the **Matrix** menu of eSetup Easergy Pro and Web HMI).

Forced control of digital outputs

For tests purposes, first set the **IED Mode** to **Test:**

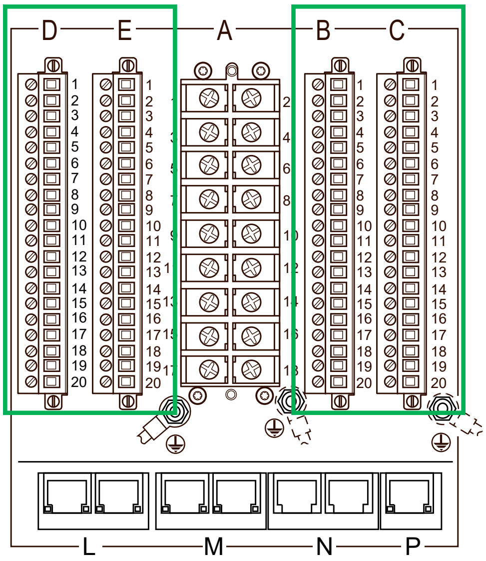
- with eSetup Easergy Pro in the **System info** setting view of the **General** menu
- by local panel in the **Device/Test** menu under the **Test** menu option

See Mode of use for testing purposes, page 283 for more information.

Default numbering of digital outputs

Every option card and slot has default numbering. Below is an example of PowerLogic P5x30 showing default numbering of DOs.

Figure 336 - Default numbering of digital outputs for PowerLogic P5x30



P533NC00

Table 154 - Example of digital outputs numbering

Option boards	Slot B	Slot C	Slot D[148]	Slot E[148]
No option	DO1...DO3 + WD			
1 x 6I/4O	DO1...DO3 + WD	DO1...DO4		
2 x 6I/4O	DO1...DO3 + WD	DO1...DO4	DO1...DO4	
3 x 6I/4O	DO1...DO3 + WD	DO1...DO4	DO1...DO4	DO1...DO4
1 x 6I/4O +1 x Arc-flash	DO1...DO3 + WD	DO1...DO4	DO1...DO3	

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[148] For PowerLogic P5x30 only

Table 154 - Example of digital outputs numbering (Continued)

Option boards	Slot B	Slot C	Slot D[149]	Slot E[149]
2 x 6I/4O +1 x Arc-flash	DO1...DO3 + WD	DO1...DO4	DO1...DO3	DO1...DO4
1 x 6I/4O +2 x Arc-flash	DO1...DO3 + WD	DO1...DO4	DO1...DO3	DO1...DO3

Characteristics

Table 155 - Characteristics of the digital outputs

Parameter	Value	Description	Note
DO1...DOn	0; 1	Status of the digital outputs: • 0 = Digital output not energized • 1 = Digital output is set active The available parameter list depends on the number and type of the I/O cards.	Editable when IED mode is set to "Test".
Mode	NO NC	Normal open Normal close	Editable when IED mode is set to "Test".
IED mode	Normal Test Test-block	In **Test** mode, digital output forcing is enabled for test purposes.	Editable parameter (password needed)
Name of output relays			
Label	String of max. 16 characters	Short name for digital outputs on the local display. Default is "DO1...DOx". x is the maximum number of the digital outputs.	Editable parameter (password needed)
Description	String of max. 32 characters	Long name for digital outputs. Default is "Digital output 1...Digital output x". x is the maximum number of the digital outputs.	Editable parameter (password needed)

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[149] For PowerLogic P5x30 only

Digital inputs

⚠WARNING

RISK OF FIRE

Do not connect power greater than 0.5 W to each digital input for ambient temperature lower than 70°C (158°F), or 0.8 W for lower than 45°C (113°F).

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Digital inputs are available for control purposes. For example, the digital inputs can provide the position of the circuit breaker and make it possible to change setting group, block/enable/disable functions, program logic, and indicate object status.

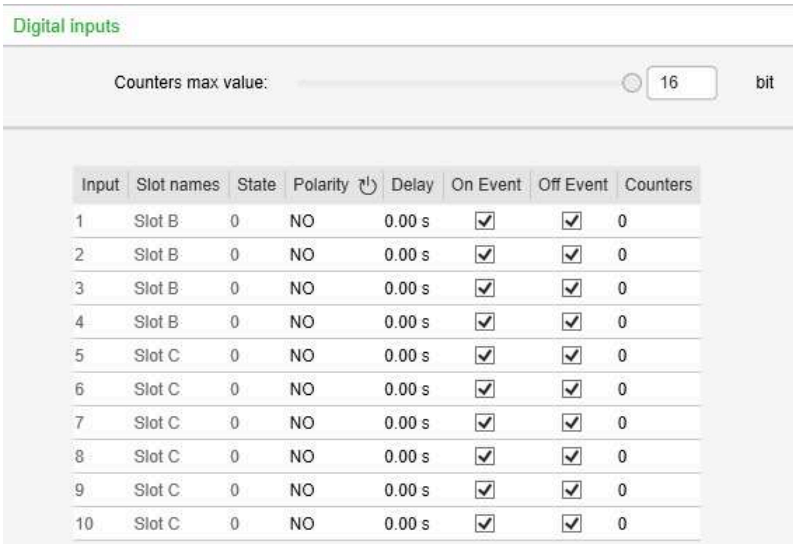
The number of available inputs depends on the number and type of option boards.

The digital inputs require an external control voltage (AC or DC) and are activated after the voltage exceeds the pick-up threshold. Deactivation follows when the voltage drops below the drop-off threshold limit.

Configuring the digital inputs

The digital inputs are set with eSetup Easergy Pro and Web HMI in the **Digital Inputs** view of the **Control** menu. They are not settable on the local panel.

Figure 337 - The Digital inputs setting section in the Digital inputs view



Digital inputs

Counters max value: 16 bit

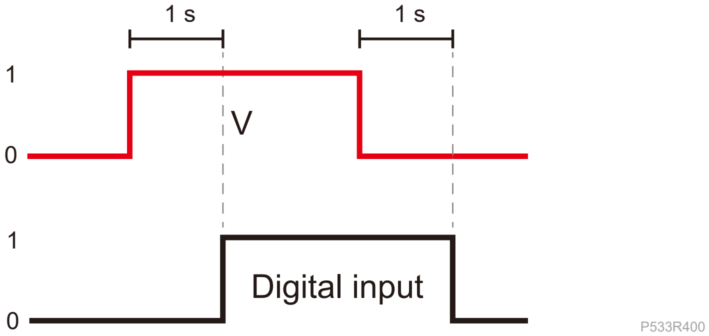
Input	Slot names	State	Polarity	Delay	On Event	Off Event	Counters
1	Slot B	0	NO	0.00 s	☑	☑	0
2	Slot B	0	NO	0.00 s	☑	☑	0
3	Slot B	0	NO	0.00 s	☑	☑	0
4	Slot B	0	NO	0.00 s	☑	☑	0
5	Slot C	0	NO	0.00 s	☑	☑	0
6	Slot C	0	NO	0.00 s	☑	☑	0
7	Slot C	0	NO	0.00 s	☑	☑	0
8	Slot C	0	NO	0.00 s	☑	☑	0
9	Slot C	0	NO	0.00 s	☑	☑	0
10	Slot C	0	NO	0.00 s	☑	☑	0

The settable items includes:

- Polarity
- Delay
- On event
- Off event
- Counter

Digital input delay determines the activation and de-activation delay for the digital input. It is used for both On and Off transitions. Digital inputs behavior when delay is set to 1 second, page 546 shows how the digital input behaves when the delay is set to 1 second.

Figure 338 - Digital inputs behavior when delay is set to 1 second



Digital inputs on/off events and alarm pop-up message display can be enabled and disabled in **Digital inputs** setting view of eSetup Easergy Pro or Web HMI.

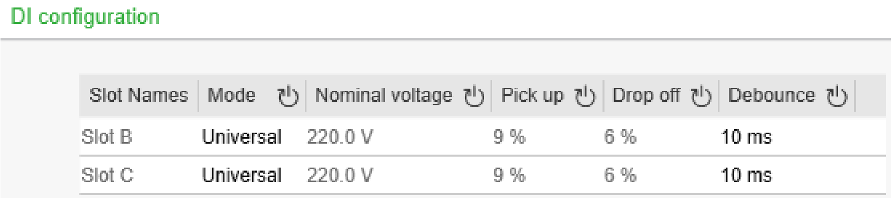
Individual operation counters are located in the same view as well. The maximum value of the counters is settable and is the same for all counters.

The status of the digital inputs can be read:

- with eSetup Easergy Pro and Web HMI in the **Digital inputs** view of the **CONTROL** menu
- by local panel in the **Digital inputs** view of the **DI** menu option in the **Control** menu
- EcoStruxure Power Device application
- Communication according to the protocol

The configuration of the digital inputs in eSetup Easergy Pro is common for all digital inputs on the same board.

Figure 339 - The DI Configuration section in the Digital inputs view



DI configuration

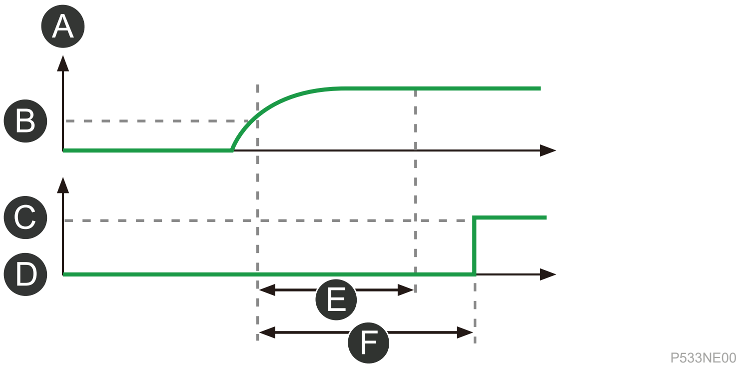
Slot Names	Mode	Nominal voltage	Pick up	Drop off	Debounce
Slot B	Universal	220.0 V	9 %	6 %	10 ms
Slot C	Universal	220.0 V	9 %	6 %	10 ms

The digital inputs can be set for the following voltage values with pre-defined setting values or settable values:

- Universal (by default)
- Standard AC or DC voltages (24 V DC, 48 V DC, 110 V DC, 220 V DC, 220 V AC, and 250 V DC)
- Customizable AC (settable from 90 V AC to 230 V AC), customizable DC (settable from 24 V DC to 250 V DC)

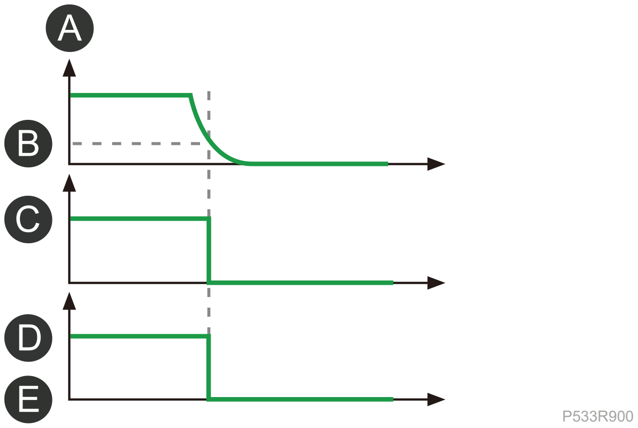
Timing diagram of a digital input during pick-up, page 547 and Timing diagram of a digital input during a drop-off, page 547 below illustrate the timing diagrams of a digital input during pick-up and drop-off:

Figure 340 - Timing diagram of a digital input during pick-up



A	Nominal voltage	B	Pick up value
C	Input seen as high level	D	Input seen as low level
E	Inrush time	F	Debounce time

Figure 341 - Timing diagram of a digital input during a drop-off



A	Nominal voltage	B	Drop-off value
C	Holding current	D	DI high
E	DI low		

Label and description texts can be edited with eSetup Easergy Pro according to the demand. Labels are the short parameter names used on the local panel and descriptions are the longer names used by eSetup Easergy Pro.

The digital input signals can be connected to the different outputs of the **Output matrix**, **Block matrix**, **Object block matrix**, **Auto-recloser 79 matrix** views in the **MATRIX** menu of eSetup Easergy Pro and Web HMI or used in the custom logic function.

Configure the DI alarm settings with local HMI

The listed DI alarm settings can be configured with local HMI:

- Inverted alarm
- display
- On Event
- Off Event

To make the configuration with local HMI, go to **Control / Digital inputs**, the page **Configuration**. On this page you can switch between the DIs with △ and ▽ buttons. Follow the process below to configure a DI:

1. press OK button to enter edit mode,
2. use ◁ and ▷ buttons to select the event to be configured,
3. use the △ button or the ▽ button to enable/disable, either of them can loop between the enable and disable.
4. After configuration, press OK button to save the configuration and quit the edit mode.

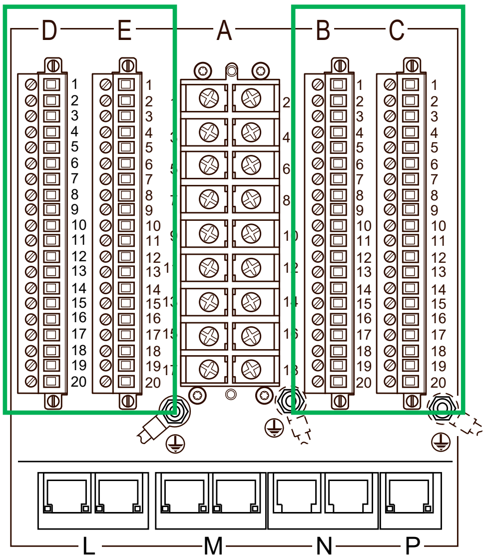
Default numbering of digital inputs

Every option card and slot has default numbering. After making any changes to the numbering, read the settings from the relay after the relay has rebooted.

Below is an example of PowerLogic P5x30 showing default numbering of digital inputs.

The number of digital inputs depends on the configuration of the cards on slots B, C, D, E. The labels and descriptions can be edited, however the input number is already fixed.

Figure 342 - Default numbering of digital inputs for PowerLogic P5x30



P533NG00

Table 156 - Example of digital inputs numbering

Option boards	Slot B	Slot C	Slot D[150]	Slot E[150]
No option	DI1...DI4			
1 x 6I40	DI1...DI4	DI1...DI6		
2 x 6I40	DI1...DI4	DI1...DI6	DI1...DI6	
3 x 6I40	DI1...DI4	DI1...DI6	DI1...DI6	DI1...DI6
1 x 6I40 +1 x Arc-flash	DI1...DI4	DI1...DI6	DI1...DI3	
2 x 6I40 +1 x Arc-flash	DI1...DI4	DI1...DI6	DI1...DI3	DI1...DI6
1 x 6I40 +2 x Arc-flash	DI1...DI4	DI1...DI6	DI1...DI3	DI1...DI3

---

[150] For PowerLogic P5x30 only

Characteristics

Table 157 - Characteristics of the digital inputs

Parameter	Value		
	Universal	**Standard voltage**	**Customizable voltage**
Mode	Universal (value by default)	24 V DC; 48 V DC; 110 V DC; 220 V DC; 220 V AC; 250 V DC	Custom 24 V DC to 250 V DC; Custom 90 V AC to 230 V AC
Pick-up ratio	> 19 V	70%	40%...80%, 154 V max.
Drop-off ratio	< 12 V	60%	20%...60%, 12 V min.
Holding current	1.3 mA	2.3 mA (V ≤ 110 V) 1.3 mA (V > 110 V)	1...27 mA
Debounce time	0...100 ms		
State	0; 1		
Polarity position	NO; NC		
Power maximum	0.5 W for ambient temperature less than 70℃ (158 ℉); 0.8 W for ambient temperature less than 45℃ (113 ℉);		
Delay	0.00...60.00 s		
On event	No; Yes		
Off event	No; Yes		
Counters	0 to 255 - 511 - 1023 - 2047 - 4095 - 8191 - 16383 - 32767 - 65535 Reset automatically to 0 if the limit is exceeded.		
Counter max value	Setting range is 8 to 16 bit counter		
Name of digital inputs	Label: short name for display on the local panel. String of max. 10 characters. Default is "DI1...DIx".		
	Description: long name for display in eSetup Easergy Pro or HMI String of max. 32 characters. Default is "Digital input 1...Digital input x".		

NOTE: Digital inputs can be assigned to a signal with normal state or inverted state.

Virtual inputs and virtual outputs

There are virtual inputs and virtual outputs that can, in many places, be used like their hardware equivalents except that they are located in the memory of PowerLogic P5. Virtual inputs can be used in many operations act like normal digital inputs such as: enable changing setting groups, block/enable/disable functions, program logics, and so on.

Virtual inputs can be selected to operate by the function buttons on local panel, the local mimic, communication or simply by using the **Virtual input** menu of eSetup Easergy Pro or Web HMI.

The activation and reset delay of virtual inputs/outputs is about 5 ms.

The status of virtual inputs and outputs can be read:

- with eSetup Easergy Pro in the **Virtual inputs** views of **CONTROL** menu and **Virtual outputs** views of **Device/Test** menu
- by local panel in **Virtual inputs** or **Virtual outputs** view of **Control** menu
- EcoStruxure Power Device application
- web HMI
- communication depending on the protocol

The virtual inputs and virtual outputs can be named through eSetup Easergy Pro or Web HMI in the Names for virtual inputs and Names for virtual outputs views of **CONTROL** menu.

The virtual input signals can be connected to different outputs of the **Output matrix**, **LED matrix**, **Block matrix**, **Object block matrix**, **Auto-recloser 79 matrix** views in the **MATRIX** menu of eSetup Easergy Pro and Web HMI or used in the custom logic function.

The virtual outputs can be controlled through output matrix (see **Output matrix** view in the **Matrix** menu of eSetup Easergy Pro and Web HMI).

Table 158 - Characteristics of the virtual inputs and outputs

Parameter	Value	Description	Note
Number of Virtual Inputs	50		
Number of Virtual Outputs	20		
VI1-VI50	0 1	Virtual input status is set to inactive. Virtual input status is set to active.	Editable when IED mode is set to "Test".
VO1-VO20	0 1	Virtual output status is set to inactive. Virtual output status is set to active.	Editable when IED mode is set to "Test".
Refresh period	5 ms	The activation and reset delay of the virtual inputs/outputs	
Event enabling	No Yes	Active edge event disabled. Active edge event enabled.	
Check L/R selection	No Yes	disabled enabled	
Name of virtual inputs and virtual outputs			
Label	String of max. 10 characters	Short name for virtual inputs and virtual outputs on the local display. Default is "VI1...VIn" and "VO1...VOn". n is the maximum number of the digital inputs or outputs.	Editable parameter (password needed)
Description	String of max. 32 characters	Long name for virtual inputs and virtual outputs. Default is "Virtual input 1 (or Virtual output 1)...Virtual input n (or Virtual output n)". n is the maximum number of the virtual inputs or virtual outputs.	Editable parameter (password needed)

Virtual input pulse time operation

VI1 to VI10 are configurable virtual inputs, they can operate on pulse mode, which is achieved by a settable VI pulse length.

When the VI pulse length is set to "0 = infinite", it keeps actual operation; and with any setting > 0 s, the VI state gets automatically reset to 0 (low/ inactive), once the pulse timer expires.

The pulse timer can be re-started while running when a command with value “1” is received, and can be reset instantaneously when a command with value "0" is received.

Matrix

General information

The PowerLogic P5 protection relay has several matrices that are used for linking the hardware and software elements together to create a protection chain:

- **Output matrix**

  Used to link various inputs, outputs, statuses and signals to send a command to the contact relays and virtual outputs, to activate disturbance recording, and to provide SOL status.
- **Block matrix**

  Used to block protection stages
- **LED matrix**

  Used to control LEDs on the local panel
- **Object block matrix**

  Used to inhibit object control
- **Auto-recloser matrix**

  Used to control auto-recloser
- **Arc-flash matrix**

  Used for Arc-flash detection functions
- **Event matrix**

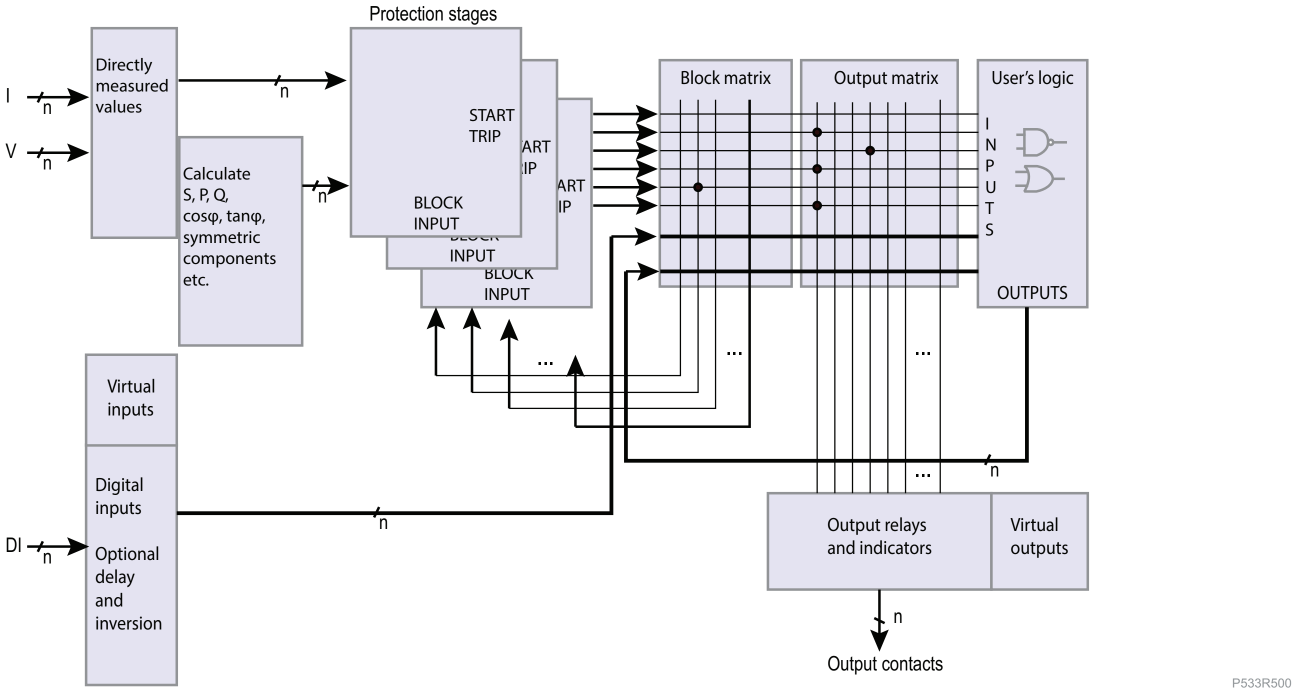
  See Logging and recording functions, page 584.
- **Goose matrix**

  Used in association with IEC61850 (see the Goose matrix view in the communication menu).

  It allows to associate up to 250 Goose messages (NIx) to a virtual input or a Goose message (NI).
- **General signals matrix**

  Used to define general trip, start and direction signals (see Configurable General start and trip signals, page 284).

Figure 343 - Blocking matrix and output matrix



Output matrix

The output matrix is used for connecting signals issued by different functions to the output relays (DO), virtual outputs (VO) and disturbance record trigger (DR).

The connecting signals to the outputs are the following:

- Protection signals from the different stages including setting changes
- Auto-recloser information
- Digital inputs
- Virtual inputs and outputs
- Object control command
- Function keys
- Goose
- Warning and alarm signals from the analogue inputs
- Voltage sag/swell and interrupt
- Timers
- InterRelay signals
- Environmental event and alarm signal from Zigbee environmental monitoring
- Thermal event and alarm signals from Zigbee thermal monitoring
- Digital CB alarm signals

The **Output matrix** setting view of eSetup Easergy Pro and Web HMI represents the state (de-energized/energized) of the digital output's coil. For example, an orange vertical line in the **Output matrix** and a logical "1" in the **Relays** view represent the energized state of the coil. The same principle applies for both NO and NC type digital outputs. The actual position (open/closed) of the digital outputs' contacts in coil's de-energized and energized state depends on the type (NO/NC) of the digital outputs. De-energized state of the coil corresponds to the normal state of the contacts.

A digital output can be configured as latched or non-latched. The releasing latches procedure is described in Releasing latches, page 558.

Programming matrix

┼ Matrix connection without latch

The connection is shown as a single bullet.

- When the input signal is activated, the output is activated
- When the input signal is released, the output is released

┼ Latched matrix connection

The latched connection is shown as a single bullet surrounded by a circle.

- When the input signal is activated, the output is activated
- When the input signal is released, the output will remain active until cleared manually (refer to Releasing latches, page 558).

┼ No connection

The line crossing is empty.

> **NOTE:** Logic outputs (see Logic functions, page 566) are also assigned automatically in the output matrix when defined in any user programmable logic scheme.

LED matrix

The LED matrix defines the use of the Alarm LED ❗, the trip LED ⚡, and the configurable LEDs on the local panel of PowerLogic P5 protection relay. A lot of functions can be assigned to each LED.

Table 159 - Inputs for LEDs

Input	Latch	Description	Note[151]
Protection, arc and programmable stages	Normal/ Latched/ BlinkLatch	Different type of protection stages can be assigned to LEDs	Set
Digital/virtual inputs and function buttons	Normal/ Latched/ BlinkLatch	All different type of inputs can be assigned to LEDs	Set
Object open/close, object final trip and object failure information	Normal/ Latched/ BlinkLatch	Information related to objects and object control	Set
Local control enabled	Normal/ Latched/ BlinkLatch	While remote/local state is selected as local the "local control enabled" is active	Set
Logic output 1-20	Normal/ Latched/ BlinkLatch	All logic outputs can be assigned to LEDs at the LED matrix	Set
Manual control indication	Normal/ Latched/ BlinkLatch	When the user has controlled the objectives	Set
Setting error, self diagnostic alarm, pwd open and setting change	Normal/ Latched/ BlinkLatch	Self diagnostic signal	Set
GOOSE NI 1-250	Normal/ Latched/ BlinkLatch	IEC 61850 goose communication signal	Set
GOOSE error	Normal/ Latched/ BlinkLatch	IEC 61850 goose communication signal	Set

---

[151] Set = an editable parameter (password needed)

Table 159 - Inputs for LEDs (Continued)

Input	Latch	Description	Note[152]
AI x warning/alarm x = 1 to 12	Normal/ Latched/ BlinkLatch	Indication of warning or alarm raised by an analogue input.	Set
AI x monitor alarm x = 1 to 12	Normal/ Latched/ BlinkLatch	Indication of undercurrent of analogue input.	Set
InterRelay signals	Normal/ Latched/ BlinkLatch	IRInx signal	Set
Zigbee connected environmental sensors	Normal/ Latched/ BlinkLatch	Environmental event and alarm signals	Set
Zigbee connected thermal sensors	Normal/ Latched/ BlinkLatch	Thermal event and alarm signals	Set
Digital CB	Normal/ Latched/ BlinkLatch	Alarm signals	Set

All the LEDs (6 for PowerLogic P5x20; 10 for PowerLogic P5x30) can be assigned as green or red in the **MATRIX** menu/**LED matrix** sub-menu of eSetup Easergy Pro. The selection of green and red at the same time will result in yellow.

The connection can be normal, latched or blink-latched (flashing).

NOTE: LEDs to be configured using their dedicated matrix.

Normal connection

When the connection is normal, the assigned LED is active when the control signal is active. After deactivation, the LED turns off. LED activation and deactivation delay when controlled is approximately 10 ms.

Latched connection

A latched LED activates when the control signal activates but remains lit even when the control signal deactivates. Latched LEDs can be released by pressing the R key on the local panel.

Blink-latched connection

When the connection is "BlinkLatch", the assigned LED is active and blinking as long as the control signal is active. After deactivation, the LED remains latched and blinking. The latch can be released by pressing the R key on the local panel.

Block matrix

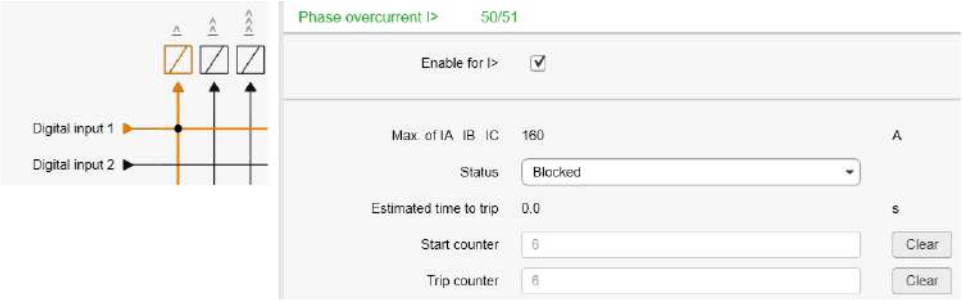
The operation of any protection stage can be blocked by the block matrix in the **MATRIX** menu/**Block matrix** sub-menu. The blocking signal can originate from the digital inputs or it can be a start or trip signal from a protection stage or an output signal from the user's programmable logic.

The Blocked status becomes visible only when the stage is about to activate.

---

[152] Set = an editable parameter (password needed)

Figure 344 - A view from the setting tool showing a DI input blocking connection (left picture) and the result for the 50/51-1 stage when the DI is active and the stage exceeds its current start value



Phase overcurrent I> 50/51

Enable for I> ☑

Max. of IA IB IC 160 A

Status Blocked

Estimated time to trip 0.0 s

Start counter 6

Trip counter 6

NOTICE

UNINTENDED AND NUISANCE TRIPPING

- In the online mode, the blocking matrix is dynamically controlled by selecting and deselecting protection stages.
- Activate the protection stages first, then store the settings in the protection relay. After that, refresh the blocking matrix before configuring it.

Failure to follow these instructions can result in unwanted shutdown of the electrical installation.

Object block matrix

The object block matrix is used to link digital inputs, virtual inputs, function buttons, protection stage outputs, object statuses, logic outputs, alarm signals, analogue input signals, InterRelay signals, Zigbee environmental and thermal signals, Digital CB signals and GOOSE signals to inhibit the control of objects, that is, circuit breakers, isolators and grounding switches.

Typical signals to inhibit controlling of the objects like circuit breaker are protection stage activation, statuses of the other objects, interlocking made in logic or GOOSE signals. These and other signals are linked to objects through the object block matrix.

Auto-recloser matrix

The auto-recloser matrix is used to link digital inputs, virtual inputs, protection stage outputs, object statuses, logic outputs, alarm signals, analogue input signals and GOOSE signals to control the auto-recloser. For more information, see Auto-recloser function (ANSI 79), page 455.

Arc-flash matrix

The arc-flash detection matrix uses three types of matrix:

- **Arc-flash light matrix**

  The arc-flash light matrix is used for connecting light signals detected by sensors or Goose or any virtual inputs to the different stages of the Arc-flash detection function.
- **Arc-flash current matrix**

  The arc-flash current matrix is used for connecting current signals and any virtual inputs to the different stages of the Arc-flash detection function.
- **Arc-flash output matrix**

  The arc-flash output matrix is used for connecting the different arc stage signals to the digital outputs.

See Arc-flash (ANSI 50ARC), page 402 for more information on the arc-flash protection function of the PowerLogic P5 protection relay.

Releasing latches

According to the matrix configurations different outputs and indicators can be latched or non-latched. A non-latched output or indicator follows the controlling signal. A latched output or indicator remains active after the controlling signal releases.

There is a common "release all latches" signal to release all the latched relays. This release signal resets all the latched digital outputs and indicators.

Each digital output can be latched or not independently through the output matrix.

The release of the latches can be done:

- Directly with the R key on the local panel
- With a digital input/output or virtual input/output set in the **CONTROL** menu/ **Release latches** sub-menu of eSetup Easergy Pro or Web HMI
- With eSetup Easergy Pro, click **Device** button in the toolbar and select **Release all latches**
- With Web HMI
- Through communication

Mimic display

The PowerLogic P5 protection relay can display multiple mimic screens (up to 5) on the local panel. The mimic screen can be entered from the main screen/default screen.

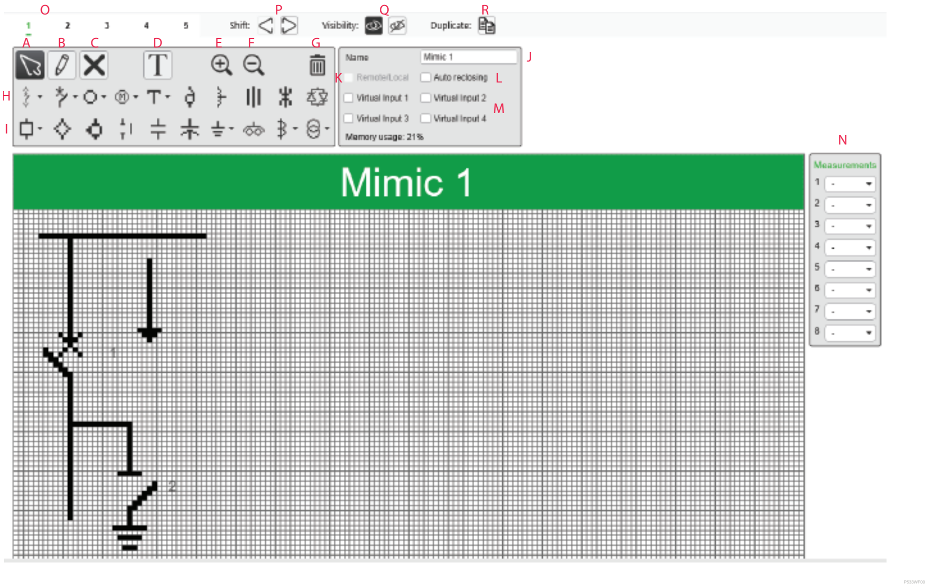
When pressing the mimic entry, the first mimic is shown on the local panel. The user can use the left/right navigation keys to switch between mimics. If the first mimic is currently displayed, only right navigation key is functional. If the 5th mimic is currently displayed, only left navigation key is functional. It is not possible to add or remove any mimic, but it can be hidden by clicking the **Visibility** button in the mimic configuration screen.

There are two ways to configure a mimic screen, from scratch, or from one existing mimic by clicking the **Duplicate** button located in the mimic configuration screen. The name and the content of each individual mimic can be edited. The content of each mimic is independent of the others. The user can click the left/right shift button to switch between mimic screens. The mimics can be configured in online mode (connected to the PowerLogic P5 by mini-USB port or Ethernet port) or offline mode.

Each mimic can display a single-line diagram, which can be created in eSetup Easergy Pro through the Mimic view of the **GENERAL** menu. Up to 8 analogue measurements (voltage, current, power...) based on the selection and up to 5 digital signals with fixed assignment can be displayed in one mimic. In order to display all the required information, the user can spread the information across multiple mimics.

Considering checking all the five mimics on default screen scenario, the user can use the up/down navigation keys to switch between mimics, and use the left/right navigation keys to view the **Main measurements**, firmware version and the **Alarm list** screens from the PowerLogic P5.

Figure 345 - Set up the Mimic view



Name: Mimic 1

Memory usage: 21%

A	**Cursor**: used to move an object To move an existing object, select the tool, point the cursor to the object until the object turns green and then drag and drop the object to the new position.
B	**Draw line**: used to draw lines in the view To draw a line, select the tool, click the left mouse button at the start point and then move the cursor to the second point and click again.
C	**Delete object**: used to delete an existing object from the view
J	Provides the PowerLogic P5 protection relay's location. The text comes from the **System info** view of the **GENERAL** menu
K	**Remote / Local** state Depending on the state, some settings and actions are not allowed The remote / Local state can be changed in the **Objects** view of the **CONTROL** menu.
L	**Auto reclosing** check box

To delete an object, select the tool, point the cursor to the object until the object turns red and click.

D **Text**: used to insert text in the view
To insert text, select the tool, click at the position to place the text and then, in the pop-up dialog box, type in the text and click the **OK** button.
Use the Cursor tool to move the text if necessary.

E **Zoom in**: used to increase the size of the view
To zoom in, click the tool until the view reaches the desired size.

F **Zoom out**: used to decrease the size of the view
To zoom out, click the tool until the view reaches the desired size.

G **Clear view**: used to remove all objects from the view
To clear the view, click the tool and select **OK** to confirm.

H Different choice of configurable objects
The object's number corresponds to the number in the **Object** menu.

I Some predefined drawings for use in the view.

To show or hide the Auto-reclosing state in the view

M **Virtual input x** check boxes
To show or hide the specified virtual inputs states in the view

N Up to 8 freely selectable measurements
To select the measurements to be shown in the view

O The sequence number of the mimic

P **Shift key**: used to switch between different mimics

Q **Visibility key**: used to hide/unhide the mimic

R **Duplicate key**: used to copy the current mimic

Table 160 - Mimic functionality

Parameter	Value	Description
Sublocation	Text field	Up to 20 characters. Fixed location.
Object 1–8	1–8	Double-click on top of the object to change the control number between 1 and 8. Number 1 corresponds to object 1 in **CONTROL** menu/ **Objects** sub menu.
Auto-reclosing	0 1	Possible to enable/disable auto-reclosing locally in local mode (L) or remotely in remote mode (R). Position can be changed.
Measurement display 1–8	Select the measurements from the drop down list	Up to 8 freely selectable measurements.
Virtual input 1–4	0 1	Change the status of virtual inputs while the password is enabled. Position can be changed.

Local panel configuration

The display and behavior of the PowerLogic P5 protection relay's local panel can be configured in the **GENERAL** menu/**Local panel conf** sub-menu of the eSetup Easergy Pro.

Table 161 - Local panel configuration

Parameter	Value	Note
Contrast of LCD screen	0–15	For PowerLogic P5x20 only.
Display backlight control	Selection of digital inputs (DI), one virtual inputs (VI), one virtual outputs (VO), or one function key (Fx).	
Backlight off timeout	0.0–2000.0 min	Configurable delay for backlight to turns off when the protection relay is not used. Default value is 60 minutes.

Table 161 - Local panel configuration (Continued)

Parameter	Value	Note
		When value is zero (0.0) backlight stays on all the time.
Display evt time not sync	Checked unchecked	Event time shown normally if relay is synchronized, or otherwise in brackets.
Object for control buttons	Object 1 - Object 6	
Mode for control buttons	Selective Direct	Two different ways of controlling the object using the control buttons (I/O) (see Controllable objects, page 561)
Fault value scaling	PU Primary	PU: analogue values displayed in % or x rated value; Primary: analogue values displayed directly in primary units.
Date style	yy-mm-dd dd.mm.yy mm/dd/yy	
Clear events	- Clear	
Default screen		Used to set the default home screen of the local panel.

Controllable objects

PowerLogic P5 protection relay allows the control of eight objects.

Objects represent all kinds of switchgear devices like circuit-breakers, disconnectors, isolator and grounding switches. Their control operation can be configured in "Select before operate" (*Selective*) or "direct control" (*Direct*) mode. Setting "Mode for control buttons" defines this mode for the control of one object (usually the CB) with the open (O) and close (I) buttons on the front panel of PowerLogic P5.

For control through SCADA communication this control mode is established within the protocol itself.

The object block matrix and logic functions can be used to configure interlocking to help ensure the control before the output pulse is issued.

Controlling of objects 1–8 is possible in the following ways:

- through the object control buttons (I/O)
- through the local panel and display using single line diagram
- through function keys
- through digital inputs
- through remote communication
- through eSetup Easergy Pro setting tool
- through Web HMI
- through the EcoStruxure Power Device application

The connection of an object to specific controlling outputs is done through the output matrix (object 1 – 8 open output, object 1 – 8 close output). There is also an output signal "Object failed" that is activated if the control of an object is not completed.

Object states

Each object has the following states:

Setting	Value	Description
Object state	Intermediate (00)	The object is under intermediate status, for example from open to close, or from close to open.
	Open (01)	Object is open
	Close (10)	Object is close
	Bad/faulty (11)	The object is under intermediate status, for example from open to close or from close to open, or the object is in bad/faulty status.

Basic settings for controllable objects

Each controllable object contains the following settings:

Setting	Value	Description
Object open DI	None, any digital input, virtual input or virtual output	Open information
Object close DI		Close information
DI for "obj ready"		Ready information
Max intermediate position time	0.02...600 s	The maximum duration of the intermediate position [153], this value represents the healthy state of the open/close motor of circuit breaker.
Max control pulse length	0.02...600 s	Pulse length for open and close commands. Control pulse stops once object changes its state
Completion timeout	0.02...600 s	Indication of object not ready
Object x control	Open/Close	Direct object control, x = 1 to 8.
Inactivity days limit	0...10000 day(s)	The duration of the object in undefined state (00 or 11).

The “Max intermediate position time” indicates the healthy state of the circuit breaker open/close motor. If the measured intermediate position time is longer than the setting, an alarm will be raised.

If changing the states takes longer than the time defined by the "Max control pulse length" setting, the object is inoperative, and the "Object failure" matrix signal is set. Also, an “undefined” event is generated.

"Completion timeout" is used to indicate when the object is not ready. If the “DI for object ready” is not set, this timeout does not make sense, but if the “DI for object ready” is set and the object is not ready for longer than the set duration of completion timeout, an “Object ready timeout” will be generated, the “Object failure” matrix signal will also be set.

NOTE: When **Object used for CB1** is set to *Object 7* or *Object 8*, the **Object open DI** of object 7 or 8 must not be set to the value *CB open remote*.

An alarm will be raised if the object stayed in undefined state (00 or 11) longer than the setting value of “Inactivity days limit”.

NOTE: The Object can only be controlled when its position is in a known state.

Output signals of controllable objects

Each controllable object has two control signals in the matrix:

Output signal	Description
Object x Open	Open control signal for the object, x = 1 to 8.
Object x Close	Close control signal for the object, x = 1 to 8.

---

[153] The duration of the intermediate position is counted by the object state from Open to Close or from Close to Open.

Local or remote control

In Local mode, the digital outputs can be controlled through the local panel, but they cannot be controlled from remote through a communication interface.

In Remote mode, the digital outputs cannot be controlled through the local panel, but only from remote through a communication interface.

The Local or Remote mode is selected by one selectable digital input or using the local/remote button on local panel. When digital input is configured to switch between Local and Remote mode, the local/remote button will not take effect and so when it is pressed an alarm message appears, to remind the user that a digital input is applied to switch the Local or Remote mode. It is in Local mode when the digital input is OFF, and it is in Remote mode when the digital input is ON.

The selection of digital input for the object control is made by 4 selections of **CONTROL/Objects/Control object x** (x = 1 to 8). The 4 selections are **DI for remote open control, DI for remote close control, DI for local open control, DI for local close control**.

Object control with digital inputs

Objects can be controlled with digital inputs, virtual inputs or virtual outputs. There are four settings for each controllable object:

Setting	Active
DI for remote open / close control	In remote state
DI for local open / close control	In local state

If the protection relay is in a local control state, the remote control inputs are ignored and vice versa. An object is controlled when a rising edge is detected from the selected input. The length of digital input pulse shall be at least 60 ms.

Object control with function keys

Each function key toggles an internal signal. This internal signal is available as an input of the output matrix, the block matrix, the auto-reclose matrix, the LED matrix and the object block matrix.

The function keys can also be used:

- To clear the minimum and maximum of current, voltage and power
- To clear the minimum and maximum of demand values and RMS demand values
- To select a setting group
- To select the IED modes (Normal / Test / Test-blocked)
- To enable / disable the auto-recloser
- To bypass the synchro-check
- As an input in the programmable logic

NOTE: If the backlight for the LCD display is switched off, pressing a function key for the first time will only light up the LCD display. The function assigned to the function key will only be triggered when this function key is pressed a second time. This configuration is also valid for the other local panel keys.

Depending on the model of the PowerLogic P5 protection relay, there are different number of available function keys on the local panel:

- F1 for PowerLogic P5 x20
- F1 to F7 for PowerLogic P5 x30

In eSetup Easergy Pro or Web HMI, the selection of function keys for the object control is made by 4 selections of **CONTROL/Objects/Control object x** (x = 1 to 8). The 4 selections are **DI for remote open control, DI for remote close control, DI for local open control, DI for local close control**

In eSetup Easergy Pro or Web HMI, the configuration of function keys is made in **CONTROL/Function buttons**. See Setting function buttons, page 564 for detail.

Setting function buttons

In the **CONTROL** menu/**Function buttons** sub-menu of the eSetup Easergy Pro or Web HMI, function buttons can be set to different type of functions:

- Fx (F1 to F7): work as function button. Status value will be changed between 0 and 1 on each pressing. The setting of pulse length is valid only when the function key is set to Fx type. When pulse length = 0, status value changes with each pressing of Fx, when length > 0, status value becomes to 1 when press, and change back to 0 after the delay time of pulse length setting.
- VI1...VI50: control the status of VI1 to VI50. VI value changes on each pressing.
- Object control: after set the function button to this value, you will have to make further settings in the **CONTROL** menu/**Objects** sub-menu of the eSetup Easergy Pro or Web HMI, in the section of Control object X, for example Control object 1, select Fx in **DI for local open control** or **DI for local close control**.
- Change test mode: if the function button is set to this function, when the button is pressed, you will be asked to set **Mode of use** (please refer to Mode of use for testing purposes, page 283) of the device.

Table 162 - Parameters for the function keys

Parameter	Value	Description
Status	0	Disabled
	1	Enabled
Selected control	V1...V50	Virtual input
	ObjCtrl	Object control
	Fn	Function key n
	ChgTstMod	Change the IED mode
Selected objects	-	No object selected
	xLocOpen; xLocClose	Shown when ObjCtrl is selected in the Selected control field.
Fn pulse length (0 = infinite)	0.00...600 s	Time delay common to all programmable function keys

Object control with I and O buttons

The PowerLogic P5 protection relay also has dedicated control buttons for objects. (**I**) stands for object closing and (O) controls object open command internally. When you press the **I** or O button on the local HMI, the HMI will display the configured object and a timer of 5 seconds. You can press the OK button within the 5 seconds to change the object to be controlled [154].

Press ⌂ button within the 5 seconds if you wish to cancel the open or close operation.

---

[154] The controlled object will be changed before next time you change it.

The configuration is made in eSetup Easergy Pro or Web HMI in **CONTROL/ Objects**, selection **Object for control buttons** and **Mode for control buttons**.

Table 163 - Parameters of control buttons

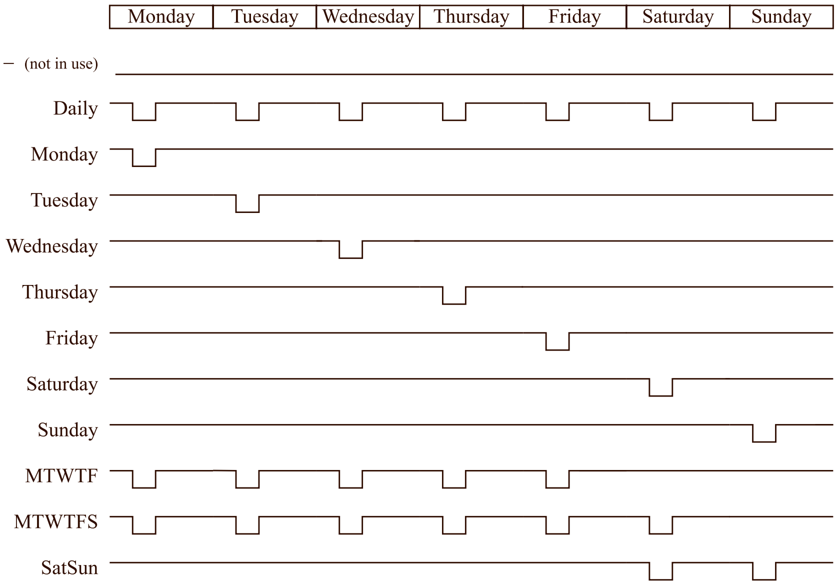
Parameter	Value	Unit	Description	Set
Object for control buttons	-		Disabled: the control buttons do not control any object.	Set
	Obj1...Obj8		Button I closes selected object if password is enabled. Button ○ opens selected object if password is enabled.	
Mode for control buttons	Selective		Control operation needs confirmation (select before operate)	
	Direct		Pressing the control button directly leads to action of the controled object.	

Timers

Description

The PowerLogic P5 protection platform includes four settable timers that can be used together with the user's programmable logic or to control setting groups and other applications that require actions based on calendar time. Each timer has its own settings. After setting the selected on-time and off-time you can then select whether the timer is activated every day or just selected days of the week (See the setting parameters for details). The timer outputs are available for logic functions and for the block and output matrices.

Figure 346 - Timer output sequence in different modes



You can force any timer, which is in use to on or off. The forcing is done by writing a new status value. Unlike the digital inputs no forcing flag is needed.

The forced timer status remains as forced until the next forced change or the next time the timer automatically changes status.

The status of each timer is stored in the non-volatile memory when the auxiliary power is switched off. At startup, the status of each timer is recovered.

Setting parameters

Table 164 - Setting parameters of timers

Parameter	Value	Description
Status	- 0 1	Not in use Output is inactive Output is active
On	hh:mm:ss	Activation time of the timer
Off	hh:mm:ss	De-activation time of the timer
Mode		For each four timers there are 12 different modes available:
	-	The timer is off and not running. The output is off, i.e. 0 all the time.
	Daily	The timer switches on and off once every day.
	Monday	The timer switches on and off every Monday.
	Tuesday	The timer switches on and off every Tuesday.
	Wednesday	The timer switches on and off every Wednesday.
	Thursday	The timer switches on and off every Thursday.
	Friday	The timer switches on and off every Friday.
	Saturday	The timer switches on and off every Saturday.
	Sunday	The timer switches on and off every Sunday.
	MTWTF	The timer switches on and off every day except Saturdays and Sundays
	MTWTFS	The timer switches on and off every day except Sundays.
	SatSun	The timer switches on and off every Saturday and Sunday.

Logic functions

PowerLogic P5 protection relay supports user-defined programmable logic for boolean signals. User-configurable logic can be used to create functionality that is not provided by the protection relay as a default. You can see and modify the logic in the **Logic** setting view of the **Control** menu in the eSetup Easergy Pro or Web HMI.

Table 165 - Available logic functions and their memory use

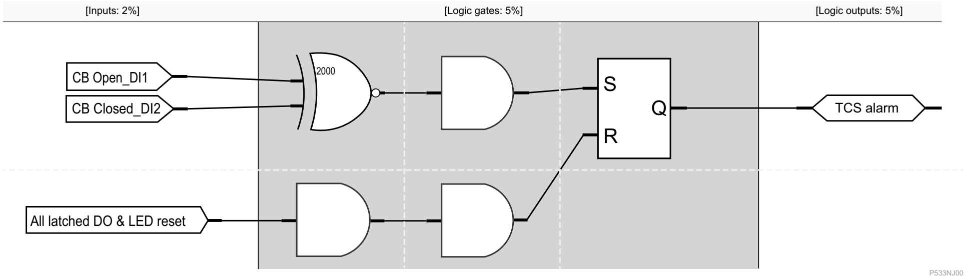
	Number of gates reserved	Maximum capacity	Maximum number of logic outputs
AND	1	Maximum number of logic gates = 120 Maximum number of signals per input = 120 Maximum number of signals = 120	20
OR	1		
XOR	1		
AND+OR	2		
CT (count + reset)	2		
INVAND	2		
INVOR	2		

Table 165 - Available logic functions and their memory use (Continued)

	Number of gates reserved	Maximum capacity	Maximum number of logic outputs
OR+AND[155]	2		
RS (set + reset)	2		
RS_D (set + D + load + reset)	4		

The consumed memory is dynamically shown on the configuration view in percentage. The first value indicates the memory consumption of inputs, the second value the memory consumption of gates, the third value the memory consumption of logic outputs, and the fourth value the memory consumption of outputs. The logic is operational as long as the memory consumption of the inputs, gates, logic outputs and outputs remains individually below or equal to 100%.

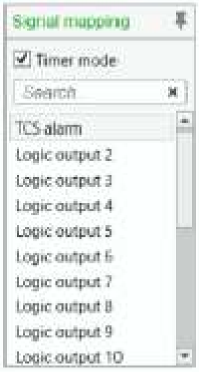
Figure 347 - Logic and memory consumption



Logic timer feature

PowerLogic P5 protection relay logic function can be used to manage accurate breaker control and alarms with flexibility thanks to the logic timer feature included. Logic timer feature offers the possibility of assigning a freely configurable time characteristic to the output signal of each Boolean equation. The logic timer can be displayed and modified in the eSetup Easergy Pro, the Web HMI, or through IEC 61850.

The logic timer feature could be configured by clicking on any Logic output in the logic diagram, a window of **Signal mapping** will be pop up:



☑ Timer mode

On **Signal mapping** window, make **Timer mode** setting checked, a Logic output (t) will be shown. By clicking on the Logic output(t), requested timer mode could be selected together with the dedicated time configured.

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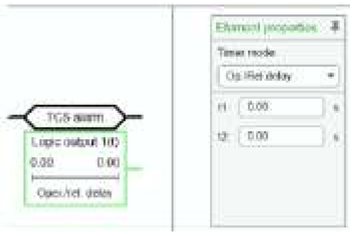
[155] by selecting “AND+OR” and ticking “Reverse”



Timer mode
Op./Rel delay
t1: 0.00 s
t2: 0.00 s

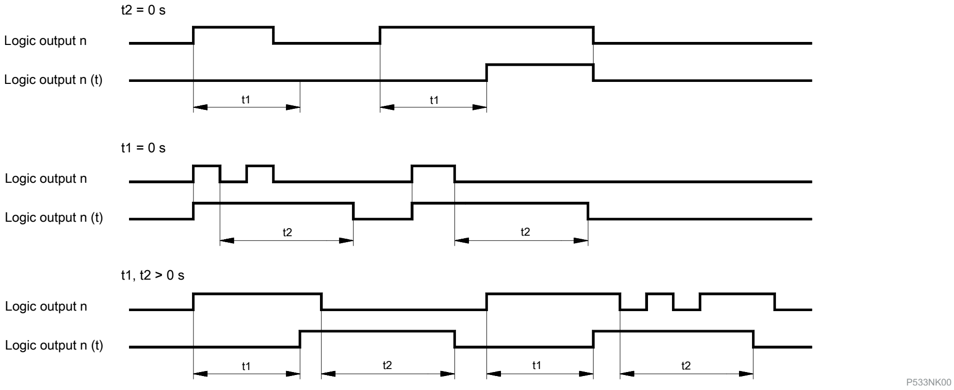
The protection relay’s HMI screen could display a countdown logic timer pop-up window. It could be enabled in the **Logic timers** view of the **Control** menu of eSetup Easergy Pro or the local panel. The popup window could be closed by pressing any key.

Table 166 - Settings and characteristics of the logic timer

Settings/characteristics	Value
Timer mode	
Setting range	Op./Rel.delay; Op.delay/Pulse; Op./Rel.retrig; Op./Pulse.retrig; Minimum time
t1	
Setting range	0...60,000.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms
t2	
Setting range	0...60,000.00 s
Resolution	0.01 s
Accuracy	±1% or ±20 ms

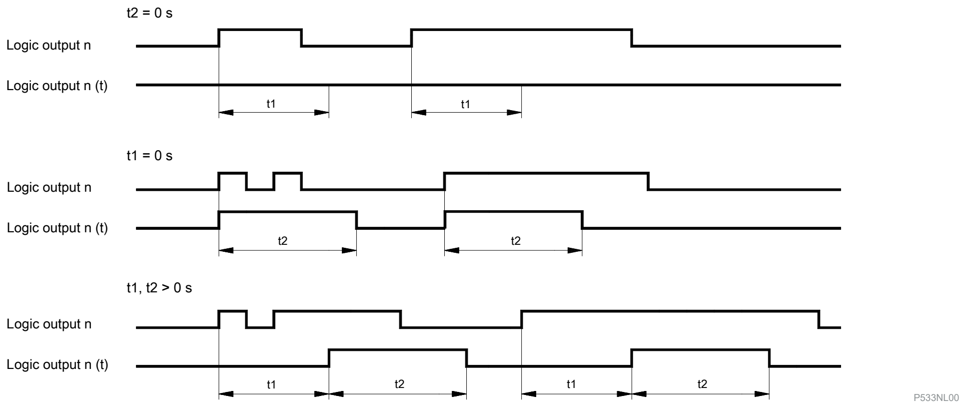
The following figures show the time characteristics for the various timer stage operating modes.

Figure 348 - Timer mode: Pickup/reset delay, non-triggerable (Op./Rel.delay)



t1	operate delay	t2	release delay

Figure 349 - Timer mode: Pulse, delayed pickup, non-triggerable (Op.delay/ Pulse)

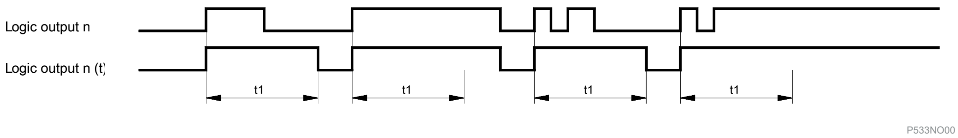


t1	operate delay	t2	pulse delay

Figure 350 - Timer mode: Pickup/reset delay, retriggerable (Op./Rel.retrig)

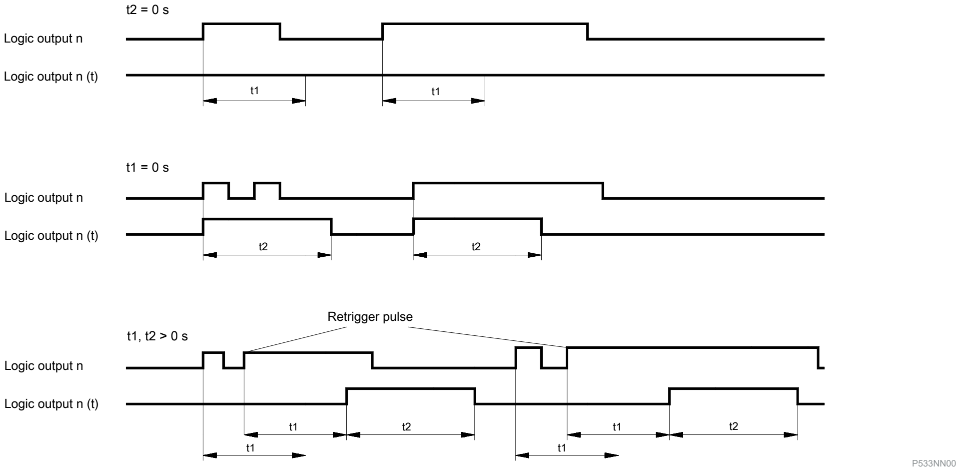
t1	operate delay	t2	release delay

Figure 351 - Timer mode: Minimum time (Minimum time)



t1 minimum time

Figure 352 - Timer mode: Pulse, delayed pickup, retriggerable (Op./Pulse. retrig)



t1	operate delay	t2	pulse delay

Table 167 - Logic gates

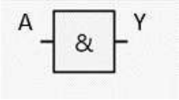
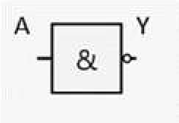
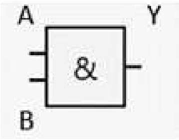
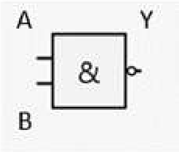
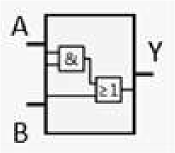
<table>
<tr><th>Logic gate</th><th>Symbol</th><th>Truth table</th></tr>
<tr><td>AND</td><td> </td><td><table><tr><td>In</td><td>Out</td></tr><tr><td>A</td><td>Y</td></tr><tr><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td></tr></table></td></tr>
<tr><td></td><td> </td><td><table><tr><td>In</td><td>Out</td></tr><tr><td>A</td><td>Y</td></tr><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td></tr></table></td></tr>
<tr><td></td><td> </td><td><table><tr><td colspan="2">In</td><td>Out</td></tr><tr><td>A</td><td>B</td><td>Y</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr></table></td></tr>
<tr><td></td><td> </td><td><table><tr><td colspan="2">In</td><td>Out</td></tr><tr><td>A</td><td>B</td><td>Y</td></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr></table></td></tr>
<tr><td>AND+OR</td><td> </td><td><table><tr><td colspan="2">In</td><td>Out</td></tr><tr><td>A</td><td>B</td><td>Y</td></tr><tr><td>0</td><td>0</td><td>0</td></tr></table></td></tr>
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Table 167 - Logic gates (Continued)

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<tr><td>0</td><td>1</td><td>1</td></tr>
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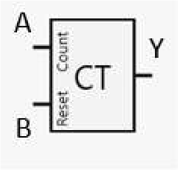
<tr><td>CT
(count+reset)</td><td>
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<tr><td>Cont</td><td>Reset</td><td>Setting</td><td>New</td></tr>
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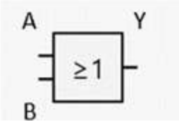
<tr><td>OR</td><td>
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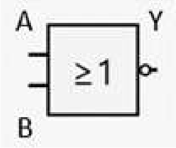
<tr><td></td><td>
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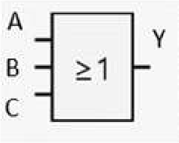
<tr><td></td><td>
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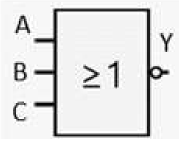
<tr><td></td><td>
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Table 167 - Logic gates (Continued)

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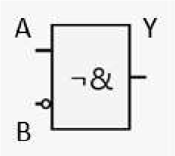
<tr><td rowspan="6">INVAND</td><td rowspan="6"> </td><td colspan="2">In</td><td>Out</td></tr>
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<tr><td>1</td><td>1</td><td>0</td></tr>
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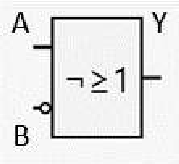
<tr><td rowspan="6">INVOR</td><td rowspan="6"> </td><td colspan="2">In</td><td>Out</td></tr>
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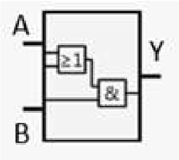
<tr><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td rowspan="6">OR+AND
(AND+OR reversed)</td><td rowspan="6"> </td><td colspan="2">In</td><td>Out</td></tr>
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<tr><td>1</td><td>0</td><td>0</td></tr>
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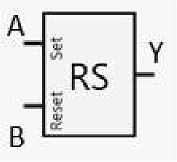
(set+reset)</td><td rowspan="6"> </td><td>A</td><td>B</td><td>Y</td></tr>
<tr><td>Set</td><td>Reset</td><td>Y</td></tr>
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<tr><td>1</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0 if last value of Y = 0
1 if last value of Y = 1</td></tr>
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Table 167 - Logic gates (Continued)

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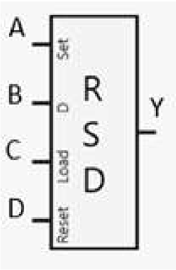
(set+D+load+reset)</td><td>
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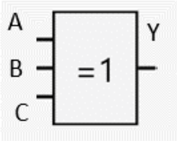
<tr><td>XOR</td><td>
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</table>

Advanced logic

PowerLogic P5 protection relay can also support an advanced programming tool (ISaGRAF™ Workbench of Rockwell Automation) for developing user-defined programmable logic. The advanced logic can be used in conjunction with the programmable logic to create a very flexible and strong logic capability. The programmable logic is optimized for execution speed whilst the advanced logic of ISaGRAF™ provides flexibility. Typically, high speed interlocks and tripping functions should use the programmable logic whilst less time demanding functions such as complex control functions are more suited to the advanced logic. ISaGRAF™ offers a solution compliant to the IEC 61131 and IEC 61499 standards.

To check if your PowerLogic P5 protection relay supports the advanced logic function, look up the second last letter of the model number. This model number can be found on the instruction label on the side plate of the device, see Equipment identification, page 48 for details, or on the device HMI in **Device/Test** menu, see Menu structure, page 256. The possible value of the second last letter varies in different firmware versions:

- For the firmware versions V01.40x.yyy or earlier:
  - C stands for Advanced logic and CS Basic.
  - D stands for Advanced logic and CS Advanced.
- For the firmware versions V01.500.101 or later:
  - F stands for Advanced logic and CS Settable (CS Basic or CS Advanced).

P 5 x _ _ - _ _ _ _ - _ _ _ _ _ - _ _ **C** _

P 5 x _ _ - _ _ _ _ - _ _ _ _ _ - _ _ **D** _

P 5 x _ _ - _ _ _ _ - _ _ _ _ _ - _ _ **F** _

ISaGRAF™ Workbench including text and graphics editors is used to develop specific custom applications in the following programming languages :

- SFC: Sequential Function Chart
- ST: Structured Text
- LD: Ladder Diagram
- FBD: Function Block Diagram
- SAMA: Scientific Apparatus Makers Association

PowerLogic P5 with ISaGRAF™ Runtime capability supports maximum 2048 boolean digital inputs and 128 boolean digital outputs. There is no limit on the number of gates and timers.

Table 168 - Settings and characteristics of the advanced logic

Settings/characteristics	Value
Inputs	
Number	2048 All boolean signals available in matrix.
Outputs	
Number	128 These outputs can be configured through matrix according to the application usage and can be used in the Programmable logic.
Execution rate	
Value	40 ms
Timer	
Accuracy	±1% or ±40 ms

The eSetup Easergy pro provides several parameters about the advanced logic function. **Project files CRC** is Cyclic Redundancy Check for project files, which is to check whether the content of the logic is changed. **Project name**, **Project comment**, **Configuration name** and **Configuration comment** can be customized in the ISaGRAF™ Workbench.

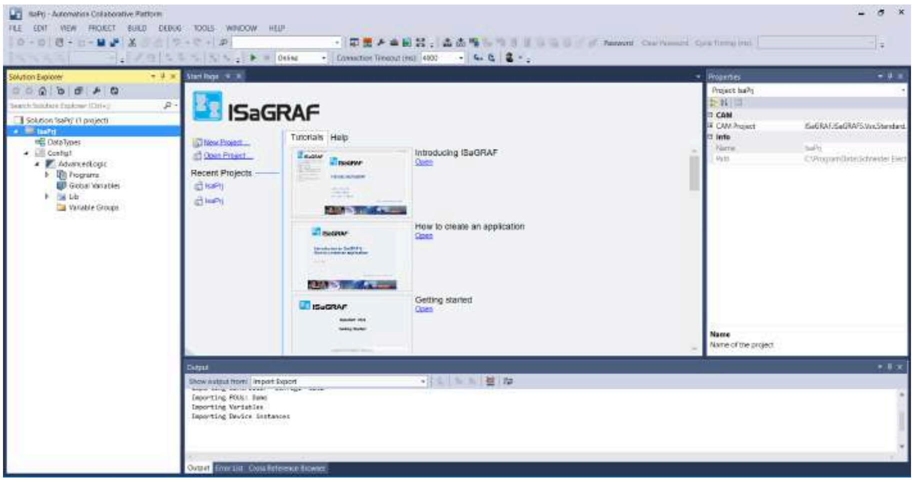
In order to create an advanced logic, the ISaGRAF™ Workbench software of Rockwell Automation needs to be installed on the computer and a license for activating the ISaGRAF™ is needed. For more information on the license, please contact RAisagraf_sales@ra.rockwell.com or local Rockwell Automation Sales Office.

Creating an advanced logic offline

1. When ISaGRAF™ Workbench with an active license is installed on the computer, the logic can be created by clicking the **Edit advanced logic** in the **CONTROL** menu/**Advanced logic** sub-menu via the eSetup Easergy Pro. Then a default project will be opened in the ISaGRAF™ Workbench automatically. Whilst editing using the ISaGRAF™ Workbench, Easergy Pro will be locked out.

   NOTE: Only PowerLogic P5 products with the correct order option will have the **Advanced logic** sub-menu.

Figure 353 - View of ISaGRAF™ Workbench of Rockwell Automation



```
Importing POUs: Done
Importing Variables
Importing Device Instances
```

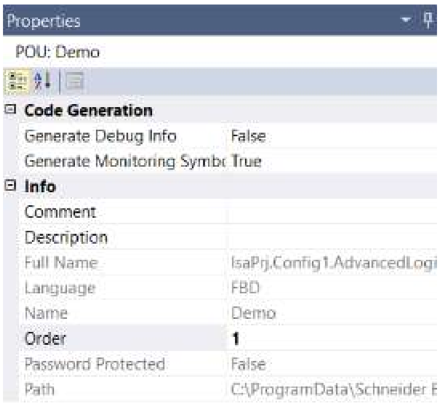
2. To create an advanced logic (in FBD as an example), double click **Demo**, which is under **IsaPrj**/**Config1**/**AdvancedLogic**/**Programs** at the left side of the ISaGRAF™ Workbench. To create an advanced logic in other programming languages, right click **Programs** and choose **add**. For more information on those properties and on building a logic in the ISaGRAF™ Workbench, click **HELP** on the title bar.

   The boolean signals of the PowerLogic P5 can be used as the variables in the ISaGRAF™ Workbench. The user can link the PowerLogic P5 signals to the variables in the ISaGRAF™ Workbench, by double clinking the variables in the logic diagram. The available signals include NI, DI, VI, VO, protection start or trip signals, and program logic output signals.

   PowerLogic P5 ISaGRAF™ logic supports a maximum of 128 boolean digital outputs. These outputs can be configured through matrix according to the application usage and can be used in the Programmable logic.

   When creating an advanced logic, in order to keep its performance, the following suggestions are recommended:

   - Try to create all the logic in one diagram. Logic is executed from top to bottom and from left to right in the ISaGRAF™ Workbench, thus follow this principle when creating logic.
   - If the logic is in multiple diagrams, pay attention to the order of those diagrams. Set the value of **Order** of the diagram, to be executed first, to 1 in the **Properties** panel, and so on.



POU: Demo

Code Generation	
Generate Debug Info	False
Generate Monitoring Symbc	True
Info	
Comment	
Description	
Full Name	IsaPrj.Config1.AdvancedLogi
Language	FBD
Name	Demo
Order	**1**
Password Protected	False
Path	C:\ProgramData\Schneider E

NOTICE

IMPROPER OPERATION

The property **resource name** should not be modified in the ISaGRAF™ Workbench.

Failure to follow these instructions can result in improper operation.

3. When the logic is built, click **Save** and close the ISaGRAF® workbench. A pop-up window showing the information “Do you want to attach advanced logic project (ISaGRAF™) to the configuration?” appears on the screen of the eSetup Easergy pro. Click **Yes**.
4. In the eSetup Easergy pro, click **Save as** to save the complete configuration file, which includes the created advanced logic, locally.
5. Connect the P5 device through the eSetup Easergy pro, and open the saved configuration file. Then **Write** the configuration file to the P5 device.

eSetup Easergy Pro is the only way to download ISaGRAF™ logic into P5 device. In the process of downloading, if there are invalid signals, an alarm window will pop-up (while the ISaGRAF™ program continues to run).

Updating an advanced logic online

1. Connect the P5 device through the eSetup Easergy Pro.

2. Click the **Edit advanced logic** in the **CONTROL** menu/**Advanced logic** sub-menu via the eSetup Easergy Pro.
3. Update the advanced logic in the ISaGRAF™ Workbench.
4. After updating, click **Save** and close the ISaGRAF™ Workbench. Then A pop-up window appears on the screen of the eSetup Easergy pro. Click **Yes**.
5. **Write** the configuration file to the P5 device via the eSetup Easergy Pro.

eSetup Easergy Pro is the only way to download ISaGRAF™ logic into P5 device.

Commissioning

NOTICE

CYBER SECURITY

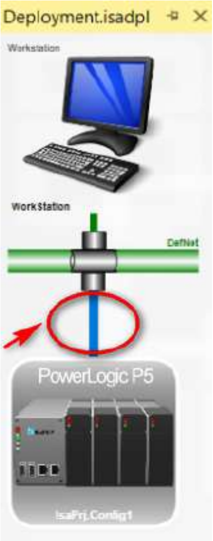
The ISaGRAF™ debugging protocols do not include security capabilities, the data transmission is in plain text. For this reason, this function must be used in secured communication networks only.

It is strongly recommended to disable this function in normal operation mode, as with default settings.

Failure to follow these instructions can result in improper operation.

PowerLogic P5 supports the online commissioning function of the advanced logic. To enable the online debug, please: in eSetup Easergy Pro, go to the **Communication** menu, in the section **Protocol configuration**, uncheck the setting **Disable advanced logic port**.

1. Click **IsaPrj**. Then click **VIEW** on the title bar, and choose **Deployment View**.
2. Select part of the wire connecting the PowerLogic P5 in the deployment window.



3. Enter the IP address of the mini-USB port or the Ethernet port of the PowerLogic P5 in the **Properties** panel at the right side of the ISaGRAF™ Workbench.
4. **Save** the configuration, click **BUILD** and choose **Build Solution the logic**.
5. Download the advanced logic via the ISaGRAF™ Workbench to the P5 device by right clicking **IsaPrj**, and then select **Download**.

6. Select **Online** and click **Start Debugging button**.

The commissioning includes:

- Users can commission the logic in the ISaGRAF™ Workbench to highlight which part of the logic is being activated.
- Users can assign different values to the input to simulate the output to check the correct behavior of the logic.

For more information on how to assign the values to the inputs in the simulation mode, please refer to the **HELP** on the title bar of the ISaGRAF™ Workbench.

NOTE: To commission an advanced logic, download it via the ISaGRAF™ Workbench (see Commissioning, page 577). After the commissioning, to execute the logic, **Write** it to the P5 device via the eSetup Easergy Pro.

Switchgear control and monitoring

Switchgear control and fail-safe position

For the PowerLogic P5 protection relay, operational reliability helps ensure the safety and availability of the installation.

This means avoiding the following 2 situations:

- Nuisance tripping of the protection

  Continuity of the electrical power supply is as vital for a manufacturer as it is for an electricity distribution company. Nuisance tripping caused by the protection can result in considerable financial losses. This situation affects the availability of the protection.

- Failure of the protection to trip

  The protection relay must detect faults in the electrical power system as quickly as possible.

  Power network systems consist of a set of components (cables, switchgear, protection relays, measurement transformers, MV/LV transformers, etc.) whose correct operation may be affected by failures. The consequences of failure of one of the power system components are varied and depend on factors specific to each power system.

  These include:

  - Power system topology
  - Type of connected users
  - Load types
  - Position of each component in the power system
  - Failure mode for each component, etc.

  In case a power system fails, it is the responsibility of the user to prioritize either continuity of the electricity supply, or shutdown of part of the power system. While designing the power system and its protection plan, knowledge of the failure modes for each element can be used to steer the failure into a particular state. This requires the failure mode for the power system elements to be as deterministic as possible.

  To comply with this approach, the PowerLogic P5 protection relay is equipped with self-tests that continuously check all its electronics and embedded software are operating correctly. The purpose of the self-tests is to put the PowerLogic P5 protection relay into a deterministic position, called the fail-safe position, in the event of failure or malfunction of one of its internal components. In the fail-safe position the PowerLogic P5 protection relay is no longer operational. All its output relays are forced into the default position and the power system is no longer protected. If the auxiliary power supply disappears, the PowerLogic P5 protection relay's contact relays are also in the off-position.

  The table below indicates the possible types of behavior in the event of PowerLogic P5 protection relay failure. Use in standard mode or in custom mode is described in the sections below.

Circuit Breaker with Shunt Trip Coil	Circuit Breaker with Undervoltage Trip Coil
The circuit breaker stays closed if PowerLogic P5 protection relay goes into the fail-safe position. Monitoring is required to detect whether the protection is no longer operational.	The circuit breaker opens automatically if PowerLogic P5 protection relay goes into the fail-safe position. The circuit breaker opens if the substation auxiliary voltage disappears.

Selecting the trip command and examples of use

NOTICE

RISK OF UNPROTECTED ELECTRICAL INSTALLATION

Always connect the watchdog output to a monitoring device to mitigate and take appropriate action when the selected trip command does not result in the installation tripping or when the PowerLogic P5 protection relay fails.

Failure to follow these instructions can result in unprotected electrical installation.

An analysis of the operational reliability of the whole installation should determine whether availability or safety of this installation should be prioritized if PowerLogic P5 protection relay is in the fail-safe position. This information is used to determine the choice of trip command as outlined in Selecting the trip command, page 580.

Table 169 - Selecting the trip command

Diagram	Control	Event	Trip	Advantage	Disadvantage
1	Shunt trip breaker or mechanical latching contactor	Internal failure or loss of the auxiliary power supply	No	Availability of the installation	Installation not protected until remedial intervention
2	Breaker with undervoltage trip coil (fail-safe)	Internal failure or loss of the auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention
3	Breaker with undervoltage trip coil (not fail-safe)	Internal failure	No	Availability of the installation	Installation not available until remedial intervention
		Loss of auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention
4	Contactor without coil latching (permanent order)	Internal failure or loss of the auxiliary power supply	Yes	Safety of the installation	Installation not available until remedial intervention

Figure 354 - Example of use with shunt trip coil (diagram 1)

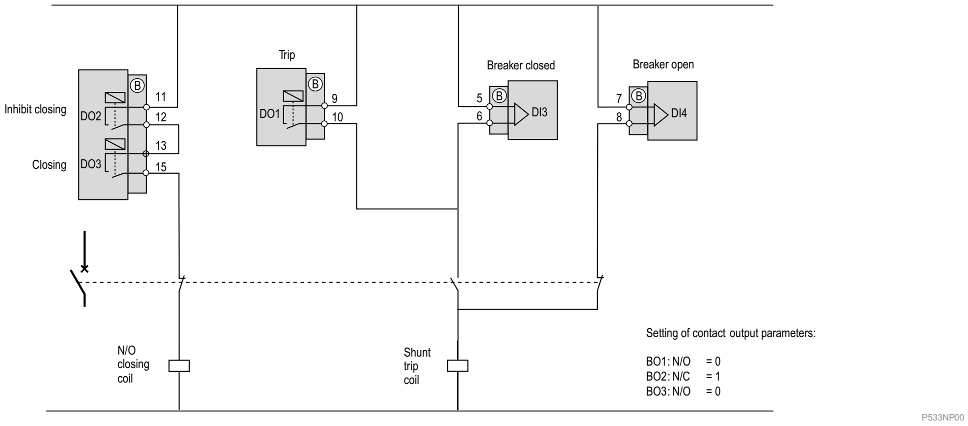


Figure 355 - Example of use with undervoltage trip coil with fail-safe condition (diagram 2)

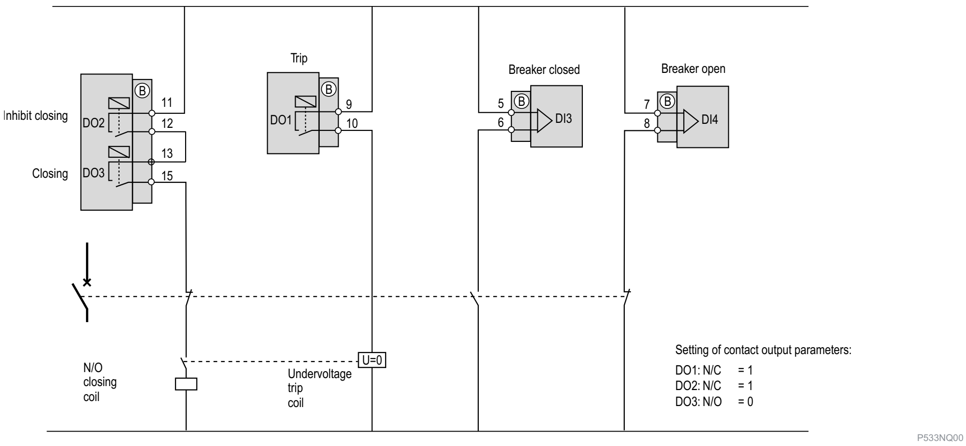
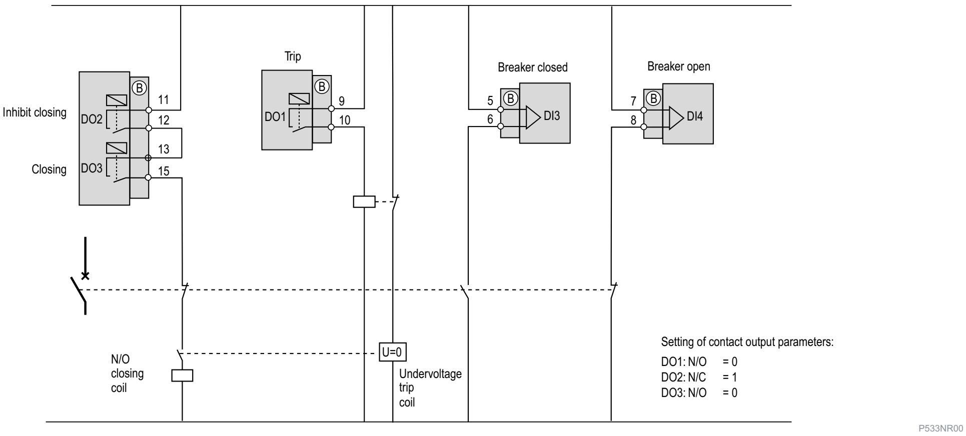
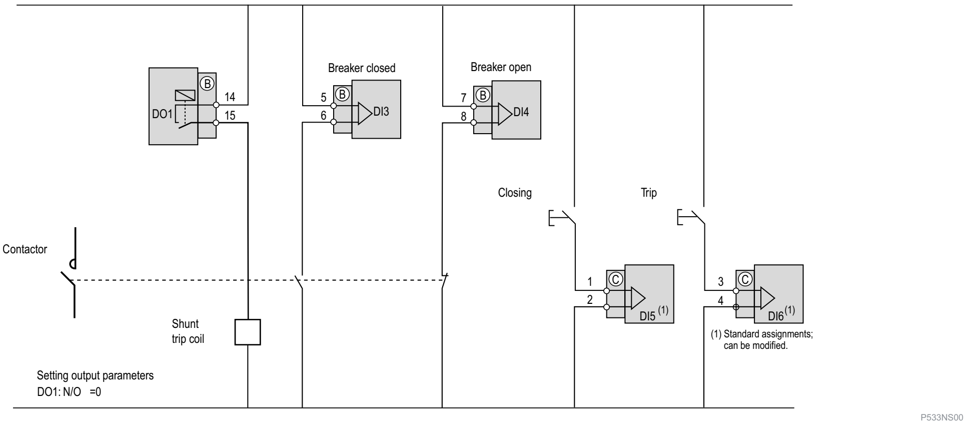


Figure 356 - Example of use with undervoltage trip coil without fail-safe condition (diagram 3)



NOTE: When using an undervoltage trip coil, it is recommended to install a free wheel diode in parallel to the opening coil in order to slow down its operation in the event of a microbreak on its power supply.

Figure 357 - Example of use with contactor under permanent order command (diagram 4)



Programmable switchgear interlocking

Switchgear interlocking can be easily done using the object block matrix.

For example, if object 1 is the circuit breaker, object 2 the isolating switch, and object 4 the ground switchgear, the blocking scheme could be configured as below:

1. When CB is closed, the isolating switch open operation is blocked.
2. When ground switchgear is closed, the CB close operation is blocked.

Local control on single-line diagram

The objects can be controlled directly on the local panel in the mimic screen that includes the single-line diagram.

1. Press the OK key.
2. With the ◁ and ▷ arrow keys, select the object, or one of the four virtual inputs, or the auto-reclosing (if they are displayed in the mimic).
3. Press the OK key to bring up the menu list.
4. Select Open or Close and then press the OK key.

   NOTE: Only the objects configured connected in Output matrix can be selected in Mimic screen.

Logging and recording functions

Time tagging

For operations and fault analysis all data are logged with an accurate date and time.

The items that are time tagged and logged are:

- Events
- Disturbance recording
- Fault data logging
- Voltage interruptions
- Maximum and minimum values of the last 31 days or last 12 months

The PowerLogic P5 protection relay time stamp resolution is 1 ms.

Event buffer

The PowerLogic P5 protection relay provides a logging and recording of all important events that happen during operation. All “operationally relevant” signals, each fully tagged with date and time at signal start and signal end, are registered and stored in chronological order. For example, an event can be, start-on, start-off, trip-on or trip-off of any protection stage, alarm-on or alarm-off, a digital input change, and so on. Each event is associated with a unique code. The selection of signals to be considered in the event logging and recording can be configured by the user.

As an example, a typical trip event is shown in Example of 50/51/67-1 trip-on event and its visibility in local panel and communication protocols, page 584.

Table 170 - Example of 50/51/67-1 trip-on event and its visibility in local panel and communication protocols

Event	Description	Local panel	Communication protocols
Code CHENN: 01E02	CH = event channel, channel 1 NN = event code, event 2	No	Yes
A-B-C	Fault type	Yes	No
Event desc: 50/51/67-1 trip on 2 pu	Event text and fault value	Yes	No
yyyy-mm-dd: 2018-01-31 hh:mm:ss:nnn: 08:35:13.413	Date Time	Yes	Yes

Timestamp is truncated to 1 ms in event list. The logged events can also be read using:

- Local panel (see the **Events list** view under the **Events** option of the **Logs** menu)
- eSetup Easergy Pro or Web HMI (see the **Event buffer** view in the **LOGS** menu)
- Communication: In this case, only the latest event can be read.

On the local panel, the code is replaced by a ranking number.

With eSetup Easergy Pro, the events can be stored to a file, which is very helpful if the PowerLogic P5 protection relay is not connected to a SCADA system.

SCADA systems are reading events using any of the available communication protocols.

Event configuration

To configure which events are recorded the event enabling matrices are used (see the Event enabling views in the **LOGS** menu of eSetup Easergy Pro). This allows the optimization of reporting by selecting the most useful events and deselecting the ones of no interest. This prevents them from being written to the event buffer.

- Event enabling - stages 1

  This matrix is used to activate an event when there is a change of the Start and Trip status of a protection function/ stage. Select **On**, **Off** or **both**.
- Event enabling - stages 2

  This matrix is similar to the Event enabling - stages 1 matrix but dedicated to functions which provide more information than start and trip signals (e.g. thermal image protection).
- Event enabling - objects

  This matrix is dedicated to generate events associated to the defined objects such as circuit breaker status and controls.
- Event enabling - AR

  This matrix is dedicated to the auto recloser function and is used to generate events associated with auto reclose states and status.
- Event enabling - logic

  This matrix is used to generate events when one of the logic equations (up to 20) gets true or false.
- Event enabling - logic (t)

  This matrix is used to generate events when one of the logic (t) equations (up to 20) gets true or false.
- Event enabling - Global trips

  This matrix is used to generate events when one of the General trips or General starts gets true or false.
- Event enabling - DO

  This matrix is used to generate events of DO On/Off.
- Event enabling - other

  This matrix is dedicated to system monitoring including setting group change.
- Event enabling - AI/O

  This matrix is used to generate Analogue I/O On/Off event.

The maximum size of the buffer is 2000 events and can be exported as a PDF file from eSetup Easergy Pro **Print** menu. 300 events can be displayed by eSetup Easergy Pro. Only the latest 300 events, or the oldest 300 events, can be read on the local panel according to the scroll order parameter.

All events are stored in non-volatile memory inside the PowerLogic P5 protection relay and can be saved every 150 ms in the backup memory if available (Extension board option).

When the buffer is filled the oldest event will be overwritten when a new event occurs. The shown resolution of a time stamp for an event is one millisecond, but the actual resolution depends on the particular function creating the event. For example, most protection stages create events with a 5 ms, 10 ms or 20 ms resolution. The absolute accuracy of all time stamps also depends on the protection relay's time synchronization.

Event buffer overflow

The normal procedure is to poll events from the PowerLogic P5 protection relay all the time. If this is not done, the event buffer could reach its limits. In that case, the oldest event is deleted and the newest is displayed with an OVF (overflow) code on the local panel.

The Event setting parameters can be configured in **Logs**/**Event logs**/**Counter** of the local panel .

Characteristics

Table 171 - Setting parameters for events

Parameter (description/label)	Value	Description
Clear events/Clear events	-	
	Clear	Clear the buffer of events
Fault value scaling/Fault value		Scaling of event fault value
	PU	Per unit scaling
	Primary	Primary scaling
Display evt time not in sync/Event synchro.	On (check mark)	Event time shown normally if relay is synchronized
	Off	Event time is shown in brackets if relay is not synchronized

Table 172 - Measured and monitored parameters for events

Parameter (description/label)	Value	Description
Event buffer size/ Counter	2000	Event buffer size

Disturbance recording

Description

The PowerLogic P5 protection relay provides for fault events a disturbance recording with the sampled analogue values of pre-selected analogue currents and voltages before, during and after a fault event. Additionally, the calculated frequency, the states of digital inputs (DI) and output (DO) signals are provided for detailed fault analysis. The complete list of provided signals is shown in Disturbance recording parameters (measurements and monitored values), page 589.

Triggering the recording

The recording can be triggered by any start or trip signal from any protection stage, by a digital input, logic output or GOOSE signals. The triggering signal is selected in the output matrix (vertical signal DR). The recording can also be triggered manually. All the recordings are time stamped. The recording can be made at 48 samples/cycle or 24 samples/cycle rate.

Reading recordings

The recordings can be downloaded with eSetup Easergy Pro. The recording is in COMTRADE format. This also means that other programs can be used to view and analyse the recordings made by the PowerLogic P5 protection relay.

PowerLogic P5 disturbance records can be read as well thru IEC 61850 and DNP3 ethernet protocols and DNP3 and IEC 60870-5-103 serial communication protocols. In case disturbance record is downloaded with sFTP, PowerLogic P5 generate and compress disturbance recorder COMTRADE data file with DEFLATE format (rfc1950) by using public domain zlib functions. To decompress the COMTRADE data file, please follow inflate API process defined in Zlib specification. For detail, please visit home page of zlib (http://www.zlib.net/).

Number of channels

A maximum of 30 records can be stored with a mix of analogue and digital signals:

- 14 Analogue signals
- 124 Digital Signals (40 Digital inputs; 20 Digital outputs; 32 Start signals; 32 Trip signals)

A pre-selection of the channels and their order in the fault recording is made per default and can be changed by the user with the parameters shown in Disturbance recording parameters (measurements and monitored values), page 589.

Table 173 - Examples of disturbance recording durations

Selected signals	Maximum time setting
4 analogue input signals, up to 40 digital input signals , up to 20 digital output signals , start and trips signals[156][157]	48/cycle: 6.06 s 24/cycle: 12.12 s
4 analogue inputs and trip signals	48/cycle: 10.92 s 24/cycle: 21.86 s
4 analogue inputs, start and trip signals	48/cycle: 9.10 s 24/cycle: 18.20 s
8 analogue signals, up to 20 digital input signals, up to 20 digital output signals and trip signals	48/cycle: 4.96 s 24/cycle: 9.92 s
8 analogue signals, up to 20 digital input signals, up to 20 digital output signals, start and trip signals	48/cycle: 4.55 s 24/cycle: 9.10 s
9 analogue input signals, frequency, up to 40 digital input signals, up to 40 digital output signals, all start and trip signals	48/cycle: 3.41 s 24/cycle: 6.82 s

---

[156] Digital input signal means digital inputs (DI), virtual inputs (VI), etc.

[157] Digital output signal means digital outputs (DO), virtual output (VO), etc.

NOTE: eSetup Easergy Pro provides directly the maximum recording length when the signals to record are selected (see the bottom section of the Disturbance recording view in the General menu).

NOTE: If the disturbance record is not correctly displayed in eSetup Easergy Pro, please try to change the setting of Encoding in Wavewin. You can find the .exe file from ...\Easergy Pro\Wavewin\Wavewin.exe. Double click **wavewin32.exe**, click on **Options**/**Display** from the menu bar, in pop-up **System Settings** window, select **Language** tab, then change the setting of **Encoding:** to UTF8, click **Ok** button.

Parameters

Table 174 - Disturbance recording parameters (measurements and monitored values)

Parameter (description/label)	Value	Description
Sample rate/SR		Sample rate per cycle (two options to select: 48/cycle or 24/cycle)
Maximum time setting/MaxLen		Maximum time setting (in second) This value depends on the number and type of the selected channels and the configured recording length.
Status/Status		Status of recording
	-	Not active
	Run	Waiting for a triggering
	Trig	Recording
Add recorder channel/AddCh		Add one channel. The maximum number of channels used simultaneously is 16. **NOTE:** For P5T30 or P5L30, delete one channel first if you want to add an extra channel. The maximum number of channels for DR is 16, so it is not possible to add more channels, even if it is a valid channel.
	IA, IB, IC	Phase current
	IN	Measured neutral current by CSH or CTs according to the model of PowerLogic P5
	VAB, VBC, VCA	Phase to phase voltage (only available in three voltage measurement modes: 2VPP+VN, 2VPP+VN+VPPy, VPP/VPPy)
	VA, VB, VC	Phase to neutral voltage (only available in four voltage measurement modes: 3VP, 3VP/VPy, 3VP/VPPy, 3VP+VN)
	VN	Neutral voltage
	f	Frequency (reference side)
	IN.sens	Sensitive neutral current
	VABy	Phase to phase voltage taken from other side of the CB for synchro-check scheme
	VAy	Phase to neutral voltage taken from other side of the CB for synchro-check scheme
	fy	Frequency (comparison side)
	DI	Digital inputs 1-20 and virtual inputs 1-4 status
	Other DI	The remaining digital inputs available and the function keys status
	DO	All digital outputs and virtual outputs 1-6 status

Table 174 - Disturbance recording parameters (measurements and monitored values) (Continued)

Parameter (description/label)	Value	Description
	Starts	Start signals of all enabled protection functions
	Trips	Trip signals of all enabled protection functions
Remove all channels/ClrCh	-; Clear	Remove all channels

Table 175 - Disturbance recording parameters (settings)

Parameter (description/label)	Value	Description
Recording length/Time	0.1...30 s	Recording length (in second)
Pre trigger time/PreTrig	0...100%	Amount of recording before triggering
Disturbance recording event	On (checkmark); Off	The event log is created or not when Disturbance recording is triggered.
Recording memory events	On (checkmark); Off	The event log is created or not when Disturbance recording is reset (clear the recording, reset the time and so on).
Manual triggering/ManTrig	-; Trig	Command to launch manually a new disturbance recording
Clear oldest buffer/Clear	-; Clear	Clear the oldest disturbance recording
Clear all buffers/ClrAll	-; Clear	Clear all the disturbance recordings

The selection of signals depends on the model of PowerLogic P5 protection relay and also on the voltage measurement mode.

Characteristics

Table 176 - Disturbance recording characteristics

Characteristics	Values	Note
Sample rate	48 samples/cycle 24 sample/cycle	
Recording time (one record)	0.1...30 s	
Pre-trigger rate	0...100%	
Number of selected analog channels	0...16	
File format	IEC 60255-24:1999 IEC 60255-24:2013	ASCII format

The recording time and the number of records depend on the time setting and the number of selected channels.

Voltage interruptions

Description

The PowerLogic P5 protection relay includes a simple function to detect voltage interruptions. The function calculates the number of voltage interruptions and the total time of the voltage-off time within a given calendar period. The period is based on the relay's real-time clock. The available periods are:

- 8 hours, 00:00...08:00, 08:00...16:00, 16:00...24:00
- one day, 00:00...24:00
- one week, Monday 00:00...Sunday 24:00
- one month, the first day 00:00...the last day 24:00
- one year, 1st January 00:00...31st December 24:00

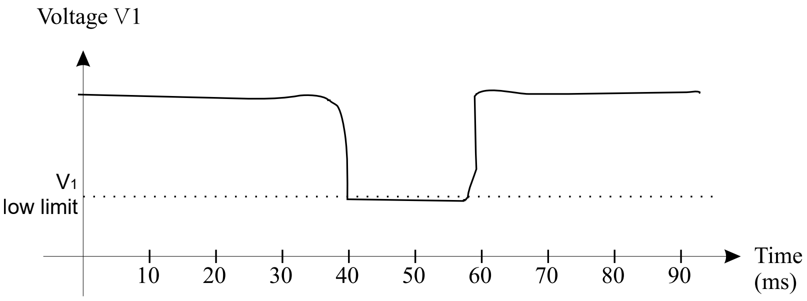
After each period, the number of interruptions and the total interruption time are stored as previous values. The interruption counter and the total time are cleared for a new period. Previous values are overwritten.

Voltage interruption is based on the value of the positive sequence voltage V1 and a set limit value. Whenever the measured V1 goes below the limit, the values of the interruption counter and the total time counter starts are incremented.

The shortest recognized interruption time is 40 ms. If the voltage-off time is shorter, it may be recognized depending on the relative depth of the voltage dip.

If the voltage has been significantly above the limit V1< and then there is a small and short under-swing, it is not recognized.

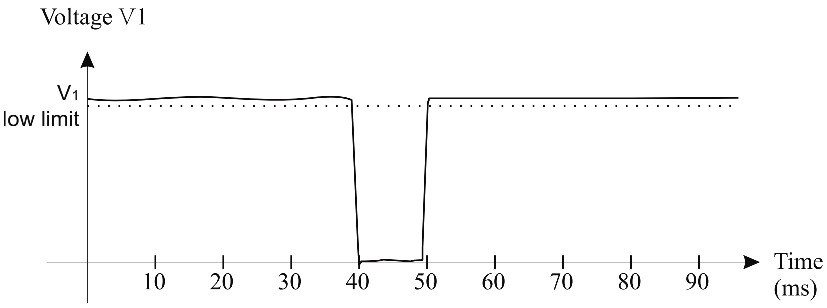
Figure 358 - A short voltage interruption which is probably not recognized



A533K100

On the other hand, if the limit V1< is high and the voltage has been near this limit, and then there is a short but very deep dip, it is recognized.

Figure 359 - A short voltage interrupt that will be recognized



A533K200

Settings and measurements

The following Setting parameters of the voltage interruption function, page 592 describes the setting parameter used for the voltage interruption and Measured and recorded values of the voltage interruption function, page 592 shows the related measured values available.

Table 177 - Setting parameters of the voltage interruption function

Parameter	Value
Setting range	10%...120% Vnom[158]
Resolution	1% Vnom[158]
Reset ratio	> 103%
Accuracy	3%
Int. Calc. period/Period	
Options	8h; Day; Week; Month; Year
Characteristic time	
Start time	< 60 ms
Disengaging time	< 60 ms

Table 178 - Measured and recorded values of the voltage interruption function

	Parameter	Value	Description
Measured value	Voltage	LOW; OK	Current voltage status
	V1		Measured positive sequence voltage
Recorded values	Interruption counter/Count		Number of voltage interruptions during the current observation period
	Prev. # of interrupts/Prev		Number of voltage interruptions during the previous observation period
	Total interrupt time/ Total		Total (summed) time of voltage interruption during the current observation period **NOTE:** Total interrupt time "5 20" means 5 days and 20 hours.
	Previous total int. time/Prev		Total (summed) time of voltage interruption during the previous observation period

---

[158] Vnom

Fault data logging

Fault log provides fault signals including the measured fault data captured during a fault sequence. The fault logs are logged in chronological order with reference to the specific fault.

A new fault log is triggered by a starting signal of a protection function.

As an example, a typical fault log is shown in Example of 50/51/67-1 LOG and its visibility in local panel and communication protocols, page 593.

There is detailed information available of the eight latest faults: date, time stamp, setting group active, fault type, fault phase, fault value, I/Vpole angle, elapsed delay, pre-fault current and fault direction.

The information can be different according to the protection functions.

Table 179 - Example of 50/51/67-1 LOG and its visibility in local panel and communication protocols

Parameters (description/label)	Value	Description
Date/Date	2022-02-28	Time stamp of the fault log, date
hh:mm:ss:ms	13:28:41.321	Time stamp, time of day
Group/SetGrp	1	Active setting group during fault
Fault type/Fault type	A-N	Fault type
Fault phase/Fault phase	A	Fault phase
50/51/67-1 fault value/ Fault value	5.00 pu	Maximum fault current
I/Vpol angle	120°	I/Vpol angle
Elapsed delay/End delay	100%	Elapsed time of the operating time setting. 100% = trip
Pre-fault current/Pre-fault current	0.00 pu	1 s average phase currents before the fault
Fault direction	Forward	Fault direction

Table 180 - Example of VT supervision and its visibility in local panel and communication protocols

Parameter (description/label)	Value	Description
Date/Date	2018-02-12	Time stamp of the fault log, date
hh:mm:ss:ms	09:45:15.245	Time stamp, time of day
V2 value/V2	x V	Negative sequence voltage
I2 value/I2	x A	Negative sequence current

The fault logs can be read via:

- Local panel

  In the **Log** view of each protection function in the **Protection** sub-menu
- eSetup Easergy Pro or Web HMI

  In each protection function view in the **Protection** menu
- Communication

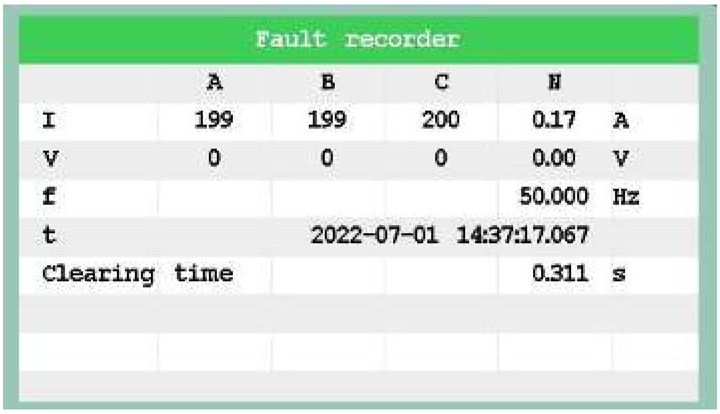
  In this case, only the latest fault logs can be read.

Fault recorder

PowerLogic P5 provides a dedicated fault recorder panel to display the last fault information. Compared to the fault data logging, fault recorder can provide additionally the magnitude of all the phases.

Fault record is triggered instantaneously by general trip signal. This function records the fault information after one power cycle since the global trip is issued.

Figure 360 - An example of fault recorder in P5x30 local panel



Fault recorder

	A	B	C	N	
I	199	199	200	0.17	A
V	0	0	0	0.00	V
f				50.000	Hz
t		2022-07-01 14:37:17.067			
Clearing time				0.311	s

> **NOTE:** The fault record is displayed only on local HMI, or been transferred by IEC 61850.

From the fault recorder panel, you will find the following information:

- IA, IB, IC magnitudes in primary [A]
- VA, VB, VC magnitudes in primary [V]
- IN.calc (derived value regardless sensing mode) in primary [A]
- VN.calc (derived value regardless voltage connection mode) in primary [V]
- Frequency magnitude f in [Hz]
- Trip time stamp (= Time when global trip (on event))
- Clearing time (the interval from trip to CB open) = Time when CB open (on event) – Time when global trip (on event)

Access fault recorder screen

After a fault occurred, the fault record can be read from local panel. There are two methods to access:

- When alarm messages popup or current view is the home screen, press ⓘ key to access the **Fault recorder** screen to check the last fault information in detail.
- After setting *Fault recorder* as default screen (in the eSetup Easergy Pro software, in **GENERAL**/**Local panel conf**.), when default screen is displayed, press ◁ or ▷ key to access the **Fault recorder** screen.

Figure 361 - Setting Fault recorder as default screen

Default screen: Mimic

Reset fault recorder value

Fault recorder value can be reset by following one of the two methods:

- On local panel, go to **LOGS & ALARMS /Fault recorder** screen, select *Clear* option.

Fault recorder 1/1

Edit:Clear fault recorder

- In eSetup Easergy Pro, go to **Device/Clear** page, enable the **Clear fault recorder** checkbox, then click **OK**.

After the reset operation, all the values will be reset to default values.

InterRelay communication log

The InterRelay communication log records the following events:

- Comm link failure on/off
- Comm failure on/off
- Comm error on/off
- Address not paired on/off
- Loopback test mode on/off
- Loopback test OK on/off
- Loopback test NOK on/off

The InterRelay communication logs can be enabled/disabled by eSetup Easergy Pro in **LOGS**/**Event enabling – other**, in the **InterRelay communication** section.

Running hour counter

Description

The running hour counter is typically used to monitor the service time of the motor or appropriate feeder. This function calculates the total active time of the selected digital input, virtual I/O or function key. The resolution is 10 seconds.

Settings / characteristics

Table 181 - Running hour counter settings/characteristics

Settings / Characteristics (description/label)	Value
Engine running hours/Run hours	
Setting range	0...876000 h
Engine running/Runs (in seconds)	
Setting range	0...3599 s
Resolution	10 s
Start counter/Starts	
Setting range	0...65535
Running hour status/Status	
Options	Stop; Run
Run hour DI link	
Options	Selection of one digital input (DI), one virtual input (VI), one virtual output (VO), or one function key (Fx).
Started at	Date and time of the last activation
Stopped at	Date and time of the last inactivation

Maximum and minimum values of the last 31 days and 12 months

Maximum and minimum values of the phase currents and active/reactive/apparent power measurements from the last 31 days and the last 12 months are stored in the relay's non-volatile memory. Corresponding time stamps are stored for the last 31 days. This can be viewed in the **LOGS** menu/**Month max** sub-menu of the eSetup Easergy Pro.

The registered values are listed in the following table:

Table 182 - Registered values

Measurement	Max	Min	Description	31 days	12 months
IA, IB, IC	■		Phase current (fundamental frequency value)		
IN.meas, IN.sens	■		Neutral current		
S	■		Apparent power	■	■
P	■	■	Active power	■	■
Q	■	■	Reactive power	■	■

The timebase can be a value from one cycle to one minute. Also a demand value can be used as the timebase and its value can be set between 10 and 60 minutes.

Table 183 - Parameters of the day and month registers

Parameter	Value	Description
Timebase		Parameter to select the type of the registered values
	20 ms	Collect min and max of one cycle values[159]
	200 ms	Collect min and max of 200 ms average values
	1 s	Collect min and max of 1 s average values
	1 min	Collect min and max of 1 minute average values
	demand	Collect min and max of demand values
ResetDays		Reset the 31 day registers
ResetMonth		Reset the 12 month registers

---

[159] This is the fundamental frequency RMS value of one cycle updated every 20 ms.

System clock and synchronization

The PowerLogic P5 protection relay's internal clock is used to time-stamp events and disturbance recordings.

The system clock should be externally synchronized to get comparable event time stamps for all the protection relays in the system.

The synchronizing is based on the difference of the internal time and the synchronizing message or pulse. This deviation is filtered and the internal time is corrected softly towards a zero deviation.

Time zone offsets

Time zone offset (or bias) can be provided to adjust the protection relay's local time. The offset can be set as a Positive (+) or Negative (-) value within a range of -15.00 to +15.00 hours and a resolution of 0.01 h. Basically, resolution by a quarter of an hour is enough.

Daylight saving time (DST)

The protection relay provides automatic daylight saving adjustments when configured. A daylight saving time (summer time) adjustment can be configured separately and in addition to a time zone offset in the **GENERAL** menu/**System clock** sub-menu of the eSetup Easergy Pro.

Daylight time standards vary widely throughout the world. Traditional daylight/ summer time is configured as one (1) hour positive bias. The new US/Canada DST standard, adopted in the spring of 2007 is one (1) hour positive bias, starting at 2:00am on the second Sunday in March, and ending at 2:00am on the first Sunday in November. In the European Union, daylight change times are defined relative to the UTC time of day instead of local time of day (as in U.S.), so European customers need to carefully check the local country rules for DST.

The daylight saving rules are by default UTC +2:00 (24-hour clock):

- Daylight saving time start: Last Sunday of March at 03.00
- Daylight saving time end: Last Sunday of October at 04.00

To help ensure proper hands-free year-around operation, automatic daylight time adjustments must be configured using the “Enable DST” setting in the **GENERAL** menu/**System clock** sub-menu of the eSetup Easergy Pro and not with the time zone offset option.

Synchronization modes and priority

PowerLogic P5 provides multiple synchronization modes. The modes and priority are listed as follows.

Priority	Mode
1	IEEE1588
2	IRIG-B
3	SNTP
4	SNTP backup
5	DI pulse signal
6	Modbus
7	IEC101/103
8	DNP3

Synchronization with DI

The clock can be recognized by reading minute pulses from digital or virtual inputs. The sync source is selected with the SyncDI setting. When a rising edge is detected from the selected input, the system clock is adjusted to the nearest minute. The length of the digital input pulse should be at least 50 ms. The delay of the selected digital input should be set to zero.

Synchronization correction

If the sync source has a known offset delay, it can be compensated with this setting. This is useful for compensating hardware delays or transfer delays of communication protocols. A positive value compensates a lagging external sync and communication delays. A negative value compensates any leading offset of the external synch source.

Sync source

When the protection relay receives new sync message, the sync source display is updated. If no new sync messages were received within the last 200 or 400 seconds, the protection relay switches over to internal sync mode.

The timeout check value is either 200 seconds or 400 seconds, depending on the following cases:

- if no SNTP server IP address is available or only one SNTP server IP address is available, the timeout check value is 200 seconds.
- if there are two available SNTP server IP addresses, the timeout check value is 400 seconds.
- if the time source is IEEE1588, the timeout check value is 400 seconds, not affected by the available number of SNTP IP addresses.

Sync source: IRIG-B

IRIG-B synchronization is supported by the IRIG-B module connected to the optional extension module of the protection relay.

Deviation

The time deviation means how much the system clock time differs from the sync source time. The time deviation is calculated after receiving a new sync message. The filtered deviation means how much the system clock was really adjusted. Filtering takes care of small deviation in sync messages.

Auto-lag/lead

The protection relay synchronizes to the sync source, meaning that it starts automatically leading or lagging to stay in sync with the master. The learning process takes a few days.

Table 184 - Clock synchronization parameters

Parameter (description/label)	Value	Description
synchronizing source/ SySrc		Clock synchronization source
	Internal	If there is no synchronizing source within 200 s or 400 s, Internal will be the clock synchronization source, refer to Synchronization modes and priority, page 599 for more information.
	DI	Digital input
	SNTP	Protocol sync
	ModBus	Protocol sync
	ModBus TCP	Protocol sync

Table 184 - Clock synchronization parameters (Continued)

Parameter (description/label)	Value	Description
	IEC101	Protocol sync
	IEC103	Protocol sync
	DNP3	Protocol sync
Minute sync pulse DI/ SyncDI[160]		The digital input used for clock synchronization. Possible value depends on the type of I/O card installed.
	-	DI not used for synchronizing.
	Select one digital or virtual input	
Synch correction/ SyOS	-10000.000... +10000.000 s	synchronization correction for any constant deviation in the synchronizing source
Auto adjust interval/ AAIntv[161]	0.0...1000.0 s	Adapted auto-adjust interval for 1 ms correction
Average drift/AvDrft	lead; lag	Adapted average clock drift sign
Sync message counter/MsgCnt	0...65535	The number of received synchronization messages or pulses
Latest time deviation/ Dev	± 32767 ms	Latest time deviation between the system clock and the received synchronization
Filtered sync deviation/FilDev	± 125 ms	Filtered synchronization deviation

Table 185 - System clock parameters

Parameter (description/label)	Value	Description
Date/Date		Current date
Time of day/Time		Current time
Date style/Style	yyyy-mm-dd	Date format
	dd-mm-yyyy	
	mm-dd-yyyy	
Time zone/Time zone	-15.00...+15.00[162]	UTC time zone for SNTP synchronization.[163]
Status of DST/DST	enabled; disabled	Daylight saving time for SNTP
Enable event	enabled; disabled	

---

[160] Set the DI delay to its minimum and the polarity so that the leading edge is the synchronizing edge.

[161] If external synchronization is used, this parameter is set automatically.

[162] A range of -11 h - +12 h would cover the whole Earth but because the International Date Line does not follow the 180° meridian, a wider range is needed.

[163] Decimal numbers are used, e.g. the time zone of 5:45 is expressed as 5.75.

Monitoring functions

Trip circuit supervision (ANSI 74)

Description

Trip circuit supervision monitors the wiring from the protective device to the circuit breaker trip coil. This function monitors the availability of the circuit when it is requested to trip and reports an issue if needed.

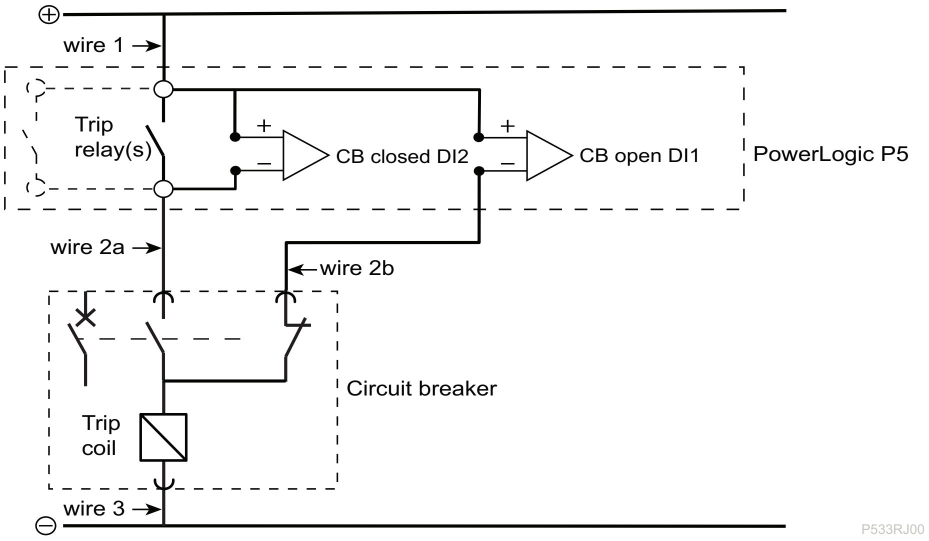
By default, this user-configurable supervision function uses the PowerLogic P5 programmable logic to monitor the circuit continuity, loss of auxiliary supply voltage or mismatching of the CB position indication contacts. Depending on user settings, the function inhibits closing of the circuit breaker.

In this user manual only the default trip circuit supervision using 2 digital inputs is described. Other schemes using just one input and external resistors can be equally set up, managed by DI configuration and logic scheme adaptation.

Trip circuit supervision scheme

The trip circuit supervision scheme using two digital inputs 52a and 52b can be implemented as illustrated in the following wiring diagram. No external resistors are needed for this scheme to function.

Figure 362 - Trip circuit supervision scheme



In the normal condition, when the trip circuit is OK, the status of inputs is opposite (0,1) or (1,0). When the trip circuit is not OK (coil, wires, auxiliary contact state or auxiliary voltage failure), both logic inputs are in the same state and an alarm is issued after a delay. This delay is needed to help prevent false signaling during breaker opening events. The timing is set based on breaker operating time and trip pulse length.

The following table summarizes the TCS alarm output depending on the CB and its auxiliary contact positions as well as possible wiring failure conditions.

CB position	Conditions	CB open DI1	CB closed DI2	TCS alarm
Closed	Trip circuit OK	Closed	Open	False
	Wire 1 failure[164]	Open	Open	True

---

[164] "failure" indicates that one or more of the components are permanently open circuit or short circuit.

CB position	Conditions	CB open DI1	CB closed DI2	TCS alarm
	Wire 2a failure[165]	Open	Open	True
	Wire 3 or trip coil failure[165]	Open	Open	True
Open	Trip circuit OK	Open	Closed	False
	Wire 1 failure[165]	Open	Open	True
	Wire 2b failure[165]	Open	Open	True
	Wire 3 or trip coil failure[165]	Open	Open	True

Figure 363 - Block diagram of trip circuit supervision (ANSI 74)

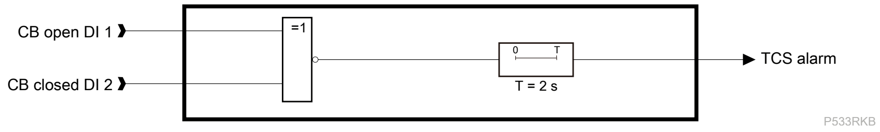
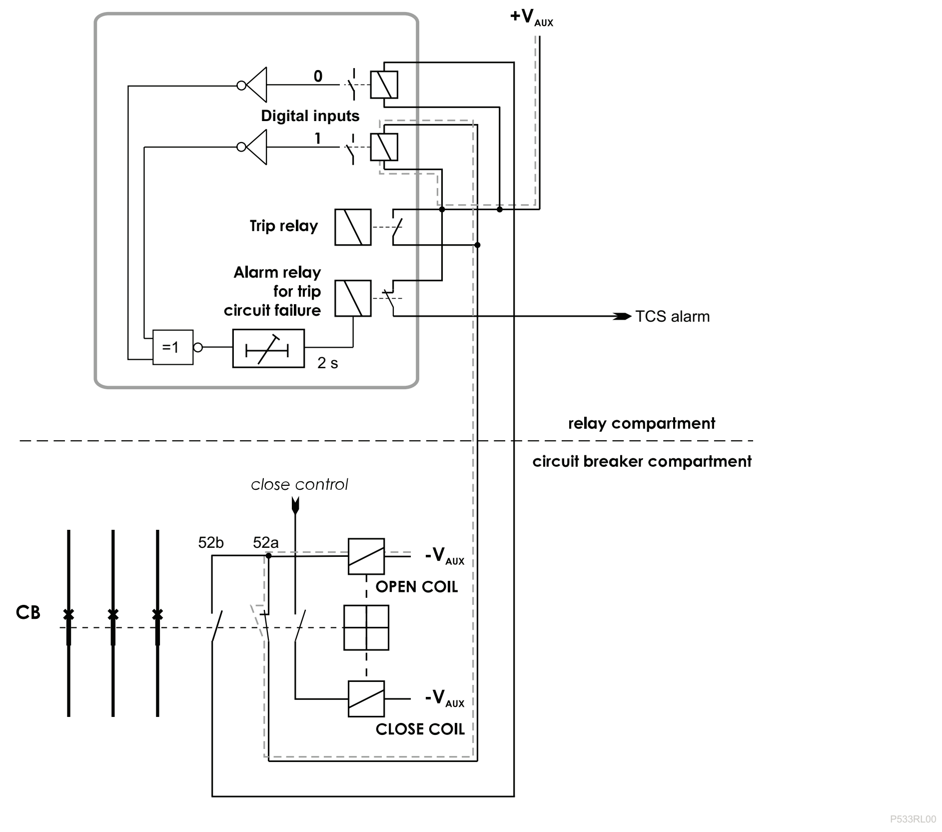


Figure 364 - TCS with two digital inputs when the CB is in closed position



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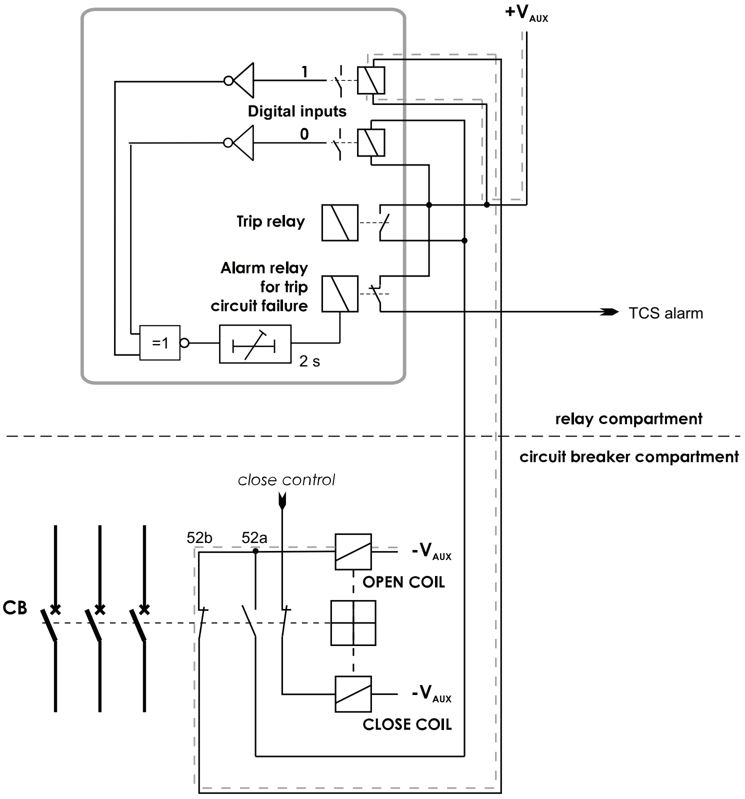
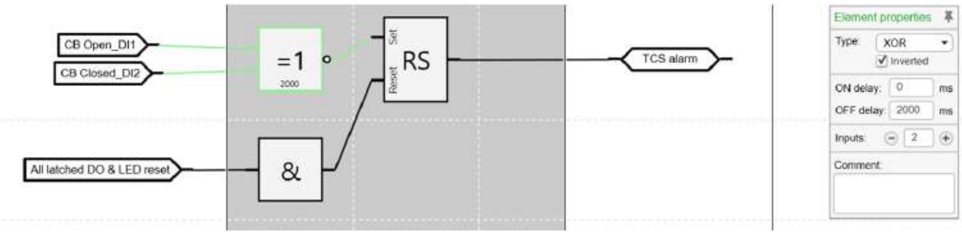
[165] "failure" indicates that one or more of the components are permanently open circuit or short circuit.

Figure 365 - TCS two digital inputs when the CB is in open position



The figure below shows the default logic configuration of TCS in PowerLogic P5. In this example the TCS is latched when an error condition is encountered and reset using a virtual input.

Figure 366 - An example of logic configuration for TCS



Element properties

Type: XOR

☑ Inverted

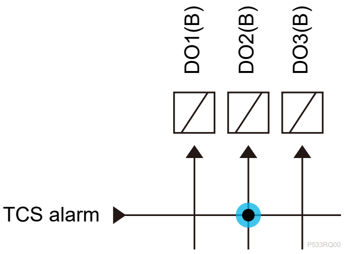
ON delay: 0 ms

OFF delay: 2000 ms

Inputs: 2

Comment:

Figure 367 - An example of output matrix configuration for TCS



Transformer monitoring (ANSI 26/63)

Introduction

The transformer monitoring function (ANSI 26/63) is used to monitor signals from external Buchholz or Thermostat devices. Big transformers are usually fitted with one or more Buchholz relays.

A Buchholz relay detects gases that arise due to normal ageing processes of the transformer insulation. After a sufficient amount of gas has accumulated, the alarm contact is activated. This measurement principle has the effect that the alarm is also activated if the filling level of the insulating oil sinks below the mounting place of the Buchholz relay due to a leakage. Since in such a case the filling level sinks quite rapidly, it is common to have a separate detection hardware for this, which then issues an insulation alarm.

The number of such relays mounted at the transformer is dependent on the size and construction details (mainly whether it is 3-phase or three single-phase transformers, and whether it is with or without tap changer(s)).

Depending on the situation, the Buchholz relay either alarms operations or trips the CBs to prevent the transformer from damages. These alarm and trip signals can be routed to the protection IEDs for logging purposes, for using its communication link to transmit the signals to the SCADA system, or in case of the Buchholz trip to activate the tripping also through the protection IED trip circuit.

Main features of transformer monitoring function:

- Log relevant events when the input signals change state
  It can log any state change of the 8 signals (5 for alarm, 2 for trip, 1 for blocking) in the event buffer.
- Feed the trip input signals into the global trip signal.
  It can show alarm on the local panel when any of the 2 trip signals (gas trip/ oil flow trip) gets asserted.

Depending on the digital input signals, transformer monitoring indicates one of the following statuses:

Table 186 - Statuses of the transformer monitoring

Status	Description
-	Normal status, function is enabled and in normal operation (= in none of the following statuses); or function is not enabled.
Alarm	Function is enabled and in normal operation (not blocked) and any of the alarm input signals is active (= any of the 5 DIs for insulation alarm/ oil temperature alarm/ gas alarm/ oil at minimum level/ oil at maximum level is active).
Trip	Function is enabled and in normal operation (not blocked) and any of the trip input signals is active (= any of the 2 DIs for gas trip/ oil flow trip is active).
Blocked	Function is enabled and input assigned at “DI for blocking” is active.

The monitoring signals are readily available in P5 matrices as DI or VI with customizable names. Customization of DI/VI names is readily available to prevent doubts and mistakes about their meanings. Therefore there is no need to add the signals from transformer monitoring into any matrix.

Available links to P5 inputs

Although the signals are wired electrical input signals from physical Buchholz relays, they can be made available not only for assignment to the P5 physical opto-coupler inputs, but also to virtual (GOOSE) inputs.

DI signal

Table below lists the digital input signal for one instance of transformer monitoring.

Table 187 - 8 signals from transformer monitoring

Signal name	Description
Insulation alarm	Insulation liquid critical (refill insulation medium)
Oil temperature alarm	Insulation liquid temperature alarm
Gas alarm	Gas in insulation liquid alarm
Oil at minimum level	Insulation liquid level minimum
Oil at maximum level	Insulation liquid level maximum
Gas trip	Gas in insulation liquid trip
Oil flow trip	Insulation liquid flow trip because of gas
Block	Input assigned at “DI for blocking” is active

Blocking input signal

The purpose of blocking input signals is to inform the function about a defect in the monitoring system (defect sensor, loss of supply voltage, and so on.). Nevertheless, even if the blocking signal is active, for safety reasons the transformer monitoring function continues to read the connected digital input signals.

If transformer monitoring function is enabled and the block input signal gets asserted, then the global trip signal gets reset once it is triggered from this function only.

Global trip signal

If transformer monitoring function is enabled and in normal operation (not blocked) and any of the trip input signals gets asserted, then it will feed the trip signal into the global trip signal.

Three cases will reset the global trip signal if it is triggered from transformer monitoring function only.

- If transformer monitoring function is enabled and in normal operation (not blocked) and all its trip input signals get reset.
- If transformer monitoring function is enabled and the block input signal gets asserted.
- If transformer monitoring function gets disabled.

Characteristics

Table 188 - Characteristics of the transformer monitoring (ANSI 26/63)

Settings and characteristics	Values
Enable for Transformer monitoring	
Options[166]	Disabled; Enabled

---

[166] Configured via Output Matrix

Table 188 - Characteristics of the transformer monitoring (ANSI 26/63) (Continued)

Settings and characteristics	Values
DI for insulation alarm	
Range	DIx; VIx
DI for oil temperature alarm	
Range	DIx; VIx
DI for gas alarm	
Range	DIx; VIx
DI for gas trip	
Range	DIx; VIx
DI for oil flow trip	
Range	DIx; VIx
DI for oil at minimum level	
Range	DIx; VIx
DI for oil at maximum level	
Range	DIx; VIx
DI for blocking	
Range	DIx; VIx

Circuit breaker monitoring

Description

Periodic maintenance of circuit breakers is necessary to help ensure that the trip circuit and mechanism operate correctly and that the interrupting capability has not been compromised due to previous fault interruptions. The PowerLogic P5 protection relay records various statistics related to each circuit breaker operation, allowing an accurate assessment of the circuit breaker condition. Statistics are recorded to allow evaluation of both the electrical wear of the breaker contacts and the mechanical wear of the breaker mechanism.

With the circuit breaker (CB) monitoring function, the maintenance plan of CB can be changed from fixed interval to a condition based flexible and economical mode. The function collects information of operating data such as interrupted currents, CB operation time and so on, to get awareness about CB condition and to plan required maintenance activities accordingly.

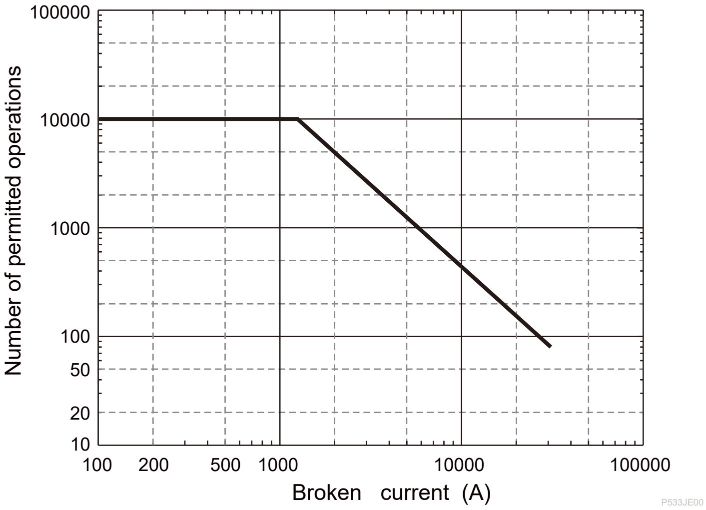
Transformer differential protection P5T30 provides one such CB monitoring element which can be linked to one CB and to the measured phase currents of that end accordingly.

Electrical wear

Breaker curve

The permitted CB operation number is defined by a CB permissible operation curve (CB wear curve). This curve is usually available in the documentation of the CB manufacturer. The curve specifies the permissible number of operations for every level of broken current.

Figure 368 - An example of circuit breaker permissible operation curve



As shown in the above figure, in the PowerLogic P5 protection relay, this curve is parameterized in the CB monitoring function with a maximum of eight points in the form of [CurveIx, CurveNx]. If less than eight points are needed, the unused points are set to [I_{BIG}, 1], where I_{BIG} is more than the maximum breaking capacity.

Table 189 - Values of the above circuit breaker wear characteristic graph

Point	Interrupted current (kA)	Number of permitted operations
1	0 (mechanical age)	10,000
2	1.25 (rated current)	10,000
3	31.0 (maximum breaking current)	80
4 - 8	100	1

The values are taken from the figure above. The table (circuit breaker curve) is edited with eSetup Easergy Pro or Web HMI in **PROTECTION/CB monitoring**.

Two alarms on “Operations left” limit

The CB monitoring function is designed with two alarms, each with two parameters:

- Alarm current level

  This parameter can be set to the CB's nominal current or any typical application current for the first alarm, and to a typical fault current for the second alarm.
- Operations left limit

  This parameter determines when an alarm is activated. When the “operations left” at the given current level drops below this limit, the alarm is started.

The permitted operations at these two alarm levels can be calculated automatically according to the breaker curve and logarithmic interpolation (see next section). Any actual interrupted current is logarithmically weighted for the two given alarm current levels and the number of operations left at the alarm points is decreased accordingly. PowerLogic P5 protection relay shows the allowed “operations left” in the **PROTECTION** menu/**CB Monitoring** sub-menu, based on the breaker curve, logarithmic interpolation and actual interrupted current.

Logarithmic interpolation

The permitted number of operations for the currents between the defined points is logarithmically interpolated using this equation:

$$C = \frac{a}{I^n}$$

P533JF00

where

C = permitted operations

I = broken current

a, n = constant according to the following two equations, where ln represents the natural logarithm function, C_k/C_{k+1} is the permitted number of operations defined by CurveN, Curve(N+1) in the breaker curve table, and I_k/I_{k+1} is the corresponding broken current defined by CurveIk, CurveI(k+1) in the breaker curve table.

$$a = C_k I_k^n$$

P533JJ00

$$n = \frac{ln \frac{C_k}{C_{k+1}}}{ln \frac{I_{k+1}}{I_k}}$$

P533JG00

Each time a trip signal is detected, the corresponding permitted operations shall be calculated based on the broken current I_{brk}:

$$C_{brk} = \frac{a}{I_{brk}^{\ n}}$$

P533JH00

The corresponding decreased number of operations of the alarm level is calculated as:

$$\Delta = \frac{C_{alarm}}{C_{brk}}$$

P533JI00

Example of logarithmic interpolation

According to the equations above and the breaker operation curve points definition taken from An example of circuit breaker permissible operation curve, page 608:

- 10000 operations at 1.25 kA
- 80 operations at 31 kA

if the alarm 2 current setting is 6 kA, then the permitted number of operations can be calculated as follows:

$$n = \frac{ln\frac{10000}{80}}{ln\frac{31000}{1250}} = 1.5038$$

P533JK00

$$a = 10000 \times 1250^{1.5038} = 454 \times 10^{6}$$

P533JL00

$$C_{alarm2} = \frac{a}{I_{brk}^{\ n}} = \frac{454 \times 10^{6}}{6000^{1.5038}} = 945$$

P533JM00

Thus, the maximum number of current-breaking operations at 6 kA is 945. A useful alarm level for “Operations left” could be in this case for example 50, which is about five percent of the maximum.

If the interrupted three phase currents are IA = 12.5 kA, IB = 12.5 kA and IC = 1.5 kA, the corresponding decreased number of operations of phases A, B for alarm 2 are calculated as:

$$C_{brk1,2} = \frac{a}{I_{brk}^{\ n}} = \frac{454 \times 10^{6}}{12500^{1.5038}} = 313$$

P533JN00

$$\Delta_{1,2} = \frac{C_{alarm}}{C_{brk}} = \frac{945}{313} = 3$$

P533JO00

In phase C, the current is less than the alarm limit current 6 kA. For such currents, the decrement is one (just mechanical wear).

Five ranges of cumulative current

Each time the CB opens, the broken current is added to the corresponding total cumulative broken current, phase by phase. The cumulative broken current is given in $(kA)^2$.

In addition to the total cumulative broken current, there are five cumulative broken current ranges to assess the breaking device pole condition. Each range’s high limit value is configurable and the low limit value equals to the high limit of its previous range. Each range has three different counters, one for each phase, to record how many times the broken current falls into the range. The cumulative broken current record is configured in the **PROTECTION** menu/**CB Monitoring** sub-menu.

The cumulative broken current is also computed by phase. When the PowerLogic P5 protection relay is in test mode or the CB has been withdrawn, the cumulative broken current is not updated.

An alarm signal will be generated when the cumulative broken current of any phase exceeds the "broken I alarm setting".

Mechanical wear

CB Open counter, Protection Trip counter and Rack out counter

The “CB Open” counter is to record the number of CB close to open operations. It is incremented even if the PowerLogic P5 protection relay is in test mode.

The “Protection Trip” counter is to record CB open operations issued from Global trip. This counter can also be preset to a custom value but it does not increment during test mode.

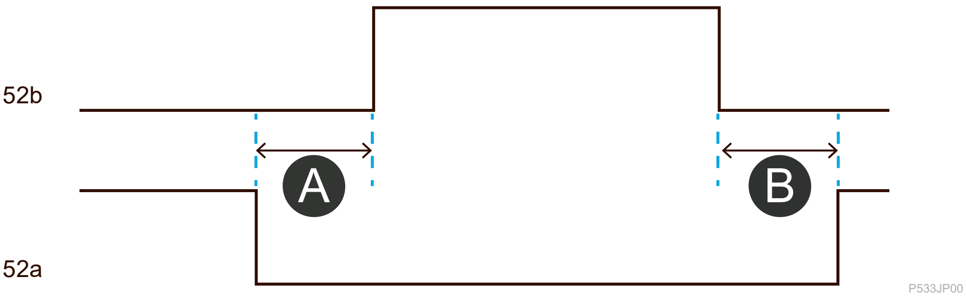
If, for whatever reason the circuit breaker does not open successfully after the pulse setting time out (configured in object), the trip counters are not incremented.

The “Rack out” counter is to record the number of racking in/out operations of the CB truck. It is incremented in both, normal and test mode.

Open time, close time and charging time

If two different digital signals are used to indicate the 52a (open) and 52b (close) status of the CB position, the open time is measured from the moment when the “52b” status becomes false to the moment when the “52a” status becomes true; the close time is measured from the moment when the “52a” status becomes false to the moment when the “52b” status becomes true, as shown in Figure below.

Figure 369 - Open and close time determination



A	Open time	B	Close time

However, if the CB position is only configured as 52a or 52b, the open time and close time will be recorded as 0 each time when its related status changes.

The charging time is computed from the moment when the CB position changes to close to the moment when the spring status changes to ready. The spring status is configured through "DI for object ready" setting in Objects.

Open/close times and charging times are recorded for 8 latest operations in the PowerLogic P5, each with a timestamp. If the time recorded exceeds the range, the time will be tagged as a "dummy" value (65535) which allows the customer to easily detect something is wrong with the CB.

Table 190 - Range of CB monitoring recording data

Recording data	Range
Opening or closing time	0...300 ms
Charging time	0...60 s
Number of mechanical operations	0...65535
Rack-in rack-out operations	0...65535

These CB open times, close times and charging times are also recorded when the PowerLogic P5 is in test mode.

Monitoring functions

CB operation time

The opening and closing time of CB is measured to monitor the healthy status of the circuit breaker, therefore, 2 settable CB runtime alarms are present in case of measured time exceeds the settings:

- The CB open op. time alarm will be raised if the CB opening time exceeds the setting.
- The CB close op. time alarm will be raised if the CB closing time exceeds the setting.

The 2 alarms can be used as input signals in matrix. If one of the 2 alarms is active, further CB close operation will be blocked. No automatic reset of these 2 alarms will happen, they can only be reset manually.

The above 2 alarms are available in the block matrix as interlocking conditions. By default they will block further close operation of the CB. A signal blocks the above 2 limit checks and alarms to avoid for example the signaling during commissioning tests, when CB position signals might not be updated during secondary injection tests.

The settings of CB operation time can be made in eSetup Easergy Pro/ **PROTECTION/CB monitoring/CB operation time**.

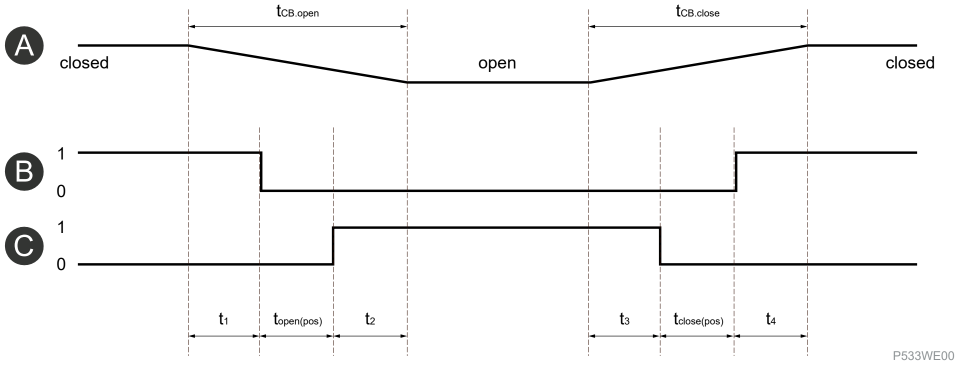
“Pos to Pos” and “Cmd to Pos”

In eSetup Easergy Pro, the CB runtime measurement mode can be selected in **PROTECTION/CB monitoring/CB operation time**, with values *Pos to Pos* or *Cmd to Pos*. “Pos to Pos” uses only CB position signals, “Cmd to Pos” uses control commands and CB position signals.

“Pos to Pos”

In “Pos to Pos” mode, the CB runtime is determined by the time between the state of the auxiliary contacts change from one to another, as described in the figure below:

Figure 370 - CB runtime determination “Pos to Pos”



A	CB main contact	B	CB closed (52b)
C	CB open (52b)		

$t_{CB.open} = t_1 + t_{open(pos)} + t_2 = t_{open(pos)} + t_{open.corr}$, with set $t_{open.corr} = t_1 + t_2$

$t_{CB.close} = t_3 + t_{close(pos)} + t_4 = t_{close(pos)} + t_{close.corr}$, with set $t_{close.corr} = t_3 + t_4$

Where:

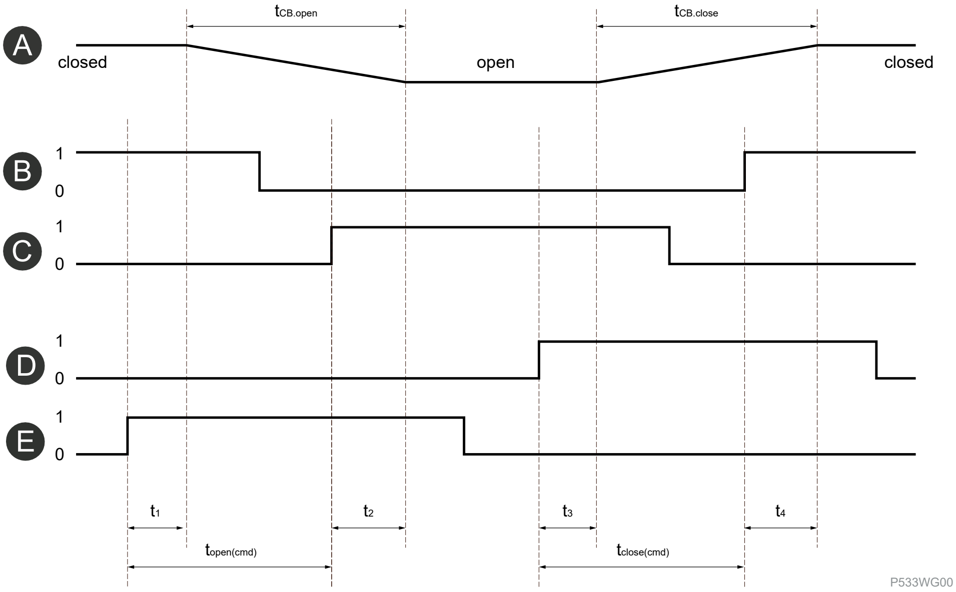
- $t_{CB.open}$ is the calculated CB open operation time.
- $t_{open(pos)}$ is the measured CB open operation time.

- t_1 is the time difference between CB main contact starts to open and its auxiliary contact (52a) status is changed from 1 to 0.
- t_2 is the time difference between CB main contact becomes open and its auxiliary contact (52b) status is changed from 0 to 1.
- $t_{open.corr}$ is the sum of t_1 and t_2, it corresponds to the setting **Correction time open op.** of eSetup Easergy Pro/**PROTECTION/CB monitoring/CB operation time**.
- $t_{CB.close}$ is the calculated CB close operation time.
- $t_{close(pos)}$ is the measured CB close time.
- t_3 is the time difference between CB main contact starts to close and its auxiliary contact (52b) status is changed from 1 to 0.
- t_4 is the time difference between CB main contact becomes closed and its auxiliary contact (52a) status is changed from 0 to 1.
- $t_{close.corr}$ is the sum of t_3 and t_4, it corresponds to the setting **Correction time close op.** of eSetup Easergy Pro/**PROTECTION/CB monitoring/CB operation time**.

"Cmd to Pos"

In "Cmd to Pos" mode, the CB runtime is determined by the time from the raising edge of the open or close command to the auxiliary contact state change, as described in the figure below:

Figure 371 - CB runtime determination "Cmd to Pos"



A	CB main contact	B	CB closed (52b)
C	CB open (52b)	D	CB close command
E	CB open command		

$t_{CB.open} = t_{open(cmd)} – t_1 + t_2 = t_{open(cmd)} + t_{open.corr},$ with set $t_{open.corr} = t_2 – t_1$

$t_{CB.close} = t_{close(cmd)} – t_3 + t_4 = t_{close(cmd)} + t_{close.corr},$ with set $t_{close.corr} = t_4 – t_3$

Where:

- $t_{CB.open}$ is the calculated CB open operation time.
- $t_{open(cmd)}$ is the measured CB open operation time.
- t_1 is the time difference between CB main contact starts to open and the CB open command is sent.

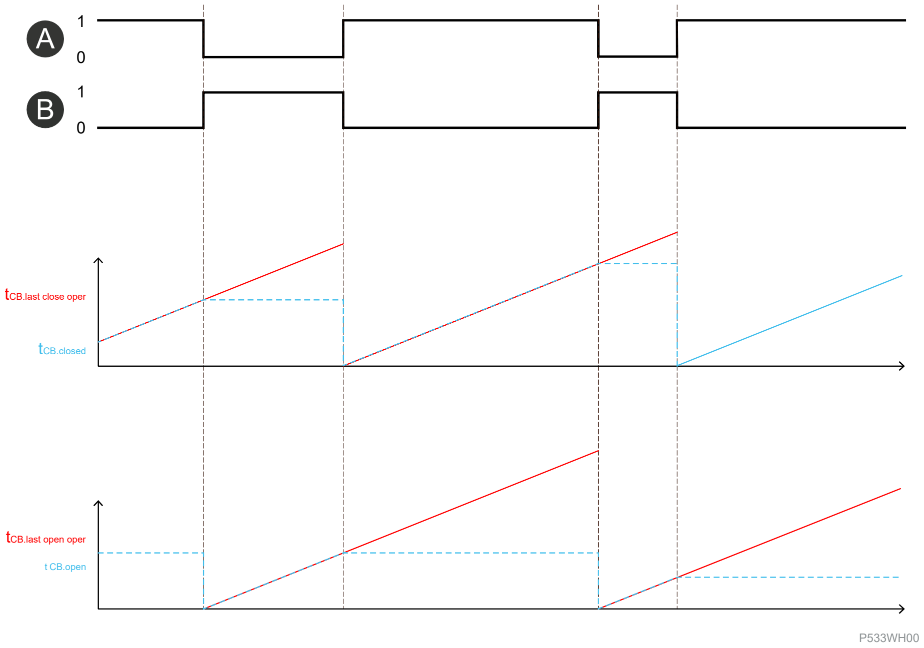
- t_2 is the time difference between CB main contact becomes open and its auxiliary contact (52a) status is changed from 0 to 1.
- $t_{open.corr}$ is the sum of t_1 and t_2, it corresponds to the setting **Correction time open op.** of eSetup Easergy Pro/**PROTECTION/CB monitoring/CB operation time**.
- $t_{CB.close}$ is the calculated CB close operation time.
- $t_{close(pos)}$ is the measured CB close time.
- t_3 is the time difference between CB main contact starts to close and the CB close command is sent.
- t_4 is the time difference between CB main contact becomes closed and its auxiliary contact (52b) status is changed from 0 to 1.
- $t_{close.corr}$ is the sum of t_3 and t_4, it corresponds to the setting **Correction time close op.** of eSetup Easergy Pro/**PROTECTION/CB monitoring/CB operation time**.

CB operating time

PowerLogic P5 monitors the time the CB stays in each position and the time since last CB operation. 4 timers are used in this function:

- $t_{CB.closed}$: the time since last CB closed condition, this timer will pause timing when CB opens.
- $t_{CB.last\ close\ oper}$: the time since last CB closed condition, reset when CB closes again.
- $t_{CB.open}$: the time since last CB open condition, this timer will pause timing when CB closes.
- $t_{CB.last\ open\ oper}$: the time since last CB open condition, reset when CB opens again.

Figure 372 - CB on/off time measurement



A	CB closed (52a)	B	CB open (52b)

The settings of CB operating time can be made in eSetup Easergy Pro/ **PROTECTION/CB monitoring/CB operating time**. There are 4 settable alarms:

- CB open alarm
- CB closed alarm
- CB last open operation alarm

- CB last close operation alarm.

Exceeding of the limit settings will initiate common alarms. When the CB position changes, the 4 alarms will reset automatically, for example:

- the CB open alarm resets upon next CB close operation.
- the CB last close operation alarm resets upon next CB close operation.

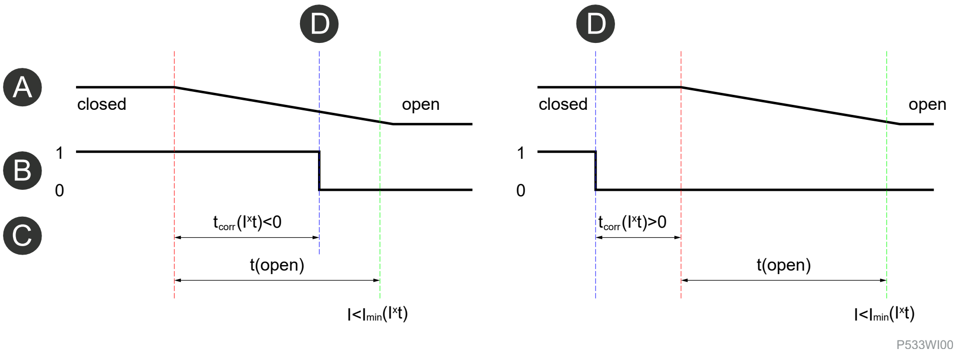
The 4 alarms can be used as input signals of matrix.

CB wear monitoring

The circuit breaker is exposed to an electrical wear, it is proportional to an exponent of broken current and the CB operation time I^xt, where:

- I is the intensity of current when the CB opens.
- t is the time the main contact moves from close to open position.

Figure 373 - Correction time and determination of CB pole opening time t (open)



A	CB main contact	B	CB closed
C	CB opening time (poles travelling time)	D	CBM (CB monitoring) trigger

The above figure shows two examples of CB opening time. The red lines indicate the time point when the CB begins to open, it is also the beginning of the t(open) window. The green lines indicate the time when the measured rms values of the currents drop below a set minimum value $I_{min}(I^xt)$, it is the end of the t(open) window. The blue lines indicate the time point of CBM trigger, it is the time when the CB is considered as “CB closed”.

A settable correction time $t_{corr}(I^xt)$ is reserved for the setting of time between the beginning of t(open) window and the CBM trigger.

The determination of CBM trigger (“CB closed” status) depends on available and assigned CB auxiliary contacts, as shown in the table below:

Table 191 - Determination of CBM trigger (“CB closed”)

Using 52a (CB open auxiliary contact) only							
Result from previous check			Result from actual check			CBM trigger	
52a	52b	CB status	52a	52b	CB status		
0		closed	0		closed	no	No change
			1		open	yes	Changes from closed to open
1		open	0		closed	no	Changes from open to closed
			1		open	no	No change
Using 52b (CB closed auxiliary contact) only							

Table 191 - Determination of CBM trigger (“CB closed”) (Continued)

Result from previous check			Result from actual check			CBM trigger	
52a	52b	CB status	52a	52b	CB status		
	0	open		0	open	no	No change
				1	closed	no	Changes from open to closed
	1	closed		0	open	yes	Changes from closed to open
				1	closed	no	No change
Using both auxiliary contacts							
Result from previous check			Result from actual check			CBM trigger	
52a	52b	CB status	52a	52b	CB status		
0	1	closed	1	0	open	yes	
0	0	undefined					Changes from closed to open
1	1	undefined					
1	0	open	1	0	open	no	No change
			0	1	closed	no	Changes from open to closed
			0	0	undefined	no	Changes from open to undefined
			1	1	undefined	no	Changes from open to undefined

The wear calculation uses the rms value of the current measured within the t(open) window. If the current is below the set minimum current $I_{min}(I^{x}t)$ at the beginning of the t(open) window (at the red line), this opening of the CB will be considered as not relevant to wear calculation. Therefore, no $I^{x}t$ calculation will be made, the measured $I^{x}t$ value will be forced to zero and the cumulated value will not increment.

The measured wear calculation $I^{x}t$ is made separately per phase and displayed per phase.

The cumulated measured wear $\sum (I^{x}t)$ is incremental to the measured wear calculation values and displayed per phase. When the cumulated wear $\sum (I^{x}t)$ of a phase exceeds the setting of Sum($I^{x}t$) warning limit, a warning will be raised. If the cumulated wear $\sum (I^{x}t)$ of a phase exceeds the setting of Sum($I^{x}t$) alarm limit, an alarm will be raised. This alarm will block further close operation of the protected CB and cannot be reset. The warnings and alarms (per phase) are input signals of matrix.

The settings of CB wear monitoring can be made in eSetup Easergy Pro/ **PROTECTION/CB monitoring/CB wear monitoring**.

CB in-service monitoring

This function monitors the duration since the CB was installed, an CB in service alarm will be raised when the cumulated time exceeds a set threshold. There is no warning but only alarm, and the alarm cannot be reset, it will block further CB close operation. Also, this alarm is input of matrix.

The setting of CB in service alarm time can be found in eSetup Easergy Pro/ **PROTECTION/CB monitoring/CB in-service monitoring**, settable in hours. The installation date is also set in **CB in-service monitoring**. If you want to change the style of date, it can be changed in **GENERAL/Local panel conf/Date style**.

Parameters of the CB monitoring function

Table 192 - Parameters of the CB monitoring function

Parameter	Value	Unit	Description	Note
CB monitoring status				
Al1A Al1B Al1C Al2A Al2B Al2C			Operation number left for - Alarm 1, phase A - Alarm 1, phase B - Alarm 1, phase C - Alarm 2, phase A - Alarm 2, phase B - Alarm 2, phase C	
Alarm				
Alarm 1				
Current level	0.00...100.00	kA	Alarm1 current level	Editable
Operation limit	100,000...1		Alarm1 limit for operations left	Editable
Alarm 2				
Current level	0.00...100.00	kA	Alarm2 current level	Editable
Operation limit	100,000...1		Alarm2 limit for operations left	Editable
Circuit breaker curve setting				
Current points (CurveIx, x = 1, 2, … 8)	0.00...100.00	kA	8 current points of the CB wear characteristic	Editable
Limit for operation left (CurveNx, x = 1, 2, … 8)	0...100,000		8 permitted operation numbers according to CurveIx	Editable
Latest broken current				
hh:mm:ss:ms / Date			Time stamp of the latest trip operation	
Phase current IA Phase current IB Phase current IC		A	Broken current of phase A Broken current of phase B Broken current of phase C	
Cumul. broken current IA/CmltvIA Cumul. broken current IB/CmltvIB Cumul. broken current IC/CmltvIC		$(kA)^2$		
CB wear monitoring				
Wear of last opening A		kA2s $(kA)^2s$	Wear of last CB opening of phase A.	
Wear of last opening B		kA2s $(kA)^2s$	Wear of last CB opening of phase B.	
Wear of last opening C		kA2s $(kA)^2s$	Wear of last CB opening of phase C.	
Cumulated wear of CB opening A	0.00...1,000,000.00	kA2s $(kA)^2s$	Cumulated wear of CB opening of phase A.	Editable
Cumulated wear of CB opening B	0.00...1,000,000.00	kA2s $(kA)^2s$	Cumulated wear of CB opening of phase B.	Editable
Cumulated wear of CB opening C	0.00...1,000,000.00	kA2s $(kA)^2s$	Cumulated wear of CB opening of phase C.	Editable

Table 192 - Parameters of the CB monitoring function (Continued)

Parameter	Value	Unit	Description	Note
$I_{min}(I^x t)$	0.05...2.00	pu	Setting of minimum current, the opening current below the set value will not be considered for the wear calculation.	Editable
$T_{corr}(I^x t)$	-100...100	ms	Setting of correction time to determine the CB opening time.	Editable
Exponent($I^x t$)	1.00...3.00		The exponent of wear calculation. For example, when Exponent($I^x t$) = 2, the calculation will be made with I^2.	Editable
Sum($I^x t$) warning limit	0…100,000	kA2s $((kA)^2 s)$	Setting of the cumulated CB wear warning.	Editable
Sum($I^x t$) alarm limit	0…100,000	kA2s $((kA)^2 s)$	Setting of the cumulated CB wear alarm.	Editable
CB operation time				
CB open op. time	0...100,000	ms	CB open operation time	
CB close op. time	0...100,000	ms	CB close operation time	
CB runtime meas. mode	Pos to Pos, Cmd to Pos		The measurement mode of CB runtime.	Selectable
Correction time open op.	–100...+100	ms	Setting of correction time for the calculation of measured CB open operation time.	Editable
Correction time close op.	–100...+100	ms	Setting of correction time for the calculation of measured CB close operation time.	Editable
CB open op. time limit	0...1000	ms	Setting of CB open operation time alarm.	Editable
CB close op. time limit	0...1000	ms	Setting of CB close operation time alarm.	Editable
CB time meas. block input	0, 1		The input signal to block the CB runtime measurement.	Selectable
CB operating time				
CB open time	0.0...10,000,000	min	Time since last CB closed condition.	Editable
CB closed time	0.0...10,000,000	min	Time since last CB open condition.	Editable
CB last open operation time	0.0...10,000,000	min	Time the CB is in open position since last open operation.	Editable
CB last close operation time	0.0...10,000,000	min	Time the CB is in closed position since last close operation.	Editable
CB open remaining time		min	Remaining time until reaching the CB closed alarm limit.	
CB closed remaining time		min	Remaining time until reaching the CB open alarm limit.	
CB open alarm limit	0.0...10,000,000	min	Setting of CB open alarm.	Editable

Table 192 - Parameters of the CB monitoring function (Continued)

Parameter	Value	Unit	Description	Note
CB closed alarm limit	0.0...10,000,000	min	Setting of CB closed alarm.	Editable
CB last open op. alarm limit	0.0...10,000,000	min	Setting of CB last open operation alarm.	Editable
CB last close op. alarm limit	0.0...10,000,000	min	Setting of CB last close operation alarm.	Editable
CB in-service monitoring				
CB in service		h	The time since the CB was put in service.	
CB installation date			The date the CB was installed.	Editable
CB in service alarm time	0...300,000	h	Setting of CB in service alarm.	Editable
CB in service alarm date			Date on which the CB in service alarm timer elapses.	
Cumulative broken current setting				
High limit	0.0...100.0	kA	High limit setting for each range	Editable
Broken I alarm setting	0...65,535		Cumulative broken current alarm threshold	Editable
Event setting				
'Op. limit alarm 1 On' event	On ; Off		Enable/disable the 'Alarm1 on' event	Editable
'Op. limit alarm 1 Off' event	On ; Off		Enable/disable the 'Alarm1 off' event	Editable
'Op. limit alarm 2 On' event	On ; Off		Enable/disable the 'Alarm2 on' event	Editable
'Op. limit alarm 2 Off' event	On ; Off		Enable/disable the 'Alarm2 off' event	Editable
‘Broken I Alarm on’ event	On ; Off		Enable/disable the ‘Broken I Alarm on’ event	Editable
‘Broken I Alarm off’ event	On ; Off		Enable/disable the ‘Broken I Alarm off’ event	Editable
CB sum($I^x t$) alarm off event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm off’ event	Editable
CB sum($I^x t$) alarm A on event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm A on’ event	Editable
CB sum($I^x t$) alarm A off event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm A off’ event	Editable
CB sum($I^x t$) alarm B on event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm B on’ event	Editable
CB sum($I^x t$) alarm B off event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm B off’ event	Editable
CB sum($I^x t$) alarm C on event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm C on’ event	Editable
CB sum($I^x t$) alarm C off event	On ; Off		Enable/disable the ‘CB sum($I^x t$) alarm C off’ event	Editable
CB open time alarm on event	On ; Off		Enable/disable the ‘CB open time alarm on’ event	Editable
CB open time alarm off event	On ; Off		Enable/disable the ‘CB open time alarm off’ event	Editable
CB close time alarm on event	On ; Off		Enable/disable the ‘CB close time alarm on’ event	Editable

Table 192 - Parameters of the CB monitoring function (Continued)

Parameter	Value	Unit	Description	Note
CB close time alarm off event	On ; Off		Enable/disable the ‘CB close time alarm off’ event	Editable
CB time meas. block on event	On ; Off		Enable/disable the ‘CB time meas. block on’ event	Editable
CB time meas. block off event	On ; Off		Enable/disable the ‘CB time meas. block off’ event	Editable
Open time log update evt	On ; Off		Enable/disable the ‘Open time log update’ event	Editable
Close time log update evt	On ; Off		Enable/disable the ‘Close time log update’ event	Editable
Charge time log update evt	On ; Off		Enable/disable the ‘Charge time log update’ event	Editable
CB open alarm on event	On ; Off		Enable/disable the ‘CB open alarm on’ event	Editable
CB open alarm off event	On ; Off		Enable/disable the ‘CB open alarm off’ event	Editable
CB closed alarm on event	On ; Off		Enable/disable the ‘CB closed alarm on’ event	Editable
CB closed alarm off event	On ; Off		Enable/disable the ‘CB closed alarm off’ event	Editable
CB last open op alarm on event	On ; Off		Enable/disable the ‘CB last open op alarm on’ event	Editable
CB last open op alarm off event	On ; Off		Enable/disable the ‘CB last open op alarm off’ event	Editable
CB last close op alarm on event	On ; Off		Enable/disable the ‘CB last close op alarm on’ event	Editable
CB last close op alarm off event	On ; Off		Enable/disable the ‘CB last close op alarm off’ event	Editable
CB in service alarm on event	On ; Off		Enable/disable the ‘CB in service alarm on’ event	Editable
CB in service alarm off event	On ; Off		Enable/disable the ‘CB in service alarm off’ event	Editable

Parameter	Accuracy
Characteristic of recorded data	
Opening or closing time	±5 ms
Charging time	±1 s
Number of mechanical operations	1
Cumulative squared broken current	±10%
Rack-in rack-out operations	1

Digital Circuit Breaker monitoring

Overview

As add-on devices of some circuit breakers of Schneider Electric, for example EvoPact HVX or other circuit breakers, for preventive or predictive maintenance of switchboard and switchgears, PowerLogic P5 protection relay has capabilities to monitor and control the MV equipment.

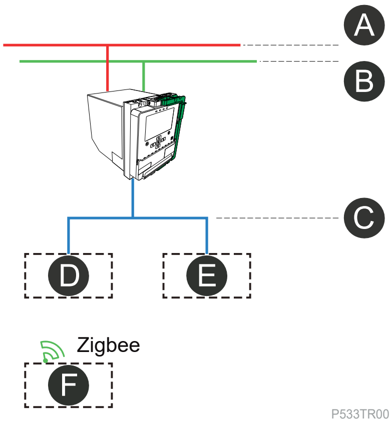
The monitoring functions help user to simplify maintenance scheduling therefore to increase service continuity. By providing general health index for the circuit breaker and health index of key components (it means the coils and so on).

The condition monitoring function uses different sensors and modules:

- PowerLogic TH110 and PowerLogic CL110 for thermal and environmental monitoring, connected directly to PowerLogic P5 through radio frequency Zigbee Green Power protocol.
- Other sensors embedded in the Schneider Electric circuit breakers, connected to the EcoStruxure Operation Server Breaker Monitoring module (EOS-BM100) to execute the following monitoring:
  - Mechanism monitoring
  - Vacuum Interrupter monitoring
  - Truck position monitoring
  - Charging motor monitoring
  - Coils monitoring
- EcoStruxure Operation Server Motor Control and Monitoring module (EOS-MCMx00 with x=1, 2) for:
  - Control of two direct current motors (EOS-MCM100) or up to 4 motors (EOS-MCM200)
  - Measure the current consumption of motor
  - Motor protection against over current
  - Motor monitoring to detect age-related degradation.
  - Interlocking logic rules for control commands such as breaker open and close, and rack in and rack out.
  - Management of automatic sequences for control of the motors and the circuit breaker.

PowerLogic P5 collects data from EOS-BM100/EOS-MCMx00 through Modbus serial (slot N or Slot M+N) to manage alarms, display the data on screen, also enable user to perform CB and switch control through communication.

Figure 374 - Monitoring and control offer architecture



A	Control network	B	Monitoring network
C	Cubicle (Modbus serial)	D	EOS-BM100
E	EOS-MCMx00	F	Zigbee sensors

The condition monitoring of MV equipment is possible with the following order references of PowerLogic P5 protection relays.

Table 193 - P5x20 and P5x30 order codes:

Model number	Slot	Communication board
AABx-xxx**EW**-xxxx	N, P	E - RS485 serial line module W - Extension module radio
AABx-xx**GGW**-xxxx	M and N, P	G - Ethernet TP with HSR/PRP and RS485 W - Extension module radio
AABx-xx**HHW**-xxxx	M and N, P	H - Ethernet FO with HSR/PRP and RS485 W - Extension module radio

The key elements of monitoring functions are as listed below:

Table 194 - Key elements Digital Circuit Breaker monitoring of PowerLogic P5 protection relay

	Features and functions	Associated modules/ sensors
Environmental monitoring	Ambient temperature and relative humidity monitoring	PowerLogic CL110
Thermal monitoring	CB power connections arms thermal monitoring	PowerLogic TH110
	Busbar connections thermal monitoring	PowerLogic TH110
	Cables connections thermal monitoring	PowerLogic TH110
	Temperature rise alarm according to temperature and current measuring	PowerLogic P5
Auxiliary circuit monitoring	Shunt release condition monitoring	EOS-BM100
	Spring charging motor condition monitoring	EOS-BM100
	Closing / Opening shunt releases current curve	EOS-BM100
Operating mechanism condition monitoring	Circuit breaker Closing / Opening time	EOS-BM100
	Circuit breaker rebounding alarm on opening	EOS-BM100
	Circuit breaker closing / opening speed	EOS-BM100
	Vacuum Interrupter contacts gap monitoring	EOS-BM100
Interrupter condition monitoring	Vacuum Interrupter contacts condition monitoring	EOS-BM100
	Poles closing / opening synchronization[167]	EOS-BM100
	Vacuum Interrupter contacts pressure monitoring	EOS-BM100
CB motorized truck, grounding switch monitoring and control	Control by Local display	PowerLogic P5
	Monitoring by local display	PowerLogic P5
	Motorized CB truck control and protection	EOS-MCMx00

---

[167] For availability, please consult Schneider Electric.

Table 194 - Key elements Digital Circuit Breaker monitoring of PowerLogic P5 protection relay (Continued)

	Features and functions	Associated modules/ sensors
	CB Truck motor condition monitoring/ Isolator motor condition monitoring	EOS-MCMx00
Ground switch monitoring	Motorized grounding switch control and protection	EOS-MCMx00
	Motorized grounding switch motors condition monitoring	EOS-MCMx00
Racking compatibility monitoring	Truck stroke monitoring (Racking compatibility monitoring)	EOS-BM100
3-Position switch monitoring	Disconnector / Ground switch monitoring (if motor selected)	EOS-MCMx00

Configuration of Digital Circuit Breaker

Configuration tool and process

The configuration of the Digital Circuit Breaker monitoring and Zigbee sensor is made by eSetup Easergy Pro.

The operations to configure are different according to the types of modules or sensors:

- Connection and configuration of EOS-BM100/EOS-MCMx00.
- Pairing operation of Zigbee sensors, please refer to Pairing of sensors, page 623.

Pairing of sensors

Preparation

Connect the device with laptop and launch eSetup Easergy Pro, login with InstallerLevel account.

Check and confirm the following items in eSetup Easergy Pro:

1. In **DEVICE/TEST** menu bar, **Device information** section, the **Order code** (model number) of the connected PowerLogic P5 device is displayed. If the 16th character of this code is “W”, it means the Zigbee module is installed.
2. If the connected PowerLogic P5 device is equipped with Zigbee module, in **GENERAL** menu tab, a section with the name **Zigbee network** will be displayed. Please check and confirm the listed items in this section:
    - The value of **Zigbee network status** is *OK*.
    - The list of **Zigbee devices** is empty if no Zigbee sensor is configured.

Pairing of sensor with PowerLogic P5 is consist of three steps:

- Import or input manually the whitelist
- Pair the sensors
- Map the sensors

Import or input manually the whitelist of sensors

PowerLogic P5 supports connection with up to 18 TH110 and 3 CL110 sensors. Normally, when the first time pairing of sensors, if there are numbers of sensors to be paired, it’s proposed to import a whitelist. A template of whitelist can be exported by eSetup Easergy Pro from **GENERAL/Zigbee network** section. There are four buttons on top right, click on **Export whitelist** button to export the template whitelist to the selected path. The exported template file is “whitelist.json”. As shown below:

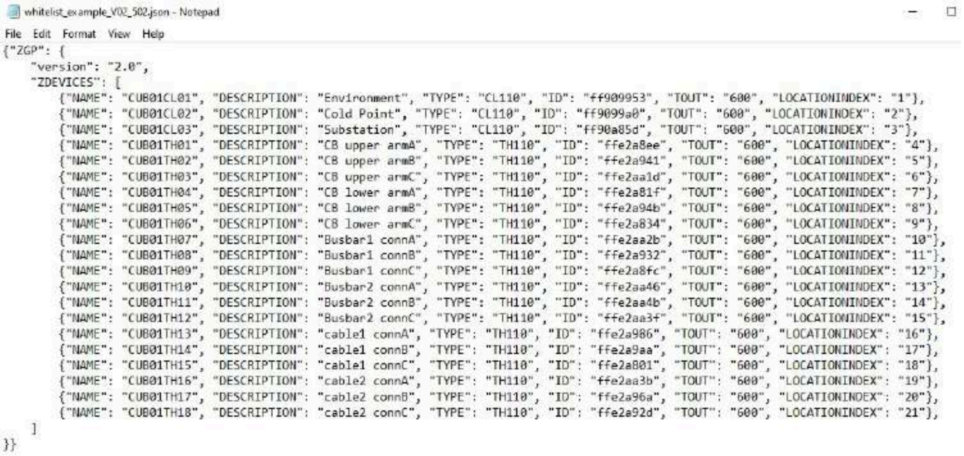
Figure 375 - Template of whitelist

```
{"ZGP": {
    "version": "2.0",
    "ZDEVICES": [
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "CL110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "CL110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "CL110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
        {"NAME": "-", "DESCRIPTION": "-", "TYPE": "TH110", "ID": "-", "TOUT": "600", "LOCATIONINDEX": "-"},
    ]
}}
```

The template whitelist.json file is not ready for import, the number of rows of key values in the field “ZDEVICES” shall be extended to be in line with the number of Zigbee sensors to be paired, and the key values shall be updated accordingly:

- NAME: the name of the sensor, with a limit of length of not more than 16 characters.
- DESCRIPTION: the description of sensor, with a limit of length of not more than 16 characters.
- TYPE: TH110 or CL110[168].
- ID: the ID must be copied from the sensor to be paired, which is normally printed on the side of the sensor.
- TOUT: time out setting of receiving sensor data. PowerLogic P5 will update sensor status from online to offline if no data reporting from senor in the given duration.
- LOCATIONINDEX: location index that the sensor is to be mapped. The value can be '-' or [1, 21]. '-' indicates the sensor is not mapped to any location. For the mapping of sensors, refer to Map the sensors, page 627.

Figure 376 - Example of whitelist



```
{"ZGP": {
    "version": "2.0",
    "ZDEVICES": [
        {"NAME": "CUB01CL01", "DESCRIPTION": "Environment", "TYPE": "CL110", "ID": "ff909953", "TOUT": "600", "LOCATIONINDEX": "1"},
        {"NAME": "CUB01CL02", "DESCRIPTION": "Cold Point", "TYPE": "CL110", "ID": "ff9099a0", "TOUT": "600", "LOCATIONINDEX": "2"},
        {"NAME": "CUB01CL03", "DESCRIPTION": "Substation", "TYPE": "CL110", "ID": "ff90a85d", "TOUT": "600", "LOCATIONINDEX": "3"},
        {"NAME": "CUB01TH01", "DESCRIPTION": "CB upper armA", "TYPE": "TH110", "ID": "ffe2a8ee", "TOUT": "600", "LOCATIONINDEX": "4"},
        {"NAME": "CUB01TH02", "DESCRIPTION": "CB upper armB", "TYPE": "TH110", "ID": "ffe2a941", "TOUT": "600", "LOCATIONINDEX": "5"},
        {"NAME": "CUB01TH03", "DESCRIPTION": "CB upper armC", "TYPE": "TH110", "ID": "ffe2aa1d", "TOUT": "600", "LOCATIONINDEX": "6"},
        {"NAME": "CUB01TH04", "DESCRIPTION": "CB lower armA", "TYPE": "TH110", "ID": "ffe2a81f", "TOUT": "600", "LOCATIONINDEX": "7"},
        {"NAME": "CUB01TH05", "DESCRIPTION": "CB lower armB", "TYPE": "TH110", "ID": "ffe2a94b", "TOUT": "600", "LOCATIONINDEX": "8"},
        {"NAME": "CUB01TH06", "DESCRIPTION": "CB lower armC", "TYPE": "TH110", "ID": "ffe2a834", "TOUT": "600", "LOCATIONINDEX": "9"},
        {"NAME": "CUB01TH07", "DESCRIPTION": "Busbar1 connA", "TYPE": "TH110", "ID": "ffe2aa2b", "TOUT": "600", "LOCATIONINDEX": "10"},
        {"NAME": "CUB01TH08", "DESCRIPTION": "Busbar1 connB", "TYPE": "TH110", "ID": "ffe2a932", "TOUT": "600", "LOCATIONINDEX": "11"},
        {"NAME": "CUB01TH09", "DESCRIPTION": "Busbar1 connC", "TYPE": "TH110", "ID": "ffe2a8fc", "TOUT": "600", "LOCATIONINDEX": "12"},
        {"NAME": "CUB01TH10", "DESCRIPTION": "Busbar2 connA", "TYPE": "TH110", "ID": "ffe2aa46", "TOUT": "600", "LOCATIONINDEX": "13"},
        {"NAME": "CUB01TH11", "DESCRIPTION": "Busbar2 connB", "TYPE": "TH110", "ID": "ffe2aa4b", "TOUT": "600", "LOCATIONINDEX": "14"},
        {"NAME": "CUB01TH12", "DESCRIPTION": "Busbar2 connC", "TYPE": "TH110", "ID": "ffe2aa3f", "TOUT": "600", "LOCATIONINDEX": "15"},
        {"NAME": "CUB01TH13", "DESCRIPTION": "cable1 connA", "TYPE": "TH110", "ID": "ffe2a986", "TOUT": "600", "LOCATIONINDEX": "16"},
        {"NAME": "CUB01TH14", "DESCRIPTION": "cable1 connB", "TYPE": "TH110", "ID": "ffe2a9aa", "TOUT": "600", "LOCATIONINDEX": "17"},
        {"NAME": "CUB01TH15", "DESCRIPTION": "cable1 connC", "TYPE": "TH110", "ID": "ffe2a801", "TOUT": "600", "LOCATIONINDEX": "18"},
        {"NAME": "CUB01TH16", "DESCRIPTION": "cable2 connA", "TYPE": "TH110", "ID": "ffe2aa3b", "TOUT": "600", "LOCATIONINDEX": "19"},
        {"NAME": "CUB01TH17", "DESCRIPTION": "cable2 connB", "TYPE": "TH110", "ID": "ffe2a96a", "TOUT": "600", "LOCATIONINDEX": "20"},
        {"NAME": "CUB01TH18", "DESCRIPTION": "cable2 connC", "TYPE": "TH110", "ID": "ffe2a92d", "TOUT": "600", "LOCATIONINDEX": "21"},
    ]
}}
```

---

[168] The type of the first 3 sensors in the whitelist must be CL110.

After prepared the whitelist, in eSetup Easergy Pro, **GENERAL/Zigbee network** section, click on **Import whitelist** to import the whitelist file.

PowerLogic P5 is compatible with the whitelist earlier than firmware version V02.501.

After imported, a pop-up window is displayed to require a reboot of device. After reboot, check the **GENERAL/Zigbee network** section, in **Zigbee network status**, the value of **Network information** should be *NETWORK OK|1*.

If there are error during the importing, eSetup Easergy Pro will show the error code in log section. The following table lists the error codes:

Table 195 - Error code list of whitelist importing

Index	Label	Note
1	File Check Ok	Whitelist file check success.
2	Bad File	Whitelist file check failed (does not exist or failed to open).
3	Bad JSON Format	Whitelist file JSON format check failed.
4	Bad DEVICES	Whitelist file DEVICES content check failed.
5	Bad Name	Whitelist file DEVICES name check failed.
6	Bad Description	Whitelist file DEVICES description check failed.
7	Bad Type	Whitelist file DEVICES type check failed.
8	Bad ID	Whitelist file DEVICES ID check failed.
9	Bad TOUT	Whitelist file DEVICES TOUT check failed.
10	Unknow Failure	Whitelist file unknow failure.

Network information is composed by two parts, the first part describes the network state, the second part is the state code. For example: “NETWORK OK|1” is composed by NETWORK OK and 1. The details are listed below:

Table 196 - Zigbee states

	State code and meaning of state code			
Network information	**0 No network**	**1 Some devices need pair/unpair**	**2 All devices OK**	**3 Network processor information internally saved**
NO NETWORK	√			
NETWORK JOINING		√	√	√
NETWORK OK		√	√	√

Manual input is another available way to fill in the whitelist, however, it is proposed when you update a single sensor or replace a sensor. In **GENERAL/Zigbee network/Zigbee devices** section, double click a cell of the list to change the value of the sensor.

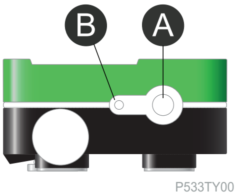
Pair the sensors

When the whitelist is imported or updated in PowerLogic P5, activate the sensors to start pairing operation.

PowerLogic TH110 is powered by the current flowing through the point where the sensor is fixed. The startup current for it is 13 A. In case of the current flowing through achieves the startup current, TH110 will power on and activate automatically.

PowerLogic CL110 is battery-powered. By default, the sensor is in “Factory mode” (sleeping mode) to be paired with any open access point as soon as the button is pressed. To launch the pairing of CL110, press the push button at the side of the sensor as shown in Push on button and green LED of PowerLogic CL110, page 626 until the green LED flashes.

Figure 377 - Push on button and green LED of PowerLogic CL110



A	Push button for pairing	B	Green LED

For the detail information of the sensors, please refer to:

- the installation guide of PowerLogic TH110 (document reference: MFR7945801) through this link: https://www.se.com/us/en/download/document/MFR7945801/
- the user guide of PowerLogic CL110 (document reference: QGH40088) through this link: https://www.se.com/uk/en/download/document/QGH40088/

There are two methods to start the pairing of the sensors at eSetup Easergy Pro side:

- Single pairing: Initiate pairing from eSetup Easergy Pro/**GENERAL**/**Zigbee network**, in the list of **Zigbee devices**. For each listed sensor, there are two buttons in the cell of **Actions**. Click on **Pair** button to initiate the pairing of the sensor. The maximum pairing window is 180 seconds.
- Massive pairing: In **Zigbee devices**, click on **Mass. pair** button to initiate massive pairing. The maximum pairing window is 210 seconds.

  NOTE: The single pairing and massive pairing are exclusive for eSetup Easergy Pro, when the **Mass. pair** button is pressed down, pressing **Pair** buttons will not be executed, vice versa. The **Mass. unpair**, **Unpair**, and **Remove** are also exclusive.

In pairing, the value of **Network information** will change to *NETWORK JOINING|1*. After paired successfully, the value will change to *NETWORK OK|1*. In **Zigbee devices** list, in column **Paired**, the value of the sensor will change from *Unpaired* to *Paired*.

To interrupt the pairing, click on **dis. Zigbee pair** button, the pairing will be stopped, the already paired sensors will be kept.

The followed table lists the buttons for the pair/unpair operations:

Table 197 - The buttons for the pair/unpair operations

Button	Function of button
Mass. pair	Massive pairing command, to launch the massively pairing after import of the whitelist or edit manually the IDs.
Mass. unpair	Massive unpairing command, to massively unpair the sensors. One of the use case is to massively unpair the paired sensors before replacing the sensors massively.
dis. Zigbee pair	Deactive pairing command, stop pairing process during pairing or massive pairing, the pairing will be stopped but already paired sensors will be kept.
Unpair	Unpair a paired sensor.
Pair	Pair a sensor.
Remove	Remove a sensor and remove its configuration from PowerLogic P5.

Map the sensors

The aim of this step is to assign mapping of paired sensors to specified location, for example the cable, the busbar, the upper and lower circuit breaker arms, and so on. In eSetup Easergy Pro/**GENERAL**/**Zigbee network**, there is a list under **Sensor mapping**, double click on the cells of **Sensor index** and select the correct index code according to the list of **Zigbee devices**.

Communication settings and configuration of EOS-BM100/EOS-MCMx00

Setting of protocol

Connect the laptop to PowerLogic P5 with USB cable, set protocol follow these steps:

1. Launch eSetup Easergy Pro.
2. Log-in as *EngineerLevel* or *InstallerLevel*.
3. In eSetup Easergy Pro/**COMMUNICATION**/**Protocol configuration**/**Serial port**, set **Remote port protocol** to *Digital CB*.
4. In **Serial port settings**, set the **Speed of transmission**, **Parity**, and **Response timeout**. The default serial port parameters are:
    - Speed of transmission = *38400* bps
    - Parity: *Even*
    - Stop bits = *1*
    - Response timeout = *1000* ms
5. Click on **Write** button on top left of eSetup Easergy Pro interface, the device will be rebooted when the writing is done. After reboot, the menu tab **DIGITAL CB** will be displayed.

Module configuration

In **DIGITAL CB** menu tab, click on **Module configuration**, the EOS-BM100 and EOS-MCMx00 module communication can be enabled/disabled by checking/ unchecking in the column **Enabled** of the table of **Module configuration**, the list of sections at left will be shown or hidden as the modules are enabled/disabled.

Address setting

In eSetup Easergy Pro/**Digital CB**/**Module configuration**, the items to be configured are:

- Enabled: enable/disable the communication between PowerLogic P5 and the modules.
- Slave ID: double click the cell to set slave ID, ensure the ID value is the same with the ID setting on the module.

To ensure the communication with PowerLogic P5, set Modbus slave ID of the module correctly:

- 11~19 for EOS-BM100, default ID is 11,
- 21~29 for EOS-MCMx00, default ID is 21.

For the detail of physical connection to PowerLogic P5, please refer to Connection of PowerLogic P5 with EOS-BM100/EOS-MCMx00, page 116.

Monitoring functions

Environmental monitoring

This function is enabled/disabled in eSetup Easergy Pro/**PROTECTION**/**Environmental monitoring**/**Environmental monitoring**.

PowerLogic P5 monitors the environmental condition of the substation by measuring the relative humidity and temperature with battery powered CL110 Zigbee sensors. One CL110 for substation environment, two CL110 in the cubicle (mainly in cable compartment for condensation).

Based on the calculation of the gap between measured values and the normal values, the environmental monitoring monitors the aging of the cubicle and provides estimated date of next maintenance.

According to IEC 62271-304, 4 levels of condensation and 2 levels of pollution are defined concerning climatic conditions and measuring the time spent in each level to determine an acceleration factor which reduces the maintenance time. The levels of severity are described in the following table:

Table 198 - Levels of condensation

Level	Description
CO	Condensation occurs not more than twice a year. Equipment used in locations with humidity and temperature control in order to avoid condensation.
CL	Non-frequent condensation, not more than twice a month. Equipment used in locations without humidity and temperature control (protection for daily variations of outside climate, but condensation cannot be excluded).
CH	Frequent condensation, more than twice a month. Equipment used in locations without temperature control.
CH+	Very frequent condensation, more than twice a week.

Table 199 - Levels of pollution

Level	Description
PL	Light pollution Ambient air not significantly polluted by dust, smoke, corrosive or flammable gases, vapours or salt.
PH	Heavy pollution Location with no special precautions to minimize presence of deposits. (excluding conductive dust and industrial smoke producing thick conductive deposits)

Considering both condensation level and pollution level, the severity degrees are defined as follows:

Table 200 - Severity degrees

		Pollution	
		PL	PH
Condensation	CO	Degree 0	Degree 1
	CL	Degree 1	Degree 2
	CH	Degree 2	Degree 3
	CH+	Degree 3	Degree 3

Degree 0 is the degree of normal maintenance period, the other degrees will shorten the maintenance period.

This monitoring will warn out in case of:

- High severity degree according to pollution and environmental conditions
- Close calculated maintenance date
- High ambient temperature or humidity

The values of aging pace and next maintenance date are recalculated every day based on the measured temperature, humidity and condensation, and set alarms in case. If the condensation alarm was started the day before and not stopped in the next day, a “full day” will be recorded and will be used in calculation of the aging pace and next maintenance date.

The features of the environmental monitoring functions are listed in the following table:

Table 201 - Features of the environmental monitoring function

Feature	Description
Condensation presence	It measures the ambient temperature, the ambient relative humidity of cable compartment or busbar of the switchgear, calculates the temperature of dew point each hour, so that to calculate the presence of condensation.
Condensation level	The monitoring function measures condensation level every day, in considering the record of last 3 days with significant condensation levels or use the exact label on the front panel since the past 365 days, it defines the condensation level from CO to CH+.
Pollution level	It is a self-declaration of pollution level PL or PH depending on the ambient air situation (significantly polluted or not).
Degree of severity	The degree of severity is calculated daily based on condensation level and pollution level. The maintenance period is re-evaluated each month, including: • Consumed Maintenance time (in day) • Ageing Pace (calculated daily) • Date of next maintenance (rounded to month, calculated daily)

Configuration of environmental monitoring

Environmental monitoring user interface in eSetup Easergy Pro

Configuration settings

- **Environmental monitoring** with check box: Enable/disable environmental algorithm, default value is *disable* (unchecked).
- **Pollution level** : Substation pollution level. The value is *PL* or *PH*, default value is *PH*.
- **Maintenance period** : Maximum period in month between maintenances, the range is [0,120], default value is *48*.
- **Last maintenance date** : Date of last maintenance.
- **Humidity threshold**: Ambient humidity maximum value (%). The range is [50, 95], default value is *90*.

  When the ambient humidity exceeds the setting of **Humidity threshold**, a “High degree of humidity” alarm is raised.
- **Temperature threshold** : Ambient temperature maximum value (℃). The range is [30, 80], default value is 70.

  When the ambient temperature exceeds the setting of **Temperature threshold**, a “High temperature” alarm is raised.

Output data

- **Environmental monitoring status** : The calculated environmental status. The possible value is *0, 1, 2*.
    - *0* – in good state
    - *1* - in pre-alarm state
    - *2* – in alarm state
- **Severity degree** : Degree of environment severity following IEC 62271-304 standard. The possible value is 0 – 3 from best to worst.

  Degrees of severity are closely linked to levels of condensation and levels of pollution. See Severity degrees, page 628.

  For the condensation level and the pollution level, see Levels of condensation, page 628 and Levels of pollution, page 628.
- **Ageing pace factor** : Rapidity of switchgear degradation due to environmental conditions. The value range is [1, 8]. *1* stands for the normal ageing, the values greater than *1* means that maintenance period is shortened.
- **Next maintenance date** : Date of the next maintenance.
- **Days at severity degree 0, Days at severity degree 1, Days at severity degree 2, Days at severity degree 3**: For each degree of severity, number of days spent in it. This cumulative information can be reset by user.

Input data

Environmental algorithm requires 1 ambient temperature data, 1 ambient humidity data and 1 cold point temperature data.

Ambient temperature and humidity data come from 1 CL110 sensor. This sensor is required configured, paired, and mapped to ambient installation point.

Cold point temperature data comes from 1 CL110 sensor. This sensor is required configured, paired, and mapped to cold point installation point.

See Configuration of Digital Circuit Breaker, page 623 for the pairing, mapping and configuration of CL110.

If there is no ambient sensor or cold point sensor configured, environmental monitoring function can not work.

Events and alarms

The environmental monitoring function can generate below events and alarms.

Table 202 - Environmental monitoring events and alarms

Alarm level	Event code	Description	Condition
Event	204E1	Env severity degree 1 event on	Severity degree changes to 1.
Event	204E2	Env severity degree 1 event off	Severity degree changes from 1 to other value.
Event	204E3	Env severity degree 2 event on	Severity degree changes to 2.
Event	204E4	Env severity degree 2 event off	Severity degree changes from 2 to other value.
Event	204E5	Maintenance date soon on	The maintenance date is coming in less than 2 months.
Event	204E6	Maintenance date soon off	The maintenance date is coming in not less than 2 months or Maintenance date overpassed.
Alarm	204E7	High degree of severity on	Severity degree changes to 3.
Alarm	204E8	High degree of severity off	Severity degree changes from 3 to other value.

Table 202 - Environmental monitoring events and alarms (Continued)

Alarm level	Event code	Description	Condition
Alarm	204E9	Maintenance date overpassed on	The next maintenance date < current date.
Alarm	204E10	Maintenance date overpassed off	The next maintenance date > current date.
Alarm	204E11	High temperature alarm on	Ambient temperature > temperature threshold
Alarm	204E12	High temperature alarm off	Ambient temperature < (temperature threshold - 3)
Alarm	204E13	High humidity alarm on	Ambient humidity > humidity threshold and lasts over 1 day
Alarm	204E14	High humidity alarm off	Ambient humidity < (humidity threshold - 3)

If cold point sensor temperate data is not valid or cold point sensor is not present, only the last 4 alarms can be generated.

Matrix signals

Environmental monitoring function provides below 2 signals to Output matrix, LED matrix, Block matrix and Object block matrix.

- **Environmental event** : Activated when one of “on” events in Environmental monitoring events and alarms, page 630 is raised. Deactivated when none of “on” events in the same table is raised.
- **Environmental alarm** : Activated when one of “on” alarm in Environmental monitoring events and alarms, page 630 is raised. Deactivated when none of “on” alarm in the same table is raised.

Environmental monitoring algorithm details

There are four types of measurement and calculation to proceed the environmental monitoring:

- Condensation presence:
  - Measure ambient temperature (T) of one cable box or busbar of the switchgear.
  - Measure relative humidity (RH) of one cable box or busbar of the switchgear.
  - Calculate temperature of dew point (Tdp) where

$$T_{dp} \approx T - \frac{100 - RH}{5}$$

P533Z900

  - Measure temperature of a cold point (Tc) in each cable box.
  - Calculate condensation presence each hour. If Tc < Tdp, there is condensation.
- Condensation level:

  Every day condensation level is measured, and the last 3 days (D1, D2 and D3) with a significant condensation level are considered.

  - If the oldest day D1 happens at less than seven days ago: Level CH+
  - If D1 happens at less than 30 days ago: Level CH
  - If D1 happens at less than 365 days ago: Level CL
  - Else: Level Co
- Pollution level:

  Self-declaration of PL of PH pollution level depending on the ambient air situation (significantly polluted or not).

- Degree of severity:

  The degree of severity is daily calculated based on pollution and condensation level.

With all the above information, maintenance periods are reduced by a factor 1, 2, 4 or 8 regarding to the degree of severity which is re-evaluated each month.

Consumed Maintenance time in day:

$M_{cons} = M_{cons} + 2^{Degree}$

The maintenance time increases by 1 to 8 days every day.

Ageing Pace (calculated daily):

$$AgingPace = \frac{M_{cons}}{D_{cur} - D_{last}}$$

P533ZA00

Where D_{cur} is the current date and D_{last} is the date of the last maintenance.

Date of next maintenance rounded to month (calculated daily):

$$D_{maint} = D_{last} + \frac{M_{per}}{AgingPace}$$

P533ZB00

Where D_{last} is the date of the last maintenance and M_{per} is the maintenance period in normal condition.

Thermal monitoring

This function is enabled/disabled in eSetup Easergy Pro/**PROTECTION**/**Thermal monitoring**/**Enable thermal monitoring**.

PowerLogic P5 monitors the quality of the connection and insulation by measuring the temperature of connections of:

- circuit breaker (arms)
- busbar
- cable

The temperature of the connections will rise if the connections are not in good condition.

The thermal monitoring uses TH110 and CL110 sensors, which output temperature value every two minutes by default with Zigbee Green Power protocol. PowerLogic P5 treats with the temperature values from sensors to provide different levels of alarms as listed below:

- Absolute Temperature
- Phase Temperature Discrepancy
- Fix relative Temperature rise
- Self-Adapted Temperature rise

Three alarm levels are defined as below:

- Events: notification of changes that are not yet alarming. This level of alarm will generate only event log, no LED light will be triggered.
- Orange alarm: Non urgent verification or part replacement requested. This level of alarm will trigger alarm signal and light on user programmable LED to yellow.
- Red alarm: Immediate action required. This level of alarm will trigger alarm signal and light on user programmable LED to red and block some application functions by configured matrix.

The following data of thermal monitoring are stored in PowerLogic P5:

Table 203 - PowerLogic P5 stored thermal monitoring data

Name of data	Type of data	Polling rate	Resolution
Each connection T°	Measured value	2 minutes	1°C
Each connection T° threshold 1	Setting	N/A	1°C
Each connection T° threshold 2	Setting	N/A	1°C
S/S Ambient T°	Measured value	2 minutes	1°C

Configuration of thermal monitoring

Standard absolute temperature algorithm

The standard absolute temperature algorithm is enabled by default if thermal monitoring is enabled.

Below settings are related to standard absolute temperature algorithm.

- Configuration settings
  - **Enable thermal monitoring**: The general switch for all 4 types of algorithms, default value is *disabled* (unchecked).
  - **Enable advanced parameters**: More settings are displayed if enabled, default value is *disabled* (unchecked). If user wants to configure the temperature alarm threshold for CB, Busbar and Cable, this check box must be enabled.
  - **Abs. temp. rise limit of busbar** : Maximum warming of the busbar point.
  - **Abs. temp. rise limit of CB** : Maximum warming of the CB point.
  - **Abs. temp. rise limit of cable** : Maximum warming of the cable point.
  - **Maximum ambient temperature** : Maximum ambient temperature.
- Output parameters
  - **Red alarm limit of busbar**: The temperature alarm limit for busbar. The value = **Abs. temp. rise limit of busbar** + **Maximum ambient temperature**.
  - **Rad alarm limit of CB :** The temperature alarm limit for CB. The value = **Abs. temp. rise limit of CB** + **Maximum ambient temperature**.
  - **Red alarm limit of cable :** The temperature alarm limit for cable. The value = **Abs. temp. rise limit of cable** + **Maximum ambient temperature**.
- Alarms and events

  Standard absolute temperature algorithm raises below alarms and events when the condition meet.

  Suppose:
  - Tx – Phase temperature of install point, x = A, B, C.
  - TH – Red alarm limit of install point.

  Install point includes CB upper arm, CB lower arm, busbar 1, busbar 2, cable 1, cable 2.

Table 204 - Standard absolute temperature algorithm events and alarms

Alarm level	Event code	Description	Condition
Alarm	205E1	CB upper-A T red alarm on	The alarm is triggered when Tx > TH, The off event is triggered when Tx < (TH - 3) or TH110 sensor is not installed, or the TH110 sensor temperature is not valid
Event	205E2	CB upper-A T red alarm off	
Alarm	205E3	CB upper-B T red alarm on	
Event	205E4	CB upper-B T red alarm off	

Table 204 - Standard absolute temperature algorithm events and alarms (Continued)

Alarm level	Event code	Description	Condition
Alarm	205E5	CB upper-C T red alarm on	
Event	205E6	CB upper-C T red alarm off	
Alarm	205E7	CB lower-A T red alarm on	
Event	205E8	CB lower-A T red alarm off	
Alarm	205E9	CB lower-B T red alarm on	
Event	205E10	CB lower-B T red alarm off	
Alarm	205E11	CB lower-C T red alarm on	
Event	205E12	CB lower-C T red alarm off	
Alarm	205E13	Cable 1-A T red alarm on	
Event	205E14	Cable 1-A T red alarm off	
Alarm	205E15	Cable 1-B T red alarm on	
Event	205E16	Cable 1-B T red alarm off	
Alarm	205E17	Cable 1-C T red alarm on	
Event	205E18	Cable 1-C T red alarm off	
Alarm	205E19	Cable 2-A T red alarm on	
Event	205E20	Cable 2-A T red alarm off	
Alarm	205E21	Cable 2-B T red alarm on	
Event	205E22	Cable 2-B T red alarm off	
Alarm	205E23	Cable 2-C T red alarm on	
Event	205E24	Cable 2-C T red alarm off	
Alarm	205E25	Busbar 1-A T red alarm on	
Event	205E26	Busbar 1-A T red alarm off	
Alarm	205E27	Busbar 1-B T red alarm on	
Event	205E28	Busbar 1-B T red alarm off	
Alarm	205E29	Busbar 1-C T red alarm on	
Event	205E30	Busbar 1-C T red alarm off	
Alarm	205E31	Busbar 2-A T red alarm on	
Event	205E32	Busbar 2-A T red alarm off	
Alarm	205E33	Busbar 2-B T red alarm on	
Event	205E34	Busbar 2-B T red alarm off	
Alarm	205E35	Busbar 2-C T red alarm on	
Event	205E36	Busbar 2-C T red alarm off	

Phase temperature discrepancy algorithm

The phase temperature discrepancy algorithm is enabled by default if thermal monitoring is enabled.

Below settings are related to phase temperature discrepancy algorithm.

- Configuration settings
  - **Enable thermal monitoring :** The general switch for all 4 types of algorithms, default value is *disabled* (unchecked).
  - **Enable advanced parameters :** More settings are displayed if enabled, default value is *disabled* (unchecked). If you want to modify the threshold ratio for first event or alarm, the setting must be *enabled* (checked).
  - **Rated current of CB :** Rated current of CB
  - **Rated current of cubicle :**Rated current of cubicle
  - **Temp. unbalance limit of busbar :** Maximum temperature of busbar point. The valid range is calculated with rated current of cubicle. The default range is [10, 25], default value is *25*.
  - **Temp. unbalance limit of CB :** Maximum temperature of CB point. The valid range is calculated with rated current of CB and PowerLogic P5 CT value. The default range is [10, 15], default value is *15*.
  - **Temp. unbalance limit of cable :** Maximum temperature of cable point. The valid range is calculated with rated current of CB and PowerLogic P5 CT value. The default range is [10, 15], default value is *15*.
  - **Temp. unbalance alarm level:** Threshold ratio for first event or alarm.
- Alarms and events

  Standard absolute temperature algorithm raises below alarms and events when the condition meet.

  Suppose:
  - **Ta** is the phase A temperature in install point.
  - **Tb** is the phase B temperature in install point.
  - **Tc** is the phase C temperature in install point.

  Install point can be cable 1, cable 2, CB upper arm, CB lower arm, busbar 1, busbar 2.
  - **Tdis** = Max(Ta, Tb, Tc) - Min(Ta, Tb, Tc)
  - **TH** = Temp. unbalance limit of cable/CB/busbar
  - **Rt** = Temp. unbalance alarm level

Table 205 - Phase temperature discrepancy algorithm events and alarms

Alarm level	Event code	Description	Condition
Alarm	206E37	CB upper T orange alarm on	The alarm is triggered when Tdis > TH, The off event is triggered when Tdis < (TH - 3)
Event	206E38	CB upper T orange alarm off	
Alarm	206E39	CB lower T orange alarm on	
Event	206E40	CB lower T orange alarm off	
Alarm	206E41	Cable 1 T orange alarm on	
Event	206E42	Cable 1 T orange alarm off	
Alarm	206E43	Cable 2 T orange alarm on	
Event	206E44	Cable 2 T orange alarm off	
Alarm	206E45	Busbar 1 T orange alarm on	
Event	206E46	Busbar 1 T orange alarm off	
Alarm	206E47	Busbar 2 T orange alarm on	
Event	206E48	Busbar 2 T orange alarm off	
Event	207E37	CB upper T overpass on	The on event is triggered when Tdis > TH*Rt The off event is triggered when Tdis < (TH*Rt - 3)
Event	207E38	CB upper T overpass off	
Event	207E39	CB lower T overpass on	
Event	207E40	CB lower T overpass off	

Table 205 - Phase temperature discrepancy algorithm events and alarms (Continued)

Alarm level	Event code	Description	Condition
Event	207E41	Cable 1 T overpass on	
Event	207E42	Cable 1 T overpass off	
Event	207E43	Cable 2 T overpass on	
Event	207E44	Cable 2 T overpass off	
Event	207E45	Busbar 1 T overpass on	
Event	207E46	Busbar 1 T overpass off	
Event	207E47	Busbar 2 T overpass on	
Event	207E48	Busbar 2 T overpass off	

Fix relative warming algorithm

The Fix relative warming algorithm is enabled by default if thermal monitoring is enabled. Fix relative warming algorithm and self-adapted relative warming algorithm are exclusive.

Below settings are related to the fix relative warming algorithm.

- Configuration settings
  - **Enable thermal monitoring :** The general switch for all 4 types of algorithms, default value is *disabled* (unchecked).
  - **Enable advanced parameters :** More settings are displayed if enabled, default value is *disabled* (unchecked). If you want to modify the threshold ratio for first event or alarm, and maximum warming of the install points, the setting must be enabled.
  - **Rated current of CB :** Rated current of CB
  - **Rated current of cubicle :** Rated current of cubicle
  - **Abs. temp. rise limit of busbar :** Maximum warming of the busbar point.
  - **Abs. temp. rise limit of CB :** Maximum warming of the CB point.
  - **Abs. temp. rise limit of cable :** Maximum warming of the cable point.
  - **Maximum ambient temperature :** Maximum ambient temperature.
  - **Relative temp. alarm level 1 :** Threshold ratio for first event.
  - **Rel. temp. rise limit of busbar :** Temperature threshold for busbar point. The valid range is calculated with rated current of cubicle and maximum warming of the busbar point. The default range is [10, 75] , default value is *75*.
  - **Rel. temp. rise limit of CB :** Temperature threshold for CB point. The valid range is calculated with rated current of CB, CT primary value of PowerLogic P5, and maximum warming of the CB point. The default range is [10, 15], default value is *15*.
  - **Rel. temp. rise limit of cable :** Temperature threshold for cable point. The valid range is calculated with rated current of CB, CT primary value of PowerLogic P5, and maximum warming of the cable point. The default range is [10, 15], default value is *15*.

- Alarms and events

  Fix relative warming algorithm raises below alarms and events when the condition meets.

  Suppose:

  - **Tx** - phase temperature in install point, x = A, B, C
  - **TH** – Rel. temp. rise limit of install point
  - **Tamb** – Ambient temperature measured by CL110
  - **Amax** – Maximum ambient temperature
  - **Wx** – Tx – Tamb or Tx – Amax if Tamb is invalid
  - **Rt -** Threshold ratio for first event

Table 206 - Fix relative warming algorithm events and alarms

Alarm level	Event code	Description	Condition
Alarm	206E1	CB upper-A T orange alm on	The alarm is triggered when Wx > TH The off event is triggered when Wx < (TH - 3)
Event	206E2	CB upper-A T orange alm off	
Alarm	206E3	CB upper-B T orange alm on	
Event	206E4	CB upper-B T orange alm off	
Alarm	206E5	CB upper-C T orange alm on	
Event	206E6	CB upper-C T orange alm off	
Alarm	206E7	CB lower-A T orange alm on	
Event	206E8	CB lower-A T orange alm off	
Alarm	206E9	CB lower-B T orange alm on	
Event	206E10	CB lower-B T orange alm off	
Alarm	206E11	CB lower-C T orange alm on	
Event	206E12	CB lower-C T orange alm off	
Alarm	206E13	Cable 1-A T orange alm on	
Event	206E14	Cable 1-A T orange alm off	
Alarm	206E15	Cable 1-B T orange alm on	
Event	206E16	Cable 1-B T orange alm off	
Alarm	206E17	Cable 1-C T orange alm on	
Event	206E18	Cable 1-C T orange alm off	
Alarm	206E19	Cable 2-A T orange alm on	
Event	206E20	Cable 2-A T orange alm off	
Alarm	206E21	Cable 2-B T orange alm on	
Event	206E22	Cable 2-B T orange alm off	
Alarm	206E23	Cable 2-C T orange alm on	
Event	206E24	Cable 2-C T orange alm off	
Alarm	206E25	Busbar 1-A T orange alm on	
Event	206E26	Busbar 1-A T orange alm off	
Alarm	206E27	Busbar 1-B T orange alm on	
Event	206E28	Busbar 1-B T orange alm off	
Alarm	206E29	Busbar 1-C T orange alm on	
Event	206E30	Busbar 1-C T orange alm off	
Alarm	206E31	Busbar 2-A T orange alm on	

Table 206 - Fix relative warming algorithm events and alarms (Continued)

Alarm level	Event code	Description	Condition
Event	206E32	Busbar 2-A T orange alm off	
Alarm	206E33	Busbar 2-B T orange alm on	
Event	206E34	Busbar 2-B T orange alm off	
Alarm	206E35	Busbar 2-C T orange alm on	
Event	206E36	Busbar 2-C T orange alm off	
Event	207E1	CB upper A T overpass on	The on event is triggered when Wx >= TH*Rt, The off event is triggered when Wx <= (TH*Rt - 3)
Event	207E2	CB upper A T overpass off	
Event	207E3	CB upper B T overpass on	
Event	207E4	CB upper B T overpass off	
Event	207E5	CB upper C T overpass on	
Event	207E6	CB upper C T overpass off	
Event	207E7	CB lower A T overpass on	
Event	207E8	CB lower A T overpass off	
Event	207E9	CB lower B T overpass on	
Event	207E10	CB lower B T overpass off	
Event	207E11	CB lower C T overpass on	
Event	207E12	CB lower C T overpass off	
Event	207E13	Cable 1-A T overpass on	
Event	207E14	Cable 1-A T overpass off	
Event	207E15	Cable 1-B T overpass on	
Event	207E16	Cable 1-B T overpass off	
Event	207E17	Cable 1-C T overpass on	
Event	207E18	Cable 1-C T overpass off	
Event	207E19	Cable 2-A T overpass on	
Event	207E20	Cable 2-A T overpass off	
Event	207E21	Cable 2-B T overpass on	
Event	207E22	Cable 2-B T overpass off	
Event	207E23	Cable 2-C T overpass on	
Event	207E24	Cable 2-C T overpass off	
Event	207E25	Busbar 1-A T overpass on	
Event	207E26	Busbar 1-A T overpass off	
Event	207E27	Busbar 1-B T overpass on	
Event	207E28	Busbar 1-B T overpass off	
Event	207E29	Busbar 1-C T overpass on	
Event	207E30	Busbar 1-C T overpass off	
Event	207E31	Busbar 2-A T overpass on	
Event	207E32	Busbar 2-A T overpass off	
Event	207E33	Busbar 2-B T overpass on	
Event	207E34	Busbar 2-B T overpass off	
Event	207E35	Busbar 2-C T overpass on	

Table 206 - Fix relative warming algorithm events and alarms (Continued)

Alarm level	Event code	Description	Condition
Event	207E36	Busbar 2-C T overpass off	

Self-adapted relative warming algorithm

The self-adapted relative warming algorithm is not enabled by default only if thermal monitoring is enabled and thermal monitoring mode is advanced. The algorithm is only applied on cable and CB install points.

Self-adaptive relative warming algorithm and fix relative warming algorithm are exclusive.

Below settings are related to self-adapted relative warming algorithm.

- Configuration settings
  - **Enable thermal monitoring :** The general switch for all 4 types of algorithms, default value is *disabled* (unchecked).
  - **Enable advanced parameters :** More settings are displayed if enabled. The default value is disabled. If you want to modify the threshold ratio for first event or alarm, and maximum warming of the install points, the setting must be enabled (checked).
  - **Rated current of CB :** Rated current of CB .
  - **Rated current of cubicle :** Rated current of cubicle.
  - **Abs. temp. rise limit of busbar :** Maximum warming of the busbar point.
  - **Abs. temp. rise limit of CB :** Maximum warming of the CB point.
  - **Abs. temp. rise limit of cable :** Maximum warming of the cable point.
  - **Maximum ambient temperature :** Maximum ambient temperature.
  - **Relative temp. alarm level 2 :** Threshold ratio for first event.
  - **Thermal time constant :** Thermal time constant of the equipment (s).
  - **Thermal monitoring mode :** The default value is Standard. If you want to enable self-adapted relative warming algorithm, the setting value must set to Advanced.
  - **Orange alarm limit of CB :** It is calculated with rated current of CB, maximum warming of install point, maximum ambient temperature, current flowing through each install point phase, CT primary value of PowerLogic P5, and thermal time constant. The setting is displayed only if Thermal monitoring mode is *Advanced*.
  - **Orange alarm limit of cable :** It is calculated with rated current of cubicle, maximum warming of install point, maximum ambient temperature, current flowing through each install point phase, CT primary value of PowerLogic P5, and thermal time constant. The setting is displayed only if Thermal monitoring mode is *Advanced*.
- Alarms and events

  Self-adapted relative warming algorithm raises below alarms and events when the condition meets.

  Suppose:
  - **Tx** - phase temperature in install point, x = A, B, C
  - **TH** – Orange alarm limit of CB or cable
  - **Tamb** – Ambient temperature measured by CL110
  - **Amax** – Maximum ambient temperature
  - **Wx** – Tx – Tamb or Tx – Amax if Tamb is invalid
  - **Rt -** Threshold ratio for first event

Table 207 - Self-adapted relative warming algorithm events and alarms

Alarm level	Event code	Description	Condition
Alarm	206E1	CB upper-A T orange alm on	The alarm is triggered when Wx > TH The off event is triggered when Wx < (TH - 3)
Event	206E2	CB upper-A T orange alm off	
Alarm	206E3	CB upper-B T orange alm on	
Event	206E4	CB upper-B T orange alm off	
Alarm	206E5	CB upper-C T orange alm on	
Event	206E6	CB upper-C T orange alm off	
Alarm	206E7	CB lower-A T orange alm on	
Event	206E8	CB lower-A T orange alm off	
Alarm	206E9	CB lower-B T orange alm on	
Event	206E10	CB lower-B T orange alm off	
Alarm	206E11	CB lower-C T orange alm on	
Event	206E12	CB lower-C T orange alm off	
Alarm	206E13	Cable 1-A T orange alm on	
Event	206E14	Cable 1-A T orange alm off	
Alarm	206E15	Cable 1-B T orange alm on	
Event	206E16	Cable 1-B T orange alm off	
Alarm	206E17	Cable 1-C T orange alm on	
Event	206E18	Cable 1-C T orange alm off	
Alarm	206E19	Cable 2-A T orange alm on	
Event	206E20	Cable 2-A T orange alm off	
Alarm	206E21	Cable 2-B T orange alm on	
Event	206E22	Cable 2-B T orange alm off	
Alarm	206E23	Cable 2-C T orange alm on	
Event	206E24	Cable 2-C T orange alm off	
Alarm	206E25	Busbar 1-A T orange alm on	
Event	206E26	Busbar 1-A T orange alm off	
Alarm	206E27	Busbar 1-B T orange alm on	
Event	206E28	Busbar 1-B T orange alm off	
Alarm	206E29	Busbar 1-C T orange alm on	
Event	206E30	Busbar 1-C T orange alm off	
Alarm	206E31	Busbar 2-A T orange alm on	
Event	206E32	Busbar 2-A T orange alm off	
Alarm	206E33	Busbar 2-B T orange alm on	
Event	206E34	Busbar 2-B T orange alm off	
Alarm	206E35	Busbar 2-C T orange alm on	
Event	206E36	Busbar 2-C T orange alm off	
Event	207E1	CB upper A T overpass on	The on event is triggered when Wx > TH*Rt The off event is triggered when Wx < (TH*Rt - 3)
Event	207E2	CB upper A T overpass off	
Event	207E3	CB upper B T overpass on	
Event	207E4	CB upper B T overpass off	

Table 207 - Self-adapted relative warming algorithm events and alarms (Continued)

Alarm level	Event code	Description	Condition
Event	207E5	CB upper C T overpass on	
Event	207E6	CB upper C T overpass off	
Event	207E7	CB lower A T overpass on	
Event	207E8	CB lower A T overpass off	
Event	207E9	CB lower B T overpass on	
Event	207E10	CB lower B T overpass off	
Event	207E11	CB lower C T overpass on	
Event	207E12	CB lower C T overpass off	
Event	207E13	Cable 1-A T overpass on	
Event	207E14	Cable 1-A T overpass off	
Event	207E15	Cable 1-B T overpass on	
Event	207E16	Cable 1-B T overpass off	
Event	207E17	Cable 1-C T overpass on	
Event	207E18	Cable 1-C T overpass off	
Event	207E19	Cable 2-A T overpass on	
Event	207E20	Cable 2-A T overpass off	
Event	207E21	Cable 2-B T overpass on	
Event	207E22	Cable 2-B T overpass off	
Event	207E23	Cable 2-C T overpass on	
Event	207E24	Cable 2-C T overpass off	

Matrix signals

Thermal monitoring function provides 3 input signals for PowerLogic P5 output matrix, LED matrix, block matrix, and object block matrix. These 3 signals are :

- Thermal event – Activated when any of on events is triggered.
- Thermal red alarm – Activated when any of red alarms above is triggered.
- Thermal orange alarm – Activated when any of orange alarms above is triggered.

Circuit breaker monitoring

Charging motor monitoring

Charging motor monitoring function is managed by EOS-BM100, it monitors the energy consumption of the load spring motor and counts the number of operations. The alarms will be raised up in case of excessive of energy/current or the duration of charging, or the number of operations has reached the threshold. There will be PowerLogic P5 events corresponding to the alarms.

Coils monitoring

The coils monitoring function is managed by EOS-BM100, it monitors the status of the MX or MN opening coils and XF closing coil and the activation time of the coils thanks to their internal self-check function[169].

At each operation, the activation time of the coils will be measured and compared with thresholds depending on coil references. The alarms will be generated in case of:

- non-activation of coil
- long reaction time
- great number of operations

The EOS-BM100 records also the number of operations.

There will be PowerLogic P5 events corresponding to the alarms and coil current curves displayed.

Mechanism monitoring

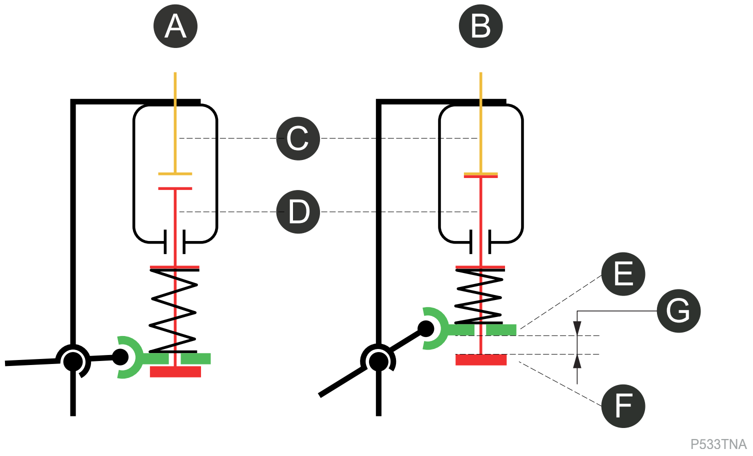
The mechanism monitoring function monitors the operating mechanism reliability, it measures the following aspects of circuit breaker:

- Operating speed: the EOS-BM100 measures speeds of the mechanism on different points, it will generates alarm in case of low speed. There will be PowerLogic P5 events corresponding to the alarms.
- The number of operations: the EOS-BM100 counts the number of operations and raises an alarm when the counted number have reached the rated value. There will be PowerLogic P5 events corresponding to the alarms.

Vacuum interrupter mechanical monitoring

This monitoring function is managed by EOS-BM100 module, it measures the erosion gap (Egap) of each phase. An alarm will be raised inside EOS-BM100 when the measured value gets out of range. There will be PowerLogic P5 events corresponding to the alarms.

Figure 378 - Erosion Gap definition



A	Opened position	B	Closed position
C	Fixed contact	D	Movable contact
E	Sensor location	F	Magnet location
G	Measured Egap		

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[169] For electronic coils only.

NOTE: The Egap measure allows to monitor contacting pressure and ensures the contact springs are enough compressed to guaranty a good opening.

Truck position monitoring

Truck position monitoring function is managed by EOS-BM100, by measuring continually the distance between the door of cubicle and the circuit breaker/ disconnector, it checks if the electrical power connections of circuit breaker/ disconnector are correctly inserted/aligned with the cubicle connectors. Alarms will be raised up in case of abnormal distance. There will be PowerLogic P5 event corresponding to the alarms.

ES motor and truck motor monitoring

Managed by EOS-MCMx00, it monitors the energy consumption of the ES motor and the truck motor and counts the number of operations. The EOS-MCMx00 measures the current of motors during the whole activation time. The alarms will be raised up in case of excessive of energy/current or the duration of charging, or the number of operations has reached the threshold.

There will be PowerLogic P5 events corresponding to the alarm and motor current curves displayed..

Circuit breaker alarm status and health index

EOS-MCMx00 monitors the CB alarm status. The status is OK (health index higher than 70%), ORANGE (health index between 30% and 70%) and RED (Health index lower than 30%) based on the worst status of coils/mechanism/ Egap /charging motor status. This status indicates the occurrence of an alarm concerning the CB.

When CB alarm status changes, there will be PowerLogic P5 alarms and events.

Circuit breaker health index is a synthesis of sub-elements of the previous monitoring functions. It is calculated based on the following aspects:

- Circuit breaker mechanism health index
- Erosion gap (Egap) health index
- Charging motor health index
- Racking device motor (truck motors) health index
- Coil health index

Alarms management

According to their severity or priority, the alarms are classed with two levels in EOS-BM100/EOS-MCMx00 and in thermal and environmental monitoring:

- Event: for event which are not alarm, since they are not abnormal conditions, but still need to be mentioned as an evolution of the condition.
- Alarm: for the abnormal conditions needed to pay attention of or even intervention.

In PowerLogic P5, events are present in event logs, alarms are present in alarm list. Real time alarm information will pop up on local HMI.

PowerLogic P5 collects alarms signals from EOS-BM100/EOS-MCMx00, converts to local alarms accordingly, or generates local alarms based on information collected from thermal monitoring and environmental monitoring.

Alarm types

Two levels of severity for alarms are defined:

- Red alarm: immediate action required (health index < 30%)
- Orange alarm: Non- urgent verification, maintenance to be planed (health index between 30% and 70%)

Control functions of Digital Circuit Breaker

PowerLogic P5 is able to operate the circuit breaker, the ES motor and truck/ disconnector motor from local HMI with push button, or remotely with control functions.

NOTE: The control functions are available only if the EOS-MCMx00 has been selected.

PowerLogic P5 is able to execute the following control operations through Modbus serial communication with EOS-MCMx00:

- Operate coil of 1 opening coil and 1 closing coil, of release coil or undervoltage coil, electronic coil or non-electronic coil.
- Send order to operate truck/disconnector motor and ES motor.

PowerLogic P5 also gives information of the reason why an operation is forbidden.

Configuration of Digital Circuit Breaker Control functions

With control objects of PowerLogic P5, it is possible to set activate/inactivate of control and define the following device controls:

- Circuit breaker: Open/Close
- Truck: racking-in and racking-out
- DS (Disconnector): Open/Close
- ES (Grounding switch): Open/Close

The selection of Remote or Local control mode is managed by PowerLogic P5.

The control function is achieved by controllable objects of PowerLogic P5, control objects can be found in eSetup Easergy Pro/**CONTROL**/**Objects**, the sections **Control object x**, x equals to 1 to 6, in where:

- the selection **Object open DI** is the setting for the open control.
- the selection **Object close DI** is the setting for the close control.
- the selection **Object DO for MCMx00 control** is setting for the control of CB or MSW.

NOTE: The **Object open DI** and **Object close DI** must be selected in pair. The selection in **Object open DI** and **Object close DI** must be relevant to the selection in **Object DO for MCMx00 control**. If not, the control will be failed.

The configurations for CB control are as follows:

1. Select *CB open* for **Object open DI**,
2. Select *CB close* for **Object close DI**,
3. Select *CB* for **Object DO for MCMx00 control**.

The configurations for MSWx (x equals to 1 to 4) control are as follows:

1. Select *MSWx open* for **Object open DI**,
2. Select *MSWx close* for **Object close DI**,
3. Select *MSWx* for **Object DO for MSWx00 control**.

Local control

In PowerLogic P5 local control mode, control commands are received from PowerLogic P5 function button or digital input.

Remote control

In PowerLogic P5 remote control mode, control commands are received from Modbus or IEC61850 client.

Order sources

PowerLogic P5 receives control orders from the following sources:

- Hardwired interface push buttons, selectors in front of the cubicle
- A remote device as Edge, SCADA

The following table lists the operations PowerLogic P5 can manage:

Table 208 - Operations PowerLogic P5 can manage

Operation	From hardwired interface	From remote device
Open/close CB	Yes	Yes
Rack in/out TRUCK	Yes	Yes
Open/Close disconnector	Yes	Yes
Open/Close ES	Yes	Yes

Delay mode

PowerLogic P5 can set operation delay time. There are two kinds of delay time selectable in front of cubicle:

- 0 s: operation start instantly
- X s: device operations will be delayed by X seconds

The setting is in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 configuration**.

CB operation

Open CB

PowerLogic P5 manages the MX1 or MX2/MN coils to open the circuit breaker.

CB is allowed to open when CB is in closed status.

CB status is shown in MIMIC or in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**/**Circuit breaker operation**. If the symbol of CB status is “?”, it means the intermediate (00) state or the bad (11) state, depends on the communication status of EOS-MCM100. If the communication status is online, the CB is in intermediate (00) state, otherwise the CB state is in bad (11) state.

In the local mode of PowerLogic P5, CB can be opened through MIMIC by push button, CB status will be updated if the operation succeeds.

In the remote mode of PowerLogic P5, the open order can be sent through Modbus TCP and IEC61850 client.

Close CB

PowerLogic P5 controls the XF coil to close the CB. CB is allowed to close when CB is in open status.

CB status is shown in MIMIC or in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**/**Circuit breaker operation**.

In the local mode of PowerLogic P5, CB can be closed through MIMIC by push button, CB status will be updated if the operation succeeds.

In the remote mode of PowerLogic P5, the close order can be sent through Modbus TCP and IEC61850 client.

Truck operation

Truck control

PowerLogic P5 can rack in/rack out truck if it is motorized with motor.

Truck is allowed to rack in when it is in racked-out and circuit breaker is open, vice versa.

Truck status is shown in MIMIC or in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**/**MSWx operation** (x equals to 1 to 4) . If the symbol of truck status is “?”, it means the intermediate (00) state or the bad (11) state, depends on the communication status of EOS-MCMx00. If the communication status is online, the truck is in intermediate (00) state, otherwise the truck is in bad (11) state.

In the local mode of PowerLogic P5, the rack in or rack out truck can be made through MIMIC by push button, truck status will be updated if the operation succeeds.

In the remote mode of PowerLogic P5, the rack in/rack out order can be sent through Modbus TCP and IEC61850 client.

Rack in and rack out truck

Control of the rack in/rack out of truck is set in **eSetup Easergy Pro**/**CONTROL**/**Objects**, in the sections **Control object x**, x equals to 1 to 6. The following setting are to be made:

- Object open DI: select *MSWy open*,
- Object close DI: select *MSWy closed*,
- Object DO for MCMx00 control: select *MSWy*,

where y equals 1 to 4.

Disconnector operation

PowerLogic P5 can open/close disconnector if it is motorized with motor.

Disconnector is allowed to open when it is in closed status and vice versa.

Disconnector status is shown in MIMIC or in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**/**MSWx operation** (x equals to 1 to 4) . If the symbol of disconnector status is “?”, it means the intermediate (00) state or the bad (11) state, depends on the communication status of EOS-MCMx00. If the communication status is online, the disconnector is in intermediate (00) state, otherwise the disconnector is in bad (11) state.

In the local mode of PowerLogic P5, the open or close of disconnector can be made through MIMIC by push button, truck status will be updated if the operation succeeds.

In the remote mode of PowerLogic P5, the open/close order can be sent through Modbus TCP and IEC61850 client.

Open and Close of disconnector

Control of the Open and Close of disconnector is set in **eSetup Easergy Pro**/**CONTROL**/**Objects**, in the sections **Control object x**, x equals to 1 to 6. The following setting are to be made:

- Object open DI: select *MSWy open*,
- Object close DI: select *MSWy closed*,

- Object DO for MCMx00 control: select *MSWy*,

where y equals 1 to 4.

Grounding Switch(ES) operation

The Grounding Switch can be controlled through PowerLogic P5 when it operates with motor.

ES is allowed to open when it is in closed status and vice versa.

ES status is shown in MIMIC or in eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**/**MSWx operation** (x equals to 1 to 4) . If the symbol of ES status is “?”, it means the intermediate (00) state or the bad (11) state, depends on the communication status of EOS-MCMx00. If the communication status is online, the ES is in intermediate (00) state, otherwise the ES is in bad (11) state.

In the local mode of PowerLogic P5, the open/close of ES can be made through MIMIC by push button, ES status will be updated if the operation succeeds.

In the remote mode of PowerLogic P5, the open/close order can be sent through Modbus TCP and IEC61850 client.

Open and Close Grounding Switch

Control of the Open and Close of Grounding Switch is set in **eSetup Easergy Pro**/**CONTROL**/**Objects**, in the sections **Control object x**, x equals to 1 to 6. The following setting are to be made:

- Object open DI: select *MSWy open*,
- Object close DI: select *MSWy closed*,
- Object DO for MCMx00 control: select *MSWy*,

where y equals 1 to 4.

Control operation diagnostics

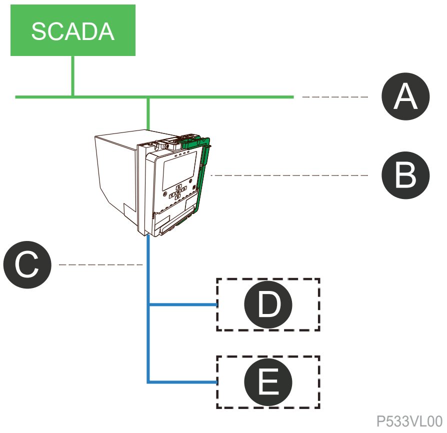
PowerLogic P5 displays the reason in case of forbidden operation or sequence order. The status can be checked through eSetup Easergy Pro/**DIGITAL CB**/**MCMx00 operation**.

Modbus gateway functions

PowerLogic P5 serves in a gateway mode by which the EcoStruxure Power Operation (EPO)/Power Monitoring Expert (PME) can communicate with EOS-BM100 and EOS-MCMx00 through Modbus TCP. In case of the protocols Digital CB and Modbus slave are both configured, PowerLogic P5 will work in gateway mode automatically.

When PowerLogic P5 works in gateway mode, the network architecture is as in the following figure:

Figure 379 - Modbus gateway network architecture



A	TCP/IP IP address: Modbus Slave IP address, port:502	B	PowerLogic P5, communicates with the EOS-BM100 and EOS-MCMx00 through unit identifier.
C	RS485	D	EOS-BM100, slave ID 11~19.
E	EOS-MCMx00, slave ID 21~29.		

Any SCADA system communicate with PowerLogic P5 by TCP/IP, meantime, PowerLogic P5 is the node of communicating with EOS-BM100 and EOS-MCMx00 through serial Modbus.

In gateway mode, function codes *03*, *04*, *05* (EOS-MCMx00), *06*, *16* are defined for communicating with EOS-BM100 and EOS-MCMx00, other function codes will be treated as illegal.

Diagnostics functions

System consistency and integrity

PowerLogic P5 makes auto-test and consistency verification to make self-test of integrity with the configuration. In case of abnormal situation found, it will generate warning for user to solve the issue.

The main checks are:

- Zigbee sensors commissioning and radio frequency communication quality
- Communication link between devices

A system alarm will be raised in case of fault/error detected.

Internal failure

PowerLogic P5 collects internal failure from EOS-BM100 and EOS-MCMx00. The events are created correspondingly.

Current transformer supervision (ANSI 60)

Description

The Current Transformer Supervision (CTS) feature is used to detect failure of one or more phase current inputs to the protection relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in:

- Incorrect operation of current protection functions
- Risks of unexpected CT secondary voltages generated

Three operation modes can be selected:

- 3I only

  If the magnitude of one phase current is below 1% Inom, while the magnitude of the other two phase currents is within 0.05 - 1.2 Inom and the angle between them is 110° - 130°, the function issues a fast alarm after 20 ms and a delayed alarm after the operation delay has elapsed.

  When the minimum value of magnitude of the three phase currents exceeds 0.1 Inom or CTS reset input is activated, the alarm will be reset.
- IN & VN

  If neutral current exceeds the pick-up value and the neutral voltage is less than the pick-up value, the function issues a fast alarm immediately and a delayed alarm after the operation delay has elapsed.

  The alarm will be reset when IN drops below 95% of the neutral current pick-up value or VN is higher than 103% of the neutral voltage pick-up value or CTS reset input is activated.
- Both

  CT failure is detected if one of the above modes is fulfilled.

CTS provides 2 signals: Fast Alarm and Latched Alarm after settable operate delay. The Fast Alarm signal is also used to block the transformer differential protection (ANSI 87T).

Both CTS signals are provided with a fix reset time of 100 ms.

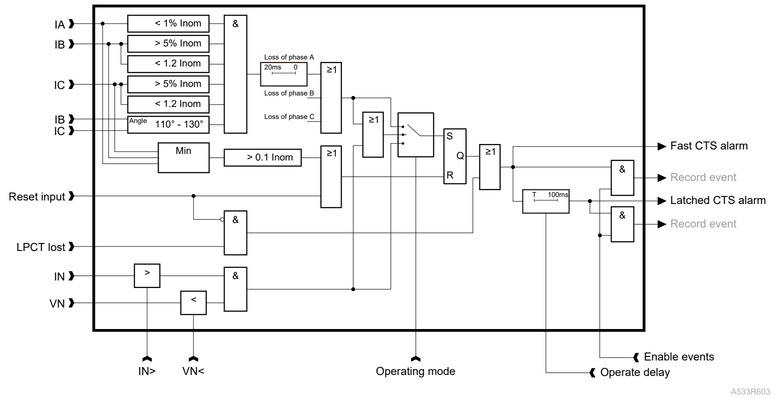
The function is inactive if only 2 phase current sensors are connected (2 CT mode). It is recommended for the user to decrease the maintenance interval for the current sensors in this mode.

In addition to supervising the phase current inputs, the CT supervision function (CTS) also provides supervision of the physical connection of LPCT. If the physical connection of any LPCT is lost, an “LPCT connection loss” alarm will be issued. Please note in this case all the three phase current measurements are lost.

With transformer differential protection P5T30 two CTS elements are available with a fix link to the measured currents of one end (CTS-1 to end 1, CTS-2 to end 2).

Block diagram

Figure 380 - Block diagram of the current transformer supervision function (of phase A as example)



Characteristics

Table 209 - Settings and characteristics of the current transformer supervision function (ANSI 60)

Settings/characteristics (description/label)	Values
Neutral current IN> / IN>	
Setting range	0.08...4.00 pu[170]
Resolution	0.01 pu[170]
Accuracy	±3%
Reset ratio	95% ± 2%
CT input selection[171]	
Setting range	CT-1 is fixed for CT supervision 1, CT-2 is fixed for CT supervision 2.
Neutral voltage VN< / VN<	
Setting range	0.01...0.30 pu[172]
Resolution	0.01 pu[172]
Accuracy	±3%
Reset ratio	103% ± 2%
Operate delay / Operate delay	
Setting range	0.04...10.00 s
Resolution	0.01 s
Accuracy	±1% or ±30 ms at IN and VN
Characteristic times	
Disengaging time	< 160 ms
CTS operating mode	
Options	3I only; IN&VN; Both
CTS reset input	

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[170] Inom

[171] Available for P5T30 only.

[172] √3 x Vnom

Table 209 - Settings and characteristics of the current transformer supervision function (ANSI 60) (Continued)

Settings/characteristics (description/label)	Values
Options	Any available DI/VI/F-button
Delayed CTS on event	
Options	Enable; Disable
Delayed CTS off event	
Options	Enable; Disable
Fast CTS on event	
Options	Enable; Disable
Fast CTS off event	
Options	Enable; Disable
Settings of CTS DIFF	
Enable CTS	On/Off
I_1>	0.05...4.00 Inom
I_2/I_1 low	5%...100%
I_2/I_1 high	5%...100%
Operate delay	0.00…10.00 s

Table 210 - Measured values of CT

Parameter	Unit	Description
Max. of IA IB IC	A	Maximum value of phase currents
Min. of IA IB IC	A	Minimum value of phase currents
IN.calc	A	IN calculated value
Measured VN	V	Measured neutral voltage
Calculated VN	V	Calculated neutral voltage

Voltage transformer supervision (ANSI 60)

Description

The PowerLogic P5 protection relay supervises the voltage transformers (VTs) wiring between the connector A terminals and the sensors. If there is a fuse in the voltage transformer circuitry, the blown fuse helps prevent or distorts the voltage measurement. Therefore, an alarm should be issued. Furthermore, in some applications, protection functions using voltage signals should be blocked to avoid false tripping such as:

- Ground fault overvoltage and directional ground fault overcurrent using calculated neutral voltage
- Phase undervoltage or negative sequence overvoltage
- Directional overcurrent
- Power

The Voltage Transformer Supervision (VTS) function detects the loss of one or several phase voltage inputs using various well known methods:

- The detection of the presence of negative sequence voltage and the absence of negative sequence current. The negative sequence voltage V2 and the negative sequence current I2 are calculated. If V2 exceeds the V2> setting and at the same time, I2 is less than the I2< setting, the function issues an alarm after the operation delay has elapsed. This criterion is meaningful only when a reasonable minimum current is flowing, i.e. if the maximum phase current is greater than the minimum current setting I>(min).
- This function detects the loss of all three voltages under load conditions when current inputs are available. If three phase voltages are dropped to a value below 30% pu (1 pu = √3 x Vprim.nom), at the same time the maximum phase current is below the maximum load current and above the minimum load current, VTS fast block signal will be activated. Minimum load current is ground charging capacitive current, which should be above line current without load.
- Digital input (DI) for indicating miniature circuit breaker (MCB open) position
- The VT supervision function (VTS) also provides supervision of the physical connections of the three phase LPVTs. If the physical connection of any phase LPVT is lost, an internal “LPVT loss” signal will be accepted to immediately trigger the VTS function.

  If according to above conditions a loss of voltage is detected, immediately a "VTS fast block" signal is issued, intended for instantaneous blocking of voltage dependent functions to help prevent maloperation. A further "VTS alarm" signal will be issued after a settable time delay to help prevent unnecessary alarming upon spurious VTS operation.
- In case that the “Enable VN compare” is set to On, “Delta_VN>” is used to compare the magnitude difference between two neutral voltages.

VT supervision will reset when all the following conditions are satisfied:

- Negative sequence voltage V2 is less than V2> setting.
- Maximum phase to phase voltage is greater than 30% pu (1 pu = √3 x Vprim. nom).
- MCB input resets.
- LPVT loss input resets.

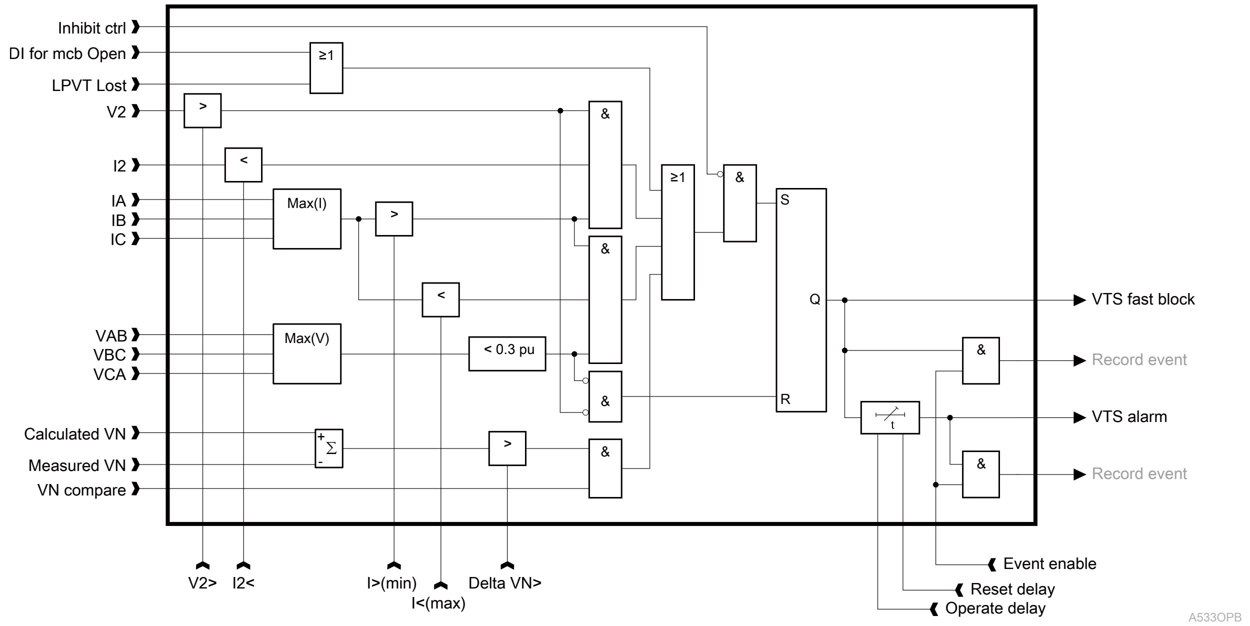
When the VT failure condition is not satisfied for 10 s, the “VTS alarm” will be reset.

In addition, the VTS function can be blocked by inhibit control function.

NOTE: For PowerLogic P5V20's VTS function, only MCB input is available.

Block diagram

Figure 381 - Block diagram of the voltage transformer supervision function



Characteristics

Table 211 - Settings and characteristics of the voltage transformer supervision function (ANSI 60)

Settings/characteristics (description/label)	Values
Enable VTS	
Options	Off/On
pickup value	
Setting range	0.02...2.00 pu[173]
Resolution	0.1
Accuracy	±2% or ± 0.2 V (secondary), whichever is bigger
pickup value	
Setting range	0.02...2.00 pu[174]
Resolution	0.01
Accuracy	±2% or 0.02 pu[174], whichever is bigger
Operate delay/Operate delay	
Setting range	0.00...60.00 s
Resolution	0.02 s
Accuracy	±1% or ±10 ms, whichever is bigger
DI for MCB position/MCB	
Options	Selection of one digital input (DI)
Inhibit ctrl/InhCtrl	

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173. √3 x Vnom
174. Inom

Table 211 - Settings and characteristics of the voltage transformer supervision function (ANSI 60) (Continued)

Settings/characteristics (description/label)	Values
Options	Selection of one input (DI; VI)
I>(min) setting/I>(min)	
Setting range	0.02...1.00 pu[175]
Resolution	0.01 pu[175]
Accuracy	±1% or 0.02 pu[175]
I<(max) setting/I<(max)	
Setting range	0.10...20.00 pu[175]
Resolution	0.01 pu[175]
Accuracy	±1% or 0.02 pu[175], whichever is bigger
V<	
Value	30% pu[176], fixed
Accuracy	±1% or ± 0.1 V (secondary), whichever is bigger
Enable VN compare	
Options	Off/On
Delta_VN>	
Setting range	0.05...1.00 pu[176]
Resolution	0.01 pu[176]
Accuracy	±2% or ± 0.2 V (secondary), whichever is bigger
Reset time (fixed)	
Value	10 s
Accuracy	30 ms
Characteristic times	
Reset time	< 30 ms
Setting group/SetGrp	
Number	1

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[175] Inom
[176] √3 x Vnom

PowerLogic P5 and bay condition monitoring

In order to provide a basic indication about the IED and bay condition, a user scalable signaling “Protection active” is provided with PowerLogic P5.

The prerequisite for this feature is that the PowerLogic P5 must be in the normal operational state (not blocked by any defect, detected by internal self-monitoring).

The configuration can be found in the **Control** menu/**Good condition** sub-menu.

Table 212 - Settings and characteristics of the good condition function

Settings/ characteristics	Description
Global trip	A trip issued by the protection function (except arc detection).
Any output latched	Any latched trip which still needs to be reset by the user.
Auto reclosing in progress	A definite trip occurred or auto-reclosing ended unsuccessfully.
Motor start inhibition	Motor start inhibition is present due to excessive number of motor starts (if this feature is enabled).

The user can select one or more of the above settings as the conditions to trigger the signaling “Protection active”. When any signal from the selected setting(s) is presented, the status of **Good condition** changes to *Protection active*, otherwise the status is in idle state.

The signaling can be used:

- For local indication via LED, for example: to increase the awareness of the PowerLogic P5 and bay condition prior to any local operation
- For local or remote indication via outputs
- As the blocking condition in object control, for example: to help prevent dangerous bay open/close commands while the status changes to *Protection active*
- For remote information by logging related event(s)

Maintenance

The PowerLogic P5 protection relays together with their extension units, communication accessories, arc-flash detection sensors and cabling, require maintenance in work according to their specification. Keep a record of the maintenance actions. The maintenance can include, but is not limited to, the following actions.

Safety instructions

This page contains important safety instructions that must be followed precisely before attempting to install, repair, service or maintain electrical equipment. Carefully read and follow the safety instructions described below.

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- NEVER work alone.
- Turn off all power supplying this equipment before working on or inside it. Consider all sources of power, including the possibility of backfeeding.
- Always use a properly rated voltage sensing device to confirm that all power is off.
- Do not power a withdrawn mobile part of the PowerLogic P5 protection relay with voltage > 24 V. Put back the withdrawable part in the fixed part before powering it on.

Failure to follow these instructions will result in death or serious injury.

⚠DANGER

FIRE HAZARD

If you are authorized to withdraw the relay:

- Disconnect the power supply before removing or replacing a module or the withdrawable part of the protection relay.
- Never touch electronics parts (risk of damage due to electrostatic discharge).
- Before replacing the withdrawable part, clean all debris and contaminants from the case, the withdrawable part, and the connectors.
- In case of module or withdrawable part replacement, perform the commissioning operations before using the protection relay.
- Apply proper tightening torque to all wire connections.

Failure to follow these instructions will result in death or serious injury.

⚠CAUTION

LOSS OF DEVICE CONFIGURATION

Never plug in or draw out the communication modules while the PowerLogic P5 protection relay is in service.

Failure to follow these instructions can result in injury or equipment damage.

Self-monitoring

Watchdog relay

The PowerLogic P5 protection relays are equipped as standard with a watchdog relay (digital output 4 in slot B). This is a changeover relay which is kept permanently in the on-position by the PowerLogic P5 protection relay. In the event of protection relay failure, or if the auxiliary power supply fails, the watchdog relay reverts to the off-position.

Maintenance/Test LED

The PowerLogic P5 protection relay has gone into the fallback position following detection by the embedded self-tests of the failure of one of its internal components. In this case, the PowerLogic P5 protection relay is no longer operational. This 🔧 LED may light up when the protection relay is energized during all the start phase of the PowerLogic P5 protection relay (for about 60 seconds). This is normal and does not indicate any internal failure. When the start phase of the protection relay is completed, the LED is off if no internal failure is detected.

Purpose of the self-tests

The PowerLogic P5 protection relay runs a series of self-diagnostic tests for hardware and software in boot sequence and also performs runtime check. These self-tests detect any failure and can avoid random PowerLogic P5 protection relay behavior. The main aim is to avoid an unwanted tripping or failure to trip in the event that it occurs on the power system or on the equipment to protect.

The PowerLogic P5 protection relay can detect two types of internal failure:

- A major failure when the protection functions cannot be processed properly or can initiate an unwanted trip. In this case, The PowerLogic P5 protection relay goes into the fallback position:
    - The output relays stay in current status, and goes to default position after the device is rebooted.
    - Watchdog relay (DO4 contact output on slot B) goes into the off-position.
    - The ⓘ LED, ⚡ LED, and the configurable LEDs are off.
    - The ON LED, on the local panel, is on.
    - The 🔧 LED on the local panel is on.
    - A message is displayed on the local panel: it allows Schneider Electric to make a diagnosis.
    - The communication is inoperative
    - The communication with eSetup Easergy Pro is inactive depending on the type of internal failure.

- A minor defect, is a malfunction of components (hardware or firmware) which is not used directly by protection functions (namely, memory, used for logging emergency events, communication channels, etc.). It shall not result in loss of PowerLogic P5 protection relay operability.
  - The output relays stay in their current status.
  - Watchdog relay (DO4 contact output on slot B) stays energized.
  - The (!) LED, ⚡ LED, and configurable LEDs stay in their current positions.
  - The ON LED, on the local panel, is on.
  - The 🔧 LED on the local panel is off.
  - An alarm message is displayed on the local panel to highlight the origin of the issue.

    Press the R key to remove the message (the alarm message is logged in the Alarm message list).
  - The communication is still operational depending on the type of the internal failure.
  - The communication with eSetup Easergy Pro, on the local panel is active depending on the type of internal failure.

List of self-tests

The self-tests are described in the table below.

Table 213 - List of self-tests

Name	Description	Execution period	Fallback position
Hardware configuration test	Checking if the actual hardware configuration matches to the product model number	On energization	YES
Power supply test	External power supply check	On energization and during operation	YES
	Internal power supply check if key microchips are supplied with correct voltage	During operation	YES
Main processor test	Microcontroller's watchdog monitoring	During operation	YES
	Monitoring of MCU temperature	On energization and during operation	YES
Internal drivers (FPGA)	Initialization FPGA code checks	On energization	YES
	Monitoring of FPGA data	During operation	NO
EEPROM memory test	Microcontroller checks of EEPROM information	On energization and during operation	YES
NOR Flash memory test	Microcontroller checks of code in NOR flash	On energization	YES
NAND flash memory test	Microcontroller checks of NAND flash usage	On energization	YES
DDRAM memory test	Microcontroller checks correct access to DRAM	On energization and during operation	YES
DDRAM partition monitoring	Microcontroller checks different partitions sizes	During operation	NO
Back up memory test	Check the information in the backup memory is correct	During operation	NO

Table 213 - List of self-tests (Continued)

	Check if the backup memory content is valid	On energization	NO
Internal bus test	Check internal bus operation is correct	On energization and during operation	YES
Display and graphic libraries	Check if the software components are correct	During operation	NO
RTD presence (MET148-2)	Check the RTD is on bus	During operation	NO
Firmware (system and application) and setting consistency	Check application file is in line with hardware and firmware	On energization	NO
	Check firmware matches to the settings	During operation	NO
Digital inputs test	Check digital input circuits are correct	On energization and during operation	YES
Digital outputs test	Check digital output circuits are correct	On energization and during operation	YES
Test of the analog input module software components	Check the presence of analogue module	On energization	YES
	Check the analog sampling is correct	During operation	NO
Calibration coefficient validity test	Check the calibration coefficients data are correct	On energization	NO
	Check calibration coefficients validity vs. conditions	During operation	NO
Test of detection of loss of the clock (RTC)	Check the clock of RTC is correct	On energization	NO, Back to default time stamp
Measurement and protection execution monitoring	Check the continuity of task execution	During operation	NO
Software execution test	Detection of operating system processing errors	On energization and during operation	YES
	Check of continuity of execution of periodic tasks	On energization and during operation	YES
Reset detection	Detection of resets of all kinds of root causes	On energization and during operation	YES

Diagnostic function

Introduction

The diagnostic function contains the following types of diagnostics:

- Diagnostic information
- Error supervision and alarm

The diagnostic information function collects system information and error information, export them to log files, provides data for technical support and troubleshooting for Schneider Electric service team.

The error supervision and alarm function supervises error and raises alarm.

Diagnostic information

Description

The diagnostic information function collects those kinds of information:

- Diagnostic information
- Memory usage self-monitoring information
- Trace edrShow information in case of IED crash/abnormal reboot
- Communication error frame record
- System viewer collect

There are two trigger modes of this function: the auto trigger and the manual trigger. Auto trigger will be triggered automatically when device failure occurred. The manual trigger is triggered manually from the local HMI.

Diagnostic information

The collection of the information listed below can be triggered both by auto trigger and by manual trigger.

Table 214 - Diagnostic information

Information	Output file
CPU Load	/sys/MW/ant.log
memory usage	/usr/sysdiag/sysdiag.txt
memory partition usage	/sys/MW/ant.log
Crash information	/usr/sysdiag/sysdiag.txt
Process tasks screenshot	/usr/sysdiag/sysdiag.txt
task stack screenshot	/usr/sysdiag/sysdiag.txt
ARP table information	/usr/sysdiag/sysdiag.txt
ports statistics	/usr/sysdiag/sysdiag.txt
Nvram management status	/sys/MW/ant.log
Regular task over run status	/sys/MW/ant.log
RSTP status	/usr/sysdiag/sysdiag.txt
RPR/HSR status	/usr/sysdiag/sysdiag.txt
PTP status	/usr/sysdiag/sysdiag.txt
Software version	/usr/sysdiag/sysdiag.txt
Vxworks version	/usr/sysdiag/sysdiag.txt

Table 214 - Diagnostic information (Continued)

Information	Output file
Hardware version	/usr/sysdiag/sysdiag.txt
Module number	/usr/sysdiag/sysdiag.txt
System upgrade logs	/sys/MW/update.log
System error log	/sys/MW/ant.log
Matrix status	/sys/MW/ant.log
Goose driver status	/usr/sysdiag/sysdiag.txt
Dst status	/sys/MW/ant.log
Trans task status	/sys/MW/ant.log
User thread status	/sys/MW/ant.log

Memory usage self-monitoring information

This function can only be triggered by auto trigger. It monitors system memory using trend and records log file, for the analyze of system memory leak issue. A self-diagnostic alarm will be reported if the memory usage is over 98%.

Trace edrShow information in case of IED crash/abnormal reboot

This function can only be triggered by auto trigger. It records the task edrShow information to help analyze and locate the cause of device crash or abnormal reboot. Normal reboot will not trigger this function.

Communication error frame record

This function can only be triggered by auto trigger, it records the error frames received by the device. The supported protocols are: DNP3, Modbus slave, IEC101, IEC103. The record includes both the content and the number of error frames.

System viewer collect

This function can only be triggered by auto trigger. The aim of this function is to analyze customer issue such as HMI frozen. If a task can not get run for over 1 minute, the system viewer collect will be triggered, if task frozen is detected, the log will be recorded.

Log files

The log files of each diagnostic functions are listed below:

Table 215 - Diagnostic information

Diagnostic function	Auto/Manual trigger	Log file name and path	File size limit
Diagnostic information	Auto and manual	/sys/MW/ant.log /usr/sysdiag/sysdiag.txt	2 MB each
Memory usage self-monitoring	Auto only	/sys/MW/ant.log	2 MB
Trace edrShow information	Auto only	/usr/sysdiag/edr.txt	512 K

Table 215 - Diagnostic information (Continued)

Diagnostic function	Auto/Manual trigger	Log file name and path	File size limit
Communication error frame record	Auto only	/usr/comm/errFrame.log /usr/comm/errFrame1.log	500 K each, 100 frames maximum, 512 bytes per frame.
System viewer collect	Auto only	/usr/sysdiag/sysview0.wvr /usr/sysdiag/sysview1.wvr /usr/sysdiag/sysview2.wvr /usr/sysdiag/sysview3.wvr /usr/sysdiag/sysview4.wvr	About 200 K each, corresponds to the duration of 500 ms.

The log files are appended written when file size is less than their limits. When the file size reaches the limit, the earliest record will be over written.

Manual trigger operation

The diagnostic information collection can be triggered manually. Follow this process to trigger the operation: on local HMI, from **Main menu** (**home menu**):

1. Go to **Device/Tst**, click on OK button.
2. Then select **Sys Diag**, click on OK button.
3. On **Sys Diag** window, click on OK button, the Sys Diag list will be dropped down and selected, click OK again.
4. Select *Implement* on the selection list and click OK button.

When information collection is completed, the status display of step 3 will be changed to – from *implement*.

Read out the log files

To read out the diagnostic log files, connect the device to the laptop and launch eSetup Easergy Pro, then:

1. Click on the **Tools** button from the tool bar, select **Device maintenance / Read maintenance log file**.
2. There will be a pop-up window informing you the device may be out of service and the protection unavailable during the process, click on **OK** button to continue.
3. In the pop-up window, select the path you wish to save the exported file, then click on **OK**.
4. The read-out process will take a few moments, a prompt window displays the status. After the process is finished, the prompt window will close automatically.

   NOTE: The exported file is encrypted, only Schneider Electric service team are authorized to decrypt the log files.

Error supervision and alarm

DI Over Voltage alarm

This function detects over voltage error of DI. When the measured DI voltage exceeds the setting threshold, it will block DI status from being changed and raise the "DI Over Voltage" alarm.

The format of DI Over Voltage alarm is:

- X: bit 16~23 stand for the SLOT number, bit 8~15 stand for the board number, bit 0~7 stand for the DI index, where X is the error value.

The threshold setting changes with the setting change of digital input mode. When the nominal voltage of selected mode is equal to or greater than 110 V, the threshold value is 254 V, when the pick-up setting is less than 110 V, the threshold is 238 V.

The setting of digital input mode can be changed by eSetup Easergy Pro in **CONTROL/Digital inputs/DI configuration**, in column **Mode**.

Backup memory

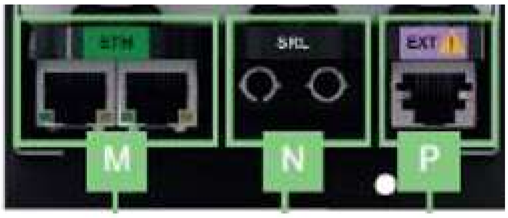
The PowerLogic P5 protection relay has an optional feature of a removable back up memory. This feature provides a mechanism for storing the product settings and other related information separately to the removable part of PowerLogic P5.

The memory allows quick, restoration of settings should there be a need to exchange the withdrawable part. As a result, the mobile part can be replaced and back in service in a matter of minutes.

The optional back up memory is included in the extension module that can be installed in Slot P. The extension module ensures as well the connection with external accessories like RTD module for temperature measurement or IRIG-B module for time synchronization. There are two types of extension modules:

Extension module	Commercial reference
Extension module and backup memory (EXT) marked with letter H in the model number or available separately	REL51034
Extension module and backup memory with wireless (Zigbee) receiver (EXR) marked with letter W in the model number or available separately	REL51044

Figure 382 - The optional extension module (slot P) that includes the back-up memory



The backup memory stores the following information:

- Settings
- Event and alarm history
- Disturbance recordings
- Product serial number
- Model number
- Persistent data included Thermal value, Running Hours, Accumulated energy etc.
- Language file
- Zigbee network file

NOTE: The PowerLogic P5 access information such as passwords and users are not stored in the backup.

Two versions of the information are held in the backup memory together with a verification CRC.

This allows one of the copies to be written and verified before erasing the second thus keeping the integrity of the data stored even if there are any power interruptions during the write process.

NOTE: There is always one valid backup version with CRC check in the backup memory even when new backup is in progress.

Automatic storage

The PowerLogic P5 automatically stores all settings, events and disturbance recordings at 2AM local time every day.

As indicated above the secured process means that the memory can not be corrupted as the save is verified before previous data is overwritten.

> **NOTE:** Due to this unique feature the important data and settings are always secured locally and not based on any remote storage on a control system.

Manual storage of settings

In addition to the daily automatic storage, the settings can be stored to the memory at any time by choosing the command from the local panel HMI.

To save the settings manually:

1. Press the ⌂ key to enter the main menu and then select the **Device/Test** icon using the arrow keys.
2. Press the OK key to enter the **Device/Test** sub menu.
3. Select the **Back-up** option using the ▽ key and press OK.
4. Press OK, select **Man. Trig** and then press OK.

```
     Backup Memory   1/2
Trigger backup memory
Status                     Idle
Man. Trig                     -
```

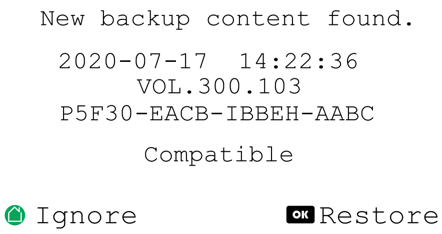
5. Press the ▽ key to select **On**.
6. The status shows **Busy**; when the storage is complete the status goes back to Idle.

Replacement of the withdrawable part

Should there be a need to replace the withdrawable part, the back-up memory provides a simple and quick mechanism to bring the protection relay back into service.

Power the unit down and extract the moving part using the green handle. If the removable part is secured with screws please follow the installation instructions (Unscrewing the front face locking screws, page 57) to remove the screws. Press the lock on the handle upwards and pull the handle. Insert the new unit with a matching model number and push the handle back to its original position and install back the screws.

After re-powering the module, the following “New backup content found” notification appears.



```
New backup content found.

 2020-07-17  14:22:36
      VOL.300.103
 P5F30-EACB-IBBEH-AABC

       Compatible

⌂ Ignore             OK Restore
```

Choose what happens with the back up memory.

Press the OK key to keep the information in the back up memory or the ⌂ button to discard and help prevent the pop up occurring again.

> **NOTE:** This action does not restore the settings. Follow the ‘Restore from Backup memory’ process described below.

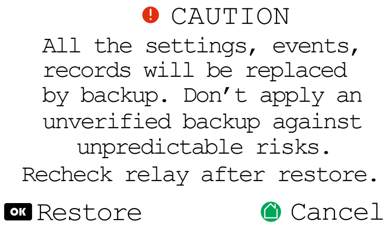
Restore from backup memory

The settings can be restored from the backup memory at any time by choosing the command from the front HMI.

To restore the settings manually:

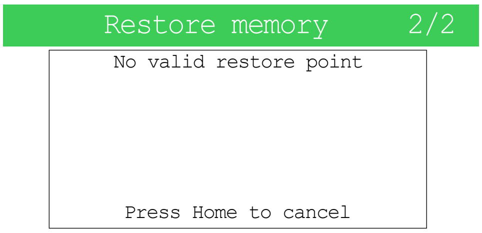
1. Press the ⌂ key to access the main menu and then select **Device/Test** by using the arrow keys.
2. Press the OK key to enter the **Device/Test** sub menu.
3. Press the ▽ key to select the **Back-up** option and then press OK.
4. Press the ▷ key to enter the second setting page **Restore Memory** and then press OK.
5. Press the ▽ key to select the **Trig restore memory** parameter and then press OK.
6. Press the ▽ key to select **On**.

   The PowerLogic P5 shows the following notification window:



CAUTION
All the settings, events,
records will be replaced
by backup. Don't apply an
unverified backup against
unpredictable risks.
Recheck relay after restore.

7. Press the OK key to accept restore.
   - If the stored file is incompatible with the hardware, "No valid restore point" notification is displayed.



No valid restore point

Press Home to cancel

   - If the file is compatible and PowerLogic P5 is connected to eSetup Easergy Pro, the device requires a manual restart when the screen indicates "RESTART".

   - If the file is compatible and there is no connection, PowerLogic P5 reboots automatically.
8. Following the reboot, the file in the back up memory is verified before restoring the settings. Press OK to accept restore.
9. In the next step the files are copied and verified.
10. When the files are restored successfully, press OK.
11. The PowerLogic P5 protection relay reboots and the restore is completed.
12. After reboot the "New backup content found" notification might pop-up again, press the ⌂ key to help prevent repetition of restore.

Restore process confirmation

The restore process can be confirmed from the local panel HMI.

1. Select the second screen in the **Back-up** sub menu by pressing the ▷ key.

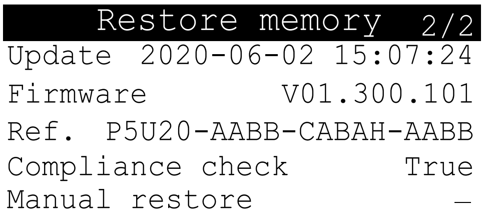
   The screen does not display any information while restoring is in progress.

2. When restoring is completed, the device information appears on the screen.

   The **Compliance check** parameter shows status “Checking” for a short while and changes to “True” after a successful restoring process.

```
Restore memory     2/2

Update                  -
Firmware                -
Ref.                    -
Compliance check        -
Manual restore          -
```



```
Restore memory  2/2
Update  2020-06-02 15:07:24
Firmware        V01.300.101
Ref.  P5U20-AABB-CABAH-AABB
Compliance check       True
Manual restore            –
```

Preventive maintenance

The PowerLogic P5 protection relay requires maintenance in order for it to work according to the specification.

⚠WARNING

UNEXPECTED SYSTEM OPERATION

Carry out periodic system testing as per the testing recommendation in this manual or if the protection system scheme has been changed.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Introduction

To obtain the maximum availability of the installation, it is essential to help ensure that the PowerLogic P5 protection relay is operational at any times.

The PowerLogic P5 protection relay's internal self-tests, the watchdog relay, and the 🔧 LED alert the user in the event of internal protection relay failure. Nevertheless, elements outside the PowerLogic P5 protection relay are not subject to these self-tests and it is therefore necessary to carry out regular preventive maintenance.

Check the PowerLogic P5 protection relay visually and pay attention to dirty components, loose wire connections, damaged wiring, user interface screen and LEDs, and other mechanical connections.

Then, to perform maintenance, carry out all the recommended commissioning tests.

First test all the digital inputs and outputs involved in tripping the circuit breaker. A test of the complete chain including the circuit breaker is also recommended.

The software setting tool, eSetup Easergy Pro, is especially useful during maintenance tests and procedures.

⚠⚠ DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, NOM-029-STPS-2011, or CSAZ462.
- The arc fault detection system is not a substitute for proper PPE when working on or near equipment being monitored by the system.
- Information on this product is offered as a tool for conducting arc-flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.
- Only qualified personnel is allowed to install and service this equipment. Read this entire set of instructions and check the technical characteristics of the device before performing such work.
- Perform wiring according to national standards (NEC) and any requirements specified by the customer.
- Observe any separately marked notes and warnings.
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on this equipment, disconnect all sources of electric power. Assume all circuits are live until they are completely de-energized, tested, and tagged. Pay particular attention to the design of the power system. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing relay to ensure that all power is off.
- The equipment must be properly grounded.
- Connect the device's protective ground to functional earth according to the connection diagrams presented in this document.
- Do not open the device. It contains no user-serviceable parts.
- Install all devices, doors and covers before turning on the power to this device.

Failure to follow these instructions will result in death or serious injury.

Intervention frequency

Test the PowerLogic P5 protection relay periodically according to the end user's safety instructions and national safety instructions or law.

The necessary time between visual inspections and functional checks depends on the installation operating conditions. Generally, we recommend to carry out periodic checks or tests every four (4) years. In corrosive or harsh offshore environments, functional testing should be carried out more often; we recommend every three (3) years.

For the testing procedures, see Commissioning, page 170.

The table below summarizes the recommended frequency of interventions.

Test	Periodicity
User interface check	1 year
Relay health check	4 years
Date and time synchronization check	4 years
Wiring and connections check	4 years
Analogue inputs operation check	4 years

Test	Periodicity
Digital inputs wiring and operation check	4 years
Digital outputs wiring and operation check	4 years
Arc-flash detection system check	3 years

Preventive maintenance tasks

User interface test

The LED and display unit test is used to check that each LED on the local panel and in each segment of the display is working correctly.

To perform the test, locate to main menu by keep pressing ⌂ button, press the *i* button, then press the ◁ button, the test will automatically start.

For the detail of the test sequence, refer to LED and screen, page 175.

Protection relay health check

⚠ CAUTION

LOSS OF DEVICE CONFIGURATION

- Never plug in or draw out the communication modules while the PowerLogic P5 protection relay is in service.
- Check and make sure that the communication module is locked.

Failure to follow these instructions can result in injury or equipment damage.

The health check includes the following tasks:

- Check that the different currents and voltages measured by the PowerLogic P5 protection relay are appropriate for the load being powered.
- Check that the PowerLogic P5 protection relay 🔧 LED is off and no maintenance message displayed on the local panel.
- Check the health of boards and modules with eSetup Easergy Pro (**Device info** view of the **Device/Test** menu)

Date and time synchronization check

Check date and time synchronization (modify date and time setting and wait for date and time synchronization).

Inspection of the rear panel

Check that the connections, including the ground terminal and the CT connections, are tight and free from corrosion.

If the CT connections are not tightened properly, this generates excessive heat rise which can lead to the destruction of connector A and the CTs.

Wiring and connection check

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Use the appropriate (3 or 4-terminal) copper jumper for common connections.
- After cabling, protect the rear connector A with the two protective caps.

Failure to follow these instructions will result in death or serious injury.

Check the wiring connections in the rear panel: for the type of screws, screwdriver to be used, and torque (see Installation, page 43).

In addition to the periodic wiring and connections check, a thermal measurement with thermal camera is recommended to make visible any warm points of the installation so that loose connections could be detected and corrected before a real issue occurs.

Check the ground connections (two ends).

Place back the two protective caps (connector A) before powering on the PowerLogic P5 protection relay.

Analogue input operation check

Check current transformers (CTs/LPCTs), voltage transformers (VTs/LPVTs), neutral current transformers (CTs), and, if used, core balanced CTs connection:

- Cable(s) (and group of cables) in the middle of the CT.
- Voltage cable shielding.
- Check that measured analogue values and angles are compliant on the local panel.

Digital input wiring and operation check

Check digital inputs statuses (in Control menu on the local panel and in the **Digital Inputs** view of the **Control** menu in eSetup Easergy Pro). Check that physical inputs states are correct, according to normal input configuration and wirings.

Digital output wiring and operation check

Check the digital outputs operation:

- If accessible, check physical digital outputs position (continuity tester).
- Check digital outputs statuses (in the Control menu on the local panel display and in the **Relays** view of the **Device/Test** menu in eSetup Easergy Pro).

Checking the trip chain

Check regularly that the complete trip chain, from the CTs to the PowerLogic P5 protection relay and through to the trip coil, is always operational.

The complete protection chain is validated during the simulation of a fault that causes tripping of the switchgear by the PowerLogic P5 protection relay.

Simply testing one function can demonstrate that the whole system is working correctly, provided it has been installed correctly.

To validate the complete protection chain, proceed as follows:

1. Select one of the protection functions that trips the switchgear.

2. Depending on the function(s) selected, inject a current or a voltage corresponding to a fault and note whether the switchgear trips.

Arc-flash detection system maintenance

⚠⚠DANGER

UNEXPECTED SYSTEM OPERATION

- If the arc-flash detection unit is no longer supplied with power or is in permanent non-operational state, the protection functions are no longer active and all the output contacts are dropped out.
- To detect a power-off or a permanent fault state, connect the watchdog (SF) output contact to a monitoring device such as SCADA or DCS.

Failure to follow these instructions will result in death or serious injury.

Keep record of the maintenance actions performed for the system.

The maintenance can include but is not limited to:

- visual inspection
- periodic testing
- hardware cleaning
- sensor condition and positioning check
- checking the obstruction of sensors

Hardware cleaning

Pay special attention to help ensure that the device, its extension units and sensors do not become dirty.

⚠⚠DANGER

UNEXPECTED SYSTEM OPERATION

- Do not use any type of solvents or gasoline to clean the device, sensors or cables.
- When cleaning the sensor, make sure that the cleaning solution does not contact anything other than the sensor.

Failure to follow these instructions will result in death or serious injury.

- If cleaning is required, wipe out dirt from the device.
- Use a dry cleaning cloth or equivalent together with mild soapy water to clean any residues from the light sensor.

Sensor condition and positioning check

Always check that the sensor remains at where it was originally designed after:

- commissioning
- sensor replacement
- modification procedure
- cleaning
- arc-flash fault
- periodic testing

Check for obstruction of the sensors.

Troubleshooting

⚠⚠DANGER

HAZARD OF ELECTRIC SHOCK, EXPLOSION OR ARC FLASH

- Apply appropriate personal protective equipment (PPE) and follow safe electrical work practices. See NFPA 70E, NOM-029-STPS-2011, or CSAZ462.
- The arc fault detection system is not a substitute for proper PPE when working on or near equipment being monitored by the system.
- Information on this product is offered as a tool for conducting arc-flash hazard analysis. It is intended for use only by qualified persons who are knowledgeable about power system studies, power distribution equipment, and equipment installation practices. It is not intended as a substitute for the engineering judgement and adequate review necessary for such activities.
- Only qualified personnel is allowed to install and service this equipment. Read this entire set of instructions and check the technical characteristics of the device before performing such work.
- Perform wiring according to national standards (NEC) and any requirements specified by the customer.
- Observe any separately marked notes and warnings.
- NEVER work alone.
- Before performing visual inspections, tests, or maintenance on this equipment, disconnect all sources of electric power. Assume all circuits are live until they are completely de-energized, tested, and tagged. Pay particular attention to the design of the power system. Consider all sources of power, including the possibility of back feeding.
- Always use a properly rated voltage sensing relay to ensure that all power is off.
- The equipment must be properly grounded.
- Connect the device's protective ground to functional earth according to the connection diagrams presented in this document.
- Do not open the device. It contains no user-serviceable parts.
- Install all devices, doors and covers before turning on the power to this device.

Failure to follow these instructions will result in death or serious injury.

Troubleshooting assistance

The PowerLogic P5 is a withdrawable protection relay. The faulty protection relay can be removed from its outer case without disconnecting the wires from the terminals. This allows to quickly replace a protection relay, provided that the spare part is available.

The replacement of a protection relay is done with the following steps:

1. Perform a diagnostic check on the protection relay:
   - The status of the watchdog relay (DO4 contact relay on slot B)
   - The status of the "(!)" and "⚡" LEDs as well as the configurable LEDs
   - The **ON** LED and the "🔧" LED on the local panel
   - The messages displayed on the local panel
   - The alarm list and maintenance file downloaded with eSetup Easergy Pro

2. Check the compatibility of the spare part: the labels on the fixed and the withdrawable parts are the same.
3. Recover the configuration from the backup memory (optional) and restart of the new protection relay, following the instructions displayed on the local panel.

The PowerLogic P5 is a modular protection relay. The modules that can be replaced individually are:

- The communication modules
- The extension modules with back-up memory

Identification of the modules can be accessed:

- From the local panel of the PowerLogic P5 protection relay (in the Device/ Test menu)
- From eSetup Easergy Pro (Boards view of the Device/test menu)
- From the web server and the EcoStruxure Power Device application

Troubleshooting the PowerLogic P5

If nothing happens when the PowerLogic P5 protection relay is switched on, troubleshoot the device according to Troubleshooting a protection relay that shows no signs of energizing, page 675 below:

Table 216 - Troubleshooting a protection relay that shows no signs of energizing

LED Indication	Possible Causes	Actions
All LEDs are off. Nothing displayed on the screen.	Connector B not plugged in.	Plug in the connector B.
	Connector B inverted with another connector: • Connector C for PowerLogic P5 x20 • Connector C, D, E for PowerLogic P5 x30	Put connectors in the correct position. Check the connector is identified according to the slot.
	Auxiliary power absent	Check the auxiliary power level (see label on the side of the device)
	Polarity reversed on terminals	Check that the + polarity is on terminal 19 and the - polarity is on terminal 20 for DC power.
	Internal failure	Change the active part.

If a maintenance message is displayed, troubleshoot the device according to Troubleshooting a protection relay according to maintenance messages, page 675 below:

Table 217 - Troubleshooting a protection relay according to maintenance messages

Message information	Possible Causes	Actions
Maintenance message with: Module ID = 3 Error type = -7	Mismatch between hardware configuration and product model number.	Check the model number on fixed part with model number on the withdrawable. 1st five characters after the application reference should be the same: P5xx0-**AAAA**-**A**xxxx-xxxx
Maintenance message with: Module ID = 3 Error type = -5 Completed by one of these references: • 3CT-CSH	Hardware failure detected on the fixed part (slot A) when the PowerLogic P5 protection relay is powered on. The message specifies the board impacted by the defect.	Change the fix part of the PowerLogic P5 protection relay with the equivalent one.

Table 217 - Troubleshooting a protection relay according to maintenance messages (Continued)

Message information	Possible Causes	Actions
- 3CT-4VT-CSH - 5CT - 5CT-4VT - 4VT - LPCT-LPVT		
Maintenance message with: Module ID = 3 Error type = -5 Completed by one of these references: - 6DI-4DO - ARC-FLASH - CPU P5x20 - CPU P5x30 - PSU30H-DI-DO - PSU30L-DI-DO - PSU20-DI-DO	Hardware failure detected on the withdrawable part when the PowerLogic P5 protection relay is powered on. The message specifies the board impacted by the defect.	Change the withdrawable part of the PowerLogic P5 protection relay with the same model number.
Alarm message completed by one of these references: - EXTENSION-BKUP - COM SRL RS485 - COM SRL FO - COM ETH 2TP-M (on slot M) - COM ETH 2FO-M (on slot M) - COM ETH 2TP-L (on slot L) - COM ETH HSR/PRP RS485 module 2TP - COM ETH HSR/PRP RS485 module 2FO	Hardware failure detected on the optional boards when the PowerLogic P5 protection relay is powered on.	Check that the hardware resources are equivalent or exceeds those used in the configuration file.
Message appears during a reboot of the PowerLogic P5 protection relay. The boot is not complete and the following message is displayed: - Firmware not complete (in English only)	Major issue on the CPU board of the PowerLogic P5 protection relay.	Change the withdrawable part of the PowerLogic P5 protection relay with the same model number.
Alarm message completed by the reference: MET148-2	MET148-2 loose connection	Check the MET148-2 module is well connected to the Extension and backup memory board. See Troubleshooting the MET148-2 module, page 680 for more information.
CT supervision Alarm message	Connection issue from CT/ LPCT transformer to the PowerLogic P5 protection relay	Check the connection from MV transformer to the analogue input of the PowerLogic P5 protection relay. Switch off/switch on the protection relay. If the failure is persistent, change the rack of the PowerLogic P5 protection relay .
VT supervision Alarm message	Connection issue from MV transformer to the PowerLogic P5 protection relay	Check the connection from MV transformer to the analogue input of the PowerLogic P5 protection relay. For LPVT, check if the three LPVTs are connected on the LPVT hub. Switch off/switch on the protection relay.

Table 217 - Troubleshooting a protection relay according to maintenance messages (Continued)

Message information	Possible Causes	Actions
		If the failure is persistent, change the rack of the PowerLogic P5 protection relay.
Alarm message completed by “RTD x Open Circuit Fault On” or by: “RTD x Short Circuit Fault On”, where x is the number of the RTD	The RTD number x on the MET148-2 module is disconnected or short-circuited.	As the message is common to the RTD channels of the MET148-2 module, go to the temperature measurement display screen to determine which RTD is affected by the defect. Measurement displayed: • Tx.x = -**** = RTD disconnected (T > 205 °C (401 °F)) • Tx.x = **** = RTD short-circuited (T < -35 °C (-31 °F)) Then check the connection of RTDs.
Alarm message “Incompatible hardware or firmware version, operation stopped”	Incompatible firmware or hardware versions	Check the firmware or hardware version.
Maintenance message with: Module ID = 17 Error type = -1	CS certificate expired or CS configuration potentially inconsistent	Please contact Schneider Electric Customer Care Center.

Recover failed device

In case of the PowerLogic P5 can not start normally, or been stuck in failed mode, you can recover the failed device with eSetup Easergy Pro:

1. Disconnect the power supply of P5.
2. Connect P5 to the laptop with eSetup Easergy Pro installed by USB cable to make firmware upgrade in low power mode.
3. Launch eSetup Easergy Pro, click on the **Tools** button on the **menu bar**, then click on **Recover failed device**.

Troubleshooting the Mini-USB port

This section introduces the troubleshooting of the Mini-USB port.

Fault	Possible Causes	Actions
System prompts “USB device not recognized” when connecting PowerLogic P5 to eSetup Easergy Pro with Mini-USB cable.	If it happens after the USB cable is disconnected from one PowerLogic P5 device and connected to another P5 device in a short time, since the computer needs time to completely release the USB communication descriptor of last connected device, when a 2nd connection is allocated with the same ID as previous one, this will cause "USB not recognized".	Leave at least 1 minute as switching time between two connections. Try 3 times if the connection is not succeeded in one time. If you have tried 3 times but the connection is still not succeeded, check the next row of this list.
System prompts “USB device not recognized” when connecting PowerLogic P5 to eSetup Easergy Pro with Mini-USB cable.	The USB connection between the PowerLogic P5 and the computer can not be setup due to the normal USB state machine status was destroyed. A rebooting of USB port may solve this issue.	1. Disconnect the Mini-USB cable from the PowerLogic P5 device. 2. Perform Mini-USB reset operation on local HMI of PowerLogic P5 device following the process: **Device/TST /Mini USB/ Reset** (press **OK** button)/ **Implement** (press **OK** button) 3. Wait for the status of reset changed from “*Implement*” to “-“. 4. Reset is done.
The USB communication between the PowerLogic P5 and the eSetup Easergy Pro cannot be established after the device is connected by Mini-USB cable, even if the network PING is successful.	The USB connection between the PowerLogic P5 and the computer cannot be setup due to the normal USB state machine status was destroyed. A rebooting of USB port may solve this issue.	1. Disconnect the Mini-USB cable from the PowerLogic P5 device. 2. Perform Mini-USB reset operation on local HMI of PowerLogic P5 device following the process: **Device/TST /Mini USB/ Reset** (press **OK** button)/ **Implement** (press **OK** button) 3. Wait for the status of reset changed from “*Implement*” to “-“. 4. Reset is done.

Troubleshooting the communication modules

	Possible Causes	Actions
Loose of communication during operation	Change of parameters (PowerLogic P5 protection relay, Scada), connection issue, hardware issue	For Ethernet board, check the traffic with the leds embedded on the RJ45 connectors. Check all the information and parameters at scada level. Check all the parameters at the PowerLogic P5 protection relay level. Check all intermediate devices (switches, etc.) installed between Scada and the PowerLogic P5 protection relay. Check the connections. Replace the communication board.
Alarm message completed by “Slot x board is missing”	The communication board on slot X is missing.	Complete the configuration with the right communication option.
Alarm message completed by “Slot x is not configured”	There is a communication board on Slot x, but the model number is not configured.	Configure the model number with the right option.
Alarm message completed by “Slot x mismatch”	There is a communication board on Slot x, but its model number does not match the existing one in the system configuration.	In order to match the communication board and the model number, take one of the following corrective measures: • Change the communication board • Configure the right model number

Troubleshooting arc-flash system

This table describes some common problems in the arc-flash system and how they can be solved.

Messages	Possible Causes	Actions
The trip signal does not reach the circuit breaker.	Faulty trip circuit wiring.	Check that the wiring of the trip circuit is not faulty.
The protection does not trip even when a sufficient light signal is provided.	The protection needs both light and current information to trip.	Check the dip switch configuration. The protection may be configured to require both the light and current condition to trip.
Faulty sensor wiring detected by the self-supervision.	Loose sensor wire.	Check the sensor wiring. The sensor wire may have loosened in the terminal blocks.
Error message indicating blocked sensor channel.	Light pulse to the arc-flash sensor is too long.	Check that the light pulse to the arc-flash sensor is not too long. If light is supplied to the arc-flash sensor for more than three seconds, the self-supervision function activates and switches the light sensor channel to daylight blocking mode, and the sensor channel is blocked. Remove the light source to reset the blocked channel.

Troubleshooting the MET148-2 module

LED Indication	RTD Link Status	Possible Causes	Actions
MET148-2 green LED off, MET148-2 red LED off.	RTD 1/2 Link Status off	Fault wiring	1. RJ45 plugs of CCA77x cords clipped correctly into sockets. 2. Check the power supply.
MET148-2 green LED on, MET148-2 red LED on.	RTD 1/2 Link Status off	No response from the MET148-2 module.	The power-on time is more than 15 s, the module needs to be powered on and initialized.
		MET148-2 module internal failure.	Change MET148-2 module.
MET148-2 green LED on, MET148-2 red LED flashing.	RTD 1/2 Link Status off	Faulty wiring, MET148-2 powered but loss of dialogue with base unit.	Check module connections: • RJ45 plugs of CCA77x cords clipped correctly into sockets. • If the MET148-2 module is the last in the chain, check that the line terminating jumper is in the **Rc** position. In all other cases, check that the jumper is in the position marked  .
MET148-2 green LED on, MET148-2 red LED off.	RTD 1 Link Status on RTD 2 Link Status off	MET148-2 module number selection jumper error.	Check the position of the module number selection jumper: • MET1 for first MET148-2 module (temperatures T1 to T8) • MET2 for second MET148- 2 module (temperatures T9 to T16). • If the jumper position needs to be changed, reboot the MET148-2 module (by disconnecting and reconnecting the interconnection cord). • Change the extension module.
	RTD 1 Link Status on RTD 2 Link Status on	More than 2 remote modules are connected.	Remove redundant MET148-2 modules and leave not more than 2 MET148-2 modules.
		The module communication is normal.	

Troubleshooting the Digital Circuit Breaker monitoring

Table 218 - List of Digital Circuit Breaker troubleshooting

Fault	Possible Causes	Actions
Paired CL110 not found	CL110 with fault.	Press power on button of CL110 for 10 s to restart the sensor.
Mass pair succeed, but few CL110/ TH110 not paired	Few sensors not successfully paired.	Try again pair operation for the sensors not paired.
CL110 low battery	Battery installed inside CL110 is exhausted.	Install a new CL110 and pair with P5.
CL110 lost	Been stolen or other reason.	Install a new CL110 and pair with P5.
Connection with EOS-BM100/ EOS-MCMx00 not stable	RJ45 cable may not be firmly connected.	Check the RJ45 plug and the cable.
EOS-BM100/EOS-MCMx00 connected and configured, but in eSetup Easergy Pro/**Digital CB**/**Module configuration**, the Status of EOS-BM100/EOS-MCMx00 is *Offline*.	Modbus slave ID setting incorrect	Check and ensure the Modbus slave ID setting of EOS-BM100/EOS-MCMx00: • 11~19 for EOS-BM100 module • 21~29 for EOS-MCMx00 module
Zigbee sensor restore failed	• The Zigbee network status is not *OK*. • Backup-ed data in EOS-BM100 with error. • The Zigbee sensor to be restored is not on line. • The Zigbee sensors to be restored makes the number of paired Zigbee sensors exceeds 18 and the sensors to be restored are not mapped.	Configure the pairing operation manually.

Troubleshooting the CLIO module

Table 219 - List of CLIO module troubleshooting

Fault	Possible Causes	Actions
PowerLogic P5 raises alarm "Analogue I/O n link state off" (n=1...3). And the measurements of the reported CLIO module(s) are not refreshed.	1. The CLIO module is not powered on. 2. Conflict of address setting of the connected CLIO module(s). 3. Cable connection fault of the reported CLIO module(s).	1. Check and ensure the CLIO module is powered on. 2. Check the address settings of the connected CLIO modules to ensure there is no address conflict. 3. Check the cable connection of the CLIO modules.
The refreshed measurements are not correct (as per assigned analogue signals), some measurements of connected module(s) are not refreshed.	Conflict of address setting of the connected CLIO modules.	Check the address settings of the connected CLIO modules to ensure there is no address conflict.
Link LED off	More than 3 CLIO modules are connected.	Remove redundant CLIO modules and leave not more than 3 CLIO modules.

Firmware upgrade

NOTE: This section applies to firmware upgrade operation only. For firmware downgrade, please contact Schneider Electric Customer Care Center.

From time to time it may be necessary to upgrade the firmware of your PowerLogic P5. There could be a number of reasons for this, new functionality, security patches or correction of product behavior.

The firmware upgrade feature of the PowerLogic P5 protection relay provides the possibility for the user to upgrade the application firmware themselves through eSetup Easergy Pro.

Upgrading the firmware requires the eSetup Easergy Pro software to be connected to the device to be upgraded. This can be done either through the mini-USB port on the local panel or one of the rear Ethernet ports.

You must also have access to the zip file containing the firmware version you wish to upgrade to. This file typically has the format PowerLogic-P5-firmware-Vxx.xxx.xxx.zip. Please contact Schneider Electric Customer Care Center to get the package.

Please be aware that the contents of this file must come from Schneider Electric and the firmware signature will be checked to help ensure that it has come from a genuine source before the product is updated.

NOTICE

RISK OF DATA LOSS

- Save your configuration files, disturbance records and events before starting the firmware upgrade.
- After the firmware upgrade is complete, the operator needs to first connect to the device and retrieve all configurations through eSetup Easergy Pro, open the saved file, and then select the **Copy all to DEVICE** option from the **File** menu.
- The operator needs to rebuild the logics and matrix.
- The operator needs to reload the second language package.

Failure to follow these instructions will result in loss of all configurations, disturbance records and events.

NOTE: Since the Digital CB protocol will be un-configured by default after the firmware upgrade, to avoid lost of Digital Circuit Breaker configurations, please backup the configurations to .epz file before upgrading and write the configurations back after the upgrade is done.

The process for upgrading the firmware on the PowerLogic P5 protection relay is as follows:

1. Connect the laptop that runs eSetup Easergy Pro to the PowerLogic P5 protection relay and log in with “InstallerLevel”.
2. Open the main menu from the top-left corner of the application, select the **Update firmware...** option, and then select the new firmware package from the folder where you saved the package.
3. The application performs the following operations before starting the upgrade:
   a. Check User's rights
   b. Checking firmware package
4. If every check is passed, the application gets ready to upgrade the firmware and prompts the user to confirm. Click **OK** to confirm and the application will reboot the device, and after that the new firmware will take effect.
5. After rebooted, a message *Firmware update successful* will be displayed in alarm list.

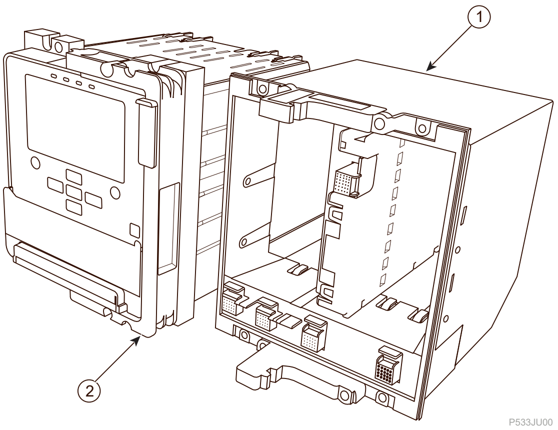
Replacing the PowerLogic P5 protection relay

The PowerLogic P5 is a withdrawable protection relay. It is made up of the following two parts (The fixed and withdrawable parts of the PowerLogic P5 protection relay, page 683):

- A rack ① including the CT/VT and LPCT/LPVT modules (fixed part). The CT/VT and LPCT/LPVT inputs are isolated and fixed. When the device is withdrawn, CTs remain connected.
- A withdrawable part ② which contains all the electronics (including the I/O board, CPU board and power supply).

  The withdrawability is realized by unlocking and pulling out the green handle on the local panel.

Figure 383 - The fixed and withdrawable parts of the PowerLogic P5 protection relay



① Fixed rack

② Withdrawable part

To limit the time of interventions for maintenance reasons, the faulty protection relay can be removed without disconnecting the wires or the connections. This allows to quickly replace an PowerLogic P5 protection relay, provided that the spare part is available.

The spare withdrawable part must be compatible with the one which is replaced. The compatibility rules are as follows:

- The spare part must have the same hardware resources
- The spare part must have the same product model number
- The spare part must have the same major software version

To avoid any unintended withdrawing, and for security reasons, the removable part is fixed to the rack by 3 screws for PowerLogic P5 x20 and 4 screws for PowerLogic P5 x30 protection relays.

The procedure for replacing the PowerLogic P5 protection relay is as follows:

Diagnosis for replacement

For the diagnostic of the protection relay, check the following:

- The status of the watchdog relay (DO4 contact relay on slot B)
- The status of the (!) LED and ⚡ LED, and the configurable LEDs
- The **ON** and 🔧 LEDs on the local panel

- The Alarm list and Maintenance file to checked and downloaded with eSetup Easergy Pro

Preliminary operations

NOTE: If the PowerLogic P5 protection relay is still working, do not hesitate to save configuration, settings and parameters to the back-up memory of the extension module (optional) if it is available in the protection relay. For saving (backup), go to the backup view of the Device/Test menu on the local panel.

1. Power off the PowerLogic P5 protection relay.
2. Unscrew the 3 screws on PowerLogic P5 x20 (or 4 for PowerLogic P5 x30) that fix the local panel to the relay outer case. Refer to Unscrewing the front face locking screws, page 57.

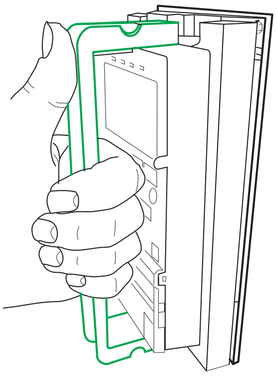
Screws	3 screws mounted on PowerLogic P5x20; 4 screws mounted on PowerLogic P5x30
Tools	(-) 6.5 mm (1/4 in.) or (+) PZ2 screwdriver (Digital torque screwdriver for installing)

3. Push upward the handle lock that locks the device handle.
4. Close the shutter of the local panel if it is open.

Removal

1. Using the device handle, pull the withdrawable part of the protection relay to detach it from the outer case (pull the device handle from the top and bottom when side access is difficult).

Figure 384 - Pulling the withdrawable part by its handle



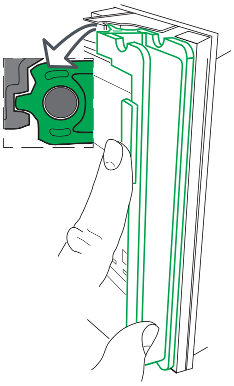
2. Extract the withdrawable part of the protection relay, using your both hands to help ensure a secure grip.
3. Check the model numbers on both the withdrawable part and the outer case.

Installation

1. Before replacing the module:
    - For compatibility of the spare part, check that the identification on the labels on the fixed and the withdrawable parts are the same.
    - Visually check the cleanliness and state of the rear connectors (rear part and lower part).
2. With the device handle fully open, insert the withdrawable (spare) part gently into the fixed part.

3. Push down the handle to lock the withdrawable part. The lock tab on the handle locks the handle to the local panel automatically.

Figure 385 - Locking the withdrawable part by the handle



4. For highly vibrating environment, put in place the screws (3 for PowerLogic P5 x20 and 4 for PowerLogic P5 x30) for locking the local panel to the relay case.

Tools	• Screws removed in the preliminary operation • (-) 6.5 mm (1/4 in.) or (+) PZ2 screwdriver
Tightening torque	1 N · m (8.85 lb-in)

NOTE: The screws are not mandatory for the installation of the spare part, but recommended for security reasons.

Subsequent operations

After installing the PowerLogic P5 protection relay, perform the following operations if necessary:

1. Switch on the PowerLogic P5 protection relay and check the relay operation. Check the model number (from the Device/Test menu on the local panel) and compare it with the associated model number displayed in eSetup Easergy Pro.
2. If an extension module with backup memory is available on the PowerLogic P5 protection relay, update the device configuration.
3. For recovery of the configuration from the backup memory (optional) and restart of the new protection relay, follow the instructions displayed on the local panel.

Change a communication module

⚠CAUTION

LOSS OF DEVICE CONFIGURATION

- Never plug in or draw out the communication modules while the PowerLogic P5 protection relay is in service.
- Check and make sure that the communication module is locked.

Failure to follow these instructions can result in injury or equipment damage.

The PowerLogic P5 is a modular protection relay; The modules which can be replaced individually are:

- The communication modules
- The external modules

Identification of the module can be accessed:

- From the local panel of the PowerLogic P5 protection relay (**Device Info** menu)
- From eSetup Easergy Pro (**Device Info** view of the **Device/Test** menu)
- From the web server and the EcoStruxure Power Device application

Preliminary operation

Before changing a communication module:

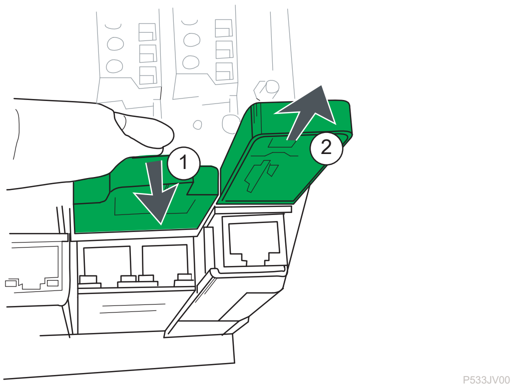
1. Power off the PowerLogic P5 protection relay.
2. Check if it there is enough space (> 15 cm or 6 in.) in the rear and lower part of the case to extract the modules. If not possible, remove the case from its support.

Removal

The module can be easily removed from the PowerLogic P5 protection relay:

1. Push down the locking tab ①.
2. Gently pull the communication module forward ②.

Figure 386 - Removing the communication module

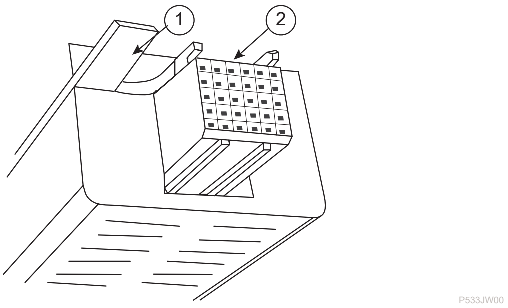


Installation

Install the module according to the following steps:

1. Before replacing the module, check visually the front plate ① and the connector ②.

Figure 387 - Front plate and connector of the communication module



2. Insert the module into its location.
3. Gently push the module to the front plate until it locks (a click is heard when the locking tab is locked).

Subsequent operation

After installing the module:

1. Check that the module is locked (visual check).
2. Switch on the PowerLogic P5 protection relay and verify that the module has been detected:
   - On the local panel, enter the **Home** menu/**Device/Test** sub-menu and check this in the **Board** menu item.
   - With eSetup Easergy Pro see the **Device/Test** menu/**Device Info** sub-menu.

Return for expert assessment

To return the PowerLogic P5 protection relay for expert assessment, use the original packaging if possible.

If the full product is returned, the active part must be installed in the fix part and properly fixed with screws.

The PowerLogic P5 protection relay must be returned accompanied by its settings sheet and the following information:

- Name and address of the initiator
- PowerLogic P5 protection relay type and serial number
- Date of the incident
- Detailed description of the incident
- LED status and message displayed at the time of the incident
- List of stored events

Maintenance of Digital Circuit Breaker

Firmware upgrade of EOS-BM100

NOTE: The firmware file of EOS-BM100 must be provided by Schneider Electric, and the firmware signature will be checked before update to help ensure that it comes from a genuine source.
This security capability helps protect the authenticity of the firmware running on the EOS-BM100 and facilitates protected file transfer: digitally signed firmware is used to help protect the authenticity of the firmware running on the EOS-BM100 and only allows firmware generated and signed by Schneider Electric.

Launch the upgrade process

To launch the process of EOS-BM100 firmware upgrade, please follow the steps listed below:

1. Connect the laptop that with eSetup Easergy Pro installed to the PowerLogic P5, launch eSetup Easergy Pro and log in with “InstallerLevel”.
2. In **DIGITAL CB** tab page, click the **Update firmware** on the top right, a dialog box will pop up.
3. In the dialog box **Update module firmware**, make selections as follows:
    - In the section of **Select file**, click on **Browse** button to select the firmware file (.sedp format).
    - After selected firmware file, eSetup Easergy Pro will verify the firmware package signature. If the signature is valid, two options of .bin files will be displayed for selection:
        - The file name contains “ssbl” is for boot loader.
        - The file name contains “firmware” is for application.

      Otherwise eSetup Easergy Pro will display the error message.
    - In the section of **Module information**:
        - in **Module** drop down list, select the module type *BM100*.
        - in **FileType** drop down list, select the type of firmware file, the selections are *Bootloader* for selected .bin file contains “ssbl” and *Application* for selected .bin file contains “firmware”.

After made the above selections in the dialog box, click on **Update** button to start the firmware upgrade process. A bar of **Upgrade process** shows the status of the upgrade.

> **NOTE:** The normal communication between PowerLogic P5 and EOS-BM100 module (including polling alarms/status/measurements, writing settings) will be paused when the firmware upgrade is in progress.

Backup and restore of EOS-BM100/EOS-MCMx00

Backup is an additional copy of data that can be used for restoring and recovery purposes. It covers settings directly or indirectly modified by the user. A backup is put in place to avoid permanent data loss and to ensure the integrity of stored data, it means user can get back to a previous version and build up the data correctly if current data are found to be in error.

Possible reasons of backup are faulty device replacement, restoring the same device and massive commissioning.

The backup and restore processes are made by eSetup Easergy Pro with the account of *InstallerLevel*. If the logged-in account is not InstallerLevel, the software will prompt to switch account.

Backup

First, save .epz file, please follow the listed operations:

1. Connect PowerLogic P5 to the laptop with eSetup Easergy Pro installed and launch eSetup Easergy Pro, login with *InstallerLevel*.
2. In eSetup Easergy Pro, click on **COMMUNICATION** menu tab, then click on **Protocol configuration**. Under Serial port, select *Digital CB* in the drop down selection of **Remote port protocol**.
3. After PowerLogic P5 reboot, go to **Digital CB** menu tab, click on **Module configuration**, enable BM100/MCMx00 in the list.
4. From the tool bar of eSetup Easergy Pro, click soft disk icon 💾 ▾ or the small triangle at right to **Save** or **Save as...** the .epz file.

Then make the backup:

1. Open the .epz file you have saved in eSetup Easergy Pro.
2. In **Digital CB** menu tab, section BM100 **configuration** or **MCMx00 configuration**, click the **Backup...** button on top at right of the interface.
3. In the pop-up window **Backup module settings**, click on **Browse** button to select folder for the backup.
4. In **Module information** frame, type in a label in the input box besides **Label** to tag the backup file. The label shall be composed by not more than 32 alphanumeric characters. Label can be empty.
5. If **Encrypted settings** is enabled, twice of password input is requested to double confirm. The password shall compliant with the following rules:
    - Length of password: 6 to 32 characters.
    - The password is a combination of upper-case and lower-case alphanumeric characters and special characters. Special characters include *!#$%&’()*+,-./:;<=>?@[^]_`{|}~*
    - If **Encrypted settings** is not enabled indicating no password required.
6. Click on **Backup** button.

    NOTE: Errors or warnings during backup process will be reported in eSetup Easergy Pro.

Restore

You can write back the configuration to EOS-BM100/EOS-MCMx00 module through eSetup Easergy Pro. Please ensure PowerLogic P5 is connected to laptop and the eSetup Easergy Pro is launched. Please make the following operations:

1. Save and open .epz file.
2. In Digital CB menu tab, click on the **Open file** button of the tool bar to open the .epz file you have saved. After file opened:
   a. In **Digital CB** menu tab, click on **Restore...** button on top at right of the interface. There will be a popup window with the warning text "Restoring the module settings...Do you want to proceed?", click **Yes** to continue or **No** to cancel.
   b. In the pop-up window, click on the **Browse** button to find the backup file.
   c. If you have enabled Encrypted settings, you will have to input password.
   d. Click on **Restore** button to restore the backup file.

      NOTE: Errors or warnings during restore process will be reported in eSetup Easergy Pro.

After the backup file is restored, please write the changes to PowerLogic P5:

1. Switch to **FILE** view of eSetup Easergy Pro, click on the small triangle of the **File** button, select **Copy all to DEVICE**, the changes will be copied to device.
2. Switch to **DEVICE** view, click on the small triangle of the **Write** button, select **Write changes**, the restored configuration will be written to EOS-BM100/EOS-MCMx00.

Restore the Zigbee connection

In the following cases, the connection to Zigbee sensors will have to be restored:

- The Zigbee board is replaced
- Update of PowerLogic P5 firmware
- PowerLogic P5 is replaced.
- Restore PowerLogic P5 from CAN board memory

The Zigbee board is replaced

After the Zigbee board is replaced by a new Zigbee board, the connection between the new Zigbee board and the Zigbee sensors will be restored by PowerLogic P5 automatically, so that the Zigbee sensors will be connected to the new Zigbee board without manual configuration.

Update of PowerLogic P5 firmware

During the update of firmware, PowerLogic P5 will restore the configuration of the connections with Zigbee sensors, the connection to the sensors will not be lost after the firmware update.

It is also possible to backup and restore the configuration through eSetup Easergy Pro, please follow the steps of Backup and restore the Zigbee connection manually, page 691.

PowerLogic P5 is replaced

Since the device is replaced, the Zigbee connection will have to be restored from the backup-ed .epz file to the new PowerLogic P5 device. Therefore the followed operations have to be made before and after replacing the PowerLogic P5:

1. Before replacing: save the configuration to .epz file to backup.
2. After replacing: restore the configuration from the saved .epz file to the new PowerLogic P5.

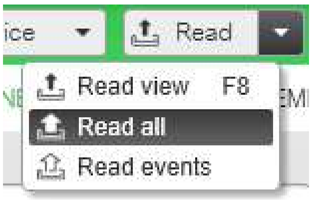
The backup and restore are made through eSetup Easergy Pro, please follow the steps of Backup and restore the Zigbee connection manually, page 691.

Backup and restore the Zigbee connection manually

To backup the Zigbee connection:

1. Connect PowerLogic P5 to the laptop with eSetup Easergy Pro installed, launch eSetup Easergy Pro and login.
2. In eSetup Easergy Pro, click the **Read** button on the tool bar, then click on **Read view** or **Read all** in the dropdown list.

Figure 388 - Read button and dropdown list



3. After read in, click the soft disk icon or the small triangle at right to **Save** or **Save as...** the .epz file.
4. The Zigbee connection is backup-ed to the .epz file.

To restore the Zigbee connection:

1. Connect PowerLogic P5 to the laptop with eSetup Easergy Pro installed, launch eSetup Easergy Pro and login.
2. In eSetup Easergy Pro, click the **Open file** button on the tool bar, select to open the .epz file with the backup of Zigbee connection.
3. After the .epz file is opened, in the **FILE** view, go to **GENERAL/Zigbee network**, click on the **File** button, then click on **Copy view to DEVICE** if you want to copy only the configuration of Zigbee network, or click on **Copy all to DEVICE** if you want to copy all.

Figure 389 - File button and dropdown list

4. Switch to the **DEVICE** view of eSetup Easergy Pro, go to **GENERAL/Zigbee network**, click on the **Restore file** button on the top right.
5. In the pop-up window, click on **Yes** to start the restore. If you click on **No**, the restore will not be started.
6. When the restore is completed, there will be a pop-up window to prompt for a restart of the PowerLogic P5, click on **Yes** to restart immediately or click on **No** to restart later.

Restore PowerLogic P5 from CAN board memory

In CAN board memory backup operation, Zigbee network configuration and connection will be stored in CAN board memory. When restore memory happens, Zigbee configuration and connection are restored to restore point automatically.

Zigbee board firmware upgrade

The operations to make the update are as follows:

1. Connect the laptop with eSetup Easergy Pro installed to PowerLogic P5, launch eSetup Easergy Pro and log in with “InstallerLevel”. If the logged-in account is not InstallerLevel, the software will prompt to switch account.
2. In eSetup Easergy Pro/**GENERAL**/**Zigbee network**, click on the **Update firmware...** button.
3. The **Update module firmware** window will be popped-up, click on the **Browse** button to select Zigbee board firmware.
4. You can find current version of the firmware of the Zigbee board after **EXR ProcApp version**, for example, “001.032.000”, it’s the version 1.32. Type in a version number newer than the current version in the input box of **Version**, for example 1.33. The input version must be newer than current version of the Zigbee board, if not, the update cannot be started.
5. In **Module information**/**Module** dropdown list, select *Zigbee*.
6. Click the **Update** button to start the update.
7. A pop-up window will be popped-up with information *Do NOT POWER OFF the device during the firmware update operation. Do you want to proceed?* Click **Yes** button to continue. If you click on the button **No**, the update process will not be started.
8. When update is finished, there will be an information *Update OK* displayed in the **Update** section, click **Close** button to finish the update.

PowerLogic CL110/PowerLogic TH110 replacing

To replace PowerLogic CL110/PowerLogic TH110, please operate as listed in followed:

1. Connect the laptop with eSetup Easergy Pro installed to PowerLogic P5, launch eSetup Easergy Pro and log in with “InstallerLevel”. If the logged-in account is not InstallerLevel, the software will prompt to switch account.
2. Unpair sensor in eSetup Easergy Pro/**GENERAL**/**Zigbee network**/**Zigbee devices** by clicking **UnPair** button of the sensor to be replaced.
3. In the list of **Zigbee devices**, double click the cells of the sensor to be replaced to type in name and ID of the sensor which will replace actual sensor.
4. Click **Pair** button of the sensor in the list.
5. Power on if the new sensor is CL110.
6. Wait until the new sensor is paired or pairing window is timeout.

Circuit breaker swapping

Before swap-in the circuit breaker, please ensure the Modbus slave ID of the EOS-BM100 module to be swapped-in is set to be the same with the EOS-BM100 module to be swapped-out so that the communication between PowerLogic P5 and the swapped-in EOS-BM100 will be rebuilt automatically.

After the circuit breaker is swapped, in PowerLogic P5 all alarms and status data of this circuit breaker will be set to default state. A "CB swap" alarm will pop up and the event will be logged in event buffer of PowerLogic P5. A “CB swap” event will be recorded as a reference to differentiate events between the swapped-out circuit breaker and the swapped-in circuit breaker.

In PowerLogic P5, circuit breaker swapping log will be created, includes swapping date, time, serial number of the swapped-in circuit breaker and the swapped-out circuit breaker, number of operations of the swapped-in circuit breaker and the swapped-out circuit breaker. The log can be checked through eSetup Easergy Pro and Web HMI, under **Digital CB**/**BM100 maintenance**.

Truck data backup and restore

PowerLogic P5 backups the truck data from EOS-MCMx00 to EOS-BM100. When PowerLogic P5 found the truck data was updated in EOS-MCMx00 it will update the backup in EOS-BM100. Since the EOS-MCMx00 module will not be swapped out with the swapped out circuit breaker, after circuit breaker swapping, the truck data of the EOS-MCMx00 will not be of the swapped in circuit breaker. To solve this issue, PowerLogic P5 will restore the truck data from the EOS-BM100 to the EOS-MCMx00.

The backup and restore are automatic, event will be created accordingly.

The truck data are as listed below:

	Data
1	Presence
2	Serial number
3	Reference
4	Manufacturing date
5	Manufacturing
6	Installation date
7	Eref status, the calibration status of energy reference
8	Number of operations
9	Eref, the energy reference, unit: Joule (J)
10	Opening time
11	Closing time
12	Running current
13	Max. running current per operation
14	Max. power per operation
15	Opening time sample 1
16	Opening time sample 2
17	Opening time sample 3
18	Opening time sample 4
19	Opening time sample 5
20	Opening time sample 6
21	Opening time sample 7
22	Opening time sample 8
23	Opening time sample 9
24	Opening time sample 10

	Data
25	Closing time sample 1
26	Closing time sample 2
27	Closing time sample 3
28	Closing time sample 4
29	Closing time sample 5
30	Closing time sample 6
31	Closing time sample 7
32	Closing time sample 8
33	Closing time sample 9
34	Closing time sample 10
35	Max. current per operation sample 1
36	Max. current per operation sample 2
37	Max. current per operation sample 3
38	Max. current per operation sample 4
39	Max. current per operation sample 5
40	Max. current per operation sample 6
41	Max. current per operation sample 7
42	Max. current per operation sample 8
43	Max. current per operation sample 9
44	Max. current per operation sample 10

Zigbee sensor backup and restore

The TH110 sensors are installed on circuit breaker arms (upper arms phase A/B/C, lower arms phase A/B/C). When circuit breaker swap happens, the installed sensors are also swapped. To avoid pairing the swapped-in sensors again, PowerLogic P5 backups these sensors before circuit breaker swap. After circuit breaker swap, PowerLogic P5 restores swapped-in sensors network automatically. PowerLogic P5 creates backup success or failure event for each sensor in event list and creates restore success or failure alarms in alarm list.

NOTE: The restore will be failed in following cases:

- The Zigbee network status is not *OK*.
- Backup-ed data in EOS-BM100 with error.
- The Zigbee sensor to be restored is offline.
- The Zigbee sensors to be restored makes the number of paired Zigbee sensors exceeds 18 and the sensors to be restored are not mapped.

In case of restore failed, please configure the pairing operation manually.

End of life

At end of life, PowerLogic P5 protection relays must be dismantled to facilitate the recovery of the various constituent materials.

The proportion of recyclable material is higher than 65%. This percentage includes the metallic materials and marked thermoplastics conforming to the current legislation, as well as the subassemblies that must be sent to specialized treatment systems: 3 to 5 electronic cards, and an LCD screen that can easily be disassembled.

It is calculated according to "ECO’DEEE recyclability and recoverability calculation method" (version V1.20, September 2008, presented to ADEME, the French Agency for Environment and Energy Management).

Revision history

Document version	Description	
P5/ANSI M/44A	First edition for initial product release	
2022-01	Firmware version	V01
	Release / Build	401.101
	Configuration tool	eSetup Easergy Pro V4.0.1 or later
		CET850 V4.0.0
P5/ANSI M/44B	Hardware version	A
2022-07	Firmware version	V01
	Release / Build	402.101
	Configuration tool	eSetup Easergy Pro 4.2.0 or later
		CET850 V4.2.0 or later
		Easergy Studio V9.4.0 or later
	Rate of change of frequency protection	Algorithm revised, frequency and frequency + RoCoF modes introduced. Increased accuracy. 9 independent stages with the same settings and performance introduced.
	Overcurrent protection	Definite time setting range updated.
	Undercurrent protection	Pick-up setting range updated. Low-current block limit setting introduced. The function is now available in P5F30.
	Broken conductor protection	Algorithm revised. The precondition for operation is the positive phase sequence component greater than 5% of nominal value. 2nd stage with the same settings and performance introduced.
	Emergency restart	New automation function for motor application introduced.
	Virtual inputs	VI1 to VI10 are configurable virtual inputs, they can operate in pulse mode with a settable pulse length.
	Default mimic	Improved manipulation of default mimic screens. Use arrow-up or arrow-down keys to scroll between visible Mimics 1-5.
	Disturbance recorder	Auto-Reclose, CB monitoring, SOL, CTS/VTS related signals added to Disturbance Recorder.
	Alarms	Fault direction added to 67/67N related alarms.
	System	Confirmation popup window displayed when firmware upgrade is completed successfully.
		Special access control by F1 button enhanced with auto log-out within 3 mins and reset button behavior.
		Connection between P5 and Easergy Pro improved.
	Communication	Ethernet/IP protocol data model updated.
		Modbus protocol data model updated.
		IEC 60870-5-103 protocol data model updated.
		Enhancements and bug fixes in IEC 61850 fPN feature.
	Advanced logic engine	Advanced logic can be now viewed with ISaGRAF Workbench Demo only (without ISaGRAF Workbench license).
	Nomenclature	Change for setting units from In/% to pu.

Document version	Description	
	Continuous engineering	Regular corrections & bug fixes package introduced.
P5/ANSI M/44C 2022-09	Hardware version	A
	Firmware version	V01
	Release / Build	402.201
	Configuration tool	eSetup Easergy Pro 4.2.0 or later
		CET850 V4.2.0 or later
		Easergy Studio V9.4.0 or later
	Rebranding to PowerLogic	The product has been renamed to PowerLogic keeping its design, specification, performance, missing profile, safety and reliability unchanged.
P5/ANSI M/44D 2023-04	Hardware version	A
	Firmware version	V01
	Release / Build	500.102
	Configuration tool	eSetup Easergy Pro 4.3.0 or later
		CET850 V4.4.2 or later
		Easergy Studio V9.4.0 or later
	Offer structure	P5T30 Transformer Differential protection relay introduced as new model in P5x30 platform.
		Settable Cybersecurity license introduced. New configuration options introduced: E - Settable CS, F - Settable CS and Advanced Logic Engine.
	Interposing CT	New possibility for neutral current measurement introduced. CSH30 interposing CT can be used now to interface CSH neutral current inputs with standard 1A or 5A core-balance CTs.
	Recording	Last fault record summary screen introduced.
		Additional sampling rate option introduced: 24 samples/ cycle.
	Cybersecurity	Compatibility with LDAP server introduced.
	Continuous engineering	Regular package of corrections & bug-fixes introduced.
P5/ANSI M/02-501A 2024-08	Hardware version	B
	Firmware version	V02
	Release / Build	501.101
	Configuration tool	eSetup Easergy Pro 4.8.0 or later
		CET850 V4.13.0 or later
	Hardware version	Introduction of hardware version B of the main board. Additional memory component (NVRAM) has been added increasing the product's memory capacity to enable further functional evolution.
	Offer structure	P5L30 Line Differential protection and control relay has been introduced as a new model in P5x30 platform. P5L30 model contains by default InterRelay module in slot L.
		Optional InterRelay communication modules have been introduced to P5x30 platform (slot L). The modules can be selected in P5F30, P5M30, P5T30 to enable relay-to-relay protection communication (ANSI 85).

Document version	Description	
		Combined HSR/PRP RJ45 + RS485 RJ45 communication module has been introduced.
	Monitoring	Digital Circuit Breaker condition monitoring and advanced control functionalities have been introduced.
		Switchgear condition monitoring functionality has been introduced.
	Measurement	Sequence voltages and currents have been added to measurements.
	Protection	Trip conditioning matrix has been introduced.
		Setting step for under-/overvoltage protection (ANSI 27/59) thresholds has been changed from 0.01 to 0.001 pu.
		Restricted earth/ground fault protection (ANSI 64REF) scaling factors low setting has been changed down to 0.01.
		Transformer monitoring function (ANSI 26/63) has been introduced to P5F30 and P5U20 models.
		Arc sensor alarms have been introduced to matrix.
		Trip circuit supervision (TCS) default logic has been enhanced.
	Digital inputs	Setting of digital inputs for nominal DC voltage range has been increased to 250V.
	Human-machine interface	Digital CB menu branch has been introduced to HMI.
		Download of the protection settings and events to USB type A port has been introduced.
		Number of customizable mimics increased from 5 to 10.
		Second default mimic for P5T30 and P5L30 models has been introduced with differential/bias currents.
		Setting to disable automatic alarm pop-up has been introduced.
	Continuous engineering	Communication diagnostics capabilities have been improved.
		Regular package of corrections and bug-fixes has been introduced.
P5/ANSI M/02-502A 2025-05	Hardware version	B
	Firmware version	V02
	Release / Build	502.101
	Configuration tool	eSetup Easergy Pro 4.10.0 or later
		CET850 V4.16.0 or later
		Easergy Studio V9.3.9 or later
	Offer structure	New accessory REL70071 - CLIO module has been adopted to the offer. This is 4 analogue inputs and 4 analogue outputs module connectable to slot P.
		New accessory EMS59574 VT Adapter for 400Vac has been adopted to the offer. This is an adapter allowing to connect P5 LPVT inputs directly to the 400 Vac low voltage line.
	Measurement	The aquisition/export of analogue 0-20 mA signals from the external process is now possible with CLIO module (REL70071). The signals can be incorporated in the logic and matrices for application flexibility.

Document version	Description	
		The LPVT measuring inputs of P5 can be connected directly to 400Vac low voltage line with VT Adapter 400Vac (EMS59574).
	Protection	Auto-reclose ANSI 79 function has been redesigned for better application flexibility.
		Ground-fault protecton elements ANSI 50N/51N/67N have been enhanced with RMS based neutral current measurement option.
	Control	All 8 objects can be controlled by PowerLogic P5.
	Continuous engineering	Regular package of corrections and bug-fixes has been introduced.

Order information

Protection and control relay

The PowerLogic P5 offer structure is presented below. The options in green are available for ordering with pre-defined configurations. In case you are interested in getting other configurations, please contact Customer Care Center.

PowerLogic P5

		Slot D	Slot E	Slot B	Slot C	Slot A	Slot L	Slot M	Slot N	Slot P	Model	Firmware	Function	Language
Application														
Feeder protection relay	P5F30 -	☐	☐	☐	☐ -	☐	☐	☐	☐	☐ -	☐	☐	☐	☐
Motor protection relay	P5M30													
Transformer differential relay	P5T30													
Line differential relay	P5L30													
Universal protection relay	P5U20													
Voltage protection relay	P5V20													
Slot D - Additional I/O in P5x30														
Without		A												
6DI + 4DO		B												
3 Arc sensors + 3DI + 3DO		C												
5DI + 5DO		D												
12DI + 4DO		E												
Slot E - Additional I/O in P5x30														
Without			A											
6DI + 4DO			B											
3 Arc sensors + 3DI + 3DO			C											
5DI + 5DO			D											
12DI + 4DO			E											
Slot B - Power supply														
48 - 250 V DC / 100 - 230 V AC + 4DI + 3DO + WD				C										
24 - 48 V DC + 4DI + 3DO + WD				D										
Slot C - Additional I/O														
without					A									
6DI + 4DO					B									
5DI + 5DO					D									
12DI + 4DO					E									
Slot A - CT/VT														
3 phase CT + 2 neutral CT (available for P5U20)						B								
3 phase CT + 1 neutral CSH (available for P5U20)						C								
4 VT (available for P5V20)						D								
3 phase CT + 2 neutral CT + 4 VT (available for P5F30, P5M30)						G								
3 phase CT + 1 neutral CSH + 4 VT (available for P5F30, P5M30)						H								
3 LPCT + 1 neutral CSH + 4 LPVT (available for P5F30, P5M30, P5U20)						I								
6 phase CT + 2 neutral CT + 1 VT (available for P5T30)						J								
3 phase CT + 2 neutral CT + 4 VT (available for P5L30)						L								
3 phase CT + 1 neutral CSH + 4 VT (available for P5L30)						M								
Slot L - 2nd Ethernet communicaition port - ordered separately														
Without							A							
REL51042 - Ethernet TP module with RSTP (2*RJ45)							B							
REL51043 - InterRelay FO module 1310 nm SM 40 km (2*LC)							D							
REL51053 - InterRelay FO module 1310 nm MM 2 km (2*LC)							E							
Slot M - Ethernet communication port - ordered separately														
Without								A						
REL51038 - Ethernet TP module with RSTP (2*RJ45)								B						
REL51039 - Ethernet FO module with RSTP (2*LC)								C						
REL51048 - Ethernet TP module with HSR/PRP and PTP (2*RJ45) + RS485 serial (2*RJ45)								G						
REL51049 - Ethernet FO module with HSR/PRP and PTP (2*LC) + RS485 serial (2*RJ45)								H						
Slot N - Serial communication port - ordered separately														
Without									A					
REL51036 - RS485 serial line module									E					
REL51040 - RS485 FO serial line module									F					
(when option G is selected on Slot M)									G					
(when option H is selected on Slot M)									H					
Slot P - Extension port - ordered separately														
REL51034 - Extension module + Backup memory - by default or to be ordered separately										H				
REL51044 - Extension module + Backup memory + Wireless Communication + Condition Monitoring										W				
Model version														
Version B											B			
Firmware version														
Latest firmware version V02.501												A		
Function packages														
Settable cybersecurity (Basic or Advanced IEC 62443 4-2 SL1)													E	
Settable cybersecurity (Basic or Advanced IEC 62443 4-2 SL1) + Advanced Logic Engine													F	
Languages														
English - English ANSI														K

NOTE: For the applicable slot occupation rules for your PowerLogic P5 protection relay ordered, refer to Slot occupation rules, page 704 to get more details.

Protection & control

For ordering, please visit www.se.com/us or www.se.com/ca and choose on of the pre-defined configurations. Alternatively, please contact Customer Care Center stating a RELxxxxx commercial reference and quantity.

Table 220 - 50 x MTO references

REL50466	Protection relay P5F30-CCCE-GAAAH-BAFK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50467	Protection relay P5F30-CCCE-IAAAH-BAFK
PowerLogic P5F30 48-250V 3LPCT 1CSH 4LPVT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50468	Protection relay P5F30-CCDE-GAAAH-BAFK
PowerLogic P5F30 24-48V 3CT 2Io 4VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50469	Protection relay P5F30-CCDE-IAAAH-BAFK
PowerLogic P5F30 24-48V 3LPCT 1CSH 4LPVT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50470	Protection relay P5F30-CECE-GAAAH-BAFK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50471	Protection relay P5F30-CECE-IAAAH-BAFK
PowerLogic P5F30 48-250V 3LPCT 1CSH 4LPVT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50472	Protection relay P5F30-CEDE-GAAAH-BAFK
PowerLogic P5F30 24-48V 3CT 2Io 4VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50473	Protection relay P5F30-CEDE-IAAAH-BAFK
PowerLogic P5F30 24-48V 3LPCT 1CSH 4LPVT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50474	Protection relay P5F30-EECE-GAAAH-BAFK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50475	Protection relay P5F30-EECE-IAAAH-BAFK
PowerLogic P5F30 48-250V 3LPCT 1CSH 4LPVT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50476	Protection relay P5F30-EEDE-GAAAH-BAFK
PowerLogic P5F30 24-48V 3CT 2Io 4VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50477	Protection relay P5F30-EEDE-IAAAH-BAFK
PowerLogic P5F30 24-48V 3LPCT 1CSH 4LPVT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50478	Protection relay P5M30-CCCE-GAAAH-BAFK
PowerLogic P5M30 48-250V 3CT 2Io 4VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50479	Protection relay P5M30-CCCE-IAAAH-BAFK
PowerLogic P5M30 48-250V 3LPCT 1CSH 4LPVT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50480	Protection relay P5M30-CCDE-GAAAH-BAFK
PowerLogic P5M30 24-48V 3CT 2Io 4VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	

Table 220 - 50 x MTO references (Continued)

REL50481	Protection relay P5M30-CCDE-IAAAH-BAFK
PowerLogic P5M30 24-48V 3LPCT 1CSH 4LPVT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50482	Protection relay P5M30-CECE-GAAAH-BAFK
PowerLogic P5M30 48-250V 3CT 2Io 4VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50483	Protection relay P5M30-CECE-IAAAH-BAFK
PowerLogic P5M30 48-250V 3LPCT 1CSH 4LPVT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50484	Protection relay P5M30-CEDE-GAAAH-BAFK
PowerLogic P5M30 24-48V 3CT 2Io 4VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50485	Protection relay P5M30-CEDE-IAAAH-BAFK
PowerLogic P5M30 24-48V 3LPCT 1CSH 4LPVT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50486	Protection relay P5M30-EECE-GAAAH-BAFK
PowerLogic P5M30 48-250V 3CT 2Io 4VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50487	Protection relay P5M30-EECE-IAAAH-BAFK
PowerLogic P5M30 48-250V 3LPCT 1CSH 4LPVT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50488	Protection relay P5M30-EEDE-GAAAH-BAFK
PowerLogic P5M30 24-48V 3CT 2Io 4VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50489	Protection relay P5M30-EEDE-IAAAH-BAFK
PowerLogic P5M30 24-48V 3LPCT 1CSH 4LPVT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50499	Protection relay P5T30-CCCE-JAAAH-BAFK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50500	Protection relay P5T30-CCDE-JAAAH-BAFK
PowerLogic P5T30 24-48V 6CT 2Io 1VT 22DI-14DO 6 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50501	Protection relay P5T30-CECE-JAAAH-BAFK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50502	Protection relay P5T30-CEDE-JAAAH-BAFK
PowerLogic P5T30 24-48V 6CT 2Io 1VT 31DI-15DO 3 Arc Sensors Advanced Logic and Cybersec Backup memory ANSI	
REL50503	Protection relay P5T30-EECE-JAAAH-BAFK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50504	Protection relay P5T30-EEDE-JAAAH-BAFK
PowerLogic P5T30 24-48V 6CT 2Io 1VT 40DI-16DO Advanced Logic and Cybersec Backup memory ANSI	
REL50515	Protection relay P5L30-CCDE-LDAAH-BAFK
PowerLogic P5L30 24-48V 3CT 2Io 4VT 22DI-14DO SM 40 km 6 Arc AdvLogic Backup ANSI	
REL50516	Protection relay P5L30-CCCE-LDAAH-BAFK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 22DI-14DO SM 40 km 6 Arc AdvLogic Backup ANSI	

Table 220 - 50 x MTO references (Continued)

REL50517	Protection relay P5L30-EEDE-LDAAH-BAFK
PowerLogic P5L30 24-48V 3CT 2Io 4VT 40DI-16DO SM 40 km AdvLogic Backup ANSI	
REL50518	Protection relay P5L30-EECE-LDAAH-BAFK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 40DI-16DO SM 40 km AdvLogic Backup ANSI	
REL50519	Protection relay P5L30-CCDE-LEAAH-BAFK
PowerLogic P5L30 24-48V 3CT 2Io 4VT 22DI-14DO MM 2 km 6 Arc AdvLogic Backup ANSI	
REL50520	Protection relay P5L30-CCCE-LEAAH-BAFK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 22DI-14DO MM 2 km 6 Arc AdvLogic Backup ANSI	
REL50521	Protection relay P5L30-EEDE-LEAAH-BAFK
PowerLogic P5L30 24-48V 3CT 2Io 4VT 40DI-16DO MM 2 km AdvLogic Backup ANSI	
REL50522	Protection relay P5L30-EECE-LEAAH-BAFK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 40DI-16DO MM 2 km AdvLogic Backup ANSI	
REL50528	Protection relay P5F30-CCCD-GAAAH-BAFK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 15DI-15DO 6 Arc sensors Adv Logic Backup ANSI	
REL50529	Protection relay P5M30-CCCD-GAAAH-BAFK
PowerLogic P5M30 48-250V 3CT 2Io 4VT 15DI-15DO 6 Arc sensors Adv Logic Backup ANSI	
REL50530	Protection relay P5T30-CCCD-JAAAH-BAFK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 15DI-15DO 6 Arc sensors Adv Logic Backup ANSI	
REL50531	Protection relay P5L30-CCCD-LEAAH-BAFK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 15DI-15DO MM 2km 6 Arc sensors AdvLogic Backup ANSI	
REL50532	Protection relay P5F30-AADE-GABAH-BAFK
PowerLogic P5F30 24-48V 3CT 2Io 4VT 16DI-8DO Eth RSTP 2*RJ45 Adv Logic Backup ANSI	
REL50533	Protection relay P5U20-AABB-IAAAH-BAEK
PowerLogic P5U20 24-250V 3LPCT 1CSH 4LPVT 10DI-8DO Backup ANSI	
REL50534	Protection relay P5F30-BACB-GAHHH-BAEK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 16DI-12DO Eth HSR/PRP 2*LC RS485 Backup ANSI	
REL50535	Protection relay P5L30-BACB-LEHHH-BAEK
PowerLogic P5L30 48-250V 3CT 2Io 4VT 16DI-12DO MM 2km Eth HSR/PRP 2*LC RS485 Backup ANSI	
REL50536	Protection relay P5T30-EACE-JAHHH-BAEK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 28DI-12DO Eth HSR/PRP 2*LC RS485 Backup ANSI	
REL50537	Protection relay P5F30-BACB-GABAH-BAEK
PowerLogic P5F30 48-250V 3CT 2Io 4VT 16DI-12DO Eth RSTP 2*RJ45 Backup ANSI	
REL50538	Protection relay P5T30-EACE-JABAH-BAEK
PowerLogic P5T30 48-250V 6CT 2Io 1VT 28DI-12DO Eth RSTP 2*RJ45 Backup ANSI	
REL50539	Protection relay P5V20-AABB-DABAH-BAEK
PowerLogic P5V20 24-250V 4VT 10DI-8DO Eth RSTP 2*RJ45 Backup ANSI	

NOTE: For the applicable slot occupation rules for your PowerLogic P5 protection relay ordered, refer to Slot occupation rules, page 704 to get more details.

NOTE: The PowerLogic P5 relays are delivered always with Basic Cybersecurity Level and can be upgraded to Advanced Cybersecurity level by a change of setting parameter.

Slot occupation rules

The slot occupation rules for PowerLogic P5 protection relay based on your ordering are stated as the table below:

30TE withdrawable HW possible combinations				No. of boards				No. of digital I/O	
	slot D	slot E	slot C	5I5O	arc-flash	6I4O	12I4O	DI	DO
A A * A	cover	cover	cover	0	0	0	0	4	3 + WD
A A * B	cover	cover	6I4O	0	0	1	0	10	7 + WD
B A * B	6I4O	cover	6I4O	0	0	2	0	16	11 + WD
B B * B	6I4O	6I4O	6I4O	0	0	3	0	22	15 + WD
C A * A	arc-flash	cover	cover	0	1	0	0	7	6 + WD
C A * B	arc-flash	cover	6I4O	0	1	1	0	13	10 + WD
C B * B	arc-flash	6I4O	6I4O	0	1	2	0	19	14 + WD
C C * A	arc-flash	arc-flash	cover	0	2	0	0	10	9 + WD
C C * B	arc-flash	arc-flash	6I4O	0	2	1	0	16	13 + WD
A A * D	cover	cover	5I5O	1	0	0	0	9	8 + WD
B A * D	6I4O	cover	5I5O	1	0	1	0	15	12 + WD
B B * D	6I4O	6I4O	5I5O	1	0	2	0	21	16 + WD
C A * D	arc-flash	cover	5I5O	1	1	0	0	12	11 + WD
C B * D	arc-flash	6I4O	5I5O	1	1	1	0	18	15 + WD
C C * D	arc-flash	arc-flash	5I5O	1	2	0	0	15	14 + WD
D A * D	5I/5O	cover	5I5O	2	0	0	0	14	13 + WD
B D * D	6I4O	5I5O	5I5O	2	0	1	0	20	17 + WD
C D * D	arc-flash	5I5O	5I5O	2	1	0	0	17	16 + WD
D D * D	5I5O	5I5O	5I5O	3	0	0	0	19	18 + WD
A A * E	cover	cover	12I4O	0	0	0	1	16	7 + WD
E A * B	12I4O	cover	6I4O	0	0	1	1	22	11 + WD
B E * B	6I4O	12I4O	6I4O	0	0	2	1	28	15 + WD
C A * E	arc-flash	cover	12I4O	0	1	0	1	19	10 + WD
C E * B	arc-flash	12I4O	6I4O	0	1	1	1	25	14 + WD
C C * E	arc-flash	arc-flash	12I4O	0	2	0	1	22	13 + WD
E A * D	12I4O	cover	5I5O	1	0	0	1	21	12 + WD
B E * D	6I4O	12I4O	5I5O	1	0	1	1	27	16 + WD
C E * D	arc-flash	12I4O	5I5O	1	1	0	1	24	15 + WD
D E * D	5I5O	12I4O	5I5O	2	0	0	1	26	17 + WD
E A * E	12I4O	cover	12I4O	0	0	0	2	28	11 + WD
E E * B	12I4O	12I4O	6I4O	0	0	1	2	34	15 + WD
C E * E	arc-flash	12I4O	12I4O	0	1	0	2	31	14 + WD
E E * D	12I4O	12I4O	5I5O	1	0	0	2	33	16 + WD
E E * E	12I4O	12I4O	12I4O	0	0	0	3	40	15 + WD

Accessories

Model number		Description
Communication Modules		
REL51038	☐	Ethernet TP module - slot M
REL51039	☐	Ethernet FO module - slot M
REL51042	☐	Ethernet TP module - slot L
REL51036	☐	RS485 serial line module - slot N
VW3A8306RC	☐	RS485 line termination accessory
LV434211	☐	RJ45 to open 2/4 wire adaptor for Modbus
REL51040	☐	Fiber optic serial line module - slot N
REL51034	☐	Extension module - slot P
LV434211	☐	RJ45 to open connector modbus adaptor
REL51048	☐	Combined Ethernet HSR/PRP 2TP + RS485 module- slots M-N
REL51049	☐	Combined Ethernet HSR/PRP FO + RS485 module - slots M-N
External modules		
59641	☐	8 temperature sensor module (MET148-2)
REL51045	☐	IRIG-B module
59660	☐	0.6m remote module connection cord
59661	☐	2m remote module connection cord
59662	☐	4m remote module connection cord
Sensors		
59635	☐	Core balance CT, Ø=120mm (CSH120)
59636	☐	Core balance CT, Ø=200mm (CSH200)
59637	☐	Core balance CT, Ø=300mm (CSH300)
59634	☐	CSH30 interposing ring CT
REL52801	☐	Arc accessory VA1DA-20 Arc sensor 20m
REL52802	☐	Arc accessory VA1DA-20S-HF Arc sensor 20m shielded halogen free
REL52803	☐	Arc accessory VA1DA-20S Arc sensor 20m shielded
REL52804	☐	Arc accessory VA1DA-6 Arc sensor 6m connect cable
REL52805	☐	Arc accessory VA1DA-6S-HF Arc sensor 6m shielded halogen free
REL52806	☐	Arc accessory VA1DA-6S Arc sensor 6m shielded
REL52807	☐	Arc accessory VA1EH-20 Arc sensor 20m pipe sensor
REL52808	☐	Arc accessory VA1EH-20S Arc sensor 20m pipe sensor shielded
REL52809	☐	Arc accessory VA1EH-6 Arc sensor 6m pipe sensor
REL52810	☐	Arc accessory VA1EH-6S Arc sensor 6m pipe sensor shielded
Mounting accessories		
REL51032	☐	20TE flush mounting accessory
REL51052	☐	30TE flush mounting accessory
REL51021	☐	19inch rack mounting accessory
REL51018	☐	30TE blanking plate for rack mounting
REL51019	☐	20TE blanking plate for rack mounting
REL51020	☐	10TE blanking plate for rack mounting
eSetup Easergy Pro connection cable		
59700	☐	PC cord USB

LPIT accessories		
EMS59572	☐	PowerLogic voltage adapter, 110 VAC
EMS59573	☐	LPVT hub connector
EMS59574	☐	PowerLogic voltage adapter, from 110 to 400 VAC
REL51037	☐	LPIT Test Box
REL51089	☐	LPCT Test Socket with cover
REL51090	☐	LPCT Test Plug
REL51092	☐	LPVT Test Socket with cover
REL51093	☐	LPVT Test Plug
P7M12025	☐	LPVT transducer
REL51095	☐	T-box 3-way RJ45 junction
Spare parts		
REL51077	☐	Spare 2 screw type connectors kit
REL51078	☐	Spare accessories kit for CT/VT
REL51079	☐	Spare accessories kit for LPCT/LPVT
REL51088	☐	Spare cable for LPIT Test Box

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