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eVD4
Breaker Integrated Protection RBX615
Technical Manual

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Conformity

The IED is designed in accordance with the international standards of the IEC 60255 series, EMC Directive 2004/108/EC and MV circuit breaker standard IEC 62271-100.

Table of contents

Section 1 Introduction

1.1 This manual

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

1.2 Intended audience

This manual addresses system engineers and installation and commissioning personnel, who use technical data during engineering, installation and commissioning, and in normal service.

The system engineer must have a thorough knowledge of protection systems, protection equipment, protection functions and the configured functional logic in the IEDs. The installation and commissioning personnel must have a basic knowledge in handling electronic equipment.

1.3 Product documentation

1.3.1 Product documentation set

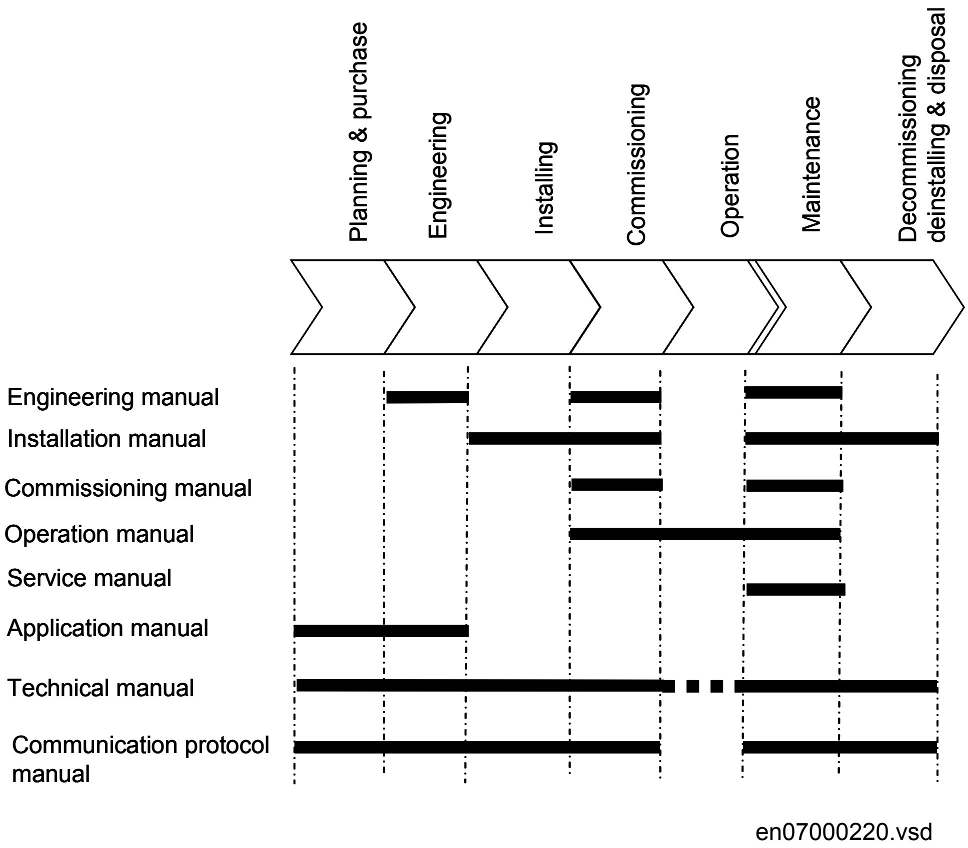


Figure 1: The intended use of manuals in different lifecycles

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and other supported protocols.

The installation manual contains instructions on how to install the IED. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the IED should be installed.

The commissioning manual contains instructions on how to commission the IED. The manual can also be used by system engineers and maintenance personnel for assistance during the testing phase. The manual provides procedures for checking of external circuitry and energizing the IED, parameter setting and configuration as well as verifying settings by secondary injection. The manual describes the process of testing an IED in a substation which is not in service. The chapters are organized in chronological order in which the IED should be commissioned.

The operation manual contains instructions on how to operate the IED once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the IED. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The troubleshooting manual contains quick answers to frequently asked questions about the IED use. The manual provides instant solutions to the problems that the end used might face while using the IED, both at commissioning and during the eVD4 life.

The service manual contains instructions on how to service and maintain the IED. The manual also provides procedures for de-energizing, de-commissioning and disposal of the IED.

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

The point list manual describes the outlook and properties of the data points specific to the IED. The manual should be used in conjunction with the corresponding communication protocol manual.

Some of the manuals are not available yet.

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2010-10-14	1.0	First release
B/2011-12-13	2.0	Content updated to correspond to the product series version

Download the latest documents from the ABB Web site http://www.abb.com/mediumvoltage.

1.3.3 Related documentation

Product series- and product-specific manuals can be downloaded from the ABB web site http://www.abb.com/mediumvoltage.

1.4 Symbols and conventions

1.4.1 Symbols

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push-button navigation in the LHMI menu structure is presented by using the push-button icons.
  To navigate between the options, use  and .
- HMI menu paths are presented in bold.
  Select **Main menu/Settings**.
- WHMI menu names are presented in bold.
  Click **Information** in the WHMI menu structure.
- LHMI messages are shown in Courier font.
  To save the changes in non-volatile memory, select `Yes` and press .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- IED input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to all product variants.

Table 1: Functions included in standard configurations

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> → (1)	67-1 (1)
	DPHLPDOC2	3I> → (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> →	67-2
Non-directional earth-fault protection, low stage	EFLPTOC1	I0> (1)	51N-1 (1)
	EFLPTOC2	I0> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	I0>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	I0>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	I0> → (1)	67N-1 (1)
	DEFLPDEF2	I0> → (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	I0>> →	67N-2
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection	ROVPTOV1	U0> (1)	59G (1)
	ROVPTOV2	U0> (2)	59G (2)
	ROVPTOV3	U0> (3)	59G (3)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)
	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection	PSPTUV1	U1<	47U+
Negative-sequence overvoltage protection	NSPTOV1	U2>	47O-
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Negative-sequence overcurrent protection for motors	MNSPTOC1	I2>M (1)	46M (1)
	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51 LR
Phase reversal protection	PREVPTOC	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/I0>BF	51BF/ 51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Protection trip conditioning	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
Control			
Fixed circuit-breaker control	FCBXCBR1	I ↔ O CB	I ↔ O CB
Withdrawable circuit-breaker control	WCBXCBR1	I ↔ O CB	I ↔ O CB
Earthing switch indication	ESSXSWI1	I ↔ O ES	I ↔ O ES
Earthing switch control	MESXSWI1	I ↔ O ES	I ↔ O ES
Truck control	TRXSWI	I ↔ O DC	I ↔ O DC
H-bridge control	HBGAPC1	HBC	HBC
	HBGAPC2	HBC	HBC
Emergency startup	ESMGAPC1	ESTART	ESTART
Auto-reclosing	DARREC1	O → I	79
Condition monitoring			
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Circuit-breaker condition monitoring	ESSCBR1	CBCM	CBCM
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Coil switch supervision (open)	OCSSCBR1	TCS (Open)	TCM (Open)
Coil switch supervision (close)	CCSSCBR1	TCS (Close)	TCM (Close)
Fuse failure supervision	SEQRFUF1	FUSEF	60
Motor runtime counter	MDSOPT1	OPTS	OPTM
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement	RESCMMXU1	I0	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	U0	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
Sensor temperature	VDSTMP	VDTS	VDTM

Section 2 RBX615 overview

2.1 Overview

RBX615 is an IED integrated into a circuit breaker and based on the Relion® technology designed for protection, control, measurement and supervision of utility substations and industrial switchgear and equipment. The design of the IED has been guided by the IEC 61850 standard for communication and interoperability of substation automation devices.

The IED features an optimized design for the integration inside the medium voltage circuit breakers with a plug & play mounting method, the compact size and ease of use. A panel HMI allows a useful and easy interaction with the IED, all the unit's signals are accessible trough the plug of the circuit breaker. Depending on the product variant, optional functionality is available at the time of order for both software and hardware, for example, autoreclosure and additional I/Os.

The IED supports a range of communication protocols including IEC 61850 with GOOSE messaging and Modbus®.

2.1.1 Product series version history

Product series version	Product series history
1.0	First product from 615 series eVD4 - RBX615 released
2.0	New product release: • New circuit-breaker condition monitoring (ESSCBR) • Function keys (EFKEY) • Support to Dbpos GOOSE • Support to Modbus RTU • New EIA-485 COM board • New Ethernet optical LC COM board

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.4 or later
- RBX615 Connectivity Package Ver. 2.0 or later

Download connectivity packages from the ABB web site http://www.abb.com/substationautomation

2.2 Local HMI

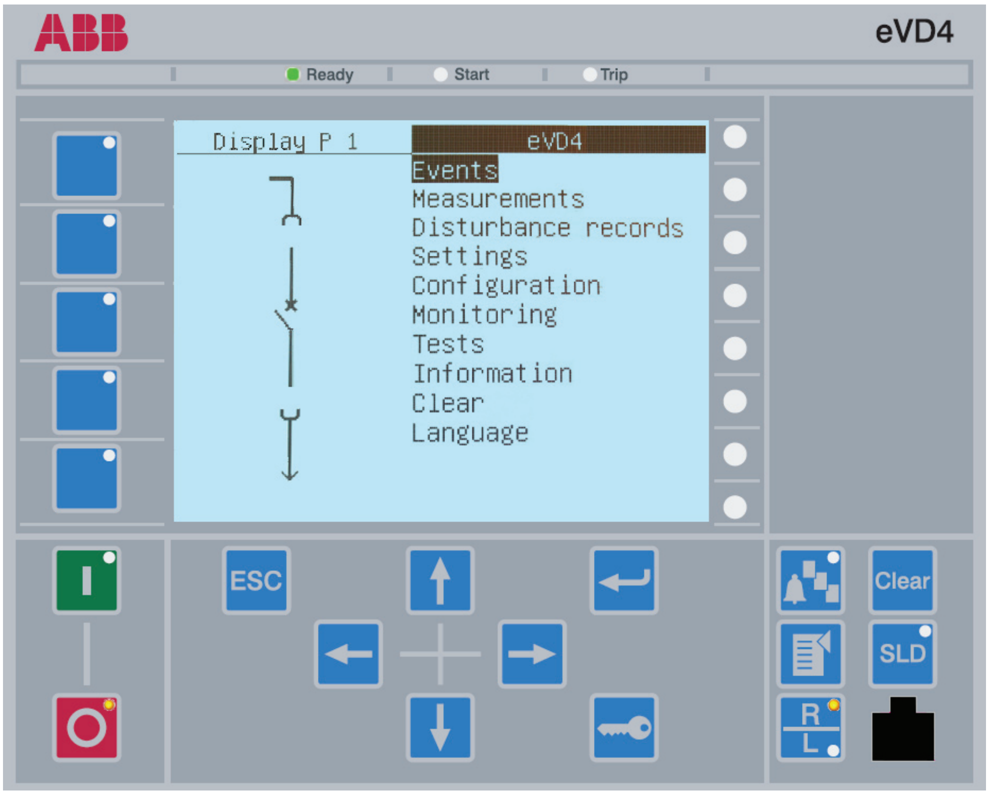


Figure 2: LHMI

The LHMI of the IED contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port
- USB port (reserved for future use)
- SD memory card slot (reserved for future use)
- Wireless adapter slot (reserved for future use)

Inquire the feature availability from ABB.

The LHMI is used for setting, monitoring and controlling.

2.2.1 LCD

The LHMI includes a graphical LCD that supports two character sizes. The character size depends on the selected language. The amount of characters and rows fitting the view depends on the character size.

Table 2: Characters and rows on the view

Character size	Rows in view	Characters on row
Small, mono-spaced (8x16 pixels)	15 rows with large screen	21
Large, variable width (16x16 pixels)	15 rows with large screen	10

The display view is divided into five basic areas.

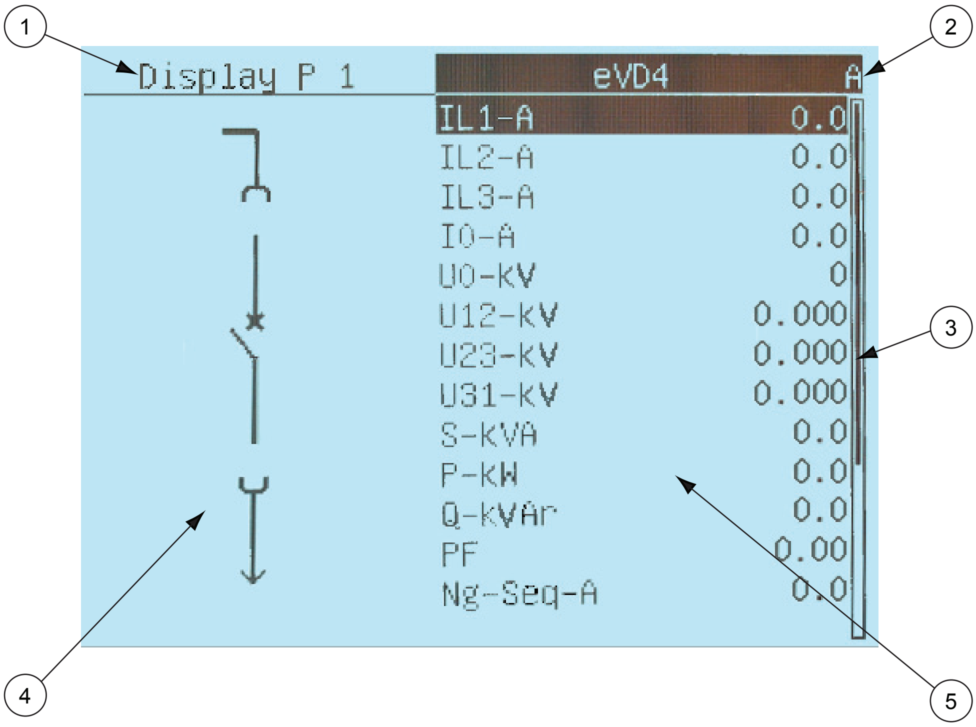


Figure 3: Display layout

1 Header
2 Icon
3 Scroll bar (displayed when needed)
4 Single-line diagram
5 Content

- The header area at the top of the display view shows the current location in the menu structure.
- The icon area at the upper right corner of the display shows the current action or user level.
  Current action is indicated by the following characters:

    - U: Font/Firmware is being updated
    - S: Parameters are being stored
    - !: Warning and/or indication

  Current user level is indicated by the following characters:

    - V: Viewer
    - O: Operator
    - E: Engineer
    - A: Administrator
- The content area shows the menu content.
- If the menu contains more rows than the display can show at a time, a scroll bar is displayed on the right.
- The single-line diagram area on the left half of the screen is always visible to show the mimic of the feeder and objects status. When selected, the corresponding header area becomes highlighted.

The display is updated either cyclically or based on changes in the source data such as parameters or events.

2.2.2 LEDs

The LHMI includes three protection indicators above the display: Ready, Start and Trip.

There are also eight matrix programmable alarm LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

The eight LEDs are visible on three virtual pages, scrollable with the Alarm pages push-button

2.2.3 Keypad

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. With the push-buttons you can give open or close commands to one primary object, for example, a circuit breaker, disconnector or switch. The push-buttons are also used to acknowledge alarms, reset indications and switch between local and remote control mode.

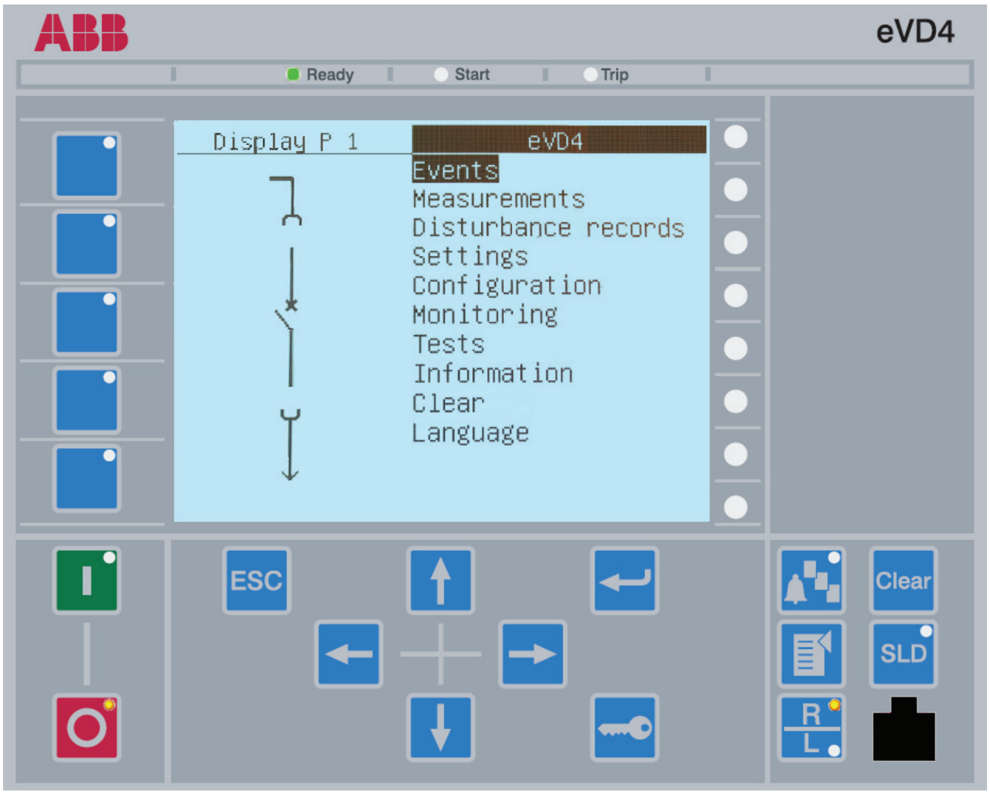


Figure 4: LHMI keypad

Object control

If the control position of the IED is set to local with the R/L button, multiple objects can be controlled in the SLD using the object control buttons of the IED.

Table 3: Object control push-buttons

Name	Description
Close	Closing the object.
Open	Opening the object.

2.2.4 Local HMI configuration flash memory

The LHMI includes a dedicated 512 kB flash memory to store the calibration data and the configuration running on the IED.

2.3 Web HMI

The WHMI enables the user to access the IED via a web browser. The supported web browser version is Internet Explorer 7.0 or later.

WHMI is disabled by default.

WHMI offers several functions.

- Alarm indications and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Phasor diagram

The menu tree structure on the WHMI is almost identical to the one on the LHMI.

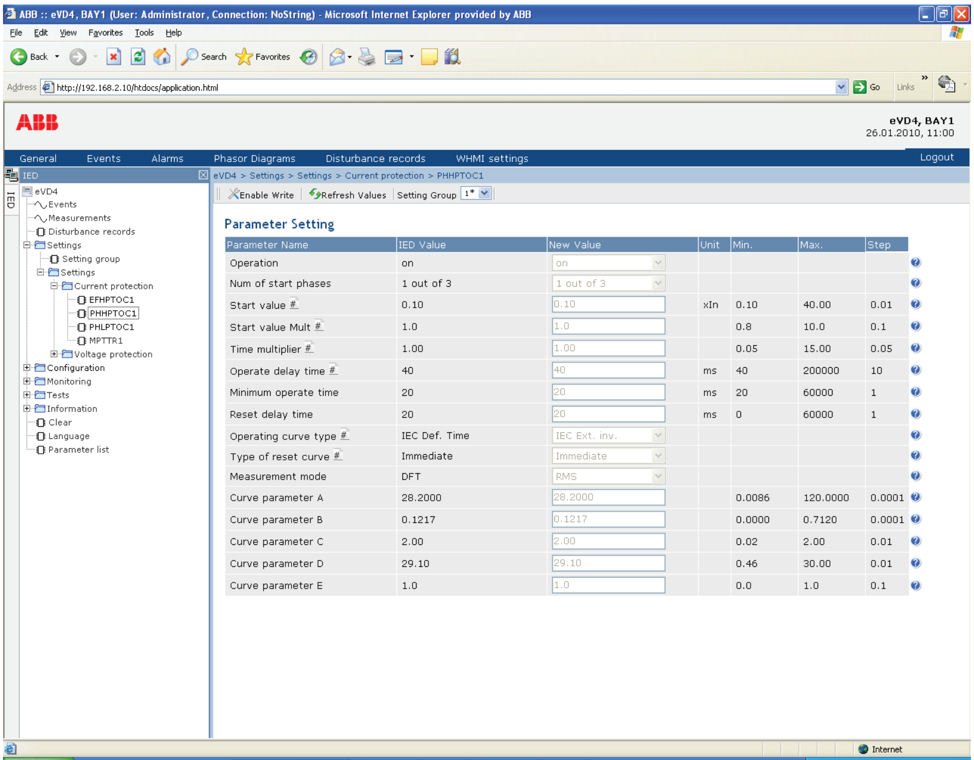


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting your laptop to the IED via the front communication port.
- Remotely over LAN/WAN.

2.4 Authorization

The user categories have been predefined for the LHMI and the WHMI, each with different rights and default passwords.

The default passwords can be changed with Administrator user rights.

User authorization is disabled by default but WHMI always uses authorization.

Table 4: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with (only locally) • Changing setting groups • Controlling • Clearing alarm and indication LEDs and textual indications
ENGINEER	• Changing settings • Clearing event list • Clearing disturbance records • Changing system settings such as IP address, serial baud rate or disturbance recorder settings • Setting the IED to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.5 Communication

The IED supports a range of communication protocols including IEC 61850 and Modbus®. Operational information and controls are available through these protocols.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and disturbance file records can be accessed using the IEC 61850 protocol. Disturbance files are available to any Ethernet-based application in the standard COMTRADE format. Further, the IED can send and receive binary signals from other IEDs (so called horizontal communication) using the IEC61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. The IED meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard. The IED can simultaneously report events to five different clients on the station bus.

The IED can support five simultaneous clients. If PCM600 reserves one client connection, only four client connections are left, for example, for IEC 61850 and Modbus.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The IED can be connected to Ethernet-based communication systems via the RJ-45 connector (100BASE-TX).

Section 3 Basic functions

3.1 General parameters

Table 5: Analog input settings, phase currents

Parameter	Values (Range)	Unit	Step	Default	Description
Rated Secondary Value	3.0...15.0	mV/Hz	0.1	3.0	Rated secondary voltage
Nominal Current	39...4000	A	1	1300	Network Nominal Current
Primary current	1.0...6000.0	A	0.1	100.0	Rated primary current
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A amplitude correction factor
Amplitude corr. B	0.900...1.100		0.001	1.000	Phase B amplitude correction factor
Amplitude corr. C	0.900...1.100		0.001	1.000	Phase C amplitude correction factor

Table 6: Analog input settings, residual current

Parameter	Values (Range)	Unit	Step	Default	Description
Secondary current	2=1A			2=1A	Secondary current
Primary current	1.0...6000.0	A	0.1	100.0	Primary current
Amplitude corr.	0.900...1.100		0.001	1.000	Amplitude correction

Table 7: Analog input settings, phase voltages

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.001...440.000	kV	0.001	20.000	Primary rated voltage
VT connection	1=Wye			1=Wye	Wye VT connection
Amplitude corr. A	0.900...1.100		0.001	1.000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Amplitude corr. B	0.900...1.100		0.001	1.000	Phase B Voltage phasor magnitude correction of an external voltage transformer
Amplitude corr. C	0.900...1.100		0.001	1.000	Phase C Voltage phasor magnitude correction of an external voltage transformer
Division ratio	1000...20.000		1	10000	Division ratio of the capacitor divider

Table 8: Alarm LED input signals

Name	Type	Default	Description
Alarm LED 1: RED	BOOLEAN	0=False	Red color status of Alarm LED 1
Alarm LED 1: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 1
Alarm LED 2: RED	BOOLEAN	0=False	Red color status of Alarm LED 2
Alarm LED 2: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 2
Alarm LED 3: RED	BOOLEAN	0=False	Red color status of Alarm LED 3
Alarm LED 3: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 3
Alarm LED 4: RED	BOOLEAN	0=False	Red color status of Alarm LED 4
Alarm LED 4: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 4
Alarm LED 5: RED	BOOLEAN	0=False	Red color status of Alarm LED 5
Alarm LED 5: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 5
Alarm LED 6: RED	BOOLEAN	0=False	Red color status of Alarm LED 6
Alarm LED 6: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 6
Alarm LED 7: RED	BOOLEAN	0=False	Red color status of Alarm LED 7
Alarm LED 7: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 7
Alarm LED 8: RED	BOOLEAN	0=False	Red color status of Alarm LED 8
Alarm LED 8: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 8
Alarm LED 9: RED	BOOLEAN	0=False	Red color status of Alarm LED 9
Alarm LED 9: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 9
Alarm LED 10: RED	BOOLEAN	0=False	Red color status of Alarm LED 10
Alarm LED 10: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 10
Alarm LED 11: RED	BOOLEAN	0=False	Red color status of Alarm LED 11
Alarm LED 11: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 11
Alarm LED 12: RED	BOOLEAN	0=False	Red color status of Alarm LED 12
Alarm LED 12: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 12
Alarm LED 13: RED	BOOLEAN	0=False	Red color status of Alarm LED 13
Alarm LED 13: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 13
Alarm LED 14: RED	BOOLEAN	0=False	Red color status of Alarm LED 14
Alarm LED 14: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 14
Alarm LED 15: RED	BOOLEAN	0=False	Red color status of Alarm LED 15

Table continues on next page

Name	Type	Default	Description
Alarm LED 15: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 15
Alarm LED 16: RED	BOOLEAN	0=False	Red color status of Alarm LED 16
Alarm LED 16: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 16
Alarm LED 17: RED	BOOLEAN	0=False	Red color status of Alarm LED 17
Alarm LED 17: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 17
Alarm LED 18: RED	BOOLEAN	0=False	Red color status of Alarm LED 18
Alarm LED 18: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 18
Alarm LED 19: RED	BOOLEAN	0=False	Red color status of Alarm LED 19
Alarm LED 19: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 19
Alarm LED 20: RED	BOOLEAN	0=False	Red color status of Alarm LED 20
Alarm LED 20: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 20
Alarm LED 21: RED	BOOLEAN	0=False	Red color status of Alarm LED 21
Alarm LED 21: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 21
Alarm LED 22: RED	BOOLEAN	0=False	Red color status of Alarm LED 22
Alarm LED 22: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 22
Alarm LED 23: RED	BOOLEAN	0=False	Red color status of Alarm LED 23
Alarm LED 23: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 23
Alarm LED 24: RED	BOOLEAN	0=False	Red color status of Alarm LED 24
Alarm LED 24: GREEN	BOOLEAN	0=False	Green color status of Alarm LED 24

Table 9: Alarm LED settings

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm LED mode	0=Follow-S [1] 1=Follow-F [2] 2=Latched-S [3] 3=LatchedAck-F-S [4]			0=Follow-S	Alarm mode for LED 1
Description				Alarm LEDs LED 1	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 2
Description				Alarm LEDs LED 2	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 3
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Description				Alarm LEDs LED 3	Description of alarm
...					
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 23
Description				Alarm LEDs LED 23	Description of alarm
Alarm LED mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for LED 24
Description				Alarm LEDs LED 24	Description of alarm

1) Non-latched mode
2) Non-latched blinking mode
3) Latched mode
4) Latched blinking mode

Table 10: Authorization settings

Parameter	Values (Range)	Unit	Step	Default	Description
Local override	0=False [1] 1=True [2]			1=True	Disable authority
Remote override	0=False [3] 1=True [4]			1=True	Disable authority
Local viewer				0	Set password
Local operator				0	Set password
Local engineer				0	Set password
Local admin				0	Set password
Remote viewer				0	Set password
Remote operator				0	Set password
Remote engineer				0	Set password
Remote admin				0	Set password

1) Authorization override is disabled, LHMI password must be entered.
2) Authorization override is enabled, LHMI password is not asked.
3) Authorization override is disabled, communication tools ask password to enter the IED.
4) Authorization override is enabled, communication tools do not need password to enter the IED, except for WHMI which always requires it.

Table 11: Binary input settings

Parameter	Values (Range)	Unit	Step	Default	Description
Threshold voltage	18...70[1] 86…250[2]	Vdc	2	18[1] 86[2]	Binary input threshold voltage
Input osc. level	2...50	events/s	1	30	Binary input oscillation suppression threshold
Input osc. hyst	2...50	events/s	1	10	Binary input oscillation suppression threshold

1) Low auxiliary voltage range
2) High auxiliary voltage range

Table 12: Ethernet front port settings

Parameter	Values (Range)	Unit	Step	Default	Description
IP address				192.168.0.254	IP address for front port (fixed)
Mac address				XX-XX-XX-XX-XX-XX	Mac address for front port

Table 13: Ethernet rear port settings

Parameter	Values (Range)	Unit	Step	Default	Description
IP address				192.168.2.10	IP address for rear port(s)
Subnet mask				255.255.255.0	Subnet mask for rear port(s)
Default gateway				192.168.2.1	Default gateway for rear port(s)
Mac address				XX-XX-XX-XX-XX-XX	Mac address for rear port(s)

Table 14: General system settings

Parameter	Values (Range)	Unit	Step	Default	Description
Rated frequency	1=50Hz 2=60Hz			1=50Hz	Rated frequency of the network
Phase rotation	1=ABC 2=ACB			1=ABC	Phase rotation order
Blocking mode	1=Freeze timer 2=Block all 3=Block OPERATE output			1=Freeze timer	Behaviour for function BLOCK inputs
Bay name				eVD4	Bay name in system
SG follow input	0=False 1=True			0=False	Enable setting group change to follow the input state

Table 15: HMI settings

Parameter	Values (Range)	Unit	Step	Default	Description
FB naming convention	1=IEC61850 2=IEC60617 3=IEC-ANSI			1=IEC61850	FB naming convention used in IED
Default view	1=Measurements 2=Main menu			1=Measurements	LHMI default view
Backlight timeout	1...60	min	1	3	LHMI backlight timeout
Web HMI mode	1=Active read only 2=Active 3=Disabled			3=Disabled	Web HMI functionality
Web HMI timeout	1...60	min	1	3	Web HMI login timeout

Table 16: IEC 61850-8-1 MMS settings

Parameter	Values (Range)	Unit	Step	Default	Description
Unit mode	1=Primary 0=Nominal 2=Primary-Nominal			0=Nominal	IEC 61850-8-1 unit mode

Table 17: MODBUS settings

Parameter	Values (Range)	Unit	Step	Default	Description
MaxTCPClients	0...5			5	Maximum number of Modbus TCP/IP clients
TCPWriteAuthority	0=No clients 1=Reg. clients 2=All clients			2=All clients	Write authority setting for Modbus TCP/IP clients
EventID	0=Address 1=UID			0=Address	Event ID selection
TimeFormat	0=UTC 1=Local			1=Local	Time format for Modbus time stamps
ClientIP1				000.000.000.000	Modbus Registered Client 1
ClientIP2				000.000.000.000	Modbus Registered Client 2
ClientIP3				000.000.000.000	Modbus Registered Client 3
ClientIP4				000.000.000.000	Modbus Registered Client 4
ClientIP5				000.000.000.000	Modbus Registered Client 5
CtlStructPWd1				****	Password for Modbus control struct 1
CtlStructPWd2				****	Password for Modbus control struct 2
CtlStructPWd3				****	Password for Modbus control struct 3
CtlStructPWd4				****	Password for Modbus control struct 4
CtlStructPWd5				****	Password for Modbus control struct 5
CtlStructPWd6				****	Password for Modbus control struct 6
CtlStructPWd7				****	Password for Modbus control struct 7
CtlStructPWd8				****	Password for Modbus control struct 8
Internal Overflow	0=False 1=True			0=False	Modbus Internal Overflow: TRUE-System level overflow occured (indication only)

Table 18: Serial communication settings

Parameter	Values (Range)	Unit	Step	Default	Description
Baudrate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baudrate for COM1

Table 19: Serial communication settings

Parameter	Values (Range)	Unit	Step	Default	Description
Baudrate	1=300 2=600 3=1200 4=2400 5=4800 6=9600 7=19200 8=38400 9=57600 10=115200			6=9600	Baudrate for COM2

Inquire ABB about the availability of this communication protocol.

Table 20: Time settings

Parameter	Values (Range)	Unit	Step	Default	Description
Date				0	Date
Time				0	Time
Time format	1=24H:MM:SS:MS 2=12H:MM:SS:MS			1=24H:MM:SS:MS	Time format
Date format	1=DD.MM.YYYY 2=DD/MM/YYYY 3=DD-MM-YYYY 4=MM.DD.YYYY 5=MM/DD/YYYY 6=YYYY-MM-DD 7=YYYY-DD-MM 8=YYYY/DD/MM			1=DD.MM.YYYY	Date format
Local time offset	-720...720	min		0	Local time offset in minutes
Synch source	0=None 1=SNTP 2=Modbus 5=IRIG-B 9=DNP 16=IEC60870-5-103			1=SNTP	Time synchronization source
IP SNTP primary				10.58.125.165	IP address for SNTP primary server
IP SNTP secondary				192.168.2.165	IP address for SNTP secondary server
DST on time				02:00	Daylight savings time on, time (hh:mm)
DST on date				01.05.	Daylight savings time on, date (dd:mm)
DST on day	0=Not in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			0=Not in use	Daylight savings time on, day of week
DST offset	-720...720	min		60	Daylight savings time offset, in minutes

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
DST off time				02:00	Daylight savings time off, time (hh:mm)
DST off date				25.09.	Daylight savings time off, date (dd:mm)
DST off day	0=Not in use 1=Mon 2=Tue 3=Wed 4=Thu 5=Fri 6=Sat 7=Sun			0=Not in use	Daylight savings time off, day of week

Table 21: -XB binary output signals

Name	Type	Default	Description
BO1	BOOLEAN	0=False	General Purpose Binary Output (BIO board)
BO2	BOOLEAN	0=False	General Purpose Binary Output (BIO board)
BO3	BOOLEAN	0=False	General Purpose Binary Output (BIO board)
BO4	BOOLEAN	0=False	General Purpose Binary Output (BIO board)
BO5	BOOLEAN	0=False	General Purpose Binary Output (PS board)
BO6	BOOLEAN	0=False	General Purpose Binary Output (PS board)
BO7[1)]	BOOLEAN	0=False	Locking Magnet –RL1 (PS board)
BO8[1)]	BOOLEAN	0=False	Closing Coil –MC (PS board)
BO9[1)]	BOOLEAN	0=False	Opening Coil –MO (PS board)
BO10	BOOLEAN	0=False	Watchdog (PS board)
BO11	BOOLEAN	0=False	Ready Status (PS board)
BO12[1)]	BOOLEAN	0=False	Truck Locking Magnet – RL2 (PS board)

1) Internal Binary Output. Not available on -XB plug

Table 22: -XB binary input signals

Name	Type	Description
BI1	BOOLEAN	General Purpose Binary Input (BIO board)
BI2	BOOLEAN	General Purpose Binary Input (BIO board)
BI3	BOOLEAN	General Purpose Binary Input (BIO board)
BI4	BOOLEAN	General Purpose Binary Input (BIO board)
BI5	BOOLEAN	General Purpose Binary Input (BIO board)
BI6	BOOLEAN	General Purpose Binary Input (BIO board)
BI7	BOOLEAN	General Purpose Binary Input (BIO board)
BI8	BOOLEAN	General Purpose Binary Input (BIO board)
BI9	BOOLEAN	General Purpose Binary Input (BIO board)
BI10	BOOLEAN	General Purpose Binary Input (BIO board)
BI11	BOOLEAN	Hardware dedicated to CB Close Command
BI12	BOOLEAN	Hardware dedicated to CB Open Command
BI13[1)]	BOOLEAN	Close Position sensor Input (BSB board)
BI14[1)]	BOOLEAN	Open Position sensor Input (BSB board)
BI15[1)]	BOOLEAN	Charged Closing Spring sensor Input (BSB board)
BI16[1)]	BOOLEAN	Truck Test Position sensor Input (BSB board)
BI17[1)]	BOOLEAN	Truck Service Position sensor Input (BSB board)

1) Internal Binary Input. Not available on -XB plug

Table 23: -XB binary input settings

Parameter	Values (Range)	Unit	Step	Default	Description
Input 1 filter time	5...1000	ms		5	Binary Input 1 (-XB Connector)
Input 2 filter time	5...1000	ms		5	Binary Input 2 (-XB Connector)
Input 3 filter time	5...1000	ms		5	Binary Input 3 (-XB Connector)
Input 4 filter time	5...1000	ms		5	Binary Input 4 (-XB Connector)
Input 5 filter time	5...1000	ms		5	Binary Input 5 (-XB Connector)
Input 6 filter time	5...1000	ms		5	Binary Input 6 (-XB Connector)
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Input 7 filter time	5...1000	ms		5	Binary Input 7 (-XB Connector)
Input 8 filter time	5...1000	ms		5	Binary Input 8 (-XB Connector)
Input 9 filter time	5...1000	ms		5	Binary Input 9 (-XB Connector)
Input 10 filter time	5...1000	ms		5	Binary Input 10 (-XB Connector)
Input 11 filter time	5...1000	ms		5	Binary Input 11 (-XB Connector)
Input 12 filter time	5...1000	ms		5	Binary Input 12 (-XB Connector)
Input 13 filter time	5...1000	ms		5	Internal Input 13
Input 14 filter time	5...1000	ms		5	Internal Input 14
Input 15 filter time	5...1000	ms		5	Internal Input 15
Input 16 filter time	5...1000	ms		5	Internal Input 16
Input 17 filter time	5...1000	ms		5	Internal Input 17
Input 1 inversion	0=False 1=True			0=False	Binary Input 1 (-XB Connector)
Input 2 inversion	0=False 1=True			0=False	Binary Input 2 (-XB Connector)
Input 3 inversion	0=False 1=True			0=False	Binary Input 3 (-XB Connector)
Input 4 inversion	0=False 1=True			0=False	Binary Input 4 (-XB Connector)
Input 5 inversion	0=False 1=True			0=False	Binary Input 5 (-XB Connector)
Input 6 inversion	0=False 1=True			0=False	Binary Input 6 (-XB Connector)
Input 7 inversion	0=False 1=True			0=False	Binary Input 7 (-XB Connector)
Input 8 inversion	0=False 1=True			0=False	Binary Input 8 (-XB Connector)
Input 9 inversion	0=False 1=True			0=False	Binary Input 9 (-XB Connector)
Input 10 inversion	0=False 1=True			0=False	Binary Input 10 (-XB Connector)
Input 11 inversion	0=False 1=True			0=False	Binary Input 11 (-XB Connector)
Input 12 inversion	0=False 1=True			0=False	Binary Input 12 (-XB Connector)
Input 13 inversion	0=False 1=True			0=False	Internal Input 13
Input 14 inversion	0=False 1=True			0=False	Internal Input 14
Input 15 inversion	0=False 1=True			0=False	Internal Input 15
Input 16 inversion	0=False 1=True			0=False	Internal Input 16
Input 17 inversion	0=False 1=True			0=False	Internal Input 17

3.2 Self-supervision

The IED's extensive self-supervision system continuously supervises the software and the electronics. It handles run-time fault situations and informs the user about the existing faults via the LHMI and the communication.

There are two types of fault indications.

- Internal faults
- Warnings

3.2.1 Internal faults

Internal fault indications have the highest priority on the LHMI. None of the other LHMI indications can override the internal fault indication.

An indication about the fault is shown as a message on the LHMI. The text `Internal Fault` with an additional text message, a code, date and time, is shown to indicate the fault type.

Different actions are taken depending on the severity of the fault. The IED tries to eliminate the fault by restarting. After the fault is found to be permanent, the IED stays in internal fault mode. All other output contacts are released and locked for the internal fault. The IED continues to perform internal tests during the fault situation.

The internal fault code indicates the type of internal IED fault. When a fault appears, record the code so that it can be reported to ABB customer service.

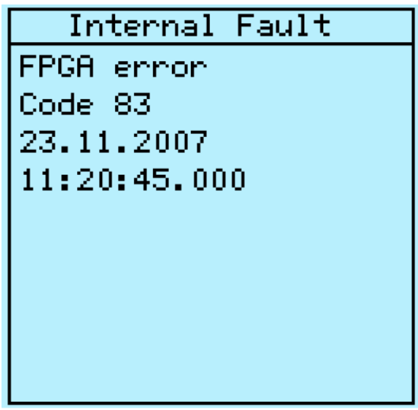


Figure 6: Fault indication

Table 24: Internal fault indications and codes

Fault indication	Fault code	Additional information
Internal Fault System error	2	An internal system error has occurred.
Internal Fault File system error	7	A file system error has occurred
Internal Fault Test	8	Internal fault test activated manually by the user.
Internal Fault SW watchdog error	10	Watchdog reset has occurred too many times within an hour.
Internal Fault SO-relay(s), BIO	41	Faulty Signal Output relay(s) in card located in slot 5 (BIO board).
Internal Fault SO-relay(s), BIO	43	Faulty Signal Output relay(s) in card located in slot 3 (BIO board).
Internal Fault SO-relay(s), PSM	44	Faulty Signal Output relay(s) in card located in slot 2 (Power supply board).
Internal Fault SO-relay(s), BSB	46	Faulty Signal Output relay(s) in card located in slot 0 (Base board).
Internal Fault Conf. error, BIO	61	Card in slot 5 is wrong type or does not belong to the original composition.
Internal Fault Conf. error, COM	62	Card in slot 4 is wrong type or does not belong to the original composition.
Internal Fault Conf. error, BIO	63	Card in slot 3 is wrong type or does not belong to the original composition.
Internal Fault Conf. error, PSM	64	Card in slot 2 is wrong type or does not belong to the original composition.
Internal Fault Conf. error, BSB	66	Card in slot 0 is wrong type, is missing or does not belong to the original composition.
Internal Fault Card error, BIO	71	Card in slot 5 is faulty.
Internal Fault Card error, COM	72	Card in slot 4 is faulty.
Internal Fault Card error, BIO	73	Card in slot 3 is faulty.
Internal Fault Card error, PSM	74	Card in slot 2 is faulty.
Internal Fault Card error, BSB	76	Card in slot 0 is faulty.
Internal Fault LHMI module	79	LHMI module is faulty. The fault indication may not be seen on the LHMI during the fault.
Internal Fault RAM error	80	Error in the RAM memory on the CPU card.
Internal Fault ROM error	81	Error in the ROM memory on the CPU card.
Internal Fault EEPROM error	82	Error in the EEPROM memory on the
Internal Fault FPGA error	83	Error in the FPGA on the CPU card.
Internal Fault RTC error	84	Error in the RTC on the CPU card.

3.2.2 Warnings

Warnings are indicated with the text `Warning` additionally provided with the name of the warning, a numeric code, and the date and time on the LHMI. The warning indication message can be manually cleared.

If a warning appears, record the name and code so that it can be provided to ABB customer service.

Figure 7: Warning

Table 25: Warning indications and codes

Warning indication	Warning code	Additional information
Warning Watchdog reset	10	A watchdog reset has occurred.
Warning Power down det.	11	The auxiliary supply voltage has dropped too low.
Warning IEC61850 error	20	Error when building the IEC 61850 data model.
Warning Modbus error	21	Error in the Modbus communication.
Warning Dataset error	24	Error in the Data set(s).
Warning Report cont. error	25	Error in the Report control block(s).
Warning GOOSE contr. error	26	Error in the GOOSE control block(s).
Warning SCL config error	27	Error in the SCL configuration file or the file is missing.
Warning Logic error	28	Too many connections in the configuration.
Warning SMT logic error	29	Error in the SMT connections.
Warning GOOSE input error	30	Error in the GOOSE connections.

Table continues on next page

Warning indication	Warning code	Additional information
Warning GOOSE Rx. error	32	Error in the GOOSE message receiving.
Warning AFL error	33	Analog channel configuration error.
Warning Param. range violation	34	Error parameter range violation
Warning System overload	35	AFL execution is overloading the system
Warning Unack card comp.	40	A new composition has not been acknowledged/accepted.
Warning Protection comm.	50	Error in protection communication.

3.3 LED indication control

The IED includes a global conditioning function LEDPTRC that is used with the protection indication LEDs.

LED indication control should never be used for tripping purposes. There is a separate trip logic function TRPPTRC available in the IED configuration.

LED indication control is preconfigured in a such way that all the protection function general start and operate signals are combined with this function (available as output signals `OUT_START` and `OUT_OPERATE`). These signals are always internally connected to Start and Trip LEDs. LEDPTRC collects and combines phase information from different protection functions (available as output signals `OUT_ST_A /_B /_C` and `OUT_OPR_A /_B /_C`). There is also combined earth fault information collected from all the earth fault functions available in the IED configuration (available as output signals `OUT_ST_NEUT` and `OUT_OPR_NEUT`).

3.4 Indication LED function MLEDGGIO

3.4.1 Function block

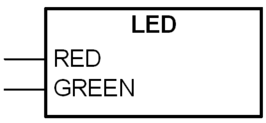


Figure 8: Function block

3.4.2 Functionality

The LED function MLEDGGIO controls the 24 HMI indication LEDs. Each HMI LED is controlled by its own LED function block where the instance number represents the LED number. The function is designed according to the IEC 61850-7-4 standard with the MLEDGGIO logical nodes.

3.4.3 Operation principle

The LED function controls the HMI bicolor indication LEDs. The `RED` and `GREEN` inputs switch on the red and green color LEDs respectively.

Up to 24 indication LEDs are available virtually. However, the HMI unit is physically equipped with eight indication LEDs. The 24 LEDs are multiplexed on three pages, eight LEDs on each. A tab indicates which page of the three is active.

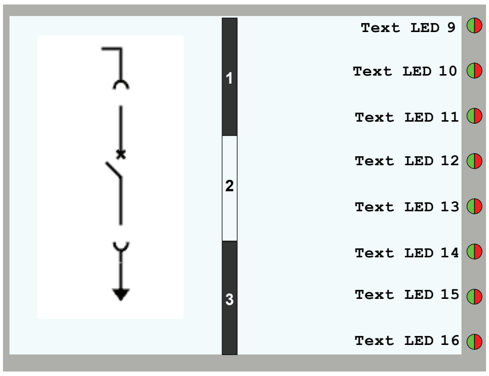


Figure 9: HMI Indication LED page (Page 2 including LEDs from 9 to 16 is active)

A dedicated page on HMI shows the strings explicating the function of each indication LED. For each LED, four strings corresponding to the LED colors can be configured.

Table 26: Strings corresponding to the LED colors

String	Color
0	OFF
1	GREEN
2	RED
3	YELLOW

The LED texts are configured using PCM Language Mapping Interface (LMI).

The indication LED page can be recalled on the HMI unit by pressing the dedicated button. The same button is used to scroll the pages. The yellow LED embedded in the button is lit to indicate that there is at least one active LED in the inactive pages.

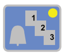


Figure 10: HMI button to recall the indication LED page

3.5 Function key control block EFKEYGGIO

3.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE
Function key control block	EFKEYGGIO	-	-

3.5.2 Function block

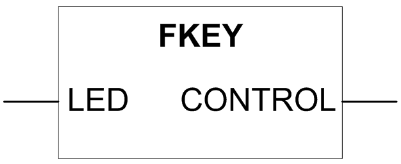


Figure 11: Function block

3.5.3 Functionality

The function key control block EFKEYGGIO is designed to handle the LHMI function keys.

The LHMI unit is equipped with five function keys each containing a LED. Both the LED behavior and the operation associated with a function key can be independently configured by the customer through a dedicated function block FKEY. The function block instance number represents the function key position number. The FKEY function block is designed according to the IEC 61850-7-4 standard with logical nodes EFKEYGGIO.

3.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The FKEY block is used both to control the status of the LED embedded in the function key and to expose the status of the key itself. Function keys are placed on the left side of the HMI.

The embedded LED is a single-color LED which has only two statuses: turned on and turned off. When the `LED` input in the FKEY block is High, the physical LED embedded in the corresponding function key is turned on. When the `LED` input in the FKEY block is Low, the LED embedded in the corresponding function is turned off.

For every function key, a short description can be given.

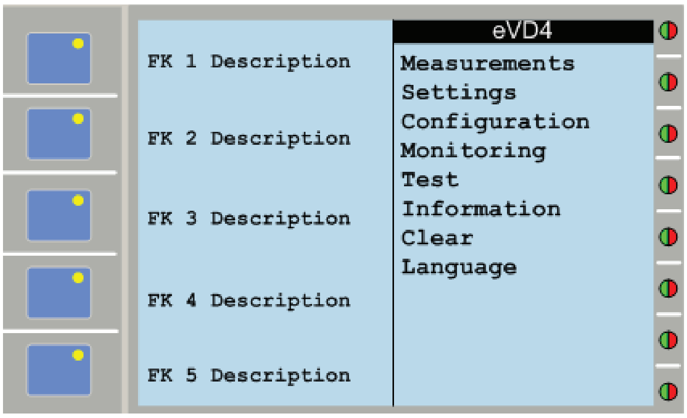


Figure 12: Layout of HMI function keys and related strings for description

The function key description page and the SLD diagram overlap on the same HMI section (the left half). Normally the SLD is shown.

For safety reasons the function keys are active only when the corresponding description page is visible. If the SLD is shown, the function keys page can be recalled by pressing one of the function keys. Pressing the function key does not trigger any action but switches the description page on. The further key pressings activate the `CONTROL` function block output.

Table 27: HMI status – function key behavior

Left side of HMI	User action	Result
SLD diagram	Press one of the function keys	The function keys' description page is shown
Function keys' description	Press one of the function keys	The operation associated with the function key is executed
Function keys' description	Press the SLD button	The SLD diagram is shown
Function keys' description	Wait 15 seconds without pressing a function key	The SLD diagram is shown

When a function key is pressed, the behavior of the `Control` output in the corresponding FKEY block can be changed according to the *Function Key Mode* parameter.

None	Button is disabled and the `Control` output is always "Low".
Toggle	`Control` output is set to "High" when the button is pressed and it is reset to "Low" in the second press.
Min pulse	The `Control` output is set to "High" for a number of ms equal to or greater than the "Pulse length" parameter value. If the button is released before the "Pulse Length" interval has elapsed, the pulse duration is equal to the "Pulse length" value in ms. If the button is pressed for a time longer than "Pulse length" interval, the `Control` output is reset to "Low" as soon as the button is released (Figure 13).
Fixed pulse	The `Control` output is set to "High" for a number of ms equal to "Pulse length" and reset to "Low" at the end of this period even if the button is still being pressed. To set again the `Control` output to "High", the button has to be released and pressed again (Figure 14).
Follow	The `Control` output is set to "High" when the button is pressed and the output is reset to "Low" when the button is released.

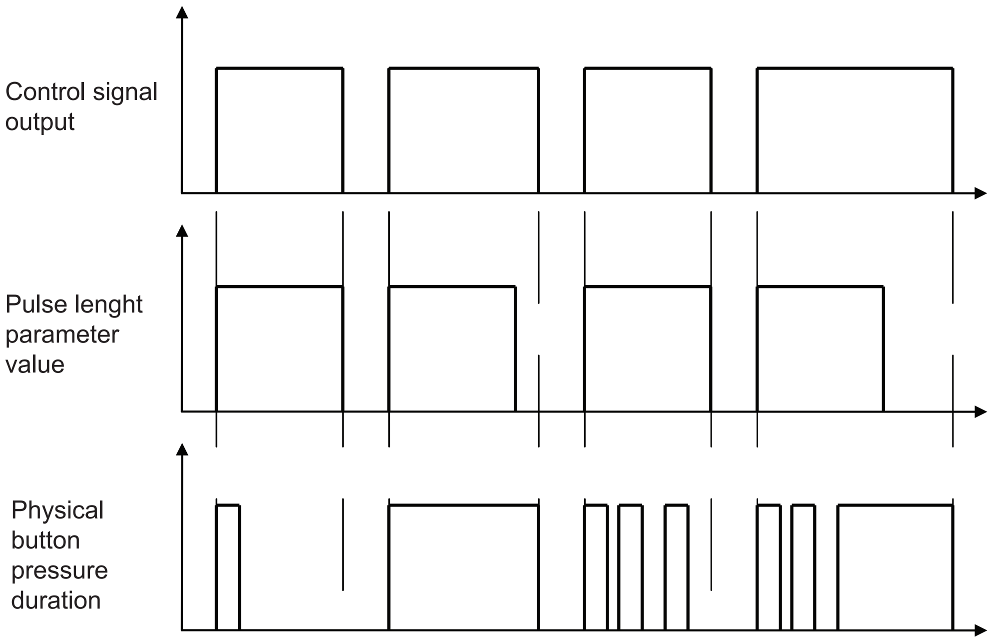


Figure 13: Control output behavior when Min pulse control mode is selected

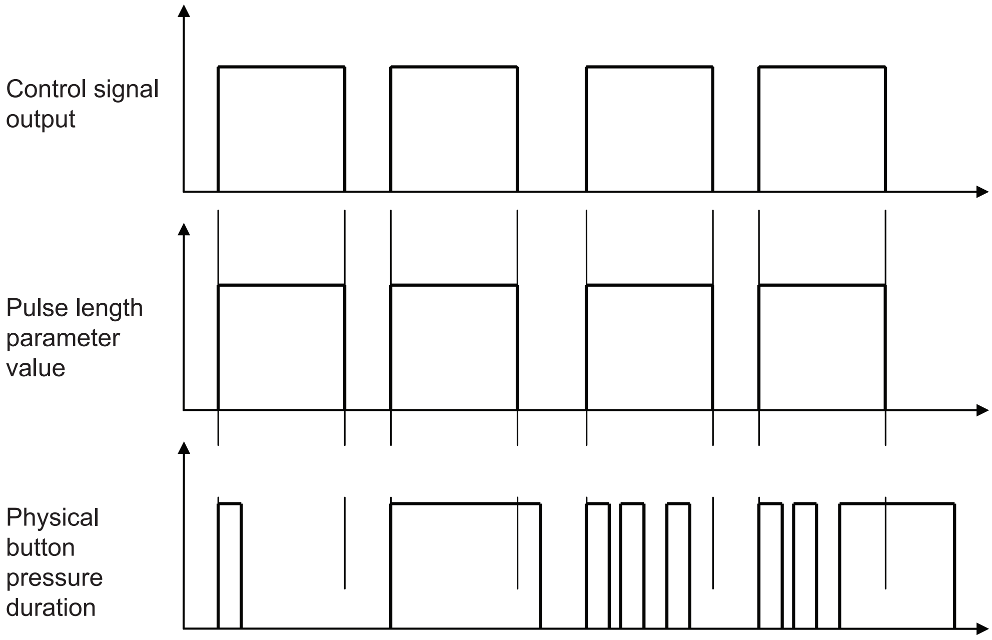


Figure 14: Control output behavior when Fixed pulse control mode is selected

3.5.5 Signals

Table 28: EFKEYGGIO Input signals

Name	Type	Default	Description
LED	BOOLEAN	0=False	Turn on/off LED in function key X[1)]

1) X - Led embedded in function key number

Table 29: EFKEYGGIO Output signals

Name	Type	Description
CONTROL	BOOLEAN	Control output of function key X[1)]

1) X - Function key number

3.5.6 Settings

Table 30: EFKEYGGIO Non group settings

Name	Values (Range)	Unit	Step	Default	Description
Pulse length	10…120000	ms	1	100	Set “Control” output duration
Control model	-1= None 1= Toggle 2= Min pulse 3= Fixed pulse 4= Follow			0= toggle	Set “Control” output behavior

3.6 IO function XBOGGIO

3.6.1 Function block

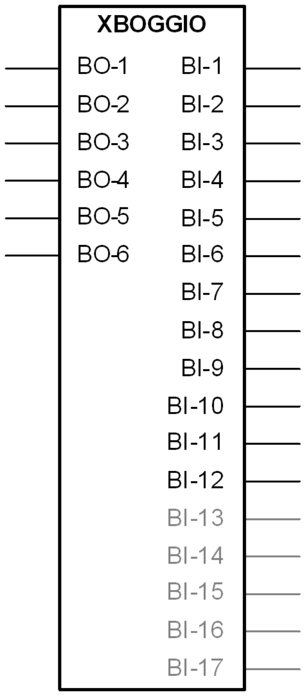


Figure 15: Function block

3.6.2 Functionality

The input-reading and output-controlling function XBOGGIO is assigned to read the inputs and control the outputs on the external terminal of the IED.

The function is designed according to the IEC 61850-7-4 standard with the GGIO logical node.

3.6.3 Operation principle

The external terminal of the IED is equipped with 12 binary inputs and 6 binary outputs.

The binary inputs from BI-13 to BI-17 are assigned to the connections that are internal to the breaker. Therefore, they are not visible in the Application Configuration tool.

Binary inputs

The binary input status from BI-1 to BI-12 is available as the output of the function block.

Binary outputs

The binary outputs can be controlled from the dedicated input on the function block. When the input is set to "TRUE", the corresponding output IED is closed.

3.7 Time synchronization

The IED has an internal real-time clock which can be either free-running or synchronized from an external source. The real-time clock is used for time stamping events, recorded data and disturbance recordings.

The IED is provided with a 48-hour capacitor back-up that enables the real-time clock to keep time in case of an auxiliary power failure.

Setting *Synch Source* determines the method how the real-time clock is synchronized. If set to “None”, the clock is free-running and the settings *Date* and *Time* can be used to set the time manually. Other setting values activate a communication protocol that provides the time synchronization. Only one synchronization method can be active at a time but SNTP provides time master redundancy.

The IED supports SNTP, DNP3, Modbus and IEC 60870-5-103 to update the real-time clock.

When Modbus TCP or DNP3 over TCP/IP is used, SNTP time synchronization should be used for better synchronization accuracy.

When the SNTP server IP setting is changed, the IED must be rebooted to activate the new IP address. The SNTP server IP settings are normally defined in the engineering phase via the SCL file.

The IED can use one of two SNTP servers, the primary or the secondary server. The primary server is mainly in use, whereas the secondary server is used if the primary server cannot be reached. While using the secondary SNTP server, the IED tries to switch back to the primary server on every third SNTP request attempt. If both the SNTP servers are offline, event time stamps have the time invalid status. The time is requested from the SNTP server every 60 seconds.

The time synchronization messages can be received from the other line end IED within the protection telegrams. The IED begins to synchronize its real-time clock with the remote end IEDs time if the Line differential time synchronization source is selected. This does not affect the protection synchronization used in the line differential protection or the selection of the remote end IEDs time synchronization method.

3.8 Parameter setting groups

There are four IED variant specific setting groups. For each setting group, the parameter setting can be made independently.

The active setting group can be changed by parameter (setting groups 1...4) or via binary input (setting groups 1...2), if a binary input is enabled for it.

To enable active setting group changing via binary input, connect any of the (free) binary inputs to SMT:Protection:0 ActSG and set the setting *SG follow input* to "TRUE" in the general system settings.

Table 31: Active setting group binary input state

BI state	Active setting group
OFF	1
ON	2

The setting group parameter is overridden when a binary input is used for changing the active setting group.

Table 32: Settings

Parameter	Setting	Value	Default	Description	Access rights
Setting group	Active group	1...4	1	Selected active group	RWRW

Not all parameters belong to a setting group. For example protection function enable/disable settings are not part of a setting group.

3.9 Recorded data

The IED has the capacity to store the records of four latest fault events. The records enable the user to analyze the four most recent power system events. Each fault record (FLTMSTA) is marked with an up-counting fault number. Slot fault record 1 always contains the newest record, and fault record 4 the oldest. The time stamp is taken from the beginning of the fault.

The fault recording period begins on the start event of any protection function and ends if any protection function operates or the start is restored without the operate event. The type of fault that triggers the fault recording is selected with the setting parameter *Trig mode*. When “From all faults” is selected, all types of detected faults trigger a new fault recording. When “From operate” is selected, only faults that cause an operate event trigger a new fault recording. Finally, when “From only start” is selected, only faults without an operate event are recorded.

The fault-related current, voltage and angle values are taken from the moment of the operate event, or from the beginning of the fault in case there is only a start event during the fault. The maximum current value collects maximum fault currents during the fault. Measuring mode for phase current and residual current values can be selected with the *A Measurement mode* setting parameter.

The data recorded depend on the product and the standard configuration.

Table 33: Fault recorder settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Trig mode	0=From all faults 1=From operate 2=From only start			0=From all faults	Triggering mode
A measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode phase currents and residual current

Table 34: Fault recorder data

Name	Type	Values (Range)	Unit	Description
Number	INT32	0...999999		Fault record number
Time	Timestamp			Time of recording
Max diff current IL1	FLOAT32	0.000...80.000		Maximum phase A differential current
Max diff current IL2	FLOAT32	0.000...80.000		Maximum phase B differential current
Max diff current IL3	FLOAT32	0.000...80.000		Maximum phase C differential current
Diff current IL1	FLOAT32	0.000...80.000		Differential current phase A
Diff current IL2	FLOAT32	0.000...80.000		Differential current phase B
Diff current IL3	FLOAT32	0.000...80.000		Differential current phase C
Max bias current IL1	FLOAT32	0.000...50.000		Maximum phase A bias current
Max bias current IL2	FLOAT32	0.000...50.000		Maximum phase B bias current
Max bias current IL3	FLOAT32	0.000...50.000		Maximum phase C bias current
Bias current IL1	FLOAT32	0.000...50.000		Bias current phase A
Bias current IL2	FLOAT32	0.000...50.000		Bias current phase B
Bias current IL3	FLOAT32	0.000...50.000		Bias current phase C

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Diff current I0	FLOAT32	0.000...80.000		Differential current residual
Bias current I0	FLOAT32	0.000...50.000		Bias current residual
Max current IL1	FLOAT32	0.000...50.000	xIn	Maximum phase A current
Max current IL2	FLOAT32	0.000...50.000	xIn	Maximum phase B current
Max current IL3	FLOAT32	0.000...50.000	xIn	Maximum phase C current
Current IL1	FLOAT32	0.000...50.000	xIn	Phase A current
Current IL2	FLOAT32	0.000...50.000	xIn	Phase B current
Current IL3	FLOAT32	0.000...50.000	xIn	Phase C current
Max current I0	FLOAT32	0.000...50.000	xIn	Maximum residual current
Current I0	FLOAT32	0.000...50.000	xIn	Residual current
Current Ng-Seq	FLOAT32	0.000...50.000	xIn	Negative sequence current
Current I0-Calc	FLOAT32	0.000...50.000	xIn	Calculated residual current
Voltage UL1	FLOAT32	0.000...4.000	xUn	Phase A voltage
Voltage UL2	FLOAT32	0.000...4.000	xUn	Phase B voltage
Voltage UL3	FLOAT32	0.000...4.000	xUn	Phase C voltage
Voltage U12	FLOAT32	0.000...4.000	xUn	Phase A to phase B voltage
Voltage U23	FLOAT32	0.000...4.000	xUn	Phase B to phase C voltage
Voltage U31	FLOAT32	0.000...4.000	xUn	Phase C to phase A voltage
Voltage U0	FLOAT32	0.000...4.000	xUn	Residual voltage
Voltage Ps-Seq	FLOAT32	0.000...4.000	xUn	Positive sequence voltage
Voltage Ng-Seq	FLOAT32	0.000...4.000	xUn	Negative sequence voltage
Angle U0 - I0	FLOAT32	-180.00...180.00	deg	Angle residual voltage - residual current
Angle U23 - IL1	FLOAT32	-180.00...180.00	deg	Angle phase B to phase C voltage - phase A current
Angle U31 - IL2	FLOAT32	-180.00...180.00	deg	Angle phase C to phase A voltage - phase B current
Angle U12 - IL3	FLOAT32	-180.00...180.00	deg	Angle phase A to phase B voltage - phase C current
PTTR thermal level	FLOAT32	0.00...99.99		PTTR calculated temperature of the protected object relative to the operate level
LNPLDF1 duration	FLOAT32	0.00...100.00	%	LNPLDF1 Start duration
PHLPTOC1 duration	FLOAT32	0.00...100.00	%	PHLPTOC1 Start duration
PHHPTOC1 duration	FLOAT32	0.00...100.00	%	PHHPTOC1 Start duration
PHHPTOC2 duration	FLOAT32	0.00...100.00	%	PHHPTOC2 Start duration
PHIPTOC1 duration	FLOAT32	0.00...100.00	%	PHIPTOC1 Start duration
DPHLPDOC1 duration	FLOAT32	0.00...100.00	%	DPHLPDOC1 Start duration
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
DPHLPDOC2 duration	FLOAT32	0.00...100.00	%	DPHLPDOC2 Start duration
DPHHPDOC1 duration	FLOAT32	0.00...100.00	%	DPHHPDOC1 Start duration
EFLPTOC1 duration	FLOAT32	0.00...100.00	%	EFLPTOC1 Start duration
EFLPTOC2 duration	FLOAT32	0.00...100.00	%	EFLPTOC2 Start duration
EFHPTOC1 duration	FLOAT32	0.00...100.00	%	EFHPTOC1 Start duration
EFIPTOC1 duration	FLOAT32	0.00...100.00	%	EFIPTOC1 Start duration
NSPTOC1 duration	FLOAT32	0.00...100.00	%	NSPTOC1 Start duration
NSPTOC2 duration	FLOAT32	0.00...100.00	%	NSPTOC2 Start duration
PDNSPTOC1 duration	FLOAT32	0.00...100.00	%	PDNSPTOC1 Start duration
PDNSPTOC1 rat. I2/I1	FLOAT32	0.00...999.99	%	PDNSPTOC1 ratio I2/I1
DEFLPDEF1 duration	FLOAT32	0.00...100.00	%	DEFLPDEF1 Start duration
DEFLPDEF2 duration	FLOAT32	0.00...100.00	%	DEFLPDEF2 Start duration
DEFHPDEF1 duration	FLOAT32	0.00...100.00	%	DEFHPDEF1 Start duration
ROVPTOV1 duration	FLOAT32	0.00...100.00	%	ROVPTOV1 Start duration
ROVPTOV2 duration	FLOAT32	0.00...100.00	%	ROVPTOV2 Start duration
ROVPTOV3 duration	FLOAT32	0.00...100.00	%	ROVPTOV3 Start duration
PHPTOV1 duration	FLOAT32	0.00...100.00	%	PHPTOV1 Start duration
PHPTOV2 duration	FLOAT32	0.00...100.00	%	PHPTOV2 Start duration
PHPTOV3 duration	FLOAT32	0.00...100.00	%	PHPTOV3 Start duration
PHPTUV1 duration	FLOAT32	0.00...100.00	%	PHPTUV1 Start duration
PHPTUV2 duration	FLOAT32	0.00...100.00	%	PHPTUV2 Start duration
PHPTUV3 duration	FLOAT32	0.00...100.00	%	PHPTUV3 Start duration
PSPTUV1 duration	FLOAT32	0.00...100.00	%	PSPTUV1 Start duration
NSPTOV1 duration	FLOAT32	0.00...100.00	%	NSPTOV1 Start duration

3.10 Non-volatile memory

In addition to the setting values, the IED can store some data in the non-volatile memory.

- Up to 50 events are stored. The stored events are visible in LHMI and WHMI only.
- Recorded data
    - Fault records
    - Maximum demands
- Circuit breaker condition monitoring
- Latched alarm and trip LEDs' status
- Trip circuit lockout
- Counter values

3.11 Binary input

3.11.1 Binary input filter time

The filter time eliminates debounces and short disturbances on a binary input. The filter time is set for each binary input of the IED.

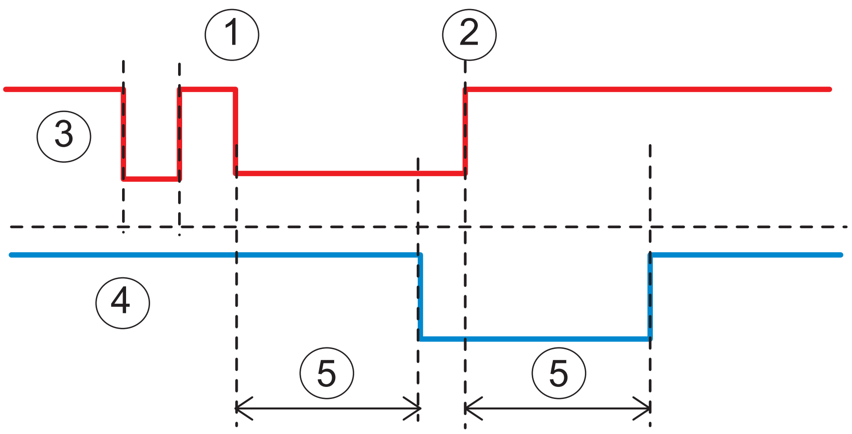


Figure 16: Binary input filtering

1 t_0

2 t_1

3 Input signal

4 Filtered input signal

5 Filter time

At the beginning, the input signal is at the high state, the short low state is filtered and no input state change is detected. The low state starting from the time t_0 exceeds the filter time, which means that the change in the input state is detected and the time tag attached to the input change is t_0. The high state starting from t_1 is detected and the time tag t_1 is attached.

Each binary input has a filter time parameter *Input # filter*, where # is the number of the binary input of the module in question (for example *Input 1 filter*).

Table 35: Input filter parameter values

Parameter	Values	Default
Input # filter	1...15000 ms	5 ms

3.11.2 Binary input inversion

The parameter *Input # invert* is used to invert a binary input.

Table 36: Binary input states

Control voltage	Input # invert	State of binary input
No	0	False (0)
Yes	0	True (1)
No	1	True (0)
Yes	1	False (0)

When a binary input is inverted, the state of the input is TRUE (1) when no control voltage is applied to its terminals. Accordingly, the input state is FALSE (0) when a control voltage is applied to the terminals of the binary input.

3.11.3 Oscillation suppression

Oscillation suppression is used to reduce the load from the system when a binary input starts oscillating. A binary input is regarded as oscillating if the number of valid state changes (= number of events after filtering) during one second is equal to or greater than the set oscillation level value. During oscillation, the binary input is blocked (the status is invalid) and an event is generated. The state of the input will not change when it is blocked, that is, its state depends on the condition before blocking.

The binary input is regarded as non-oscillating if the number of valid state changes during one second is less than the set oscillation level value minus the set oscillation hysteresis value. Note that the oscillation hysteresis must be set lower than the oscillation level to enable the input to be restored from oscillation. When the input returns to a non-oscillating state, the binary input is deblocked (the status is valid) and an event is generated.

Table 37: Oscillation parameter values

Parameter	Values	Default
Input osc. level	2...50 events/s	50 events/s
Input osc. hyst.	2...50 events/s	10 events/s

3.12 GOOSE functions

3.12.1 GOOSERCV_BIN

3.12.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
GOOSE receiving block for single-binary inputs	GOOSERCV_BIN	-	-

3.12.1.2 Function block

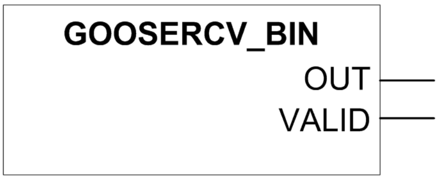


Figure 17: Function block

3.12.1.3 Functionality

GOOSE function blocks are used for connecting incoming GOOSE data to application. They support BOOLEAN and Dbpos data types.

GOOSERCV_BIN is used to connect the GOOSE binary inputs to the application.

Common signals

The `VALID` output indicates the validity of the received GOOSE data, which means in case of valid that the GOOSE communication is working and the received data quality bits (if configured) indicate good process data. Invalid status is caused either by bad data quality bits or a GOOSE communication failure.

See IEC 61850 engineering guide for details.

The `OUT` output sends the received GOOSE value for the application. Default value (0) is used if the `VALID` output indicates an invalid status. The `IN` input is defined in the GOOSE configuration and can be seen always in the SMT sheet.

Settings

The GOOSE function blocks do not have any parameters available in LHMI or PCM600.

3.12.1.4 Operation principle

GOOSERCV_BIN is used to connect the GOOSE binary inputs to the application.

GOOSERCV_BIN can be instantiated multiple times inside the designed application (a maximum of 100 times).

3.12.1.5 Signals

Table 38: GOOSERCV_BIN Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.12.2 GOOSERCV_DP

3.12.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
GOOSE receiving block for double-binary inputs	GOOSERCV_DP	-	-

3.12.2.2 Function block

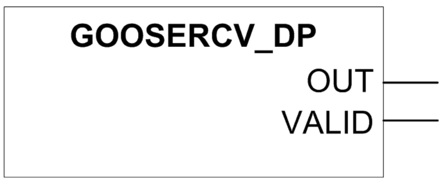


Figure 18: Function block

3.12.2.3 Functionality

GOOSE function blocks are used for connecting incoming GOOSE data to application. They support BOOLEAN and Dbpos data types.

GOOSERCV_DP is used to connect the GOOSE double-binary inputs to the application.

Common signals

The VALID output indicates the validity of the received GOOSE data, which means in case of valid that the GOOSE communication is working and the received data quality bits (if configured) indicate good process data. Invalid status is caused either by bad data quality bits or a GOOSE communication failure.

See IEC 61850 engineering guide for details.

The OUT output sends the received GOOSE value for the application. Default value (0) is used if the VALID output indicates an invalid status. The IN input is defined in the GOOSE configuration and can be seen always in the SMT sheet.

Settings

The GOOSE function blocks do not have any parameters available in LHMI or PCM600.

3.12.2.4 Operation principle

GOOSERCV_DP is used to connect the GOOSE double-binary inputs to the application.

GOOSERCV_DP can be instantiated multiple times inside the designed application (a maximum of 20 times).

3.12.2.5 Signals

Table 39: GOOSERCV_DP Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.12.3 DBTOBOOL

3.12.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Double-point type variable converter	DBTOBOOL	-	-

3.12.3.2 Function block

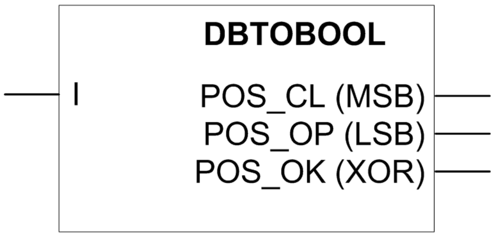


Figure 19: Function block

3.12.3.3 Operation principle

The DBTOBOOL function is used to convert a double-point type variable into the two corresponding binary statuses. It is customized for the position indication of the switching devices.

Table 40: Status indication

I	POS_OP	POS_CL	POS_OK
1 (01) - Open position	1=True	0=False	1=True
2 (10) - Closed position	0=False	1=True	1=True
3 (11) - Faulty or Bad position	1=True	1=True	0=False
0 (00) - Intermediate position	0=False	0=False	0=False

DBTOBOOL can be instantiated multiple times inside the designed application (a maximum of 20 times).

3.12.3.4 Signals

Table 41: GOOSERCV_DP Input signals

Name	Type	Default	Description
I	Dbpos	0	Input signal

Table 42: DBTOBOOL Output signals

Name	Type	Description
POS_CL (MSB)	BOOLEAN	Most Significant Bit (MSB)
POS_OP (LSB)	BOOLEAN	Least Significant Bit (LSB)
POS_OK (XOR)	BOOLEAN	OK position signal

3.13 Logic functions

3.13.1 Functionality

The logic functions can be instantiated multiple times inside the designed application. The parameter and the communication profile are not available for these functions.

3.13.2 Constant 0 and constant 1

3.13.2.1 Function block

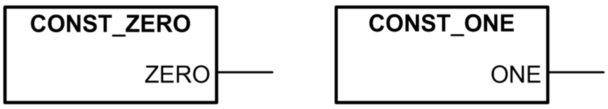


Figure 20: Function blocks

3.13.2.2 Operation principle

The CONST_ZERO and CONST_ONE function blocks continuously send a logical 0 and a logical 1 respectively to their outputs.

3.13.3 Inverter logic gate

3.13.3.1 Function block

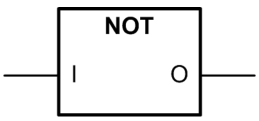


Figure 21: Function block

3.13.3.2 Operation principle

The inverter (NOT gate) inverts the boolean input signal and sends it to its output.

3.13.4 AND logic gate

3.13.4.1 Function block

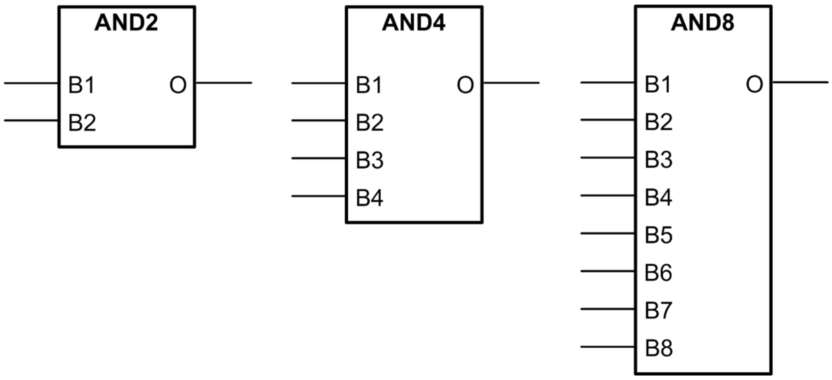


Figure 22: Function blocks

3.13.4.2 Operation principle

The AND logic gates execute a logical AND interconnection on their inputs. The result of this logical operation is available on the output. Therefore a logical 1 appears on the output when all inputs are set to logical 1.

The AND logic gates shown in the function block symbol differ only in the number of inputs.

3.13.5 OR logic gate

3.13.5.1 Function block

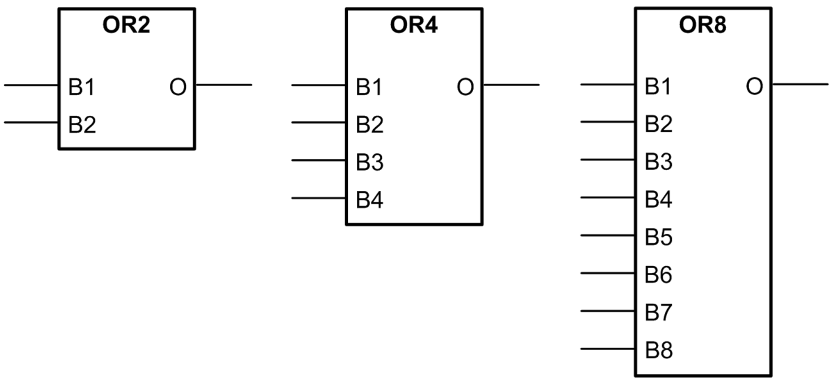


Figure 23: Function blocks

3.13.5.2 Operation principle

The OR logic gates execute a logical OR interconnection of their inputs. The result of this logical operation is available on the output. Therefore a logical 1 appears on the output when one of the inputs is set to logical 1.

The OR logic gates shown in the function block symbol differ only in the number of inputs.

3.13.6 Exclusive OR logic gate

3.13.6.1 Function block

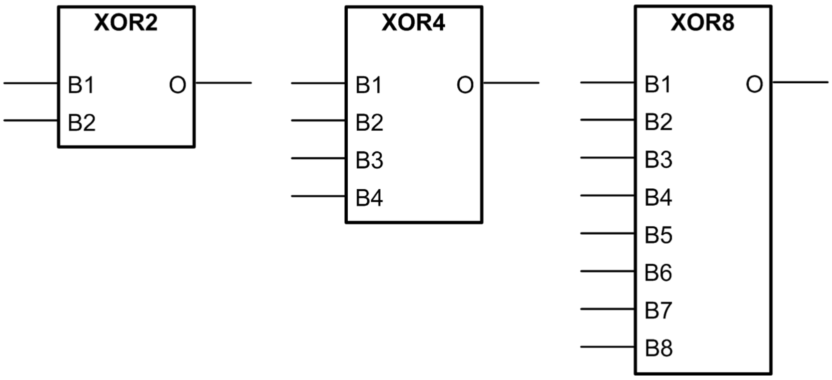


Figure 24: Function blocks

3.13.6.2 Operation principle

The exclusive OR logic gates execute a logical exclusive OR interconnection of their inputs (left side of the function block). The result of this logical operation is available at the output (right side of the function block). Therefore a logical 1 appears at the output when at least one of the inputs is set to logical 1.

In contrast to the OR logic gate, a logical 0 appears on the output if all inputs are set to logical 1. The exclusive OR logic gates shown in the function block symbols differ only in the number of inputs.

3.13.7 JK flip-flop

3.13.7.1 Function block

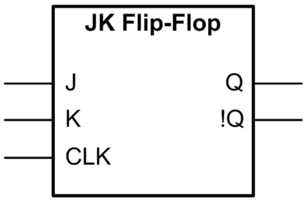


Figure 25: Function block

3.13.7.2 Operation principle

A logical 1 at the `J` input (logical 0 at the `K` input) combined with a falling slope at the `CLK` timing input results in a logical 1 at the `Q` output. A logical 1 at the `K` input (logical 0 at the `J` input) combined with a falling slope at the `CLK` timing input results in a logical 0 at the `Q` output.

If the input signals are reset to logical 0, the signals remain active at the outputs regardless of the timing input.

If both inputs are at logical 1, the signals at the two outputs with the falling slope are inverted at the timing input.

Table 43: JK Flip-Flop logic table

tn		tn+1		
J	K	Q	!Q	Note
0	0	Qn	!Qn	The prior state remains.
0	1	0	1	
1	0	1	0	
1	1	!Qn	Qn	The prior state is inverted.

tn The time before the falling slope at the timing input.

tn+1 The time after the falling slope at the timing input.

3.13.8 SR flip-flop

3.13.8.1 Function block

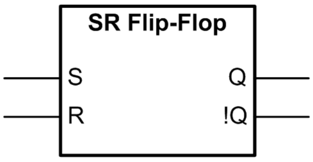


Figure 26: Function block

3.13.8.2 Operation principle

A logical 1 at the S input results in a logical 1 at the Q output. A logical 1 at the R input results in a logical 0 at the Q output.

If the input signals are reset to logical 0, the signals remain active at the outputs. If both inputs are at logical 1, the R input is dominant. However, this state contradicts the basic flip-flop principle of two stable states and must therefore be avoided.

Table 44: JK Flip-Flop logic table

R	S	Q	!Q
0	0	Qn	!Qn
0	1	1	0
1	0	0	1
1	1	0	1

3.13.9 D flip-flop

3.13.9.1 Function block

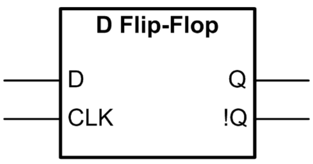


Figure 27: Function block

3.13.9.2 Operation principle

The signal at the D input of the flip flop is transferred with the next positive slope of the Q output. The CLK timing pulses produce a delayed output of the input signal on the output.

Table 45: D Flip-Flop logic table

tn	tn+1	
D	Q	!Q
0	0	1
1	1	0

t_n The time before the rising slope at the timing input.

t_{n+1} The time after the rising slope at the timing input.

3.13.10 T flip-flop

3.13.10.1 Function block

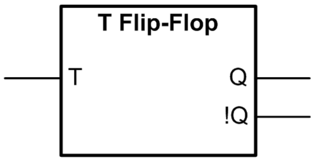


Figure 28: Function block

3.13.10.2 Operation principle

The signals at the outputs are inverted with the positive slope at the timing `T` input. `Q` is logical 0 as the output state to ensure that there is a defined state during the IED starting procedure. The signal at the output is always opposite to the signal at the `Q` output.

This enables the T flip-flop to operate as a binary divider. The period duration of the signals at the outputs is double the length of the clock at the `T` input. A constant frequency clock signal is required.

3.14 Logic functions with parameters

3.14.1 Functionality

The logic functions with parameters can be instantiated multiple times (a maximum of 20 times) inside the designed application. The operation of these functionalities is configured with a number of parameters. The parameters are compatible with the IEC61850 standard.

3.14.2 Counter

3.14.2.1 Function block

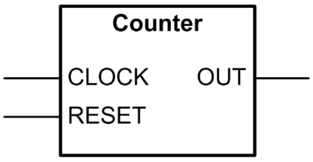


Figure 29: Function block

3.14.2.2 Operation principle

The counter function puts a logical 1 on its output after a preset number of cycles are sent to the timing input `CLOCK`. The output is set with the rising slope of the last required input impulse.

If a logical 1 is set to the `RESET` input, the output is reset to logical 0, the counting process is stopped and the internal counter is set to 0.

3.14.2.3 Signals

Table 46: Counter outputs

Name	Type	Description
OUT	BOOLEAN	Output signal

3.14.2.4 Settings

Table 47: Counter Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Counter	15…65 000	ms	1	0	Time

3.14.3 Pulse generator

3.14.3.1 Function block

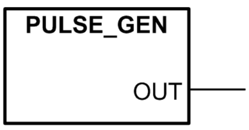


Figure 30: Function block

3.14.3.2 Operation principle

The pulse generator function sends a pulse sequence at its output. The logical 1 and logical 0 values alternate in this process. Their duration can be set in the configuration dialog.

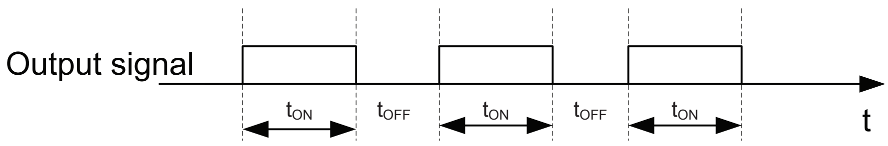


Figure 31: Setting options for the pulse generator

3.14.3.3 Signals

Table 48: PULSE_GEN outputs

Name	Type	Description
OUT	BOOLEAN	Output signal

3.14.3.4 Settings

Table 49: PULSE_GEN Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
On duration	15…65 000	ms	1	15	Pulse high width
Off duration	15…65 000	ms	1	15	Pulse low width

3.14.4 Drop delay and rise delay

3.14.4.1 Function block

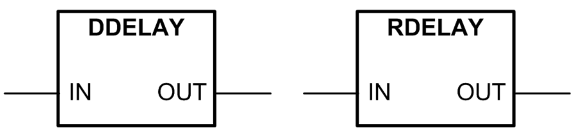


Figure 32: Function blocks

3.14.4.2 Operation principle

The drop delay and rise delay functions delay the falling and rising slope of a logical signal at the input.

The delayed logical signal is available at the output. The delay period is configured from the parameter.

3.14.4.3 Signals

Table 50: DDELAY and RDELAY inputs

Name	Type	Default	Description
IN	BOOLEAN	0= False	Input signal

Table 51: DDELAY and RDELAY outputs

Name	Type	Description
OUT	BOOLEAN	Output signal

3.14.4.4 Settings

Table 52: DDELAY non group settings

Parameter	IEC61850	Values (Range)	Unit	Step	Default	Description
Delay time	LD0.DDLGGIO1.DropDlyX.setVal	15…65 000	ms	1	15	Delay time

X= Drop delay instance number

Table 53: RDELAY non group settings

Parameter	IEC61850	Values (Range)	Unit	Step	Default	Description
Delay time	LD0.RDLGGIO1.RiseDlyX.setVal	15…65 000	ms	1	15	Delay time

3.14.5 Retriggerable monoflop

3.14.5.1 Function block

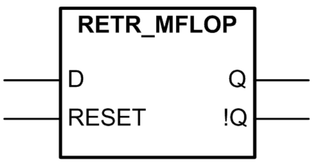


Figure 33: Function block

3.14.5.2 Operation principle

The logical value at the D input is directly incorporated (with its own rising slope) into the Q output. It remains there for a configurable time. Finally, the output falls back to the stable state of logical 0. The Q output is set immediately to logical 0 by a logical 1 on the reset input (RESET). If a rising slope occurs at the D input again when the output is still at logical 1, the timing circuit is restarted.

The signal at the !Q output is always opposite to the signal at the Q output.

3.14.5.3 Signals

Table 54: RETR_MFLOP inputs

Name	Type	Default	Description
D	BOOLEAN	0=False	D input
RESET	BOOLEAN	0=False	Reset signal

Table 55: RETR_MFLOP outputs

Name	Type	Description
Q	BOOLEAN	Output signal
!Q	BOOLEAN	Inverted output signal

3.14.5.4 Settings

Table 56: RETR_MFLOP Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Retain time	15…65 000	ms	1	15	Output retain time

3.14.6 Nonretriggerable monoflop

3.14.6.1 Function block

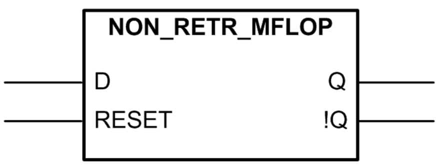


Figure 34: Function block

3.14.6.2 Operation principle

The logical value at the D input is directly incorporated (with its own rising slope) into the Q output. It remains there for the configured time. Finally, the output falls back to the only stable state of logical 0. The Q output is set immediately to logical 0 by a logical 1 on the reset input (RESET). If a rising slope occurs at the D input again when the output is still at logical 1, this signal is ignored.

The signal at the !Q output is always opposite to the signal at the Q output.

3.14.6.3 Signals

Table 57: NON_RETR_MFLOP inputs

Name	Type	Default	Description
D	BOOLEAN	0=False	D input
RESET	BOOLEAN	0=False	Reset signal

Table 58: NON_RETR_MFLOP outputs

Name	Type	Description
Q	BOOLEAN	Output signal
!Q	BOOLEAN	Inverted output signal

3.14.6.4 Settings

Table 59: NON_RETR_MFLOP Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Retain time	15…65 000	ms	1	15	Output retain time

3.15 Configuration and calibration data restore

The IED has the capacity to store the running configuration and circuit breaker calibration data as an archive file in the LHMI flash memory.

The user can retrieve the archived data upon command. Configuring a new IED when a broken IED is replaced or configuring a number of IEDs which use the same configuration is easier.

Section 4 Protection functions

4.1 Three-phase current protection

4.1.1 Three-phase non-directional overcurrent protection PHxPTOC

4.1.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase non-directional overcurrent protection - Low stage	PHLPTOC	3I>	51P-1
Three-phase non-directional overcurrent protection - High stage	PHHPTOC	3I>>	51P-2
Three-phase non-directional overcurrent protection - Instantaneous stage	PHIPTOC	3I>>>	50P/51P

4.1.1.2 Function block

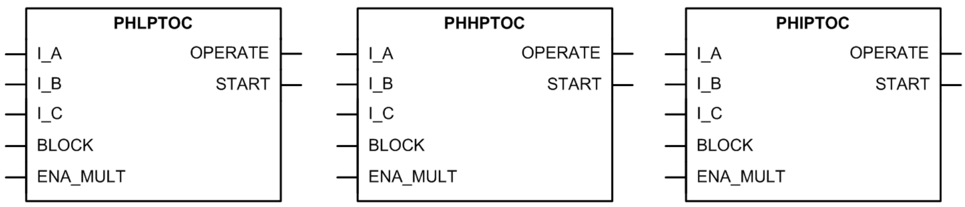


Figure 35: Function block

4.1.1.3 Functionality

The three-phase overcurrent protection PHxPTOC is used as one-phase, two-phase or three-phase non-directional overcurrent and short-circuit protection for feeders.

The function starts when the current exceeds the set limit. The operate time characteristics for low stage PHLPTOC and high stage PHHPTOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).The instantaneous stage PHIPTOC always operates with the DT characteristic.

In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

The function contains a blocking functionality. It is possible to block function outputs, timers or the function itself, if desired.

4.1.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the three-phase non-directional overcurrent protection can be described using a module diagram. All the modules in the diagram are explained in the next sections.

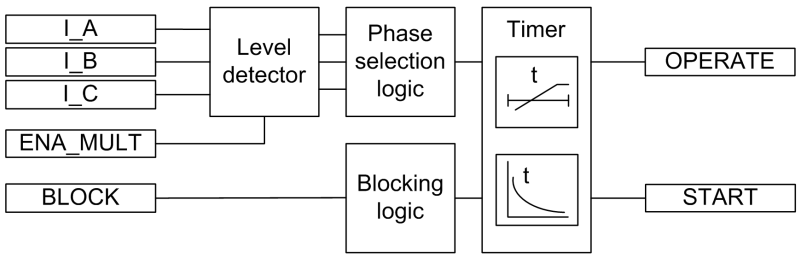


Figure 36: Functional module diagram. I_A, I_B and I_C represent phase currents.

Level detector

The measured phase currents are compared phasewise to the set *Start value*. If the measured value exceeds the set *Start value*, the level detector reports the exceeding of the value to the phase selection logic. If the `ENA_MULT` input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The IED does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

The start value multiplication is normally done when the inrush detection function (INRPHAR) is connected to the `ENA_MULT` input.

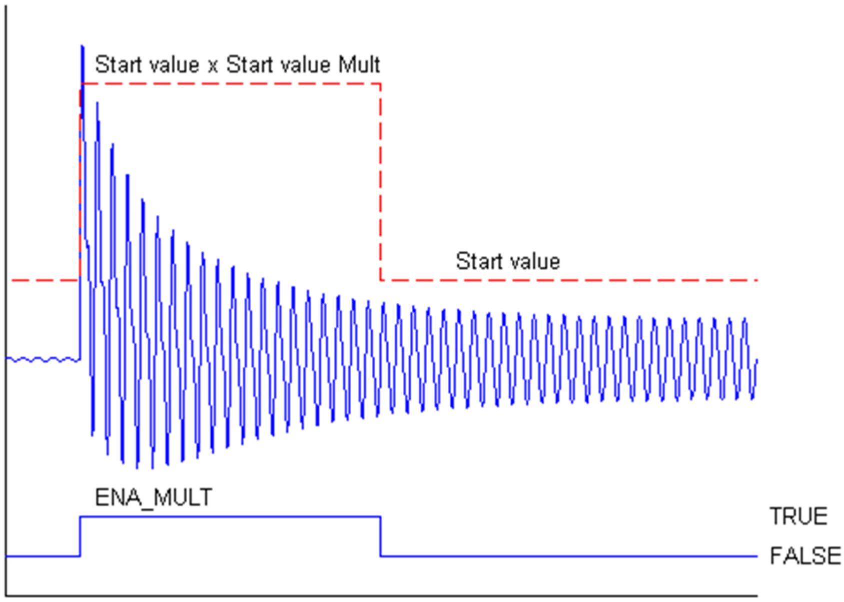


Figure 37: Start value behavior with `ENA_MULT` *input activated*

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of start phases* setting, the phase selection logic activates the timer module.

Timers

Once activated, the timer activates the `START` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate"

causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the START output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT operate and reset times.

The setting parameter *Minimum operate time* defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentual ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/*Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.1.1.5 Measurement modes

The function operates on four alternative measurement modes: "RMS", "DFT", "Peak-to-Peak" and "P-to-P + backup". The measurement mode is selected with the setting *Measurement mode*.

Table 60: Measurement modes supported by PHxPTOC stages

Measurement mode	Supported measurement modes		
	PHLPTOC	PHHPTOC	PHIPTOC
RMS	x	x	
DFT	x	x	
Peak-to-Peak	x	x	
P-to-P + backup			x

For a detailed description of the measurement modes, see the General function block features section in this manual.

4.1.1.6 Timer characteristics

PHxPTOC supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* and *Type of reset curve* settings. When the DT characteristic is selected, it is only affected by the *Operate delay time* and *Reset delay time* settings.

The relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The following characteristics, which comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages:

Table 61: Timer characteristics supported by different stages

Operating curve type	Supported by	
	PHLPTOC	PHHPTOC
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	x
(10) IEC Very Inverse	x	x

Table continues on next page

Operating curve type	Supported by	
	PHLPTOC	PHHPTOC
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	x
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable	x	x
(18) RI type	x	
(19) RD type	x	

PHIPTOC supports only definite time characteristic.

For a detailed description of timers, see the General function block features section in this manual.

Table 62: Reset time characteristics supported by different stages

Reset curve type	Supported by		
	PHLPTOC	PHHPTOC	Note
(1) Immediate	x	x	Available for all operate time curves
(2) Def time reset	x	x	Available for all operate time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

The *Type of reset curve* setting does not apply to PHIPTOC or when the DT operation is selected. The reset is purely defined by the *Reset delay time* setting.

4.1.1.7 Application

PHxPTOC is used in several applications in the power system. The applications include but are not limited to:

- Selective overcurrent and short-circuit protection of feeders in distribution and subtransmission systems
- Back-up overcurrent and short-circuit protection of power transformers and generators
- Overcurrent and short-circuit protection of various devices connected to the power system, for example, shunt capacitor banks, shunt reactors and motors
- General back-up protection

PHxPTOC is used for single-phase, two-phase and three-phase non-directional overcurrent and short-circuit protection. Typically, overcurrent protection is used for clearing two and three-phase short circuits. Therefore, the user can choose how many phases, at minimum, must have currents above the start level for the function to operate. When the number of start-phase settings is set to "1 out of 3", the operation of PHxPTOC is enabled with the presence of high current in one-phase.

When the setting is "2 out of 3" or "3 out of 3", single-phase faults are not detected. The setting "3 out of 3" requires the fault to be present in all three phases.

Many applications require several steps using different current start levels and time delays. PHxPTOC consists of three protection stages:

- Low PHLPTOC
- High PHHPTOC
- Instantaneous PHIPTOC.

PHLPTOC is used for overcurrent protection. The function contains several types of time-delay characteristics. PHHPTOC and PHIPTOC are used for fast clearance of very high overcurrent situations.

Transformer and busbar overcurrent protection with reverse blocking principle

By implementing a full set of overcurrent protection stages and blocking channels between the protection stages of the incoming feeders, bus-tie and outgoing feeders, it is possible to speed up the operation of overcurrent protection in the busbar and transformer LV-side faults without impairing the selectivity. Also, the security degree of busbar protection is increased, because there is now a dedicated, selective and fast busbar protection functionality, which is based on the blockable overcurrent protection principle. The additional time selective stages on the transformer HV- and LV-sides provide increased security degree of back-up protection for the transformer, busbar and also for the outgoing feeders.

Depending on the overcurrent stage in question, the selectivity of the scheme in Figure 38 is based on the operating current, operating time or blockings between successive overcurrent stages. With blocking channels the operating time of the protection can be drastically shortened, if compared to the simple time selective protection. In addition to the busbar protection, this blocking principle is applicable for the protection of transformer LV terminals and short lines. The functionality and performance of the proposed overcurrent protections can be summarized as seen in the table.

Table 63: Proposed functionality of numerical transformer and busbar over current protection. DT = definite time, IDMT = inverse definite minimum time

O/C-stage	Operating char.	Selectivity mode	Operation speed	Sensitivity
HV/3I>	DT/IDMT	time selective	low	very high
HV/3I>>	DT	blockable/time selective	high/low	high
HV/3I>>>	DT	current selective	very high	low
LV/3I>	DT/IDMT	time selective	low	very high
LV/3I>>	DT	time selective	low	high
LV/3I>>>	DT	blockable	high	high

In case the bus-tie breaker is open, the operating time of the blockable overcurrent protection is approximately 100 ms (relaying time). When the bus-tie breaker is closed, that is, the fault current flows to the faulted section of the busbar from two directions, the operation time becomes as follows: first the bus-tie relay unit trips the tie breaker in the above 100 ms, which reduces the fault current in to a half. After this the incoming feeder relay unit of the faulted bus section trips the breaker in approximately 250 ms (relaying time), which becomes the total fault clearing time in this case.

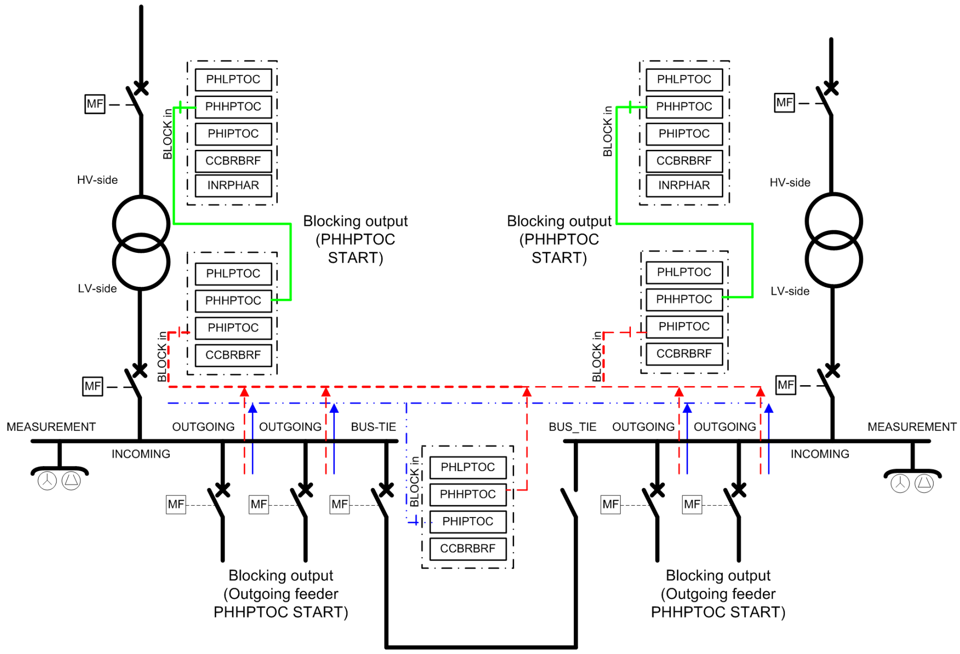


Figure 38: Numerical overcurrent protection functionality for a typical sub-transmission/distribution substation (feeder protection not shown). Blocking output = digital output signal from the start of a protection stage, Blocking in = digital input signal to block the operation of a protection stage

The operating times of the time selective stages are very short, because the grading margins between successive protection stages can be kept short. This is mainly due to the advanced measuring principle allowing a certain degree of CT saturation, good operating accuracy and short retardation times of the numerical units. So, for example, a grading margin of 150 ms in the DT mode of operation can be used, provided that the circuit breaker interrupting time is shorter than 60 ms.

The sensitivity and speed of the current-selective stages become as good as possible due to the fact that the transient overreach is practically zero. Also, the effects of switching inrush currents on the setting values can be reduced by using the IED logic, which recognizes the transformer energizing inrush current and blocks the operation or multiplies the current start value setting of the selected overcurrent stage with a predefined multiplier setting.

Finally, a dependable trip of the overcurrent protection is secured by both a proper selection of the settings and an adequate ability of the measuring transformers to reproduce the fault current. This is important in order to maintain selectivity and also for the protection to operate without additional time delays. For additional information about available measuring modes and current transformer requirements, refer to section where general function block features are described in the IED technical manual.

Radial outgoing feeder overcurrent protection

The basic requirements for feeder overcurrent protection are adequate sensitivity and operation speed taking into account the minimum and maximum fault current levels along the protected line, selectivity requirements, inrush currents and the thermal and mechanical withstand of the lines to be protected.

In many cases the above requirements can be best fulfilled by using a multiple-stage over current units. Figure 39 shows an example of this. A brief coordination study has been carried out between the incoming and outgoing feeders.

The protection scheme is implemented with three-stage numerical over current protection, where the low-set stage PHLPTOC operates in IDMT-mode and the two higher stages PHHPTOC and PHIPTOC in DT-mode. Also the thermal withstand of the line types along the feeder and maximum expected inrush currents of the feeders are shown. Faults occurring near the station, where the fault current levels are the highest, are cleared rapidly by the instantaneous stage in order to minimize the effects of severe short circuit faults. The influence of the inrush current is taken into consideration by connecting the inrush current detector to the start value multiplying input of the instantaneous stage. By this way the start value is multiplied with a predefined setting during the inrush situation and nuisance tripping can be avoided.

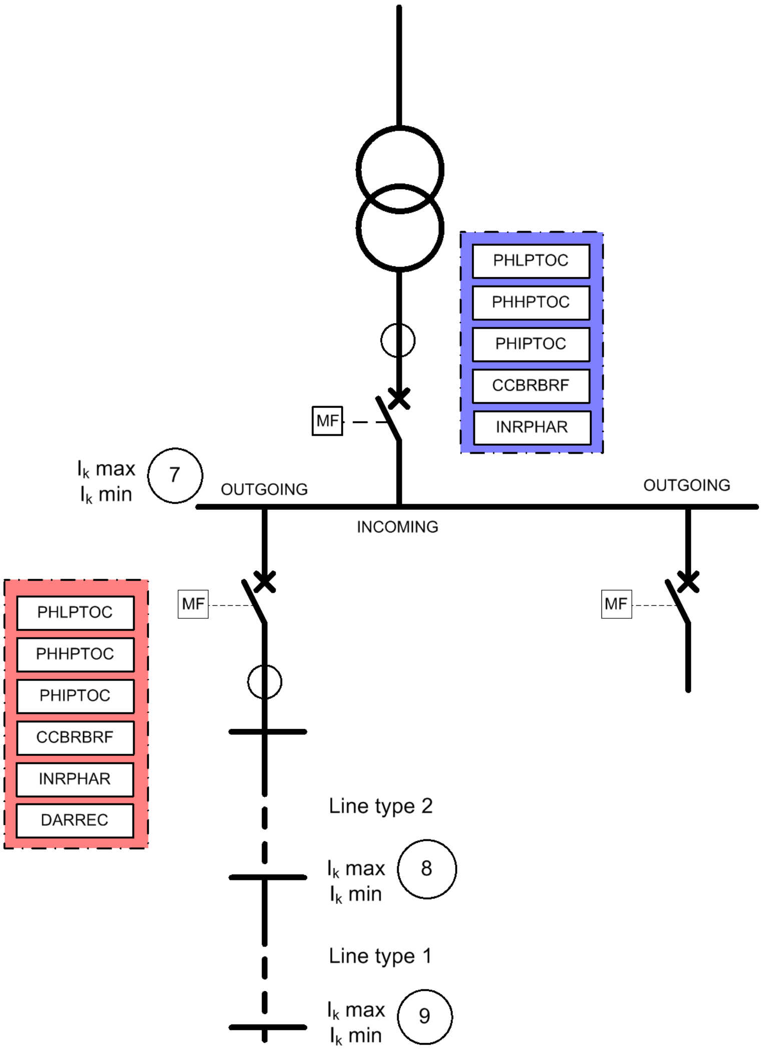


Figure 39: Functionality of numerical multiple-stage overcurrent protection

The coordination plan is an effective tool to study the operation of time selective operation characteristics. All the points mentioned earlier, required to define the overcurrent protection parameters, can be expressed simultaneusly in a coordination plan. In Figure 40 the coordination plan shows an example of operation characteristics in the LV-side incoming feeder and radial outgoing feeder.

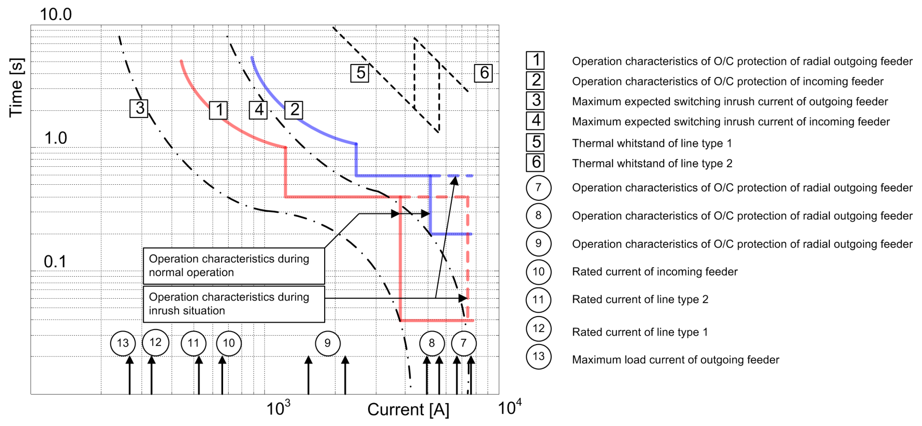


Figure 40: Example coordination of numerical multiple-stage overcurrent protection

4.1.1.8 Signals

Table 64: PHLPTOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 65: PHHPTOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 66: PHIPTOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 67: PHLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 68: PHHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 69: PHIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.1.9 Settings

Table 70: PHLPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...5.00	xIn	0.01	0.05	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 71: PHLPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

Table 72: PHHPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 73: PHHPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

Table 74: PHIPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	1.00...40.00	xIn	0.01	1.00	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Operate delay time	20...200000	ms	10	20	Operate delay time

Table 75: PHIPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.1.10 Monitored data

Table 76: PHLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHLPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 77: PHHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHHPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 78: PHIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHIPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.1.11 Technical data

Table 79: PHxPTOC Technical data

Characteristic		Value
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz
	PHLPTOC	±1.5% of the set value or ±0.002 x I_n
	PHHPTOC and PHIPTOC	±1.5% of set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n)

Table continues on next page

Characteristic		Value		
Start time 1)2)		Minimum	Typical	Maximum
	PHIPTOC: I_{Fault} = 2 x set *Start value* I_{Fault} = 10 x set *Start value*	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	PHHPTOC and PHLPTOC: I_{Fault} = 2 x set *Start value*	22 ms	24 ms	25 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 30 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms 3)		
Suppression of harmonics		RMS: No suppression DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression P-to-P+backup: No suppression		

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 x I_n, f_n = 50 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 x I_n, *Start value* multiples in range of 1.5 to 20

4.1.1.12 Technical revision history

Table 80: PHIPTOC Technical revision history

Technical revision	Change
C	Minimum and default values changed to 20 ms for the *Operate delay time* setting. Minimum value changed to 1.00 x I_n for the *Start value* setting.

Table 81: PHHPTOC Technical revision history

Technical revision	Change
C	*Measurement mode* "P-to-P + backup" replaced with "Peak-to-Peak"

Table 82: PHLPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting

4.1.2 Three-phase directional overcurrent protection DPHxPDOC

4.1.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase directional overcurrent protection - Low stage	DPHLPDOC	3I> ->	67-1
Three-phase directional overcurrent protection - High stage	DPHHPDOC	3I>> ->	67-2

4.1.2.2 Function block

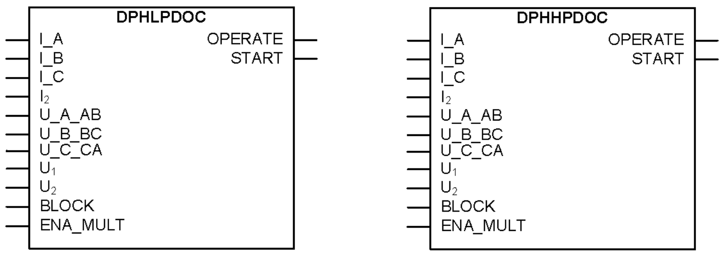


Figure 41: Function block

4.1.2.3 Functionality

The three-phase overcurrent protection DPHxPDOC is used as one-phase, two-phase or three-phase directional overcurrent and short-circuit protection for feeders.

DPHxPDOC starts when the value of the current exceeds the set limit and directional criterion is fulfilled. The operate time characteristics for low stage DPHLPDOC and high stage DPHHPDOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

The function contains a blocking functionality. It is possible to block function outputs, timers or the function itself, if desired.

4.1.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the directional overcurrent protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

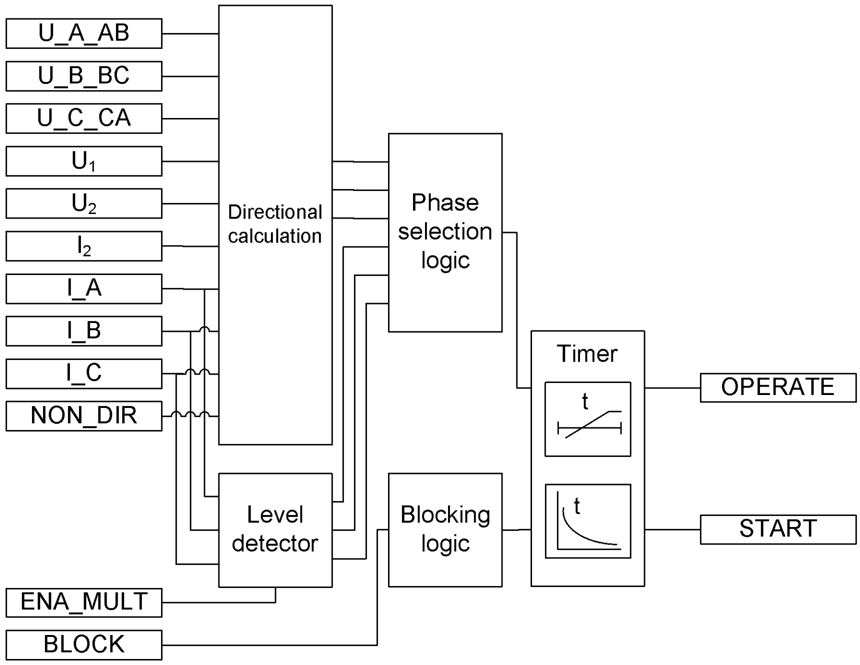


Figure 42: Functional module diagram

Directional calculation

The directional calculation compares the current phasors to the polarizing phasor. The suitable polarization quantities can be selected out of the positive-sequence voltage, negative-sequence voltage, self-polarizing (faulted) voltage or cross-polarizing voltages (healthy voltages). The polarizing method is defined with the *Pol quantity* setting.

Table 83: Polarizing quantities

Polarizing quantity	Description
Pos. seq. volt	Positive-sequence voltage
Neg. seq. volt	Negative-sequence voltage
Self pol	Self-polarization
Cross pol	Cross-polarization

The directional operation can be selected with the *Directional mode* setting. "Non-directional", "Forward" or "Reverse" operation can be selected. By setting the value of *Allow Non Dir* to "True", the non-directional operation is allowed when the directional information is invalid.

The *Characteristic angle* setting is used to turn the directional characteristic. The value of *Characteristic angle* should be chosen in such a way that all the faults in the operating direction are seen in the operating zone and all the faults in the opposite direction are seen in the non-operating zone. The value of *Characteristic angle* depends on the network configuration.

Reliable operation requires both the operating and polarizing quantities to exceed certain minimum amplitude levels. The minimum amplitude level for the operating quantity (current) is set with the *Min operate current* setting. The minimum amplitude level for the polarizing quantity (voltage) is set with the *Min operate voltage* setting. If the amplitude level of the operating quantity or polarizing quantity is below the set level, the direction information of the corresponding phase is set to "Unknown".

The polarizing quantity validity can remain valid even if the amplitude of the polarizing quantity falls below the value of the *Min operate voltage* setting. In this case, the directional information is provided by a special memory function for a time defined with the *Voltage Mem time* setting.

DPHxPDOC is provided with a memory function to secure a reliable and correct directional IED operation in case of a close short circuit or an earth fault characterized by an extremely low voltage. At sudden loss of the polarization quantity, the angle difference is calculated on the basis of a fictive voltage. The fictive voltage is calculated using the positive phase sequence voltage measured before the fault occurred, assuming that the voltage is not affected by the fault. The memory function enables the function to operate up to a maximum of three seconds after a total loss of voltage. This time can be set with the *Voltage Mem time* setting. The voltage memory cannot be used for the "Negative sequence voltage" polarization because it is not possible to substitute the positive sequence voltage for negative sequence voltage without knowing the network unsymmetry level. This is the reason why the fictive voltage angle and corresponding direction information are frozen immediately for this polarization mode when the need for voltage memory arises and these are kept frozen until the time set with *Voltage Mem time* elapses.

When the voltage falls below *Min operate voltage* at a close fault, the fictive voltage is used to determine the phase angle. The measured voltage is applied again as soon as the voltage rises above *Min operate voltage* and hysteresis. The fictive voltage is also discarded if the measured voltage stays below *Min operate voltage* and hysteresis for longer than *Voltage Mem time* or if the fault current disappears while the fictive voltage is in use. When the voltage is below *Min operate voltage* and hysteresis and the fictive voltage is unusable, the fault direction cannot be determined. The fictive voltage can be unusable for two reasons:

- The fictive voltage is discarded after *Voltage Mem time*
- The phase angle cannot be reliably measured before the fault situation.

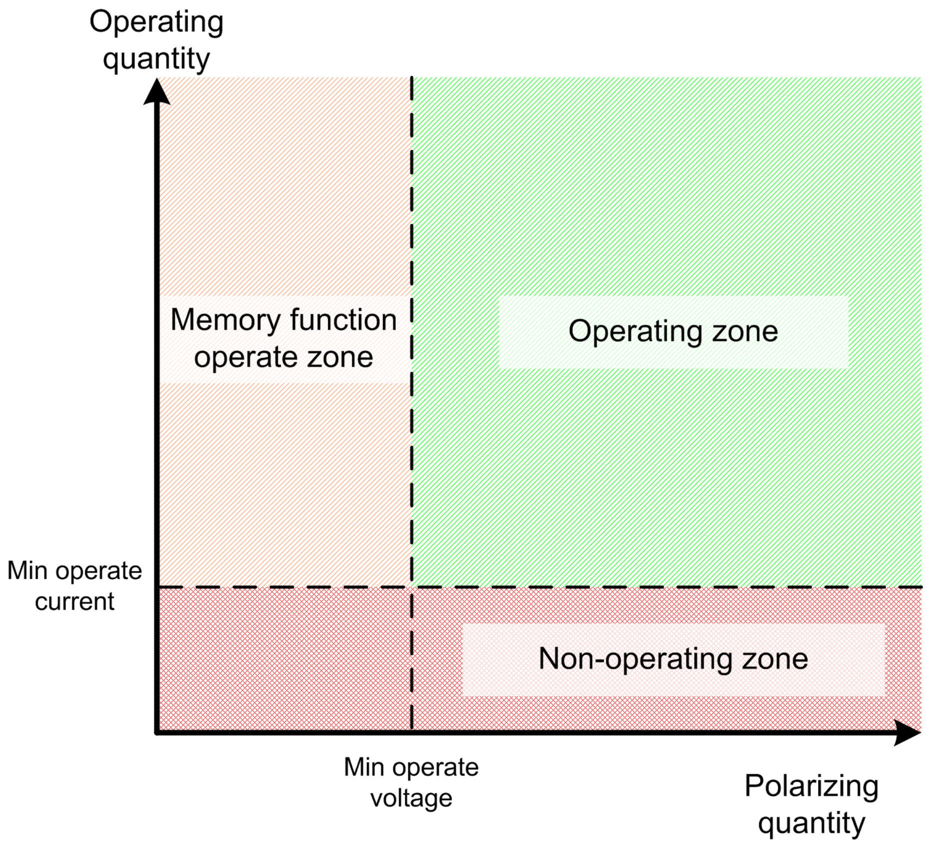


Figure 43: Operating zones at minimum magnitude levels

Level detector

The measured phase currents are compared phasewise to the set *Start value*. If the measured value exceeds the set *Start value*, the level detector reports the exceeding of the value to the phase selection logic. If the ENA_MULT input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The IED does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

The start value multiplication is normally done when the inrush detection function (INRPHAR) is connected to the ENA_MULT input. See more details on the inrush detection function in the relevant chapter.

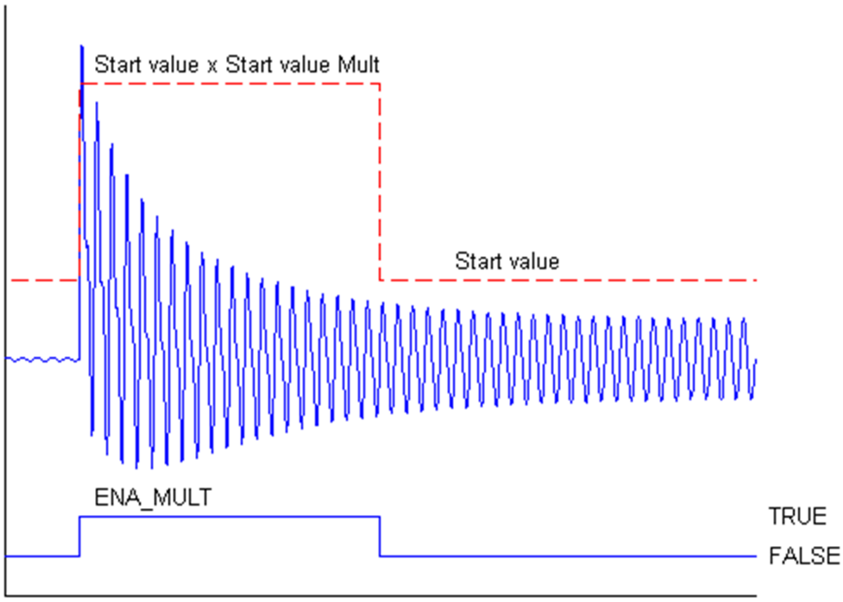


Figure 44: Start value behavior with `ENA_MULT` *input activated*

Phase selection logic

If the fault criteria are fulfilled in the level detector and the directional calculation, the phase selection logic detects the phase or phases in which the measured current exceeds the setting. If the phase information matches the *Num of start phases* setting, the phase selection logic activates the timer module.

Timer

Once activated, the timer activates the `START` output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate"

causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the `START` output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT operate and reset times.

The setting parameter *Minimum operate time* defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.1.2.5 Measuring modes

The function operates on three alternative measurement modes: “RMS”, “DFT” and “Peak-to-Peak” . The measurement mode is selected with the *Measurement mode* setting.

Table 84: Measurement modes supported by DPHxPDOC stages

Measurement mode	Supported measurement modes	
	DPHLPDOC	DPHHPDOC
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

4.1.2.6 Directional overcurrent characteristics

The forward and reverse sectors are defined separately. The forward operation area is limited with the *Min forward angle* and *Max forward angle* settings. The reverse operation area is limited with the *Min reverse angle* and *Max reverse angle* settings.

The sector limits are always given as positive degree values.

In the forward operation area, the *Max forward angle* setting gives the counterclockwise sector and the *Min forward angle* setting gives the corresponding clockwise sector, measured from the *Characteristic angle* setting.

In the reverse operation area, the *Max reverse angle* setting gives the counterclockwise sector and the *Min reverse angle* setting gives the corresponding clockwise sector, measured from the complement of the *Characteristic angle* setting, for example, 180 degrees phase shift.

Relay characteristic angle (RCA) is set positive if the operating current lags the polarizing quantity and negative if the operating current leads the polarizing quantity.

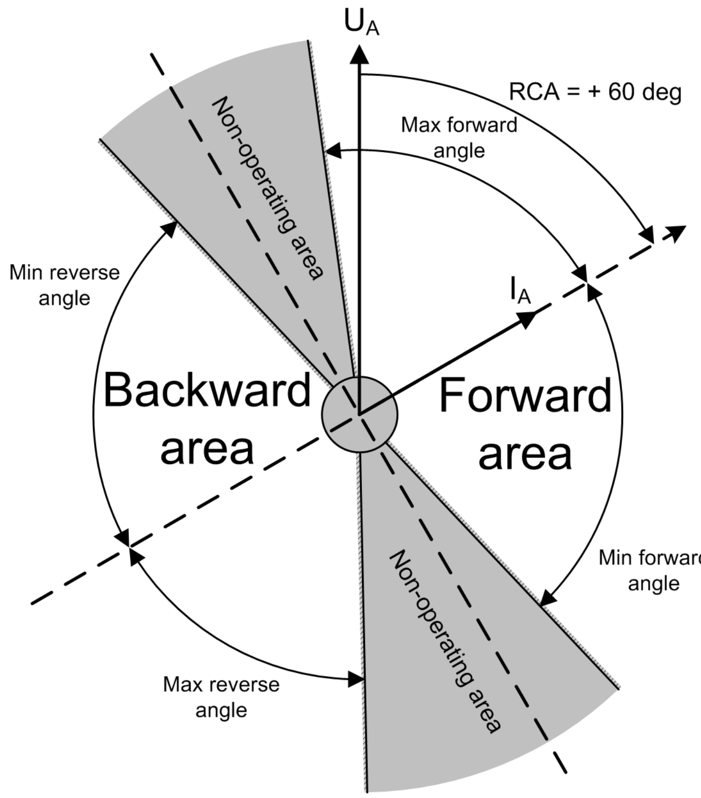


Figure 45: Configurable operating sectors

Table 85: Momentary per phase direction value for monitored data view

Criterion for per phase direction information	The value for DIR_A/_B/_C
The ANGLE_X is not in any of the defined sectors, or the direction cannot be defined due too low amplitude	0 = unknown
The ANGLE_X is in the forward sector	1 = forward
The ANGLE_X is in the reverse sector	2 = backward
(The ANGLE_X is in both forward and reverse sectors, that is, when the sectors are overlapping)	3 = both

Table 86: Momentary phase combined direction value for monitored data view

Criterion for phase combined direction information	The value for DIRECTION
The direction information (DIR_X) for all phases is unknown	0 = unknown
The direction information (DIR_X) for at least one phase is forward, none being in reverse	1 = forward
The direction information (DIR_X) for at least one phase is reverse, none being in forward	2 = backward
The direction information (DIR_X) for some phase is forward and for some phase is reverse	3 = both

FAULT_DIR gives the detected direction of the fault during fault situations, that is, when the START output is active.

Self polarizing as polarizing method

Table 87: Equations for calculating angle difference for self polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	I_A	U_A	$ANGLE\_A = \varphi(\underline{U}_A) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	I_B	U_B	$ANGLE\_B = \varphi(\underline{U}_B) - \varphi(\underline{I}_B) - \varphi_{RCA}$
C	I_C	U_C	$ANGLE\_C = \varphi(\underline{U}_C) - \varphi(\underline{I}_C) - \varphi_{RCA}$
A - B	$\underline{I}_A - \underline{I}_B$	U_{AB}	$ANGLE\_A = \varphi(\underline{U}_{AB}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA}$
B - C	$\underline{I}_B - \underline{I}_C$	U_{BC}	$ANGLE\_B = \varphi(\underline{U}_{BC}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA}$
C - A	$\underline{I}_C - \underline{I}_A$	U_{CA}	$ANGLE\_C = \varphi(\underline{U}_{CA}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA}$

In an example case of the phasors in a single phase earth fault where the faulted phase is phase A, the angle difference between the polarizing quantity U_A and operating quantity I_A is marked as φ. In the self polarization method, there is no need to rotate the polarizing quantity.

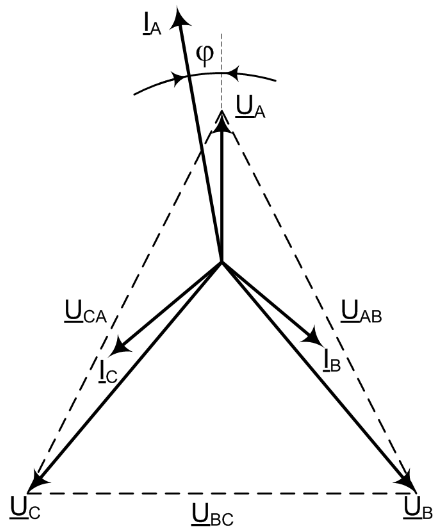


Figure 46: Single-phase earth fault, phase A

In an example case of a two-phase short circuit failure where the fault is between phases B and C, the angle difference is measured between the polarizing quantity U_{BC} and operating quantity $\underline{I}_B$ - $\underline{I}_C$ in the self polarizing method.

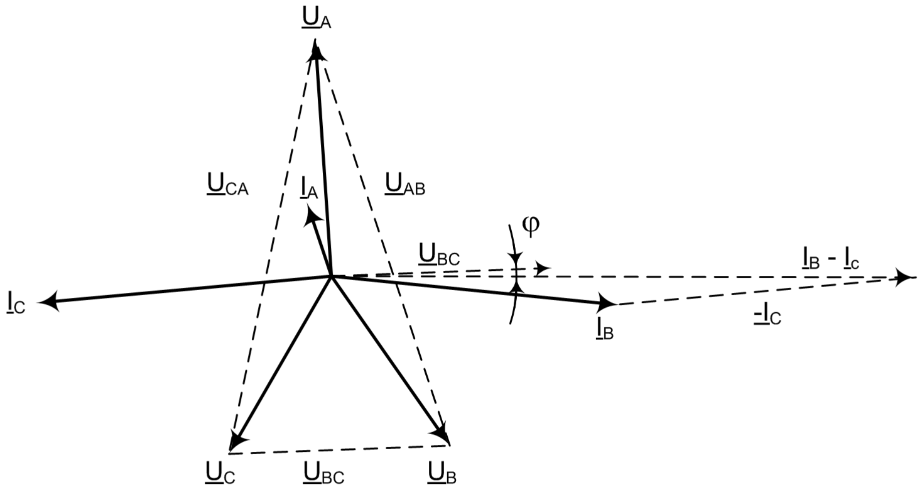


Figure 47: Two-phase short circuit, short circuit is between phases B and C

Cross polarizing as polarizing quantity

Table 88: Equations for calculating angle difference for cross polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	I_A	U_{BC}	$ANGLE\_A = \varphi(\underline{U}_{BC}) - \varphi(\underline{I}_A) - \varphi_{RCA} + 90^o$
B	I_B	U_{CA}	$ANGLE\_B = \varphi(\underline{U}_{CA}) - \varphi(\underline{I}_B) - \varphi_{RCA} + 90^o$
C	I_C	U_{AB}	$ANGLE\_C = \varphi(\underline{U}_{AB}) - \varphi(\underline{I}_C) - \varphi_{RCA} + 90^o$
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{U}_{BC}$ - $\underline{U}_{CA}$	$ANGLE\_A = \varphi(\underline{U}_{BC} - \underline{U}_{CA}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 90^o$
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{U}_{CA}$ - $\underline{U}_{AB}$	$ANGLE\_B = \varphi(\underline{U}_{CA} - \underline{U}_{AB}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} + 90^o$
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{U}_{AB}$ - $\underline{U}_{BC}$	$ANGLE\_C = \varphi(\underline{U}_{AB} - \underline{U}_{BC}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 90^o$

The angle difference between the polarizing quantity U_{BC} and operating quantity I_A is marked as φ in an example of the phasors in a single-phase earth fault where the faulted phase is phase A. The polarizing quantity is rotated with 90 degrees. The characteristic angle is assumed to be ~ 0 degrees.

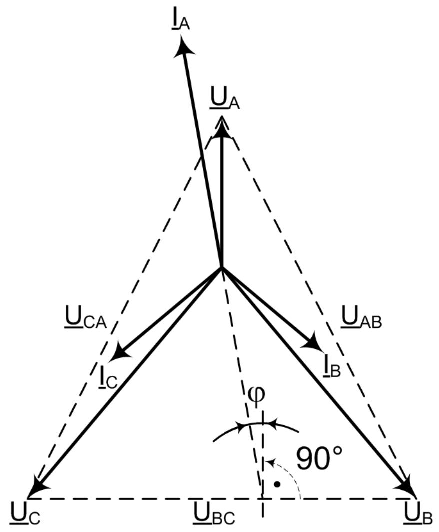


Figure 48: Single-phase earth fault, phase A

In an example of the phasors in a two-phase short circuit failure where the fault is between the phases B and C, the angle difference is measured between the polarizing quantity $\underline{U}_{AB}$ and operating quantity $\underline{I}_B$ - $\underline{I}_C$ marked as φ.

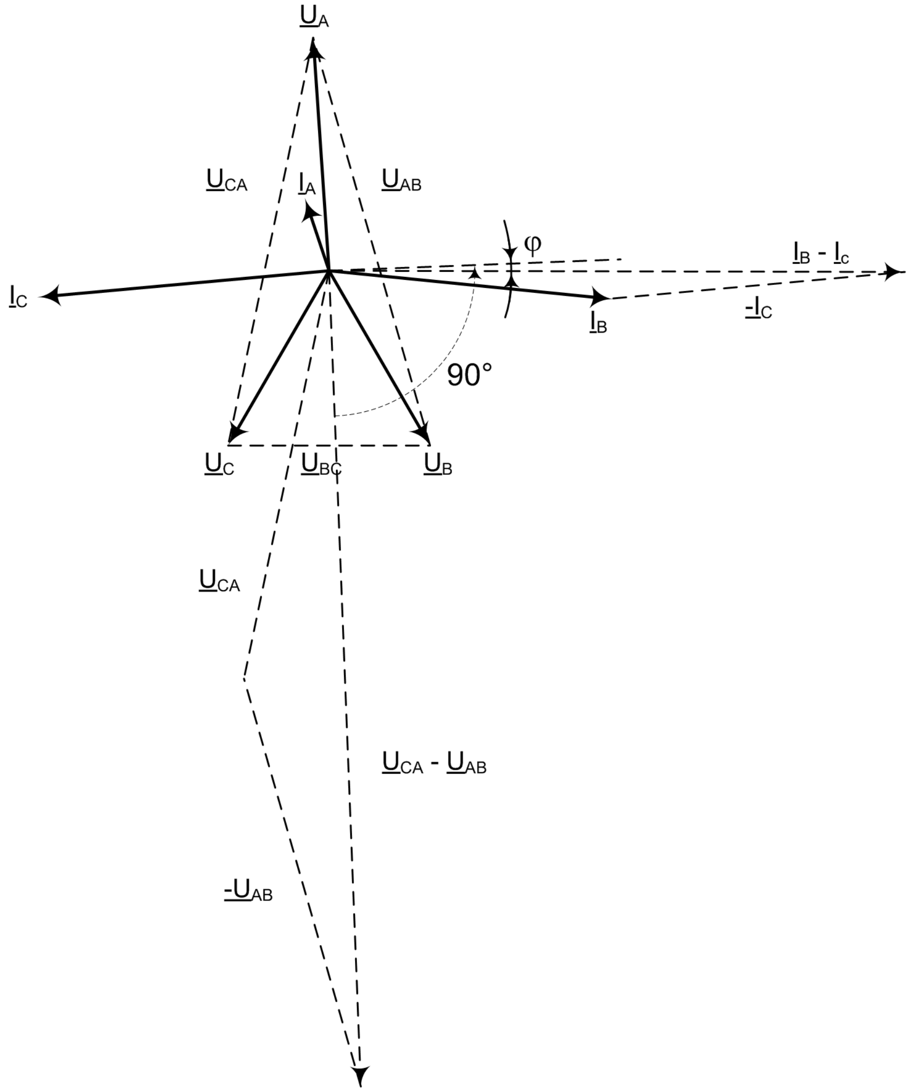


Figure 49: Two-phase short circuit, short circuit is between phases B and C

The equations are valid when network rotating direction is counter-clockwise, that is, ABC. If the network rotating direction is reversed, 180 degrees is added to the calculated angle difference. This is done automatically with a system parameter *Phase rotation*.

Negative sequence voltage as polarizing quantity

When the negative voltage is used as the polarizing quantity, the angle difference between the operating and polarizing quantity is calculated with the same formula for all fault types:

$$ANGLE\_X = \varphi(-\underline{U}2) - \varphi(\underline{I}2) - \varphi_{RCA}$$

(Equation 1)

This means that the actuating polarizing quantity is -U2.

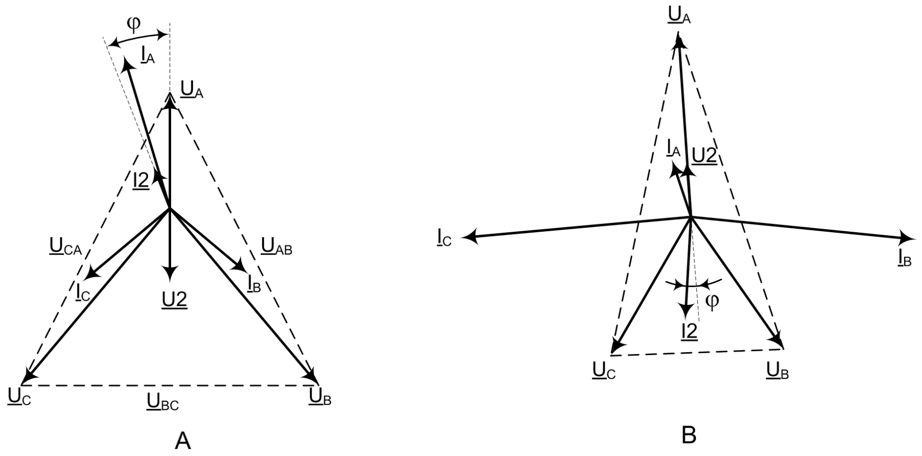


Figure 50: Phasors in a single-phase earth fault, phases A-N, and two-phase short circuit, phases B and C, when the actuating polarizing quantity is the negative sequence voltage -U2

Positive sequence voltage as polarizing quantity

Table 89: Equations for calculating angle difference for positive sequence quantity polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	I_A	U1	$ANGLE\_A = \varphi(\underline{U}1) - \varphi(\underline{I}_A) - \varphi_{RCA}$
B	I_B	U1	$ANGLE\_B = \varphi(\underline{U}1) - \varphi(\underline{I}_B) - \varphi_{RCA} - 120^\circ$
C	I_C	U1	$ANGLE\_C = \varphi(\underline{U}1) - \varphi(\underline{I}_C) - \varphi_{RCA} + 120^\circ$
A - B	$\underline{I}_A$ - $\underline{I}_B$	U1	$ANGLE\_A = \varphi(\underline{U}1) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 30^\circ$
B - C	$\underline{I}_B$ - $\underline{I}_C$	U1	$ANGLE\_B = \varphi(\underline{U}1) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} - 90^\circ$
C - A	$\underline{I}_C$ - $\underline{I}_A$	U1	$ANGLE\_C = \varphi(\underline{U}1) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 150^\circ$

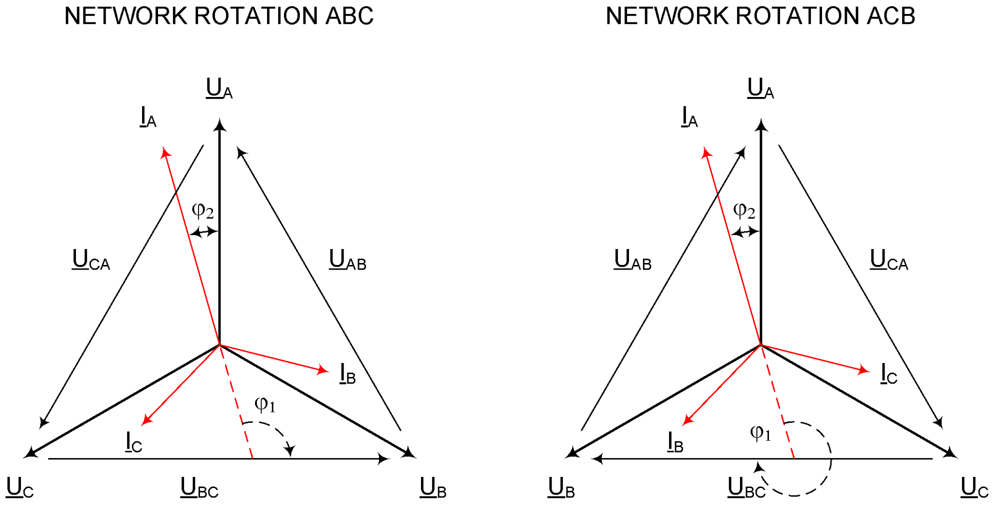


Figure 51: Phasors in a single-phase earth fault, phase A to ground, and two-phase short circuit, phases B-C are short circuited, when the polarizing quantity is the positive sequence voltage U1

Network rotating direction

Typically, the network rotating direction is counter-clockwise and defined as "ABC". If the network rotating direction is reversed, meaning clockwise, that is, "ACB", the equations for calculating the angle difference needs to be changed. The network rotating direction is defined with a system parameter *Phase rotation*. The change in the network rotating direction affects the phase-to-phase voltages polarization method where the calculated angle difference needs to be rotated 180 degrees. Also, when the sequence components are used, which are, the positive sequence voltage or negative sequence voltage components, the calculation of the components are affected but the angle difference calculation remains the same. When the phase-to-ground voltages are used as the polarizing method, the network rotating direction change has no effect on the direction calculation.

The network rotating direction is set in the IED using the parameter in the HMI menu: **Configuration/System/Phase rotation**. The default parameter value is "ABC".

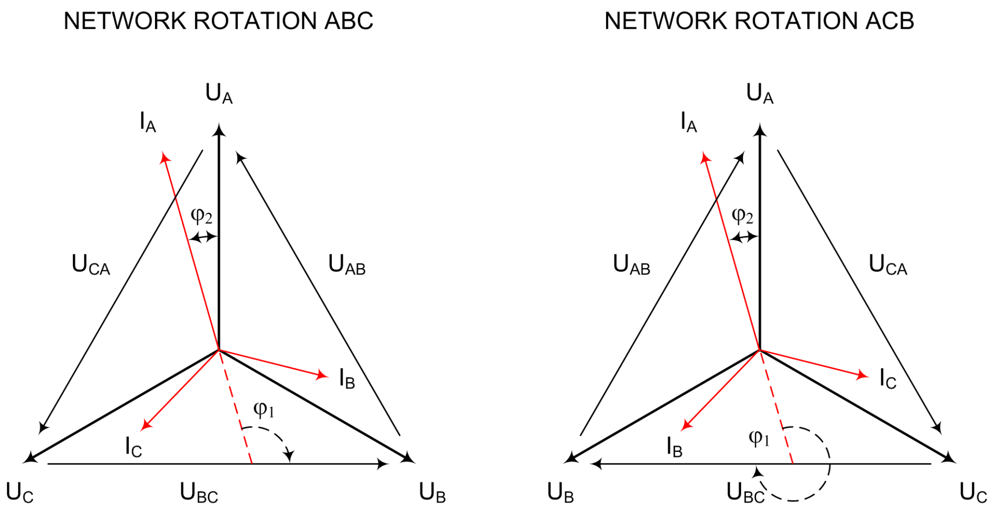


Figure 52: Examples of network rotating direction

4.1.2.7 Application

DPHxPDOC is used as short-circuit protection in three-phase distribution or sub transmission networks operating at 50 or 60 Hz.

In radial networks, the phase overcurrent relays are often sufficient for the short circuit protection of lines, transformers and other equipment. The current-time characteristic should be chosen according to the common practice in the network. It is recommended to use the same current-time characteristic for all overcurrent relays in the network. This includes the overcurrent protection of transformers and other equipment.

The phase overcurrent protection can also be used in closed ring systems as short circuit protection. Because the setting of a phase overcurrent protection system in closed ring networks can be complicated, a large number of fault current calculations are needed. There are situations with no possibility to have the selectivity with a protection system based on overcurrent relays in a closed ring system.

In some applications, the possibility of obtaining the selectivity can be improved significantly if DPHxPDOC is used. This can also be done in the closed ring networks and radial networks with the generation connected to the remote in the system thus giving fault current infeed in reverse direction. Directional overcurrent relays are also used to have a selective protection scheme, for example, in case of parallel distribution lines or power transformers fed by the same single source. In ring connected supply feeders between substations or feeders with two feeding sources, DPHxPDOC is also used.

Parallel lines or transformers

When the lines are connected in parallel and if a fault occurs in one of the lines, it is practical to have DPHxPDOC to detect the direction of the fault. Otherwise, there is a risk that the fault situation in one part of the feeding system can de-energize the whole system connected to the LV side.

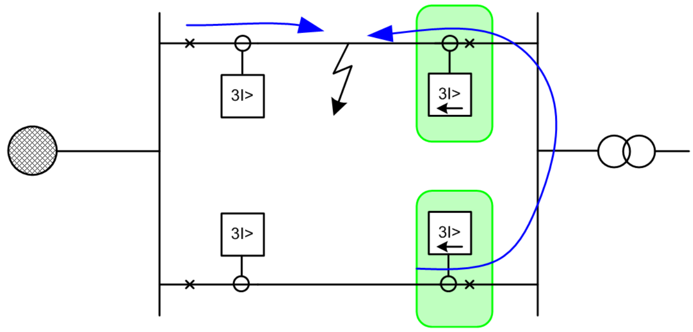


Figure 53: Overcurrent protection of parallel lines using directional relays

DPHxPDOC can be used for parallel operating transformer applications. In these applications, there is a possibility that the fault current can also be fed from the LV-side up to the HV-side. Therefore, the transformer is also equipped with directional overcurrent protection.

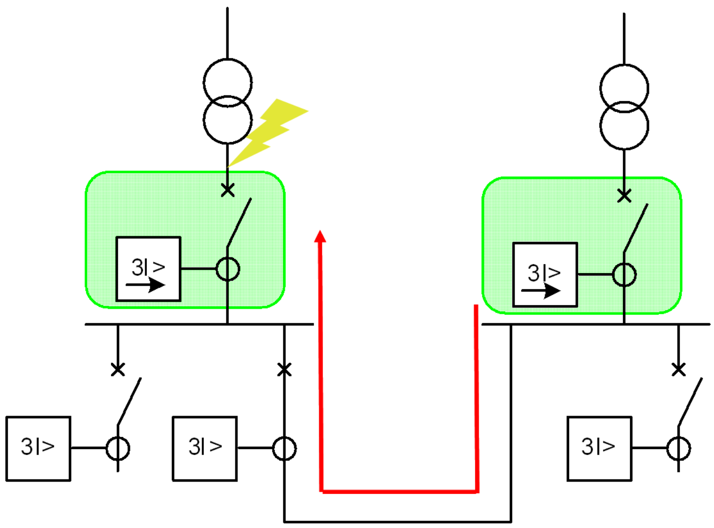


Figure 54: Overcurrent protection of parallel operating transformers

Closed ring network topology

The closed ring network topology is used in applications where electricity distribution for the consumers is secured during network fault situations. The power is fed at least from two directions which means that the current direction can be varied. The time grading between the network level stages is challenging without unnecessary delays in the time settings. In this case, it is practical to use the directional overcurrent relays to achieve a selective protection scheme. Directional overcurrent functions can be used in closed ring applications. The arrows define the operating direction of the directional functionality. The double arrows define the non-directional functionality where faults can be detected in both directions.

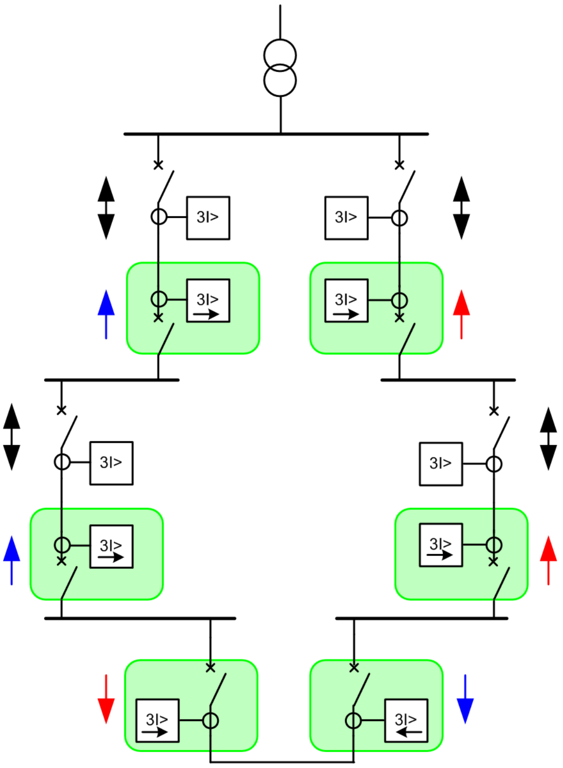


Figure 55: Closed ring network topology where feeding lines are protected with directional overcurrent relays

4.1.2.8 Signals

Table 90: DPHLPDOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative phase sequence current
U_A_AB	SIGNAL	0	Phase-to-earth voltage A or phase-to-phase voltage AB
U_B_BC	SIGNAL	0	Phase-to-earth voltage B or phase-to-phase voltage BC
U_C_CA	SIGNAL	0	Phase-to-earth voltage C or phase-to-phase voltage CA

Table continues on next page

Name	Type	Default	Description
U_1	SIGNAL	0	Positive phase sequence voltage
U_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enabling signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 91: DPHHPDOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative phase sequence current
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
U_1	SIGNAL	0	Positive phase sequence voltage
U_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enabling signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 92: DPHLPDOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 93: DPHHPDOC Output signals

Name	Type	Description
START	BOOLEAN	Start
OPERATE	BOOLEAN	Operate

4.1.2.9 Settings

Table 94: DPHLPDOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...5.00	xIn	0.01	0.05	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 95: DPHLPDOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Min operate current	0.01...1.00	xIn	0.01	0.01	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage

Table 96: DPHHPDOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Operate delay time	40...200000	ms	10	40	Operate delay time
Characteristic angle	-179...180	deg	1	60	Characteristic angle
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Max forward angle	0...90	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...90	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...90	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...90	deg	1	80	Minimum phase angle in reverse direction
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Pol quantity	-2=Pos. seq. volt. 1=Self pol 4=Neg. seq. volt. 5=Cross pol			5=Cross pol	Reference quantity used to determine fault direction

Table 97: DPHHPDOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min operate current	0.01...1.00	xIn	0.01	0.01	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation

4.1.2.10 Monitored data

Table 98: DPHLPDOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
DPHLPDOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 99: DPHHPDOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information

Table continues on next page

Name	Type	Values (Range)	Unit	Description
DIR_A	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward 3=both		Direction phase C
ANGLE_A	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase A
ANGLE_B	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase B
ANGLE_C	FLOAT32	-180.00...180.00	deg	Calculated angle difference, Phase C
DPHHPDOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.2.11 Technical data

Table 100: DPHxPDOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current/ voltage measured: f_n ±2Hz		
	DPHLPDOC	Current: ±1.5% of the set value or ±0.002 x I_n Voltage: ±1.5% of the set value or ±0.002 x U_n Phase angle: ±2°		
	DPHHPDOC	Current: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n) Voltage: ±1.5% of the set value or ±0.002 x U_n Phase angle: ±2°		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 x set *Start value*	37 ms	40 ms	42 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Table continues on next page				

Characteristic	Value
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms[3)]
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

1) *Measurement mode* and *Pol quantity* = default, current before fault = 0.0 x I_n, voltage before fault = 1.0 x U_n, f_n = 50 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 x I_n, *Start value* multiples in range of 1.5 to 20

4.1.3 Three-phase thermal overload protection for overhead lines and cables T1PTTR

4.1.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase thermal overload protection for overhead lines and cables	T1PTTR	3Ith>	49F

4.1.3.2 Function block

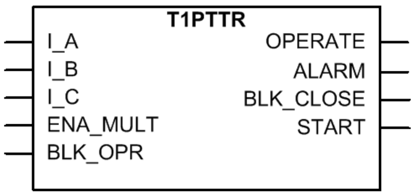


Figure 56: Function block

4.1.3.3 Functionality

The increased utilization of power systems closer to the thermal limits has generated a need for a thermal overload function also for power lines.

A thermal overload is in some cases not detected by other protection functions, and the introduction of the thermal overload function T1PTTR allows the protected circuit to operate closer to the thermal limits.

An alarm level gives an early warning to allow operators to take action before the line trips. The early warning is based on the three-phase current measuring function using a thermal model with first order thermal loss with the settable time constant. If the temperature rise continues the function will operate based on the thermal model of the line.

Re-energizing of the line after the thermal overload operation can be inhibited during the time the cooling of the line is in progress. The cooling of the line is estimated by the thermal model.

4.1.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the three-phase thermal protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

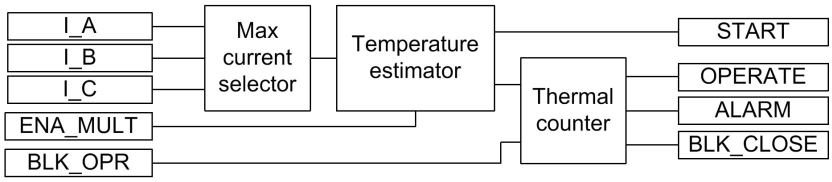


Figure 57: Functional module diagram. I_A, I_B and I_C represent phase currents.

Max current selector

The sampled analog phase currents are preprocessed and the RMS value of each phase current is derived for each phase current. These phase current values are fed to the function.

The max current selector of the function continuously checks the highest phase current value. The selector reports the highest value to the temperature estimator.

Temperature estimator

From the largest of the three-phase currents, a final temperature is calculated according to the expression:

$$\Theta_{final} = \left(\frac{I}{I_{ref}}\right)^2 \cdot T_{ref}$$

(Equation 2)

I	the largest phase current
I_{ref}	set *Current reference*
T_{ref}	set *Temperature rise*

The ambient temperature is added to the calculated final temperature estimation, and the ambient temperature value used in the calculation is also available in the monitored data as TEMP_AMB. If the final temperature estimation is larger than the set *Maximum temperature*, the START output is activated.

The *Current reference* and *Temperature rise* setting values are used in the final temperature estimation together with the ambient temperature. It is suggested to set these values to the maximum steady state current allowed for the line or cable under emergency operation for a few hours per years. Current values with the corresponding conductor temperatures are given in cable manuals. These values are given for conditions such as ground temperatures, ambient air temperature, the way of cable laying and ground thermal resistivity.

Thermal counter

The actual temperature at the actual execution cycle is calculated as:

$$\Theta_n = \Theta_{n-1} + \left(\Theta_{final} - \Theta_{n-1}\right) \cdot \left(1 - e^{-\frac{\Delta t}{\tau}}\right)$$

(Equation 3)

Θ_n	calculated present temperature
Θ_{n-1}	calculated temperature at previous time step
Θ_{final}	calculated final temperature with actual current
Δt	time step between calculation of actual temperature
τ	thermal time constant for the protected device (line or cable), set *Time constant*

The actual temperature of the protected component (line or cable) is calculated by adding the ambient temperature to the calculated temperature, as shown above. The ambient temperature can be given a constant value. The calculated component temperature can be monitored as it is exported from the function as a real figure.

When the component temperature reaches the set alarm level *Alarm value*, the output signal ALARM is set. When the component temperature reaches the set trip level *Maximum temperature*, the OPERATE output is activated. The OPERATE signal pulse length is fixed to 100 ms.

There is also a calculation of the present time to operation with the present current. This calculation is only performed if the final temperature is calculated to be above the operation temperature:

$$t_{operate} = -\tau \cdot \ln\left(\frac{\Theta_{final} - \Theta_{operate}}{\Theta_{final} - \Theta_n}\right)$$

(Equation 4)

Caused by the thermal overload protection function, there can be a lockout to reconnect the tripped circuit after operating. The lockout output BLK_CLOSE is activated at the same time when the OPERATE output is activated and is not reset until the device temperature has cooled down below the set value of the *Reclose temperature* setting. The *Maximum temperature* value must be set at least 2 degrees above the set value of *Reclose temperature*.

The time to lockout release is calculated, that is, the calculation of the cooling time to a set value. The calculated temperature can be reset to its initial value (the *Initial temperature* setting) via a control parameter that is located under the clear menu. This is useful during testing when the secondary injected current has given a calculated false temperature level.

$$t_{lockout\_release} = -\tau \cdot \ln\left(\frac{\Theta_{final} - \Theta_{lockout\_release}}{\Theta_{final} - \Theta_n}\right)$$

(Equation 5)

Here the final temperature is equal to the set or measured ambient temperature.

In some applications, the measured current can involve a number of parallel lines. This is often used for cable lines where one bay connects several parallel cables. By setting the *Current multiplier* parameter to the number of parallel lines (cables), the actual current on one line is used in the protection algorithm. To activate this option, the ENA_MULT input must be activated.

The *Env temperature Set* setting is used to define the ambient temperature.

The temperature calculation is initiated from the value defined with the *Initial temperature* setting parameter. This is done in case the IED is powered up or if the function is turned "Off" and back "On" or reset through the Clear menu. The temperature is also stored in the nonvolatile memory and restored in case the IED is restarted.

The thermal time constant of the protected circuit is given in minutes with the *Time constant* setting. Please see cable manufacturers' manuals for further details.

4.1.3.5 Application

The lines and cables in the power system are constructed for a certain maximum load current level. If the current exceeds this level, the losses will be higher than expected. As a consequence, the temperature of the conductors will increase. If the temperature of the lines and cables reaches too high values, it can cause a risk of damages by, for example, the following ways:

- The sag of overhead lines can reach an unacceptable value.
- If the temperature of conductors, for example aluminium conductors, becomes too high, the material will be destroyed.
- In cables the insulation can be damaged as a consequence of overtemperature, and therefore phase-to-phase or phase-to-earth faults can occur.

In stressed situations in the power system, the lines and cables may be required to be overloaded for a limited time. This should be done without any risk for the above-mentioned risks.

The thermal overload protection provides information that makes temporary overloading of cables and lines possible. The thermal overload protection estimates the conductor temperature continuously. This estimation is made by using a thermal model of the line/cable that is based on the current measurement.

If the temperature of the protected object reaches a set warning level, a signal is given to the operator. This enables actions in the power system to be done before dangerous temperatures are reached. If the temperature continues to increase to the maximum allowed temperature value, the protection initiates a trip of the protected line.

4.1.3.6 Signals

Table 101: T1PTTR Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
ENA_MULT	BOOLEAN	0=False	Enable Current multiplier
BLK_OPR	BOOLEAN	0=False	Block signal for operate outputs

Table 102: T1PTTR Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start
ALARM	BOOLEAN	Thermal Alarm
BLK_CLOSE	BOOLEAN	Thermal overload indicator. To inhibite reclose.

4.1.3.7 Settings

Table 103: T1PTTR Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Env temperature Set	-50...100	°C	1	40	Ambient temperature used when no external temperature measurement available
Current multiplier	1...5		1	1	Current multiplier when function is used for parallel lines
Current reference	0.05...4.00	xIn	0.01	1.00	The load current leading to Temperature raise temperature
Temperature rise	0.0...200.0	°C	0.1	75.0	End temperature rise above ambient
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Time constant	60...60000	s	1	2700	Time constant of the line in seconds.
Maximum temperature	20.0...200.0	°C	0.1	90.0	Temperature level for operate
Alarm value	20.0...150.0	°C	0.1	80.0	Temperature level for start (alarm)
Reclose temperature	20.0...150.0	°C	0.1	70.0	Temperature for reset of block reclose after operate

Table 104: T1PTTR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Initial temperature	-50.0...100.0	°C	0.1	0.0	Temperature raise above ambient temperature at startup

4.1.3.8 Monitored data

Table 105: T1PTTR Monitored data

Name	Type	Values (Range)	Unit	Description
TEMP	FLOAT32	-100.0...9999.9	°C	The calculated temperature of the protected object
TEMP_RL	FLOAT32	0.00...99.99		The calculated temperature of the protected object relative to the operate level
T_OPERATE	INT32	0...600000	ms	Estimated time to operate
T_ENA_CLOSE	INT32	0...600000	ms	Estimated time to deactivate BLK_CLOSE
TEMP_AMB	FLOAT32	-99...999	°C	The ambient temperature used in the calculation
T1PTTR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.3.9 Technical data

Table 106: T1PTTR Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2 Hz
	Current measurement: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Operate time accuracy[1)]	±2.0% of the theoretical value or ±0.50 s

1) Overload current > 1.2 x Operate level temperature

4.1.3.10 Technical revision history

Table 107: T1PTTR Technical revision history

Technical revision	Change
C	Removed the *Sensor available* setting parameter

4.1.4 Motor stall protection JAMPTOC

4.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor stall protection	JAMPTOC	Ist>	51LR

4.1.4.2 Function block

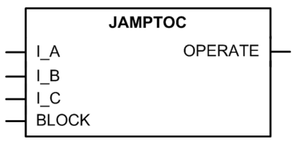


Figure 58: Function block

4.1.4.3 Functionality

The stalled motor protection JAMPTOC is used for protecting the motor in stall or mechanical jam situations during the running state.

When the motor is started, a separate function is used for the startup protection and JAMPTOC is normally blocked during the startup period. When the motor has passed the starting phase, JAMPTOC monitors the magnitude of phase currents.

The function starts when the measured current exceeds the breakdown torque level, that is, above the set limit. The operation characteristic is definite time.

The function contains a blocking functionality. It is possible to block function outputs, timers or the function itself, if desired.

4.1.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the stalled motor protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

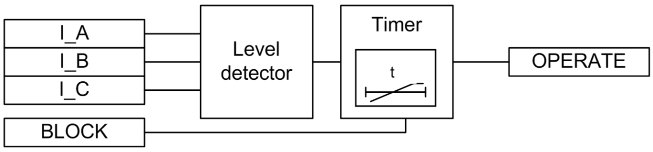


Figure 59: Functional module diagram

Level detector

The measured phase currents are compared to the set *Start value*. The TRMS values of the phase currents are considered for the level detection. The timer module is enabled if at least two of the measured phase currents exceed the set *Start value*.

Timer

Once activated, the internal `START` signal is activated. The value is available only through the Monitored data view. The time characteristic is according to DT. When the operation timer has reached the *Operate delay time* value, the `OPERATE` output is activated.

When the timer has elapsed but the motor stall condition still exists, the `OPERATE` output remains active until the phase current values drop below the *Start value*, that is, until the stall condition persists. If the drop-off situation occurs while the operate time is still counting, the reset timer is activated. If the drop-off time exceeds the set *Reset delay time*, the operate timer is reset.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

4.1.4.5 Application

The motor protection during stall is primarily needed to protect the motor from excessive temperature rise, as the motor draws large currents during the stall phase. This condition causes a temperature rise in the stator windings. Due to reduced speed, the temperature also rises in the rotor. The rotor temperature rise is more critical when the motor stops.

The physical and dielectric insulations of the system deteriorate with age and the deterioration is accelerated by the temperature increase. Insulation life is related to the time interval during which the insulation is maintained at a given temperature.

An induction motor stalls when the load torque value exceeds the breakdown torque value, causing the speed to decrease to zero or to some stable operating point well below the rated speed. This occurs, for example, when the applied shaft load is suddenly increased and is greater than the producing motor torque due to the bearing failures. This condition develops a motor current almost equal to the value of the locked-rotor current.

JAMPTOC is designed to protect the motor in stall or mechanical jam situations during the running state. To provide a good and reliable protection for motors in a stall situation, the temperature effects on the motor have to be kept within the allowed limits.

4.1.4.6 Signals

Table 108: JAMPTOC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 109: JAMPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate

4.1.4.7 Settings

Table 110: JAMPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Start value	0.10...10.00	xIn	0.01	2.50	Start value
Operate delay time	100...120000	ms	10	2000	Operate delay time
Reset delay time	0...60000	ms	1	100	Reset delay time

4.1.4.8 Monitored data

Table 111: JAMPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START	BOOLEAN	0=False 1=True		Start
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
JAMPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.4.9 Technical data

Table 112: JAMPTOC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: fn ±2Hz
	±1.5% of the set value or ±0.002 x I_n
Reset time	< 40 ms
Reset ratio	Typical 0.96
Retardation time	< 35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

4.1.5 Loss of load protection LOFLPTUC

4.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loss of load protection	LOFLPTUC	3I<	37

4.1.5.2 Function block

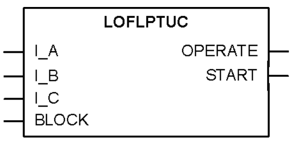


Figure 60: Function block

4.1.5.3 Functionality

The loss of load protection LOFLPTUC is used to detect a sudden load loss which is considered as a fault condition.

LOFLPTUC starts when the current is less than the set limit. It operates with the definite time (DT) characteristics, which means that the function operates after a predefined operate time and resets when the fault current disappears.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer or the function itself, if desired.

4.1.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the loss of load protection can be described using a module diagram. All the modules in the diagram are explained in the next sections.

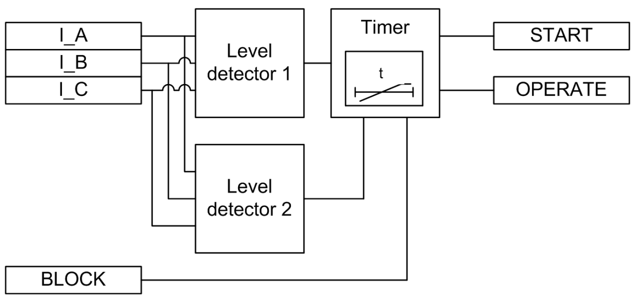


Figure 61: Functional module diagram

Level detector 1

This module compares the phase currents (RMS value) to the set *Start value high* setting. If all the phase current values are less than the set *Start value high* value, the loss of load condition is detected and an enable signal is sent to the timer. This signal is disabled after one or several phase currents have exceeded the set *Start value high* value of the element.

Level detector 2

This is a low-current detection module which monitors the de-energized condition of the motor. It compares the phase currents (RMS value) to the set *Start value low* setting. If any of the phase current values is less than the set *Start value low*, a signal is sent to block the operation of the timer.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate* *delay time*, the OPERATE output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the START output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

The BLOCK signal blocks the operation of the function and resets the timer.

4.1.5.5 Application

When a motor runs with a load connected, it draws a current equal to a value between the no-load value and the rated current of the motor. The minimum load current can be determined by studying the characteristics of the connected load. When the current drawn by the motor is less than the minimum load current drawn, it can be inferred that the motor is either disconnected from the load or the coupling mechanism is faulty. If the motor is allowed to run in this condition, it may aggravate the fault in the coupling mechanism or harm the personnel handling the machine. Therefore, the motor has to be disconnected from the power supply as soon as the above condition is detected.

LOFLPTUC detects the condition by monitoring the current values and helps disconnect the motor from the power supply instantaneously or after a delay according to the requirement.

When the motor is at standstill, the current will be zero and it is not recommended to activate the trip during this time. The minimum current drawn by the motor when it is connected to the power supply is the no load current, that is, the higher start value current. If the current drawn is below the lower start value current, the motor is disconnected from the power supply. LOFLPTUC detects this condition and interprets that the motor is de-energized and disables the function to prevent unnecessary trip events.

4.1.5.6 Signals

Table 113: LOFLPTUC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block all binary outputs by resetting timers

Table 114: LOFLPTUC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.5.7 Settings

Table 115: LOFLPTUC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value low	0.01...0.50	xIn	0.01	0.10	Current setting/Start value low
Start value high	0.01...1.00	xIn	0.01	0.50	Current setting/Start value high
Operate delay time	400...600000	ms	10	2000	Operate delay time

Table 116: LOFLPTUC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.5.8 Monitored data

Table 117: LOFLPTUC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
LOFLPTUC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.5.9 Technical data

Table 118: LOFLPTUC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2 Hz
	±1.5% of the set value or ±0.002 x I_n
Start time	Typical 300 ms
Reset time	< 40 ms
Reset ratio	Typical 0.96
Retardation time	< 35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

4.1.6 Three-phase thermal overload protection for motors MPTTR

4.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase thermal overload protection for motors	MPTTR	3Ith>M	49M

4.1.6.2 Function block

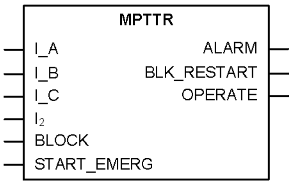


Figure 62: Function block

4.1.6.3 Functionality

The motor thermal overload protection function MPTTR protects the electric motors from overheating. MPTTR models the thermal behavior of motor on the basis of the measured load current and disconnects the motor when the thermal content reaches 100 percent. The thermal overload conditions are the most often encountered abnormal conditions in industrial motor applications. The thermal overload conditions are typically the result of an abnormal rise in the motor running current, which produces an increase in the thermal dissipation of the motor and temperature or reduces cooling. MPTTR prevents an electric motor from drawing excessive current and overheating, which causes the premature insulation failures of the windings and, in worst cases, burning out of the motors.

4.1.6.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the motor thermal overload protection function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

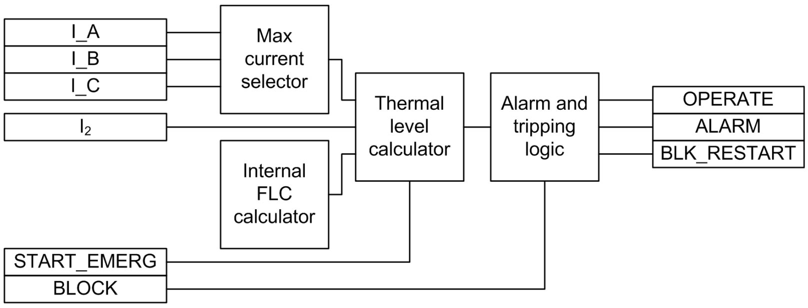


Figure 63: Functional module diagram

Max current selector

The max current selector selects the highest phase current and reports it to the thermal level calculator.

Internal FLC calculator

The FLC of the motor is defined by the manufacturer at an ambient temperature of 40°C. Special considerations are required with an application where the ambient temperature of a motor exceeds or remains below 40°C. A motor operating at a higher temperature, even if at or below rated load, can subject the motor windings to excessive temperature similar to that resulting from overload operation at normal ambient temperature. The motor rating has to be appropriately reduced for operation in such high ambient temperatures. Similarly, when the ambient temperature is considerably lower than the nominal 40°C, it appears that the motor is loaded beyond its rating. For calculating thermal level it is better that the FLC values are scaled for different temperatures. The scaled currents are known as internal FLC. An internal FLC is calculated based on the ambient temperature shown in the table. The *Env temperature mode* setting decides whether the thermal level calculations are based on FLC or internal FLC.

When the value of the *Env temperature mode* setting is set to the “FLC Only” mode, no internal FLC is calculated. Instead, the FLC given in the data sheet of the manufacturer is used. When the value of the *Env temperature mode* setting is set to “Set Amb Temp” mode, internal FLC is calculated based on the ambient temperature taken as input through the *Env temperature Set* setting.

Table 119: Modification of internal FLC

Ambient Temperature T_{amb}	Internal FLC
<20°C	FLC x 1.09
20 to <40°C	FLC x (1.18 - T_{amb} x 0.09/20)
40°C	FLC
>40 to 65°C	FLC x (1 –[(T_{amb} -40)/100])
>65°C	FLC x 0.75

The ambient temperature is used for calculating thermal level and it is available through the monitored data view from the TEMP_AMB output. The activation of the BLOCK input does not affect the TEMP_AMB output.

Thermal level calculator

The module calculates the thermal load considering the TRMS and negative sequence currents. The heating up of the motor is determined by the square value of the load current. However, in case of unbalanced phase currents, the negative sequence current also causes additional heating. By deploying a protection based on both current components, abnormal heating of the motor is avoided.

The thermal load is calculated based on different situations or operations and it also depends on phase current level. The equations used for the heating up calculations are:

$$\theta_B = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times \left(1 - e^{-t/\tau}\right) \times p\%$$

(Equation 6)

$$\theta_A = \left[\left(\frac{I}{k \times I_r}\right)^2 + K_2 \times \left(\frac{I_2}{k \times I_r}\right)^2\right] \times \left(1 - e^{-t/\tau}\right) \times 100\%$$

(Equation 7)

I	TRMS value of the measured max of phase currents
I_r	set *Rated current*, FLC or internal FLC
I_2	measured negative sequence current
k	set value of *Overload factor*
K_2	set value of *Negative Seq factor*
p	set value of *Weighting factor*
τ	time constant

The equation θ_B is used when the values of all the phase currents are below the overload limit, that is, k x I_r. The equation θ_A is used when the value of any one of the phase currents exceeds the overload limit.

During overload condition, the thermal level calculator calculates the value of θ_B in background, and when the overload ends the thermal level is brought linearly from θ_A to θ_B with a speed of 1.66 percent per second. For the motor at standstill, that is, when the current is below the value of 0.12 x I_r, the cooling is expressed as:

$$\theta = \theta_{02} \times e^{\frac{-t}{\tau}}$$

(Equation 8)

θ_{02} initial thermal level when cooling begins

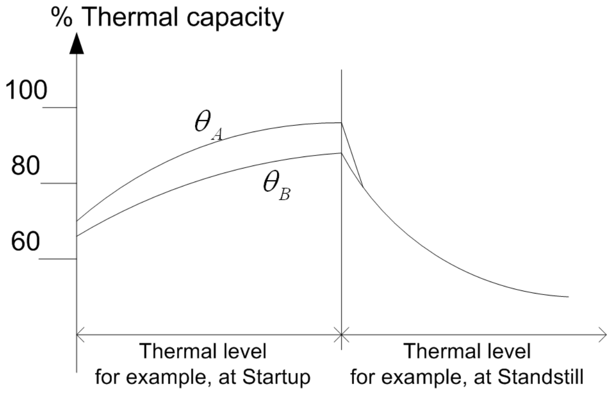


Figure 64: Thermal behavior

The required overload factor and negative sequence current heating effect factor are set by the values of the *Overload factor* and *Negative Seq factor* settings.

In order to accurately calculate the optimal thermal load, different time constants are used in the above equations. These time constants are employed based on different motor running conditions, for example starting, normal or stop, and are set through the *Time constant start*, *Time constant normal* and *Time constant stop* settings. Only one time constant is valid at a time.

Table 120: Time constant and the respective phase current values

Time constant (tau) in use	Phase current
Time constant start	Any current whose value is over 2.5 x I_r
Time constant normal	Any current whose value is over 0.12 x I_r and all currents are below 2.5 x I_r
Time constant stop	All the currents whose values are below 0.12 x I_r

The *Weighting factor p* setting determines the ratio of the thermal increase of the two curves θ_A and θ_B.

The thermal level at the power-up of the IED is defined by the *Initial thermal Val* setting.

The temperature calculation is initiated from the value defined in the *Initial thermal Val* setting. This is done if the IED is powered up or the function is turned off and back on or reset through the Clear menu.

The calculated temperature of the protected object relative to the operate level, the TEMP_RL output, is available through the monitored data view. The activation of the BLOCK input does not affect the calculated temperature.

The thermal level at the beginning of the startup condition of a motor and at the end of the startup condition is available through the monitored data view at the THERMLEV_ST and THERMLEV_END outputs respectively. The activation of the BLOCK input does not have any effect on these outputs.

Alarm and tripping logic

The module generates the alarm, restart inhibit and tripping signals.

When the thermal level exceeds the set value of the *Alarm thermal value* setting, the ALARM output is activated. Sometimes a condition arises when it becomes necessary to inhibit the restarting of a motor, for example in case of some extreme starting condition like long starting time. If the thermal content exceeds the set value of the *Restart thermal val* setting, the BLK_RESTART output is activated. The time for the next possible motor startup is available through the monitored data view from the T_ENARESTART output. The T_ENARESTART output estimates the time for the BLK_RESTAR deactivation considering as if the motor is stopped.

When the value of the emergency start signal START_EMERG increases, the thermal level is set to a value below the thermal restart inhibit level. This allows at least one motor startup, even though the thermal level has exceeded the restart inhibit level.

When the thermal content reaches 100 percent, the OPERATE output is activated. The OPERATE output is deactivated when the value of the measured current falls below 12 percent of *Rated current* or the thermal content drops below 100 percent.

The activation of the BLOCK input blocks the ALARM, BLK_RESTART and OPERATE outputs.

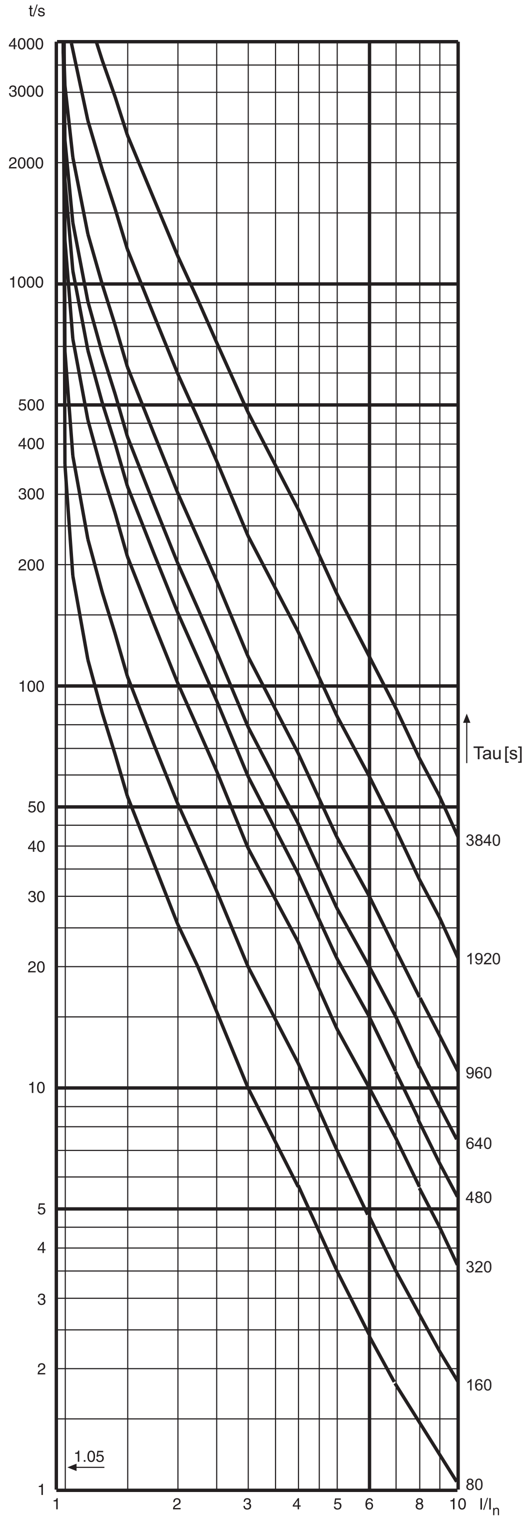


Figure 65: Trip curves when no prior load and p=20...100 %. Overload factor = 1.05.

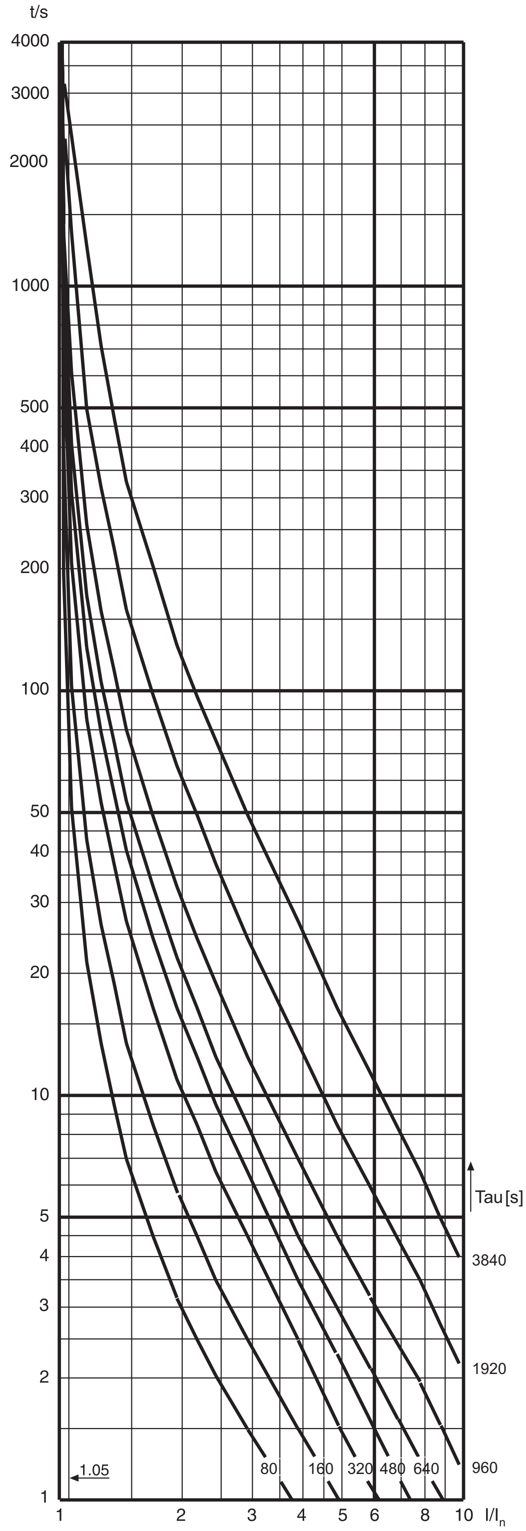


Figure 66: Trip curves at prior load 1 x FLC and p=100 %, Overload factor = 1.05.

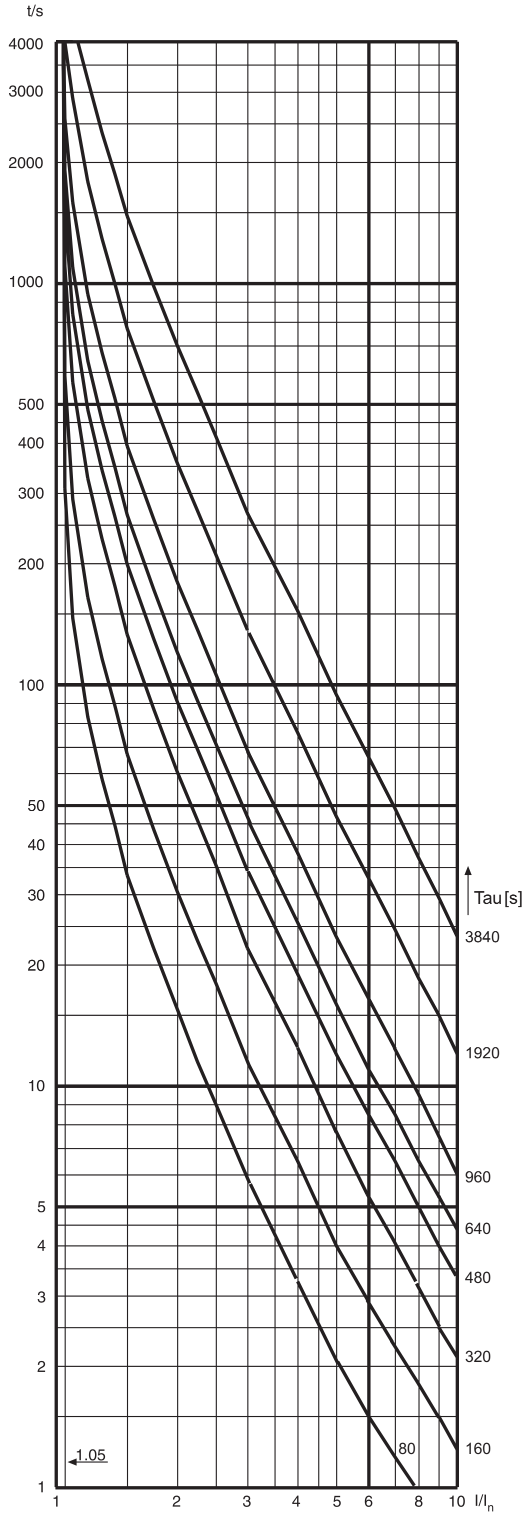


Figure 67: Trip curves at prior load 1 x FLC and p=50 %. Overload factor = 1.05.

4.1.6.5 Application

MPTTR is intended to limit the motor thermal level to predetermined values during the abnormal motor operating conditions. This prevents a premature motor insulation failure.

The abnormal conditions result in overheating and include overload, stalling, failure to start, high ambient temperature, restricted motor ventilation, reduced speed operation, frequent starting or jogging, high or low line voltage or frequency, mechanical failure of the driven load, improper installation and unbalanced line voltage or single phasing. The protection of insulation failure by the implementation of current sensing cannot detect some of these conditions, such as restricted ventilation. Similarly, the protection by sensing temperature alone can be inadequate in cases like frequent starting or jogging. The thermal overload protection addresses these deficiencies to a larger extent by deploying a motor thermal model based on load current.

The thermal load is calculated using the true RMS value and negative sequence value of the current. The heating up of the motor is determined by the square value of the load current. However, while calculating the thermal level, the rated current should be re-rated or de-rated depending on the value of the ambient temperature. Apart from current, the rate at which motor heats up or cools is governed by the time constant of the motor.

Setting the weighting factor

There are two thermal curves: one which characterizes the short-time loads and long-time overloads and which is also used for tripping and another which is used for monitoring the thermal condition of the motor. The value of the *Weighting factor p* setting determines the ratio of the thermal increase of the two curves.

The "*Weighting factor p* = to 100 percent", it produces a pure single time constant thermal unit, which is used for application with the cables. As presented in Figure 68, the hot curve with the value of "*Weighting factor p* = 100 percent" only allows an operate time which is about 10 percent of that with no prior load. For example, when the set time constant is 640 seconds, the operate time with the prior load 1 x FLC (full Load Current) and overload factor 1.05 is only 2 seconds, even if the motor could withstand at least 5 to 6 seconds. To allow the use of the full capacity of the motor, a lower value of *Weighting factor p* should be used.

Normally, an approximate value of half of the thermal capacity is used when the motor is running at full load. Thus by setting "*Weighting factor p* = 50 percent", the IED notifies a 45 to 50 percent thermal capacity use at full load.

For direct-on-line started motors with hot spot tendencies, the value of *Weighting factor p* is typically set to "50 percent", which will properly distinguish between short-time thermal stress and long-time thermal history. After a short period of thermal stress, for example a motor startup, the thermal level starts to decrease quite sharply, simulating the leveling out of the hot spots. Consequently, the probability of successive allowed startups increases.

When protecting the objects without hot spot tendencies, for example motors started with soft starters, and cables, the value of *Weighting factor p* is set to "100 percent". With the value of *Weighting factor p* set to "100 percent", the thermal level decreases slowly after a heavy load condition. This makes the protection suitable for applications where no hot spots are expected. Only in special cases where the thermal overload protection is required to follow the characteristics of the object to be protected more closely and the thermal capacity of the object is very well known, a value between "50" and "100 percent" is required.

For motor applications where, for example, two hot starts are allowed instead of three cold starts, the value of the setting "*Weighting factor p*= 40 percent" has proved to be useful. Setting the value of *Weighting factor p* significantly below "50 percent" should be handled carefully as there is a possibility to overload the protected object as a thermal unit might allow too many hot starts or the thermal history of the motor has not sufficiently been taken into account.

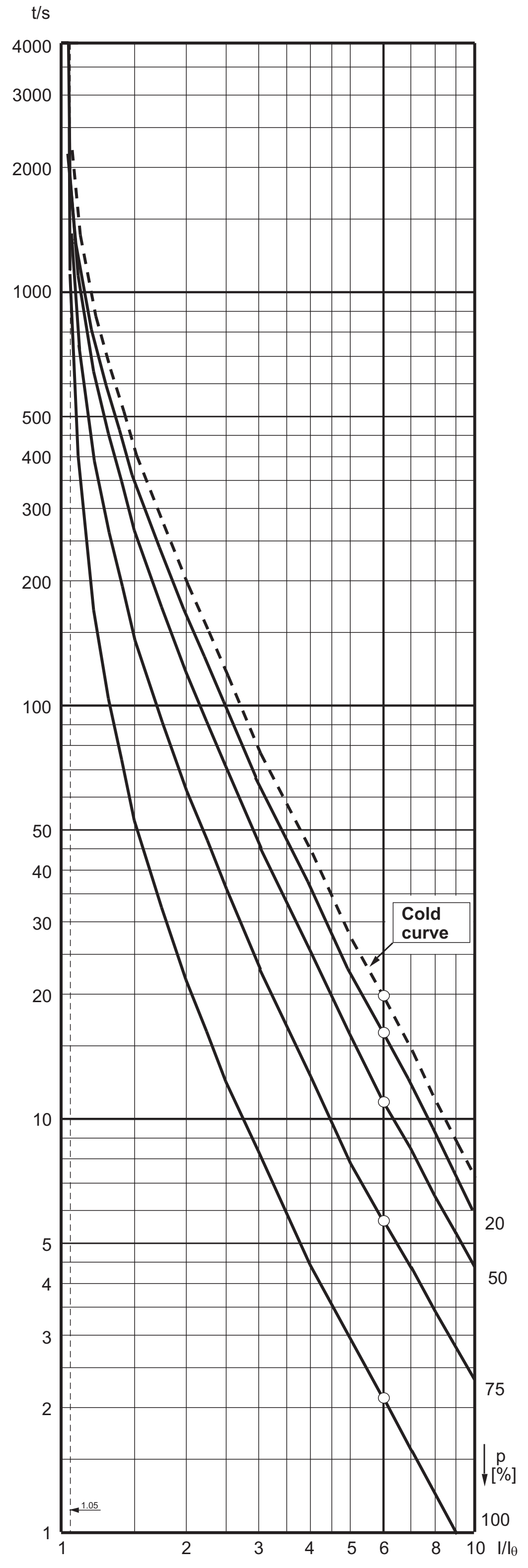


Figure 68: The influence of Weighting factor p at prior load 1xFLC, timeconstant = 640 sec, and Overload factor = 1.05

Setting the overload factor

The value of the *Overload factor* allows utilization of the entire thermal capacity of the motor. Typically, value 1.05 is used. The value of the *Overload factor* should be high for a motor to take higher overload without tripping.

Setting the negative sequence factor

During the unbalance condition, the symmetry of the stator currents is disturbed and a counter-rotating negative phase sequence (NPS) current is set up. An increased stator current causes additional heating in the stator and the NPS current excessive heating in the rotor. Also mechanical problems like rotor vibration can occur.

The most common cause of unbalance for three-phase motors is the loss of phase resulting in an open fuse, connector or conductor. Often mechanical problems can be more severe than the heating effects and therefore a separate unbalance protection is used.

Unbalances in other connected loads in the same busbar can also affect the motor. A voltage unbalance typically produces 5 to 7 times higher current unbalance. Because the thermal overload protection is based on the highest TRMS value of the phase current, the additional heating in stator winding is automatically taken into account. For more accurate thermal modeling, the *Negative Seq factor* setting is used for taking account of the rotor heating effect.

$$Negative\,Seq\ factor = \frac{R_{R2}}{R_{R1}}$$

(Equation 9)

R_{R2} rotor positive sequence resistance

R_{R1} rotor negative sequence resistance

A conservative estimate for the setting can be calculated:

$$Negative\,Seq\ factor = \frac{175}{I_{LR}^2}$$

I_{LR} locked rotor current (multiple of set *Rated current*). The same as the startup current at the beginning of the motor startup.

For example, if the rated current of a motor is 230 A, startup current is 5.7 x I_r,

$$Negative\,Seq\ factor = \frac{175}{5.7^2} = 5.4$$

Setting the thermal restart level

The restart disable level can be calculated as follows:

$$\theta_i = 100\% - \left(\frac{startup\ time\ of\ the\ motor}{operate\ time\ when\ no\ prior\ load} \times 100\% + margin \right)$$

(Equation 10)

For instance, if the startup time of the motor is 11 seconds and the calculated operate time of the thermal protection stage with no prior load is 25 seconds, one motor startup uses 11/25 ≈ 45 percent of the thermal capacity of the motor. Therefore, the restart disable level must be set to below 100 percent - 45 percent = 55 percent, for example to 50 percent (100 percent - (45 percent + margin), where margin is 5 percent).

Setting the thermal alarm level

Tripping due to high overload is avoided by reducing the load of the motor on a prior alarm.

The value of *Alarm thermal value* is set to a level which allows the use of the full thermal capacity of the motor without causing a trip due to a long overload time. Generally, the prior alarm level is set to a value of 80 to 90 percent of the trip level.

4.1.6.6 Signals

Table 121: MPTTR Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
START_EMERG	BOOLEAN	0=False	Signal for indicating the need for emergency start

Table 122: MPTTR Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
ALARM	BOOLEAN	Thermal Alarm
BLK_RESTART	BOOLEAN	Thermal overload indicator, to inhibit restart

4.1.6.7 Settings

Table 123: MPTTR Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Overload factor	1.00...1.20		0.01	1.05	Overload factor (k)
Alarm thermal value	50.0...100.0	%	0.1	95.0	Thermal level above which function gives an alarm
Restart thermal Val	20.0...80.0	%	0.1	40.0	Thermal level above which function inhibits motor restarting
Negative Seq factor	0.0...10.0		0.1	0.0	Heating effect factor for negative sequence current
Weighting factor p	20.0...100.0	%	0.1	50.0	Weighting factor (p)
Time constant normal	80...4000	s	1	320	Motor time constant during the normal operation of motor
Time constant start	80...4000	s	1	320	Motor time constant during the start of motor
Time constant stop	80...8000	s	1	500	Motor time constant during the standstill condition of motor
Env temperature mode	1=FLC Only 3=Set Amb Temp			1=FLC Only	Mode of measuring ambient temperature
Env temperature Set	-20.0...70.0	°C	0.1	40.0	Ambient temperature used when no external temperature measurement available

Table 124: MPTTR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Rated current	0.30...2.00	xIn	0.01	1.00	Rated current (FLC) of the motor
Initial thermal Val	0.0...100.0	%	0.1	74.0	Initial thermal level of the motor

4.1.6.8 Monitored data

Table 125: MPTTR Monitored data

Name	Type	Values (Range)	Unit	Description
TEMP_RL	FLOAT32	0.00...9.99		The calculated temperature of the protected object relative to the operate level
TEMP_AMB	FLOAT32	-99...999	°C	The ambient temperature used in the calculation
THERMLEV_ST	FLOAT32	0.00...9.99		Thermal level at beginning of motor startup
THERMLEV_END	FLOAT32	0.00...9.99		Thermal level at the end of motor startup situation
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
T_ENARESTART	INT32	0...99999	s	Estimated time to reset of block restart
MPTTR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status
Therm-Lev	FLOAT32	0.00...9.99		Thermal level of protected object (1.00 is the operate level)

4.1.6.9 Technical data

Table 126: MPTTR Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	Current measurement: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Operate time accuracy[1)]	±2.0% of the theoretical value or ±0.50 s

1) Overload current > 1.2 x Operate level temperature

4.2 Earth-fault protection

4.2.1 Non-directional earth-fault protection EFxPTOC

4.2.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Non-directional earth-fault protection - Low stage	EFLPTOC	I0>	51N-1
Non-directional earth-fault protection - High stage	EFHPTOC	I0>>	51N-2
Non-directional earth-fault protection - Instantaneous stage	EFIPTOC	I0>>>	50N/51N

4.2.1.2 Function block

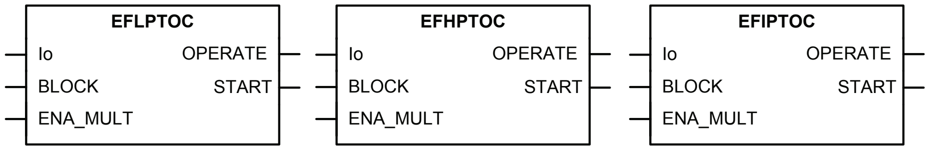


Figure 69: Function block

4.2.1.3 Functionality

The earth-fault function EFxPTOC is used as non-directional earth-fault protection for feeders.

The function starts and operates when the residual current exceeds the set limit. The operate time characteristic for low stage EFLPTOC and high stage EFHPTOC can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). The instantaneous stage EFIPTOC always operates with the DT characteristic.

In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

The function contains a blocking functionality. It is possible to block function outputs, timers or the function itself, if desired.

4.2.1.4 Operating principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the non-directional earth-fault protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

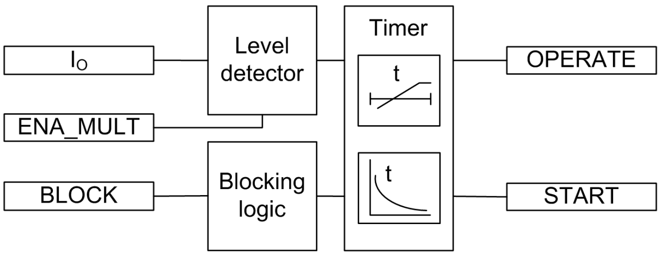


Figure 70: Functional module diagram. I_0 represents the residual current.

Level detector

The measured residual current is compared to the set *Start value*. If the measured value exceeds the set *Start value*, the level detector sends an enabling signal to the timer module. If the ENA_MULT input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The IED does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

The start value multiplication is normally done when the inrush detection function (INRPHAR) is connected to the ENA_MULT input. See more details on the inrush detection function in the relevant chapter.

Timer

Once activated, the timer activates the START output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the OPERATE output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the START output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT operate and reset times.

The setting parameter *Minimum operate time* defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.2.1.5 Measurement modes

The function operates on three alternative measurement modes: "RMS", "DFT" and "Peak-to-Peak". The measurement mode is selected with the *Measurement mode* setting.

Table 127: Measurement modes supported by EFxPTOC stages

Measurement mode	Supported measurement modes		
	EFLPTOC	EFHPTOC	EFIPTOC
RMS	x	x	
DFT	x	x	
Peak-to-Peak	x	x	x

For a detailed description of the measurement modes, see the General function block features section in this manual.

4.2.1.6 Timer characteristics

EFxPTOC supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* and *Type of reset curve* settings. When the DT characteristic is selected, it is only affected by the *Operate delay time* and *Reset delay time* settings.

The relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The following characteristics, which comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages:

Table 128: Timer characteristics supported by different stages

Operating curve type	Supported by	
	EFLPTOC	EFHPTOC
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	x
(10) IEC Very Inverse	x	x
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	x
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable curve	x	x
(18) RI type	x	
(19) RD type	x	

EFIPTOC supports only definite time characteristics.

For a detailed description of timers, see the General function block features section in this manual.

Table 129: Reset time characteristics supported by different stages

Reset curve type	Supported by		
	EFLPTOC	EFHPTOC	Note
(1) Immediate	x	x	Available for all operate time curves
(2) Def time reset	x	x	Available for all operate time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

The *Type of reset curve* setting does not apply to EFIPTOC or when the DT operation is selected. The reset is purely defined by the *Reset delay time* setting.

4.2.1.7 Application

EFxPTOC is designed for protection and clearance of earth faults in distribution and sub-transmission networks where the neutral point is isolated or earthed via a resonance coil or through low resistance. It also applies to solidly earthed networks and earth-fault protection of different equipment connected to the power systems, such as shunt capacitor bank or shunt reactors and for back-up earth-fault protection of power transformers.

Many applications require several steps using different current start levels and time delays. EFxPTOC consists of three different protection stages:

- Low (EFLPTOC)
- High (EFHPTOC)
- Instantaneous (EFIPTOC).

EFLPTOC contains several types of time-delay characteristics. EFHPTOC and EFIPTOC are used for fast clearance of serious earth faults.

4.2.1.8 Signals

Table 130: EFLPTOC Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 131: EFHPTOC Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 132: EFIPTOC Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 133: EFLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 134: EFHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 135: EFIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.1.9 Settings

Table 136: EFLPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...5.000	xIn	0.005	0.010	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 137: EFLPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
I0 signal Sel	1=Measured I0 2=Calculated I0			1=Measured I0	Selection for used I0 signal

Table 138: EFHPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 9=IEC Norm. inv. 10=IEC Very inv. 12=IEC Ext. inv. 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 139: EFHPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve
I0 signal Sel	1=Measured I0 2=Calculated I0			1=Measured I0	Selection for used I0 signal

Table 140: EFIPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	1.00...40.00	xIn	0.01	1.00	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Operate delay time	20...200000	ms	10	20	Operate delay time

Table 141: EFIPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
I0 signal Sel	1=Measured I0 2=Calculated I0			1=Measured I0	Selection for used I0 signal

4.2.1.10 Monitored Data

Table 142: EFLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFLPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 143: EFHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFHPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 144: EFIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFIPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.1.11 Technical data

Table 145: EFxPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
	EFLPTOC	±1.5% of the set value or ±0.002 x I_n		
	EFHPTOC and EFIPTOC	±1.5% of set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n)		
Start time [1)2)]		Minimum	Typical	Maximum
	EFIPTOC: I_{Fault} = 2 x set *Start value* I_{Fault} = 10 x set *Start value*	16 ms 11 ms	19 ms 12 ms	23 ms 14 ms
	EFHPTOC and EFLPTOC: I_{Fault} = 2 x set *Start value*	22 ms	24 ms	25 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 30 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [3)]		
Suppression of harmonics		RMS: No suppression DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression		

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 x I_n, f_n = 50 Hz, earth-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 x I_n, *Start value* multiples in range of 1.5 to 20

4.2.1.12 Technical revision history

Table 146: EFIPTOC Technical revision history

Technical revision	Change
C	Minimum and default values changed to 20 ms for the *Operate delay time* setting Minimum value changed to 1.00 x I_n for the *Start value* setting.

Table 147: EFHPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting

Table 148: EFLPTOC Technical revision history

Technical revision	Change
C	*Start value* step changed to 0.005

4.2.2 Directional earth-fault protection DEFxPDEF

4.2.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional earth-fault protection - Low stage	DEFLPDEF	I0>->	67N-1
Directional earth-fault protection - High stage	DEFHPDEF	I0>>->	67N-2

4.2.2.2 Function block

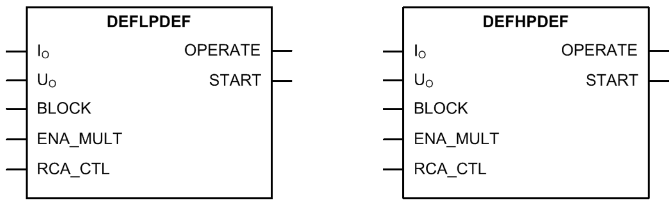


Figure 71: Function block

4.2.2.3 Functionality

The earth-fault function DEFxPDEF is used as directional earth-fault protection for feeders.

The function starts and operates when the residual current and residual voltage (-U_0) exceed the set limits and the angle between them is inside the set operating sector. The operate time characteristic for low stage (DEFLPDEF) and high stage (DEFHPDEF) can be selected to be either definite time (DT) or inverse definite minimum time (IDMT).

In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current-dependent timer characteristics.

The function contains a blocking functionality. It is possible to block function outputs, timers or the function itself, if desired.

4.2.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the directional earth-fault protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

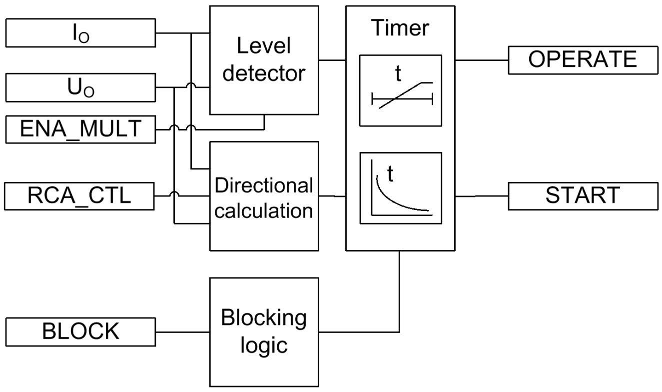


Figure 72: Functional module diagram. I_0 and U_0 represent the residual current and residual voltage.

Level detector

The measured residual current is compared to the set *Start value*. For directional operation, the residual voltage (-Uo) also needs to be compared to the set *Voltage start value*. If both limits are exceeded, the level detector sends an enabling signal to the timer module. When the *Enable voltage limit* setting is set to "False," *Voltage start value* has no effect and the level detection is purely based on the residual current. If the `ENA_MULT` input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

The IED does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

The start value multiplication is normally done when the inrush detection function (INRPHAR) is connected to the `ENA_MULT` input. See more details on the inrush detection function in the relevant chapter.

Directional calculation

The directional calculation module monitors the angle between the measured residual current and residual voltage (-Uo). When the angle is in the operation sector, the module sends the enabling signal to the timer module.

For defining the operation sector, there are five modes available through the *Operation mode* setting.

Table 149: Operation modes

Operation mode	Description
Phase angle	The operating sectors for forward and reverse are defined with the settings *Min forward angle*, *Max forward angle*, *Min reverse angle* and *Max reverse angle*.
IoSin	The operating sectors are defined as "forward" when the mathematical expression has a positive value and "reverse" when the value is negative
IoCos	As "IoSin" mode. Only cosine is used for calculating the operation current.
Phase angle 80	The sector maximum values are frozen to 80 degrees, respectively. Only *Min forward angle* and *Min reverse angle* are settable.
Phase angle 88	The sector maximum values are frozen to 88 degrees. Otherwise as "Phase angle 80" mode.

The directional operation can be selected with the *Directional mode* setting. "Non-directional", "Forward" or "Reverse" operation can be selected. The operation criterion is selected with the *Operation mode* setting. By setting *Allow Non Dir* to "True", non-directional operation is allowed when directional information is invalid.

The *Characteristic angle* setting is used in the "Phase angle" mode to adjust the operation according to the method of neutral point earthing so that in an isolated network the *Characteristic angle* (φ_{RCA}) = -90° and in a compensated network φ_{RCA} = 0°. In addition, the characteristic angle can be changed via the control signal `RCA_CTL`, in which case the alternatives are -90° and 0°. The operation of `RCA_CTL` depends on the *Characteristic angle* setting.

The *Correction angle* setting can be used to improve selectivity when there are inaccuracies due to measurement transformers. The setting decreases the operation sector. The correction can only be used with the "IoCos" or "IoSin" modes.

The minimum signal level which allows directional operation can be set using the *Min operate current* and *Min operate voltage* settings.

When polarizing quantity (residual voltage (-Uo)) is inverted because of switched voltage measurement cables, the correction can be done by setting *Pol reversal* to "True", which turns polarizing quantity by 180 degrees.

For definitions of the different directional earth-fault characteristics, see the Directional earth-fault characteristics section in this manual.

The directional calculation module calculates several values which are presented in the monitored data.

Table 150: Monitored data values

Monitored data values	Description
FAULT_DIR	The detected direction of fault during fault situations, that is, when START output is active.
DIRECTION	The momentary operating direction indication output.
ANGLE	Also called operating angle, shows the angle difference between the U_0 (polarizing quantity) and I_0 (operating quantity).
ANGLE_RCA	The angle difference between the operating angle and *Characteristic angle*, that is, ANGLE_RCA = ANGLE – *Characteristic angle*.
I_OPER	The current that is used for fault detection. If the *Operation mode* setting is "Phase angle", "Phase angle 80" or "Phase angle 88", I_OPER is the measured neutral current. If the *Operation mode* setting is "IoSin", I_OPER is calculated as follows I_OPER = I_0 x sin(ANGLE). If the *Operation mode* setting is "IoCos", I_OPER is calculated as follows I_OPER = I_0 x cos(ANGLE).

Monitored data values are accessible on the LHMI or through tools via communications.

Timer

Once activated, the timer activates the START output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the OPERATE output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate"

causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the START output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT operate and reset times.

The setting parameter *Minimum operate time* defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.2.2.5 Directional earth-fault principles

In many cases it is difficult to achieve selective earth-fault protection based on the magnitude of residual current only. To obtain a selective earth-fault protection scheme, it is necessary to take the phase angle of I_0 into account. This is done by comparing the phase angle of I_0 to that of the residual voltage ($-U_0$).

Relay characteristic angle

The *Characteristic angle*, also known as Relay Characteristic Angle (RCA), Relay Base Angle or Maximum Torque Angle (MTA), is used in the "Phase angle" mode to turn the directional characteristic, if the expected fault current angle does not coincide with the polarizing quantity to produce the maximum torque. That is, RCA is the angle between the maximum torque line and polarizing quantity. If the polarizing quantity is in phase with the maximum torque line, RCA is 0 degrees. The angle is positive if operating current lags the polarizing quantity and negative if it leads the polarizing quantity.

Example 1.

The "Phase angle" mode is selected, compensated network (φRCA = 0 deg)

=> *Characteristic angle* = 0 deg

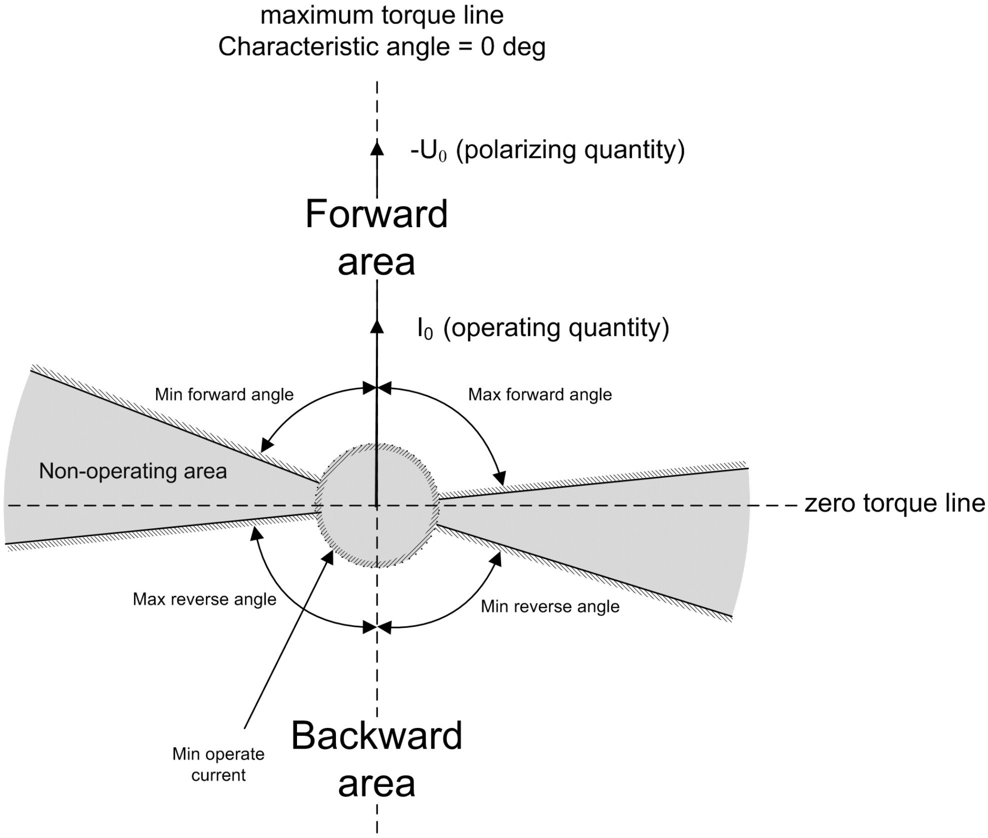


Figure 73: Definition of the relay characteristic angle, RCA=0 degrees in a compensated network

Example 2.

The "Phase angle" mode is selected, solidly earthed network (φRCA = +60 deg)

=> *Characteristic angle* = +60 deg

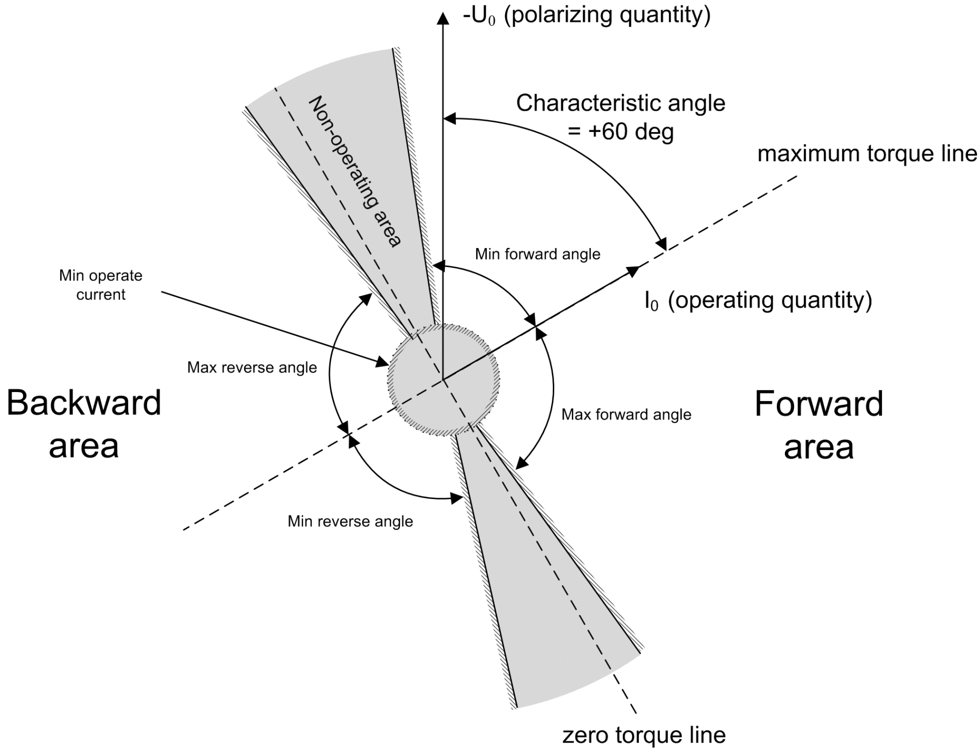


Figure 74: Definition of the relay characteristic angle, RCA=+60 degrees in a solidly earthed network

Example 3.

The "Phase angle" mode is selected, isolated network (φRCA = -90 deg)

=> *Characteristic angle* = -90 deg

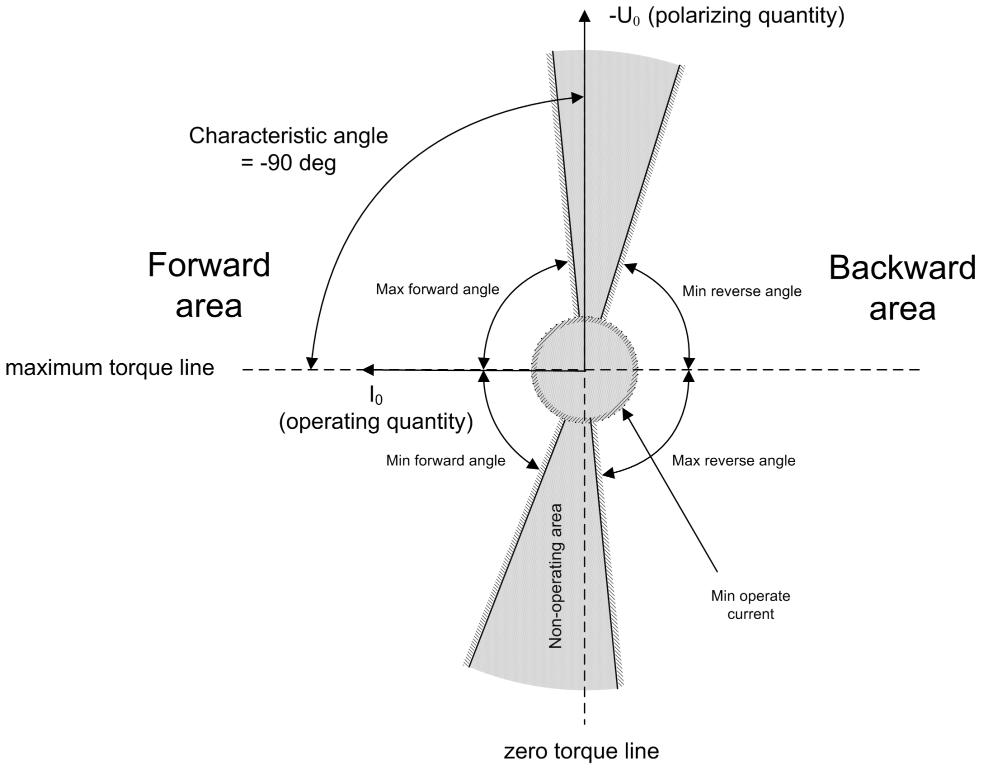


Figure 75: Definition of the relay characteristic angle, RCA=–90 degrees in an isolated network

Directional earth-fault protection in an isolated neutral network

In isolated networks, there is no intentional connection between the system neutral point and earth. The only connection is through the line-to-earth capacitances (C_0) of phases and leakage resistances (R_0). This means that the residual current is mainly capacitive and has a phase shift of –90 degrees compared to the residual voltage ($-U_0$). Consequently, the relay characteristic angle (RCA) should be set to -90 degrees and the operation criteria to $I_0\sin(\varphi)$ or phase angle. The width of the operating sector in the phase angle criteria can be selected with the settings *Min forward angle*, *Max forward angle*, *Min reverse angle* or *Max reverse angle*. The figure below describes how earth fault current is defined in isolated neutral networks.

For definitions of different directional earth-fault characteristics, refer to the Technical manual.

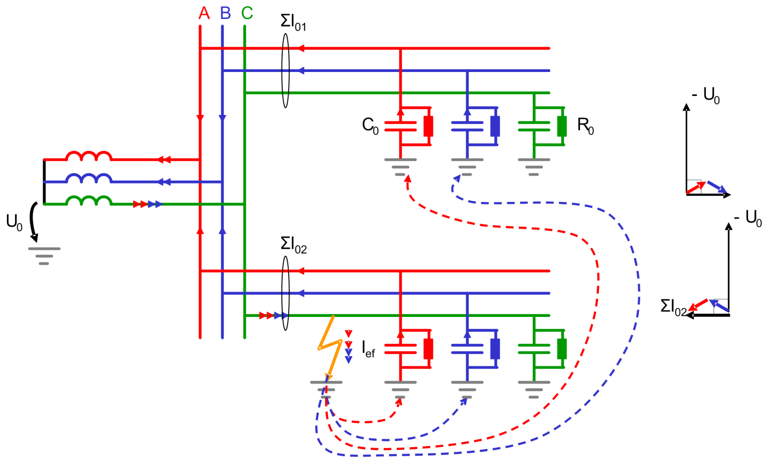


Figure 76: Earth-fault situation in an isolated network

Directional earth-fault protection in a compensated network

In compensated networks, the capacitive fault current and the inductive resonance coil current compensate each other. The protection cannot be based on the reactive current measurement, since the current of the compensation coil would disturb the operation of the relays. In this case, the selectivity is based on the measurement of the active current component. The magnitude of this component is often small and must be increased by means of a parallel resistor in the compensation equipment. When measuring the resistive part of the residual current, the relay characteristic angle (RCA) should be set to 0 degrees and the operation criteria to $I_0\cos(\varphi)$ or phase angle. The figure below describes how earth fault current is defined in compensated neutral networks.

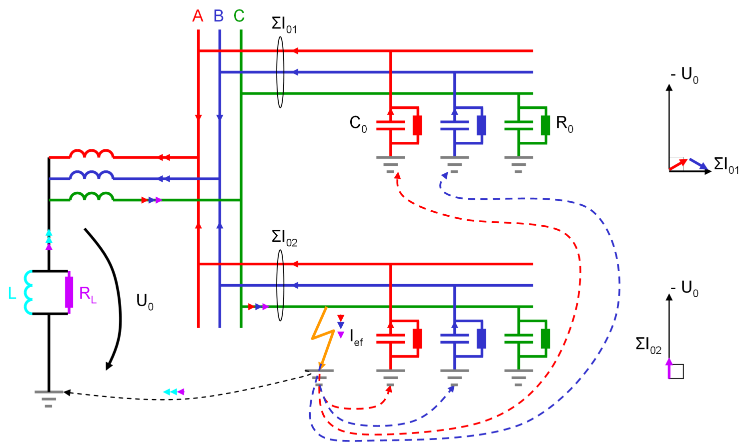


Figure 77: Earth-fault situation in a compensated network

The Petersen coil or the earthing resistor may be temporarily out of operation. To keep the protection scheme selective, it is necessary to update the characteristic angle setting accordingly. This is done with an auxiliary input in the relay which receives a signal from an auxiliary switch of the disconnector of the Petersen coil in compensated networks or of the earthing resistor in earthed networks. As a result the characteristic angle is set automatically to suit the earthing method used. The RCA_CTL input can be used to change the I_0 characteristic:

Table 151: Relay characteristic angle control in $I_0 sin(φ)$ and $I_0 cos(φ)$ operation criteria

Operation criteria setting:	RCA_CTL = FALSE	RCA_CTL = TRUE
I_0sin(φ)	Actual operation criteria: I_0sin(φ)	Actual operation criteria: I_0cos(φ)
I_0cos(φ)	Actual operation criteria:I_0cos(φ)	Actual operation criteria: I_0sin(φ)

Table 152: Characteristic angle control in phase angle operation mode

Characteristic angle setting	RCA_CTL = FALSE	RCA_CTL = TRUE
-90°	φRCA = -90°	φRCA = 0°
0°	φRCA = 0°	φRCA = -90°

Usage of the extended phase angle characteristic

In addition to the RCA_CTL input, the extended phase angle characteristic can be used when the compensation coil is temporarily disconnected in compensated networks. When the extended operation area is used, the operation area is wide enough to detect earth faults selectively in compensated networks regardless of whether the compensation coil is connected or not. Therefore, the RCA_CTL input is not required if the extended operation area is used.

Sometimes the distance between the start point and the IED is long which makes it impractical to apply the scheme based on signal wiring between the relay and the Petersen coil or the earthing resistor. This is the case for instance, when a directional earth-fault relay is used in an MV-switching substation some kilometers from the HV/MV -substation in which the earthing facilities are located. Another example is when HV/MV-substations are connected in parallel but located far from each other.

It is easy to give the tripping sector such a width that all possible directions of the I_0-phasors of a faulty line are covered by one and the same sector. Thus, the problem of setting the characteristic angle according to the earthing status of the network is easily solved. There is no need to change any settings when a Petersen coil or an earthing resistor is switched on or off. Auxiliary switches and other pieces of extra hardware are no longer required for ensuring the selectivity of the directional earth-fault protection.

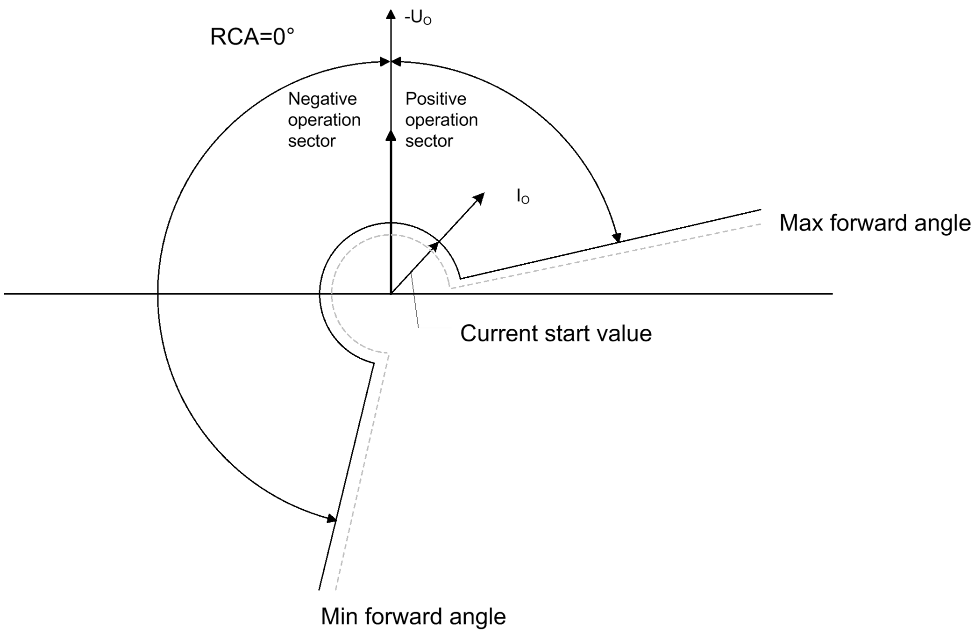


Figure 78: Extended operation area in directional earth-fault protection

4.2.2.6 Measurement modes

The function operates on three alternative measurement modes: "RMS", "DFT" and "Peak-to-Peak". The measurement mode is selected with the *Measurement mode* setting.

Table 153: Measurement modes supported by DEFxPDEF stages

Measurement mode	Supported measurement modes	
	DEFLPDEF	DEFHPDEF
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

For a detailed description of the measurement modes, see the General function block features section in this manual.

4.2.2.7 Timer characteristics

DEFxPDEF supports both DT and IDMT characteristics. The user can select the timer characteristics with the *Operating curve type* setting.

The relay provides 16 IDMT characteristics curves, of which seven comply with the IEEE C37.112 and six with the IEC 60255-3 standard. Two curves follow the special characteristics of ABB praxis and are referred to as RI and RD. In addition to this, a user programmable curve can be used if none of the standard curves are applicable. The user can choose the DT characteristic by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

The following characteristics, which comply with the list in the IEC 61850-7-4 specification, indicate the characteristics supported by different stages:

Table 154: Timer characteristics supported by different stages

Operating curve type	Supported by	
	DEFLPDEF	DEFHPDEF
(1) ANSI Extremely Inverse	x	x
(2) ANSI Very Inverse	x	
(3) ANSI Normal Inverse	x	x
(4) ANSI Moderately Inverse	x	
(5) ANSI Definite Time	x	x
(6) Long Time Extremely Inverse	x	
(7) Long Time Very Inverse	x	
(8) Long Time Inverse	x	
(9) IEC Normal Inverse	x	
(10) IEC Very Inverse	x	
(11) IEC Inverse	x	
(12) IEC Extremely Inverse	x	
(13) IEC Short Time Inverse	x	
(14) IEC Long Time Inverse	x	
(15) IEC Definite Time	x	x
(17) User programmable curve	x	x
(18) RI type	x	
(19) RD type	x	

For a detailed description of the timers, see the General function block features section in this manual.

Table 155: Reset time characteristics supported by different stages

Reset curve type	Supported by		
	DEFLPDEF	DEFHPDEF	Note
(1) Immediate	x	x	Available for all operate time curves
(2) Def time reset	x	x	Available for all operate time curves
(3) Inverse reset	x	x	Available only for ANSI and user programmable curves

4.2.2.8 Directional earth-fault characteristics

Phase angle characteristic with an additional operating sector

The operation criterion phase angle is selected with the *Operation mode* setting using the value "Phase angle".

When the phase angle criterion is used, the function indicates whether the operating quantity is within the forward or reverse operation sector or within the non-directional sector.

The forward and reverse sectors are defined separately. The forward operation area is limited with the *Min forward angle* and *Max forward angle* settings. The reverse operation area is limited with the *Min reverse angle* and *Max reverse angle* settings.

The sector limits are always given as positive degree values.

In the forward operation area, the *Max forward angle* setting gives the clockwise sector and the *Min forward angle* setting correspondingly the anti-clockwise sector, measured from the *Characteristic angle* setting.

In the reverse operation area, the *Max reverse angle* setting gives the clockwise sector and the *Min reverse angle* setting correspondingly the anti-clockwise sector, measured from the complement of the *Characteristic angle* setting (180 degrees phase shift) .

The relay characteristic angle (RCA) is set to positive if the operating current lags the polarizing quantity. It is set to negative if it leads the polarizing quantity.

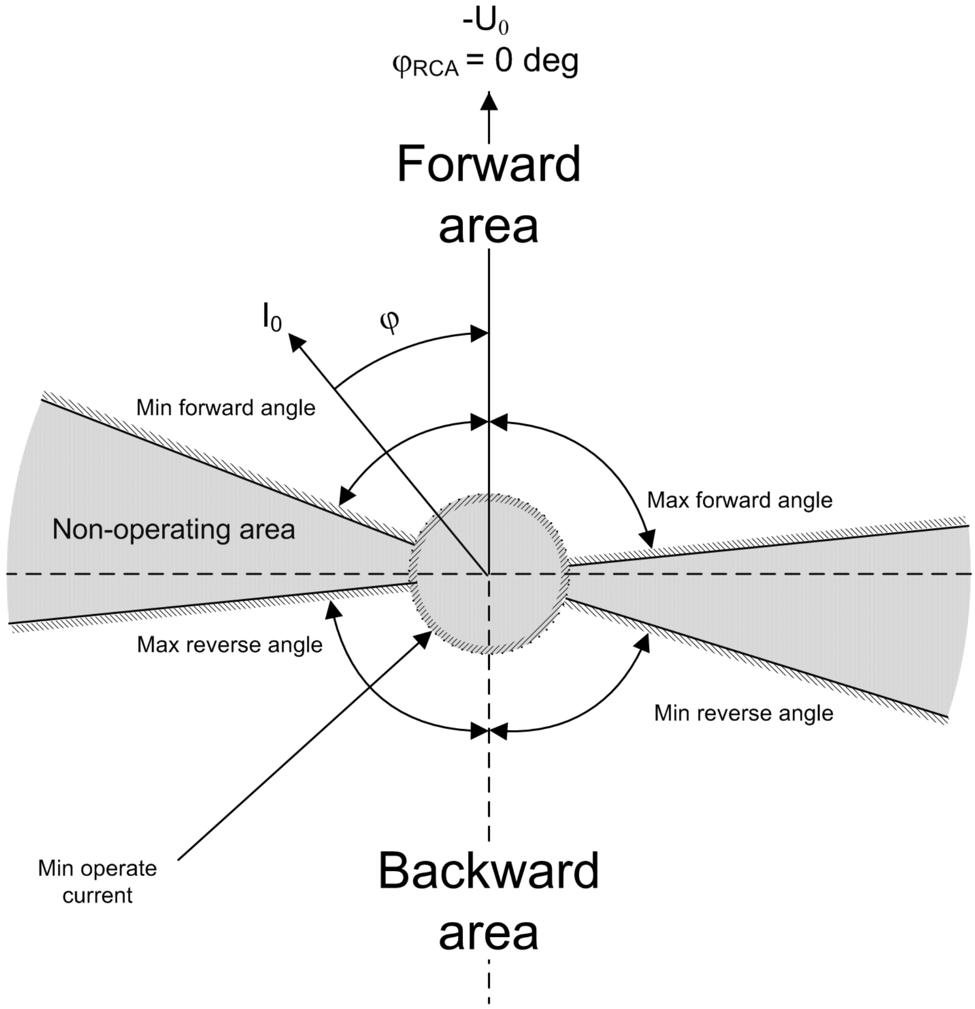


Figure 79: Configurable operating sectors in phase angle characteristic

Table 156: Momentary operating direction

Fault direction	The value for DIRECTION
Angle between the polarizing and operating quantity is not in any of the defined sectors.	0 = unknown
Angle between the polarizing and operating quantity is in the forward sector.	1= forward
Angle between the polarizing and operating quantity is in the reverse sector.	2 = backward
Angle between the polarizing and operating quantity is in both the forward and the reverse sectors, that is, the sectors are overlapping.	3 = both

Directional operation is not allowed (the setting *Allow non dir* is "False") when the measured polarizing or operating quantities are not valid, that is, their magnitude is below the set minimum values. The minimum values can be defined with the settings *Min operate current* and *Min operate voltage*. In case of low magnitudes, the FAULT_DIR and DIRECTION outputs are set to 0 = unknown, except when the *Allow non dir* setting is "True". In that case, the function is allowed to operate in the directional mode as non-directional, since the directional information is invalid.

The RCA_CTL input is used in compensated networks where the compensation coil sometimes can be disconnected. When the coil is disconnected, the compensated network becomes isolated and the *Characteristic angle* setting (φRCA) must be changed. This can be done automatically with the RCA_CTL input. Note that the RCA_CTL input only works when the *Characteristic angle* setting is set to exactly -90 degrees or 0 degrees. The value of the input affects the *Characteristic angle* setting in the following way:

Table 157: Characteristic angle control in phase angle operation mode

Characteristic angle setting	RCA_CTL = "False"	RCA_CTL = "True"
-90°	φRCA = -90°	φRCA = 0°
0°	φRCA = 0°	φRCA = -90°

I_0sin(φ) and I_0cos(φ) criteria

A more modern approach to directional protection is the active or reactive current measurement. The operating characteristic of the directional operation depends on the earthing principle of the network. The I_0sin(φ) characteristic is used in an isolated network, measuring the reactive component of the fault current caused by the earth capacitance. The I_0cos(φ) characteristic is used in a compensated network, measuring the active component of the fault current.

The operation criteria I_0sin(φ) and I_0cos(φ) are selected with the *Operation mode* setting using the values "IoSin" or "IoCos", respectively.

In isolated networks, I_0sin(φ) does not differ from the phase angle criterion, since the phase angle of the operating quantity is fairly close to -90 degrees. Furthermore, in completely compensated networks the fault current is usually mostly resistive. Therefore, the phase angle and I_0cos(φ) criteria are equally sensitive. However, if the fault is in the background network, the fault current of a sound and healthy line is almost fully capacitive and its phase angle is close to the operation area of the component. Therefore, the I_0cos(φ) characteristic is recommended, since the risk of faulty operation is smaller than with the phase angle criterion.

The angle correction setting can be used to improve selectivity. The setting decreases the operation sector. The correction can only be used with the I_0sin(φ) or I_0cos(φ) criterion. The RCA_CTL input is used to change the I_0 characteristic:

Table 158: Relay characteristic angle control in I_0sin(φ) and I_0cos(φ) operation criterion

Operation criteria:	`RCA_CTL` = "False"	`RCA_CTL` = "True"
I_0sin(φ)	Actual operation criterion: I_0sin(φ)	Actual operation criterion: I_0cos(φ)
I_0cos(φ)	Actual operation criterion: I_0cos(φ)	Actual operation criterion: I_0sin(φ)

When the I_0sin(φ) or I_0cos(φ) criterion is used, the component indicates a forward or reverse-type fault through the `FAULT_DIR` and `DIRECTION` outputs, in which 1 equals a forward fault and 2 equals a reverse fault. Directional operation is not allowed (the *Allow non dir* setting is "False") when the measured polarizing or operating quantities are not valid, that is, when their magnitude is below the set minimum values. The minimum values can be defined with the *Min operate current* and *Min operate voltage* settings. In case of low magnitude, the `FAULT_DIR` and `DIRECTION` outputs are set to 0 = unknown, except when the *Allow non dir* setting is "True". In that case, the function is allowed to operate in the directional mode as non-directional, since the directional information is invalid.

The calculated I_0sin(φ) or I_0cos(φ) current used in direction determination can be read through the `I_OPER` monitored data. The value can be passed directly to a decisive element, which provides the final start and operate signals.

The `I_OPER` monitored data gives an absolute value of the calculated current. Otherwise, the value of a current in a reverse area is negative.

The following examples show the characteristics of the different operation criteria:

Example 1.

I_0sin(φ) criterion selected, forward-type fault

=> `FAULT_DIR = 1`

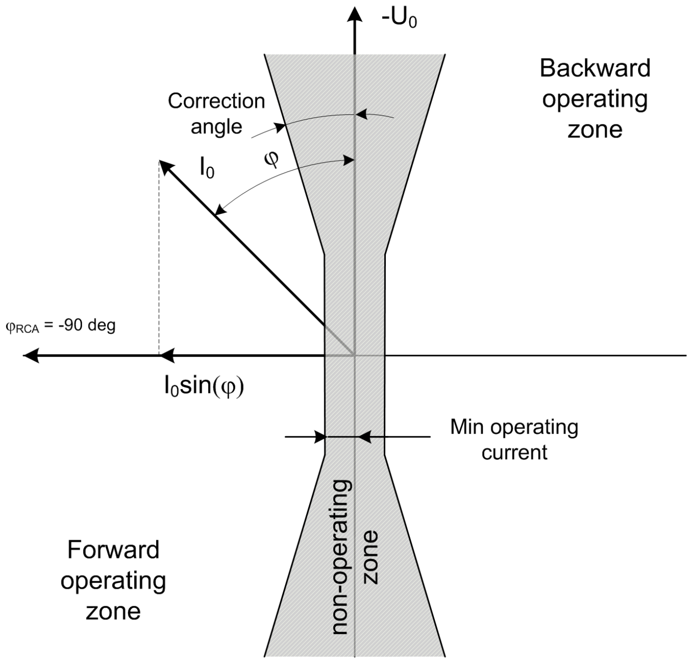


Figure 80: Operating characteristic I_0sin(φ) in forward fault

The operating sector is limited by Angle correction, that is, the operating sector is 180 degrees - 2*(Angle correction).

Example 2.

I_0sin(φ) criterion selected, reverse-type fault

```
=> FAULT_DIR = 2
```

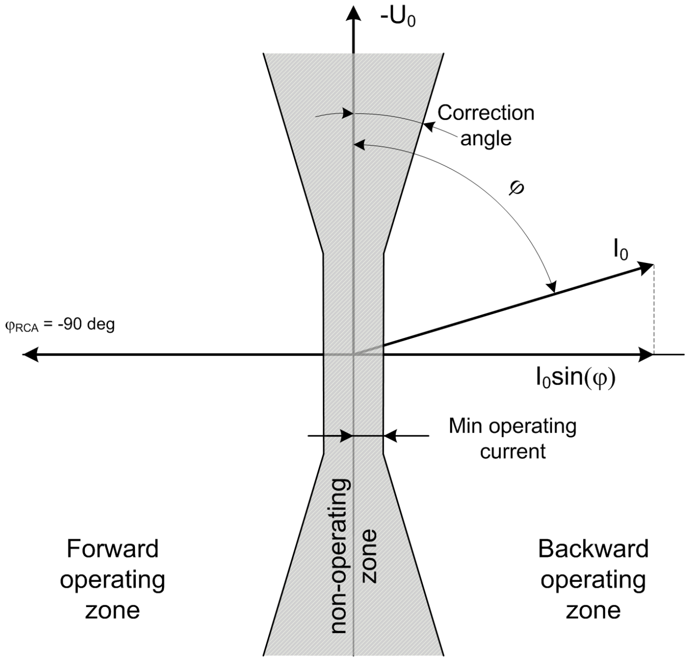


Figure 81: Operating characteristic $I_0sin(φ)$ in reverse fault

Example 3.

I_0cos(φ) criterion selected, forward-type fault

=> `FAULT_DIR = 1`

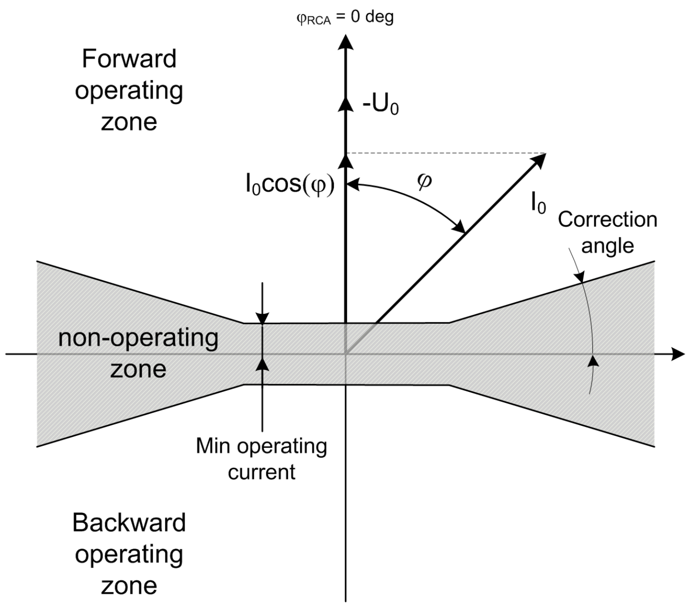


Figure 82: Operating characteristic $I_0cos(φ)$ in forward fault

Example 4.

$I_0\cos(\varphi)$ criterion selected, reverse-type fault

`=> FAULT_DIR = 2`

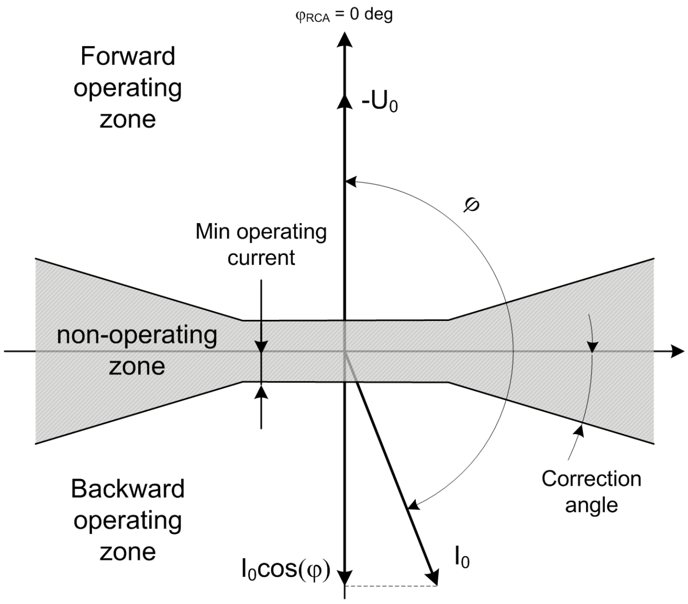


Figure 83: Operating characteristic $I_0\cos(\varphi)$ in reverse fault

Phase angle, classic 80

The operation criterion phase angle classic 80 is selected with the *Operation mode* setting using the value "Phase angle 80".

Phase angle classic 80 implements the same functionality as the phase angle, but with the following differences:

- The *Max forward angle* and *Max reverse angle* settings are not settable but have a fixed value of 80 degrees
- The sector limits of the fixed sectors are rounded.

The sector rounding is used for cancelling the CT measurement errors at low current amplitudes. When the current amplitude falls below three percent of the nominal current, the sector is reduced to 70 degrees at the fixed sector side. This makes the protection more selective, which means that the phase angle measurement errors do not cause faulty operation.

There is no sector rounding on the other side of the sector.

If the current amplitude falls below one percent of the nominal current, the direction enters the non-directional area.

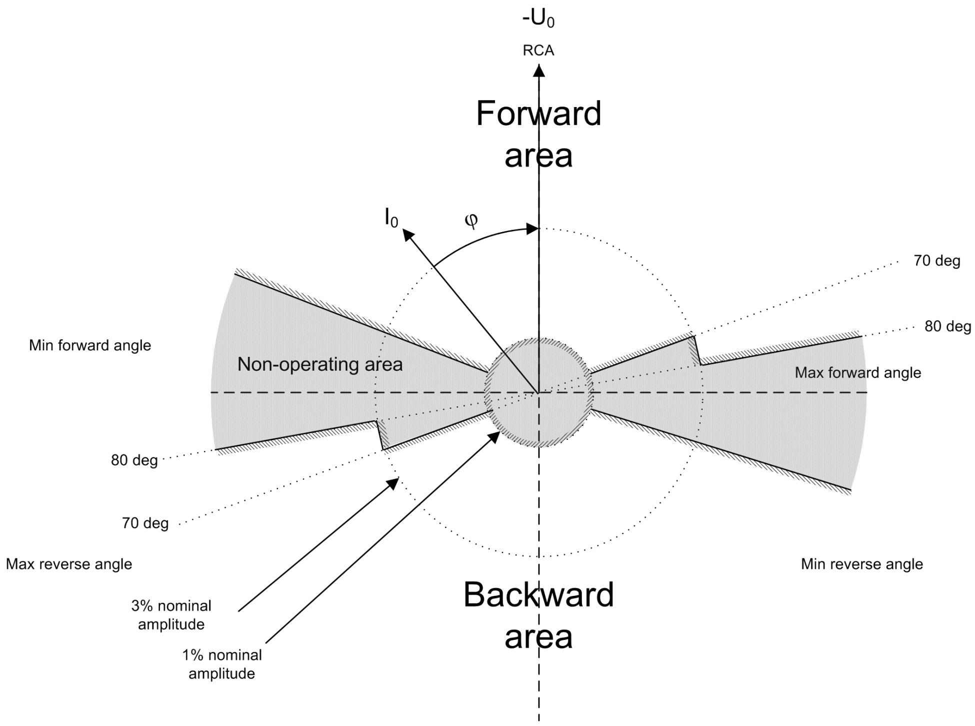


Figure 84: Operating characteristic for phase angle classic 80

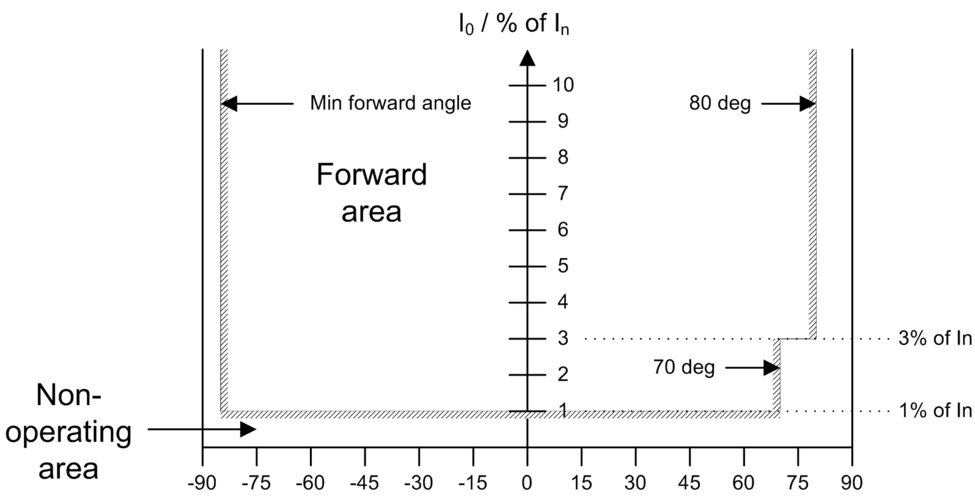


Figure 85: Phase angle classic 80 amplitude

Phase angle, classic 88

The operation criterion phase angle classic 88 is selected with the *Operation mode* setting using the value "Phase angle 88".

Phase angle classic 88 implements the same functionality as the phase angle, but with the following differences:

- The *Max forward angle* and *Max reverse angle* settings are not settable, but have a fixed value of 88 degrees
- The sector limits of the fixed sectors are rounded.

Sector rounding in the phase angle classic 88 consists of three parts:

- If the current amplitude is between 1...20 percent of the nominal current, the sector limit increases linearly from 73 degrees to 85 degrees
- If the current amplitude is between 1...100 percent of the nominal current, the sector limit increases linearly from 85 degrees to 88 degrees
- If the current amplitude is more than 100 percent of the nominal current, the sector limit is 88 degrees.

There is no sector rounding on the other side of the sector.

If the current amplitude falls below one percent of the nominal current, the direction enters the non-directional area.

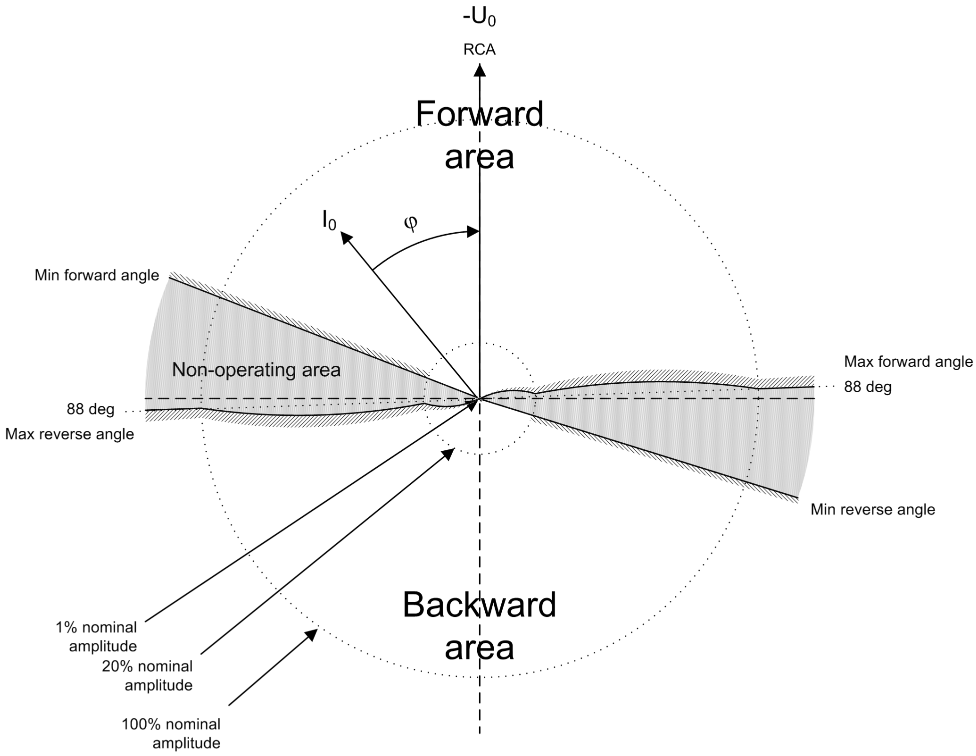


Figure 86: Operating characteristic for phase angle classic 88

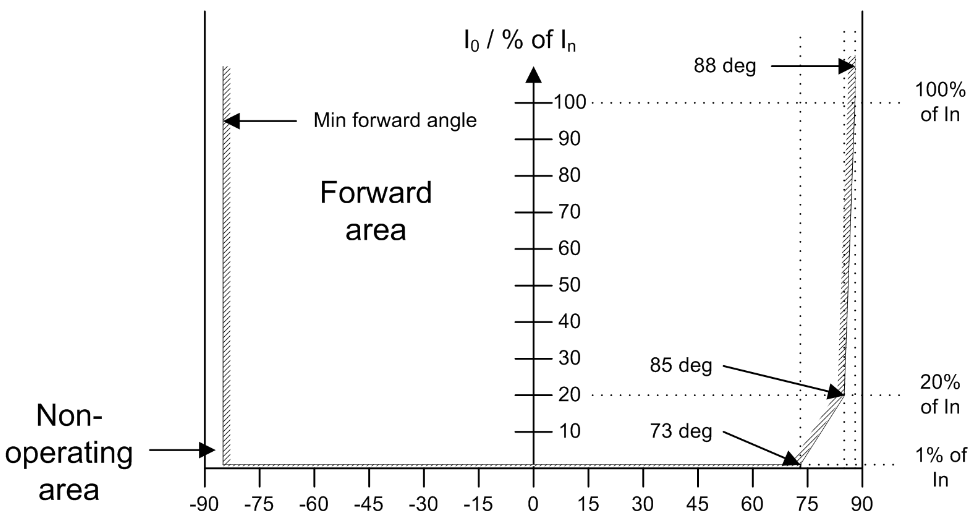


Figure 87: Phase angle classic 88 amplitude

4.2.2.9 Application

The directional earth-fault protection (DEFxPDEF) is designed for protection and clearance of earth faults and for earth-fault protection of different equipment connected to the power systems, such as shunt capacitor banks or shunt reactors, and for backup earth-fault protection of power transformers.

Many applications require several steps using different current start levels and time delays. DEFxPDEF consists of two different stages:

- low (DEFLPDEF)
- high (DEFHPDEF)

DEFLPDEF contains several types of time delay characteristics. DEFHPDEF is used for fast clearance of serious earth faults.

The protection can be based on the phase angle criterion with extended operating sector. It can also be based on measuring either the reactive part Iosin(φ) or the active part Iocos(φ) of the residual current. In isolated networks or in networks with high impedance earthing, the phase-to-earth fault current is significantly smaller than the short-circuit currents. In addition, the magnitude of the fault current is almost independent of the fault location in the network.

The function uses the residual current components Iocos(φ) or Iosin(φ) according to the earthing method, where φ is the angle between the residual current and the reference residual voltage (-Uo). In compensated networks, the phase angle criterion with extended operating sector can also be used. When the relay characteristic angle RCA is 0 degrees, the negative quadrant of the operation sector can be extended with the *Min forward angle* setting. The operation sector can be set between 0 and -180 degrees, so that the total operation sector is from +90 to -180 degrees. In other words, the sector can be up to 270 degrees wide. This allows the protection settings to stay the same when the resonance coil is disconnected from between the neutral point and earth.

System neutral earthing is meant to protect personnel and equipment and to reduce interference for example in telecommunication systems. The neutral earthing sets challenges for protection systems, especially for earth-fault protection.

In isolated networks, there is no intentional connection between the system neutral point and earth. The only connection is through the line-to-earth capacitances (C_0) of phases and leakage resistances (R_0). This means that the residual current is mainly capacitive and has –90 degrees phase shift compared to the residual voltage (-Uo). The characteristic angle is -90 degrees.

In resonance-earthed networks, the capacitive fault current and the inductive resonance coil current compensate each other. The protection cannot be based on the reactive current measurement, since the current of the compensation coil would disturb the operation of the relays. In this case, the selectivity is based on the measurement of the active current component. This means that the residual current is mainly resistive and has zero phase shift compared to the residual voltage (-Uo) and the characteristic angle is 0 degrees. Often the magnitude of this component is small, and must be increased by means of a parallel resistor in the compensation equipment.

In networks where the neutral point is earthed through low resistance, the characteristic angle is also 0 degrees (for phase angle). Alternatively, Iocos(φ) operation can be used.

In solidly earthed networks, the *Characteristic angle* is typically set to +60 degrees for the phase angle. Alternatively, Iosin(φ) operation can be used with a reversal polarizing quantity. The polarizing quantity can be rotated 180 degrees by setting the *Pol reversal* parameter to "True" or by switching the polarity of the residual voltage measurement wires. Although the Iosin(φ) operation can be used in solidly earthed networks, the phase angle is recommended.

Connection of measuring transformers in directional earth fault applications

The residual current Io can be measured with a core balance current transformer or the residual connection of the phase current signals. If the neutral of the network is either isolated or earthed with high impedance, a core balance current transformer is recommended to be used in earth-fault protection. To ensure sufficient accuracy of residual current measurements and consequently the selectivity of the scheme, the core balance current transformers should have a transformation ratio of at least 70:1. Lower transformation ratios such as 50:1 or 50:5 are not recommended.

Attention should be paid to make sure the measuring transformers are connected correctly so that DEFxPDEF is able to detect the fault current direction without failure. As directional earth fault uses residual current and residual voltage (-Uo), the poles of the measuring transformers must match each other and also the fault current direction. Also the earthing of the cable sheath must be taken into notice when using core balance current transformers. The following figure describes how measuring transformers can be connected to the IED.

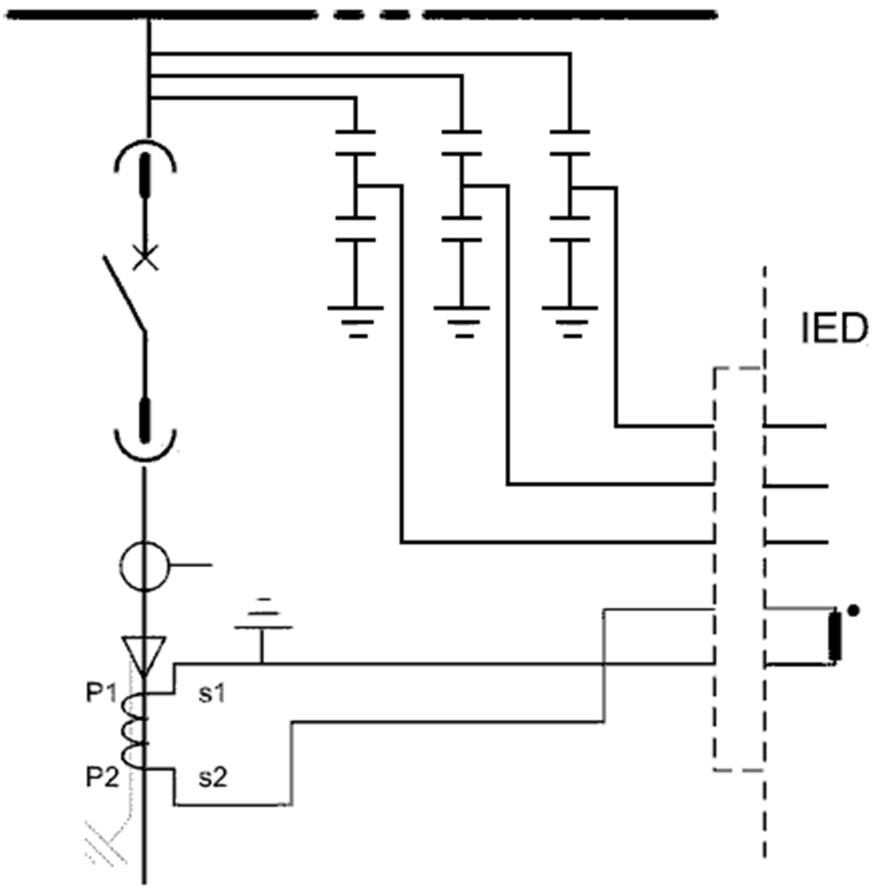


Figure 88: Connection of measuring transformers

4.2.2.10 Signals

Table 159: DEFLPDEF Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
U_0	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
RCA_CTL	BOOLEAN	0=False	Relay characteristic angle control

Table 160: DEFHPDEF Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
U_0	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
RCA_CTL	BOOLEAN	0=False	Relay characteristic angle control

Table 161: DEFLPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 162: DEFHPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.2.11 Settings

Table 163: DEFLPDEF Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...5.000	xIn	0.005	0.010	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Operate delay time	60...200000	ms	10	60	Operate delay time
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	88	Minimum phase angle in reverse direction
Voltage start value	0.010...1.000	xUn	0.001	0.010	Voltage start value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 164: DEFLPDEF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	60...60000	ms	1	60	Minimum operate time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min operate current	0.005...1.000	xIn	0.001	0.005	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage
Correction angle	0.0...10.0	deg	0.1	0.0	Angle correction
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

Table 165: DEFHPDEF Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.10...40.00	xIn	0.01	0.10	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Directional mode	1=Non-directional 2=Forward 3=Reverse			2=Forward	Directional mode
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operating curve type	1=ANSI Ext. inv. 3=ANSI Norm. inv. 5=ANSI Def. Time 15=IEC Def. Time 17=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type
Operate delay time	60...200000	ms	10	60	Operate delay time
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	88	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	88	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	88	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	88	Minimum phase angle in reverse direction
Voltage start value	0.010...1.000	xUn	0.001	0.010	Voltage start value
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 166: DEFHPDEF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	60...60000	ms	1	60	Minimum operate time for IDMT curves
Allow Non Dir	0=False 1=True			0=False	Allows prot activation as non-dir when dir info is invalid
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
Min operate current	0.005...1.000	xIn	0.001	0.005	Minimum operating current
Min operate voltage	0.01...1.00	xUn	0.01	0.01	Minimum operating voltage
Correction angle	0.0...10.0	deg	0.1	0.0	Angle correction

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

4.2.2.12 Monitored data

Table 167: DEFLPDEF Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
I_OPER	FLOAT32	0.00...40.00		Calculated operating current
DEFLPDEF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 168: DEFHPDEF Monitored data

Name	Type	Values (Range)	Unit	Description
FAULT_DIR	Enum	0=unknown 1=forward 2=backward 3=both		Detected fault direction
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
DIRECTION	Enum	0=unknown 1=forward 2=backward 3=both		Direction information
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
ANGLE	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
I_OPER	FLOAT32	0.00...40.00		Calculated operating current
DEFHPDEF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.2.13 Technical data

Table 169: DEFxPDEF Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
	DEFLPDEF	Current: ±1.5% of the set value or ±0.002 x I_n Voltage ±1.5% of the set value or ±0.002 x U_n Phase angle: ±2°		
	DEFHPDEF	Current: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.1…10 x I_n) ±5.0% of the set value (at currents in the range of 10…40 x I_n) Voltage: ±1.5% of the set value or ±0.002 x U_n Phase angle: ±2°		
Start time [1)2)]		Minimum	Typical	Maximum
	DEFHPDEF and DEFLPTDEF: I_{Fault} = 2 x set *Start value*	61 ms	64 ms	66 ms
Table continues on next page				

Characteristic	Value
Reset time	< 40 ms
Reset ratio	Typical 0.96
Retardation time	< 30 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms [3)]
Suppression of harmonics	RMS: No suppression DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression

1) *Measurement mode* = default (depends on stage), current before fault = 0.0 x I_n, f_n = 50 Hz, earth-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 x I_n, *Start value* multiples in range of 1.5 to 20

4.2.2.14 Technical revision history

Table 170: DEFHPDEF Technical revision history

Technical revision	Change
B	Maximum value changed to 180 deg for the *Max forward angle* setting

Table 171: DEFLPDEF Technical revision history

Technical revision	Change
B	Maximum value changed to 180 deg for the *Max forward angle* setting. *Start value* step changed to 0.005

4.3 Unbalance protection

4.3.1 Negative phase-sequence current protection NSPTOC

4.3.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative phase-sequence current protection	NSPTOC	I2>	46

4.3.1.2 Function block

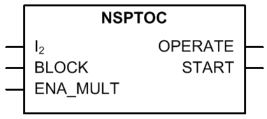


Figure 89: Function block

4.3.1.3 Functionality

The negative phase-sequence current protection NSPTOC is used for increasing sensitivity to detect single phase and phase-to-phase faults, unbalanced loads due to, for example, broken conductors or to unsymmetrical feeder voltages.

NSPTOC can also be used for detecting broken conductors.

The function is based on the measurement of the negative phase-sequence current. In a fault situation, the function starts when the negative phase sequence current exceeds the set limit. The operate time characteristics can be selected to be either definite time (DT) or inverse definite minimum time (IDMT). In the DT mode, the function operates after a predefined operate time and resets when the fault current disappears. The IDMT mode provides current dependent timer characteristics.

The function contains a blocking functionality. It is possible to block function outputs, timers, or the function itself, if desired.

4.3.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of negative phase-sequence current protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

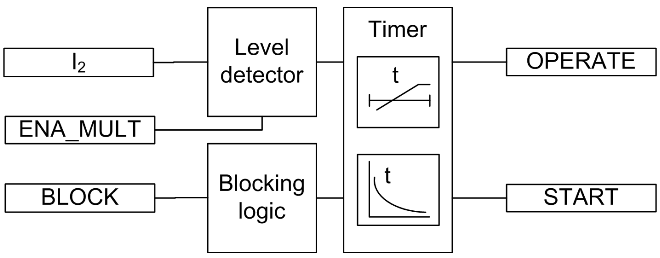


Figure 90: Functional module diagram. I_2 represents negative phase sequence current.

Level detector

The measured negative phase-sequence current is compared to the set *Start value*. If the measured value exceeds the set *Start value*, the level detector activates the timer module. If the ENA_MULT input is active, the set *Start value* is multiplied by the set *Start value Mult*.

Care needs to be taken when selecting *Start value* and *Start value Mult* even if the product of these settings exceeds the *Start value* setting range.

The IED does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

Timer

Once activated, the timer activates the START output. Depending on the value of the *Operating curve type* setting, the time characteristics are according to DT or IDMT. When the operation timer has reached the value of *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the OPERATE output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation happens, that is, a fault suddenly disappears before the operate delay is exceeded, the timer reset state is activated. The functionality of the timer in the reset state depends on the combination of the *Operating curve type*, *Type of reset curve* and *Reset delay time* settings. When the DT characteristic is selected, the reset timer runs until the set *Reset delay time* value is exceeded. When the IDMT curves are selected, the *Type of reset curve* setting can be set to "Immediate", "Def time reset" or "Inverse reset". The reset curve type "Immediate" causes an immediate reset. With the reset curve type "Def time reset", the reset time depends on the *Reset delay time* setting. With the reset curve type "Inverse reset", the reset time depends on the current during the drop-off situation. If the drop-off situation continues, the reset timer is reset and the START output is deactivated.

The "Inverse reset" selection is only supported with ANSI or user programmable types of the IDMT operating curves. If another operating curve type is selected, an immediate reset occurs during the drop-off situation.

The setting *Time multiplier* is used for scaling the IDMT operate and reset times.

The setting parameter *Minimum operate time* defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with great care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/*Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.3.1.5 Application

Since the negative sequence current quantities are not present during normal, balanced load conditions, the negative sequence overcurrent protection elements can be set for faster and more sensitive operation than the normal phase-overcurrent protection for fault conditions occurring between two phases. The negative sequence overcurrent protection also provides a back-up protection functionality for the feeder earth-fault protection in solid and low resistance earthed networks.

The negative sequence overcurrent protection provides the back-up earth-fault protection on the high voltage side of a delta-wye connected power transformer for earth faults taking place on the wye-connected low voltage side. If an earth fault occurs on the wye-connected side of the power transformer, negative sequence current quantities appear on the delta-connected side of the power transformer.

Multiple time curves and time multiplier settings are also available for coordinating with other devices in the system.

4.3.1.6 Signals

Table 172: NSPTOC Input signals

Name	Type	Default	Description
I_2	SIGNAL	0	Negative phase sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 173: NSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.1.7 Settings

Table 174: NSPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.01...5.00	xIn	0.01	0.30	Start value
Start value Mult	0.8...10.0		0.1	1.0	Multiplier for scaling the start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...200000	ms	10	40	Operate delay time
Operating curve type	1=ANSI Ext. inv. 2=ANSI Very inv. 3=ANSI Norm. inv. 4=ANSI Mod. inv. 5=ANSI Def. Time 6=L.T.E. inv. 7=L.T.V. inv. 8=L.T. inv. 9=IEC Norm. inv. 10=IEC Very inv. 11=IEC inv. 12=IEC Ext. inv. 13=IEC S.T. inv. 14=IEC L.T. inv. 15=IEC Def. Time 17=Programmable 18=RI type 19=RD type			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset			1=Immediate	Selection of reset curve type

Table 175: NSPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Minimum operate time	20...60000	ms	1	20	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.0086...120.0000			28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120			0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00			2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00			29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0			1.0	Parameter E for customer programmable curve

4.3.1.8 Monitored data

Table 176: NSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
NSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.1.9 Technical data

Table 177: NSPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x I_n		
Start time 1)2)		Minimum	Typical	Maximum
	I_{Fault} = 2 x set *Start value* I_{Fault} = 10 x set *Start value*	22 ms 14 ms	24 ms 16 ms	25 ms 17 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Table continues on next page				

Characteristic	Value
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms [3)]
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,…

1) Negative sequence current before fault = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 2.5 x I_n, *Start value* multiples in range of 1.5 to 20

4.3.1.10 Technical revision history

Table 178: NSPTOC Technical revision history

Technical revision	Change
B	Minimum and default values changed to 40 ms for the *Operate delay time* setting

4.3.2 Phase discontinuity protection PDNSPTOC

4.3.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase discontinuity protection	PDNSPTOC	I2/I1>	46PD

4.3.2.2 Function block

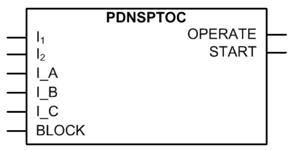


Figure 91: Function block

4.3.2.3 Functionality

The phase discontinuity protection PDNSPTOC is used for detecting unbalance situations caused by broken conductors.

The function starts and operates when the unbalance current I_2/I_1 exceeds the set limit. To prevent faulty operation at least one phase current needs to be above the minimum level. PDNSPTOC operates with DT characteristic.

The function contains a blocking functionality. It is possible to block the function output, timer or the function itself, if desired.

4.3.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the phase discontinuity protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

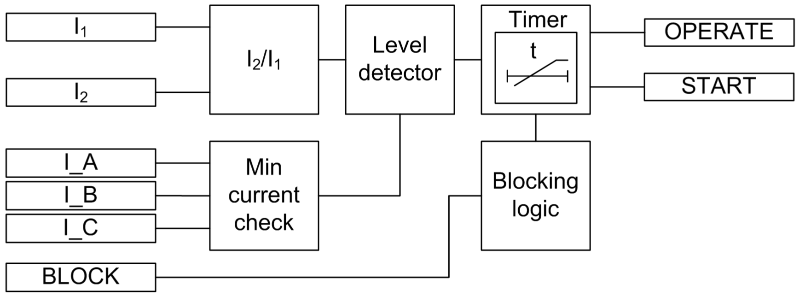


Figure 92: Functional module diagram. I_1 and I_2 represent positive and negative phase sequence currents. I_A, I_B and I_C represent phase currents.

I_2/I_1

The I_2/I_1 module calculates the ratio of the negative and positive phase sequence current. It reports the calculated value to the level detector.

Level detector

The level detector compares the calculated ratio of negative and positive phase sequence currents to the set *Start value*. If the calculated value exceeds the set *Start value* and the min current check module has exceeded the minimum phase current limit, the level detector reports the exceeding of the value to the timer.

Min current check

The min current check module checks if the measured phase currents are above the set *Min phase current*. At least one of the phase currents needs to be above the set limit to enable the level detector module.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

4.3.2.5 Application

In three-phase distribution and subtransmission network applications the phase discontinuity in one phase can cause increase of zero sequence voltage and short overvoltage peaks and also oscillation in the corresponding phase.

PDNSPTOC is a three-phase protection with DT characteristic, designed for detecting broken conductors in distribution and subtransmission networks. The function is applicable for both overhead lines and underground cables.

The operation of PDNSPTOC is based on the ratio of positive and negative sequence currents. This gives better sensitivity and stability compared to plain negative sequence current protection since the calculated ratio of positive and negative sequence currents is relatively constant during load variations.

When the three phase currents are measured, the positive-sequence current is calculated:

$$I_1 = \frac{1}{3}\left(Ia + aIb + a^2 Ic\right)$$

(Equation 11)

The negative sequence current is calculated:

$$I_2 = \frac{1}{3}\left(Ia + a^2 Ib + aIc\right)$$

(Equation 12)

I_a, I_b, I_c phase current vectors

α phase rotation operator (defined to rotate a phasor component forward by 120 degrees)

The unbalance of the network is detected by monitoring the negative and positive sequence current ratio, where the negative-phase sequence current value is I_2 and I_1 is the positive-phase sequence current value. The unbalance is calculated:

$$Iratio = \frac{I_2}{I_1}$$

(Equation 13)

Broken conductor fault situation can occur in phase A in a feeder.

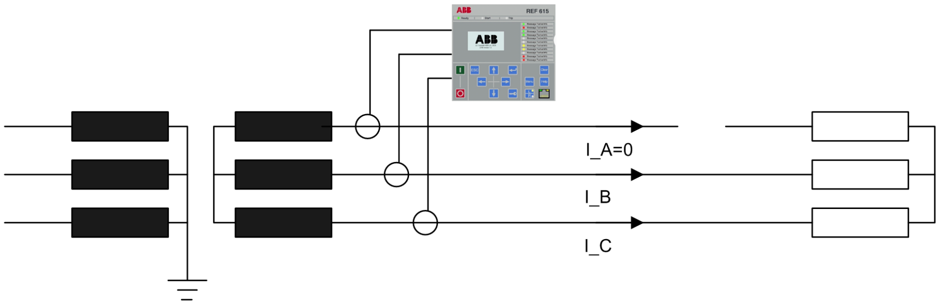


Figure 93: Broken conductor fault situation in phase A in a distribution or subtransmission feeder

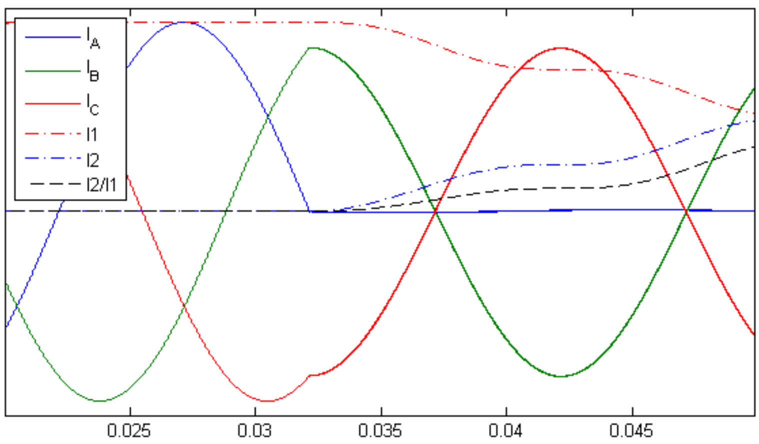


Figure 94: Three-phase current quantities during the broken conductor fault in phase A with the ratio of negative and positive sequence currents

4.3.2.6 Signals

Table 179: PDNSPTOC Input signals

Name	Type	Default	Description
I_1	SIGNAL	0	Positive phase sequence current
I_2	SIGNAL	0	Negative phase sequence current
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 180: PDNSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.2.7 Settings

Table 181: PDNSPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	10...100	%	1	10	Start value
Operate delay time	100...30000	ms	1	100	Operate delay time

Table 182: PDNSPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
Min phase current	0.05...0.30	xIn	0.01	0.10	Minimum phase current

4.3.2.8 Monitored data

Table 183: PDNSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
RATIO_I2_I1	FLOAT32	0.00...999.99	%	Measured current ratio I2 / I1
PDNSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.2.9 Technical data

Table 184: PDNSPTOC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2 Hz
	±2% of the set value
Start time	< 70 ms
Reset time	< 40 ms
Reset ratio	Typical 0.96
Retardation time	< 35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

4.3.3 Phase reversal protection PREVPTOC

4.3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase reversal protection	PREVPTOC	I2>>	46 R

4.3.3.2 Function block

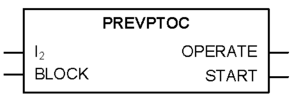


Figure 95: Function block

4.3.3.3 Functionality

The phase-reversal protection PREVPTOC is used to detect the reversed connection of the phases to a three-phase motor by monitoring the negative phase-sequence current I_2 of the motor.

PREVPTOC starts and operates when I_2 exceeds the set limit. PREVPTOC operates on definite time (DT) characteristics. PREVPTOC is based on the calculated I_2, and the function detects too high I_2 values during the motor startup. The excessive I_2 values are caused by incorrectly connected phases, which in turn makes the motor rotate in the opposite direction.

The function contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

4.3.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the phase-reversal protection can be described using a module diagram. All the modules in the diagram are explained in the next sections.

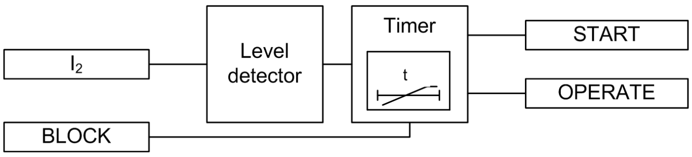


Figure 96: Functional module diagram

Level detector

The level detector compares the negative phase-sequence current to the set *Start value*. If the I_2 value exceeds the set *Start value*, the level detector sends an enabling signal to the timer module.

Timer

Once activated, the timer activates the `START` output. When the operation timer has reached the set *Operate delay time* value, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value of 200 ms, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

4.3.3.5 Application

The rotation of a motor in the reverse direction is not a desirable operating condition. When the motor drives fans and pumps, for example, and the rotation direction is reversed due to a wrong phase sequence, the driven process can be disturbed and the flow of the cooling air of the motor can become reversed too. With a motor designed only for a particular rotation direction, the reversed rotation direction can lead to an inefficient cooling of the motor due to the fan design.

In a motor, the value of the negative phase-sequence component of the phase currents is very negligible when compared to the positive-sequence component of the current during a healthy operating condition of the motor. But when the motor is started with the phase connections in the reverse order, the magnitude of I_2 is very high. So whenever the value of I_2 exceeds the start value, the function detects the reverse rotation direction and provides an operate signal that disconnects the motor from the supply.

4.3.3.6 Signals

Table 185: PREVPTOC Input signals

Name	Type	Default	Description
I_2	SIGNAL	0	Negative sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 186: PREVPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.3.7 Settings

Table 187: PREVPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.00	xIn	0.01	0.75	Start value
Operate delay time	100...60000	ms	10	100	Operate delay time

Table 188: PREVPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

4.3.3.8 Monitored data

Table 189: PREVPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PREVPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.3.9 Technical data

Table 190: PREVTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: fn ±2Hz		
		±1.5% of the set value or ±0.002 x I_n		
Start time 1)2)		Minimum	Typical	Maximum
	I_{Fault} = 2.0 x set *Start value*	22 ms	24 ms	25 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

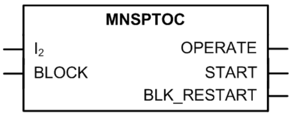
1) Negative-sequence current before = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.3.4 Negative phase-sequence time overcurrent protection MNSPTOC

4.3.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative phase-sequence time overcurrent protection	MNSPTOC	I2>M	46M

4.3.4.2 Function block



4.3.4.3 Functionality

The unbalance protection based on negative-phase-sequence current function MNSPTOC protects electric motors from phase unbalance. A small voltage unbalance can produce a large negative-sequence current flow in the motor. For example, a 5 percent voltage unbalance produces a stator negative-sequence current of 30 percent of the full load current, which can severely heat the motor. MNSPTOC detects the large negative-sequence current and disconnects the motor.

4.3.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the unbalance protection based on negative phase-sequence current can be described using a module diagram. All the modules in the diagram are explained in the next sections.

Figure 97: Functional module diagram

Level detector

The calculated negative-sequence current is compared to the *Start value* setting. If the measured value exceeds the *Start value* setting, the function activates the timer module.

Timer

Once activated, the timer activates the `START` output. Depending on the value of the set *Operating curve type*, the time characteristics are according to DT or IDMT. When the operation timer has reached the value set by *Operate delay time* in the DT mode or the maximum value defined by the inverse time curve, the `OPERATE` output is activated.

In a drop-off situation, that is, when the value of the negative-sequence current drops below the *Start value* setting, the reset timer is activated and the `START` output resets after the time delay of *Reset delay time* for the DT characteristics. For IDMT, the reset time depends on the curve type selected.

For the IDMT curves, it is possible to define the minimum and maximum operate times with the *Minimum operate time* and *Maximum operate time* settings. The *Machine time Mult* setting parameter corresponds to the machine constant, equal to the I_2^2t constant of the machine, as stated by the machine manufacturer. In case there is a mismatch between the used CT and the protected motor's nominal current values, it is possible to fit the IDMT curves for the protected motor by using the *Rated current* setting.

The activation of the `OPERATE` output activates the `BLK_RESTART` output. The deactivation of the `OPERATE` output activates the cooling timer. The timer is set to the value entered in the *Cooling time* setting. The `BLK_RESTART` output is kept active until the cooling timer is exceeded. If the negative-sequence current increases above the set value during this period, the `OPERATE` output is activated immediately.

The operation timer counting can be frozen to the prevailing value by activating the `FR_TIMER` input.

The `T_ENARESTART` output indicates the duration for which the `BLK_RESTART` output remains active, that is, it indicates the remaining time of the cooling timer. The value is available through the Monitored data view.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

4.3.4.5 Timer characteristics

MNSPTOC supports both DT and IDMT characteristics. The user can select the DT timer characteristics by selecting the “ANSI Def. Time” or “IEC Def. Time” in the *Operating curve type* setting. The functionality is identical in both cases. When the DT characteristics are selected, the functionality is only affected by the *Operate delay time* and *Reset delay time* settings.

The IED provides two user-programmable IDMT characteristics curves, "Inv. curve A" and "Inv. curve B".

Current-based inverse definite minimum type curve (IDMT)

In inverse-time modes, the operate time depends on the momentary value of the current: the higher the current, the faster the operate time. The operate time calculation or integration starts immediately when the current exceeds the set *Start value* and the `START` output is activated.

The `OPERATE` output of the component is activated when the cumulative sum of the integrator calculating the overcurrent situation exceeds the value set by the inverse time mode. The set value depends on the selected curve type and the setting values used.

The *Minimum operate time* and *Maximum operate time* settings define the minimum operate time and maximum operate time possible for the IDMT mode. For setting these parameters, a careful study of the particular IDMT curves is recommended.

Inv. curve A

The inverse time equation for curve type A is:

$$t[s] = \frac{k}{\left(\frac{I_2}{I_r}\right)^2}$$

(Equation 14)

t[s]	Operate time in seconds
k	Set *Machine time Mult*
I_2	Negative-sequence current
I_r	Set *Rated current*

If the negative-sequence current drops below the *Start value* setting, the reset time is defined as:

$$t[s] = a \times \left(\frac{b}{100}\right)$$

(Equation 15)

t[s]	Reset time in seconds
a	set *Cooling time*
b	percentage of start time elapse (START_DUR)

When the reset period is initiated, the time for which START has been active is saved. Now, if the fault reoccurs, that is, the negative-sequence current rises above the set value during the reset period, the operate calculations are continued using the saved values. However, if the reset period elapses without a fault being detected, the operate timer is reset and the saved values of start time and integration are cleared.

Inv. curve B

The inverse time equation for curve type B is:

$$t[s] = \frac{k}{\left(\frac{I_2}{I_r}\right)^2 - \left(\frac{I_S}{I_r}\right)^2}$$

(Equation 16)

t[s] Operate time in seconds

k *Machine time Mult*

I_2 Negative-sequence current

I_S Set *Start value*

I_r Set *Rated current*

If the fault disappears, the negative-sequence current drops below the *Start value* setting and the START output is deactivated. However, the function does not reset instantaneously, but instead it depends on the equation or the *Cooling time* setting.

The timer can be reset in two ways:

- With a drop in the negative-sequence current below start value, the subtraction in the denominator becomes negative and the cumulative sum starts to decrease. The decrease in the sum indicates the cooling of the machine and the cooling speed depends on the value of the negative-sequence current. If the sum reaches zero without a fault being detected, the accumulation stops and the timer is reset.
- If the reset time set through the *Cooling time* setting elapses without a fault being detected, the timer is reset.

The reset period thus continues for a time equal to the *Cooling time* setting or until the operate time decreases to zero, whichever is less.

4.3.4.6 Application

In a three-phase motor, the conditions that can lead to unbalance are single phasing, voltage unbalance from the supply and single-phase fault. The negative sequence current damages the motor during the unbalanced voltage condition, and therefore the negative sequence current is monitored to check the unbalance condition.

When the voltages supplied to an operating motor become unbalanced, the positive-sequence current remains substantially unchanged, but the negative-sequence current flows due to the unbalance. For example, if the unbalance is caused by an open circuit in any phase, a negative-sequence current flows and it is equal and opposite to the previous load current in a healthy phase. The combination of positive and negative-sequence currents produces phase currents approximately 1.7 times the previous load in each healthy phase and zero current in the open phase.

The negative-sequence currents flow through the stator windings inducing negative-sequence voltage in the rotor windings. This can result in a high rotor current that damages the rotor winding. The frequency of the induced current is approximately twice the supply frequency. Due to skin effect, the induced current with a frequency double the supply frequency encounters high rotor resistance which leads to excessive heating even with phase currents with value less than the rated current of the motor.

The negative-sequence impedance of induction or a synchronous motor is approximately equal to the locked rotor impedance, which is approximately one-sixth of the normal motor impedance, considering that the motor has a locked-rotor current of six times the rated current. Therefore, even a three percent voltage unbalance can lead to 18 percent stator negative sequence current in windings. The severity of this is indicated by a 30-40 percent increase in the motor temperature due to the extra current.

4.3.4.7 Signals

Table 191: MNSPTOC Input signals

Name	Type	Default	Description
I_2	SIGNAL	0	Negative sequence current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 192: MNSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start
BLK_RESTART	BOOLEAN	Overheated machine reconnection blocking

4.3.4.8 Settings

Table 193: MNSPTOC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.01...0.50	xIn	0.01	0.20	Start value
Operating curve type	5=ANSI Def. Time 15=IEC Def. Time 17=Inv. Curve A 18=Inv. Curve B			15=IEC Def. Time	Selection of time delay curve type
Machine time Mult	5.0...100.0		0.1	5.0	Machine related time constant
Operate delay time	100...120000	ms	10	1000	Operate delay time

Table 194: MNSPTOC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Rated current	0.30...2.00	xIn	0.01	1.00	Rated current (Ir) of the machine (used only in the IDMT)
Maximum operate time	500000...7200000	ms	1000	1000000	Max operate time regardless of the inverse characteristic
Minimum operate time	100...120000	ms	1	100	Minimum operate time for IDMT curves
Cooling time	5...7200	s	1	50	Time required to cool the machine
Reset delay time	0...60000	ms	1	20	Reset delay time

4.3.4.9 Monitored data

Table 195: MNSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
T_ENARESTART	FLOAT32	0.00...7200.00	s	Estimated time to reset of block restart
MNSPTOC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.4.10 Technical data

Table 196: MNSPTOC Technical data

<table>
<tr><th colspan="2">Characteristic</th><th colspan="3">Value</th></tr>
<tr><td colspan="2" rowspan="2">Operation accuracy</td><td colspan="3">Depending on the frequency of the current measured: fn ±2Hz</td></tr>
<tr><td colspan="3">±1.5% of the set value or ±0.002 x I_n</td></tr>
<tr><td rowspan="2">Start time[1)2)]</td><td rowspan="2">I_{Fault} = 2.0 x set *Start value*</td><td>Minimum</td><td>Typical</td><td>Maximum</td></tr>
<tr><td>22 ms</td><td>24 ms</td><td>25 ms</td></tr>
<tr><td colspan="2">Reset time</td><td colspan="3">< 40 ms</td></tr>
<tr><td colspan="2">Reset ratio</td><td colspan="3">Typical 0.96</td></tr>
<tr><td colspan="2">Retardation time</td><td colspan="3">< 35 ms</td></tr>
<tr><td colspan="2">Operate time accuracy in definite time mode</td><td colspan="3">±1.0% of the set value or ±20 ms</td></tr>
<tr><td colspan="2">Operate time accuracy in inverse time mode</td><td colspan="3">±5.0% of the theoretical value or ±20 ms[3)]</td></tr>
<tr><td colspan="2">Suppression of harmonics</td><td colspan="3">DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…</td></tr>
</table>

1) Negative-sequence current before = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) *Start value* multiples in range of 1.10 to 5.00

4.4 Voltage protection

4.4.1 Three-phase overvoltage protection PHPTOV

4.4.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase overvoltage protection	PHPTOV	3U>	59

4.4.1.2 Function block

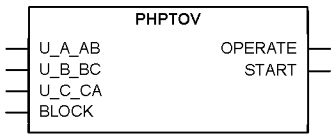


Figure 98: Function block

4.4.1.3 Functionality

The three-phase overvoltage protection PHPTOV is applied on power system elements, such as generators, transformers, motors and power lines, to protect the system from excessive voltages that could damage the insulation and cause insulation breakdown. The three-phase overvoltage function includes a settable value for the detection of overvoltage either in a single phase, two phases or three phases.

PHPTOV includes both definite time (DT) and inverse definite minimum time (IDMT) characteristics for the delay of the trip.

The function contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

4.4.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the three-phase overvoltage protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

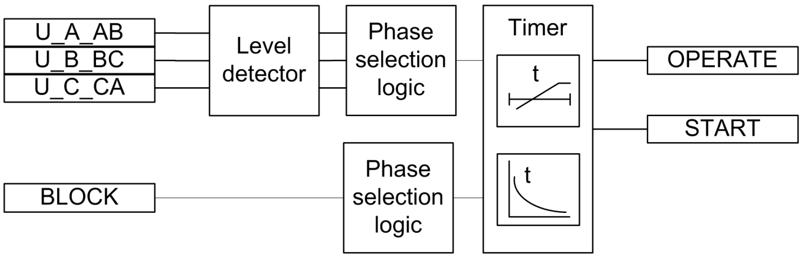


Figure 99: Functional module diagram

Level detector

The fundamental frequency component of the measured three-phase voltages are compared phasewise to the set value of the *Start value* setting. If the measured value is higher than the set value of the *Start value* setting, the level detector enables the phase selection logic module. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly differs from the *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

The *Voltage selection* setting is used for selecting phase-to-earth or phase-to-phase voltages for protection.

For the voltage IDMT operation mode, the used IDMT curve equations contain discontinuity characteristics. The *Curve Sat relative* setting is used for preventing undesired operation.

For a more detailed description of the IDMT curves and the use of the *Curve Sat Relative* setting, see the General function block features section in this manual.

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases matches with the set *Num of start phases*, the phase selection logic activates the timer.

Timer

Once activated, the timer activates the `START` output. Depending on the value of the set *Operating curve type*, the time characteristics are selected according to DT or IDMT.

For a detailed description of the voltage IDMT curves, see the General function block features section in this manual.

When the operation timer has reached the value set by *Operate delay time* in the DT mode or the maximum value defined by the IDMT, the OPERATE output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation occurs, that is, a fault suddenly disappears before the operate delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected operate time characteristics. If the DT characteristics are selected, the reset timer runs until the set *Reset delay time* value is exceeded. If the drop-off situation exceeds the set *Reset delay time*, the timer is reset and the START output is deactivated.

When the IDMT operate time curve is selected, the functionality of the timer in the drop-off state depends on the combination of the *Type of reset curve* and *Reset delay time* settings.

Table 197: The reset time functionality with the IDMT operate time curve selected

Type of reset curve	Desctiption of operation
“Immediate”	The operate timer is reset instantaneously when drop-off occurs
“Def time reset”	The operate timer is frozen during drop-off. Operate timer is reset after the set *Reset delay time* is exceeded
“DT Lin decr rst”	The operate timer value linearly decreases during the drop-off situation. The operate timer is reset after the set *Reset delay time* is exceeded

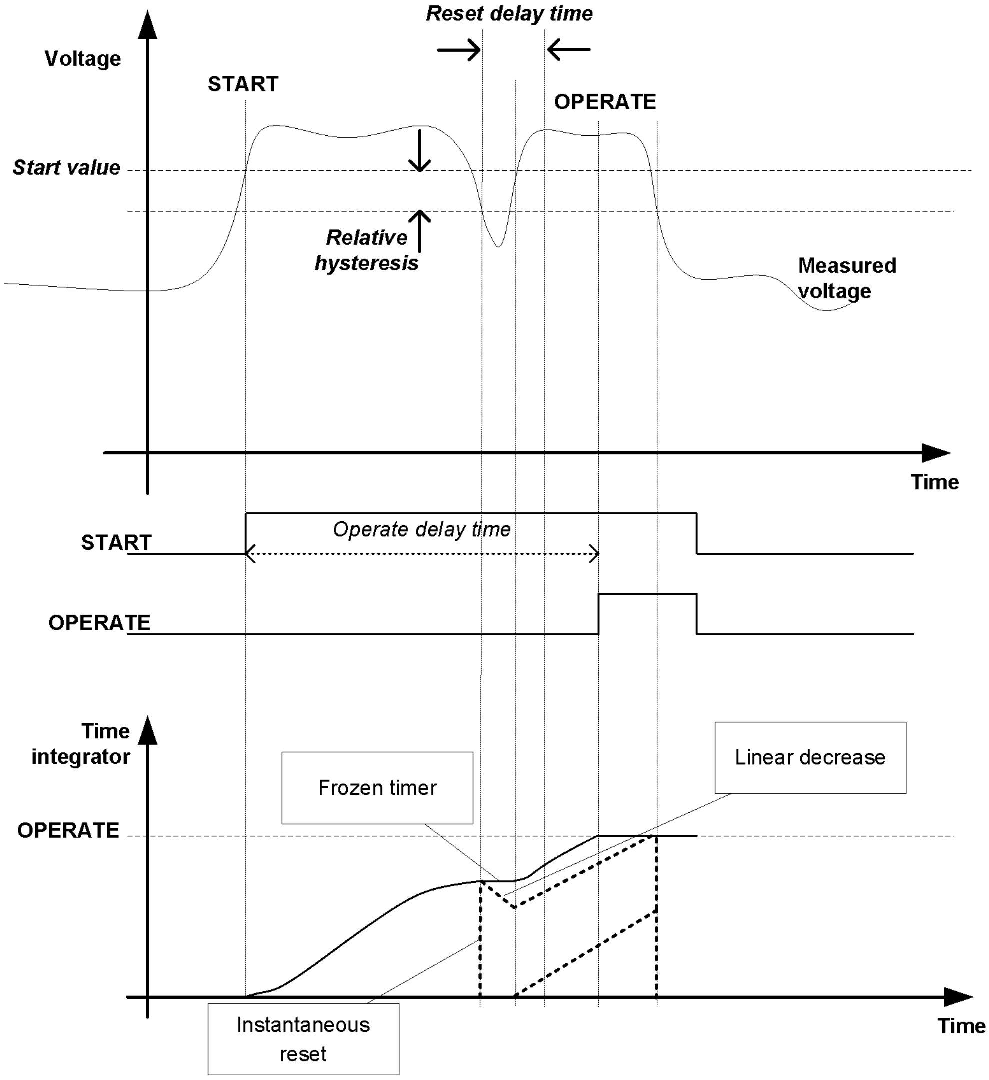


Figure 100: Behavior of different IDMT reset modes. The value for Type of reset curve is "Def time reset". Also other reset modes are presented for the time integrator.

The *Time multiplier* setting is used for scaling the IDMT operate times.

The *Minimum operate time* setting parameter defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with care because the operation time is according to the IDMT curve but always at least the value of the *Minimum operate time* setting. For more information. see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting **Configuration/System/Blocking mode** which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the `BLOCK` input signal activation is preselected with the global *Blocking mode* setting.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

The "Freeze timers" mode of blocking has no effect during the “Inverse reset” mode.

4.4.1.5 Timer characteristics

The operating curve types supported by PHPTOV are:

Table 198: Timer characteristics supported by IDMT operate curve types

Operating curve type
(5) ANSI Def. Time
(15) IEC Def. Time
(17) Inv. Curve A
(18) Inv. Curve B
(19) Inv. Curve C
(20) Programmable

4.4.1.6 Application

Overvoltage in a network occurs either due to the transient surges on the network or due to prolonged power frequency overvoltages. Surge arresters are used to protect the network against the transient overvoltages, but the IED protection function is used to protect against power frequency overvoltages.

The power frequency overvoltage may occur in the network due to contingencies such as:

- The defective operation of the automatic voltage regulator when the generator is in isolated operation.
- Operation under manual control with the voltage regulator out of service. A sudden variation of load, in particular the reactive power component, gives rise to a substantial change in voltage because of the inherent large voltage regulation of a typical alternator.
- Sudden loss of load due to the tripping of outgoing feeders, leaving the generator isolated or feeding a very small load. This causes a sudden rise in the terminal voltage due to the trapped field flux and overspeed.

If a load sensitive to overvoltage remains connected, it leads to equipment damage.

It is essential to provide power frequency overvoltage protection, in the form of time delayed element, either IDMT or DT to prevent equipment damage.

4.4.1.7 Signals

Table 199: PHPTOV Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 200: PHPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.1.8 Settings

Table 201: PHPTOV Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.60	xUn	0.01	1.10	Start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...300000	ms	10	40	Operate delay time
Operating curve type	5=ANSI Def. Time 15=IEC Def. Time 17=Inv. Curve A 18=Inv. Curve B 19=Inv. Curve C 20=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 202: PHPTOV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Minimum operate time	40...60000	ms	1	40	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.4.1.9 Monitored data

Table 203: PHPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.1.10 Technical data

Table 204: PHPTOV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 x set *Start value*	22 ms	24 ms	26 ms
Reset time		< 40 ms		
Reset ratio		Depends of the set *Relative hysteresis*		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 x U_n, Voltage before fault = 0.9 x U_n, f_n = 50 Hz, overvoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Maximum *Start value* = 1.20 x U_n, *Start value* multiples in range of 1.10 to 2.00

4.4.2 Three-phase undervoltage protection PHPTUV

4.4.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase undervoltage protection	PHPTUV	3U<	27

Function block

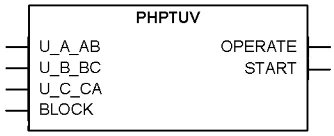


Figure 101: Function block

Functionality

The three-phase undervoltage protection PHPTUV is used to disconnect from the network devices, for example electric motors, which are damaged when subjected to service under low voltage conditions. PHPTUV includes a settable value for the detection of undervoltage either in a single phase, two phases or three phases.

The function contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the three-phase undervoltage protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

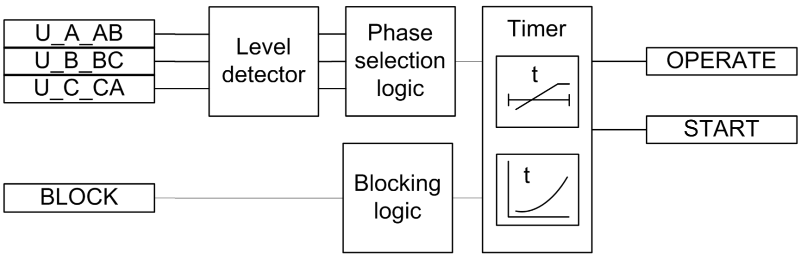


Figure 102: Functional module diagram

Level detector

The fundamental frequency component of the measured three-phase voltages are compared phasewise to the set *Start value*. If the measured value is lower than the set value of the *Start value* setting, the level detector enables the phase selection logic module. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly varies above or below the *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

The *Voltage selection* setting is used for selecting the phase-to-earth or phase-to-phase voltages for protection.

For the voltage IDMT mode of operation, the used IDMT curve equations contain discontinuity characteristics. The *Curve Sat relative* setting is used for preventing unwanted operation.

For a more detailed description on IDMT curves and use of the *Curve Sat Relative* setting, see the General function block features section in this manual.

The level detector contains a low-level blocking functionality for cases where one of the measured voltages is below the desired level. This feature is useful when it is wanted to avoid unnecessary starts and operates during, for example, an autoreclose sequence. The low-level blocking is activated by default (*Enable block value* is set to "True") and the blocking level can be set with the *Voltage block value* setting.

Phase selection logic

If the fault criteria are fulfilled in the level detector, the phase selection logic detects the phase or phases in which the fault level is detected. If the number of faulty phases matches the set *Num of start phases*, the phase selection logic activates the timer.

Timer

Once activated, the timer activates the `START` output. Depending on the value of the set *Operating curve type*, the time characteristics are selected according to DT or IDMT.

For a detailed description of the voltage IDMT curves, see the General function block features section in this manual.

When the operation timer has reached the value set by *Operate delay time* in the DT mode or the maximum value defined by the IDMT, the `OPERATE` output is activated.

When the user programmable IDMT curve is selected, the operate time characteristics are defined by the parameters *Curve parameter A*, *Curve parameter B*, *Curve parameter C*, *Curve parameter D* and *Curve parameter E*.

If a drop-off situation occurs, that is, a fault suddenly disappears before the operate delay is exceeded, the reset state is activated. The behavior in the drop-off situation depends on the selected operate time characteristics. If the DT characteristics are selected, the reset timer runs until the set *Reset delay time* value is exceeded. If the drop-off situation exceeds the set *Reset delay time*, the timer is reset and the `START` output is deactivated.

When the IDMT operate time curve is selected, the functionality of the timer in the drop-off state depends on the combination of the *Type of reset curve* and *Reset delay time* settings.

Table 205: The reset time functionality with the IDMT operate time curve selected

Type of reset curve	Desctiption of operation
“Immediate”	The operate timer is reset instantaneously when drop-off occurs
“Def time reset”	The operate timer is frozen during drop-off. Operate timer is reset after the set *Reset delay time* is exceeded
“DT Lin decr rst”	The operate timer value linearly decreases during the drop-off situation. The operate timer is reset after the set *Reset delay time* is exceeded

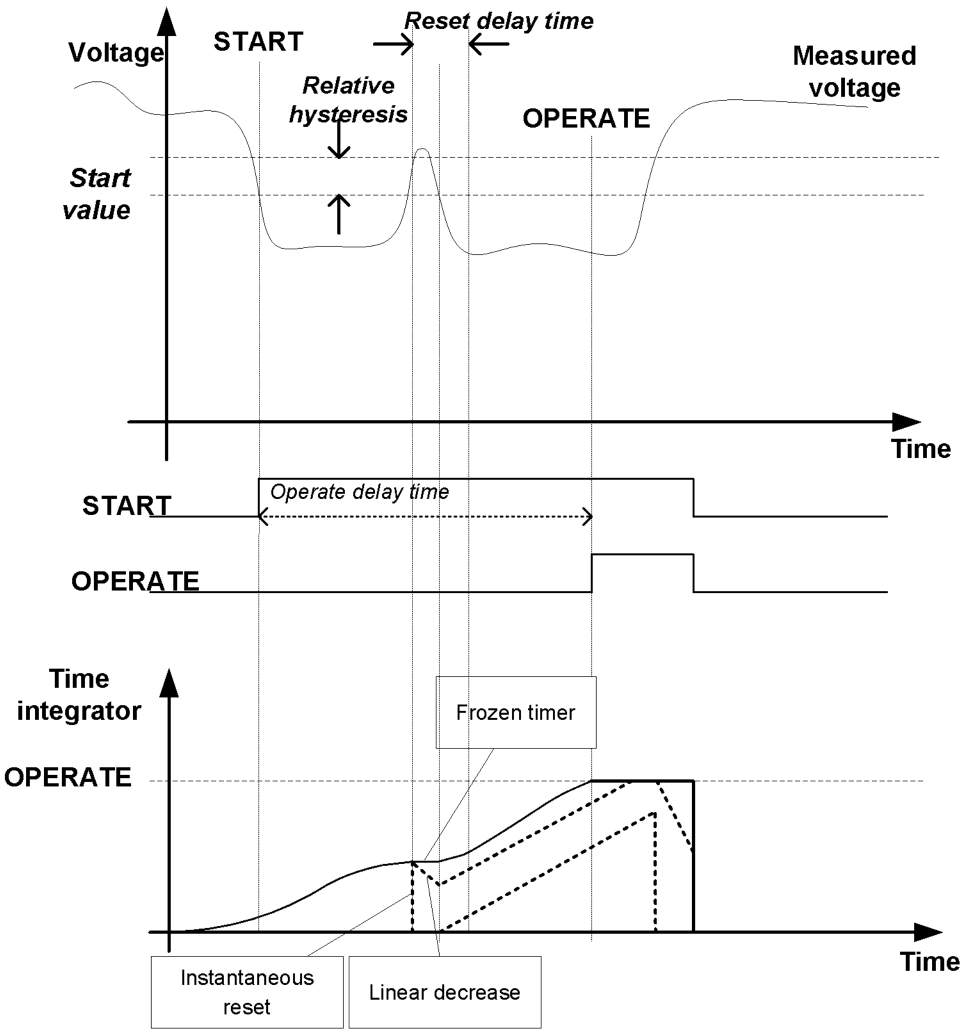


Figure 103: Behavior of different IDMT reset modes. The value for Type of reset curve is “Def time reset”. Also other reset modes are presented for the time integrator.

The *Time multiplier* setting is used for scaling the IDMT operate times.

The *Minimum operate time* setting parameter defines the minimum desired operate time for IDMT. The setting is applicable only when the IDMT curves are used.

The *Minimum operate time* setting should be used with care because the operation time is according to the IDMT curve, but always at least the value of the *Minimum operate time* setting. For more information, see the General function block features section in this manual.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting Configuration/System/ *Blocking mode* which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the `BLOCK` input signal activation is preselected with the global *Blocking mode* setting.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the `OPERATE` output is not activated.

The "Freeze timers" mode of blocking has no effect during the "Inverse reset" mode.

Timer characteristics

The operating curve types supported by PHPTUV are:

Table 206: Supported IDMT operate curve types

Operating curve type
(5) ANSI Def. Time
(15) IEC Def. Time
(21) Inv. Curve A
(22) Inv. Curve B
(23) Programmable

Application

PHPTUV is applied to power system elements, such as generators, transformers, motors and power lines, to detect low voltage conditions. Low voltage conditions are caused by abnormal operation or a fault in the power system. PHPTUV can be used in combination with overcurrent protections. Other applications are the detection of a no-voltage condition, for example before the energization of a high voltage line, or an automatic breaker trip in case of a blackout. PHPTUV is also used to initiate voltage correction measures, such as insertion of shunt capacitor banks, to compensate for a reactive load and thereby to increase the voltage.

PHPTUV can be used to disconnect from the network devices, such as electric motors, which are damaged when subjected to service under low voltage conditions. PHPTUV deals with low voltage conditions at power system frequency. Low voltage conditions can be caused by:

- Malfunctioning of a voltage regulator or incorrect settings under manual control (symmetrical voltage decrease)
- Overload (symmetrical voltage decrease)
- Short circuits, often as phase-to-earth faults (unsymmetrical voltage increase).

PHPTUV prevents sensitive equipment from running under conditions that could cause overheating and thus shorten their life time expectancy. In many cases, PHPTUV is a useful function in circuits for local or remote automation processes in the power system.

Signals

Table 207: PHPTUV Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 208: PHPTUV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Settings

Table 209: PHPTUV Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...1.20	xUn	0.01	0.90	Start value
Time multiplier	0.05...15.00		0.05	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	60...300000	ms	10	60	Operate delay time
Operating curve type	5=ANSI Def. Time 15=IEC Def. Time 21=Inv. Curve A 22=Inv. Curve B 23=Programmable			15=IEC Def. Time	Selection of time delay curve type
Type of reset curve	1=Immediate 2=Def time reset -1=DT Lin decr rst			1=Immediate	Selection of reset curve type

Table 210: PHPTUV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Num of start phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required for operate activation
Minimum operate time	60...60000	ms	1	60	Minimum operate time for IDMT curves
Reset delay time	0...60000	ms	1	20	Reset delay time
Curve parameter A	0.005...200.000			1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00			1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0			0.0	Parameter C for customer programmable curve
Curve parameter D	0.000...60.000			0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000			1.000	Parameter E for customer programmable curve
Curve Sat Relative	0.0...3.0		0.1	2.0	Tuning parameter to avoid curve discontinuities
Voltage block value	0.05...1.00	xUn	0.01	0.20	Low level blocking for undervoltage mode
Enable block value	0=False 1=True			1=True	Enable internal blocking
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

Monitored data

Table 211: PHPTUV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTUV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Technical data

Table 212: PHPTUV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: fn ±2Hz		
		±1.5% of the set value or ±0.002 x U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 0.9 x set *Start value*	62 ms	64 ms	66 ms
Reset time		< 40 ms		
Reset ratio		Depends of the set *Relative hysteresis*		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 x U_n, Voltage before fault = 1.1 x U_n, f_n = 50 Hz, undervoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact
3) Minimum *Start value* = 0.50, *Start value* multiples in range of 0.90 to 0.20

4.4.3 Residual overvoltage protection ROVPTOV

4.4.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual overvoltage protection	ROVPTOV	U0>	59G

4.4.3.2 Function block

Figure 104: Function block

4.4.3.3 Functionality

The residual overvoltage protection ROVPTOV is used in distribution networks where the residual overvoltage can reach non-acceptable levels, for example, in high impedance earthing.

The function starts when the residual voltage exceeds the set limit. ROVPTOV operates with the definite time (DT) characteristic.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer or the function itself, if desired.

4.4.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the residual overvoltage protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

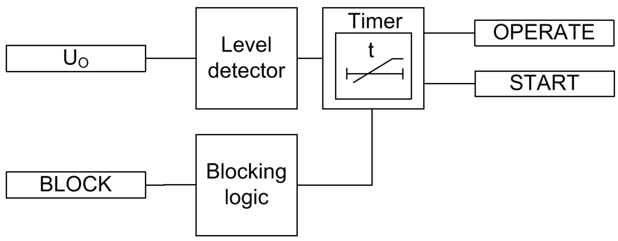


Figure 105: Functional module diagram. U_0 represents the residual voltage.

Level detector

The measured or calculated residual voltage is compared to the set *Start value*. If the value exceeds the set *Start value*, the level detector sends an enabling signal to the timer.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated. If the fault disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the START output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.4.3.5 Application

ROVPTOV is designed to be used for earth fault protection in isolated neutral, resistance earthed or reactance earthed systems. In compensated networks, starting of the function can be used to control the switching device of the neutral resistor. The function can also be used for back-up protection of feeders for busbar protection when more dedicated busbar protection would not be justified.

In compensated and isolated neutral systems, the system neutral voltage, that is, the residual voltage, increases in case of any fault connected to earth. Depending on the type of the fault and the fault resistance, the residual voltage reaches different values. The highest residual voltage, equal to the phase-earth voltage, is achieved for a single-phase earth fault. The residual voltage increases approximately the same amount in the whole system and does not provide any guidance in finding the faulty component. Therefore, this function is often used as a backup protection or as a release signal for the feeder earth-fault protection.

The protection can also be used for earth-fault protection of generators and motors and for the unbalance protection of capacitor banks.

The residual voltage can be calculated internally based on the measurement of the three-phase voltage. This voltage can also be measured by a single-phase voltage transformer, located between a transformer star point and earth, or by using an open-delta connection of three single-phase voltage transformers.

4.4.3.6 Signals

Table 213: ROVPTOV Input signals

Name	Type	Default	Description
U_0	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 214: ROVPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.3.7 Settings

Table 215: ROVPTOV Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.000	xUn	0.001	0.030	Residual overvoltage start value
Operate delay time	40...300000	ms	1	40	Operate delay time

Table 216: ROVPTOV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time

4.4.3.8 Monitored data

Table 217: ROVPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
ROVPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 218: ROVPTOV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x U_n		
Start time1)2)		Minimum	Typical	Maximum
	U_{Fault} = 1.1 x set *Start value*	29 ms	31 ms	32 ms
Reset time		< 40 ms		
Reset ratio		Typical 0.96		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1) Residual voltage before fault = 0.0 x U_n, f_n = 50 Hz, residual voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.4.4 Negative sequence overvoltage protection NSPTOV

4.4.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative-sequence overvoltage protection	NSPTOV	U2>	47O-

4.4.4.2 Function block

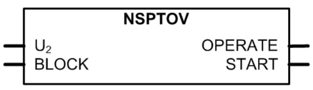


Figure 106: Function block

4.4.4.3 Functionality

The negative sequence overvoltage protection NSPTOV is used to detect negative phase sequence overvoltage conditions. NSPTOV is used for protection of machines.

The function starts when the negative phase sequence voltage exceeds the set limit. NSPTOV operates with the definite time (DT) characteristics.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer or the function itself, if desired.

4.4.4.4 Operating principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the negative-sequence overvoltage protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

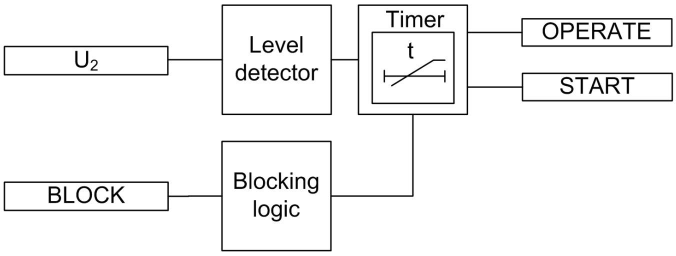


Figure 107: Functional module diagram. U_2 is used for representing negative phase sequence voltage.

Level detector

The calculated negative-sequence voltage is compared to the set *Start value* setting. If the value exceeds the set *Start value*, the level detector enables the timer.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated if the overvoltage condition persists. If the negative sequence voltage normalizes before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the `BLOCK` input and the global setting "**Configuration/System/*Blocking mode***" which selects the blocking mode. The `BLOCK` input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.4.4.5 Application

A continuous or temporary voltage unbalance may appear in the network for various reasons. Mainly, the voltage unbalance occurs due to broken conductors or asymmetrical loads and is characterized by the appearance of a negative sequence component of the voltage. In rotating machines, the voltage unbalance results in a current unbalance, which heats the rotors of the machines. The rotating machines, therefore, do not tolerate continuous negative phase sequence voltage higher than typically 1-2 percent x U_n.

The negative sequence component current I_2, drawn by an asynchronous or a synchronous machine, is linearly proportional to the negative sequence component voltage U_2. When U_2 is P% of U_n, I_2 is typically about 5 x P% x I_n.

The negative sequence overcurrent NSPTOC blocks are used to accomplish selective protection against the voltage and current unbalance for each machine separately. Alternatively, the protection can be implemented with the NSPTOV function, monitoring the voltage unbalance of the bus bar.

If the machines have unbalance protection of their own, the NSPTOV operation can be applied as a backup protection or it can be used as an alarm. The latter can be applied when it is not required to trip loads tolerating voltage unbalance better than the rotating machines.

If there is a considerable degree of voltage unbalance in the network, the rotating machines should not be connected to the network at all. This logic can be implemented by inhibiting the closure of the circuit breaker if the NSPTOV operation has started. This scheme also prevents connecting the machine to the network if the phase sequence of the network is not correct.

An appropriate value for the setting parameter *Voltage start value* is approximately 3 percent of U_n. A suitable value for the setting parameter *Operate delay time* depends on the application. If the NSPTOV operation is used as backup protection, the operate time should be set in accordance with the operate time of NSPTOC used as main protection. If the NSPTOV operation is used as main protection, the operate time should be approximately one second.

4.4.4.6 Signals

Table 219: NSPTOV Input signals

Name	Type	Default	Description
U_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 220: NSPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.4.7 Settings

Table 221: NSPTOV Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.000	xUn	0.001	0.030	Start value
Operate delay time	40...120000	ms	1	40	Operate delay time

Table 222: NSPTOV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time

4.4.4.8 Monitored data

Table 223: NSPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
NSPTOV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.4.9 Technical data

Table 224: NSPTOV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: fn ±2Hz		
		±1.5% of the set value or ±0.002 x U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 x set *Start value* U_{Fault} = 2.0 x set *Start value*	33 ms 24 ms	35 ms 26 ms	37 ms 28 ms
Reset time		< 40 ms		
Table continues on next page				

Characteristic	Value
Reset ratio	Typical 0.96
Retardation time	< 35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

1) Negative-sequence voltage before fault = 0.0 x U_n, f_n = 50 Hz, negative-sequence overvoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.4.5 Positive sequence undervoltage protection PSPTUV

4.4.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Positive-sequence undervoltage protection	PSPTUV	U1	47U+

4.4.5.2 Function block

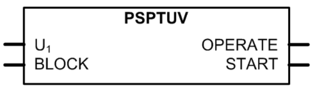


Figure 108: Function block

4.4.5.3 Functionality

The positive-sequence undervoltage protection PSPTUV is used to detect positive phase sequence undervoltage conditions. PSPTUV is used for protection of small power generation plants. The function helps in isolating an embedded plant from a fault line when the fault current fed by the plant is too low to start an overcurrent function but high enough to maintain the arc. Fast isolation of all the fault-current sources is necessary for a successful autoreclosure from the network-end circuit breaker.

The function starts when the positive phase sequence voltage goes below the set limit. PSPTUV operates with the definite time (DT) characteristics.

The function contains a blocking functionality. It is possible to block function outputs, the definite timer or the function itself, if desired.

4.4.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the positive-sequence undervoltage protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

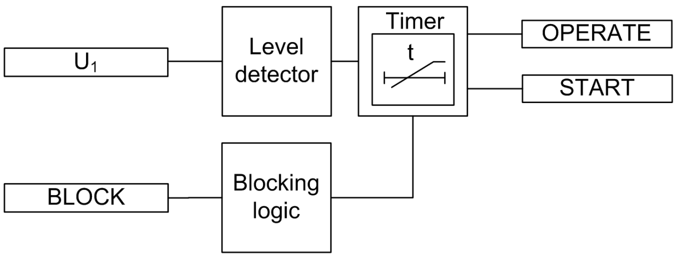


Figure 109: Functional module diagram. U_1 is used for representing positive-phase sequence voltage.

Level detector

The calculated positive sequence voltage is compared to the set *Start value* setting. If the value goes below the set *Start value*, the level detector enables the timer. The *Relative hysteresis* setting can be used for preventing unnecessary oscillations if the input signal slightly varies from the *Start value* setting. After leaving the hysteresis area, the start condition has to be fulfilled again and it is not sufficient for the signal to only return to the hysteresis area.

The level detector contains a low-level blocking functionality for cases where the positive sequence voltage is below the desired level. This feature is useful when it is wanted to avoid unnecessary starts and operates during, for example, an auto-reclose sequence. The low-level blocking is activated by default (*Enable block value* is set to "True") and the blocking level can be set with the *Voltage block value* setting.

Timer

Once activated, the timer activates the `START` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output is activated if the undervoltage condition persists. If the positive sequence voltage normalizes before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operate timer resets and the `START` output is deactivated.

The timer calculates the start duration value START_DUR which indicates the percentage ratio of the start situation and the set operate time. The value is available through the Monitored data view.

Blocking logic

There are three operation modes in the blocking functionality. The operation modes are controlled by the BLOCK input and the global setting "**Configuration/System/ *Blocking mode***" which selects the blocking mode. The BLOCK input can be controlled by a binary input, a horizontal communication input or an internal signal of the relay program. The influence of the BLOCK signal activation is preselected with the global setting *Blocking mode*.

The *Blocking mode* setting has three blocking methods. In the "Freeze timers" mode, the operate timer is frozen to the prevailing value. In the "Block all" mode, the whole function is blocked and the timers are reset. In the "Block OPERATE output" mode, the function operates normally but the OPERATE output is not activated.

4.4.5.5 Application

PSPTUV can be applied for protecting a power station used for embedded generation when network faults like short circuits or phase-to-earth faults in a transmission or a distribution line cause a potentially dangerous situations for the power station. A network fault may be dangerous for the power station for various reasons. The operation of the protection may cause an islanding condition, also called a loss-of-mains condition, in which a part of the network, that is, an island fed by the power station is isolated from the rest of the network. There is then a risk of an autoreclosure taking place when the voltages of different parts of the network do not synchronize, which is a straining incident for the power station. Another risk is that the generator may lose synchronism during the network fault. A sufficiently fast trip of the utility circuit breaker of the power station can avoid these risks.

The lower the three-phase symmetrical voltage of the network is, the higher is the probability that the generator loses the synchronism. The positive sequence voltage is also available during asymmetrical faults. It is an appropriate criterion for detecting the risk of loss of synchronism than, for example, the lowest phase-to-phase voltage.

Analyzing the loss of synchronism of a generator is rather complicated and requires a model of the generator with its prime mover and controllers. The generator may be able to operate synchronously even if the voltage drops by a few tens of percent for some hundreds of milliseconds. The setting of PSPTUV is thus determined by the need to protect the power station from the risks of the islanding conditions since that requires a higher setting value.

The loss of synchronism of a generator means that the generator is unable to operate as a generator with the network frequency but enters into an unstable condition in which it operates by turns as a generator and a motor. Such a condition stresses the generator thermally and mechanically. This kind of loss of synchronism should not be mixed with the one between an island and the utility network. In the islanding situation, the condition of the generator itself is normal but the phase angle and the frequency of the phase-to-phase voltage may be different from the corresponding voltage in the rest of the network. The island may get a frequency of its own relatively fast when fed by a small power station with a low inertia.

PSPTUV complements other loss-of-grid protection principles based on frequency and voltage operation.

4.4.5.6 Signals

Table 225: PSPTUV Input signals

Name	Type	Default	Description
U_1	SIGNAL	0	Positive phase sequence voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 226: PSPTUV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.5.7 Settings

Table 227: PSPTUV Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.010...1.200	xUn	0.001	0.500	Start value
Operate delay time	40...120000	ms	10	40	Operate delay time
Voltage block value	0.01...1.00	xUn	0.01	0.20	Internal blocking level
Enable block value	0=False 1=True			1=True	Enable Internal Blocking

Table 228: PSPTUV Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

4.4.5.8 Monitored data

Table 229: PSPTUV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PSPTUV	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.5.9 Technical data

Table 230: PSPTUV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 0.99 x set *Start value*	51 ms	53 ms	54 ms
	U_{Fault} = 0.9 x set *Start value*	43 ms	45 ms	46 ms
Reset time		< 40 ms		
Reset ratio		Depends of the set *Relative hysteresis*		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 x U_n, Positive sequence voltage before fault = 1.1 x U_n, f_n = 50 Hz, positive sequence undervoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

4.5 Motor startup supervision STTPMSU

4.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Motor startup supervision	STTPMSU	Is2tn<	49,66,48,51LR

4.5.2 Function block

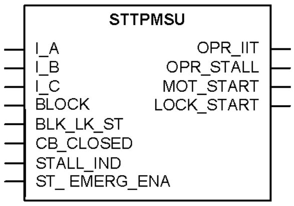


Figure 110: Function block

4.5.3 Functionality

The motor startup supervision function STTPMSU is designed for protection against excessive starting time and locked rotor conditions of the motor during starting. For good and reliable operation of motor, the thermal stress during the motor starting is maintained within the allowed limits.

The starting of motor is supervised by monitoring the TRMS magnitude of all the phase currents or by monitoring the status of the circuit breaker connected to the motor.

During the startup period of the motor, STTPMSU calculates the integral of I^2t value. If the calculated value exceeds the set value, the operate signal is activated.

STTPMSU has the provision to check the locked rotor condition of the motor using the speed switch, which means checking if the rotor is able to rotate or not. This feature operates after a predefined operating time.

STTPMSU also protects the motor from an excessive number of startups. Upon exceeding the specified number of startups within certain duration, STTPMSU blocks further starts. The restart of the motor is also inhibited after each start and continues to be inhibited for a set duration. When the lock of start of motor is enabled, STTPMSU gives the time remaining until the restart of the motor.

STTPMSU contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

4.5.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the motor startup supervision function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

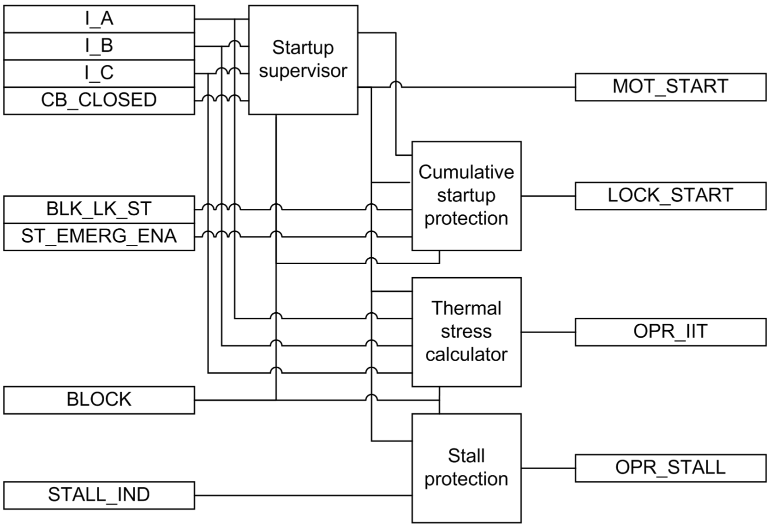


Figure 111: Functional module diagram

Startup supervisor

This module detects the starting of the motor. The starting and stalling motor conditions are detected in four different modes of operation. This is done through the *Operation mode* setting.

When the *Operation mode* setting is operated in the "IIt" mode, the function calculates the value of the thermal stress of the motor during the startup condition. In this mode, the startup condition is detected by monitoring the TRMS currents.

The *Operation mode* setting in the "IIt, CB" mode enables the function to calculate the value of the thermal stress when a startup is monitored in addition to the CB_CLOSED input.

In the "IIt & stall" mode, the function calculates the thermal stress of the motor during the startup condition. In this mode, the startup condition is detected by monitoring the TRMS currents. In the "IIt & stall" mode, the function also checks for motor stalling by monitoring the speed switch.

In the "IIt & stall, CB" mode, the function calculates the thermal stresses of the motor during the startup condition. The startup condition is monitored in addition to the circuit breaker status. In the "IIt & stall, CB" mode, the function also checks for motor stalling by monitoring the speed switch.

When the measured current value is used for startup supervision in the "IIt" and "IIt & stall" modes, the module initially recognizes the de-energized condition of the motor when the values of all three phase currents are less than *Motor standstill A* for longer than 100 milliseconds. If any of the phase currents of the de-energized condition rises to a value equal or greater than the *Motor standstill A*, the MOT_START output signal is activated indicating that the motor startup is in progress. The MOT_START output remains active until the values of all three phase currents drop below 90 percent of the set value of *Start detection A* and remain below that level for a time of *Str over delay time*, that is, until the startup situation is over.

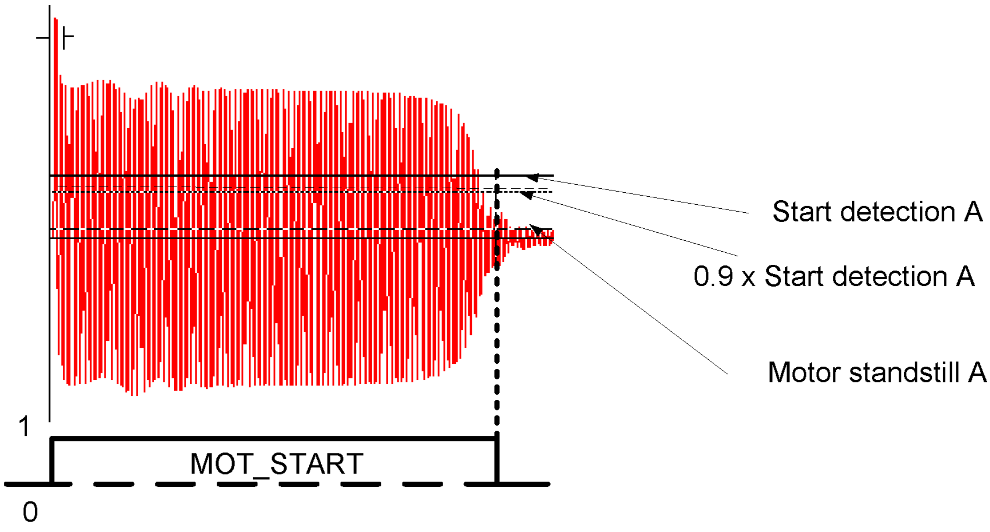


Figure 112: Functionality of startup supervision in "IIt and IIt&stall" mode

In case of the "IIt, CB" or "IIt & stall, CB" modes, the function initially recognizes the de-energized condition of the motor when the value of all three phase currents is below the value of the *Motor standstill A* setting for 100 milliseconds. The beginning of the motor startup is recognized when CB is closed, that is, when the `CB_CLOSED` input is activated and at least one phase current value exceeds the *Motor standstill A* setting.

But in normal practice, these two events do not take place at the same instant, that is, the CB main contact is closed first, in which case the phase current value rises above 0.1 pu and after some delay the CB auxiliary contact gives the information of the `CB_CLOSED` input. In some cases, the `CB_CLOSED` input can be active but the value of current may not be greater than the value of the *Motor standstill A* setting. To allow both possibilities, a time slot of 200 milliseconds is provided for current and the `CB_CLOSED` input. If both events occur during this time, the motor startup is recognized.

The motor startup ends either within the value of the *Str over delay time* setting from the beginning of the startup or the opening of CB or when the `CB_CLOSED` input is deactivated. The operation of the `MOT_START` output signal in this operation mode is as illustrated in Figure 113

This CB mode can be used in soft-started or slip ring motors for protection against too high a starting current, that is, a problem in starting and so on.

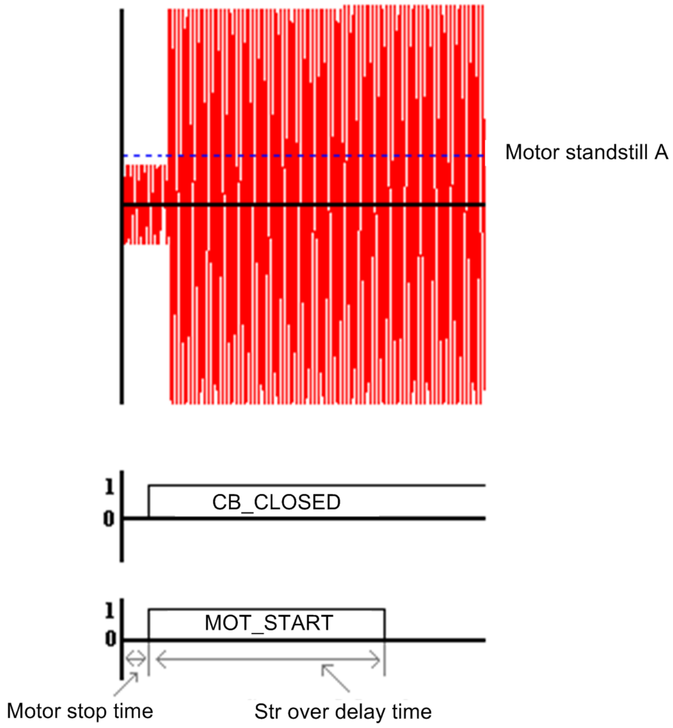


Figure 113: Functionality of startup supervision in "IIt, CB" mode and "IIt and stall, CB" mode

The *Str over delay time* setting has different purposes in different modes of operation:

- In the "IIt" or "IIt & stall" modes, the aim of this setting is to check for the completion of the motor startup period. The purpose of this time delay setting is to allow for short interruptions in the current without changing the state of the MOT_START output. In this mode of operation, the value of the setting is in the range of around 100 milliseconds.
- In the "IIt, CB" or "IIt & stall, CB" modes, the purpose of this setting is to check for the life of the protection scheme after the CB_CLOSED input has been activated. Based on the values of the phase currents, the completion of the startup period cannot be judged. So in this mode of operation, the value of the time delay setting can even be as high as within the range of seconds, for example around 30 seconds.

The BLOCK input signal is used to block the operation of the MOT_START output. The activation of the BLOCK input signal deactivates the MOT_START output.

Thermal stress calculator

Because of the high current surges during the startup period, a thermal stress is imposed on the rotor. With less air circulation in the ventilation of the rotor before it reaches its full speed, the situation becomes even worse. Consequently, a long startup causes a rapid heating of the rotor.

This module calculates the thermal stress developed in the motor during startup. The heat developed during the starting can be calculated using the formula,

$$W = R_s \int_0^t i_s^2(t)\,dt$$

(Equation 17)

R_s combined rotor and stator resistance

i_s starting current of the motor

t starting time of the motor

This equation is normally represented as the integral of I²t. It is a commonly used method in protective relays to protect the motor from thermal stress during starting. The advantage of this method over the traditional definite time overcurrent protection is that when the motor is started with a reduced voltage as in the star-delta starting method, the starting current is lower. This allows more starting time for the motor since the module is monitoring the integral of I²t.

The module calculates the accumulated heat continuously and compares it to the limiting value obtained from the product of the square of the values of the *Motor start-up A* and *Motor start-up time* settings. When the calculated value of the thermal stress exceeds this limit, the OPR_IIT output is activated.

The module also measures the time START_TIME required by the motor to attain the rated speed and the relative thermal stress IIT_RL. The values are available through the monitored data view.

The BLOCK input is used to reset the operation of thermal stress calculator. The activation of the BLOCK input signal blocks the operation of the OPR_IIT output.

Stall protection

This module is activated only when the selected *Operation mode* setting value is "IIt & stall" or "IIt & stall, CB".

The startup current is specific to each motor and depends on the startup method used, like direct on-line, autotransformer and rotor resistance insertion. The startup time depends on the load connected to the motor.

Based on the motor characteristics supplied by the manufacturer, this module is required if the stalling time is shorter than or too close to the starting time. In such cases, a speed switch must be used to indicate whether a motor is accelerating during startup or not.

At motor standstill, the STALL_IND input is active. It indicates that the motor is not running. When the motor is started, at certain revolution the activation of the

STALL_IND input by the speed switch indicates that the motor is running. If the input is activated within *Lock rotor time*, the OPR_STALL output is activated.

The module calculates the duration of the motor in stalling condition, the STALL_RL output indicating the percent ratio of the start situation and the set value of *Lock rotor time*. The value is available through the monitored data view.

The BLOCK input signal is used to block the operation of the OPR_STALL output. The activation of the BLOCK input resets the operate timer.

Cumulative startup protection

This module protects the motor from an excessive number of startups.

Whenever the motor is started, the latest value of START_TIME is added to the existing value of T_ST_CNT and the updated cumulative startup time is available at T_ST_CNT. If the value of T_ST_CNT is greater than the value of *Cumulative time Lim*, the LOCK_START output, that is, the lockout condition for the restart of motor, is enabled. The LOCK_START output remains high until the T_ST_CNT value reduces to a value less than the value of *Cumulative time Lim*. The start time counter reduces at the rate of the value of *Counter Red rate*.

The LOCK_START output becomes activated at the start of MOT_START. The output remains active for a period of *Restart inhibit time*.

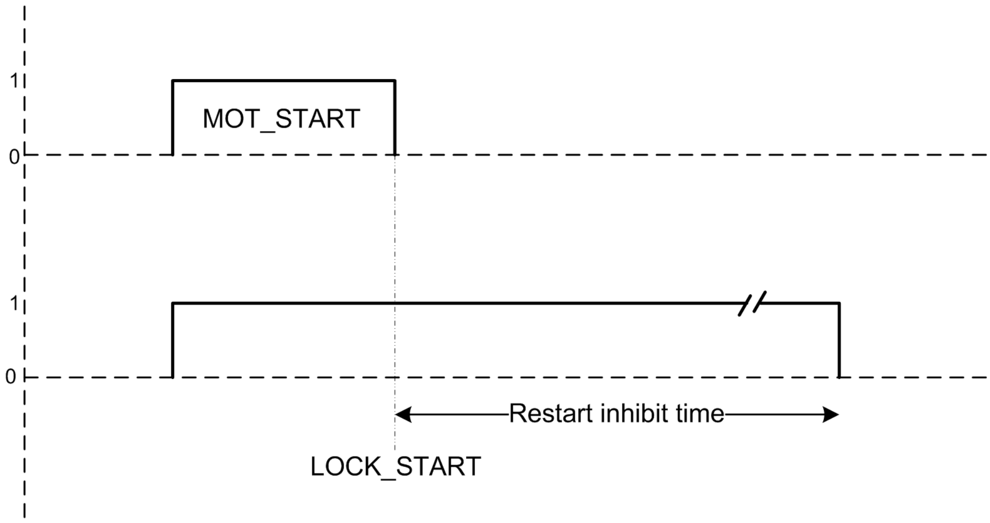


Figure 114: Time delay for cumulative start

This module also protects the motor from consecutive startups. When the LOCK_START output is active, T_RST_ENA shows the possible time for next restart. The value of T_RST_ENA is calculated by the difference of *Restart inhibit time* and the elapsed time from the instant LOCK_START is enabled.

When the ST_EMERG_ENA emergency start is set high, the value of the cumulative startup time counter is set to *Cumulative time Lim* - 60s × *Emg start Red rate*. This disables LOCK_START and in turn makes the restart of the motor possible.

This module also calculates the total number of startups occurred, START_CNT. The value can be reset from the clear menu.

The calculated values of T_RST_ENA, T_ST_CNT and START_CNT are available through the monitored data view.

The BLK_LK_ST input signal is used to block the operation of the LOCK_START output. The activation of the BLOCK input resets the complete operation of the cumulative startup counter module.

4.5.5 Application

When a motor is started, it draws a current well in excess of the motor's full load rating throughout the period it takes for the motor to run up to the rated speed. The motor starting current decreases as the motor speed increases and the value of current remains close to the rotor locked value for most of the acceleration period.

The full voltage starting or the direct-on-line starting method is used out of the many methods used for starting the induction motor. If there is either an electrical or mechanical constraint, this starting method is not suitable. The full voltage starting produces the highest starting torque. A high starting torque is generally required to start a high-inertia load to limit the acceleration time. In this method, full voltage is applied to the motor when the switch is in the "On" position. This method of starting results in a large initial current surge, which is typically four to eight times that of the full-load current drawn by the motor. If a star-delta starter is used, the value of the line current will only be about one-third of the direct-on-line starting current.

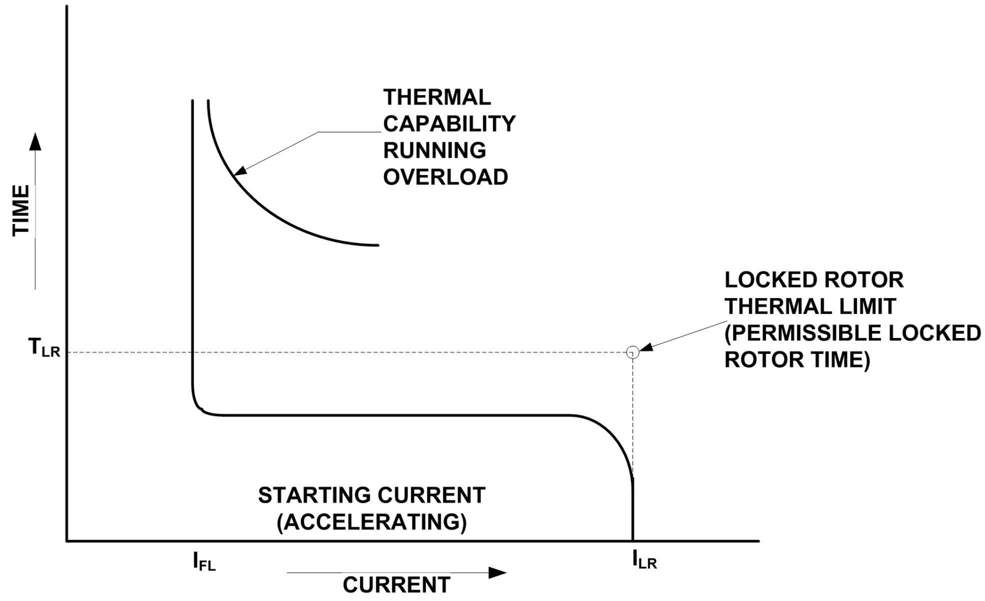


Figure 115: Typical motor starting and capability curves

The startup supervision of a motor is an important function because of the higher thermal stress developed during starting. During the startup, the current surge imposes a thermal strain on the rotor. This is exaggerated as the air flow for cooling is less because the fans do not rotate in their full speed. Moreover, the difference of speed between the rotating magnetic field and the rotor during the startup time induces a high magnitude of slip current in the rotor at frequencies higher than when the motor is at full speed. The skin effect is stronger at higher frequencies and all these factors increase the losses and the generated heat. This is worse when the rotor is locked.

The starting current for slip-ring motors is less than the full load current and therefore it is advisable to use the circuit breaker in the closed position to indicate the starting for such type of motors.

The starting times vary depending on motor design and load-torque characteristics. The time taken may vary from less than two seconds to more than 60 seconds. The starting time is determined for each application.

When the permissible stall time is less than the starting time of the motor, the stalling protection is used and the value of the time delay setting should be set slightly less than the permissible stall time. The speed switch on the motor shaft must be used for detecting whether the motor begins to accelerate or not. However, if the safe stall time is longer than the startup time of the motor, the speed switch is not required.

The failure of a motor to accelerate or to reach its full nominal speed in an acceptable time when the stator is energized is caused by several types of abnormal conditions, including a mechanical failure of the motor or load bearings, low supply voltage, open circuit in one phase of a three-phase voltage supply or too high starting voltage. All these abnormal conditions result in overheating.

Repeated starts increase the temperature to a high value in the stator or rotor windings, or both, unless enough time is allowed for the heat to dissipate. To ensure a safe operation it is necessary to provide a fixed-time interval between starts or limit the number of starts within a period of time. This is why the motor manufacturers have restrictions on how many starts are allowed in a defined time interval. This function does not allow starting of the motor if the number of starts exceeds the set level in the register that calculates them. This insures that the thermal effects on the motor for consecutive starts stay within permissible levels.

For example, the motor manufacturer may state that three starts at the maximum are allowed within 4 hours and the startup situation time is 60 seconds. By initiating three successive starts we reach the situation as illustrated. As a result, the value of the register adds up to a total of 180 seconds. Right after the third start has been initiated, the output lock of start of motor is activated and the fourth start will not be allowed, provided the time limit has been set to 121 seconds.

Furthermore, a maximum of three starts in 4 hours means that the value of the register should reach the set start time counter limit within 4 hours to allow a new start. Accordingly, the start time counter reduction should be 60 seconds in 4 hours and should thus be set to 60 s / 4 h = 15 s / h.

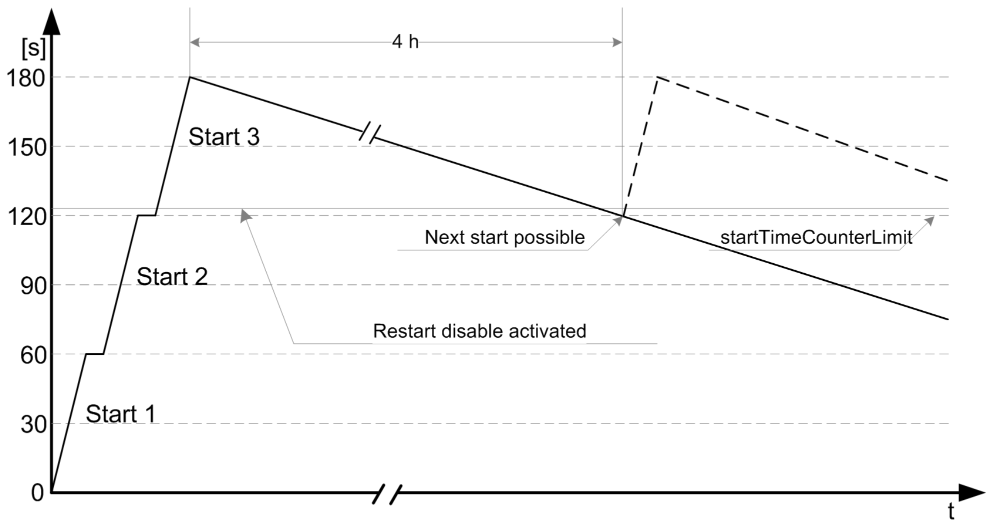


Figure 116: Typical motor-starting and capability curves

Setting of *Cumulative time Lim*

Cumulative time Lim is calculated by

$$\sum t_{si} = (n-1) \times t + margin$$

(Equation 18)

n	specified maximum allowed number of motor startups
t	startup time of the motor (in seconds)
margin	safety margin (~10...20 percent)

Setting of *Counter Red rate*

Counter Red rate is calculated by

$$\Delta \sum t_s = \frac{t}{t_{reset}}$$

(Equation 19)

t	specified start time of the motor in seconds
t_{reset}	duration during which the maximum number of motor startups stated by the manufacturer can be made; time in hours

4.5.6 Signals

Table 231: STTPMSU Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block of function
BLK_LK_ST	BOOLEAN	0=False	Blocks lock out condition for restart of motor
CB_CLOSED	BOOLEAN	0=False	Input showing the status of motor circuit breaker
STALL_IND	BOOLEAN	0=False	Input signal for showing the motor is not stalling
ST_EMERG_ENA	BOOLEAN	0=False	Enable emergency start to disable lock of start of motor

Table 232: STTPMSU Output signals

Name	Type	Description
OPR_IIT	BOOLEAN	Operate/trip signal for thermal stress.
OPR_STALL	BOOLEAN	Operate/trip signal for stalling protection.
MOT_START	BOOLEAN	Signal to show that motor startup is in progress
LOCK_START	BOOLEAN	Lock out condition for restart of motor.

4.5.7 Settings

Table 233: STTPMSU Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start detection A	0.1...10.0	xIn	0.1	1.5	Current value for detecting starting of motor.
Motor start-up A	1.0...10.0	xIn	0.1	2.0	Motor starting current
Motor start-up time	1...80	s	1	5	Motor starting time
Lock rotor time	2...120	s	1	10	Permitted stalling time
Str over delay time	0...60000	ms	1	100	Time delay to check for completion of motor startup period

Table 234: STTPMSU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operation mode	1=IIt 2=IIt, CB 3=IIt + stall 4=IIt + stall, CB			1=IIt	Motor start-up operation mode
Counter Red rate	2.0...250.0	s/h	0.1	60.0	Start time counter reduction rate
Cumulative time Lim	1...500	s	1	10	Cumulative time based restart inhibit limit
Emg start Red rate	0.00...100.00	%	0.01	20.00	Start time reduction factor when emergency start is On
Restart inhibit time	0...250	min	1	30	Time delay between consecutive startups
Motor standstill A	0.05...0.20	xIn	0.01	0.12	Current limit to check for motor standstill condition

4.5.8 Monitored data

Table 235: STTPMSU Monitored data

Name	Type	Values (Range)	Unit	Description
START_CNT	INT32	0...999999		Number of motor start-ups occurred
START_TIME	FLOAT32	0.0...999.9	s	Measured motor latest startup time in sec
T_ST_CNT	FLOAT32	0.0...99999.9	s	Cumulated start-up time in sec
T_RST_ENA	INT32	0...999	min	Time left for restart when lockstart is enabled in minutes
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
IIT_RL	FLOAT32	0.00...100.00	%	Thermal stress relative to set maximum thermal stress
STALL_RL	FLOAT32	0.00...100.00	%	Start time relative to the operate time for stall condition
STTPMSU	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.9 Technical data

Table 236: STTPMSU Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2Hz		
		±1.5% of the set value or ±0.002 x I_n		
Start time[1)2)]		Minimum	Typical	Maximum
	I_{Fault} = 1.1 x set *Start detection A*	27 ms	30 ms	34 ms
Operate time accuracy		±1.0% of the set value or ±20 ms		
Reset ratio		Typical 0.90		

1) Current before = 0.0 x I_n, f_n = 50 Hz, overcurrent in one phase, results based on statistical distribution of 1000 measurements
2) Includes the delay of the signal output contact

Section 5 Protection related functions

5.1 Three-phase inrush detector INRPHAR

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase inrush detector	INRPHAR	3I2f>	68

5.1.2 Function block

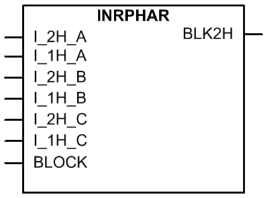


Figure 117: Function block

5.1.3 Functionality

The transformer inrush detection INRPHAR is used to coordinate transformer inrush situations in distribution networks.

Transformer inrush detection is based on the following principle: the output signal BLK2H is activated once the numerically derived ratio of second harmonic current I_2H and the fundamental frequency current I_1H exceeds the set value.

The operate time characteristic for the function is of definite time (DT) type.

The function contains a blocking functionality. Blocking deactivates all outputs and resets timers.

5.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the inrush current detection function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

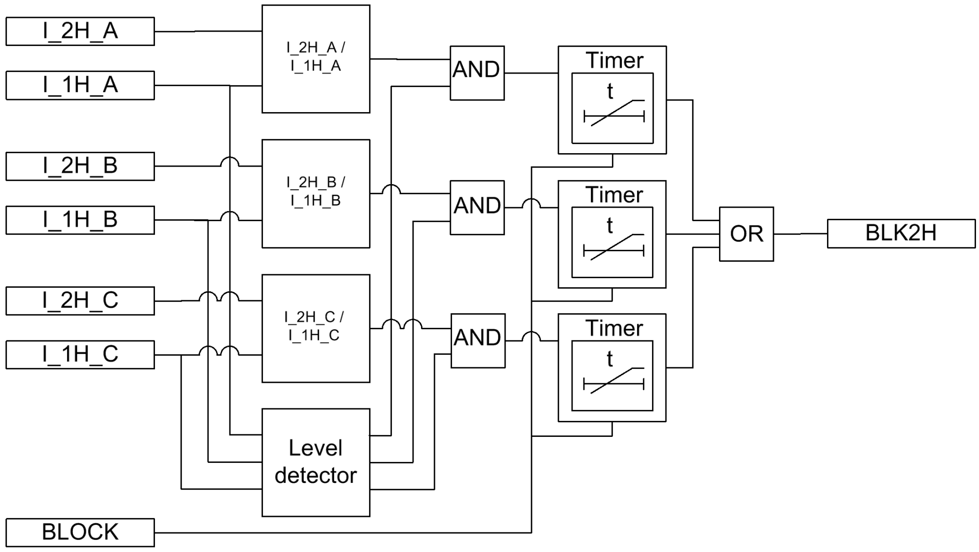


Figure 118: Functional module diagram. I_1H and I_2H represent fundamental and second harmonic values of phase currents.

I_2H/I_1H

This module calculates the ratio of the second harmonic (I_2H) and fundamental frequency (I_1H) phase currents. The calculated value is compared to the set *Start value*. If the calculated value exceeds the set *Start value*, the module output is activated.

Level detector

The output of the phase-specific level detector is activated when the fundamental frequency current I_1H exceeds five percent of the nominal current.

Timer

Once activated, the timer runs until the set *Operate delay time* value. The time characteristic is according to DT. When the operation timer has reached the *Operate delay time* value, the BLK2H output is activated. After the timer has elapsed and the inrush situation still exists, the BLK2H signal remains active until the I_2H/I_1H ratio drops below the value set for the ratio in all phases, that is, until the inrush situation is over. If the drop-off situation occurs within the operate time, the reset timer is activated. If the drop-off time exceeds *Reset delay time*, the operate timer is reset.

The BLOCK input can be controlled with a binary input, a horizontal communication input or an internal signal of the relay program. The activation of the BLOCK input prevents the BLK2H output from being activated.

It is recommended to use the second harmonic and waveform-based inrush blocking from the TR2PTDF function if available.

5.1.5 Application

Transformer protections require high stability to avoid tripping during magnetizing inrush conditions. A typical example of an inrush detector application is doubling the start value of an overcurrent protection during inrush detection.

The inrush detection function can be used to selectively block overcurrent and earth-fault function stages when the ratio of second harmonic component over the fundamental component exceeds the set value.

Other applications of this function include the detection of inrush in lines connected to a transformer.

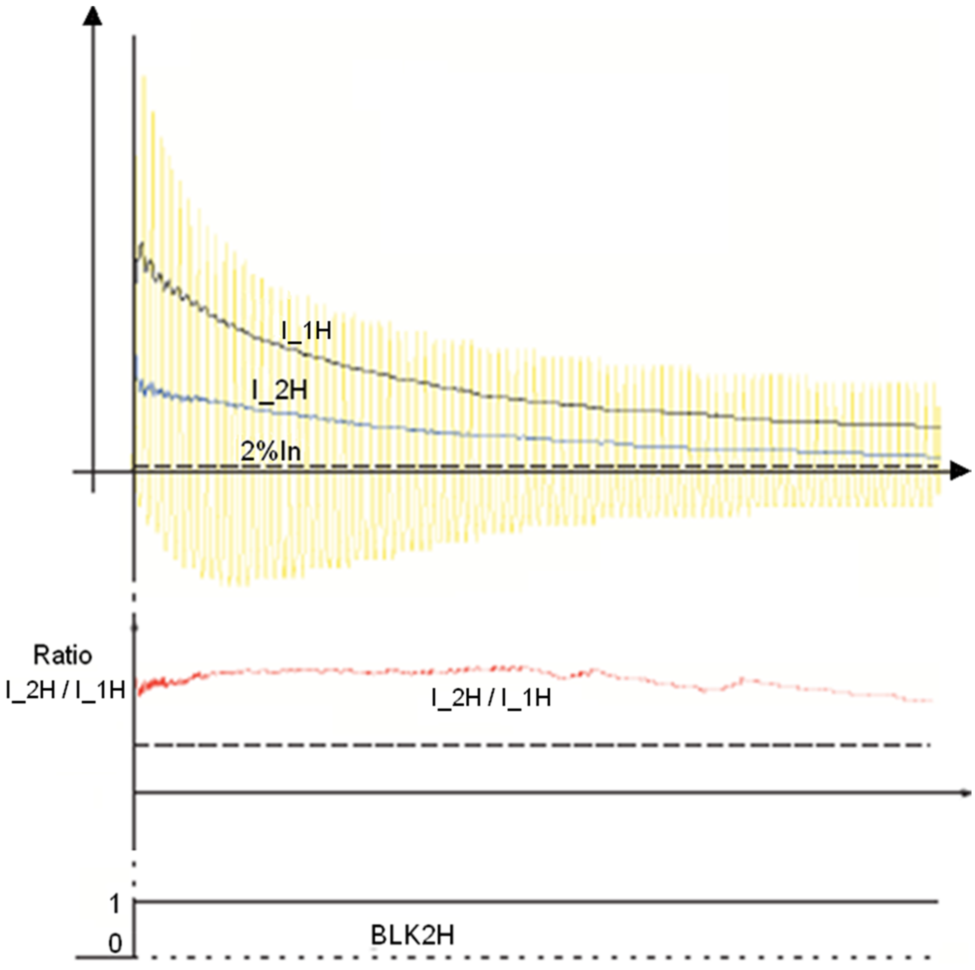


Figure 119: Inrush current in transformer

5.1.6 Signals

Table 237: INRPHAR Input signals

Name	Type	Default	Description
I_2H_A	SIGNAL	0	Second harmonic phase A current
I_1H_A	SIGNAL	0	Fundamental frequency phase A current
I_2H_B	SIGNAL	0	Second harmonic phase B current
I_1H_B	SIGNAL	0	Fundamental frequency phase B current
I_2H_C	SIGNAL	0	Second harmonic phase C current
I_1H_C	SIGNAL	0	Fundamental frequency phase C current
BLOCK	BOOLEAN	0=False	Block input status

Table 238: INRPHAR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

5.1.7 Settings

Table 239: INRPHAR Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	5...100	%	1	20	Ratio of the 2. to the 1. harmonic leading to restraint
Operate delay time	20...60000	ms	1	20	Operate delay time

Table 240: INRPHAR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Reset delay time	0...60000	ms	1	20	Reset delay time

5.1.8 Monitored data

Table 241: INRPHAR Monitored data

Name	Type	Values (Range)	Unit	Description
INRPHAR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.1.9 Technical data

Table 242: INRPHAR Technical data

Characteristic	Value
Operation accuracy	At the frequency $f=f_n$
	Current measurement: ±1.5% of the set value or ±0.002 x I_n Ratio I2f/I1f measurement: ±5.0% of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typical 0.96
Operate time accuracy	+35 ms / -0 ms

5.2 Circuit breaker failure protection CCBRBRF

5.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker failure protection	CCBRBRF	3I>/Io>BF	51BF/51NBF

5.2.2 Function block

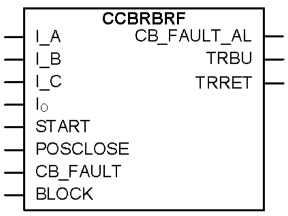


Figure 120: Function block

5.2.3 Functionality

The breaker failure function CCBRBRF is activated by trip commands from the protection functions. The commands are either internal commands to the terminal or external commands through binary inputs. The start command is always a default for three-phase operation. CCBRBRF includes a three-phase conditional or unconditional re-trip function, and also a three-phase conditional back-up trip function.

CCBRBRF uses the same levels of current detection for both re-trip and back-up trip. The operating values of the current measuring elements can be set within a predefined setting range. The function has two independent timers for trip purposes: a re-trip timer for the repeated tripping of its own breaker and a back-up timer for the trip logic operation for upstream breakers. A minimum trip pulse length can be set independently for the trip output.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

5.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the breaker failure protection can be described using a module diagram. All the blocks in the diagram are explained in the next sections. Also further information on the retrip and backup trip logics is given in sub-module diagrams.

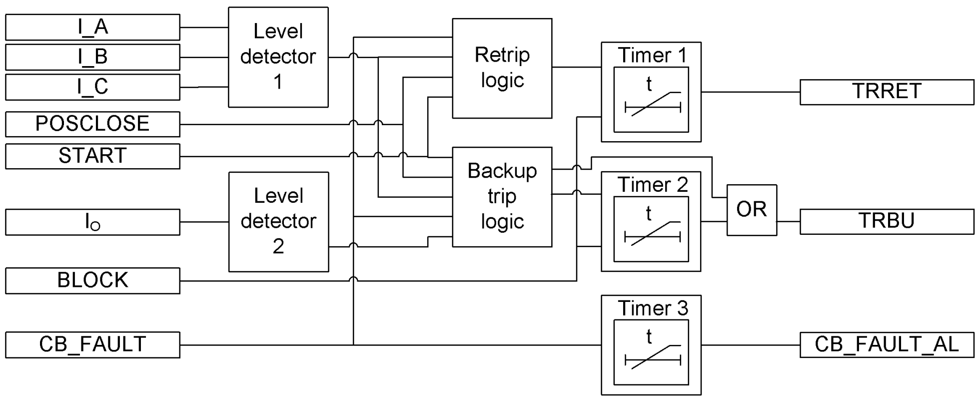


Figure 121: Functional module diagram. I_A, I_B and I_C represent phase currents and I_0 residual current.

Level detector 1

The measured phase currents are compared phasewise to the set *Current value*. If the measured value exceeds the set *Current value*, the level detector reports the exceeding of the value to the retrip and backup trip logics. The parameter should be set low enough so that situations with a small fault current or high load current can be detected. The setting can be chosen in accordance with the most sensitive protection function to start the breaker failure protection.

Level detector 2

The measured residual current is compared to the set *Current value Res*. If the measured value exceeds the set *Current value Res*, the level detector reports the exceeding of the value to the backup trip logic. In high-impedance earthed systems, the residual current at phase-to-earth faults are normally much smaller than the short circuit currents. To detect a breaker failure at single-phase earth faults in these systems, it is necessary to measure the residual current separately. In effectively earthed systems, also the setting of the earth-fault current protection can be chosen at a relatively low current level. The *CB failure trip mode* is set "1 out of 4". The current setting should be chosen in accordance with the setting of the sensitive earth-fault protection.

Retrip logic

The operation of the retrip logic can be described with a module diagram:

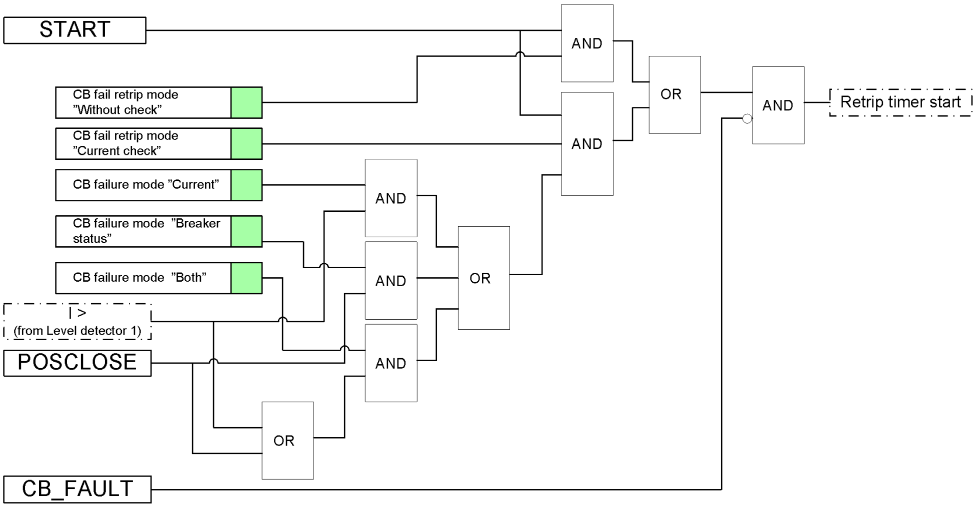


Figure 122: Retrip logic internal design

The retrip function operates with or without a current check selected with the *CB fail retrip mode* setting. In "Current check" mode, the retrip is only performed if the current through the circuit breaker exceeds the *Current value* level. In "Without check" mode, the retrip is done without checking the phase currents.

The *CB failure mode* setting is used to select the mode with which the breaker fault is detected. In the "Current" mode, the detection is based on the current level exceeding. In the "Breaker status" mode, the detection is based on the closed position of the circuit breaker after a trip signal is issued, that is, after a long duration of the trip signal. In the "Both" mode, the detection is based either on the exceeding of the *Current value* level or on the long duration of the trip signal. When external information of a circuit breaker fault is connected to the active `CB_FAULT` input, the retrip function is not allowed to operate. The blocking is used to disable the whole function.

Backup trip logic

The operation of the backup trip logic can be described with a module diagram:

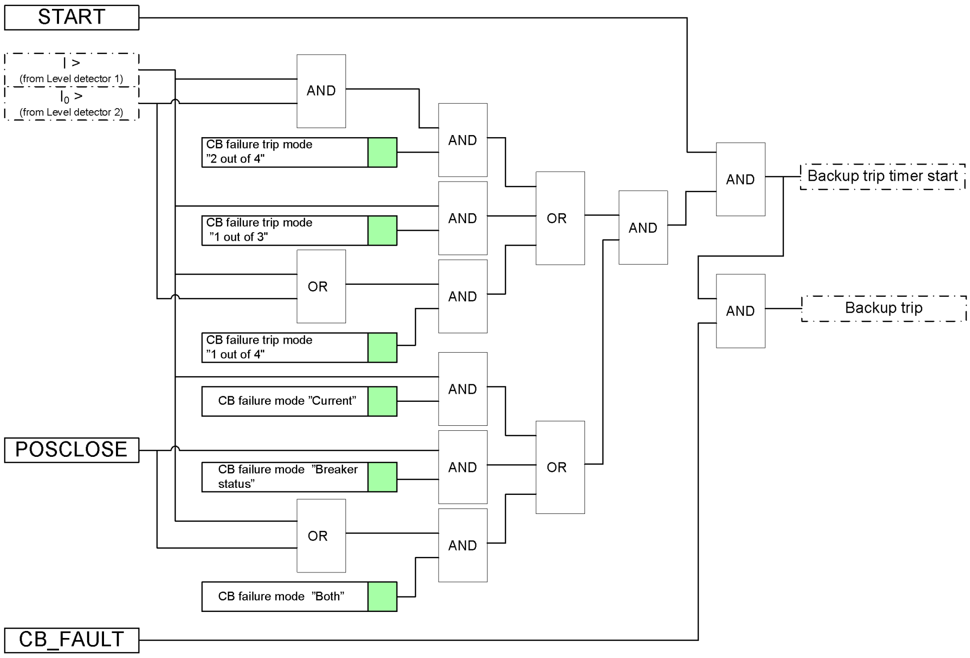


Figure 123: Backup trip logic internal design

The current detection characteristics can be selected with the *CB failure trip mode* setting in the following three options:

- "1 out of 3" in which detecting opening failure (high current) in one phase only is sufficient
- "1 out of 4" in which detecting opening failure (high current) or high residual current in one phase only is sufficient
- "2 out of 4" in which at least two high currents (phase current and residual current) are required for breaker failure detection.

In most applications, "1 out of 3" is sufficient. In the "Breaker status" mode, the backup trip is done when the status inputs indicate that the circuit breaker is in the closed state.

The setting *CB failure mode* is used to select the mode with which the breaker fault is detected. In the "Current" mode, the detection is based on the current level exceeding. In the "Breaker status" mode, the detection is based on the closed position of the circuit breaker after a trip signal is issued, that is, after a long duration of the trip signal. In the "Both" mode, the detection is based either on the exceeding of the *Current value Res* level, depending on the current detection mode, or on the long duration of the trip signal. When external information on a circuit breaker fault is connected to the active `CB_FAULT` input, the backup trip function is issued to the upstream breaker without delay. The blocking is used for disabling the whole function.

Timer 1

Once activated, the timer runs until the set *Retrip time* value has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `TRRET` output is activated. A typical setting is 0 - 50 ms.

Timer 2

Once activated, the timer runs until the set *CB failure delay* value has elapsed. The time characteristic is according to DT. When the operation timer has reached the set maximum time value *CB failure delay*, the `TRBU` output is activated. The value of this setting is made as low as possible at the same time as any unwanted operation is avoided. A typical setting is 90 - 150 ms which is also dependent on the retrip timer.

The minimum time delay for the retrip can be estimated as:

$$CBfailuredelay \geq Retriptime + t_{cbopen} + t_{BFP\_reset} + t_{margin}$$

(Equation 20)

t_{cbopen}	maximum opening time for the circuit breaker
t_{BFP_reset}	maximum time for the breaker failure protection to detect the correct breaker function (the current criteria reset)
t_{margin}	safety margin

It is often required that the total fault clearance time is less than the given critical time. This time often depends on the ability to maintain transient stability in case of a fault close to a power plant.

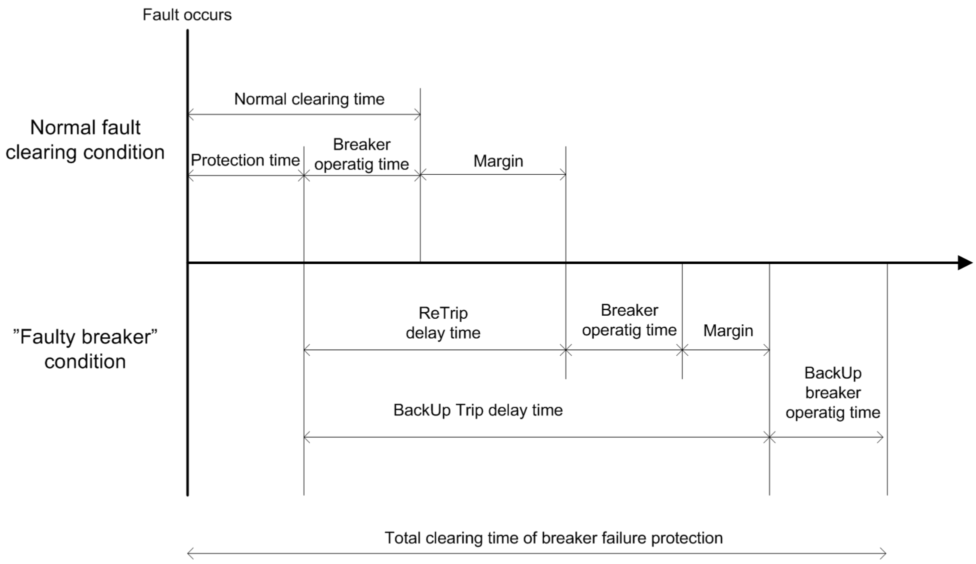


Figure 124: Timeline of breaker failure protection

Timer 3

This module is activated by the CB_FAULT signal. Once activated, the timer runs until the set *CB fault delay* value has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the CB_FAULT_AL output is activated. After the set time an alarm is given so that actions can be done to repair the circuit breaker. A typical value is 5 s.

5.2.5 Application

The n-1 criterion is often used in the design of a fault clearance system. This means that the fault is cleared even if some component in the fault clearance system is faulty. A circuit breaker is a necessary component in the fault clearance system. For practical and economical reasons, it is not feasible to duplicate the circuit breaker for the protected component, but breaker failure protection is used instead.

The breaker failure function issues a back-up trip command to adjacent circuit breakers in case the original circuit breaker fails to trip for the protected component. The detection of a failure to break the current through the breaker is made by measuring the current or by detecting the remaining trip signal (unconditional).

CCBRBRF can also retrip. This means that a second trip signal is sent to the protected circuit breaker. The retrip function is used to increase the operational reliability of the breaker. The function can also be used to avoid back-up tripping of several breakers in case mistakes occur during IED maintenance and tests.

CCBRBRF is initiated by operating different protection functions or digital logics inside the IED. It is also possible to initiate the function externally through a binary input.

CCBRBRF can be blocked by using an internally assigned signal or an external signal from a binary input. This signal blocks the function of the breaker failure protection even when the timers have started or the timers are reset.

The retrip timer is initiated after the start input is set to true. When the pre-defined time setting is exceeded, CCBRBRF issues the retrip and sends a trip command, for example, to the circuit breaker's second trip coil. Both a retrip with current check and an unconditional retrip are available. When a retrip with current check is chosen, the retrip is performed only if there is a current flow through the circuit breaker.

The backup trip timer is also initiated at the same time as the retrip timer. If CCBRBRF detects a failure in tripping the fault within the set backup delay time, which is longer than the retrip time, it sends a backup trip signal to the chosen backup breakers. The circuit breakers are normally upstream breakers which feed fault current to a faulty feeder.

The backup trip always includes a current check criterion. This means that the criterion for a breaker failure is that there is a current flow through the circuit breaker after the set backup delay time.

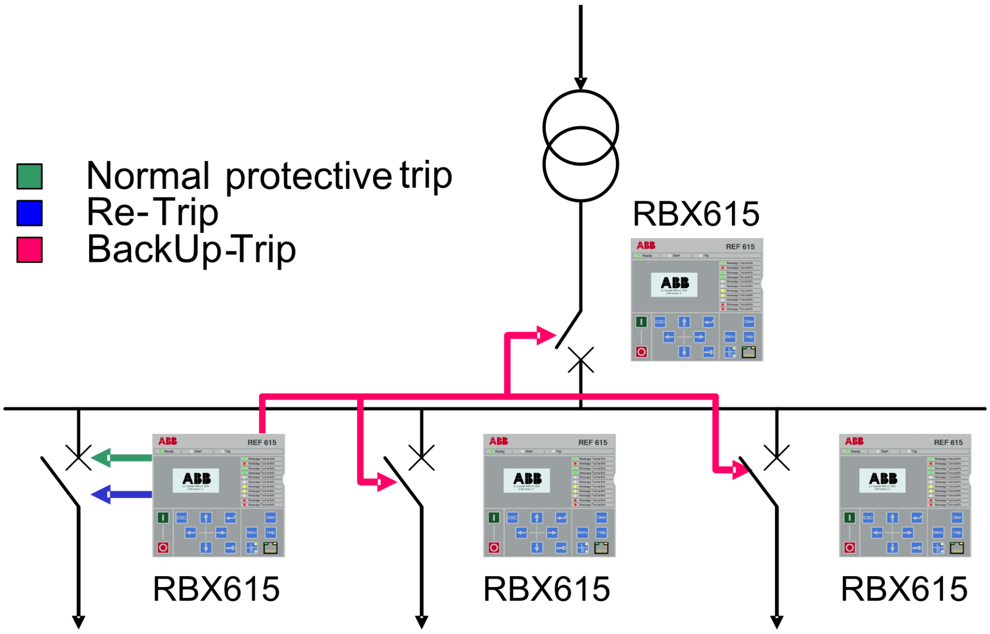


Figure 125: Typical breaker failure protection scheme in distribution substations

5.2.6 Signals

Table 243: CCBRBRF Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_0	SIGNAL	0	Residual current
START	BOOLEAN	0=False	CBFP start command
POSCLOSE	BOOLEAN	0=False	CB in closed position
CB_FAULT	BOOLEAN	0=False	CB faulty and unable to trip
BLOCK	BOOLEAN	0=False	Block CBFP operation

Table 244: CCBRBRF Output signals

Name	Type	Description
CB_FAULT_AL	BOOLEAN	Delayed CB failure alarm
TRBU	BOOLEAN	Backup trip
TRRET	BOOLEAN	Retrip

5.2.7 Settings

Table 245: CCBRBRF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Current value	0.05...1.00	xIn	0.05	0.30	Operating phase current
Current value Res	0.05...1.00	xIn	0.05	0.30	Operating residual current
CB failure trip mode	1=2 out of 4 2=1 out of 3 3=1 out of 4			1=2 out of 4	Backup trip current check mode
CB failure mode	1=Current 2=Breaker status 3=Both			1=Current	Operating mode of function
CB fail retrip mode	1=Off 2=Without Check 3=Current check			1=Off	Operating mode of retrip logic
Retrip time	0...60000	ms	10	20	Delay timer for retrip
CB failure delay	0...60000	ms	10	150	Delay timer for backup trip
CB fault delay	0...60000	ms	10	5000	Circuit breaker faulty delay
Measurement mode	2=DFT 3=Peak-to-Peak			2=DFT	Phase current measurement mode of function
Trip pulse time	0...60000	ms	10	20	Pulse length of retrip and backup trip outputs

5.2.8 Monitored data

Table 246: CCBRBRF Monitored data

Name	Type	Values (Range)	Unit	Description
CCBRBRF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.2.9 Technical data

Table 247: CCBRBRF Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	±1.5% of the set value or ±0.002 x I_n
Operate time accuracy	±1.0% of the set value or ±20 ms

5.3 Protection trip conditioning TRPPTRC

5.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Protection trip conditioning	TRPPTRC	Master Trip	94/86

5.3.2 Function block

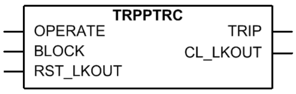


Figure 126: Function block

5.3.3 Functionality

The protection trip conditioning function TRPPTRC is used as a trip command collector and handler after the protection functions. The features of this function influence the trip signal behavior of the circuit breaker. The user can set the minimum trip pulse length when the non-latched mode is selected. It is also possible to select the latched or lockout mode for the trip signal.

5.3.4 Principle of operation

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

When the TRPPTRC function is disabled, all trip outputs which are intended to go through the function to the circuit breaker trip coil are blocked!

The operation of a trip logic function can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

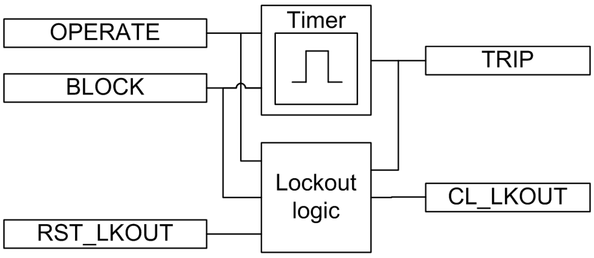


Figure 127: Functional module diagram

Timer

The user can adjust the duration of the TRIP output signal from the TRPPTRC function with the *Trip pulse time* setting when the "Non-latched" operation mode is used. The pulse length should be long enough to secure the opening of the breaker. For three-pole tripping, TRPPTRC has a single input OPERATE, through which all trip output signals are routed from the protection functions within the IED, or from external protection functions via one or more of the IED's binary inputs. The function has a single trip output TRIP for connecting the function to one or more of the IED's binary outputs, and also to other functions within the IED requiring this signal.

The BLOCK input blocks the TRIP output and resets the timer.

Lockout logic

TRPPTRC is provided with possibilities to activate a lockout. When activated, the lockout can be manually reset after checking the primary fault by activating the RST_LKOUT input or from the LHMI clear menu parameter. When using the "Latched" mode, the resetting of the TRIP output can done similarly as when using the "Lockout" mode. It is also possible to reset the "Latched" mode remotely through a separate communication parameter.

The minimum pulse trip function is not active when using the "Lockout" or "Latched" modes but only when the "Non-latched" mode is selected.

The CL_LKOUT and TRIP outputs can be blocked with the BLOCK input.

Table 248: Operation modes for the TRPPTRC trip output

Mode	Operation
Non-latched	The *Trip pulse length* parameter gives the minimum pulse length for TRIP
Latched	TRIP is latched ; both local and remote clearing is possible.
Lockout	TRIP is locked and can be cleared only locally via menu or the RST_LKOUT input.

5.3.5 Application

All trip signals from different protection functions are routed through the trip logic. The most simplified alternative of a logic function is linking the trip signal and ensuring that the signal is long enough.

The tripping logic in the protection relay is intended to be used in the three-phase tripping for all fault types (3ph operating). To prevent the closing of a circuit breaker after a trip, the function can block the CBXCBR closing.

The TRPPTRC function is intended to be connected to one trip coil of the corresponding circuit breaker. If tripping is needed for another trip coil or another circuit breaker which needs, for example, different trip pulse time, another trip logic function can be used. The two instances of the PTRC function are identical, only the names of the functions, TRPPTRC1 and TRPPTRC2, are different. Therefore, even if all references are made only to TRPPTRC1, they also apply to TRPPTRC2.

The inputs from the protection functions are connected to the `OPERATE` input. Usually, a logic block OR is required to combine the different function outputs to this input. The `TRIP` output is connected to the binary outputs on the IO board. This signal can also be used for other purposes within the IED, for example when starting the breaker failure protection.

TRPPTRC is used for simple three-phase tripping applications.

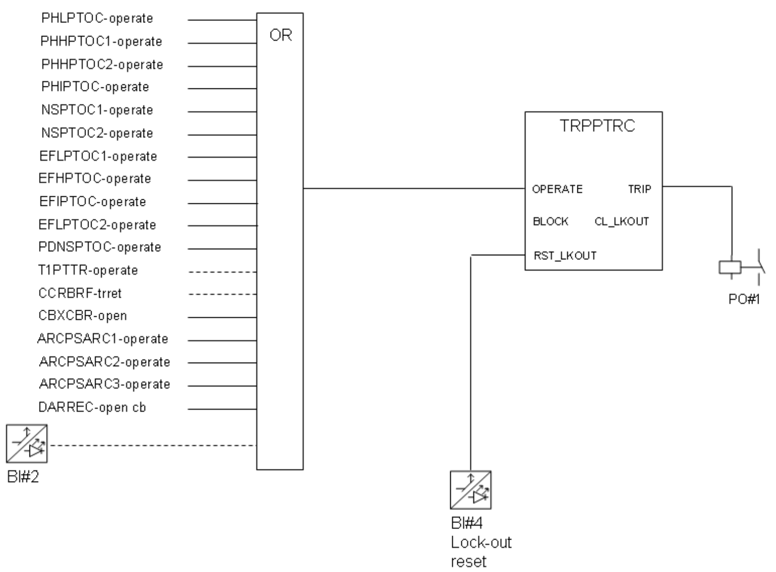


Figure 128: Typical TRPPTRC connection

Lock-out

TRPPTRC is provided with possibilities to activate a lockout. When activated, the lockout can be manually reset after checking the primary fault by activating the RST_LKOUT input or from the LHMI clear menu parameter. When using the “Latched” mode, the resetting of the TRIP output can done similarly as when using the “Lockout” mode. It is also possible to reset the “Latched” mode remotely through a separate communication parameter.

The minimum pulse trip pulse function is not active when using the “Lockout” or “Latched” modes but only when the “Non-latched” mode is selected.

5.3.6 Signals

Table 249: TRPPTRC Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block of function
OPERATE	BOOLEAN	0=False	Request to trip circuit breaker.
RST_LKOUT	BOOLEAN	0=False	Input for resetting the circuit breaker lockout function

Table 250: TRPPTRC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip output signal
CL_LKOUT	BOOLEAN	Circuit breaker lockout output (set until reset)

5.3.7 Settings

Table 251: TRPPTRC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Trip pulse time	20...60000	ms	1	150	Minimum duration of trip output signal
Trip output mode	1=Non-latched 2=Latched 3=Lockout			1=Non-latched	Select the operation mode for trip output

5.3.8 Monitored data

Table 252: TRPPTRC Monitored data

Name	Type	Values (Range)	Unit	Description
TRPPTRC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.4 Emergency start function ESMGAPC

5.4.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Emergency start function	ESMGAPC	ESTART	ESTART

5.4.2 Function block

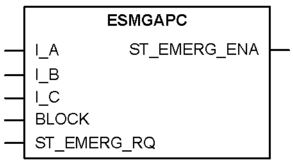


Figure 129: Function block

5.4.3 Functionality

An emergency condition can arise in cases where the motor needs to be started despite knowing that this can increase the temperature above limits or cause a thermal overload that can damage the motor. The emergency start function ESMGAPC allows motor startups during such emergency conditions. ESMGAPC is only to force the IED to allow the restarting of the motor. After the emergency start input is activated, the motor can be started normally. ESMGAPC itself does not actually restart the motor.

The function contains a blocking functionality. It is possible to block function outputs, timer or the function itself, if desired.

5.4.4 Operation principle

The operation of the emergency start function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

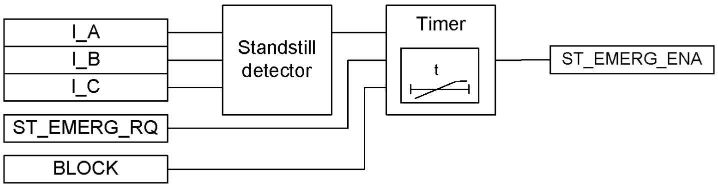


Figure 130: Functional module diagram

Standstill detector

The module detects if the motor is in a standstill condition. The standstill condition can be detected based on the phase current values. If all three phase currents are below the set value of *Motor standstill A*, the motor is considered to be in a standstill condition.

Timer

The timer is a fixed 10-minute timer which is activated when the ST_EMERG_RQ input is activated and motor standstill condition is fulfilled. Thus, the activation of the ST_EMERG_RQ input activates the ST_EMERG_ENA output, provided that the motor is in a standstill condition. The ST_EMERG_ENA output remains active for 10 minutes or as long as the ST_EMERG_RQ input is high, whichever takes longer.

The activation of the BLOCK input blocks and also resets the timer.

The function also provides the ST_EMERG_ENA output change date and time, T_ST_EMERG. The information is available through the Monitored data view.

5.4.5 Application

If the motor needs to be started in an emergency condition at the risk of damaging the motor, all the external restart inhibits are ignored, allowing the motor to be restarted. Furthermore, if the calculated thermal level is higher than the restart inhibit level at an emergency start condition, the calculated thermal level is set slightly below the restart inhibit level. Also, if the register value of the cumulative startup time counter exceeds the restart inhibit level, the value is set slightly below the restart disable value to allow at least one motor startup.

The activation of the ST_EMERG_RQ digital input allows to perform emergency start. The IED is forced to a state which allows the restart of motor, and the operator can now restart the motor. A new emergency start cannot be made until the 10 minute time-out has passed or until the emergency start is released, whichever takes longer.

The last change of the emergency start output signal is recorded.

5.4.6 Signals

Table 253: ESMGAPC Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ST_EMERG_RQ	BOOLEAN	0=False	Emergency start input

Table 254: ESMGAPC Output signals

Name	Type	Description
ST_EMERG_ENA	BOOLEAN	Emergency start

5.4.7 Settings

Table 255: ESMGAPC Group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Motor standstill A	0.05...0.20	xIn	0.01	0.12	Current limit to check for motor standstill condition

Table 256: ESMGAPC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On

5.4.8 Monitored data

Table 257: ESMGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
T_ST_EMERG	Timestamp			Emergency start activation timestamp
ESMGAPC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Section 6 Supervision functions

6.1 Coil switch supervision xCSSCBR

6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Open coil switch supervision	OCSSCBR	TCS	TCM
Closed coil switch supervision	CCSSCBR	TCS	TCM

6.1.2 Function block

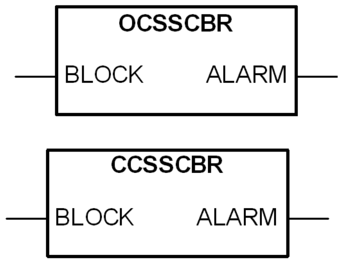


Figure 131: Function blocks

6.1.3 Functionality

The open coil switch supervision function OCSSCBR and closed coil switch supervision function CCSSCBR are designed to supervise control circuits. A dedicated circuit verifies the continuity of the coil to detect any invalidity in the control circuit. A coil switch failure is reported to the corresponding function block in the IED configuration.

The function starts and operates when a coil switch failure is detected. The operate time characteristic type is DT for the function. The function operates after a predefined operating time and resets when the fault disappears.

The function contains a blocking functionality. Blocking deactivates the `ALARM` output and resets the timer.

6.1.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the coil switch supervision function can be described using a module diagram. All the modules in the diagram are explained in the next sections

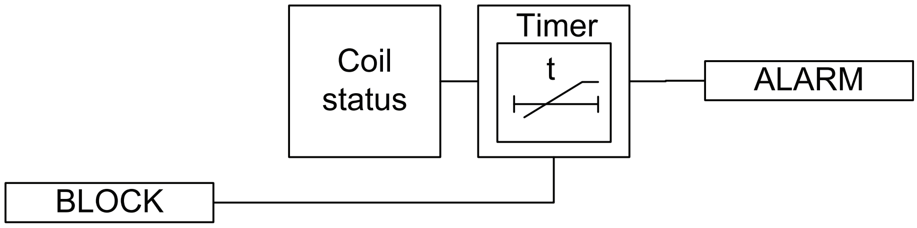


Figure 132: Functional module diagram

Coil status

The module receives the coil switch status from the hardware. A detected failure in the trip circuit activates the timer.

Timer

Once activated, the timer runs until the time set in the *Operate delay time* setting has elapsed. The time characteristic is according to DT. When the operation timer reaches the maximum time value, the `ALARM` output is activated. If a drop-off situation occurs during the operate time counting, the reset timer is activated. If the drop-off time exceeds the *Reset delay time* setting, the operation timer is reset.

If the drop-off period is longer than the time defined in the *Reset delay time* setting, the DT timer resets when the time defined in the *Reset delay time* setting has elapsed.

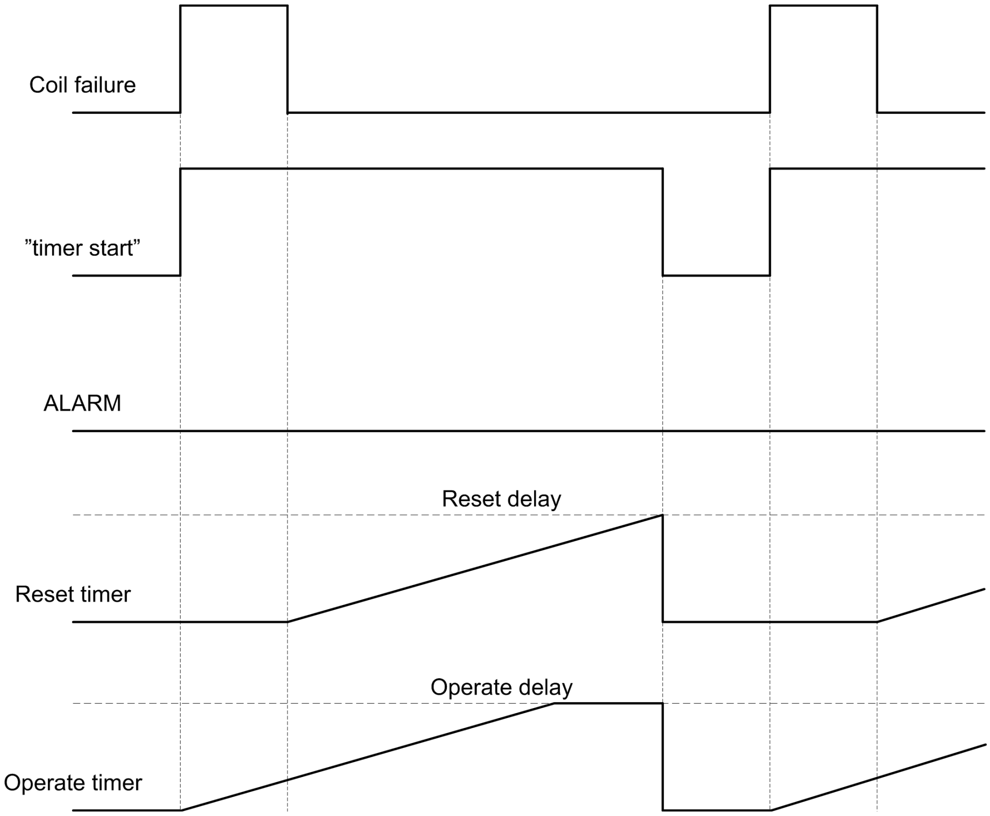


Figure 133: The drop-off period is longer than the set reset time

If the drop-off period is shorter than the set reset time and the DT timer operate time has elapsed during the drop-off period, the `Operate` output is activated once the trip circuit fault is reported again.

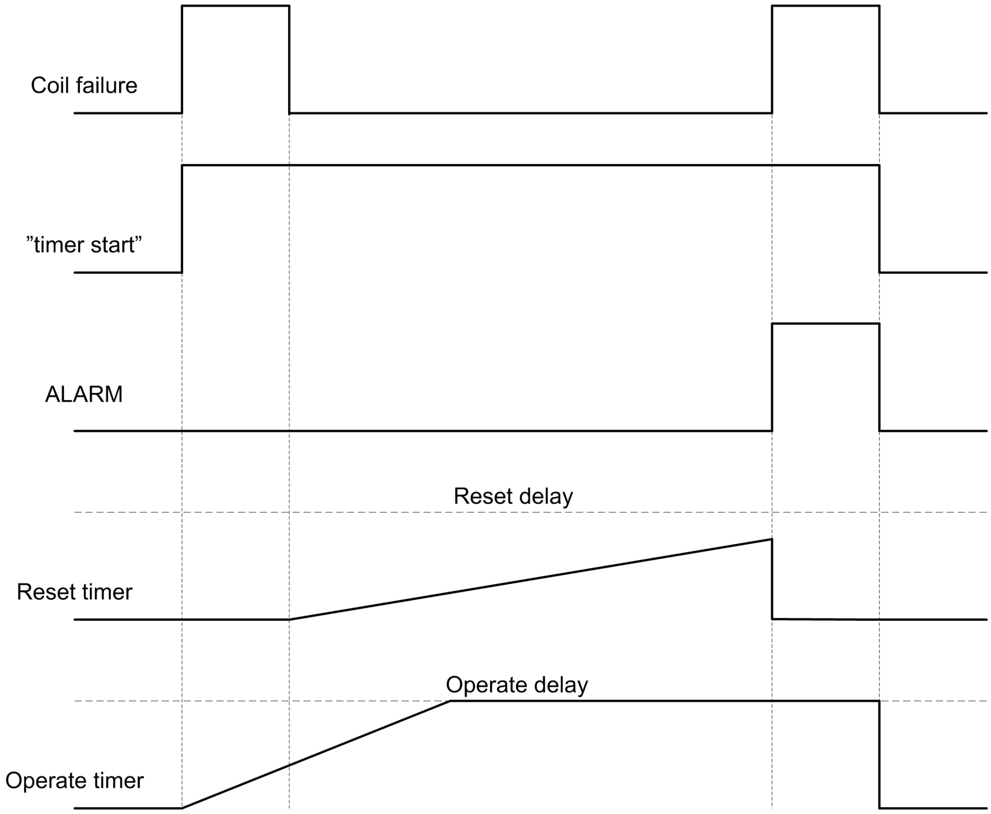


Figure 134: The drop-off period is shorter than the set reset time

Blocking

The BLOCK input can be controlled with a binary input, a horizontal communication input or an internal signal of the relay program. The activation of the BLOCK input prevents the ALARM output to be activated, and DT timer is reset.

6.1.5 Signals

Table 258: OCSSCBR Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block input status

Table 259: CCSSCBR Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block input status

Table 260: OCSSCBR Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

Table 261: CCSSCBR Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

6.1.6 Settings

Table 262: OCSSCBR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operate delay time	20...300000	ms	1	3000	Operate delay time
Reset delay time	20...60000	ms	1	1000	Reset delay time

Table 263: CCSSCBR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operate delay time	20...300000	ms	1	3000	Operate delay time
Reset delay time	20...60000	ms	1	1000	Reset delay time

6.1.7 Monitored data

Table 264: OCSSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
OCSSCBR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 265: CCSSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
CCSSCBR	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.2 Current circuit supervision CCRDIF

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current circuit supervision	CCRDIF	MCS 3I	MCS 3I

6.2.2 Function block

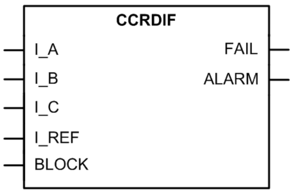


Figure 135: Function block

6.2.3 Functionality

The current circuit supervision function CCRDIF is used for monitoring current transformer secondary circuits.

CCRDIF calculates internally the sum of phase currents (I_A, I_B and I_C) and compares the sum against the measured single reference current (I_REF). The reference current must originate from other three-phase CT cores than the phase currents (I_A, I_B and I_C) and it is to be externally summated, that is, outside the IED.

CCRDIF detects a fault in the measurement circuit and issues an alarm or blocks the protection functions to avoid unwanted tripping.

It must be remembered that the blocking of protection functions at an occurring open CT circuit means that the situation remains unchanged and extremely high voltages stress the secondary circuit.

6.2.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of current circuit supervision can be described by using a module diagram. All the blocks in the diagram are explained in the next sections.

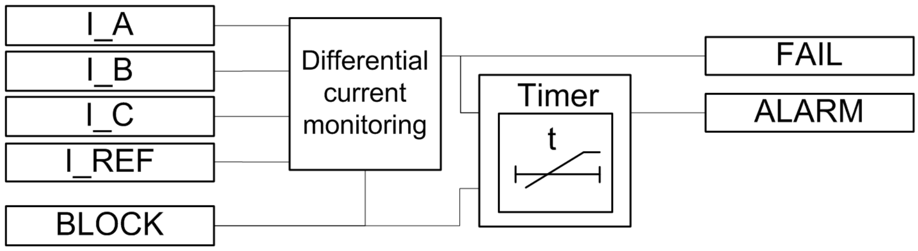


Figure 136: Functional module diagram

Differential current monitoring

Differential current monitoring supervises the difference between the summed phase currents I_A, I_B and I_C and the reference current I_REF.

The current operating characteristics can be selected with the *Start value* setting. When the highest phase current is less than 1.0 xIn, the differential current limit is defined with *Start value*. When the highest phase current is more that 1.0 xIn, the differential current limit is calculated with the formula:

$$MAX(I\_A, I\_B, I\_C) \times Startvalue$$

(Equation 21)

The differential current is limited to 1.0 xIn.

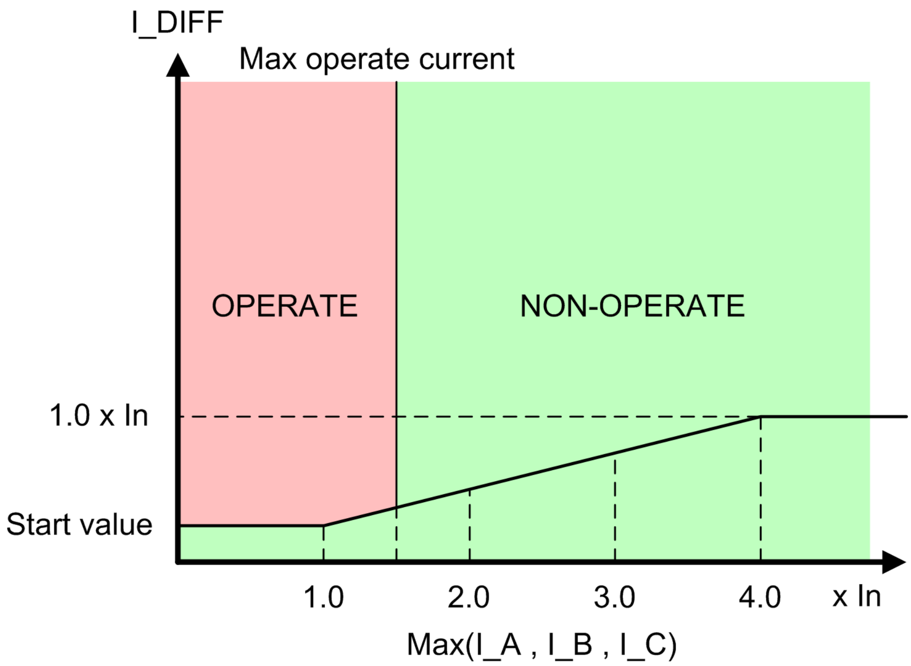


Figure 137: CCRDIF operating characteristics

When the differential current I_DIFF is in the operating region, the FAIL output is activated.

The function is internally blocked if any phase current is higher than the set *Max operate current*. When the internal blocking activates, the FAIL output is deactivated immediately. The internal blocking is used for avoiding false operation during a fault situation when the current transformers are saturated due to high fault currents.

The value of the differential current is available through the Monitored data view on the LHMI or through other communication tools. The value is calculated with the formula:

$$I\_DIFF = \left|\overline{I\_A} + \overline{I\_B} + \overline{I\_C}\right| - \left|\overline{I\_REF}\right|$$

(Equation 22)

The *Start value* setting is given in units of xIn of the phase current transformer. The possible difference in the phase and reference current transformer ratios is internally compensated by scaling I_REF with the value derived from the *Primary current* setting values. These setting parameters can be found in the Basic functions section.

The activation of the BLOCK input activates the FAIL output immediately.

Timer

The timer is activated with the FAIL signal. The ALARM output is activated after a fixed 200 ms delay. FAIL needs to be active during the delay.

When the internal blocking is activated, the FAIL output is deactivated immediately. The ALARM output is deactivated after a fixed 3 s delay, and the FAIL is deactivated.

The deactivation happens only when the highest phase current is more than 5 percent of the nominal current (0.05 xIn).

When the line is de-energized, the deactivation of the ALARM output is prevented.

The activation of the BLOCK input deactivates the ALARM output.

6.2.5 Application

Open or short-circuited current transformer cores can cause unwanted operation in many protection functions such as differential, earth-fault current and negative sequence current functions. When currents from two independent three-phase sets of CTs or CT cores measuring the same primary currents are available, reliable current circuit supervision can be arranged by comparing the currents from the two sets. When an error in any CT circuit is detected, the protection functions concerned can be blocked and an alarm given.

In case of high currents, the unequal transient saturation of CT cores with a different remanence or saturation factor may result in differences in the secondary currents from the two CT cores. Unwanted blocking of protection functions during the transient stage must then be avoided.

The supervision function must be sensitive and have a short operate time in order to prevent unwanted tripping from fast-acting, sensitive numerical protections in case of faulty CT secondary circuits.

Open CT circuits create extremely high voltages in the circuits which may damage the insulation and cause further problems. This must be taken into consideration especially when the protection functions are blocked.

When the reference current is not connected to the IED, the function should be turned off. Otherwise, the `FAIL` output is activated when unbalance occurs in the phase currents even if there was nothing wrong with the measurement circuit.

Reference current measured with earth current transformer

The function compares the sum of phase currents to the current measured with the earth CT.

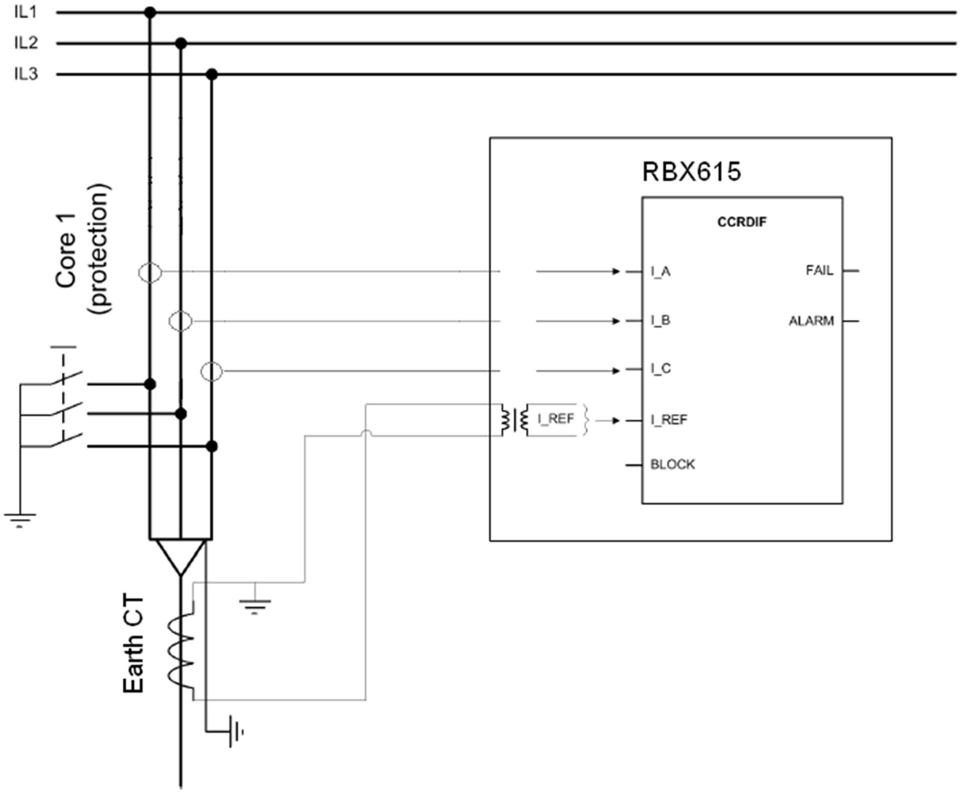


Figure 138: Connection diagram for reference current measurement with earth current transformer

6.2.6 Signals

Table 266: CCRDIF Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_REF	SIGNAL	0	Reference current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 267: CCRDIF Output signals

Name	Type	Description
FAIL	BOOLEAN	Fail output
ALARM	BOOLEAN	Alarm output

6.2.7 Settings

Table 268: CCRDIF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation On / Off
Start value	0.05...0.20	xIn	0.01	0.05	Minimum operate current differential level
Max operate current	1.00...5.00	xIn	0.01	1.50	Block of the function at high phase current

6.2.8 Monitored data

Table 269: CCRDIF Monitored data

Name	Type	Values (Range)	Unit	Description
IDIFF	FLOAT32	0.00...40.00	xIn	Differential current
CCRDIF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.2.9 Technical data

Table 270: CCRDIF Technical data

Characteristic	Value
Operate time[1)]	< 30 ms

1) Including the delay of the output contact.

6.3 Fuse failure supervision SEQRFUF

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fuse failure supervision	SEQRFUF	FUSEF	60

6.3.2 Function block

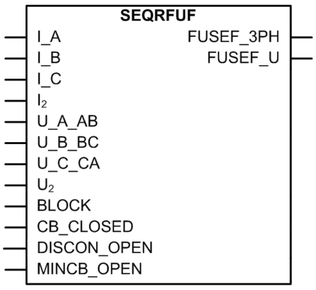


Figure 139: Function block

6.3.3 Functionality

The fuse failure supervision function SEQRFUF is used to block the voltage measuring functions at failures in the secondary circuits between the voltage transformer and IED to avoid unwanted operations.

SEQRFUF has two algorithms, a negative phase-sequence based algorithm and delta current and delta voltage algorithm.

A criterion based on the delta current and the delta voltage measurements can be activated to detect three-phase fuse failures which usually are more associated with the voltage transformer switching during station operations.

6.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the fuse failure supervision function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

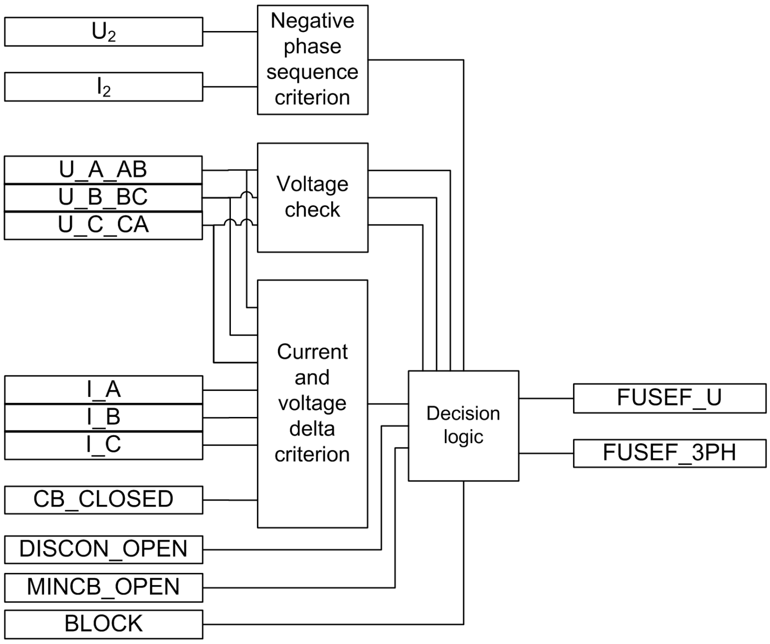


Figure 140: Functional module diagram

Negative phase-sequence criterion

A fuse failure based on the negative phase-sequence criterion is detected if the measured negative phase-sequence voltage exceeds the set *Neg Seq voltage Lev* value and the measured negative phase-sequence current is below the set *Neg Seq current Lev* value. The detected fuse failure is reported to the decision logic module.

Voltage check

The phase voltage magnitude is checked when deciding whether the fuse failure is a three-, two- or a single-phase fault.

The module makes a phase-specific comparison between each voltage input and the *Seal in voltage* setting. In case the input voltage is lower than the setting, the corresponding phase is reported to the decision logic module.

Current and voltage delta criterion

The delta function can be activated by setting the *Change rate enable* parameter to "True". Once the function is activated, it operates in parallel with the negative phase-sequence based algorithm. The current and voltage are continuously measured in all three phases to calculate:

- Change of voltage dU/dt
- Change of current dI/dt

The calculated delta quantities are compared to the respective set values of the *Current change rate* and *Voltage change rate* settings.

The delta current and delta voltage algorithms detect a fuse failure if there is a sufficient negative change in the voltage amplitude without a sufficient change in the current amplitude in each phase separately. This is performed when the circuit breaker is closed. Information about the circuit breaker position is connected to the `CB_CLOSED` input.

There are two conditions for activating the current and voltage delta function:

- The magnitude of ΔU exceeds the corresponding value of the *Min Op voltage delta* setting and the magnitude of ΔI is below the value of the *Min Op current delta* setting in any phase at the same time due to the closure of the circuit breaker, that is, `CB_CLOSED` = TRUE.
- The magnitude of ΔU exceeds the value of the *Min Op voltage delta* setting and the magnitude of ΔI is below the *Min Op current delta* setting in any phase at the same time since the magnitude of the phase current in the same phase exceeds the *Current level* setting.

The first condition requires the delta criterion to be fulfilled in any phase at the same time as the circuit breaker is closed. Opening the circuit breaker at one end and energizing the line from the other end onto a fault could lead to an improper operation of SEQRFUF with an open breaker. If this is considered to be an important disadvantage, the `CB_CLOSED` input is to be connected to FALSE.

The second condition requires the delta criterion to be fulfilled in one phase together with high current for the same phase. The measured phase current is used to reduce the risk of a false fuse failure detection. If the current on the protected line is low, a voltage drop in the system (not caused by the fuse failure) is not followed by a current change and a false fuse failure can occur. To prevent this, the minimum phase current criterion is checked.

The fuse failure detection is active until the voltages return above the *Min Op voltage delta* setting. If a voltage in a phase is below the *Min Op voltage delta* setting, a new fuse failure detection for that phase is not possible until the voltage returns above the setting value.

Decision logic

The fuse failure detection outputs `FUSEF_U` and `FUSEF_3PH` are controlled according to the detection criteria or external signals.

Table 271: Fuse failure output control

Fuse failure detection criterion	Conditions and function response
Negative phase-sequence criterion	If a fuse failure is detected based on the negative phase-sequence criterion, the FUSEF_U output is activated.
	If the fuse failure detection is active for more than five seconds and at the same time all the phase voltage values are below the set value of the *Seal in voltage* setting with *Enable seal in* turned to "Yes", the function activates the FUSE_3PH output signal.
	The FUSEF_U output signal is also activated if all the phase voltages are above the *Seal in voltage* setting for more than 60 seconds and at the same time the negative sequence voltage is above *Neg Seq voltage Lev* for more than 5 seconds, all the phase currents are below the *Current dead Lin Val* setting and the circuit breaker is closed, that is,CB_CLOSED is TRUE.
Current and voltage delta function criterion	If the current and voltage delta criterion detects a fuse failure condition, but all the voltages are not below the *Seal in voltage* setting, only the FUSEF_U output is activated.
	If the fuse failure detection is active for more than five seconds and at the same time all the phase voltage values are below the set value of the *Seal in voltage* setting with *Enable seal in* turned to "Yes", the function activates the FUSE_3PH output signal.
External fuse failure detection	The MINCB_OPEN input signal is supposed to be connected through an IED binary input to the N.C. auxiliary contact of the miniature circuit breaker protecting the VT secondary circuit. The MINCB_OPEN signal sets the FUSEF_U output signal to block all the voltage-related functions when MCB is in the open state.
	The DISCON_OPEN input signal is supposed to be connected through an IED binary input to the N.C. auxiliary contact of the line disconnector. The DISCON_OPEN signal sets the FUSEF_U output signal to block the voltage-related functions when the line disconnector is in the open state.

It is recommended to always set *Enable seal in* to "Yes". This secures that the blocked protection functions remain blocked until normal voltage conditions are restored if the fuse failure has been active for 5 seconds, that is, the fuse failure outputs are deactivated when the normal voltage conditions are restored.

The activation of the BLOCK input deactivates both FUSEF_U and FUSEF_3PH outputs.

6.3.5 Application

Some protection functions operate on the basis of the measured voltage value in the IED point. These functions can fail if there is a fault in the measuring circuits between the voltage transformers and the IED.

A fault in the voltage measuring circuit is referred to as a fuse failure. This term is misleading since a blown fuse is just one of the many possible reasons for a broken circuit. Since incorrectly measured voltage can result in a faulty operation of some of the protection functions, it is important to detect the fuse failures. A fast fuse failure detection is one of the means to block voltage-based functions before they operate.

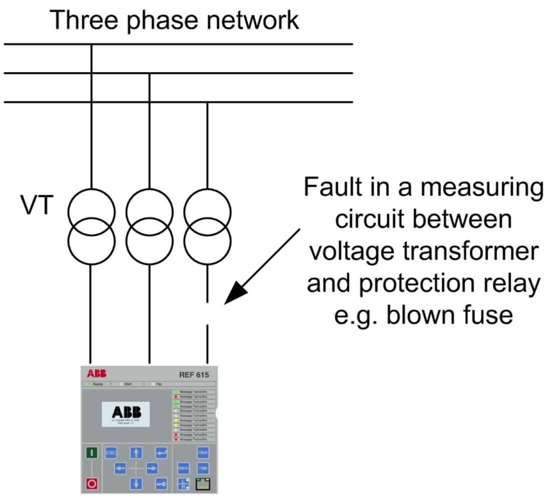


Figure 141: Fault in a circuit from the voltage transformer to the IED

A fuse failure occurs due to blown fuses, broken wires or intended substation operations. The negative sequence component-based function can be used to detect different types of single-phase or two-phase fuse failures. However, at least one of the three circuits from the voltage transformers must not be broken. The supporting delta-based function can also detect a fuse failure due to three-phase interruptions.

In the negative sequence component-based part of the function, a fuse failure is detected by comparing the calculated value of the negative sequence component voltage to the negative sequence component current. The sequence entities are calculated from the measured current and voltage data for all three phases. The purpose of this function is to block voltage-dependent functions when a fuse failure is detected. Since the voltage dependence differs between these functions, SEQRFUF has two outputs for this purpose.

6.3.6 Signals

Table 272: SEQRFUF Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
I_2	SIGNAL	0	Negative sequence current
U_A_AB	SIGNAL	0	Phase A voltage
U_B_BC	SIGNAL	0	Phase B voltage
U_C_CA	SIGNAL	0	Phase C voltage
U_2	SIGNAL	0	Negative phase sequence voltage
BLOCK	BOOLEAN	0=False	Block of function
CB_CLOSED	BOOLEAN	0=False	Active when circuit breaker is closed
DISCON_OPEN	BOOLEAN	0=False	Active when line disconnector is open
MINCB_OPEN	BOOLEAN	0=False	Active when external MCB opens protected voltage circuit

Table 273: SEQRFUF Output signals

Name	Type	Description
FUSEF_3PH	BOOLEAN	Three-phase start of function
FUSEF_U	BOOLEAN	General start of function

6.3.7 Settings

Table 274: SEQRFUF Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Neg Seq current Lev	0.03...0.20	xIn	0.01	0.03	Operate level of neg seq undercurrent element
Neg Seq voltage Lev	0.03...0.20	xUn	0.01	0.10	Operate level of neg seq overvoltage element
Current change rate	0.01...0.50	xIn	0.01	0.15	Operate level of change in phase current
Voltage change rate	0.50...0.90	xUn	0.01	0.60	Operate level of change in phase voltage
Change rate enable	0=False 1=True			0=False	Enabling operation of change based function
Min Op voltage delta	0.01...1.00	xUn	0.01	0.70	Minimum operate level of phase voltage for delta calculation
Min Op current delta	0.01...1.00	xIn	0.01	0.10	Minimum operate level of phase current for delta calculation
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Seal in voltage	0.01...1.00	xUn	0.01	0.70	Operate level of seal-in phase voltage
Enable seal in	0=False 1=True			0=False	Enabling seal in functionality
Current dead Lin Val	0.05...1.00	xIn	0.01	0.05	Operate level for open phase current detection

6.3.8 Monitored data

Table 275: SEQRFUF Monitored data

Name	Type	Values (Range)	Unit	Description
SEQRFUF	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.3.9 Technical data

Table 276: SEQRFUF Technical data

Characteristic	Value	
Operate time[1)]		
• NPS function	U_{Fault} = 1.1 x set *Neg Seq voltage Lev*	< 33 ms
	U_{Fault} = 5.0 x set *Neg Seq voltage Lev*	< 18 ms
• Delta function	ΔU = 1.1 x set *Voltage change rate*	< 30 ms
	ΔU = 2.0 x set *Voltage change rate*	< 24 ms

1) Includes the delay of the signal output contact, f_n = 50 Hz, fault voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

6.4 Operation time counter MDSOPT

6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Operation time counter	MDSOPT	OPTS	OPTM

6.4.2 Function block

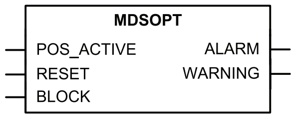


Figure 142: Function block

6.4.3 Functionality

The generic operation time counter function MDSOPT calculates and presents the accumulated operation time of a machine or device as the output. The unit of time for accumulation is hour. The function generates a warning and an alarm when the accumulated operation time exceeds the set limits. It utilizes a binary input to indicate the active operation condition.

The accumulated operation time is one of the parameters for scheduling a service on the equipment like motors. It indicates the use of the machine and hence the mechanical wear and tear. Generally, the equipment manufacturers provide a maintenance schedule based on the number of hours of service.

6.4.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The operation of the generic operation time counter can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

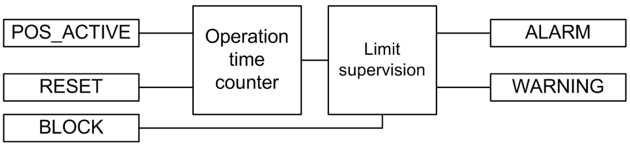


Figure 143: Functional module diagram

Operation time counter

This module counts the operation time. When `POS_ACTIVE` is active, the count is continuously added to the time duration until it is deactivated. At any time the `OPR_TIME` output is the total duration for which `POS_ACTIVE` is active. The unit of time duration count for `OPR_TIME` is hour. The value is available through the Monitored data view.

The `OPR_TIME` output is a continuously increasing value and it is stored in a non-volatile memory. When `POS_ACTIVE` is active, the `OPR_TIME` count starts increasing from the previous value. The count of `OPR_TIME` saturates at the final value of 299999, that is, no further increment is possible. The activation of RESET can reset the count to the *Initial value* setting.

Limit Supervision

This module compares the motor run-time count to the set values of *Warning value* and *Alarm value* to generate the WARNING and ALARM outputs respectively when the counts exceed the levels.

The activation of the WARNING and ALARM outputs depends on the *Operating time mode* setting. Both WARNING and ALARM occur immediately after the conditions are met if *Operating time mode* is set to “Immediate”. If *Operating time mode* is set to “Timed Warn”, WARNING is activated within the next 24 hours at the time of the day set using the *Operating time hour* setting. If *Operating time mode* is set to “Timed Warn Alm”, the WARNING and ALARM outputs are activated at the time of day set using *Operating time hour*.

The *Operating time hour* setting is used to set the hour of day in Coordinated Universal Time (UTC). The setting has to be adjusted according to the local time and local daylight-saving time.

The function contains a blocking functionality. Activation of the BLOCK input blocks both WARNING and ALARM.

6.4.5 Application

The machine operating time since commissioning indicates the use of the machine. For example, the mechanical wear and lubrication requirement for the shaft bearing of the motors depend on the use hours.

If some motor is used for long duration runs, it might require frequent servicing, while for a motor that is not used regularly the maintenance and service are scheduled less frequently. The accumulated operating time of a motor together with the appropriate settings for warning can be utilized to trigger the condition based maintenance of the motor.

The operating time counter combined with the subsequent reset of the operating-time count can be used to monitor the motor's run time for a single run.

Both the long term accumulated operating time and the short term single run duration provide valuable information about the condition of the machine and device. The information can be co-related to other process data to provide diagnoses for the process where the machine or device is applied.

6.4.6 Signals

Table 277: MDSOPT Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block input status
POS_ACTIVE	BOOLEAN	0=False	When active indicates the equipment is running
RESET	BOOLEAN	0=False	Resets the accumulated operation time to initial value

Table 278: MDSOPT Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm accumulated operation time exceeds Alarm value
WARNING	BOOLEAN	Warning accumulated operation time exceeds Warning value

6.4.7 Settings

Table 279: MDSOPT Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Warning value	0...299999	h	1	8000	Warning value for operation time supervision
Alarm value	0...299999	h	1	10000	Alarm value for operation time supervision
Initial value	0...299999	h	1	0	Initial value for operation time supervision
Operating time hour	0...23	h	1	0	Time of day when alarm and warning will occur
Operating time mode	1=Immediate 2=Timed Warn 3=Timed Warn Alm			1=Immediate	Operating time mode for warning and alarm

6.4.8 Monitored data

Table 280: MDSOPT Monitored data

Name	Type	Values (Range)	Unit	Description
MDSOPT	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status
OPR_TIME	INT32	0...299999	h	Total operation time in hours

6.4.9 Technical data

Table 281: MDSOPT Technical data

Description	Value
Motor run-time measurement accuracy[1)]	±0.5%

1) Of the reading, for a stand-alone IED, without time synchronization.

Section 7 Condition monitoring functions

7.1 Circuit breaker condition monitoring ESSCBR

7.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/ IEEEidentification
Circuit breaker condition monitoring	ESSCBR	CBCM	CBCM

7.1.2 Function block

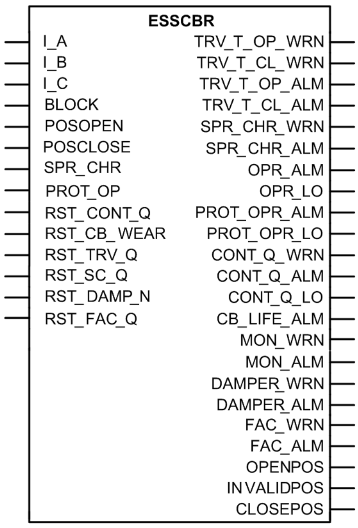


Figure 144: Function block

7.1.3 Functionality

The circuit breaker condition monitoring function ESSCBR is used to monitor different parameters of the circuit breaker. For proper functioning of the circuit breaker, it is essential to monitor the circuit breaker inactivity, the number of operation cycles, the damper and spring charge quality, the contact and breaker wear and the contact travel time. Warning, alarm and lockout signals are generated when the calculated values exceed the threshold settings.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

7.1.4 Operation principle

The function can be enabled and disabled with the Operation setting. The corresponding parameter values are "On" and "Off".

The operation of circuit breaker condition monitoring can be described with a module diagram. All the modules in the diagram are explained in the next sections.

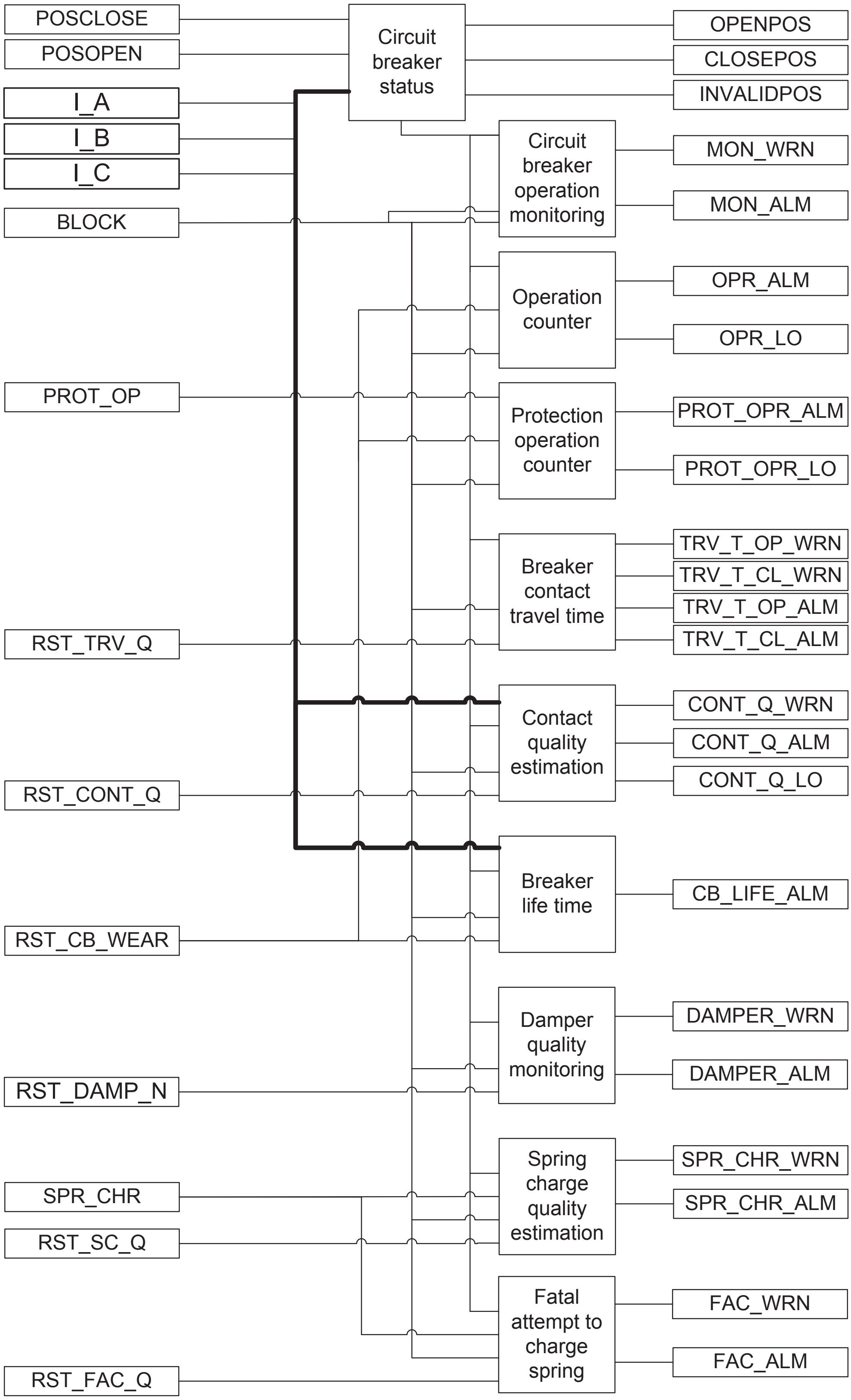


Figure 145: Functional module diagram of ESSCBR

7.1.4.1 Circuit breaker status

The circuit breaker status subfunction monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position. The operation of the breaker status monitoring can be described with a module diagram. All the modules in the diagram are explained in the next sections.

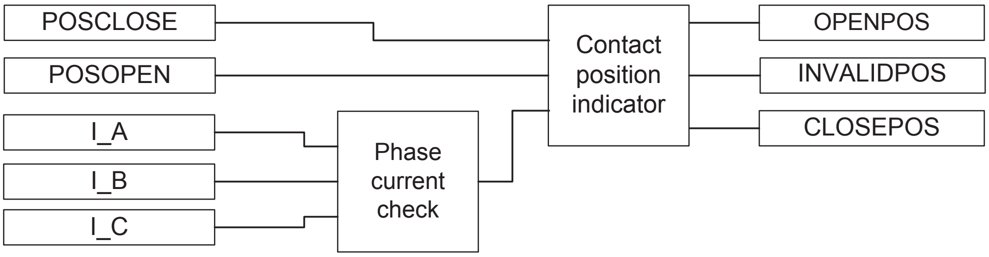


Figure 146: Functional module diagram for monitoring circuit breaker status

Contact position indicator

The circuit breaker status is open if the auxiliary input contact POSCLOSE is low, the POSOPEN input is high and the current is zero. The circuit breaker is closed when the POSOPEN input is low and the POSCLOSE input is high. The breaker is in the intermediate position if both the auxiliary contacts have the same value, that is, both are in the logical level "0", or if the auxiliary input contact POSCLOSE is low and the POSOPEN input is high but the current is not zero.

The status of the breaker is indicated with the binary outputs OPENPOS, INVALIDPOS and CLOSEPOS for open, intermediate and closed position respectively.

Phase current check

In addition to auxiliary input contacts, the module takes three-phase currents to detect the position of the circuit breaker.

7.1.4.2 Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring subfunction is to indicate if the circuit breaker has not been operated for a long time.

The operation of the circuit breaker operation monitoring can be described with a module diagram. All the modules in the diagram are explained in the next sections.

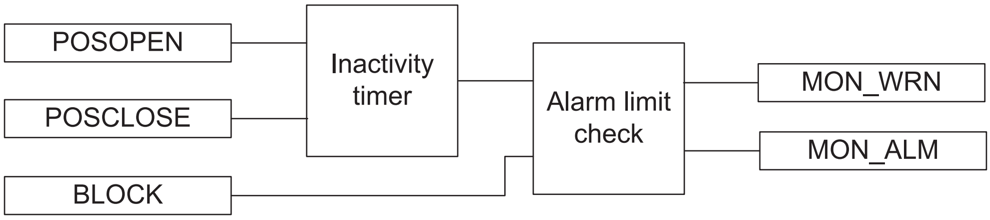


Figure 147: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

Inactivity timer

The module calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. The calculation is done by monitoring the states of the POSOPEN and POSCLOSE auxiliary contacts.

The inactive days INA_DAYS are available in the monitored data view. It is also possible to set the initial inactive days with the *Ini inactive days* parameter.

Alarm limit check

The measured inactivity time INA_DAYS is continuously compared to the set thresholds, which define the normal, warning and alarm zones.

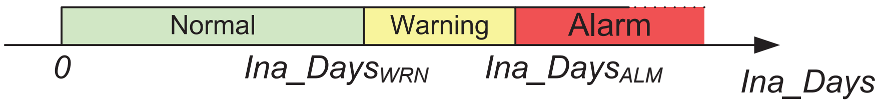


Figure 148: Inactivity time thresholds

If the value of INA_DAYS drops into the warning zone defined by the warning inactive days margin and alarm inactive days margin threshold settings *Wrn_Inactive_Days_Margin* and *Alm_Inactive_Days_Margin*, the output MON_WRN is activated.

If the value of INA_DAYS drops into the alarm zone defined by the alarm inactive days margin threshold setting *Alm_Inactive_Days_Margin*, the output MON_ALM is activated.

7.1.4.3 Operation counter

The operation counter calculates the number of breaker operation cycles.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

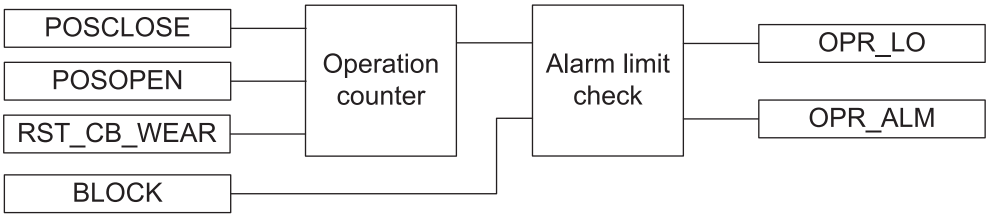


Figure 149: Functional module diagram for counting circuit breaker operations

Operation counter

The operation counter counts the number of operations based on the state change of the binary auxiliary contact inputs `POSCLOSE` and `POSOPEN`.

The number of operations `NO_OPR` is available in the monitored data view on the LHMI or through tools via communications. The old circuit breaker operation counter value can be taken into use by writing the value to the *Counter initial Val* parameter and by setting the parameter *Reset CB wear* in the clear menu from WHMI or LHMI.

Alarm limit check

The `OPR_ALM` operation alarm is generated when the number of operations exceeds the value set with the *Alarm Op number* threshold setting. However, if the number of operations increases further and exceeds the limit value set with the *Lockout Op number* setting, the `OPR_LO` output is activated.

The binary outputs `OPR_LO` and `OPR_ALM` are deactivated when the `BLOCK` input is activated.

7.1.4.4 Protection operation counter

The protection operation counter calculates the number of breaker operation cycles due to protection intervention.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

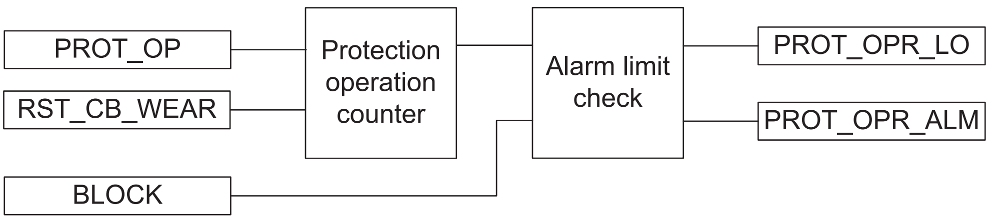


Figure 150: Functional module diagram for counting circuit breaker operations

Protection operation counter

The protection operation counter counts the number of operations caused by a protection intervention based on the state change of the input PROT_OP.

The number of operations NO_PROT_OPR is available through the monitored data view on the LHMI or through tools via communications. The old circuit breaker protection operation counter value can be taken into use by writing the value to the *Protection Counter Initial Value* parameter and by setting the parameter *CB wear* values in the clear menu from WHMI or LHMI.

Alarm limit check

The PROT_OPR_ALM operation alarm is generated when the number of operations exceeds the value set with the *Alarm Prot Op Number* threshold setting. However, if the number of operations increases further and exceeds the limit value set with the *Lockout Prot Op Number* setting, also the output PROT_OPR_LO is activated.

The outputs PROT_OPR_LO and PROT_OPR_ALM are deactivated when the input BLOCK is activated.

7.1.4.5 Breaker contact travel time

High traveling times indicate changes to the lubrication of the shaft or to the properties of the opening or closing spring such as spring constant. Therefore, detecting the excessive traveling time is an indication for maintenance of the circuit breaker mechanism. In the opening cycle operation, the main contact starts opening. The inputs POSCLOSE becomes low, POSOPEN becomes high and the main contact reaches its final open position. In the closing cycle, the first main contact starts closing. The inputs POSOPEN becomes low, POSCLOSE becomes high and the main contact reaches its final closed position.

The breaker contact travel time module calculates the breaker contact travel time for the closing and opening operation and it estimates the quality of open or closing mechanism. The operation of the breaker contact travel time measurement can be described with a module diagram. All the modules in the diagram are explained in the next sections.

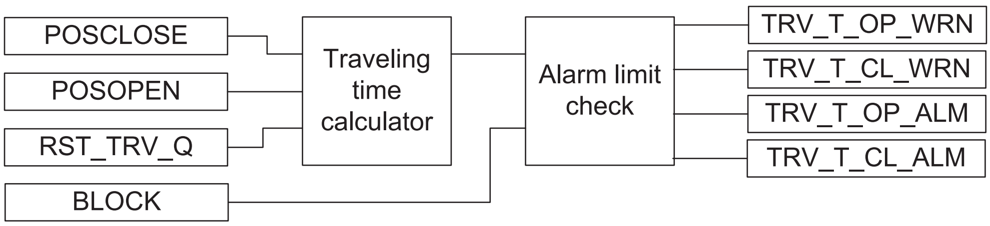


Figure 151: Functional module diagram for breaker contact travel time

Traveling time calculator

The times t_{op} and t_{CL} (that is TRV_OP_T and TRV_CL_T) are computed by measuring the time differences between the POSOPEN and POSCLOSE contact signals commutations. t_{OP_cor} and t_{CL_cor} can be computed during breaker factory tests by measuring times t_1, t_2, t_3 and t_4.

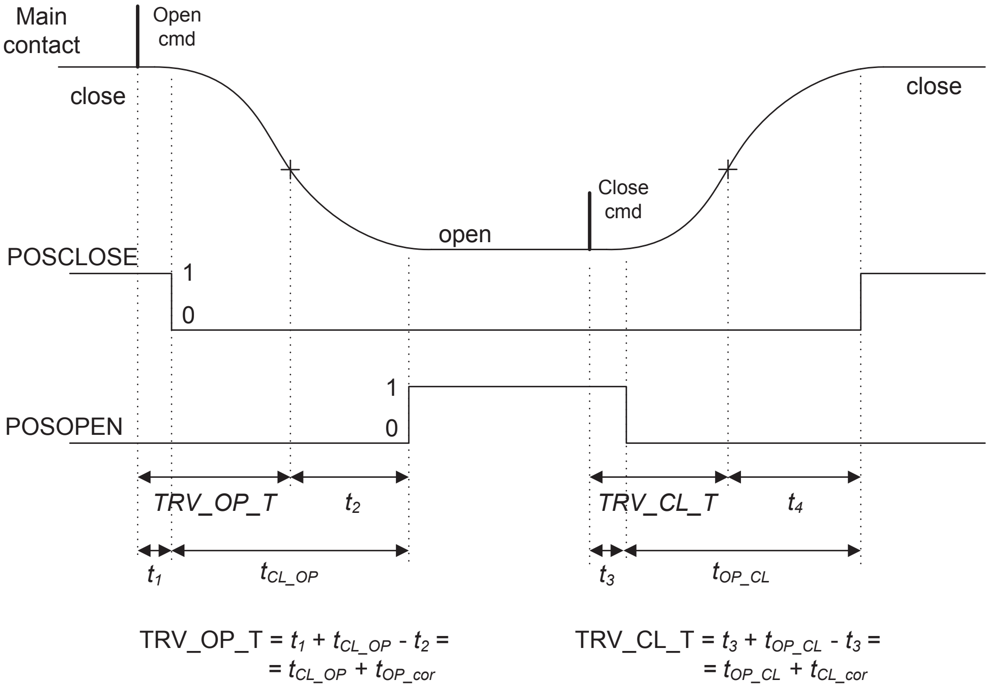


Figure 152: Travel time calculation

The opening and closing quality Q_{OP} and Q_{CL} have values ranging in [0, 100], with 100 meaning a new breaker and 0 a breaker at the end of breaker life. Travel time algorithm computes the qualities by weighting the operations that are within the different opening or closing travel time zones (normal, warning and alarm). Each quality Q_X with X∈{OP, CL} can be computed at the n-th opening or closing operation.

$$Q_X(n) = \begin{cases} \min\left\{1, Q_X(n-1)\times\left(1+q_{TD,N}\right)\right\}, & T_X \in \text{Normal Zone} \\ Q_X(n-1)\times\left(1-q_{TD,W}\right), & T_X \in \text{Warning Zone} \\ Q_X(n-1)\times\left(1-q_{TD,A}\right), & T_X \in \text{Alarm Zone} \end{cases}$$

$q_{TD,N}$ the travel time quality deduction rate in normal zone

$q_{TD,W}$ the travel time quality deduction rate in warning zone

$q_{TD,A}$ the travel time quality deduction rate in alarm zone

$Q_{OP}(0) = Q_{OP\_init}$ and $Q_{CL}(0) = Q_{CL\_init}$. The set of limits on the travel time ($t_{OP\_min\_ALM}$, $t_{OP\_max\_ALM}$, $t_{CL\_min\_ALM}$, $t_{CL\_max\_ALM}$) are computed.

The travel time qualities TRV_OP_Q Q_{OP} and TRV_CL_Q Q_{CL} are available in the monitored data view on the LHMI or through tools via communications.

The values can be reset by setting the parameter RST_T_QUALITY Q_{RST_T} to true. The values for Q_{OP_init} and Q_{CL_init} can be set to account for initial contact qualities deviating from a new breaker ($Q_{OP\_init} = 100$, $Q_{CL\_init} = 100$).

Alarm limit check

The measured opening and closing travel times TRV_OP_T and TRV_CL_T are continuously compared with the set thresholds, which define the normal, warning and alarm zones.

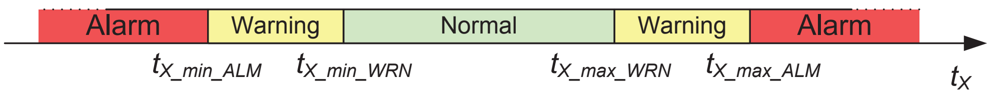


Figure 153: Travel time thresholds

If the measured travel time T_X with $X \in \{OP, CL\}$ is in the alarm zone, an event is generated and it is signaled in the monitored data by setting an *OverThreshold_Status* (OT_STATUS) flag.

The last measured opening and closing travel times (TRV_OP_T and TRV_CL_T) and OT_STATUS are available through the monitored data view on the LHMI or through tools via communications.

The measured opening and closing travel time qualities are continuously compared with the set thresholds, which define the normal, warning and alarm zones.

Figure 154: Travel time quality thresholds

If the value of quality Q_{OP} drops into the warning zone defined by the warning travel open time quality margin and alarm travel open time quality margin threshold settings (*Wrn_Travel_Open_Quality_Margin* and *Alm_Travel_Open_Quality_Margin*), the output TRV_T_OP_WRN is activated.

If the value of quality Q_{OP} drops into the alarm zone defined by the alarm travel open time quality margin threshold setting (*Alm_Travel_Open_Quality_Margin*), the output TRV_T_OP_ALM is activated.

If the value of quality Q_{CL} drops into the warning zone defined by the warning travel close time quality margin and alarm travel close time quality margin threshold settings (*Wrn_Travel_Close_Quality_Margin* and *Alm_Travel_Close_Quality_Margin*), the output TRV_T_CL_WRN is activated.

If the value of quality Q_{CL} drops into the alarm zone defined by the alarm travel close time quality margin threshold settings (*Alm_Travel_Close_Quality_Margin*), the output TRV_T_CL_ALM is activated.

It is possible to block the outputs TRV_T_OP_WRN and TRV_T_CL_WRN warning and the TRV_T_OP_ALM and TRV_T_CL_ALM alarm signals by activating the input BLOCK.

7.1.4.6 Contact quality estimation

The arcing produced during arc separation leads to a high temperature of the contacts' surface and to the melting and evaporation of material.

In the opening phase of the contact, the quality estimation calculates the evaporation of contact material based on the time-resolved current $I_{A,B,C}(t)$.

The operation of the contact quality estimation can be described with a module diagram. All the modules in the diagram are explained in the next sections.

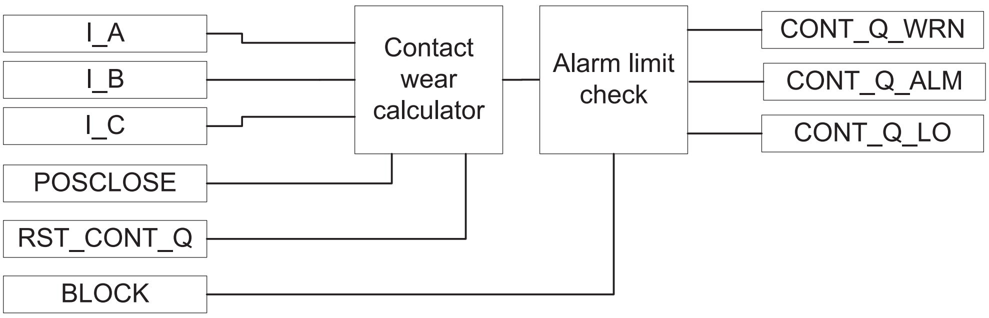
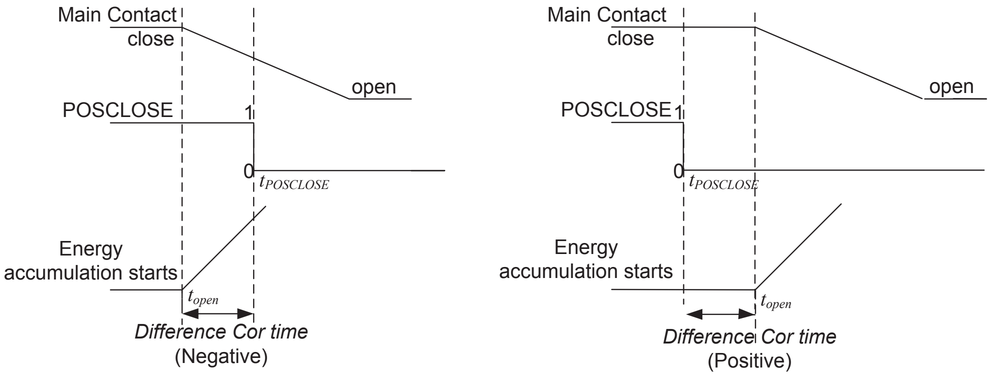


Figure 155: Functional module diagram for calculation of the contact quality and alarm

Contact wear calculator

The contact wear calculator calculates the accumulated contact wear for each pole. The function is initiated with the input POSCLOSE open events at $t_{POSCLOSE}$. It ends when the RMS of the current becomes lower than the *Accumulated Stop Current* setting value.



$$t_{open} = t_{POSCLOSE} + \Delta t_{corr}$$

Figure 156: Significance of the Difference Cor time setting

The *Difference Cor Time* (Δt_{corr}) setting is used to correct the time signal $t_{POSCLOSE}$ from the auxiliary contact to the time when the main contact opens, t_{open}. When the setting is positive, the auxiliary contact has opened and the delay is equal to the value set with the *Difference Cor Time*, the calculation of energy starts. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

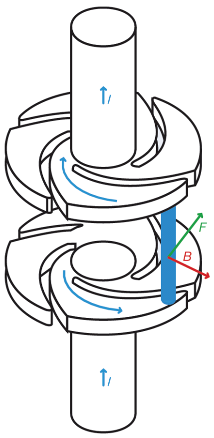


Figure 157: TMF contact with a running arc

Different arcing phases are distinguished to determine the contact wear. The physical model considers three different erosion mechanisms. These are modeled separately with corresponding evaporation rates. The sum of the integrals over the specific time of each evaporation phase provides the result of the total wear. The wear depends on a number of parameters. These are specific to each contact pole and need to be entered.

The calculation needs to be done for all three current, `I_A`, `I_B` and `I_C`.

Phase 0 is the diffuse-arcing phase. It starts from the time t_{open}, which is calculated.

$$t_{open} = t_{POSCLOSE} + \Delta t_{corr}$$

The end of this phase is given by $I_{constricted}$, which varies for each VI type and can be defined by setting *I_constricted*. Its value is normally between 10 kA and 15 kA. For current values above $I_{constricted}$, the arc is constricted (Phase 1 and Phase 2).

Phase 1 is the constricted arcing phase. The end of this phase is given by t_{run}, which is calculated,

$$t_{run} = t_{open} + \Delta t_{run}$$

where the *Difference Run Time* (Δt_{run}) varies with different VI types and can be defined by setting.

Phase 2 is the running arc phase. It starts from t_{run} and completes when phase current equals $I_{constricted}$.

The arc completes with the second part of Phase 0, which ends at time t_{end}, that is, when the instantaneous phase current becomes lower than the value set by the *Accumulated Stop Current* setting.

The contact quality is computed for each pole: $Q_{A,B,C}$. It ranges from 0 to 100, with 100 meaning a new contact and 0 a breaker at the end of breaker life.

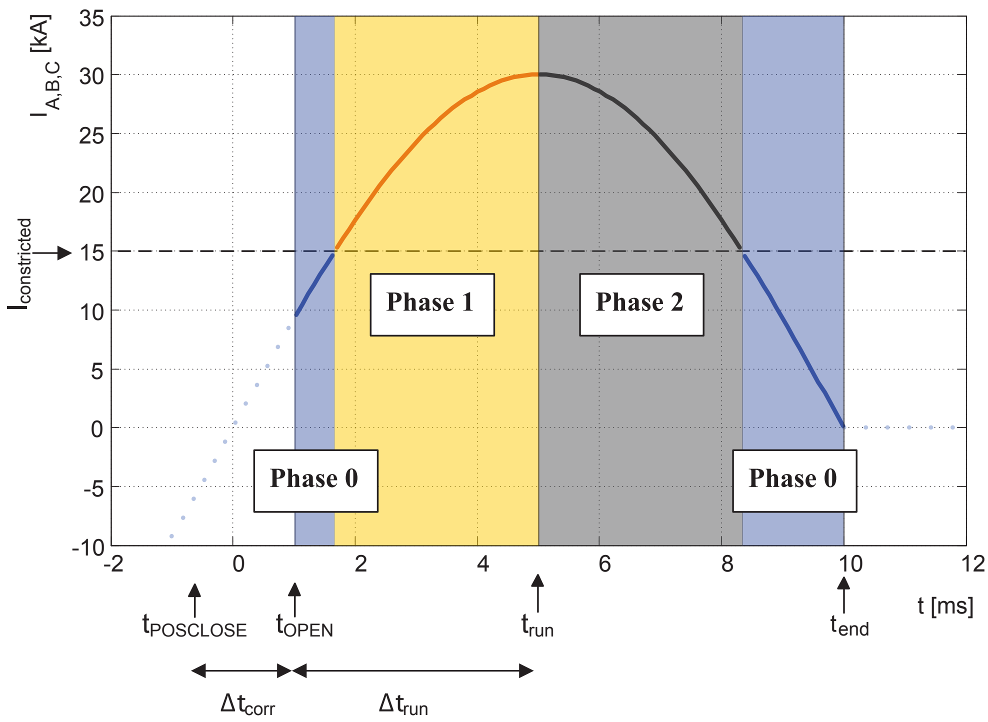


Figure 158: The arcing phases of the TMF contacts

Time-discrete algorithm

If the currents are sampled at equidistant times t_i, the calculation of the contact quality is done with the equation.

$$Q_{A.B.C} = \max\left\{0, Q_{Init_{A,B,C}} - \sum_{\substack{opening\\operation}} \left(\frac{d_{wear_{A,B,C}}}{d_{\max}}\right)\right\}$$

(Equation 23)

$$d_{wear_{A,B,C}} = \sum_{t_{open} \le t_i \le t_{end}} \begin{cases} K_0 \left|I_{A,B,C}(t_i)\right|^{\alpha_0} \Delta t, & \left|I(t_i)\right| < I_{constricted} \\ K_1 \left|I_{A,B,C}(t_i)\right|^{\alpha_1} \Delta t, & \left|I(t_i)\right| \ge I_{constricted}, t < t_{run} \\ K_2 \left|I_{A,B,C}(t_i)\right|^{\alpha_2} \Delta t, & \left|I(t_i)\right| \ge I_{constricted}, t \ge t_{run} \end{cases}$$

(Equation 24)

$Q_{A,B,C}$	Monitored data CONTACT_ QUALITY _A (_B, _C)
$Q_{Init\ A,B,C}$	Set *Init* contact quality
$d_{wear\ A,B,C}$	Contact wear during one *CB* opening cycle (μm)
d_{max}	Set *Max contact wear* (μm)
$I_{constricted}$	Set *I_constricted* (KA)
K_0, K_1, K_2	Set *K_0*, *K_1* and *K_2* (μm / $KA^{\alpha0,\alpha1,\alpha2}s$)
α0, α1, α2,	Set *Alpha_0 exponent*, *Alpha_1 exponent* and *Alpha_2 exponent*
$I(t_i)$	Measured current (KA)
t_{run}	Set *Difference Run Time* (ms)
Δt	Sample period (s)

The accumulated contact quality outputs `CONTACT_i_Q` (with i = A, B, C) are available in the monitored data view on the LHMI or through tools via communications.

The values can be reset to initial value by activating the input `RST_CONT_Q` or from the LHMI menu-clearing parameter. The values for $Q_{Init\ A,B,C}$ can be set to account for initial contact qualities deviating from a new contact ($Q_{Init\ A,B,C}$ = 100).

Alarm limit check

The measured $Q_{A,B,C}$ qualities are continuously compared with the set thresholds, which defines the normal, warning and alarm zones.

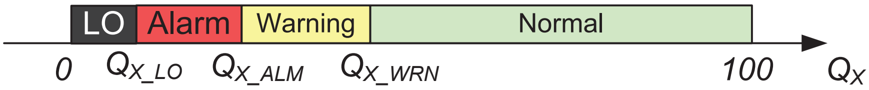


Figure 159: Contact quality thresholds

If the value of quality $Q_{A,B,C}$ drops into the warning zone defined by the warning contact quality margin and alarm contact quality margin threshold settings (*Wrn_Contact_Quality_Margin* and *Alm_Contact_Quality_Margin*), the output CONT_Q_WRN is activated.

If the value of quality $Q_{A,B,C}$ drops into the alarm zone defined by the alarm contact quality margin and lo contact quality margin threshold settings (*Alm_Contact_Quality_Margin* and *LO_Contact_Quality_Margin*), the output CONT_Q_ALM is activated. However, when the contact quality is below the limit value set with the *LockOut Contact Quality Margin* threshold setting (*LO_Contact_Quality_Margin*), also the output CONT_Q_LO is activated.

The outputs CONT_Q_WRN, CONT_Q_ALM and CONT_Q_LO can be blocked by activating the input BLOCK.

7.1.4.7 Breaker lifetime

When the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current. The remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer. When the circuit breaker is opened, the remaining life decreases with at least one.

The operation of the remaining life of the circuit breaker subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

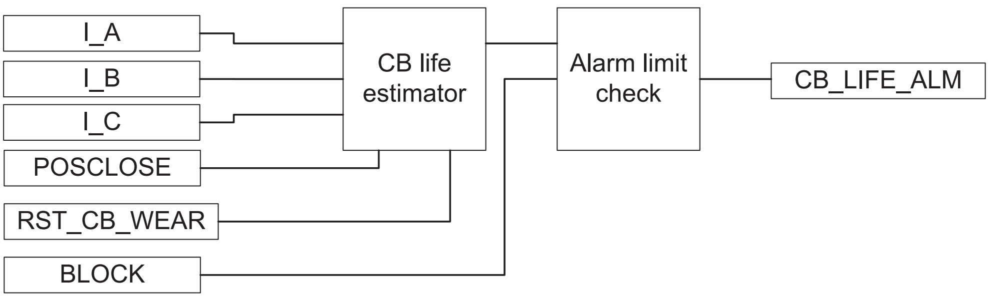


Figure 160: Functional module diagram for estimating the life of the circuit breaker

Circuit breaker lifetime estimator

The circuit breaker lifetime estimator module calculates the remaining life of the circuit breaker.

If the tripping current is less than the rated operating current set with the *Rated Op current*, the remaining operation of the breaker reduces by one operation.

If the tripping current is more than the rated fault current set with the *Rated Fault current*, the possible operations are zero.

The remaining life at a specific current (n_s) in between these two values is calculated based on the trip curve given by the manufacturer. The parameters *Op Number Rated* (n_r) and *Op Number Fault* (n_f) set the number of operations, thus the breaker can perform at the rated current and fault current, respectively.

At every operation, the remaining life of the circuit breaker is reduced by the number of possible operations at the rated current corresponding to a single operation at a specific current (n_{sr}), given by the ratio between *Op Number Rated* and *Op Number Specific* (n_s).

$$RemLife(t+1) = RemLife(t) - n_{sr}$$

(Equation 25)

$$n_{sr} = \frac{n_r}{n_s}$$

(Equation 26)

The remaining lifetime is calculated separately for all three phases and it is available as a monitored data value CB_LIFE_A(_B,_C).

The calculated values can be cleared by setting the parameter *CB wear* values in the clearing menu from LHMI or WHMI.

Clearing the *CB wear* values also resets the operation counter.

Alarm limit check

When the remaining life of any phase drops below the *Life alarm level* threshold setting, the corresponding circuit breaker life alarm `CB_LIFE_ALM` is activated.

It is possible to deactivate the `CB_LIFE_ALM` alarm signal by activating the binary input `BLOCK`. The old circuit breaker operation counter value can be taken into use by writing the value to the parameter *Initial CB Rmn life* and resetting the value via the clearing menu from WHMI or LHMI under the *Clear CB* wear values menu.

7.1.4.8 Damper quality monitoring

The damper quality is monitored by analyzing the bouncing of the contacts. The detection of bouncing is possible using the inductive sensor. When a bouncing occurs, the inductive sensor which is open goes off for a few milliseconds and then is on again.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

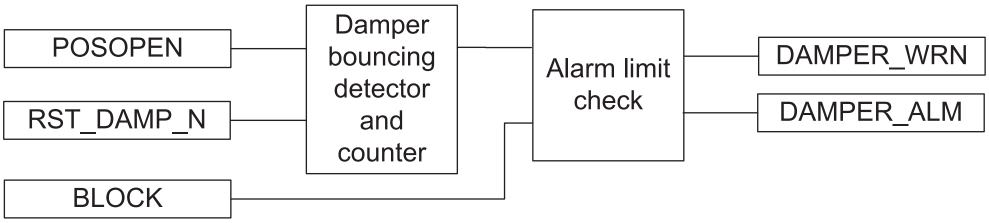


Figure 161: Functional module diagram for damper quality measurement and alarm

The duration of variation of the binary input POSOPEN indicates when a bouncing occurs. A statistical analysis of the bouncing of damper in terms of the underlying probabilities shows that bouncing is very exceptional in the life of a damper.

As the damper quality degrades quickly with the number K of failures (operation with bouncing) occurred in the last N operations, the easiest way to estimate the damper quality is by counting the failures.

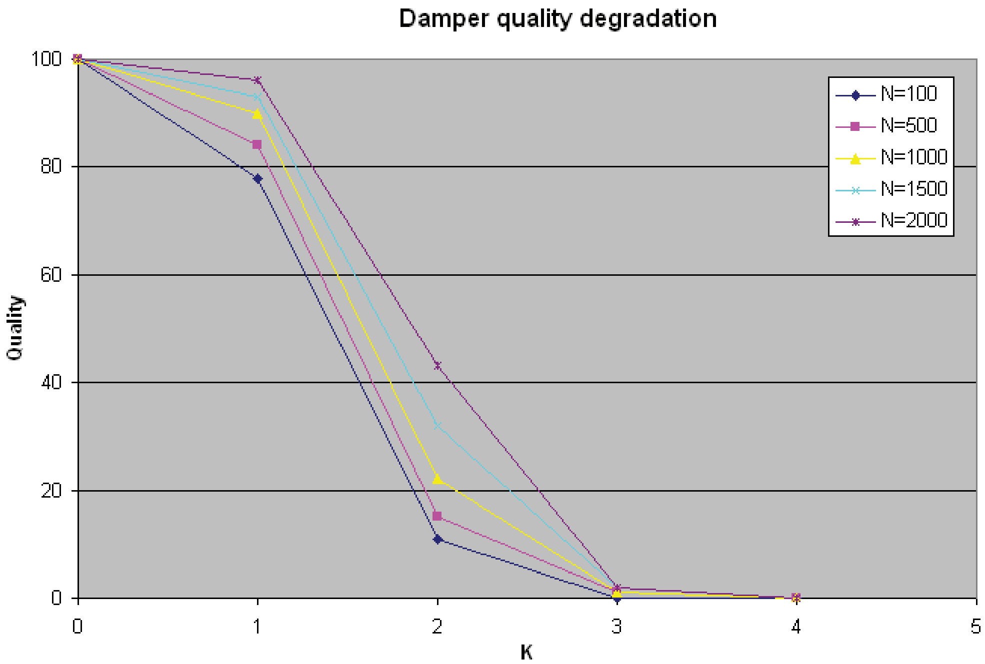


Figure 162: Damper quality degradation curves for different window size N

Damper bouncing detector and counter

The number K of failures (operation with bouncing) occurred in the last N operations is used as indication of damper quality.

The counter value and damper history can be reset by setting the input RST_DAMP_N to true. It is possible to store and recover the damper history as the last five fault operation indexes (*Last_Damper_Occurrence*1,2,3,4,5, set to N by default).

Alarm limit check

The number K of failures occurred in the last N operations is continuously compared with the set thresholds, which define the normal, warning and alarm zones.

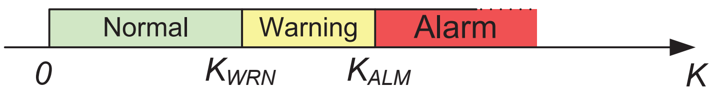


Figure 163: Damper quality thresholds

If the value of K drops into the warning zone defined by the warning damper margin and alarm damper margin threshold settings (*Wrn_Damper_Margin* and *Alm_Damper_Margin*), the output DAMPER_WRN is activated. If the value of K drops into the alarm zone defined by the alarm damper margin threshold setting (*Alm_Damper_Margin*), the output DAMPER_ALM is activated. *Wrn_Damper_Margin* and *Alm_Damper_Margin* are configured during factory tests.

It is possible to block the DAMPER_WRN and DAMPER_ALM alarm signals by activating the input BLOCK.

7.1.4.9 Spring charge quality estimation

The circuit breaker spring should be charged within a specified time. Long spring charging can be due to early motor failures or higher friction forces. A smaller recharging time can be due to a lower spring constant k. Therefore, detecting long or small spring-charging time indicates that it is time for circuit breaker maintenance.

The circuit breaker spring-charged indication subfunction calculates the spring-charging time.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

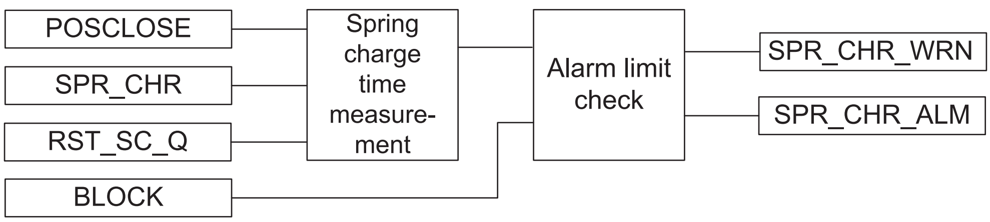


Figure 164: Functional module diagram for circuit breaker spring-charged indication and alarm

Spring charge time measurement

Two binary inputs, POSCLOSE and SPR_CHR, indicate spring charging started and spring charged, respectively. The spring-charging time t_{SC} is calculated from the difference of these two signal timings.

The spring-charge time t_{SC} (SPR_CHR_T) is available in the monitored data view on the LHMI or through tools via communications.

The *Recharge Quality* Q_{SC} of n-th spring charge operation is computed.

$$Q_{SC}(n)=\begin{cases}\min\left\{1, Q_{SC}(n-1)\times\left(1+q_{SD,N}\right)\right\}, & t_{SC}\in \text{Normal Zone}\\ Q_{SC}(n-1)\times\left(1-q_{SD,W}\right), & t_{SC}\in \text{Warning Zone}\\ Q_{SC}(n-1)\times\left(1-q_{SD,A}\right), & t_{SC}\in \text{Alarm Zone}\end{cases}$$

$q_{SD,N}$ the spring charge quality recovery and deduction rates in normal zone

$q_{SD,W}$ the spring charge quality recovery and deduction rates in warning zone

$q_{SD,A}$ the spring charge quality recovery and deduction rates in alarm zone

The spring charge quality Q_{SC} (SPR_CHR_Q) is available in the monitored data view on the LHMI or through tools via communications.

The values can be reset by setting the parameter RST_SC_QUALITY Q_{RST_SC} to true. The values for Q_{SC_init} can be set to account for initial contact qualities deviating from a new contact (Q_{SC_init} = 100).

Alarm limit check

The measured spring charge time SPR_CHR_T is continuously compared with the set thresholds, which define the normal, warning and alarm zones.

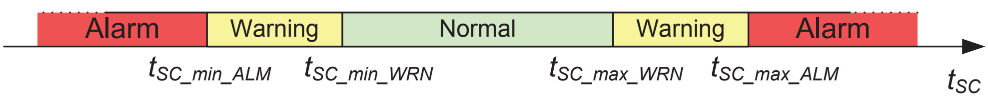


Figure 165: Spring change time thresholds

$$\left.\begin{aligned} t_{SC\_min\_ALM} &= SC_{min\_alm}\times t_{SCcal}\\ t_{SC\_min\_WRN} &= SC_{min\_wrn}\times t_{SCcal}\end{aligned}\right\}\Rightarrow \text{Spring wear}$$

$$\left.\begin{aligned} t_{SC\_max\_WRN} &= SC_{max\_wrn}\times t_{SCcal}\\ t_{SC\_max\_ALM} &= SC_{max\_alm}\times t_{SCcal}\end{aligned}\right\}\Rightarrow \text{Motor/friction wear}$$

SC_{min_alm} and SC_{max_alm} are normal fluctuations of the recharge operation. An auxiliary voltage between 85% and 110% is specified, leading to a range of 80% to 140% for the charging time. In addition, the fluctuation of the individual charging operations needs to be added. The measurements found are at least 20% (in one measurement between 75% and 137%), resulting in a range for the charging time between 60% and 190%.

SC_{min_wrn} and SC_{max_wrn} can be defined as a percentage of the corresponding alarm thresholds (for example 10% of SC_{min_alm} and SC_{max_alm}).

If the measured spring-charge time t_{SC} is in the alarm zone, an event is generated and it is signaled in the monitored data by setting flag *OverThreshold_Status* (OT_STATUS). It is also available in the monitored data view on the LHMI or through tools via communications.

The measured spring charge quality is continuously compared with the set thresholds, which define the normal, warning and alarm zones.

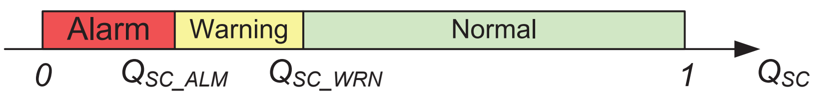


Figure 166: Spring charge quality thresholds

If the value of quality Q_{SC} drops into the warning zone defined by the warning spring charge time quality margin and alarm spring charge time quality margin threshold settings (*Wrn_Spring_Quality_Margin* and *Alm_Spring_Quality_Margin*), the output SPR_CHR_WRN is activated.

If the value of quality Q_{SC} drops into the alarm zone defined by the alarm spring charge time quality margin threshold setting (*Alm_Spring_Quality_Margin*), the output SPR_CHR_ALM is activated.

It is possible to block the output signals SPR_CHR_WRN and SPR_CHR_ALM by activating the input BLOCK.

7.1.4.10 Fatal attempt to charge

Due to the recharge mechanics there can be a sudden slip-through which triggers a recharge operation. This failed attempt to charge can be detected when the motor is started at the closing of the breaker in the normal operation, and sensor detects when the spring is completely charged. Therefore an approach to track a slip-through is to check whether the sensor signals that the spring has been charged without any closing operation.

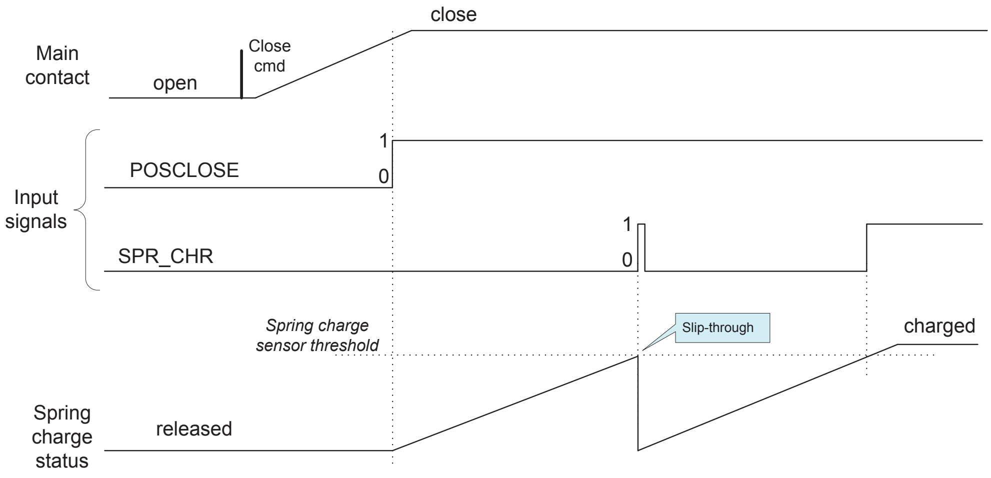


Figure 167: Recharge operation triggered by a slip-through

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

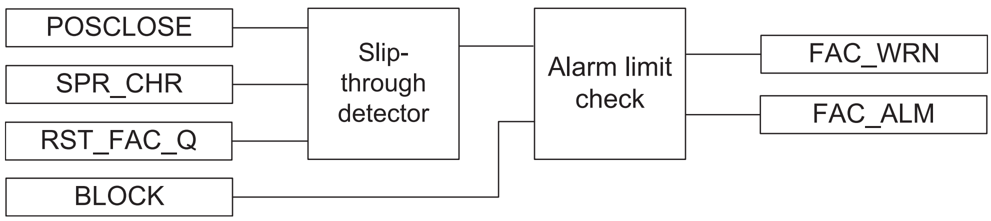


Figure 168: Functional module diagram for circuit breaker spring fatal attempt to charge alarm

Slip-through detection

A slip-through occurred when a `SPR_CHR` rising edge transition occurs while waiting for `POSCLOSE` rising edge.

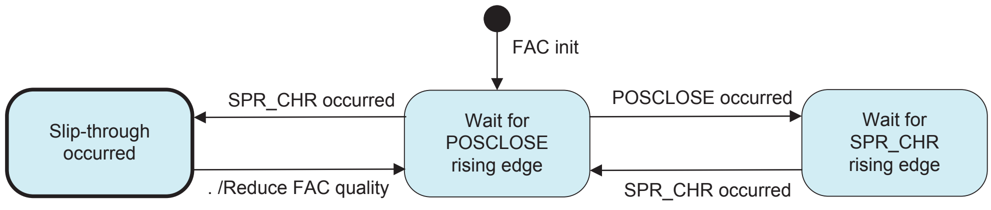


Figure 169: State diagram for circuit breaker spring fatal attempt to charge

The fatal attempt to charge (FAC) quality Q_{FAC} of n-th spring charge operation is computed.

$$Q_{FAC}(n) = \begin{cases} \max\{0, Q_{FAC}(n-1) - Q_{FD}\}, & \text{slip-through} \\ Q_{FAC}(n-1), & \text{otherwise} \end{cases}$$

$Q_{FAC}(0) = Q_{FAC\_init}$,

Q_{FD} deduction rate of Q_{FAC}

The spring *FAC* quality Q_{FAC} is available in the monitored data view on the LHMI or through tools via communications.

The values can be reset by setting the parameter RST_FAC_QUALITY Q_{RST_FAC} to true. The values for Q_{FAC_init} can be set to account for initial contact qualities deviating from a new contact ($Q_{FAC\_init} = 100$).

Alarm limit check

If the value of quality Q_{FAC} drops below the value set with the alarm fatal attempt to charge quality margin threshold setting (*Alm_Fatal_Quality_Margin*), the subfunction generates the FAC_ALM alarm.

The measured fatal attempt to charge quality Q_{FAC} is continuously compared with the set thresholds, which defines the normal, warning and alarm zones.

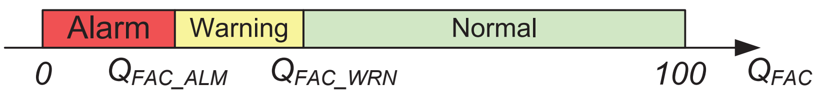


Figure 170: Spring charge quality thresholds

If the value of quality Q_{FAC} drops into the warning zone defined by the warning fatal attempt to charge quality margin and alarm fatal attempt to charge quality margin threshold settings (*Wrn_Fatal_Attempt_Charge_Quality_Margin* and *Alm_Fatal_Attempt_Charge_Quality_Margin*), the output FAC_WRN is activated. If the value of quality Q_{FAC} drops into the alarm zone defined by the alarm fatal attempt to charge quality margin threshold settings (Alm_Fatal_Attempt_Charge_Quality_Margin), the output FAC_ALM is activated.

It is possible to block the FAC_WRN and FAC_ALM signals by activating the input BLOCK.

7.1.5 Application

ESSCBR includes different measuring and monitoring subfunctions.

Circuit breaker status

Circuit breaker status monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position.

Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring is to indicate that the circuit breaker has not been operated for a long time. ESSCBR calculates the number of days the circuit breaker has remained inactive, that is, if it has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.

Operation counter

Routine maintenance of the breaker, such as lubricating breaker mechanism, is generally based on a number of operations. A suitable threshold setting to raise an alarm when the number of operation cycle exceeds the set limit helps preventive maintenance. This can also be used to indicate the requirement for oil sampling for dielectric testing in case of an oil circuit breaker.

The change of state can be detected from the binary input of the auxiliary contact. There is a possibility to set an initial value for the counter which can be used to initialize this functionality after a period of operation or in case of refurbished primary equipment.

Breaker contact travel time

High travelling times indicate the need for maintenance of the circuit breaker mechanism. Therefore, detecting excessive travelling time is needed. During the opening cycle operation, the main contact starts opening. The auxiliary contact A opens, the auxiliary contact B closes, and the main contact reaches its opening position. During the closing cycle, the first main contact starts closing. The auxiliary contact B opens, the auxiliary contact A closes and the main contact reaches its closed position. The travel times are calculated based on the state changes of the auxiliary contacts and the adding correction factor to consider the time difference of the main contacts and the auxiliary contacts position change.

Contact quality estimation

The setting values for the contact quality estimation should be defined in accordance with the used CB type.

Table 282: Recommended setting values for different CB types

CB type	Alpha_0 exponent	Alpha_1 exponent	Alpha_2 exponent	K_0	K_1	K_2	I_constricted	Difference run time	Max contact wear
Not in use	0	0	0	0	0	0	0 (kA)	0.0 (ms)	0 (µm)
ABB VD4 VG 6	1	2.3	2.3	3	1.76	0.56	15 (kA)	3.0 (ms)	2500 (µm)

The settings can be done according to Table 2 if energy $\sum I^y t$ is to be calculated instead of contact quality estimation. The factor y is known as the current exponent and that value can be set to settings *Alpha_0 exponent*, *Alpha_1 exponent* and *Alpha_2 exponent*. The factor y depends on the type of the circuit breaker. For oil circuit breakers, the factor y is normally two. In case of a high-voltage system, the factor y can be 1.4...1.5.

Table 283: Setting examples for energy accumulation

CB type	Alpha_0 exponent	Alpha_1 exponent	Alpha_2 exponent	K_0	K_1	K_2	I_constricted	Difference run time	Max contact wear
Oil CB	2	2	2	1	1	1	0 (kA)	0.0 (ms)	e.g. 2500 (kAαs)
HV CB	1.5	1.5	1.5	1	1	1	0 (kA)	0.0 (ms)	e.g. 2500 (kAαs)

Breaker lifetime

Every time the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current, and the remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer.

Example of breaker life time estimation

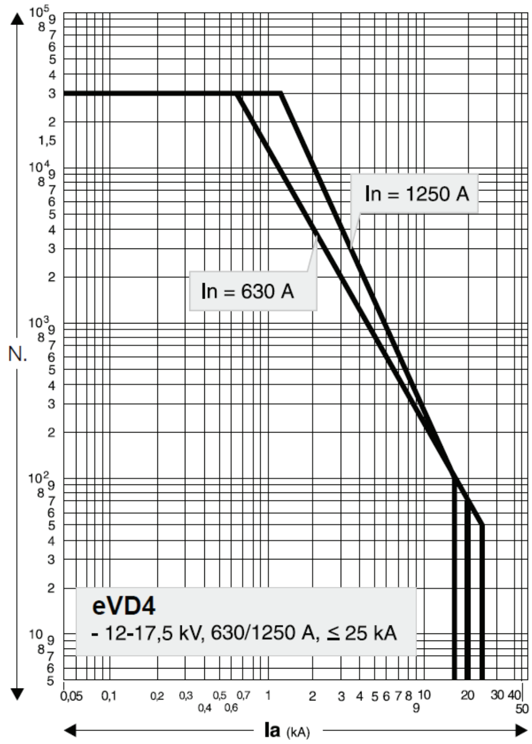


Figure 171: Trip curves for a typical 12kV-17.5kV, 630/1250A, <25kA vacuum interrupter

N the number of closing-opening operations allowed for the circuit breaker (n_s)

Ia the current at the time of tripping of the circuit breaker (I)

Calculation of Directional Coef

The trip curves for a typical vacuum interrupter show that there are 30000 possible operations at the rated operating current of 630 A and 100 operations at the rated fault current 16 kA.

The directional coefficient is calculated.

$$Directional\ Coef = \frac{\log\left(\frac{n_f}{n_r}\right)}{\log\left(\frac{I_f}{I_r}\right)} = -1.76335$$

(Equation 27)

I_r Rated operating current = 630 A

I_f Rated fault current = 16000 A

n_r Op number rated = 30000

n_f Op number fault = 100

Calculation for estimating the remaining life

The possible opening cycles n_s at a specific tripping current I can be calculated .

$$n_s = n_r \times \left(\frac{I}{I_r}\right)^{Directional\ Coef}$$

(Equation 28)

For instance, if the tripping current is 10kA the number of possible operations is

$$\mathrm{n_s} = 30000 \times \left(\frac{10000\ \mathrm{A}}{630\ \mathrm{A}}\right)^{-1.76335} \approx 229$$

The number of possible operations at the rated current corresponding to a single operation at a specific current can be computed.

$$\mathrm{n_{sr}} = \left(\frac{n_r}{n_s}\right) = \left(\frac{I_r}{I}\right)^{Directional\ Coef}$$

(Equation 29)

Therefore, one operation at 10 kA is now equivalent to (30000/229) = 131 operations at the rated current. It is also assumed that prior to this tripping, the remaining life of the circuit breaker is 15000 operations. Therefore, after one operation of 10 kA, the remaining life of the circuit breaker is (15000 - 131) = 14869 at the rated operating current.

Table 284: eVD4 breaking curve points

In [A]	Ia,max [kA]	Ir [A]	nr	If [A]	nf	DirCoef
630	20.0	630	30000	20000	70	-1.753
	25.0			25000	50	-1.738
	31.5			31500	50	-1.635
Table continues on next page						

In [A]	Ia,max [kA]	Ir [A]	nr	If [A]	nf	DirCoef
1250	17.5	1250	30000	17500	100	-2.161
	31.5			31500	50	-1.982
	40.0			40000	50	-1.846
1600	20.0	1600	30000	20000	80	-2.347
	31.5			31500	50	-2.147
	40.0			40000	50	-1.987
2000	25.0	2000	30000	25000	50	-2.533
	31.5			31500	50	-2.320
	40.0			40000	50	-2.135
2500	25.0	2500	30000	25000	50	-2.778
	31.5			31500	50	-2.525
3150	25.0	3150	30000	25000	80	-2.861
	31.5			31500	50	-2.778

Damper quality monitoring

The damper quality is computed by analyzing the bouncing of the contacts. The detection of bouncing is possible using the inductive sensor. When a bouncing occurs, the inductive opened sensor goes off for a few milliseconds and then is on again.

Spring charge indication

For normal operation of the circuit breaker, the circuit breaker spring should be charged within a specified time. Therefore, detecting long spring-charging time indicates that it is time for the circuit breaker maintenance. The last value of the spring-charging time can be used as a service value.

Fatal attempt to charge

Due to the recharge mechanics, there can be a sudden slip-through which triggers a recharging operation. This failed attempt to charge can be detected when the motor is started at the closing of the breaker in the normal operation. Therefore the easiest approach to track a slip-through is to check whether the motor starts or restarts even if there is no closing operation.

7.1.6 Signals

Table 285: ESSCBR input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0	Block all the alarm and lockout indication
Table continues on next page			

Name	Type	Default	Description
POSOPEN	BOOLEAN	0	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0	Signal for close position of apparatus from I/O
SPR_CHR	BOOLEAN	0	CB spring charged input
PROT_OP	BOOLEAN	0	Protection intervention input
RST_CONT_Q	BOOLEAN	0	Reset input for CB contact quality estimation
RST_CB_WEAR	BOOLEAN	0	Reset input for CB remaining life and operation counter
RST_TRV_Q	BOOLEAN	0	Reset input for CB closing and opening travel times quality estimator
RST_SC_Q	BOOLEAN	0	Reset input for the recharge quality of the CB spring
RST_SC_Q	BOOLEAN	0	Reset input for quality estimation of CB dampers
RST_FAC_Q	BOOLEAN	0	Reset input for quality estimation of fatal attempt to recharge of CB spring

Table 286: ESSCBR output signals

Name	Type	Description
OPENPOS	BOOLEAN	CB is in open position
INVALIDPOS	BOOLEAN	CB is in invalid position (not positively open or closed)
CLOSEPOS	BOOLEAN	CB is in closed position
MON_WRN	BOOLEAN	CB 'not operated for long time' warning
MON_ALM	BOOLEAN	CB 'not operated for long time' alarm
OPR_ALM	BOOLEAN	Number of CB operations exceeds alarm limit
OPR_LO	BOOLEAN	Number of CB operations exceeds lockout limit
PROT_OPR_ALM	BOOLEAN	Number of CB operations (due to protection) exceeds alarm limit
PROT_OPR_LO	BOOLEAN	Number of CB operations (due to protection) exceeds lockout limit
TRV_T_OP_WRN	BOOLEAN	CB open travel time quality drops in the warning zone
TRV_T_CL_WRN	BOOLEAN	CB close travel time quality drops in the warning zone
TRV_T_OP_ALM	BOOLEAN	CB open travel time quality drops in the alarm zone
TRV_T_CL_ALM	BOOLEAN	CB close travel time quality drops in the alarm zone
SPR_CHR_WRN	BOOLEAN	Spring charging quality has dropped in the warning zone
SPR_CHR_ALM	BOOLEAN	Spring charging quality has dropped in the alarm zone
FAC_WRN	BOOLEAN	Fatal attempt to recharge drops below the set value
FAC_ALM	BOOLEAN	Fatal attempt to recharge drops below the set value
DAMPER_WRN	BOOLEAN	CB dampers quality drops in the warning zone
DAMPER_ALM	BOOLEAN	CB dampers quality drops in the alarm zone

Table continues on next page

Name	Type	Description
CB_LIFE_ALM	BOOLEAN	Remaining life of CB reduced to Life alarm level
CONT_Q_WRN	BOOLEAN	Quality of the worst contact in the warning zone
CONT_Q_ALM	BOOLEAN	Quality of the worst contact in the alarm zone
CONT_Q_LO	BOOLEAN	Quality of the worst contact in the lockout zone

7.1.7 Settings

Table 287: Non-group settings

Name	Values (Range)	Unit	Step	Default	Description
Operation	1 = On 5 = Off	-	-	1 = On	Operation Off / On
Open time correction	0...100	ms	1	10	Open time correction for calculation of open travel time
Close time correction	0...100	ms	1	10	Close time correction for calculation of close travel time
Open init quality	0...100	%	1	100	Setting for open initial quality
Close init quality	0...100	%	1	100	Setting for close initial quality
Travel time quality deduction Wrn	0...100	%	1	10	Factor of deduction of the Travel Time Quality in Warning zone
Travel time quality deduction Alm	0...100	%	1	20	Factor of deduction of the Travel Time Quality in Alarm zone
Travel time quality recover	0...100	%	1	5	Factor of recover of the Travel Time Quality in Normal zone
Alarm Open time min	0...200	ms	1	9 1)	Alarm level setting for open travel time
Warning Open time min	0...200	ms	1	1011	Warning level setting for open travel time
Warning Open time max	0...200	ms	1	12 1)	Warning level setting for open travel time
Alarm Open time max	0...200	ms	1	13 1)	Alarm level setting for open travel time
Alarm Close time min	0...200	ms	1	9 1)	Alarm level setting for close travel time
Warning Close time min	0...200	ms	1	10 1)	Warning level setting for close travel time
Warning Close time max	0...200	ms	1	12 1)	Warning level setting for close travel time
Alarm Close time max	0...200	ms	1	13 1)	Alarm level setting for close travel time
Wrn_Travel_Open_Quality_Margin	0...100	%	1	20	Setting of warning level for the open travel time quality
Wrn_Travel_Close_Quality_Margin	0...100	%	1	20	Setting of warning level for the close travel time quality
Alm_Travel_Open_Quality_Margin	0...100	%	1	10	Setting of alarm level for the open travel time quality
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
Alm_Travel_Close_Quality_Margin	0...100	%	1	10	Setting of alarm level for the close travel time quality
Spring charge init quality	0...100	%	1	100	Setting for spring charging initial quality
Spring charge quality deduction Wrn	0 ...100	%	1	10	Factor of deduction of the Spring Charge Quality in Warning zone
Spring charge quality deduction Alm	0...100	%	1	20	Factor of deduction of the Spring Charge Quality in Alarm zone
Spring charge quality recover	0...100	%	1	5	Factor of recover of the Spring Charge Quality in Normal zone
Warning Spring charge time max	0...90000	ms	100	13500	Warning level setting for spring charging time of CB.
Warning Spring charge time min	0...90000	ms	100	5500	Warning level setting for spring charging time of CB.
Alarm Spring charge time max	0...90000	ms	100	15000	Alarm level setting for spring charging time of CB.
Alarm Spring charge time min	0...90000	ms	100	5000	Alarm level setting for spring charging time of CB.
Wrn_Spring_Quality_Margin	0...100	%	1	20	Setting of warning level for the spring charge quality
Alm_Spring_Quality_Margin	0...100	%	1	10	Setting of alarm level for the spring charge quality
Ini inactive days	0...9999	Day	1	0	Initial value of the inactive days counter
Wrn Inactive days	0...9999	Day	1	2000	Warning limit value of the inactive days counter
Alm Inactive days	0...9999	Day	1	3000	Alarm limit value of the inactive days counter
Op Counter initial Value	0...99999	-	1	0	Operation numbers counter initialization value
Alarm Op number	0...99999	-	1	2000	Alarm limit for number of operations
Lockout Op number	0...99999	-	1	3000	Lockout limit for number of operations
Protection Op Counter initial Value	0...99999	-	1	0	Protection Operation numbers counter initialization value
Alarm Protection Op number	0...99999	-	1	150	Alarm limit for number of protection operations
Lockout Protection Op number	0...99999	-	1	200	Lockout limit for number of protection operations
Difference Cor time	-10.0…10.0	ms	0.1	1.5	Correction factor for time difference in auxiliary and main contacts open time
Difference run time	0.0...10.0	ms	0.1	3.0	Time from contact separation t_{open} to a running arc t_{run}
Accumulated stop current	5.00...500.00	A	0.01	10.00	RMS current setting below which contact quality calculation stops
Alpha_0 Current exponent	0.00...4.00	-	0.01	1.00 [1)]	Current exponent 0 for diffuse arc contact quality calculation
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
Alpha_1 Current exponent	0.00...4.00	-	0.01	2.30 [1)]	Current exponent 1 for diffuse arc contact quality calculation
Alpha_2 Current exponent	0.00...4.00	-	0.01	2.30 [1)]	Current exponent 2 for diffuse arc contact quality calculation
K_0	0.00...100.00	μm/KA^{α0}s	0.01	3.0 [1)]	Current coefficient 0 for diffused contact quality calculation
K_1	0.00...100.00	μm/KA^{α1}s	0.01	1.76 [1)]	Current coefficient 1 for constricted contact quality calculation
K_2	0.00...100.00	μm/KA^{α2}s	0.01	0.56 [1)]	Current coefficient 2 for running arc contact quality calculation
I_constricted	0.0...30.0	KA	0.1	15	Constriction current setting
Max contact wear	0...10	mm	0.1	2.5	Maximum allowable contact erosion
Init contact quality	0...100	%	1	100	Initial quality of contact ABC
Wrn_Contact_Quality_Margin	0...100	%	1	20	Warning level setting for the contact with the lowest quality
Alm_Contact_Quality_Margin	0...100	%	1	10	Alarm level setting for the contact with the lowest quality
LO_Contact_Quality_Margin	0...100	%	1	5	Lockout level setting for the contact with the lowest quality
Damper initial occurrence 1	0...2000	%	1	0	Initial fault operation 1st occurrence position
Damper initial occurrence 2	0...2000	%	1	0	Initial fault operation 2nd occurrence position
Damper initial occurrence 3	0...2000	%	1	0	Initial fault operation 3rd occurrence position
Damper initial occurrence 4	0...2000	%	1	0	Initial fault operation 4th occurrence position
Damper initial occurrence 5	0...2000	%	1	0	Initial fault operation 5th occurrence position
N_window	100...2000	-	100	100	Window size to consider mechanical bounces
Wrn_Damper_Margin	0...5	%	1	2	Setting of warning level for the damper quality
Alm_Damper_Margin	0...5	%	1	3	Setting of alarm level for the damper quality
Fatal Attempt init quality	0...100	%	1	100	Setting for the fatal attempt to recharge initial quality
Fatal Attempt Deduction	0...100	%	1	10	Fatal attempt to recharge quality deduction rate.
Wrn_Fatal_Quality_Margin	0...100	%	1	20	Setting of warning level for the fatal attempt to recharge quality
Alm_Fatal_Quality_Margin	0...100	%	1	10	Setting of alarm level for the fatal attempt to recharge quality
Directional Coef	-3.00...-0.50	-	0.01	-1.76	Directional coefficient for CB life calculation
Rated Op current	100.00...5000.00	A	10.00	630.00	Rated operating current of the breaker
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
Rated fault current	500.00...75000.00	A	500.00	16000.00	Rated fault current of the breaker
Op number rated	1...99999	-	1	30000	Number of operations possible at rated current
Op number fault	1...10000	-	1	100	Number of operations possible at rated fault current
Initial CB Rmn life	0.. 99999	-	1	30000	Initial value for the CB remaining life
Alm_Life_Time_Level	0...99999	-	1	5000	Alarm level for CB remaining life

1) depends on breaker type: values given are for VD4-VG6. These values are determined in a calibration process in production.

7.1.8 Monitored data

Table 288: ESSCBR monitored data

Name	Type	Values (Range)	Unit	Description
NO_OPR	INTEGER	0…99999	-	Number of CB operation cycle
NO_PROT_OPR	INTEGER	0…99999	-	Number of CB operation cycle due to protection intervention
INA_DAYS	INTEGER	0…9999	-	The number of days CB has been inactive
TRV_OP_T	INTEGER	0…60000	Time [ms]	Travel time of the CB during opening operation
TRV_CL_T	INTEGER	0…60000	Time [ms]	Travel time of the CB during closing operation
TRV_OT_STATUS	BOOLEAN	0…1	-	Travel time over-threshold status indication
TRV_OP_Q	INTEGER	0…100	%	Quality of CB travel speed during opening operation
TRV_CL_Q	INTEGER	0…100	%	Quality of CB travel speed during closing operation
SPR_CHR_T	REAL	0.00…99.99	Time [s]	The charging time of the CB spring
SPR_OT_STATUS	BOOLEAN	0…1	-	Spring charge time over-threshold status indication
SPR_CHR_Q	INTEGER	0…100	%	Quality of the spring charge system
FAC_Q	INTEGER	0…100	%	Quality due to fatal attempt to recharge spring
CB_LIFE_A	INTEGER	-9999…99999	-	CB Remaining life phase A
CB_LIFE_B	INTEGER	-9999…99999	-	CB Remaining life phase B
CB_LIFE_C	INTEGER	-9999…99999	-	CB Remaining life phase C
CONTACT_A_Q	INTEGER	0…100	%	Contact quality of contact, phase A
CONTACT_B_Q	INTEGER	0…100	%	Contact quality of contact, phase B
CONTACT_C_Q	INTEGER	0…100	%	Contact quality of contact, phase C
ESSCBR	Enum	1 = on 2 = blocked 3 = test 4 = test/blocked 5 = off	-	Status

7.1.9 Technical data

Table 289: ESSCBR Technical data

Characteristic	Value
Current measuring accuracy	±1.5% or ±0.002 x In (at currents in the range of 0.1…10 x In) ±5.0% (at currents in the range of 10…40 x In)
Operate time accuracy	±1.0% of the set value or ±20 ms
Travelling time measurement	+10 ms / -0 ms

Section 8 Measurement functions

8.1 Basic measurements

8.1.1 Functions

The three-phase current measurement function, CMMXU, is used for monitoring and metering the phase currents of the power system.

The three-phase voltage measurement function, VMMXU, is used for monitoring and metering the phase-to-phase voltages of the power system. The phase-to-earth voltages are also available in VMMXU.

The residual current measurement function, RESCMMXU, is used for monitoring and metering the residual current of the power system.

The residual voltage measurement function, RESVMMXU, is used for monitoring and metering the residual voltage of the power system.

The sequence current measurement, CSMSQI, is used for monitoring and metering the phase sequence currents.

The sequence voltage measurement, VSMSQI, is used for monitoring and metering the phase sequence voltages.

The three-phase power and energy measurement PEMMXU is used for monitoring and metering the active power P, reactive power Q, apparent power S, power factor PF and for calculating the accumulated energy separately as forward active, reverse active, forward reactive and reverse reactive. PEMMXU calculates these quantities with the fundamental frequency phasors, that is, the DFT values of the measured phase current and phase voltage signals.

The information of the measured quantity is available for the operator both locally in LHMI and remotely to a network control center with communication.

8.1.2 Measurement functionality

The functions can be enabled or disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

Some of the measurement functions operate on two alternative measurement modes: "DFT" and "RMS". The measurement mode is selected with the *X Measurement mode* setting. Depending on the measuring function if the measurement mode cannot be selected, the measuring mode is "DFT".

Demand value calculation

The demand value is calculated separately for each phase. The demand function is implemented by means of a function that calculates the linear average of the signal measured over a settable demand time interval. A new demand value is obtained once in a minute, indicating the analog signal demand over the demand time interval preceding the update time. The actual rolling demand values are stored in the memory until the value is updated at the end of the next time interval. The switching of the demand interval without the loss of data is done by storing the one minute demand values in the memory until the longest demand interval is available. The maximum demand values for each phase are recorded with time stamps. The recorded values are reset with a command.

The demand value calculation is only available in the three-phase current measurement function, CMMXU.

Value reporting

The measurement functions are capable to report new values for network control center (SCADA system) based on the following functions:

- Zero point clamping
- Deadband supervision
- Limit value supervision

In the three-phase voltage measurement function, VMMXU, the supervision functions are based on the phase-to-phase voltages. However, the phase-to-earth voltage values are also reported together with the phase-to-phase voltages.

Zero point clamping

A measured value under zero point clamping limit is forced to zero. This allows the noise in the input signal to be ignored. The active clamping function forces both the actual measurement value and the angle value of the measured signal to zero. In the three-phase or sequence measuring functions, each phase or sequence component has a separate zero point clamping function. The zero value detection operates so that, once the measured value exceeds or falls below the value of zero clamping limit, new values are reported.

Table 290: Zero point clamping limits

Function	Zero clamping limit
Three-phase current measurement (CMMXU)	1%of nominal (In)
Three-phase voltage measurement (VMMXU)	1% of nominal (Un)
Residual current measurement (RESCMMXU)	1% of nominal (In)
Residual voltage measurement (RESVMMXU)	1% of nominal (Un)

Table continues on next page

Function	Zero clamping limit
Phase sequence current measurement (CSMSQI)	1% of the nominal (In)
Phase sequence voltage measurement (VSMSQI)	1% of the nominal (Un)
Three-phase power and energy measurement (PEMMXU)	1.5% of the nominal (Sn)

Limit value supervision

The limit value supervision function indicates whether the measured value of X_INST exceeds or falls below the set limits. The measured value has the corresponding range information X_RANGE and has a value in the range of 0 to 4:

- 0: "normal"
- 1: "high"
- 2: "low"
- 3: "high-high"
- 4: "low-low"

The range information changes and the new values are reported.

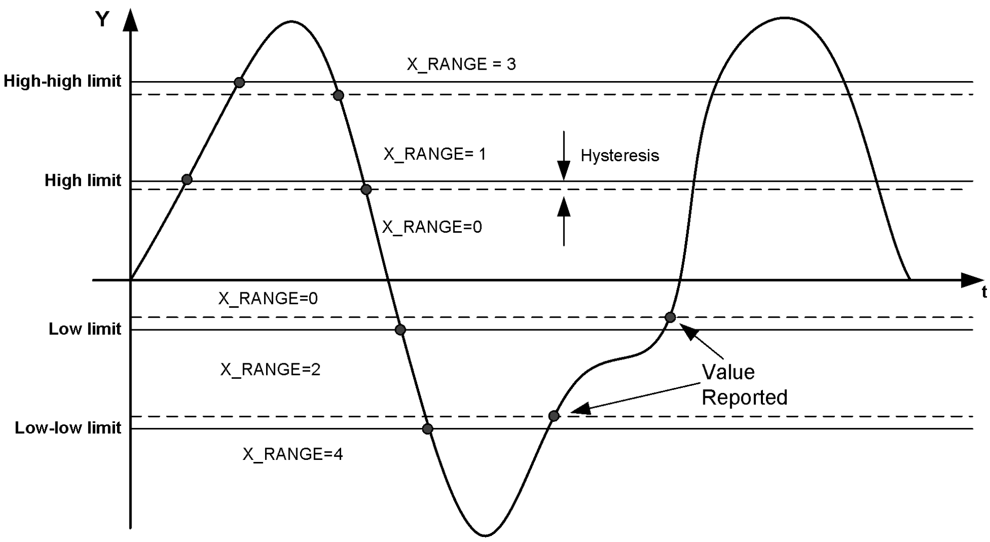


Figure 172: Presentation of operating limits

The range information can also be decoded into boolean output signals on some of the measuring functions and the number of phases required to exceed or undershoot the limit before activating the outputs and can be set with the *Num of phases* setting in the three-phase measurement functions, CMMXU and VMMXU. The limit supervision boolean alarm and warning outputs can be blocked. The settings involved for limit value supervision are :

Table 291: Settings for limit value supervision

Function	Settings for limit value supervision	
Three-phase current measurement (CMMXU)	High limit	*A high limit*
	Low limit	*A low limit*
	High-high limit	*A high high limit*
	Low-low limit	*A low low limit*
Three-phase voltage measurement (VMMXU)	High limit	*V high limit*
	Low limit	*V low limit*
	High-high limit	*V high high limit*
	Low-low limit	*V low low limit*
Residual current measurement (RESCMMXU)	High limit	*A high limit res*
	Low limit	-
	High-high limit	*A Hi high limit res*
	Low-low limit	-
Residual voltage measurement (RESVMMXU)	High limit	*V high limit res*
	Low limit	-
	High-high limit	*V Hi high limit res*
	Low-low limit	-
Phase sequence current measurement (CSMSQI)	High limit	*Ps Seq A high limit*, *Ng Seq A high limit*, *Zro A high limit*
	Low limit	*Ps Seq A low limit*, *Ng Seq A low limit*, *Zro A low limit*
	High-high limit	*Ps Seq A Hi high Lim*, *Ng Seq A Hi high Lim*, *Zro A Hi high Lim*
	Low-low limit	*Ps Seq A low low Lim*, *Ng Seq A low low Lim*, *Zro A low low Lim*
Phase sequence voltage measurement (VSMSQI)	High limit	*Ps Seq V high limit*, *Ng Seq V high limit*, *Zro V high limit*
	Low limit	*Ps Seq V low limit*, *Ng Seq V low limit*, *Zro V low limit*
	High-high limit	*Ps Seq V Hi high Lim*, *Ng Seq V Hi high Lim*, *Zro V Hi high Lim*
	Low-low limit	*Ps Seq V low low Lim*, *Ng Seq V low low Lim*,
Three-phase power and energy measurement (PEMMXU)	High limit	-
	Low limit	-
	High-high limit	-
	Low-low limit	-

Deadband supervision

The deadband supervision function reports the measured value according to integrated changes over a time period.

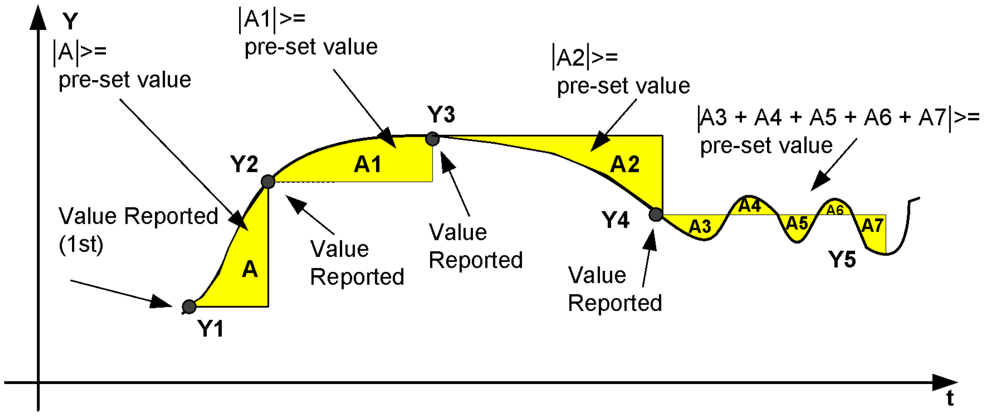


Figure 173: Integral deadband supervision

The deadband value used in the integral calculation is configured with the *X deadband* setting. The value represents the percentage of the difference between the maximum and minimum limit in the units of 0.001 percent * seconds.

The reporting delay of the integral algorithms in seconds is calculated with the formula:

$$t(s) = \frac{(\max - \min) \times deadband / 1000}{|\Delta Y| \times 100\%}$$

(Equation 30)

Example for CMMXU:

A deadband = 2500 (2.5% of the total measuring range of 40)

`I_INST_A` = `I_DB_A` = 0.30

If `I_INST_A` changes to 0.40, the reporting delay is:

$$t(s) = \frac{(40 - 0) \times 2500 / 1000}{|0.40 - 0.30| \times 100\%} = 10s$$

Table 292: Parameters for deadband calculation

Function	Settings	Maximum/minimum (=range)
Three-phase current measurement (CMMXU)	*A deadband*	*40 / 0 (=40xIn)*
Three-phase voltage measurement (VMMXU)	*V Deadband*	*4 / 0 (=4xUn)*
Residual current measurement (RESCMMXU)	*A deadband res*	*40 / 0 (=40xIn)*
Residual voltage measurement (RESVMMXU)	*V deadband res*	*4 / 0 (=4xUn)*
Phase sequence current measurement (CSMSQI)	*Ps Seq A deadband, Ng Seq A deadband, Zro A deadband*	*40 / 0 (=40xIn)*
Phase sequence voltage measurement (VSMSQI)	*Ps Seq V deadband, Ng Seq V deadband, Zro V deadband*	*4/0 (=4xUn)*
Three-phase power and energy measurement (PEMMXU)	-	

In the three-phase power and energy measurement function, PEMMXU, the deadband supervision is done separately for apparent power S, with the pre-set value of fixed 10 percent of the Sn and the power factor PF, with the pre-set values fixed at 0.10. All the power measurement related values P, Q, S and PF are reported simultaneously when either one of the S or PF values exceeds the pre-set limit.

Power and energy calculation

The three-phase power is calculated from the phase-to-earth voltages and phase-to-earth currents. The power measurement function is capable of calculating complex power based on the fundamental frequency component phasors (DFT).

$$\overline{S} = (\overline{U}_A \cdot \overline{I}^*_A + \overline{U}_B \cdot \overline{I}^*_B + \overline{U}_C \cdot \overline{I}^*_C)$$

(Equation 31)

Once the complex apparent power is calculated, P, Q, S and PF are calculated with the equations:

$$P = \mathrm{Re}(\overline{S})$$

(Equation 32)

$$Q = \mathrm{Im}(\overline{S})$$

(Equation 33)

$$S = \left|\overline{S}\right| = \sqrt{P^2 + Q^2}$$

(Equation 34)

$$Cos\varphi = \frac{P}{S}$$

(Equation 35)

Depending on the unit multiplier selected with *Power unit Mult*, the calculated power values are presented in units of kVA/kW/kVAr or in units of MVA/MW/MVAr.

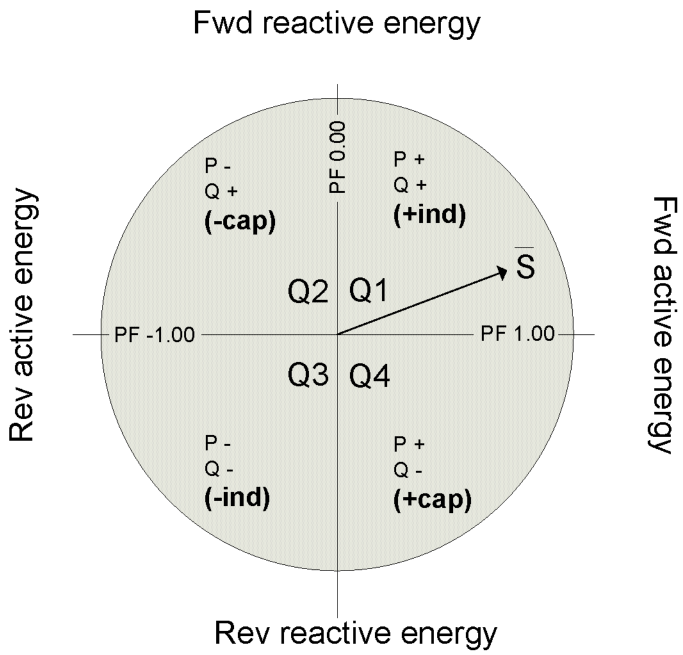


Figure 174: Complex power and power quadrants

Table 293: Power quadrants

Quadrant	Current	P	Q	PF	Power
Q1	Lagging	+	+	0…+1.00	+ind
Q2	Lagging	-	+	0…-1.00	-cap
Q3	Leading	-	-	0…-1.00	-ind
Q4	Leading	+	-	0…+1.00	+cap

The active power P direction can be selected between forward and reverse with *Active power Dir* and correspondingly the reactive power Q direction can be selected with *Reactive power Dir*. This affects also the accumulated energy directions.

The accumulated energy is calculated separately as forward active (EA_FWD_ACM), reverse active (EA_RV_ACM), forward reactive (ER_FWD_ACM) and reverse active (ER_RV_ACM). Depending on the value of the unit multiplier selected with *Energy unit Mult*, the calculated power values are presented in units of kWh/kVArh or in units of MWh/MVArh.

When the energy counter reaches its maximum value defined, the counter value is reset and restarted from the zero. Changing the value of the *Energy unit Mult* setting resets the accumulated energy values to the initial values, that is, EA_FWD_ACM to *Forward Wh Initial*, EA_RV_ACM to *Reverse Wh Initial*, ER_FWD_ACM to *Forward WArh Initial* and ER_RV_ACM to *Reverse WArh Initial*. It is also possible to reset the accumulated energy to initial values through a parameter or with the RSTACM input.

Sequence components

The phase-sequence current components are calculated from the phase currents according to:

$$\bar{I}_0 = (\bar{I}_A + \bar{I}_B + \bar{I}_C)/3$$

(Equation 36)

$$\bar{I}_1 = (\bar{I}_A + a \cdot \bar{I}_B + a^2 \cdot \bar{I}_C)/3$$

(Equation 37)

$$\bar{I}_2 = (\bar{I}_A + a^2 \cdot \bar{I}_B + a \cdot \bar{I}_C)/3$$

(Equation 38)

The phase-sequence voltage components are calculated from the phase-to-earth voltages when *VT connection* is selected as “Wye” with the formulae:

$$\overline{U}_0 = (\overline{U}_A + \overline{U}_B + \overline{U}_C)/3$$

(Equation 39)

$$\overline{U}_1 = (\overline{U}_A + a \cdot \overline{U}_B + a^2 \cdot \overline{U}_C)/3$$

(Equation 40)

$$\overline{U}_2 = (\overline{U}_A + a^2 \cdot \overline{U}_B + a \cdot \overline{U}_C)/3$$

(Equation 41)

When *VT connection* is selected as “Delta”, the positive and negative phase sequence voltage components are calculated from the phase-to-phase voltages according to the formulae:

$$\overline{U}_1 = (\overline{U}_{AB} - a^2 \cdot \overline{U}_{BC})/3$$

(Equation 42)

$$\overline{U}_2 = (\overline{U}_{AB} - a \cdot \overline{U}_{BC})/3$$

(Equation 43)

8.1.3 Measurement function applications

The measurement functions are used for power system measurement, supervision and reporting to LHMI, a monitoring tool within PCM600, or to the station level, for example, with IEC 61850. The possibility to continuously monitor the measured values of active power, reactive power, currents, voltages, power factors and so on, is vital for efficient production, transmission, and distribution of electrical energy. It provides a fast and easy overview of the present status of the power system to the system operator. Additionally, it can be used during testing and commissioning of protection and control IEDs to verify the proper operation and connection of instrument transformers, that is, the current transformers (CTs) and voltage transformers (VTs). The proper operation of the IED analog measurement chain can be verified during normal service by a periodic comparison of the measured value from the IED to other independent meters.

When the zero signal is measured, the noise in the input signal can still produce small measurement values. The zero point clamping function can be used to ignore the noise in the input signal and, hence, prevent the noise to be shown in the user display. The zero clamping is done for the measured analog signals and angle values.

The demand values are used to neglect sudden changes in the measured analog signals when monitoring long time values for the input signal. The demand values are linear average values of the measured signal over a settable demand interval. The demand values are calculated for the measured analog three-phase current signals.

The limit supervision indicates, if the measured signal exceeds or goes below the set limits. Depending on the measured signal type, up to two high limits and up to two low limits can be set for the limit supervision.

The deadband supervision reports a new measurement value if the input signal has gone out of the deadband state. The deadband supervision can be used in value reporting between the measurement point and operation control. When the deadband supervision is properly configured, it helps in keeping the communication load in minimum and yet measurement values are reported frequently enough.

8.1.4 Three-phase current CMMXU

8.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase current	CMMXU	3I	3I

8.1.4.2 Function block

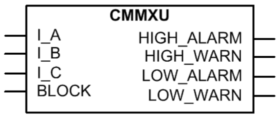


Figure 175: Function block

8.1.4.3 Signals

Table 294: CMMXU Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 295: CMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning
LOW_WARN	BOOLEAN	Low warning
LOW_ALARM	BOOLEAN	Low alarm

8.1.4.4 Settings

Table 296: CMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
Num of phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required by limit supervision
Demand interval	0=1 minute 1=5 minutes 2=10 minutes 3=15 minutes 4=30 minutes 5=60 minutes 6=180 minutes			0=1 minute	Time interval for demand calculation
A high high limit	0.00...40.00	xIn		1.40	High alarm current limit
A high limit	0.00...40.00	xIn		1.20	High warning current limit
A low limit	0.00...40.00	xIn		0.00	Low warning current limit
A low low limit	0.00...40.00	xIn		0.00	Low alarm current limit
A deadband	100...100000			2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.4.5 Monitored data

Table 297: CMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
IL1-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase A
IL2-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase B
IL3-A	FLOAT32	0.00...40.00	xIn	Measured current amplitude phase C
Max demand IL1	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase A
Max demand IL2	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase B
Max demand IL3	FLOAT32	0.00...40.00	xIn	Maximum demand for Phase C
Time max demand IL1	Timestamp			Time of maximum demand phase A
Time max demand IL2	Timestamp			Time of maximum demand phase B
Time max demand IL3	Timestamp			Time of maximum demand phase C
I_INST_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of instantaneous value
I_DB_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of reported value
I_DMD_A	FLOAT32	0.00...40.00	xIn	Demand value of IL1 current
I_RANGE_A	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL1 Amplitude range
I_INST_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of instantaneous value
I_DB_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of reported value
I_DMD_B	FLOAT32	0.00...40.00	xIn	Demand value of IL2 current
I_RANGE_B	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL2 Amplitude range
I_INST_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of instantaneous value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
I_DB_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of reported value
I_DMD_C	FLOAT32	0.00...40.00	xIn	Demand value of IL3 current
I_RANGE_C	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL3 Amplitude range

8.1.4.6 Technical data

Table 298: CMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f_n ±2Hz
	±0.5% or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.4.7 Technical revision history

Table 299: CMMXU Technical revision history

Technical revision	Change
B	Menu changes

8.1.5 Three-phase voltage VMMXU

8.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase voltage	VMMXU	3U	3U

8.1.5.2 Function block

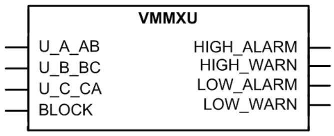


Figure 176: Function block

8.1.5.3 Signals

Table 300: VMMXU Input signals

Name	Type	Default	Description
U_A_AB	SIGNAL	0	Phase to earth voltage A or phase to phase voltage AB
U_B_BC	SIGNAL	0	Phase to earth voltage B or phase to phase voltage BC
U_C_CA	SIGNAL	0	Phase to earth voltage C or phase to phase voltage CA
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 301: VMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning
LOW_WARN	BOOLEAN	Low warning
LOW_ALARM	BOOLEAN	Low alarm

8.1.5.4 Settings

Table 302: VMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
Num of phases	1=1 out of 3 2=2 out of 3 3=3 out of 3			1=1 out of 3	Number of phases required by limit supervision
V high high limit	0.00...4.00	xUn		1.40	High alarm voltage limit
V high limit	0.00...4.00	xUn		1.20	High warning voltage limit
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit
V low low limit	0.00...4.00	xUn		0.00	Low alarm voltage limit
V deadband	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.5.5 Monitored data

Table 303: VMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
U12-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase AB
U23-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase BC
U31-kV	FLOAT32	0.00...4.00	xUn	Measured phase to phase voltage amplitude phase CA
U_INST_AB	FLOAT32	0.00...4.00	xUn	U12 Amplitude, magnitude of instantaneous value
U_DB_AB	FLOAT32	0.00...4.00	xUn	U12 Amplitude, magnitude of reported value
U_RANGE_AB	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U12 Amplitude range
U_INST_BC	FLOAT32	0.00...4.00	xUn	U23 Amplitude, magnitude of instantaneous value
U_DB_BC	FLOAT32	0.00...4.00	xUn	U23 Amplitude, magnitude of reported value
U_RANGE_BC	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U23 Amplitude range
U_INST_CA	FLOAT32	0.00...4.00	xUn	U31 Amplitude, magnitude of instantaneous value
U_DB_CA	FLOAT32	0.00...4.00	xUn	U31 Amplitude, magnitude of reported value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
U_RANGE_CA	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U31 Amplitude range
U_INST_A	FLOAT32	0.00...4.00	xUn	UL1 Amplitude, magnitude of instantaneous value
U_INST_B	FLOAT32	0.00...4.00	xUn	UL2 Amplitude, magnitude of instantaneous value
U_INST_C	FLOAT32	0.00...4.00	xUn	UL3 Amplitude, magnitude of instantaneous value

8.1.5.6 Technical data

Table 304: VMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz At voltages in range 0.01…1.15 x U_n
	±0.5% or ±0.002 x U_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.6 Neutral current RESCMMXU

8.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Neutral current	RESCMMXU	I0	I0

8.1.6.2 Function block

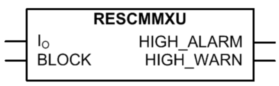


Figure 177: Function block

8.1.6.3 Signals

Table 305: RESCMMXU Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Residual current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 306: RESCMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.1.6.4 Settings

Table 307: RESCMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
A Hi high limit res	0.00...40.00	xIn		0.20	High alarm current limit
A high limit res	0.00...40.00	xIn		0.05	High warning current limit
A deadband res	100...100000			2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.6.5 Monitored data

Table 308: RESCMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
I0-A	FLOAT32	0.00...40.00	xIn	Measured residual current
I0_INST	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of instantaneous value
I0_DB	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of reported value
I0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual current Amplitude range

8.1.6.6 Technical data

Table 309: RESCMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f/f_n = ±2Hz
	±0.5% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.7 Residual voltage RESVMMXU

8.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual voltage	RESVMMXU	U0	U0

8.1.7.2 Function block

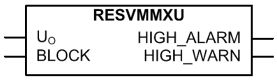


Figure 178: Function block

8.1.7.3 Signals

Table 310: RESVMMXU Input signals

Name	Type	Default	Description
U_0	SIGNAL	0	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 311: RESVMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.1.7.4 Settings

Table 312: RESVMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
V Hi high limit res	0.00...4.00	xUn		0.20	High alarm voltage limit
V high limit res	0.00...4.00	xUn		0.05	High warning voltage limit
V deadband res	100...100000			10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.7.5 Monitored data

Table 313: RESVMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
U0-kV	FLOAT32	0.00...4.00	xUn	Measured residual voltage
U0_INST	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of instantaneous value
U0_DB	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of reported value
U0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual voltage Amplitude range

8.1.7.6 Technical data

Table 314: RESVMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: $f/f_n = \pm 2Hz$
	±0.5% or ±0.002 x U_n
Suppression of harmonics	DFT: -50dB at f = n x f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.8 Phase sequence current CSMSQI

8.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence current	CSMSQI	I1, I2, I0	I1, I2, I0

8.1.8.2 Function block

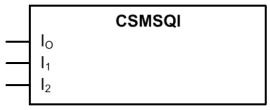


Figure 179: Function block

8.1.8.3 Signals

Table 315: CSMSQI Input signals

Name	Type	Default	Description
I_0	SIGNAL	0	Zero sequence current
I_1	SIGNAL	0	Positive sequence current
I_2	SIGNAL	0	Negative sequence current

8.1.8.4 Settings

Table 316: CSMSQI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Ps Seq A Hi high Lim	0.00...40.00	xIn		1.40	High alarm current limit for positive sequence current
Ps Seq A high limit	0.00...40.00	xIn		1.20	High warning current limit for positive sequence current
Ps Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for positive sequence current
Ps Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for positive sequence current
Ps Seq A deadband	100...100000			2500	Deadband configuration value for positive sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Ng Seq A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for negative sequence current
Ng Seq A High limit	0.00...40.00	xIn		0.05	High warning current limit for negative sequence current
Ng Seq A low limit	0.00...40.00	xIn		0.00	Low warning current limit for negative sequence current
Ng Seq A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for negative sequence current
Ng Seq A deadband	100...100000			2500	Deadband configuration value for negative sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)
Zro A Hi high Lim	0.00...40.00	xIn		0.20	High alarm current limit for zero sequence current
Zro A High limit	0.00...40.00	xIn		0.05	High warning current limit for zero sequence current
Zro A low limit	0.00...40.00	xIn		0.00	Low warning current limit for zero sequence current
Zro A low low Lim	0.00...40.00	xIn		0.00	Low alarm current limit for zero sequence current
Zro A deadband	100...100000			2500	Deadband configuration value for zero sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.8.5 Monitored data

Table 317: CSMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
Ng-Seq-A	FLOAT32	0.00...40.00	xIn	Measured negative sequence current
Ps-Seq-A	FLOAT32	0.00...40.00	xIn	Measured positive sequence current
Zro-Seq-A	FLOAT32	0.00...40.00	xIn	Measured zero sequence current
I2_INST	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, instantaneous value
I2_DB	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, reported value
I2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence current amplitude range
I1_INST	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, instantaneous value
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
I1_DB	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, reported value
I1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence current amplitude range
I0_INST	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, instantaneous value
I0_DB	FLOAT32	0.00...40.00	xIn	Zero sequence current amplitude, reported value
I0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence current amplitude range

8.1.8.6 Technical data

Table 318: CSMSQI Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: f/f_n = ±2 Hz
	±1.0% or ±0.002 x I_n at currents in the range of 0.01...4.00 x I_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.1.9 Phase sequence voltage VSMSQI

8.1.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase sequence voltage	VSMSQI	U1, U2, U0	U1, U2, U0

8.1.9.2 Function block

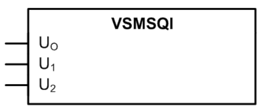


Figure 180: Function block

8.1.9.3 Signals

Table 319: VSMSQI Input signals

Name	Type	Default	Description
U_0	SIGNAL	0	Zero sequence voltage
U_1	SIGNAL	0	Positive phase sequence voltage
U_2	SIGNAL	0	Negative phase sequence voltage

8.1.9.4 Settings

Table 320: VSMSQI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Ps Seq V Hi high Lim	0.00...4.00	xUn		1.40	High alarm voltage limit for positive sequence voltage
Ps Seq V high limit	0.00...4.00	xUn		1.20	High warning voltage limit for positive sequence voltage
Ps Seq V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for positive sequence voltage
Ps Seq V low low Lim	0.00...4.00	xUn		0.00	Low alarm voltage limit for positive sequence voltage
Ps Seq V deadband	100...100000			10000	Deadband configuration value for positive sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)
Ng Seq V Hi high Lim	0.00...4.00	xUn		0.20	High alarm voltage limit for negative sequence voltage
Ng Seq V High limit	0.00...4.00	xUn		0.05	High warning voltage limit for negative sequence voltage
Ng Seq V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for negative sequence voltage
Ng Seq V low low Lim	0.00...4.00	xUn		0.00	Low alarm voltage limit for negative sequence voltage
Ng Seq V deadband	100...100000			10000	Deadband configuration value for negative sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)
Zro V Hi high Lim	0.00...4.00	xUn		0.20	High alarm voltage limit for zero sequence voltage
Zro V High limit	0.00...4.00	xUn		0.05	High warning voltage limit for zero sequence voltage

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Zro V low limit	0.00...4.00	xUn		0.00	Low warning voltage limit for zero sequence voltage
Zro V low low Lim	0.00...4.00	xUn		0.00	Low alarm voltage limit for zero sequence voltage
Zro V deadband	100...100000			10000	Deadband configuration value for zero sequence voltage for integral calculation. (percentage of difference between min and max as 0,001 % s)

8.1.9.5 Monitored data

Table 321: VSMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
Ng-Seq-kV	FLOAT32	0.00...4.00	xUn	Measured negative sequence voltage
Ps-Seq-kV	FLOAT32	0.00...4.00	xUn	Measured positive sequence voltage
Zro-Seq-kV	FLOAT32	0.00...4.00	xUn	Measured zero sequence voltage
U2_INST	FLOAT32	0.00...4.00	xUn	Negative sequence voltage amplitude, instantaneous value
U2_DB	FLOAT32	0.00...4.00	xUn	Negative sequence voltage amplitude, reported value
U2_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Negative sequence voltage amplitude range
U1_INST	FLOAT32	0.00...4.00	xUn	Positive sequence voltage amplitude, instantaneous value
U1_DB	FLOAT32	0.00...4.00	xUn	Positive sequence voltage amplitude, reported value
U1_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Positive sequence voltage amplitude range
U0_INST	FLOAT32	0.00...4.00	xUn	Zero sequence voltage amplitude, instantaneous value
U0_DB	FLOAT32	0.00...4.00	xUn	Zero sequence voltage amplitude, reported value
U0_RANGE	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Zero sequence voltage amplitude range

8.1.9.6 Technical data

Table 322: VSMSQI Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2Hz At voltages in range 0.01…1.15 x U_n
	±1.0% or ±0.002 x U_n
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.1.10 Three-phase power and energy measurement PEMMXU

8.1.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase power and energy measurement	PEMMXU	P, E	P, E

8.1.10.2 Function block

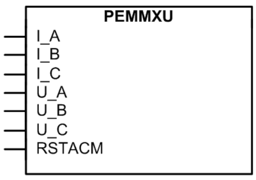


Figure 181: Function block

8.1.10.3 Signals

Table 323: PEMMXU Input signals

Name	Type	Default	Description
I_A	SIGNAL	0	Phase A current
I_B	SIGNAL	0	Phase B current
I_C	SIGNAL	0	Phase C current
U_A	SIGNAL	0	Phase A voltage
U_B	SIGNAL	0	Phase B voltage
U_C	SIGNAL	0	Phase C voltage
RSTACM	BOOLEAN	0=False	Reset of accumulated energy reading

8.1.10.4 Settings

Table 324: PEMMXU Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Power unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the power related values
Energy unit Mult	3=Kilo 6=Mega			3=Kilo	Unit multiplier for presentation of the energy related values
Active power Dir	1=Forward 2=Reverse			1=Forward	Direction of active power flow: Forward, Reverse
Reactive power Dir	1=Forward 2=Reverse			1=Forward	Direction of reactive power flow: Forward, Reverse
Forward Wh Initial	0...999999999		1	0	Preset Initial value for forward active energy
Reverse Wh Initial	0...999999999		1	0	Preset Initial value for reverse active energy
Forward WArh Initial	0...999999999		1	0	Preset Initial value for forward reactive energy
Reverse WArh Initial	0...999999999		1	0	Preset Initial value for reverse reactive energy

8.1.10.5 Monitored data

Table 325: PEMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
S-kVA	FLOAT32	-999999.9...999999.9	kVA	Total Apparent Power
P-kW	FLOAT32	-999999.9...999999.9	kW	Total Active Power
Q-kVAr	FLOAT32	-999999.9...999999.9	kVAr	Total Reactive Power
PF	FLOAT32	-1.00...1.00		Average Power factor
S_INST	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of instantaneous value
S_DB	FLOAT32	-999999.9...999999.9	kVA	Apparent power, magnitude of reported value
P_INST	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of instantaneous value
P_DB	FLOAT32	-999999.9...999999.9	kW	Active power, magnitude of reported value
Q_INST	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of instantaneous value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
Q_DB	FLOAT32	-999999.9...999999.9	kVAr	Reactive power, magnitude of reported value
PF_INST	FLOAT32	-1.00...1.00		Power factor, magnitude of instantaneous value
PF_DB	FLOAT32	-1.00...1.00		Power factor, magnitude of reported value
EA_RV_ACM	INT128	0...999999999	kWh	Accumulated reverse active energy value
ER_RV_ACM	INT128	0...999999999	kVArh	Accumulated reverse reactive energy value
EA_FWD_ACM	INT128	0...999999999	kWh	Accumulated forward active energy value
ER_FWD_ACM	INT128	0...999999999	kVArh	Accumulated forward reactive energy value

8.1.10.6 Technical data

Table 326: PEMMXU Technical data

Characteristic	Value
Operation accuracy	At all three currents in range 0.10…1.20 x I_n At all three voltages in range 0.50…1.15 x U_n At the frequency f_n ±1Hz Active power and energy in range |PF| > 0.71 Reactive power and energy in range |PF| < 0.71
	±1.5% for power (S, P and Q) ±0.015 for power factor ±1.5% for energy
Suppression of harmonics	DFT: -50 dB at f = n x f_n, where n = 2, 3, 4, 5,…

8.2 Voltage sensor temperature measurement VDSTMP

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage sensor temperature-measuring function	VDSTMP	3T	3T

8.2.2 Function block

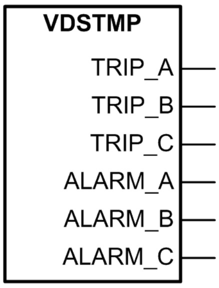


Figure 182: Function block

8.2.3 Functionality

The voltage sensor temperature-measuring function VDSTMP is used to acquire the temperature value of the IED voltage sensor. The voltage measurement provided by the voltage divider depends significantly on the temperature of the sensor so that compensation is required to achieve a proper precision in the voltage measurement.

The function is designed according to the IEC 61850-7-4 standard with the logical node VDSTMP1.

8.2.4 Operation principle

The voltage sensor temperature-measuring function is assigned to acquire the temperature of the voltage sensor whose measurements are affected by temperature. The voltage sensor consists of a capacitive divider incorporating a silicon temperature sensor.

The temperature value of each of the three voltage dividers is used to compensate the voltage measurement on the basis of the thermal characteristic of the voltage sensor itself.

For each sensor, VDSTMP provides alarm and trip outputs whose activation threshold can be configured.

8.2.5 Application

VDSTMP is a mandatory function for all IED applications.

8.2.6 Signals

Table 327: VDSTMP Output signals

Name	Type	Description
TRIP_A	BOOLEAN	Trip phase A
TRIP_B	BOOLEAN	Trip phase B
TRIP_C	BOOLEAN	Trip phase C
ALARM_A	BOOLEAN	Alarm phase A
ALARM_B	BOOLEAN	Alarm phase B
ALARM_C	BOOLEAN	Alarm phase C

8.2.7 Settings

Table 328: VDSTMP Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Alarm value	-5...150	°C	1	100	Alarm value for temperature supervision
Trip value	-5...150	°C	1	150	Trip value for temperature supervision
Temperature corr. A	-30.000...30.000	ohm	0.001	0.000	Phase A voltage temperature measurement correction
Temperature corr. B	-30.000...30.000	ohm	0.001	0.000	Phase B voltage temperature measurement correction
Temperature corr. C	-30.000...30.000	ohm	0.001	0.000	Phase C voltage temperature measurement correction

8.2.8 Monitored data

Table 329: VDSTMP Monitored data

Name	Type	Values (Range)	Unit	Description
TEMP_A	FLOAT32	-99...999	°C	Phase A voltage temperature
TEMP_B	FLOAT32	-99...999	°C	Phase B voltage temperature
TEMP_C	FLOAT32	-99...999	°C	Phase C voltage temperature
VDSTMP	Enum	1=on 5=off		Status

8.3 Disturbance recorder

8.3.1 Functionality

The IED is provided with a disturbance recorder featuring up to 12 analog and 64 binary signal channels. The analog channels can be set to record either the waveform or the trend of the currents and voltage measured.

The analog channels can be set to trigger the recording function when the measured value falls below or exceeds the set values. The binary signal channels can be set to start a recording on the rising or the falling edge of the binary signal or both.

By default, the binary channels are set to record external or internal IED signals, for example the start or trip signals of the IED stages, or external blocking or control signals. Binary IED signals such as a protection start or trip signal, or an external IED control signal over a binary input can be set to trigger the recording. The recorded information is stored in a non-volatile memory and can be uploaded for subsequent fault analysis.

8.3.1.1 Recorded analog inputs

The user can map any analog signal type of the IED to each analog channel of the disturbance recorder by setting the *Channel selection* parameter of the corresponding analog channel. In addition, the user can enable or disable each analog channel of the disturbance recorder by setting the *Operation* parameter of the corresponding analog channel to "on" or "off".

All analog channels of the disturbance recorder that are enabled and have a valid signal type mapped are included in the recording.

8.3.1.2 Triggering alternatives

The recording can be triggered by any or several of the following alternatives:

- Triggering according to the state change of any or several of the binary channels of the disturbance recorder. The user can set the level sensitivity with the *Level trigger mode* parameter of the corresponding binary channel.
- Triggering on limit violations of the analog channels of the disturbance recorder (high and low limit)
- Manual triggering via the *Trig recording* parameter (LHMI or communication)
- Periodic triggering.

Regardless of the triggering type, each recording generates events through state changes of the *Recording started*, *Recording made* and *Recording stored* status parameters. The *Recording stored* parameter indicates that the recording has been stored to the non-volatile memory. In addition, every analog channel and binary channel of the disturbance recorder has its own *Channel triggered* parameter.

Manual trigger has the *Manual triggering* parameter and periodic trigger has the *Periodic triggering* parameter. A state change in any of these parameters also generates an event that gives individual information about the reason of the triggering. COMTRADE files provide unambiguous information about the reason of the triggering, usually only for the binary channels but in some cases also for the analog channels.

Triggering by binary channels

Input signals for the binary channels of the disturbance recorder can be formed from any of the digital signals that can be dynamically mapped. A change in the status of a monitored signal triggers the recorder according to the configuration and settings. Triggering on the rising edge of a digital input signal means that the recording sequence starts when the input signal is activated. Correspondingly, triggering on the falling edge means that the recording sequence starts when the active input signal resets. It is also possible to trigger from both edges. In addition, if preferred, the monitored signal can be non-triggering. The trigger setting can be set individually for each binary channel of the disturbance recorder with the *Level trigger mode* parameter of the corresponding binary channel.

Triggering by analog channels

The trigger level can be set for triggering in a limit violation situation. The user can set the limit values with the *High trigger level* and *Low trigger level* parameters of the corresponding analog channel. Both high level and low level violation triggering can be active simultaneously for the same analog channel. If the duration of the limit violation condition exceeds the filter time of approximately 50 ms, the recorder triggers. In case of a low level limit violation, if the measured value falls below approximately 0.05 during the filter time, the situation is considered to be a circuit-breaker operation and therefore, the recorder does not trigger. This is useful especially in undervoltage situations. The filter time of approximately 50 ms is common to all the analog channel triggers of the disturbance recorder. The value used for triggering is the calculated peak-to-peak value.

Manual triggering

The recorder can be triggered manually via the LHMI or via communication by setting the *Trig recording* parameter to TRUE.

Periodic triggering

Periodic triggering means that the recorder automatically makes a recording at certain time intervals. The user can adjust the interval with the *Periodic trig time* parameter. If the value of the parameter is changed, the new setting takes effect when the next periodic triggering occurs. Setting the parameter to zero disables the triggering alternative and the setting becomes valid immediately. If a new non-zero setting needs to be valid immediately, the user should first set the *Periodic trig time* parameter to zero and then to the new value. The user can monitor the time remaining to the next triggering with the `Time to trigger` monitored data which counts downwards.

8.3.1.3 Length of recordings

The user can define the length of a recording with the *Record length* parameter. The length is given as the number of fundamental cycles.

According to the memory available and the number of analog channels used, the disturbance recorder automatically calculates the remaining amount of recordings that fit into the available recording memory. The user can see this information with the `Rem. amount of rec` monitored data. The fixed memory size allocated for the recorder can fit in two recordings that are ten seconds long. The recordings contain data from all analog and binary channels of the disturbance recorder, at the sample rate of 32 samples per fundamental cycle.

The user can view the number of recordings currently in memory with the `Number of recordings` monitored data. The currently used memory space can be viewed with the `Rec. memory used` monitored data. It is shown as a percentage value.

The maximum number of recordings is 100.

8.3.1.4 Sampling frequencies

The sampling frequency of the disturbance recorder analog channels depends on the set rated frequency. One fundamental cycle always contains the amount of samples set with the *Storage rate* parameter. Since the states of the binary channels are sampled once per task execution of the disturbance recorder, the sampling frequency of binary channels is 400 Hz at the rated frequency of 50 Hz and 480 Hz at the rated frequency of 60 Hz.

Table 330: Sampling frequencies of the disturbance recorder analog channels

Storage rate (samples per fundamental cycle)	Recording length	Sampling frequency of analog channels, when the rated frequency is 50 Hz	Sampling frequency of binary channels, when the rated frequency is 50 Hz	Sampling frequency of analog channels, when the rated frequency is 60 Hz	Sampling frequency of binary channels, when the rated frequency is 60 Hz
32	1* Record length	1600 Hz	400 Hz	1920 Hz	480 Hz
16	2* Record length	800 Hz	400 Hz	960 Hz	480 Hz
8	4 * Record length	400 Hz	400 Hz	480 Hz	480 Hz

8.3.1.5 Uploading of recordings

The IED stores COMTRADE files to the `C:\COMTRADE\` folder. The files can be uploaded with the PCM tool or any appropriate computer software that can access the `C:\COMTRADE\` folder.

One complete disturbance recording consists of two COMTRADE file types: the configuration file and the data file. The file name is the same for both file types. The configuration file has .CFG and the data file .DAT as the file extension.

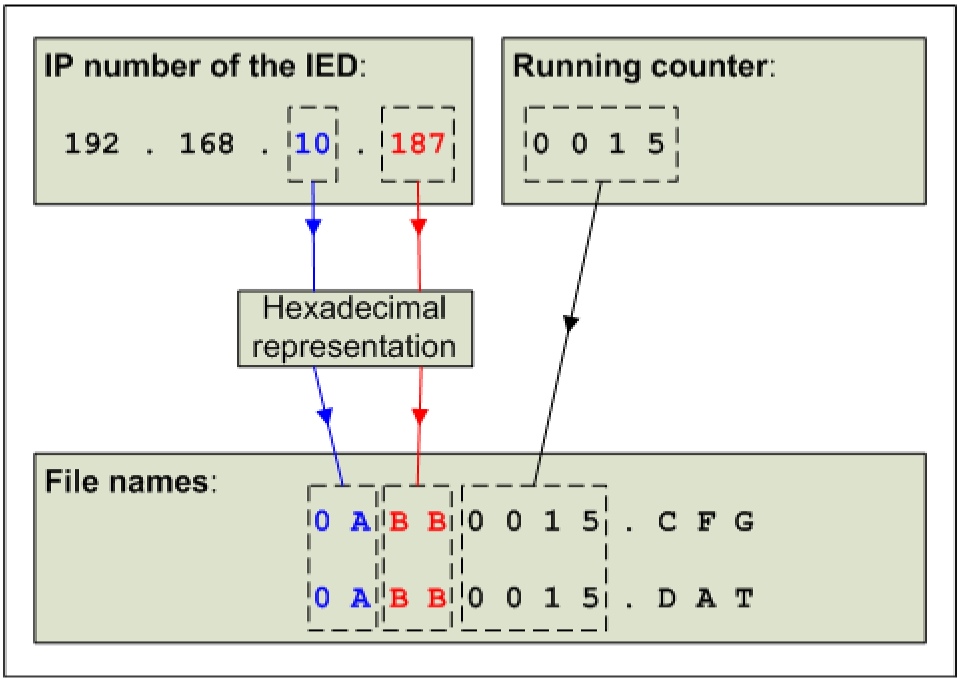


Figure 183: Disturbance recorder file naming

The naming convention of 8+3 characters is used in COMTRADE file naming. The file name is composed of the last two octets of the IED's IP number and a running counter, which has a range of 1...9999. A hexadecimal representation is used for the IP number octets. The appropriate file extension is added to the end of the file name.

8.3.1.6 Deletion of recordings

There are several ways to delete disturbance recordings. The recordings can be deleted individually or all at once.

Individual disturbance recordings can be deleted with the PCM tool or any appropriate computer software, which can access the IED's `C:\COMTRADE` folder. The disturbance recording is not removed from the IED memory until both of the corresponding COMTRADE files, .CFG and .DAT, are deleted. The user may have to delete both of the files types separately, depending on the software used.

Deleting all disturbance recordings at once is done either with the PCM tool or any appropriate computer software, or from the LHMI via the **Clear/Disturbance records** menu. Deleting all disturbance recordings at once also clears the pre-trigger recording in progress.

8.3.1.7 Storage mode

The disturbance recorder can capture data in two modes: waveform and trend mode. The user can set the storage mode individually for each trigger source with the *Storage mode* parameter of the corresponding analog channel or binary channel, the *Stor. mode manual* parameter for manual trigger and the *Stor. mode periodic* parameter for periodic trigger.

In the waveform mode, the samples are captured according to the *Storage rate* and *Pre-trg length* parameters.

In the trend mode, one RMS value is recorded for each enabled analog channel, once per fundamental cycle. The binary channels of the disturbance recorder are also recorded once per fundamental cycle in the trend mode.

Only post-trigger data is captured in trend mode.

The trend mode enables recording times of 32 * *Record length*.

8.3.1.8 Pre-trigger and post-trigger data

The waveforms of the disturbance recorder analog channels and the states of the disturbance recorder binary channels are constantly recorded into the history memory of the recorder. The user can adjust the percentage of the data duration preceding the triggering, that is, the so-called pre-trigger time, with the *Pre-trg length* parameter. The duration of the data following the triggering, that is, the so-called post-trigger time, is the difference between the recording length and the pre-trigger time. Changing the pre-trigger time resets the history data and the current recording under collection.

8.3.1.9 Operation modes

Disturbance recorder has two operation modes: saturation and overwrite mode. The user can change the operation mode of the disturbance recorder with the *Operation mode* parameter.

Saturation mode

In saturation mode, the captured recordings cannot be overwritten with new recordings. Capturing the data is stopped when the recording memory is full, that is, when the maximum number of recordings is reached. In this case, the event is sent via the state change (TRUE) of the *Memory full* parameter. When there is memory available again, another event is generated via the state change (FALSE) of the *Memory full* parameter.

Overwrite mode

When the operation mode is "Overwrite" and the recording memory is full, the oldest recording is overwritten with the pre-trigger data collected for the next recording. Each time a recording is overwritten, the event is generated via the state change of the *Overwrite of rec.* parameter. The overwrite mode is recommended, if it is more important to have the latest recordings in the memory. The saturation mode is preferred, when the oldest recordings are more important.

New triggerings are blocked in both the saturation and the overwrite mode until the previous recording is completed. On the other hand, a new triggering can be accepted before all pre-trigger samples are collected for the new recording. In such a case, the recording is as much shorter as there were pre-trigger samples lacking.

8.3.1.10 Exclusion mode

Exclusion mode is on, when the value set with the *Exclusion time* parameter is higher than zero. During the exclusion mode, new triggerings are ignored if the triggering reason is the same as in the previous recording. The *Exclusion time* parameter controls how long the exclusion of triggerings of same type is active after a triggering. The exclusion mode only applies to the analog and binary channel triggerings, not to periodic and manual triggerings.

When the value set with the *Exclusion time* parameter is zero, the exclusion mode is disabled and there are no restrictions on the triggering types of the successive recordings.

The exclusion time setting is global for all inputs, but there is an individual counter for each analog and binary channel of the disturbance recorder, counting the remaining exclusion time. The user can monitor the remaining exclusion time with the *Exclusion time rem* parameter of the corresponding analog or binary channel. The *Exclusion time rem* parameter counts downwards.

8.3.2 Configuration

The user can configure the disturbance recorder with the PCM600 tool or any tool supporting the IEC 61850 standard.

The user can enable or disable the disturbance recorder with the *Operation* parameter under the **Configuration/Disturbance recorder/General** menu.

One analog signal type of the IED can be mapped to each of the analog channels of the disturbance recorder. The mapping is done with the *Channel selection* parameter of the corresponding analog channel. The name of the analog channel is user-configurable. The user can modify it by writing the new name to the *Channel id text* parameter of the corresponding analog channel.

Any external or internal digital signal of the IED which can be dynamically mapped can be connected to the binary channels of the disturbance recorder. These signals can be, for example, the start and trip signals from protection function blocks or the external binary inputs of the IED. The connection is made with dynamic mapping to the binary channel of the disturbance recorder using SMT of PCM600. It is also possible to connect several digital signals to one binary channel of the disturbance recorder. In that case, the signals can be combined with logical functions, for example AND and OR. The user can configure the name of the binary channel and modify it by writing the new name to the *Channel id text* parameter of the corresponding binary channel.

Note that the *Channel id text* parameter is used in COMTRADE configuration files as a channel identifier.

The recording always contains all binary channels of the disturbance recorder. If one of the binary channels is disabled, the recorded state of the channel is continuously FALSE and the state changes of the corresponding channel are not recorded. The corresponding channel name for disabled binary channels in the COMTRADE configuration file is Unused BI.

To enable or disable a binary channel of the disturbance recorder, the user can set the *Operation* parameter of the corresponding binary channel to the values "on" or "off".

The states of manual triggering and periodic triggering are not included in the recording, but they create a state change to the *Periodic triggering* and *Manual triggering* status parameters, which in turn create events.

The *Recording started* parameter can be used to control the indication LEDs of the IED. The output of the *Recording started* parameter is TRUE due to the triggering of the disturbance recorder, until all the data for the corresponding recording is recorded.

The IP number of the IED and the content of the *Bay name* parameter are both included in the COMTRADE configuration file for identification purposes.

8.3.3 Application

The disturbance recorder is used for post-fault analysis and for verifying the correct operation of protection IEDs and circuit breakers. It can record both analog and binary signal information. The analog inputs are recorded as instantaneous values and converted to primary peak value units when the IED converts the recordings to the COMTRADE format.

COMTRADE is the general standard format used in storing disturbance recordings.

The binary channels are sampled once per task execution of the disturbance recorder. The task execution interval for the disturbance recorder is the same as for the protection functions. During the COMTRADE conversion, the digital status values are repeated so that the sampling frequencies of the analog and binary channels correspond to each other. This is required by the COMTRADE standard.

The disturbance recorder follows the 1999 version of the COMTRADE standard and uses the binary data file format.

8.3.4 Settings

Table 331: Non-group general settings for disturbance recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Disturbance recorder on/off
Record length	10...500	fundamental cycles	1	50	Size of the recording in fundamental cycles
Pre-trg length	0...100	%	1	50	Length of the recording preceding the triggering
Operation mode	1=Saturation 2=Overwrite		1	1	Operation mode of the recorder
Exclusion time	0...1 000 000	ms	1	0	The time during which triggerings of same type are ignored
Storage rate	32, 16, 8	samples per fundamental cycle		32	Storage rate of the waveform recording
Periodic trig time	0...604 800	s	10	0	Time between periodic triggerings
Stor. mode periodic	0=Waveform 1=Trend / cycle		1	0	Storage mode for periodic triggering
Stor. mode manual	0=Waveform 1=Trend / cycle		1	0	Storage mode for manual triggering

Table 332: Non-group analog channel settings for disturbance recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	1=on	Analog channel is enabled or disabled
Channel selection	0=Disabled, 1=I0A 2=IL1A 3=IL2A 4=IL3A 5=I0B 6=IL1B 7=IL2B 8=IL3B 9=U0A 10=U1A 11=U2A 12=U3A 13=U0B 14=U1B 15=U2B 16=U3B 17=SI0A 18=SI1A 19=SI2A 20=SU0A 21=SU1A 22=SU2A 23=SI0B 24=SI1B 25=SI2B 26=SU0B 27=SU1B 28=SU2B		0	0=Disabled	Select the signal to be recorded by this channel
Channel id text	0 to 64 characters, alphanumeric			DR analog channel X	Identification text for the analog channel used in the COMTRADE format
High trigger level	0.00...60.00	pu	0.01	10.00	High trigger level for the analog channel
Low trigger level	0.00...2.00	pu	0.01	0.00	Low trigger level for the analog channel
Storage mode	0=Waveform 1=Trend / cycle		1	0	Storage mode for the analog channel

Table 333: Non-group binary channel settings for disturbance recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off		1	5=off	Binary channel is enabled or disabled
Level trigger mode	1=Positive or Rising 2=Negative or Falling 3=Both 4=Level trigger off		1	1=Rising	Level trigger mode for the binary channel
Storage mode	0=Waveform 1=Trend / cycle		1	0	Storage mode for the binary channel
Channel id text	0 to 64 characters, alphanumeric			DR binary channel X	Identification text for the analog channel used in the COMTRADE format

Table 334: Control data for disturbance recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Trig recording	0=Cancel 1=Trig				Trigger the disturbance recording
Clear recordings	0=Cancel 1=Clear				Clear all recordings currently in memory

8.3.5 Monitored data

Table 335: Monitored data for disturbance recorder

Parameter	Values (Range)	Unit	Step	Default	Description
Number of recordings	0...100				Number of recordings currently in memory
Rem. amount of rec.	0...100				Remaining amount of recordings that fit into the available recording memory, when current settings are used
Rec. memory used	0...100	%			Storage mode for the binary channel
Time to trigger	0...604 800	s			Time remaining to the next periodic triggering

8.3.6 Technical revision history

Table 336: RDRE Technical revision history

Technical revision	Change
B	ChNum changed to EChNum (RADR's). RADR9...12 added (Analog channel 9 -12). RBDR33...64 added (Binary channel 33 - 64).
C	Enum update for Channel selection parameters (DR.RADRx.EChNum.setVal) Std. enum changes to Clear and Manual Trig

Section 9 Control functions

9.1 Circuit breaker control FCBXCBR

9.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker control function	FCBXCBR	I<->0 CB	I<->0 CB

9.1.2 Function block

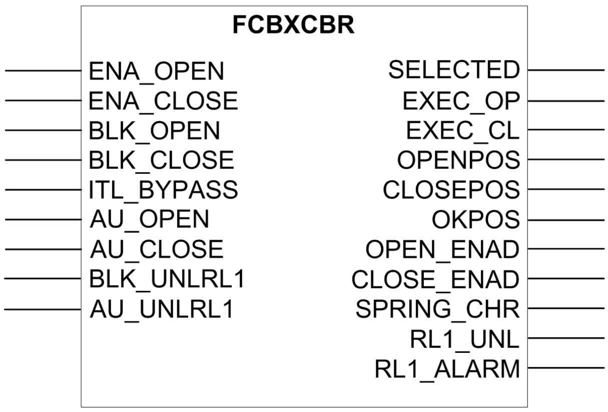


Figure 184: Function block

9.1.3 Functionality

The circuit breaker control function FCBXCBR is used for circuit breaker control and status information purposes. This function executes commands and evaluates block conditions and different time supervision conditions. The function performs an execution command only if all the conditions indicate that a switch operation is allowed. The actuation of the command consists in operating the open and closed coil switches. If erroneous conditions occur, the function indicates an appropriate cause value. The function is designed according to the IEC 61850-7-4 standard with the CILO, CSWI and XCBR logical nodes.

FCBXCBR has an operation counter for the closing and opening cycles. The counter value can be read and written remotely using the LHMI.

9.1.4 Operation principle

Status indication and validity check

The object state is defined by two inductive position sensors detecting the open and closed positions. The breaker status is brought out on outputs OPENPOS and CLOSEPOS together with the OKPOS information. The reporting of a faulty or intermediate position of the circuit breaker (Pos.stVal) contacts occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 337: Status indication

Status (POSITION)	OPENPOS	CLOSEPOS	OKPOS
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

Blocking

FCBXCBR has a blocking functionality to prevent human errors that can cause serious injuries or damage the system components.

The basic principle for all blocking signals is that they affect the commands of other clients, for example, the operator place and protection and autoreclose functions. The blocking principles are:

- Enabling the opening command: The function is used to block the operation of the opening command. This blocking signal also affects the OPEN input of the immediate command.
- Enabling the closing command: The function is used to block the operation of the closing command. This blocking signal also affects the CLOSE input of the immediate command.

The ITL_BYPASS input is used if the interlocking functionality needs to be bypassed. When the ITL_BYPASS input is "TRUE," the circuit breaker control is made possible by discarding the ENA_OPEN and ENA_CLOSE input states. However, since the BLK_OPEN and BLK_CLOSE input signals have a higher priority, they are not bypassed with the interlocking bypass functionality.

The RL1 locking magnet represents an additional blocking mechanism for safety purposes. It is not affected by the ITL_BYPASS input.

Closing spring status check

The status of the spring providing energy for the opening and closing operations is signaled on the dedicated SPRING_CHR output (1=Spring charged). The spring status enables the closing command. The closing operation is possible only if the energy stored in the spring is enough to accomplish the opening and closing operations sequentially. When the closing command is received, the spring is checked and if it is not charged the command is blocked. The opening operation is always possible regardless of the spring status.

Locking magnet RL1

A mechanical block can be mounted for safety purposes to avoid uncontrolled closing operations. The RL1 magnet is activated through the AU_UNRL1 input to unlock the breaker closing. The BLK_UNRL1 blocking input should be "FALSE" or left unconnected to allow the RL1 switching.

If the RL1 magnet is mounted, the AU_UNRL1 input should be active when the closing command is provided to the IED. Otherwise the command is rejected. If the RL1 magnet is not mounted, the AU_UNRL1 input has no effect on the breaker operation.

The actuation of the mechanical unlocking operation takes 100 ms. So if a closing command is received before the time has elapsed for the actuation of the mechanical unlocking operation, the command is deferred until the unlocking operation is supposed to be concluded.

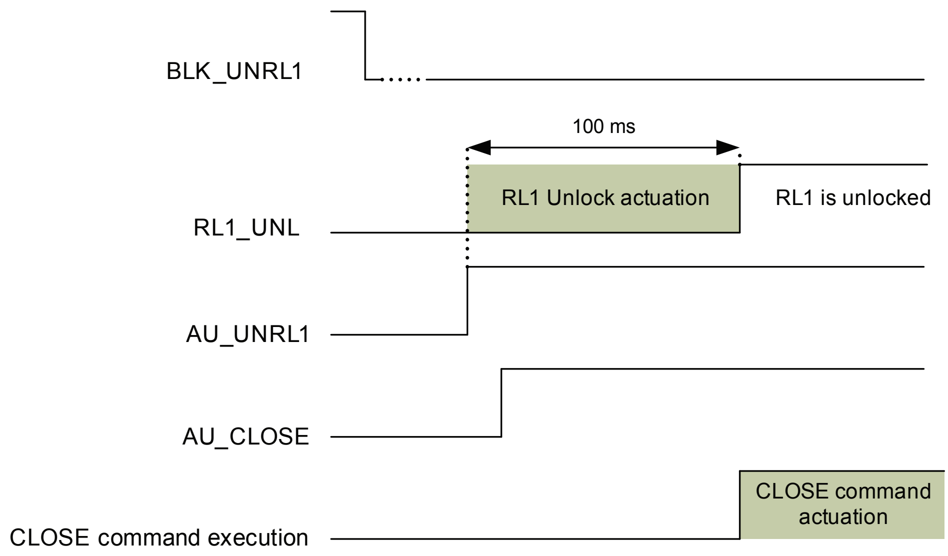


Figure 185: Time diagram for the RL1 logic

If the AU_UNRL1 input remains active after executing the RL1_UNL unlock command, the magnet remains unlocked. If AU_UNRL1 is cleared, the magnet remains unlocked until the circuit breaker reaches the closed position after a closing command or a one-minute time-out is expired or the BLK_UNRL1 input is set. The expiration of the one-minute time-out condition outlines that after unlocking the RL1 magnet, the closing operation can be accomplished in a minute. The RL1 magnet continuity is periodically checked and if it is not confirmed, the RL1_ALARM output pin is activated.

Opening and closing operations

FCBXCBR is also assigned to control the opening and closing actuators. The breaker actuation is obtained by a mechanism by getting energy from a dedicated spring. The opening and closing operations are physically triggered by two coil switches which are operated through the pulse commands whose statuses are visible on the dedicated `EXE_OP` and `EXE_CL` outputs.

The corresponding opening and closing operations are available through communication, binary inputs or LHMI commands. As a prerequisite for the control commands, the enabling and blocking functionalities are available for both the closing and opening commands and the spring is charged. If the control command is executed against the blocking or if the enabling of the corresponding command is not valid, FCBXCBR1 generates an error message.

Opening and closing pulse widths

The pulse width type can be defined with the *Adaptive pulse* setting. The function provides two modes to characterize the opening and closing pulse widths. When the *Adaptive pulse* setting is set to "TRUE," it causes a variable pulse width. This means that the output pulse is deactivated when the object state shows that the circuit breaker has entered the correct state. In any case, the maximum pulse length is given by the *Pulse length* setting. If the breaker is in closed position and a closing command is provided, no pulse is given. Contrarily, in case of opening command, the opening pulse is always given regardless of the breaker position.

When the *Adaptive pulse* setting is set to "FALSE," the function always uses the maximum pulse width defined by the user-configurable *Pulse length* setting. The *Pulse length* setting is the same for both the opening and closing commands. When the circuit breaker already is in the right position, the maximum pulse length is given.

The *Pulse length* setting does not affect the length of the trip pulse.

Control methods

The command execution mode can be set with the *Control model* setting. The alternatives for command execution are direct control and secured object control. The secure object control can be used to secure controlling.

The secured object control (SBO) is an important feature of the communication protocols that support horizontal communication because the command reservation and interlocking signals can be transferred through a bus. All the secured control operations require two-step commands with a selection and an execution step.

Secured object control	Description
Command authority	Ensures that the command source is authorized to operate the object
Mutual exclusion	Ensures that only one command source at a time can control the object
Interlocking	Allows only safe commands
Execution	Supervises the command execution
Command canceling	Cancels the controlling of a selected object

In the direct operate method, a single message is used to initiate the control action of a physical device. The direct operate method uses less communication network capacity and bandwidth than the SBO method because the procedure needs fewer messages for accurate operation.

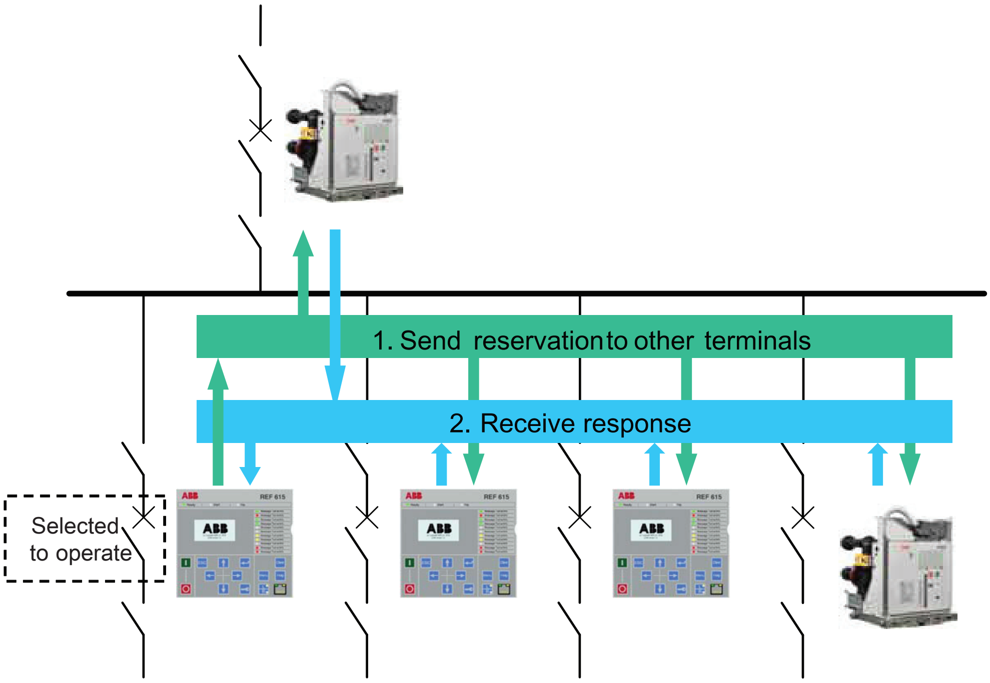


Figure 186: Control procedure in the SBO method

Control from HMI single-line diagram

FCBXCBR can be controlled from the HMI single-line diagram.

Figure 187: Breaker symbols for the intermediate, open, closed and faulty position

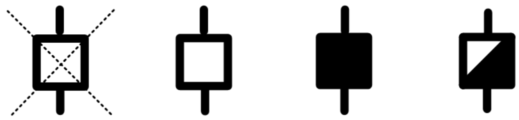


Figure 188: Alternate breaker symbols for the intermediate, open, closed and faulty position

Breaker control takes place through IEC 61850 Data Object (CTRL.FCBXCBR1.Pos).

9.1.5 Application

FCBXCBR1 is a mandatory function in case the breaker typology is fixed.

9.1.6 Signals

Table 338: FCBXCBR Input signals

Name	Type	Default	Description
ENA_OPEN	BOOLEAN	1=True	Enables opening
ENA_CLOSE	BOOLEAN	1=True	Enables closing
BLK_OPEN	BOOLEAN	0=False	Blocks opening
BLK_CLOSE	BOOLEAN	0=False	Blocks closing
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE
AU_OPEN	BOOLEAN	0=False	Input signal used to open the breaker
AU_CLOSE	BOOLEAN	0=False	Input signal used to close the breaker
BLK_UNLRL1	BOOLEAN	0=False	Block RL1 unlocking
AU_UNLRL1	BOOLEAN	0=False	RL1 unlock command

Table 339: FCBXCBR Output signals

Name	Type	Description
SELECTED	BOOLEAN	Object selected
EXE_OP	BOOLEAN	Executes the command for open direction
EXE_CL	BOOLEAN	Executes the command for close direction
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok
OPEN_ENAD	BOOLEAN	Opening is enabled based on the input status
CLOSE_ENAD	BOOLEAN	Closing is enabled based on the input status
SPRING_CHR	BOOLEAN	Spring charged indication
RL1_UNL	BOOLEAN	RL1 coil status
RL1_ALARM	BOOLEAN	RL1 Coil alarm

9.1.7 Settings

Table 340: FCBXCBR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Select timeout	10000...300000	ms	10000	60000	Select timeout in ms
Pulse length	10...60000	ms	1	100	Open and close pulse length
Operation	1=on 5=off			1=on	Operation mode on/off/test
Operation counter	0...50000			0	Breaker operation cycles
Control model	0=status-only 1=direct-with-normal-security 4=sbo-with-enhanced-security			4=sbo-with-enhanced-security	Select control model
Adaptive pulse	0=False 1=True			1=True	Stop in rigth position
Event delay	0...10000	ms	1	100	Event delay of the intermediate position
Operation timeout	10...60000	ms		500	Timeout for negative termination

9.1.8 Monitored data

Table 341: FCBXCBR Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication

9.2 Circuit breaker control WCBXCBR

9.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker control function	WCBXCBR	I<->0 CB	I<->0 CB

9.2.2 Function block

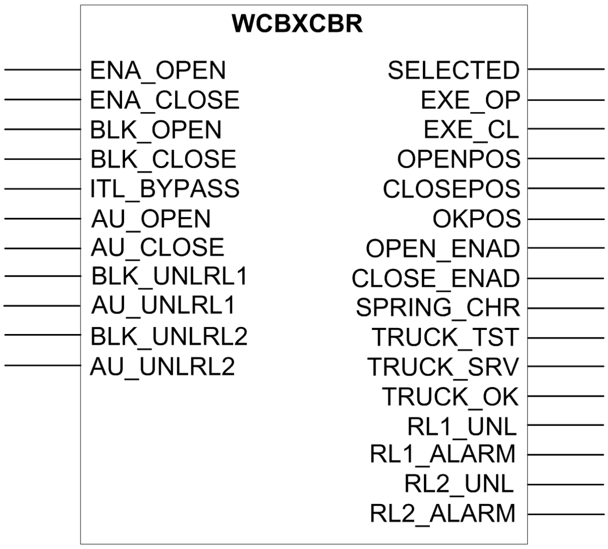


Figure 189: Function block

9.2.3 Functionality

The circuit breaker control function WCBXCBR is intended for withdrawable circuit breaker control and status information purposes. This function executes commands and evaluates block conditions and different time supervision conditions. The function performs an execution command only if all the conditions indicate that a switch operation is allowed. The actuation of the command consists of operating the open and closed coil switches. If erroneous conditions occur, the function indicates an appropriate cause value. WCBXCBR is also assigned to monitor the truck status.

The function is designed according to the IEC 61850-7-4 standard with the CILO, CSWI and XCBR logical nodes.

WCBXCBR has an operation counter for the closing and opening cycles. The counter value can be read and written remotely using the LHMI .

9.2.4 Operation principle

Status indication and validity check

The object state is defined by two inductive position sensors detecting the open and closed positions. The breaker status is brought out on outputs OPENPOS and CLOSEPOS together with the OKPOS information. The reporting of a faulty or intermediate position of the circuit breaker (Pos.stVal) contacts occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 342: Status indication

Status (POSITION)	OPENPOS	CLOSEPOS	OKPOS
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

Blocking

WCBXCBR has a blocking functionality to prevent human errors that can cause serious injuries or damage the system components.

The basic principle for all blocking signals is that they affect the commands of other clients, for example, the operator place and protection and autoreclose functions. The blocking principles are:

- Enabling the opening command: The function is used to block the operation of the opening command. This blocking signal also affects the OPEN input of the immediate command.
- Enabling the closing command: The function is used to block the operation of the closing command. This blocking signal also affects the CLOSE input of the immediate command.

The ITL_BYPASS input is used if the interlocking functionality needs to be bypassed. When the ITL_BYPASS input is "TRUE," the circuit breaker control is made possible by discarding the ENA_OPEN and ENA_CLOSE input states. However, since the BLK_OPEN and BLK_CLOSE input signals have a higher priority, they are not bypassed with the interlocking bypass functionality.

The RL1 and RL2 locking magnets represent an additional blocking mechanism for safety purposes. They are not affected by the ITL_BYPASS input.

Closing spring status check

The status of the spring providing energy for the opening and closing operations is signaled on the dedicated SPRING_CHR output (1=Spring charged). The spring status enables the closing command. The closing operation is possible only if the energy stored in the spring is enough to accomplish the opening and closing operations sequentially. When the closing command is received, the spring is checked and if it is not charged the command is blocked. The opening operation is always possible regardless of the spring status.

Locking magnet RL1

A mechanical block can be mounted for safety purposes to avoid uncontrolled closing operations. The RL1 magnet is activated through the AU_UNRL1 input to unlock the breaker closing. The BLK_UNRL1 blocking input should be "FALSE" or left unconnected to allow the RL1 switching.

If the RL1 magnet is mounted, the AU_UNRL1 input should be active when the closing command is provided to the IED. Otherwise the command is rejected. If the RL1 magnet is not mounted, the AU_UNRL1 input has no effect on the breaker operation.

The actuation of the mechanical unlocking operation takes 100 ms. So if a closing command is received before the time has elapsed for the actuation of the mechanical unlocking operation, the command is deferred until the unlocking operation is supposed to be concluded.

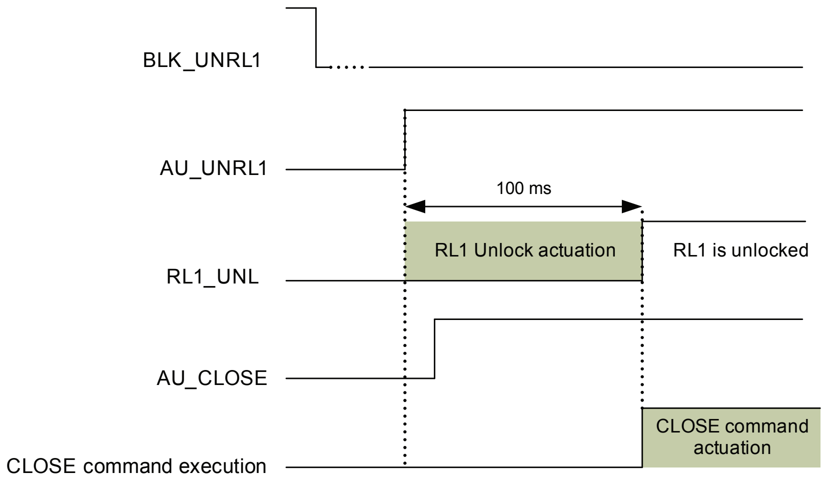


Figure 190: Time diagram for the RL1 logic

If the AU_UNRL1 input remains active after executing the RL1_UNL unlock command, the magnet remains unlocked. If AU_UNRL1 is cleared, the magnet remains unlocked until the circuit breaker reaches the closed position after a closing command or a one-minute time-out is expired or the BLK_UNRL1 input is set. The expiration of the one-minute time-out condition outlines that after unlocking the RL1 magnet, the closing operation can be accomplished in a minute. The RL1 magnet continuity is periodically checked and if it is not confirmed, the RL1_ALARM output pin is activated.

Opening and closing operations

WCBXCBR is also assigned to control the opening and closing actuators. The breaker actuation is obtained by a mechanism by getting energy from a dedicated spring. The opening and closing operations are physically triggered by two coil switches which are operated through the pulse commands whose statuses are visible on the dedicated `EXE_OP` and `EXE_CL` outputs.

The corresponding opening and closing operations are available through communication, binary inputs or LHMI commands. As a prerequisite for the control commands, the enabling and blocking functionalities are available for both the closing and opening commands and the spring is charged. If the control command is executed against the blocking or if the enabling of the corresponding command is not valid, WCBXCBR1 generates an error message.

Opening and closing pulse widths

The pulse width type can be defined with the *Adaptive pulse* setting. The function provides two modes to characterize the opening and closing pulse widths. When the *Adaptive pulse* setting is set to "TRUE," it causes a variable pulse width. This means that the output pulse is deactivated when the object state shows that the circuit breaker has entered the correct state. In any case, the maximum pulse length is given by the *Pulse length* setting. If the breaker is in closed position and a closing command is provided, no pulse is given. Contrarily, in case of opening command, the opening pulse is always given regardless of the breaker position.

When the *Adaptive pulse* setting is set to "FALSE," the function always uses the maximum pulse width defined by the user-configurable *Pulse length* setting. The *Pulse length* setting is the same for both the opening and closing commands. When the circuit breaker already is in the right position, the maximum pulse length is given.

The *Pulse length* setting does not affect the length of the trip pulse.

Control methods

The command execution mode can be set with the *Control model* setting. The alternatives for command execution are direct control and secured object control. The secure object control can be used to secure controlling.

The secured object control (SBO) is an important feature of the communication protocols that support horizontal communication because the command reservation and interlocking signals can be transferred through a bus. All the secured control operations require two-step commands with a selection and an execution step.

Secured object control	Description
Command authority	Ensures that the command source is authorized to operate the object
Mutual exclusion	Ensures that only one command source at a time can control the object
Interlocking	Allows only safe commands
Execution	Supervises the command execution
Command canceling	Cancels the controlling of a selected object

In the direct operate method, a single message is used to initiate the control action of a physical device. The direct operate method uses less communication network capacity and bandwidth than the SBO method because the procedure needs fewer messages for accurate operation.

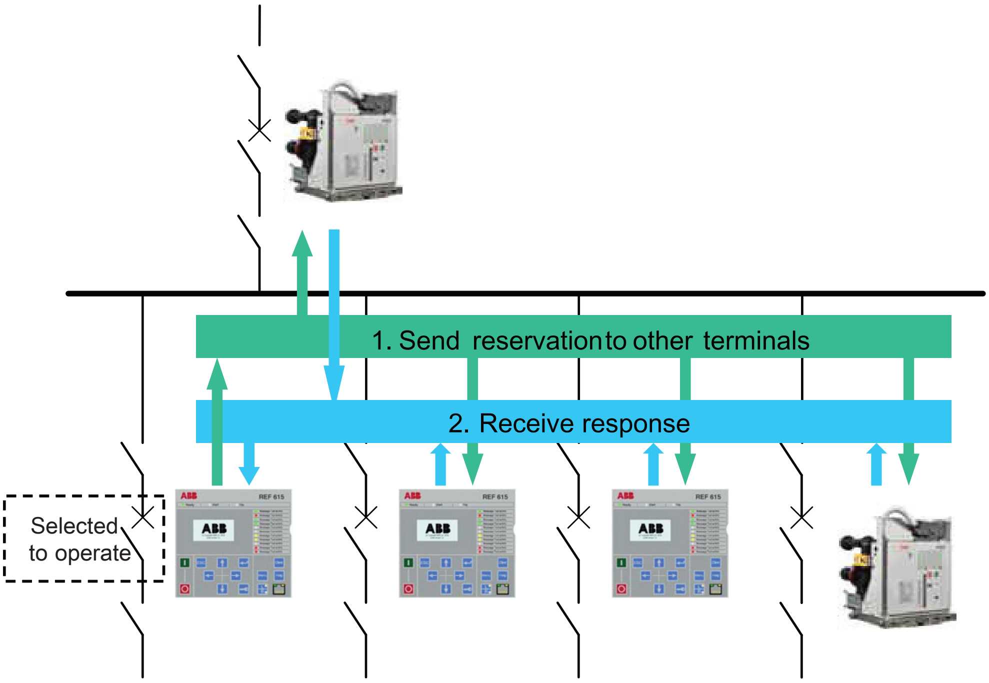


Figure 191: Control procedure in the SBO method

Control from HMI single-line diagram

WCBXCBR can be controlled from the HMI single-line diagram.

Figure 192: Breaker symbols for the intermediate, open, closed and faulty position

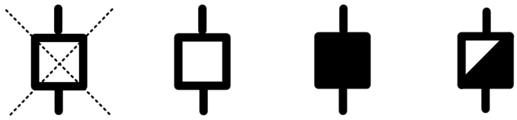


Figure 193: Alternate breaker symbols for the intermediate, open, closed and faulty position

Breaker control takes place through IEC 61850 Data Object (CTRL.WCBXCBR1.Pos).

Truck status indication and validity check

The truck status is defined by two inductive position sensors detecting the test and service positions. The breaker status is brought out on the `TRUCK_TST` and `TRUCK_SRV` outputs together with the `TRUCK_OK` information. The reporting of a faulty or intermediate position of truck contacts occurs after the *Event delay* setting, assuming that the truck is still in a corresponding state.

Table 343: Truck status indication

Status (TRUCK_POS)	TRUCK_TST	TRUCK_SRV	TRUCK_OK
1=Test	1=True	0=False	1=True
2=Service	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

The truck status can be monitored from the HMI single-line diagram.

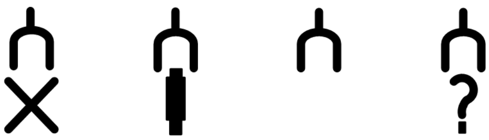


Figure 194: IEC truck symbols for the intermediate, service, test and faulty position

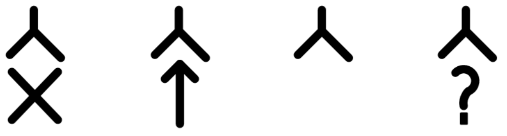


Figure 195: ANSI truck symbols for the intermediate, service, test and faulty position

The truck status is monitored through IEC 61850 Data Object (CTRL.WCBCSWI1.TrkPos).

Locking magnet RL2

A mechanical block can be mounted for safety purposes to avoid uncontrolled circuit breaker rack-in and rack-out operations. The RL2 magnet is activated through the `AU_UNRL2` input to unlock the breaker racking. The `BLK_UNRL2` blocking input should be "FALSE" or left unconnected to allow the RL2 switching.

The actuation of the mechanical unlocking operation takes 100 ms. If `AU_UNRL2` remains active, the magnet remains unlocked. The breaker closing commands are rejected until RL2 is unlocked.

If `AU_UNRL2` is cleared, the magnet remains unlocked until one of the conditions is verified. The conditions are:

1. The circuit breaker reaches the end position (Test or Service) after the racking operation.
2. The circuit breaker is in the Service position and the breaker enters the closed state.
3. The `BLK_UNRL2` input is set.
4. A one-minute time-out has expired.

The expiration of the one-minute time-out condition outlines that after unlocking the RL2 magnet, the racking operation can be accomplished within a minute.

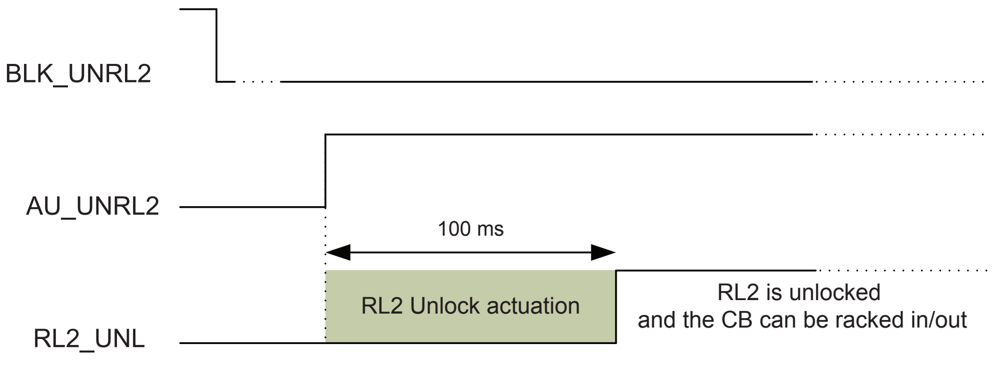


Figure 196: Time diagram for the RL2 logic

If the RL2 magnet is not mounted, the RL2 related inputs and outputs have no relevance. The RL2 magnet's continuity is periodically checked and if it is not confirmed, the RL2_ALARM output pin is activated.

9.2.5 Application

WCBXCBR1 is a mandatory function if the breaker typology is withdrawable. In this case, the application presumably includes TRXSWI for the truck control and HBGAPC for the H-bridge control.

The status of truck (TRUCK_TST, TRUCK_SRV and TRUCK_OK) is supposed to be connected to the appropriate inputs of TRXSWI.

9.2.6 Signals

Table 344: WCBXCBR Input signals

Name	Type	Default	Description
ENA_OPEN	BOOLEAN	1=True	Enables opening
ENA_CLOSE	BOOLEAN	1=True	Enables closing
BLK_OPEN	BOOLEAN	0=False	Blocks opening
BLK_CLOSE	BOOLEAN	0=False	Blocks closing
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE
AU_OPEN	BOOLEAN	0=False	Input signal used to open the breaker
AU_CLOSE	BOOLEAN	0=False	Input signal used to close the breaker
BLK_UNLRL1	BOOLEAN	0=False	Block RL1 unlocking
AU_UNLRL1	BOOLEAN	0=False	RL1 unlock command
BLK_UNLRL2	BOOLEAN	0=False	Block RL2 unlocking
AU_UNLRL2	BOOLEAN	0=False	RL2 unlock command

Table 345: WCBXCBR Output signals

Name	Type	Description
SELECTED	BOOLEAN	Object selected
EXE_OP	BOOLEAN	Executes the command for open direction
EXE_CL	BOOLEAN	Executes the command for close direction
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok
OPEN_ENAD	BOOLEAN	Opening is enabled based on the input status
CLOSE_ENAD	BOOLEAN	Closing is enabled based on the input status
SPRING_CHR	BOOLEAN	Spring charged indication
TRUCK_TST	BOOLEAN	Truck test position

Table continues on next page

Name	Type	Description
TRUCK_SRV	BOOLEAN	Truck service position
TRUCK_OK	BOOLEAN	Truck position is ok
RL1_UNL	BOOLEAN	RL1 coil status
RL1_ALARM	BOOLEAN	RL1 Coil alarm
RL2_UNL	BOOLEAN	RL2 coil status
RL2_ALARM	BOOLEAN	RL2 Coil alarm

9.2.7 Settings

Table 346: WCBXCBR Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Select timeout	10000...300000	ms	10000	60000	Select timeout in ms
Pulse length	10...60000	ms	1	100	Open and close pulse length
Operation	1=on 5=off			1=on	Operation mode on/off/test
Operation counter	0...50000			0	Breaker operation cycles
Control model	0=status-only 1=direct-with-normal-security 4=sbo-with-enhanced-security			4=sbo-with-enhanced-security	Select control model
Adaptive pulse	0=False 1=True			1=True	Stop in rigth position
Event delay	0...10000	ms	1	100	Event delay of the intermediate position
Operation timeout	10...60000	ms		500	Timeout for negative termination

9.2.8 Monitored data

Table 347: WCBXCBR Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication
TRUCK_POS	Dbpos	0=intermediate 1=test 2=service 3=faulty		Truck position indication

9.3 Earthing switch control

9.3.1 Earthing switch indication ESSXSWI

9.3.1.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Earthing switch indication	ESSXSWI	I<-> ES	I<-> ES

9.3.1.2 Function block

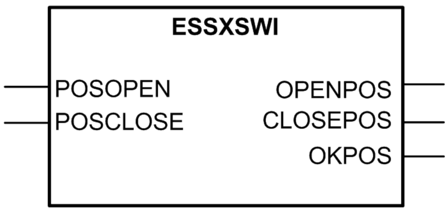


Figure 197: Function block

9.3.1.3 Functionality

The earthing switch indication function ESSXSWI indicates the open, closed and undefined states of the earthing switch both remotely and locally.

ESSXSWI is designed according to the IEC 61850-7-4 standard with the logical node XSWI.

9.3.1.4 Operation principle

The conbody element is the main body-level element for a concept.

Status indication

The object state is defined by two digital inputs `OPEN` and `CLOSE`. The debounces and short disturbances in an input are eliminated by filtering. The digital input filtering time can be adjusted separately for each digital input used by the function block. The validity of digital inputs that indicate the state of the object is used as additional information in indications and event logging. The reporting of faulty or intermediate position of the circuit breaker (Pos.stVal) contacts occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 348: Status indication

Status (POSITION)	OPENPOS	CLOSEPOS	OKPOS
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

The earth switch status can be monitored from the HMI single-line diagram.

Figure 198: Earth Switch symbols for the intermediate, open, closed and faulty position

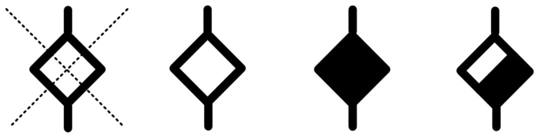


Figure 199: Alternate Earth Switch symbols for the intermediate, open, closed and faulty positions

The earth switch status is monitored through the IEC61850 data object “CTRL.ESSXSWI1.Pos.stVal”.

9.3.1.5 Application

In HMI single-line diagram, the earth symbol is suggested to be used together with the switch symbol as shown in the figure for the earth switch symbols for the intermediate, open, closed and faulty positions.

9.3.1.6 Signals

Table 349: ESSXSWI Input signals

Name	Type	Default	Description
POSOPEN	BOOLEAN	0=False	Apparatus open position
POSCLOSE	BOOLEAN	0=False	Apparatus close position

Table 350: ESSXSWI Output signals

Name	Type	Description
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok

9.3.1.7 Settings

Table 351: ESSXSWI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Event delay	0...10000	ms	1	100	Event delay of the intermediate position

9.3.1.8 Monitored data

Table 352: ESSXSWI Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication

9.3.2 Earth switch control MESXSWI

9.3.2.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Earth switch control	MESXSWI	I<-> ES	I<-> ES

9.3.2.2 Function block

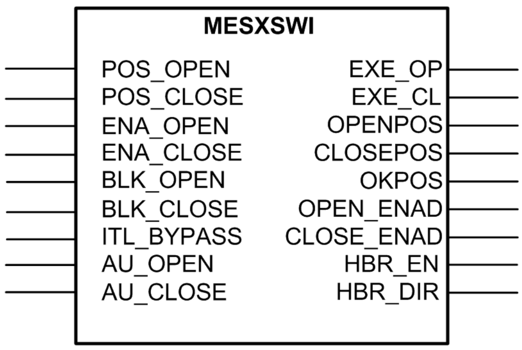


Figure 200: Function block

9.3.2.3 Functionality

The earth switch control function MESXSWI is intended for earth switch control and status information purposes. MESXSWI executes commands and evaluates block conditions and different time supervision conditions. MESXSWI performs an execution command only if all conditions indicate that a switch operation is allowed. The actuation of the command consists in controlling the H-Bridge driving the switch motor. If erroneous conditions occur, MESXSWI indicates an appropriate cause value.

MESXSWI is designed according to the IEC 61850-7-4 standard with the logical nodes CILO, CSWI and XSWI.

9.3.2.4 Operation principle

Switch operation

MESXSWI controls the motor moving the switch from closed to open position and vice versa.

An electrical motor actuates the motion of the shaft driving the apparatus to earth (open position) and line (closed position). The motor control scheme is assumed to be based on an H-Bridge whose control is assigned to a dedicated object (HBGAPC). The `HBR_EN` and `HBR_DIR` outputs represent the enabling of the actuator (H-Bridge) and the direction of the motion respectively.

`HBR_EN` remains active until the switch end position has been reached. In any case, `HBR_EN` is deactivated after a time given by the *Pulse length* setting.

The start movement commands can be provided through the dedicated inputs `AU_OPEN` and `AU_CLOSE` or through HMI or communication. The status of the operation is visible on the dedicated outputs `EXE_OPEN` and `EXE_CLOSE`.

The opening and closing commands are accepted only if the breaker status is open.

Status indication

The object state is defined by two digital inputs, `OPEN` and `CLOSE`. The debounces and short disturbances in an input are eliminated by filtering. The digital input filtering time can be adjusted separately for each digital input used by the function block. The switch status is brought out on the `OPENPOS` and `CLOSEPOS` outputs together with the OKPOS information. The reporting of faulty or intermediate position of circuit breaker (Pos.stVal) contacts occurs after the *Event delay* setting, assuming that the switch is still in a corresponding state.

Table 353: Status indication

Status (POSITION	OPENPOS	CLOSEPOS	OKPOS
1=Open	1=True	0=False	1=True
2=Closed	0=False	1=True	1=True
3=Faulty/Bad (11)	1=True	1=True	0=False
0=Intermediate (00)	0=False	0=False	0=False

Blocking

MESXSWI has a blocking functionality to prevent human errors that can cause serious injuries to the operator and damages to the system components.

The basic principle for all blocking signals is that they affect the commands of other clients, for example, the operator place and the protection and autoreclose functions. The blocking principles are:

- Enabling the open command: The function is used to block the operation of the open command. This block signal also affects the OPEN input of the immediate command. If the switch movement is ongoing and AU_OPEN is passive, as soon as BLK_OPEN is activated, the earth switch is stopped.
- Enabling the close command: the function is used to block the operation of the close command. This block signal also affects the CLOSE input of the immediate command. If the switch movement is ongoing and AU_CLOSE is passive, as soon as BLK_CLOSE is activated, the earth switch is stopped.

The ITL_BYPASS input is used if the interlocking functionality requires to be bypassed. When ITL_BYPASS is "TRUE", the switch control is made possible by discarding the ENA_OPEN and ENA_CLOSE input states. However, the BLK_OPEN and BLK_CLOSE input signals are not bypassed with the interlocking bypass functionality since they always have a higher priority.

Control from HMI Single-Line Diagram

MESXSWI can be controlled from the HMI single-line diagram.

Figure 201: Earth Switch symbols for the intermediate, open, closed and faulty positions

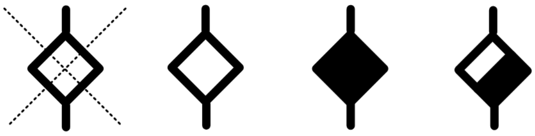


Figure 202: Alternate Earth Switch symbols for the intermediate, open, closed and faulty positions

The earth switch control takes place through the IEC61850 data object "CTRL.MESSXSWI1.Pos".

9.3.2.5 Application

The HBR_EN and HBR_DIR outputs are connected to HBGAPC (H-Bridge control) to control the switch motor.

In HMI SLD, the earth symbol is suggested to be used with the switch symbol shown in Figure 201.

9.3.2.6 Signals

Table 354: MESXSWI Input signals

Name	Type	Default	Description
POS_OPEN	BOOLEAN	0=False	Apparatus open position
POS_CLOSE	BOOLEAN	0=False	Apparatus close position
ENA_OPEN	BOOLEAN	1=True	Enables opening
ENA_CLOSE	BOOLEAN	1=True	Enables closing
BLK_OPEN	BOOLEAN	0=False	Blocks opening
BLK_CLOSE	BOOLEAN	0=False	Blocks closing
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE
AU_OPEN	BOOLEAN	0=False	Input signal used to open the breaker
AU_CLOSE	BOOLEAN	0=False	Input signal used to close the breaker

Table 355: MESXSWI Output signals

Name	Type	Description
EXE_OP	BOOLEAN	Executes the command for open direction
EXE_CL	BOOLEAN	Executes the command for close direction
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok
OPEN_ENAD	BOOLEAN	Opening is enabled based on the input status
CLOSE_ENAD	BOOLEAN	Closing is enabled based on the input status
HBR_EN	BOOLEAN	Enables H Bridge operation
HBR_DIR	BOOLEAN	Selects H Bridge direction

9.3.2.7 Settings

Table 356: MESXSWI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation mode on/off/test
Operation counter	0...10000			0	Breaker operation cycles
Control model	0=status-only 1=direct-with-normal-security			1=direct-with-normal-security	Select control model
Pulse length	10...60000		1	45000	Pulse length

9.3.2.8 Monitored data

Table 357: MESXSWI Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication

9.4 H-bridge control HBGAPC

9.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEE C37.2 device number
H-bridge control	HBGAPC	HBC	HBC

9.4.2 Function block

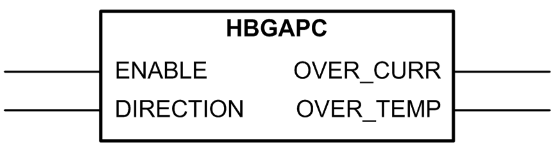


Figure 203: Function block

9.4.3 Functionality

H-bridge is a switching circuit used to apply a controlled voltage to a DC motor. The voltage applied across the motor can be either positive, that is, forward operation, or negative, that is, reverse operation.

The IED is equipped with two H-bridges usable to feed the motors operating trucks or switching devices like the line disconnector or earthing switch.

The function is designed according to the IEC 61850-7-4 standard with the logical node HBGAPC.

9.4.4 Operation principle

Motor control

H-bridge control controls the motor voltage and simultaneously checks the current level through the H-bridge circuit. The DIRECTION input sets the direction of the movement. Input value "0" means reverse and "1" forward direction.

The ENABLE input enables the H-bridge to feed the motor with voltage.

Alarms

During the H-bridge operations, the motor current and temperature of the power circuitry are constantly monitored. If they reach critical values, alarms are issued on the dedicated outputs OVER_CURR and OVER_TEMP.

9.4.5 Application

HBGAPC2 is assigned to move trucks, and therefore it is interconnected with TRXSWI.

The truck motion control is minimal. When the target position is reached, H-bridge is disabled so that the motor operation stops.

HBGAPC1 can be freely assigned to other motorized devices like the earthing switch or line disconnector.

9.4.6 Signals

Table 358: HBGAPC Input signals

Name	Type	Default	Description
ENABLE	BOOLEAN	0=False	Enables H Bridge
DIRECTION	BOOLEAN	0=False	Backward/Forward

Table 359: HBGAPC Output signals

Name	Type	Description
OVER_CURR	BOOLEAN	Over current indication
OVER_TEMP	BOOLEAN	Over temperature indication

9.5 Truck control TRXSWI

9.5.1 Identification

Functional description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Truck control function	TRXSWI	I<->0 DC	I<->0 DC

9.5.2 Function block

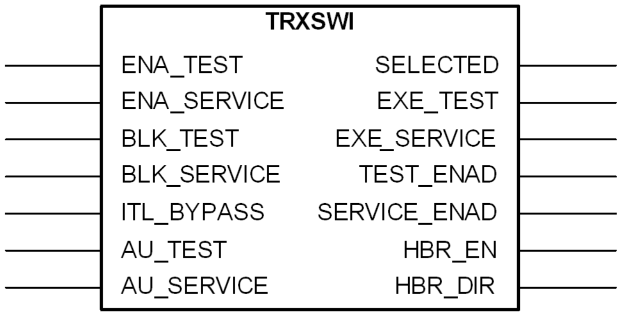


Figure 204: Function block

9.5.3 Functionality

The truck control function TRXSWI is intended for truck control purposes. TRXSWI executes commands and evaluates block conditions and different time supervision conditions. The function performs an execution command only if all conditions indicate that a switch operation is allowed. The actuation of the command consists in controlling the H-Bridge driving the truck motor. The function is designed according to the IEC 61850-7-4 standard with the logical nodes CILO, CSWI and XSWI.

The truck control function has an operation counter for racking in and out cycles. The operator can read and write the counter value remotely from an operator place via LHMI.

9.5.4 Operation principle

Truck operation

TRXSWI is assigned to control the motorized truck racking the breaker in and out.

An electrical motor actuates the motion of the shaft driving the breaker in (service position) and out (test position) of the switchgear. The motor control scheme is assumed to be based on an H-Bridge whose control is assigned to a dedicated object, the H-bridge control HBGAPC. The HBR_EN and HBR_DIR outputs represent the enabling of the actuator (H-Bridge) and the direction of the motion respectively. The HBR_EN output remains active until the track end position has been reached. In any case, the HBR_EN output is deactivated after a time given by the *Pulse length* setting.

The commands to start the movement can be provided through the dedicated inputs AU_TEST and AU_SERVICE through HMI or communication. The status of the operation is visible on the dedicated outputs EXE_TEST and EXE_SERVICE. These commands are accepted only if the breaker is in the open position.

Blocking

TRXSWI has a blocking functionality to prevent human errors that can cause serious injuries to the operator and damages to the system components.

The basic principle for all blocking signals is that they affect the commands of other clients, for example, the operator place and the protection and autoreclose functions. The blocking principles are:

- Enabling command "move to test position": The BLK_TEST input is used to block moving to test position. This block signal also affects the AU_TEST input of the immediate command. If the truck movement is ongoing and AU_TEST is passive, as soon as BLK_TEST is activated, the truck is stopped.
- Enabling command "move to test service": The BLK_SERVICE input is used to block moving to test position. This block signal also affects the AU_SERVICE input of the immediate command. If the truck movement is ongoing and AU_SERVICE is passive, as soon as BLK_SERVICE is activated, the truck is stopped.

The ITL_BYPASS input is used if the interlocking functionality needs to be bypassed. When ITL_BYPASS is TRUE, the truck control is made possible by discarding the ENA_TEST and ENA_SERVICE input states. However, the BLK_TEST and BLK_SERVICE input signals are not bypassed with the interlocking bypass functionality since they always have a higher priority.

Control from HMI Single-Line diagram

TRXSWI can be controlled from the HMI single-line diagram.

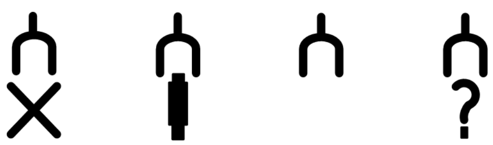


Figure 205: IEC truck symbols for the intermediate, service, test and faulty positions

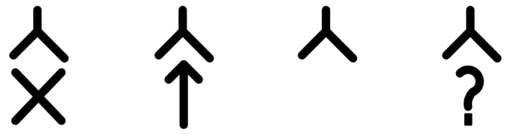


Figure 206: ANSI truck symbols for the intermediate, service, test and faulty positions

Truck control takes place through the IEC61850 data object “CTRL.TRXSWI1.Pos.stVal”.

9.5.5 Application

The correct operation of TRXSWI is possible only if WCBXCBR is installed. WCBXCBR acquires the status of the breaker open and closed position sensors and the truck test and service position sensors. The status of the position sensors is provided to TRXSWI.

The `HBR_EN` and `HBR_DIR` outputs are connected to HBGAPC2 (H-Bridge control) to control the truck motor.

9.5.6 Signals

Table 360: TRXSWI Input signals

Name	Type	Default	Description
ENA_TEST	BOOLEAN	1=True	Enables test position
ENA_SERVICE	BOOLEAN	1=True	Enables service position
BLK_TEST	BOOLEAN	0=False	Blocks moving to test
BLK_SERVICE	BOOLEAN	0=False	Blocks moving to service
ITL_BYPASS	BOOLEAN	0=False	Discards ENA_TEST and ENA_SERVICE interlocking when TRUE
AU_TEST	BOOLEAN	0=False	Executes the command for test position
AU_SERVICE	BOOLEAN	0=False	Executes the command for service position

Table 361: TRXSWI Output signals

Name	Type	Description
SELECTED	BOOLEAN	Object selected
EXE_TEST	BOOLEAN	Executes the command for test direction
EXE_SERVICE	BOOLEAN	Executes the command for service direction
TEST_ENAD	BOOLEAN	Moving to test is enabled based on the input status
SERVICE_ENAD	BOOLEAN	Moving to service is enabled based on the input status
HBR_EN	BOOLEAN	Enable H Bridge operation
HBR_DIR	BOOLEAN	Select H Bridge direction

9.5.7 Settings

Table 362: TRXSWI Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse length	10...60000	ms	1	45000	Test and service pulse length
Operation	1=on 5=off			0	Operation mode on/off/test
Operation counter	0...10000			0	Truck operation cycles
Control model	0=status-only 1=direct-with-normal-security			1=direct-with-normal-security	Select control model

9.5.8 Monitored data

Table 363: TRXSWI Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Truck position indication

9.6 Auto-recloser DARREC

9.6.1 Identification

Function description	IEC 61850 logical node name	IEC 60617 identification	ANSI/IEEE C37.2 device number
Auto-recloser	DARREC	O-->I	79

9.6.2 Function block

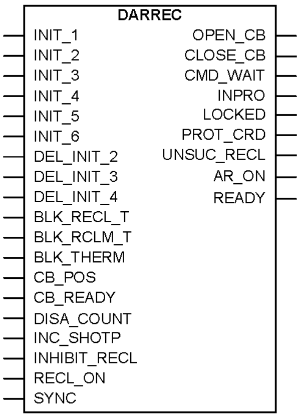


Figure 207: Function block

9.6.3 Functionality

About 80 to 85 percent of faults in the MV overhead lines are transient and automatically cleared with a momentary de-energization of the line. The rest of the faults, 15 to 20 percent, can be cleared by longer interruptions. The de-energization of the fault location for a selected time period is implemented through automatic reclosing, during which most of the faults can be cleared.

In case of a permanent fault, the automatic reclosing is followed by final tripping. A permanent fault must be located and cleared before the fault location can be re-energized.

The auto-reclose function (AR) can be used with any circuit breaker suitable for auto-reclosing. The function provides five programmable auto-reclose shots which can perform one to five successive auto-reclosings of desired type and duration, for instance one high-speed and one delayed auto-reclosing.

When the reclosing is initiated with starting of the protection function, the auto-reclose function can execute the final trip of the circuit breaker in a short operate time, provided that the fault still persists when the last selected reclosing has been carried out.

9.6.3.1 Protection signal definition

The *Control line* setting defines which of the initiation signals are protection start and trip signals and which are not. With this setting, the user can distinguish the blocking signals from the protection signals. The *Control line* setting is a bit mask, that is, the lowest bit controls the `INIT_1` line and the highest bit the `INIT_6` line. Some example combinations of the *Control line* setting are as follows:

Table 364: *Control line setting definition*

Control line setting	`INIT_1`	`INIT_2` `DEL_INIT_2`	`INIT_3` `DEL_INIT_3`	`INIT_4` `DEL_INIT_4`	`INIT_5`	`INIT_6`
0	other	other	other	other	other	other
1	prot	other	other	other	other	other
2	other	prot	other	other	other	other
3	prot	prot	other	other	other	other
4	other	other	prot	other	other	other
5	prot	other	prot	other	other	other
...63	prot	prot	prot	prot	prot	prot

prot = protection signal

other = non-protection signal

When the corresponding bit or bits in both the *Control line* setting and the `INIT_X` line are TRUE:

- The `CLOSE_CB` output is blocked until the protection is reset
- If the `INIT_X` line defined as the protection signal is activated during the discrimination time, the AR function goes to lockout
- If the `INIT_X` line defined as the protection signal stays active longer than the time set by the *Max trip time* setting, the AR function goes to lockout (long trip)
- The `UNSUC_RECL` output is activated after a pre-defined two minutes (alarming earth-fault).

9.6.3.2 Zone coordination

Zone coordination is used in the zone sequence between local protection units and downstream devices. At the falling edge of the `INC_SHOTP` line, the value of the shot pointer is increased by one, unless a shot is in progress or the shot pointer already has the maximum value.

The falling edge of the `INC_SHOTP` line is not accepted if any of the shots are in progress.

9.6.3.3 Master and slave scheme

With the cooperation between the AR units in the same IED or between IEDs, sequential reclosings of two breakers at a line end in a 1½-breaker, double breaker or ring-bus arrangement can be achieved. One unit is defined as a master and it executes the reclosing first. If the reclosing is successful and no trip takes place, the second unit, that is the slave, is released to complete the reclose shot. With persistent faults, the breaker reclosing is limited to the first breaker.

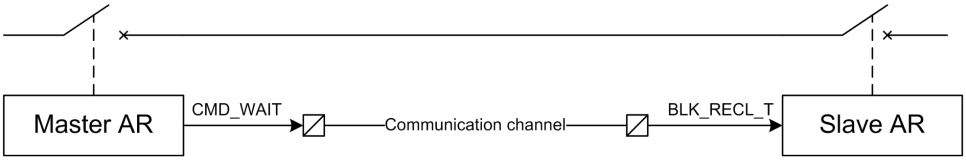


Figure 208: Master and slave scheme

If the AR unit is defined as a master by setting its terminal priority to high:

- The unit activates the CMD_WAIT output to the low priority slave unit whenever a shot is in progress, a reclosing is unsuccessful or the BLK_RCLM_T input is active
- The CMD_WAIT output is reset one second after the reclose command is given or if the sequence is unsuccessful when the reclaim time elapses.

If the AR unit is defined as a slave by setting its terminal priority to low:

- The unit waits until the master releases the BLK_RECL_T input (the CMD_WAIT output in the master). Only after this signal has been deactivated, the reclose time for the slave unit can be started.
- The slave unit is set to a lockout state if the BLK_RECL_T input is not released within the time defined by the *Max wait time* setting , which follows the initiation of an auto-reclose shot.

If the terminal priority of the AR unit is set to "none", the AR unit skips all these actions.

9.6.3.4 Thermal overload blocking

An alarm or start signal from the thermal overload protection (T1PTTR) can be routed to the input BLK_THERM to block and hold the reclose sequence. The BLK_THERM signal does not affect the starting of the sequence. When the reclose time has elapsed and the BLK_THERM input is active, the shot is not ready until the BLK_THERM input deactivates. Should the BLK_THERM input remain active longer than the time set by the setting *Max block time*, the AR function goes to lockout.

If the BLK_THERM input is activated when the auto wait timer is running, the auto wait timer is reset and the timer restarted when the BLK_THERM input deactivates.

9.6.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "On" and "Off".

The reclosing operation can be enabled and disabled with the *Reclosing operation* setting. This setting does not disable the function, only the reclosing functionality. The setting has three parameter values: "Enable," External Ctl" and "Off." The setting value "On" enables the reclosing operation and "Off" disables it. When the setting value "External Ctl" is selected, the reclosing operation is controlled with the RECL_ON input.

The operation of an autoreclose function can be described using a module diagram. All the blocks in the diagram are explained in the next sections.

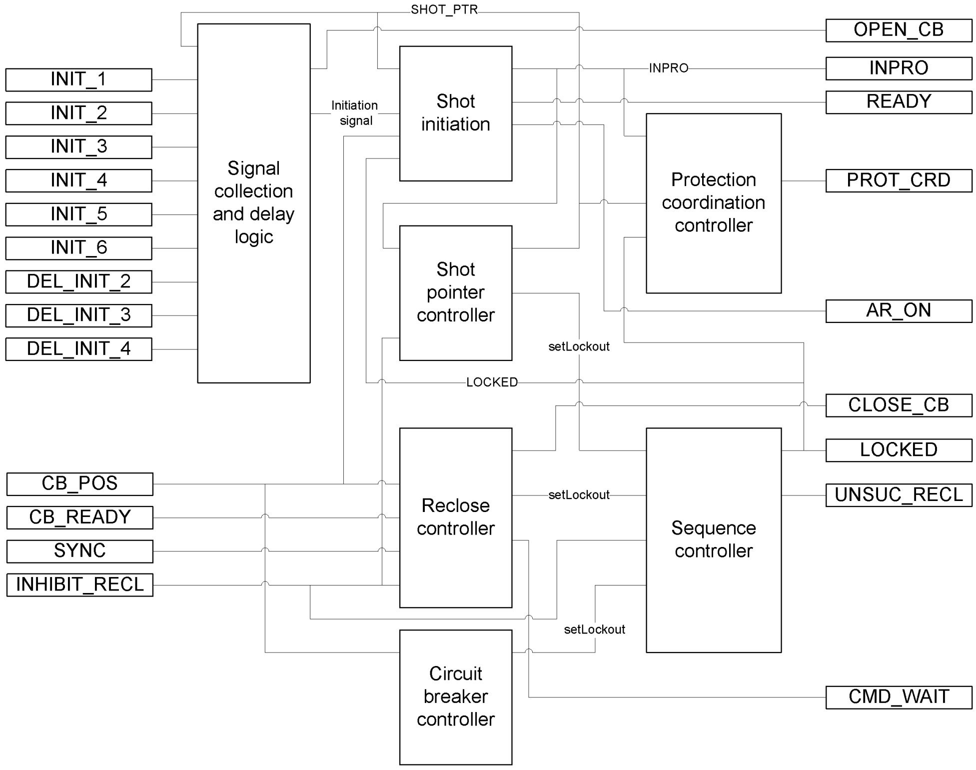


Figure 209: Functional module diagram

9.6.4.1 Signal collection and delay logic

When the protection trips, the initiation of auto-reclose shots is in most applications executed with the INIT_1...6 inputs. The DEL_INIT2...4 inputs are not used. In some countries, starting the protection stage is also used for the shot initiation. This is the only time when the DEL_INIT inputs are used.

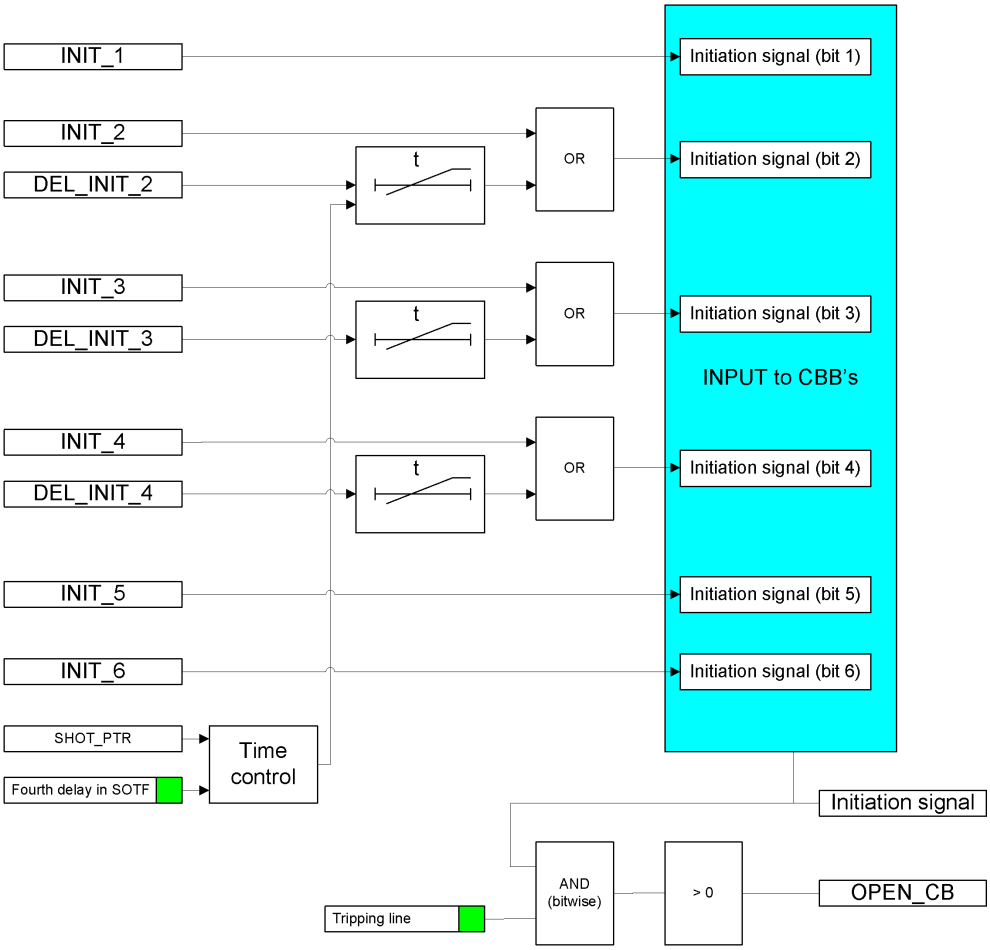


Figure 210: Schematic diagram of delayed initiation input signals

In total, the AR function contains six separate initiation lines used for the initiation or blocking of the auto-reclose shots. These lines are divided into two types of channels. In three of these channels, the signal to the AR function can be delayed, whereas the other three channels do not have any delaying capability.

Each channel that is capable of delaying a start signal has four time delays. The time delay is selected based on the shot pointer in the AR function. For the first reclose attempt, the first time delay is selected; for the second attempt, the second time delay and so on. For the fourth and fifth attempts, the time delays are the same.

Time delay settings for the `DEL_INIT_2` signal are as follows:

- *Str 2 delay shot 1*
- *Str 2 delay shot 2*
- *Str 2 delay shot 3*
- *Str 2 delay shot 4*

Time delay settings for the `DEL_INIT_3` signal are as follows:

- *Str 3 delay shot 1*
- *Str 3 delay shot 2*
- *Str 3 delay shot 3*
- *Str 3 delay shot 4*

Time delay settings for the `DEL_INIT_4` signal are as follows:

- *Str 4 delay shot 1*
- *Str 4 delay shot 2*
- *Str 4 delay shot 3*
- *Str 4 delay shot 4*

Normally, only two or three reclose attempts are made. The third and fourth times are used to provide the so called fast final trip to lockout.

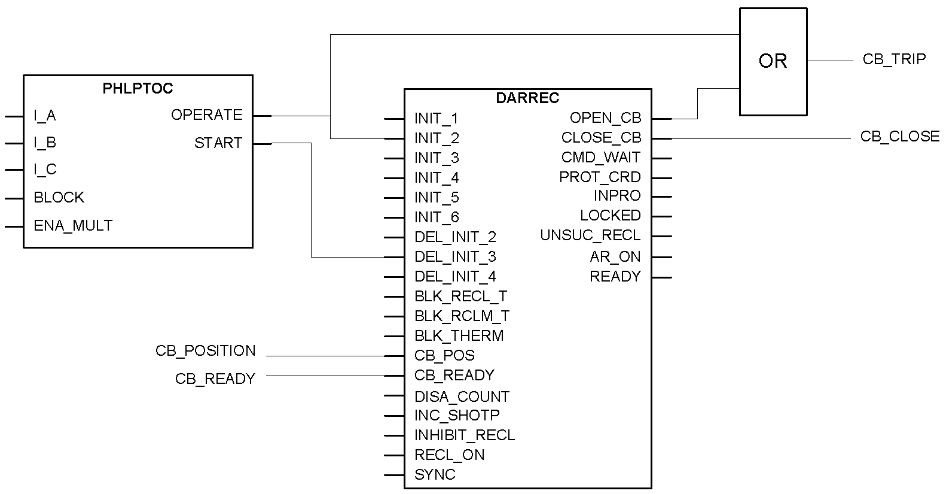


Figure 211: Auto-reclose configuration example

Delayed `DEL_INIT_2...4` signals are used only when the auto-reclose shot is initiated with the start signal of a protection stage. After a start delay, the AR function opens the circuit breaker and an auto-reclose shot is initiated. When the shot is initiated with the trip signal of the protection, the protection function trips the circuit breaker and simultaneously initiates the auto-reclose shot.

If the circuit breaker is manually closed against the fault, that is, if SOTF is used, the fourth time delay can automatically be taken into use. This is controlled with the internal logic of the AR function and the *Fourth delay in SOTF* parameter.

A typical auto-reclose situation is where one auto-reclose shot has been performed after the fault was detected. There are two types of such cases: operation initiated with protection start signal and operation initiated with protection trip signal. In both cases, the auto-reclose sequence is successful: the reclaim time elapses and no new sequence is started.

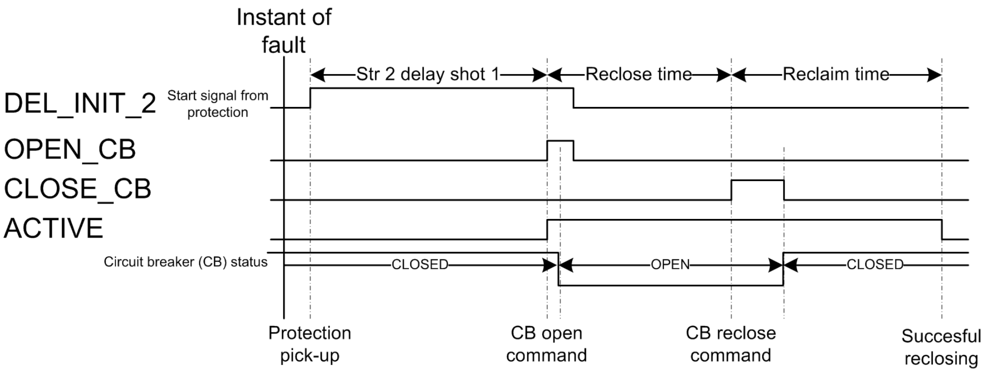


Figure 212: Signal scheme of auto-reclose operation initiated with protection start signal

The auto-reclose shot is initiated with a start signal of the protection function after the start delay time has elapsed. The auto-reclose starts when the *Str 2 delay shot 1* setting elapses.

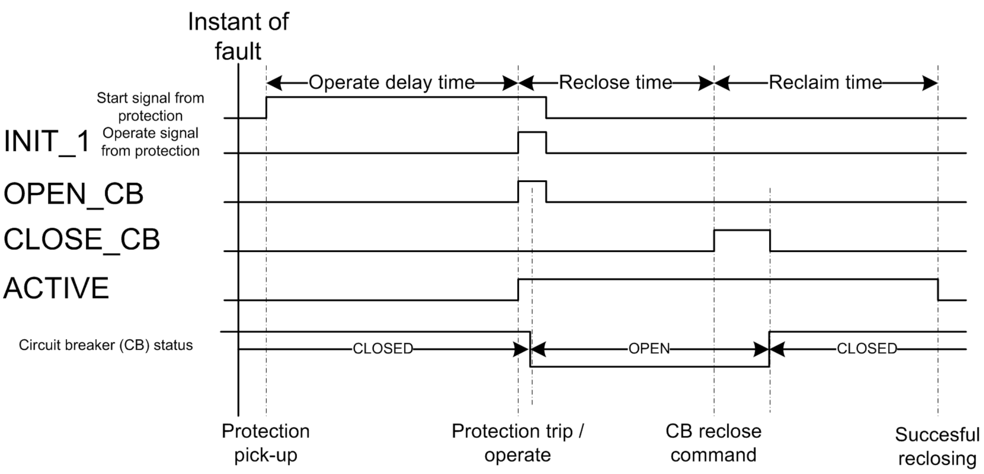


Figure 213: Signal scheme of auto-reclose operation initiated with protection operate signal

The auto-reclose shot is initiated with a trip signal of the protection function. The auto-reclose starts when the protection operate delay time elapses.

Normally, all trip and start signals are used to initiate an auto-reclose shot and trip the circuit breaker. If any of the input signals INIT_X or DEL_INIT_X are used for blocking, the corresponding bit in the *Tripping line* setting must be FALSE. This is to ensure that the circuit breaker does not trip from that signal, that is, the signal does not activate the OPEN_CB output. The default value for the setting is "63", which means that all initiation signals activate the OPEN_CB output. The lowest bit in the *Tripping line* setting corresponds to the INIT_1 input, the highest bit to the INIT_6 line.

9.6.4.2 Shot initiation

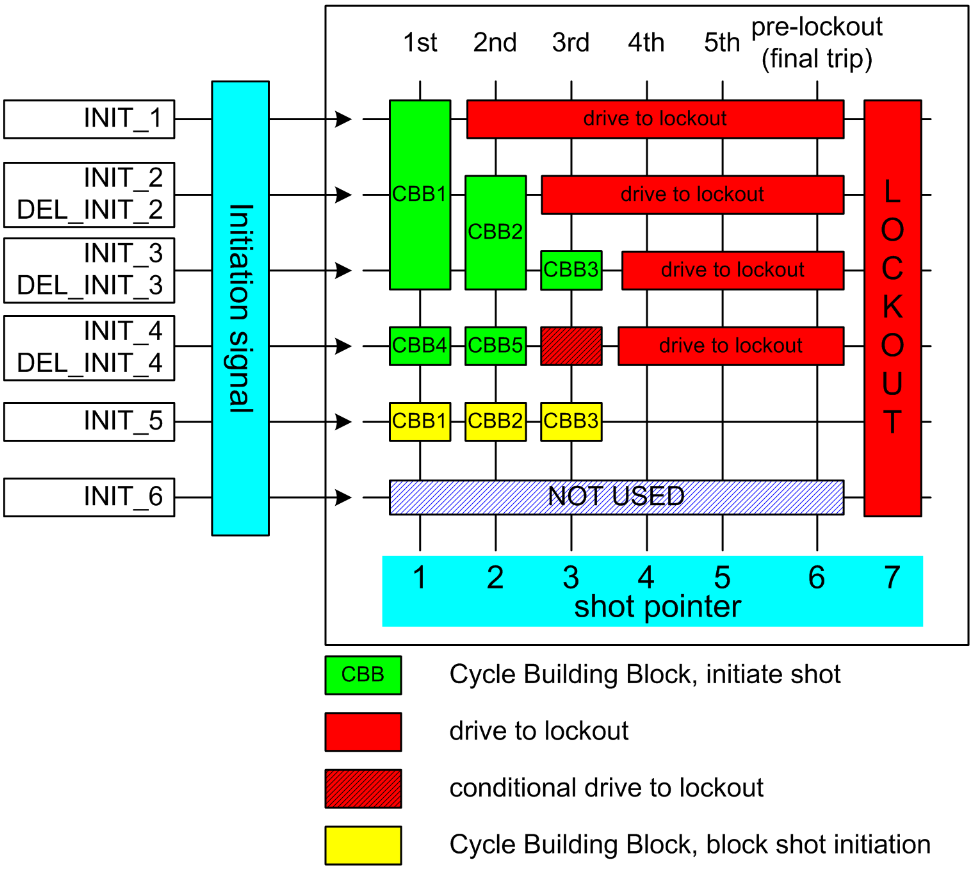


Figure 214: Example of an auto-reclose program with a reclose scheme matrix

In the AR function, each shot can be programmed to locate anywhere in the reclose scheme matrix. The shots are like building blocks used to design the reclose program. The building blocks are called CBBs. All blocks are alike and have settings which give the attempt number (columns in the matrix), the initiation or blocking signals (rows in the matrix) and the reclose time of the shot.

The settings related to CBB configuration are:

- *First...Seventh reclose time*
- *Init signals CBB1…CBB7*
- *Blk signals CBB1…CBB7*
- *Shot number CBB1…CBB7*

The reclose time defines the open and dead times, that is, the time between the `OPEN_CB` and the `CLOSE_CB` commands. The *Init signals CBBx* setting defines the initiation signals. The *Blk signals CBBx* setting defines the blocking signals that are related to the CBB (rows in the matrix). The *Shot number CBB1…CBB7* setting defines which shot is related to the CBB (columns in the matrix). For example, CBB1 settings are:

- *First reclose time* = 1.0s
- *Init signals CBB1* = 7 (three lowest bits: 111000 = 7)
- *Blk signals CBB1* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB1* = 1

CBB2 settings are:

- *Second reclose time* = 10s
- *Init signals CBB2* = 6 (the second and third bits: 011000 = 6)
- *Blk signals CBB2* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB2* = 2

CBB3 settings are:

- *Third reclose time* = 30s
- *Init signals CBB3* = 4 (the third bit: 001000 = 4)
- *Blk signals CBB3* = 16 (the fifth bit: 000010 = 16)
- *Shot number CBB3* = 3

CBB4 settings are:

- *Fourth reclose time* = 0.5s
- *Init signals CBB4* = 8 (the fourth bit: 000100 = 8)
- *Blk signals CBB4* = 0 (no blocking signals related to this CBB)
- *Shot number CBB4* = 1

If a shot is initiated from the `INIT_1` line, only one shot is allowed before lockout. If a shot is initiated from the `INIT_3` line, three shots are allowed before lockout.

A sequence initiation from the `INIT_4` line leads to a lockout after two shots. In a situation where the initiation is made from both the `INIT_3` and `INIT_4` lines, a third shot is allowed, that is, CBB3 is allowed to start. This is called conditional lockout. If the initiation is made from the `INIT_2` and `INIT_3` lines, an immediate lockout occurs.

The `INIT_5` line is used for blocking purposes. If the `INIT_5` line is active during a sequence start, the reclose attempt is blocked and the AR function goes to lockout.

If more than one CBBs are started with the shot pointer, the CBB with the smallest individual number is always selected. For example, if the `INIT_2` and `INIT_4` lines are active for the second shot, that is, the shot pointer is 2, CBB2 is started instead of CBB5.

Even if the initiation signals are not received from the protection functions, the AR function can be set to continue from the second to the fifth reclose shot. The AR function can, for example, be requested to automatically continue with the sequence when the circuit breaker fails to close when requested. In such a case, the AR function issues a `CLOSE_CB` command. When the wait close time elapses, that is, the closing of the circuit breaker fails, the next shot is automatically started. Another example is the embedded generation on the power line, which can make the synchronism check fail and prevent the reclosing. If the auto-reclose sequence is continued to the second shot, a successful synchronous reclosing is more likely than with the first shot, since the second shot lasts longer than the first one.

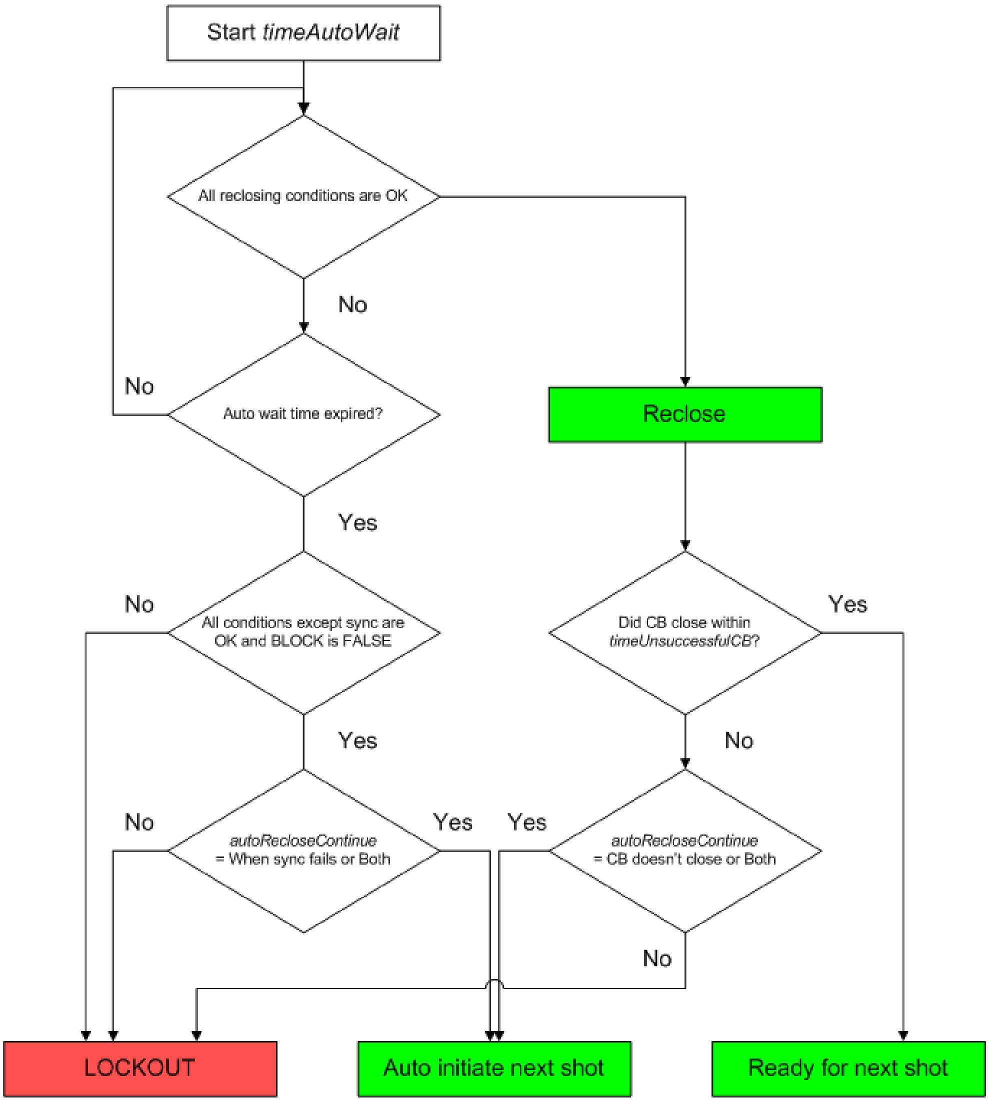


Figure 215: Logic diagram of auto-initiation sequence detection

Automatic initiation can be selected with the *Auto initiation Cnd* setting to be the following:

- Not allowed: no automatic initiation is allowed
- When the synchronization fails, the automatic initiation is carried out when the auto wait time elapses and the reclosing is prevented due to a failure during the synchronism check
- When the circuit breaker does not close, the automatic initiation is carried out if the circuit breaker does not close within the wait close time after issuing the reclose command
- Both: the automatic initiation is allowed when synchronization fails or the circuit breaker does not close.

The *Auto init* parameter defines which INIT_X lines are activated in the auto-initiation. The default value for this parameter is "0", which means that no auto-initiation is selected.

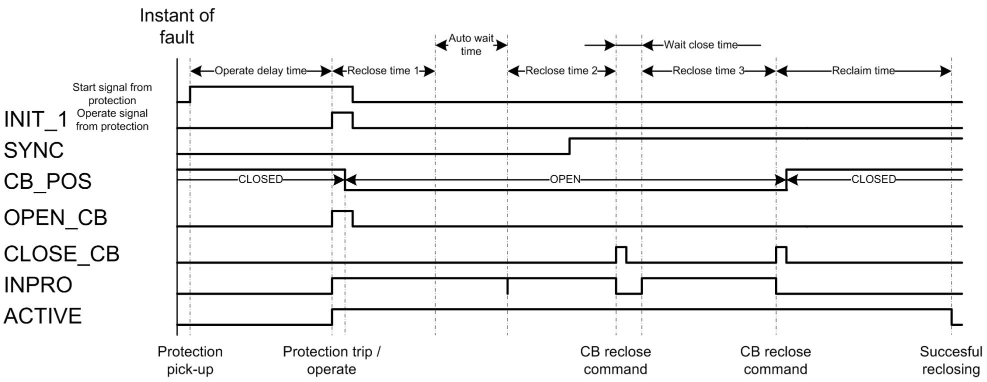


Figure 216: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

In the first shot, the synchronization condition is not fulfilled (SYNC is FALSE). When the auto wait timer elapses, the sequence continues to the second shot. During the second reclosing, the synchronization condition is fulfilled and the close command is given to the circuit breaker after the second reclose time has elapsed.

After the second shot, the circuit breaker fails to close when the wait close time has elapsed. The third shot is started and a new close command is given after the third reclose time has elapsed. The circuit breaker closes normally and the reclaim time starts. When the reclaim time has elapsed, the sequence is concluded successful.

9.6.4.3 Shot pointer controller

The execution of a reclose sequence is controlled by a shot pointer. It can be adjusted with the SHOT_PTR monitored data.

The shot pointer starts from an initial value "1" and determines according to the settings whether or not a certain shot is allowed to be initiated. After every shot, the shot pointer value increases. This is carried out until a successful reclosing or lockout takes place after a complete shot sequence containing a total of five shots.

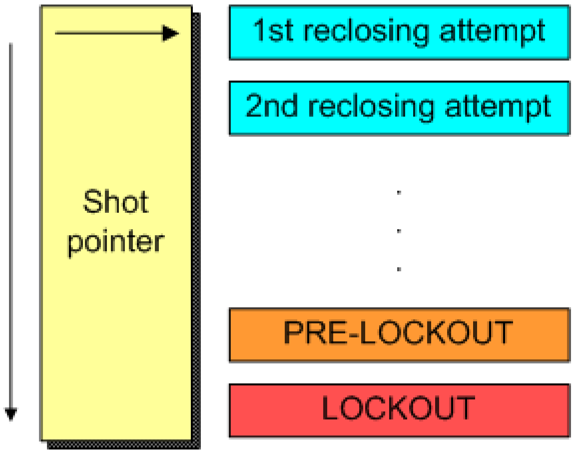


Figure 217: Shot pointer function

Every time the shot pointer increases, the reclaim time starts. When the reclaim time ends, the shot pointer sets to its initial value, unless no new shot is initiated. The shot pointer increases when the reclose time elapses or at the falling edge of the `INC_SHOTP` signal.

When `SHOT_PTR` has the value six, the AR function is in a so called pre-lockout state. If a new initiation occurs during the pre-lockout state, the AR function goes to lockout. Therefore, a new sequence initiation during the pre-lockout state is not possible.

The AR function goes to the pre-lockout state in the following cases:

- During SOTF
- When the AR function is active, it stays in a pre-lockout state for the time defined by the reclaim time
- When all five shots have been executed
- When the frequent operation counter limit is reached. A new sequence initiation forces the AR function to lockout.

9.6.4.4 Reclose controller

The reclose controller calculates the reclose, discrimination and reclaim times. The reclose time is started when the `INPRO` signal is activated, that is, when the sequence starts and the activated CBB defines the reclose time.

When the reclose time has elapsed, the `CLOSE_CB` output is not activated until the following conditions are fulfilled:

- The SYNC input must be TRUE if the particular CBB requires information about the synchronism
- All AR initiation inputs that are defined protection lines (using the *Control line* setting) are inactive
- The circuit breaker is open
- The circuit breaker is ready for the close command, that is, the CB_READY input is TRUE.

If at least one of the conditions is not fulfilled within the time set with the *Auto wait time* parameter, the auto-reclose sequence is locked.

The synchronism requirement for the CBBs can be defined with the *Synchronisation set* setting, which is a bit mask. The lowest bit in the *Synchronisation set* setting is related to CBB1 and the highest bit to CBB7. For example, if the setting is set to "1", only CBB1 requires synchronism. If the setting is it set to "7", CBB1, CBB2 and CBB3 require the SYNC input to be TRUE before the reclosing command can be given.

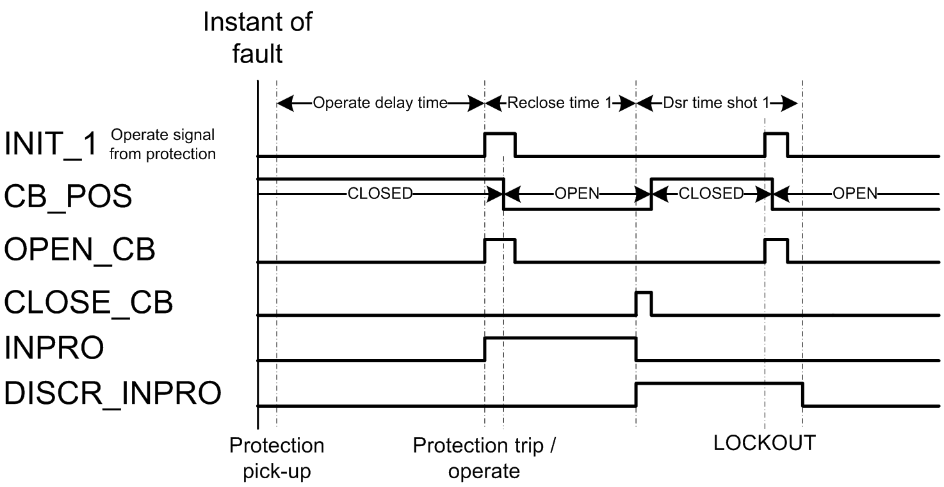


Figure 218: Initiation during discrimination time - AR function goes to lockout

The discrimination time starts when the close command CLOSE_CB has been given. If a start input is activated before the discrimination time has elapsed, the AR function goes to lockout. The default value for each discrimination time is zero. The discrimination time can be adjusted with the *Dsr time shot 1…4* parameter.

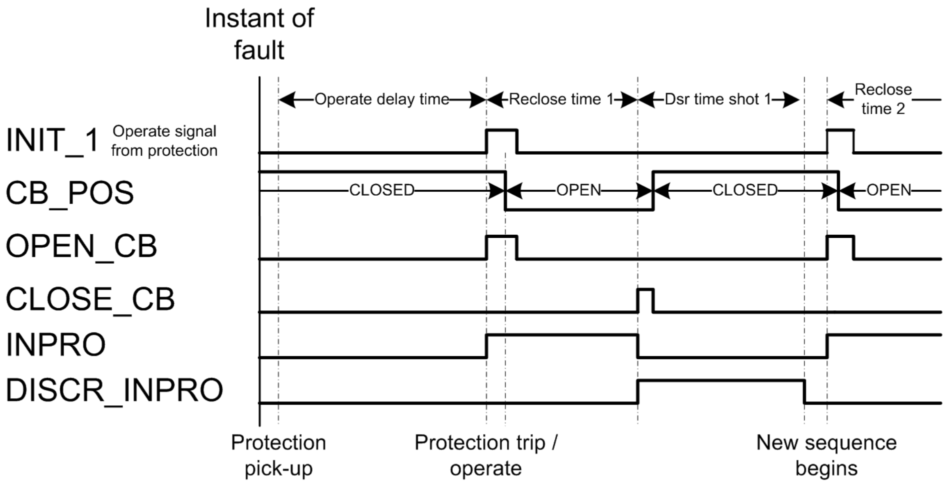


Figure 219: Initiation after elapsed discrimination time - new shot begins

9.6.4.5 Sequence controller

When the LOCKED output is active, the AR function is in lockout. This means that new sequences cannot be initialized, because AR is insensitive to initiation commands. It can be released from the lockout state in the following ways:

- The function is reset through communication with the *RsRec* parameter
- The lockout is automatically reset after the reclaim time, if the *Auto lockout reset* setting is in use.

If the *Auto lockout reset* setting is not in use, the lockout can be released only with the *RsRec* parameter.

The AR function can go to lockout for many reasons:

- The INHIBIT_RECL input is active
- All shots have been executed and a new initiation is made (final trip)
- The time set with the *Auto wait time* parameter expires and the automatic sequence initiation is not allowed because of a synchronization failure
- The time set with the *Wait close time* parameter expires, that is, the circuit breaker does not close or the automatic sequence initiation is not allowed due to a closing failure of the circuit breaker
- A new shot is initiated during the discrimination time
- The time set with the *Max wait time* parameter expires, that is, the master unit does not release the slave unit

- The frequent operation counter limit is reached and new sequence is initiated. The lockout is released when the recovery timer elapses
- The protection trip signal has been active longer than the time set with the *Max wait time* parameter since the shot initiation
- The circuit breaker is closed manually during an auto-reclose sequence and the manual close mode is FALSE.

9.6.4.6 Protection coordination controller

The PROT_CRD output is used for controlling the protection functions. In several applications, such as fuse-saving applications involving down-stream fuses, tripping and initiation of shot 1 should be fast (instantaneous or short-time delayed). The tripping and initiation of shots 2, 3 and definite tripping time should be delayed.

In this example, two overcurrent elements PHLPTOC and PHIPTOC are used. PHIPTOC is given an instantaneous characteristic and PHLPTOC is given a time delay.

The PROT_CRD output is activated, if the SHOT_PTR value is the same or higher than the value defined with the *Protection crd limit* setting and all initialization signals have been reset. The PROT_CRD output is reset under the following conditions:

- If the cut-out time elapses
- If the reclaim time elapses and the AR function is ready for a new sequence
- If the AR function is in lockout or disabled, that is, if the value of the *Protection crd mode* setting is "AR inoperative" or "AR inop, CB man".

The PROT_CRD output can also be controlled with the *Protection crd mode* setting. The setting has the following modes:

- "no condition": the PROT_CRD output is controlled only with the *Protection crd limit* setting
- "AR inoperative": the PROT_CRD output is active, if the AR function is disabled or in the lockout state, or if the INHIBIT_RECL input is active
- "CB close manual": the PROT_CRD output is active for the reclaim time if the circuit breaker has been manually closed, that is, the AR function has not issued a close command
- "AR inop, CB man": both the modes "AR inoperative" and "CB close manual" are effective
- "always": the PROT_CRD output is constantly active

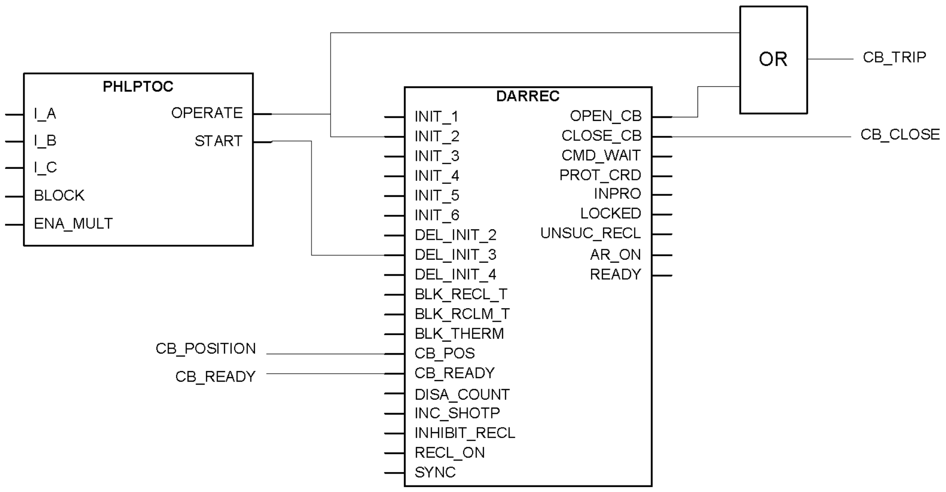


Figure 220: Configuration example of using the `PROT_CRD` *output for protection blocking*

If the *Protection crd limit* setting has the value "1", the instantaneous three-phase over-current protection function PHIPTOC is disabled or blocked after the first shot.

9.6.4.7 Circuit breaker controller

Circuit breaker controller contains two features: SOTF and frequent-operation counter. SOTF protects the AR function in permanent faults.

The circuit breaker position information is controlled with the *CB closed Pos status* setting. The setting value "TRUE" means that when the circuit breaker is closed, the `CB_POS` input is TRUE. When the setting value is "FALSE", the `CB_POS` input is FALSE, provided that the circuit breaker is closed. The reclose command pulse time can be controlled with the *Close pulse time* setting: the `CLOSE_CB` output is active for the time set with the *Close pulse time* setting. The `CLOSE_CB` output is deactivated also when the circuit breaker is detected to be closed, that is, when the `CB_POS` input changes from open state to closed state. The *Wait close time* setting defines the time after the `CLOSE_CB` command activation, during which the circuit breaker should be closed. If the closing of circuit breaker does not happen during this time, the auto-reclose function is driven to lockout or, if allowed, an auto-initiation is activated.

The main motivation for auto-reclosing to begin with is the assumption that the fault is temporary by nature, and that a momentary de-energizing of the power line and an automatic reclosing restores the power supply. However, when the power line is manually energized and an immediate protection trip is detected, it is very likely that the fault is of a permanent type. A permanent fault is, for example, energizing a power line into a forgotten earthing after a maintenance work along the power line. In such cases, SOTF is activated, but only for the reclaim time after energizing the power line and only when the circuit breaker is closed manually and not by the AR function.

SOTF disables any initiation of an auto-reclose shot. The energizing of the power line is detected from the CB_POS information.

SOTF is activated when the AR function is enabled or when the AR function is started and the SOTF should remain active for the reclaim time.

When SOTF is detected, the parameter *SOTF* is active.

If the *Manual close mode* setting is set to FALSE and the circuit breaker has been manually closed during an auto-reclose shot, the AR unit goes to an immediate lockout.

If the *Manual close mode* setting is set to TRUE and the circuit breaker has been manually closed during an auto-reclose shot (the INPRO is active), the shot is considered as completed.

When SOTF starts, reclaim time is restarted, provided that it is running.

The frequent-operation counter is intended for blocking the auto-reclose function in cases where the fault causes repetitive auto-reclose sequences during a short period of time. For instance, if a tree causes a short circuit and, as a result, there are auto-reclose shots within a few minutes interval during a stormy night. These types of faults can easily damage the circuit breaker if the AR function is not locked by a frequent-operation counter.

The frequent-operation counter has three settings:

- *Frq Op counter limit*
- *Frq Op counter time*
- *Frq Op recovery time*

The *Frq Op counter limit* setting defines the number of reclose attempts that are allowed during the time defined with the *Frq Op counter time* setting. If the set value is reached within a pre-defined period defined with the *Frq Op counter time* setting, the AR function goes to lockout when a new shot begins, provided that the counter is still above the set limit. The lockout is released after the recovery time has elapsed. The recovery time can be defined with the *Frq Op recovery time* setting .

If the circuit breaker is manually closed during the recovery time, the reclaim time is activated after the recovery timer has elapsed.

9.6.5 Counters

The AR function contains six counters. Their values are stored in a semi-retain memory. The counters are increased at the rising edge of the reclose command. The counters count the following situations:

- `COUNTER`: counts every reclose command activation
- `CNT_SHOT1`: counts reclose commands that are executed from shot 1
- `CNT_SHOT2`: counts reclose commands that are executed from shot 2
- `CNT_SHOT3`: counts reclose commands that are executed from shot 3
- `CNT_SHOT4`: counts reclose commands that are executed from shot 4
- `CNT_SHOT5`: counts reclose commands that are executed from shot 5

The counters are disabled through communication with the *DsaCnt* parameter. When the counters are disabled, the values are not updated.

The counters are reset through communication with the *RsCnt* parameter.

9.6.5.1 Application

Modern electric power systems can deliver energy to users very reliably. However, different kind of faults can occur. Protection relays play an important role in detecting failures or abnormalities in the system. They detect faults and give commands for corresponding circuit breakers to isolate the defective element before excessive damage or a possible power system collapse occurs. A fast isolation also limits the disturbances caused for the healthy parts of the power system.

The faults can be transient, semi-transient or permanent. Permanent fault, for example in power cables, means that there is a physical damage in the fault location that must first be located and repaired before the network voltage can be restored.

In overhead lines, the insulating material between phase conductors is air. The majority of the faults are flash-over arcing faults caused by lightning, for example. Only a short interruption is needed for extinguishing the arc. These faults are transient by nature.

A semi-transient fault can be caused for example by a bird or a tree branch falling on the overhead line. The fault disappears on its own if the fault current burns the branch or the wind blows it away.

Transient and semi-transient faults can be cleared by momentarily de-energizing the power line. Using the auto-reclose function minimizes interruptions in the power system service and brings the power back on-line quickly and effortlessly.

The basic idea of the auto-reclose function is simple. In overhead lines, where the possibility of self-clearing faults is high, the auto-reclose function tries to restore the power by reclosing the breaker. This is a method to get the power system back into normal operation by removing the transient or semi-transient faults. Several trials, that is, auto-reclose shots are allowed. If none of the trials is successful and the fault persists, definite final tripping follows.

The auto-reclose function can be used with every circuit breaker that has the ability for a reclosing sequence. In DARREC auto-reclose function the implementing method of auto-reclose sequences is patented by ABB

Table 365: Important definitions related to auto-reclosing

auto-reclose shot	an operation where after a preset time the breaker is closed from the breaker tripping caused by protection
auto-reclose sequence	a predefined method to do reclose attempts (shots) to restore the power system
SOTF	If the protection detects a fault immediately after an open circuit breaker has been closed, it indicates that the fault was already there. It can be, for example, a forgotten earthing after maintenance work. Such closing of the circuit breaker is known as switch on to fault. Autoreclosing in such conditions is prohibited.
final trip	Occurs in case of a permanent fault, when the circuit breaker is opened for the last time after all programmed auto-reclose operations. Since no auto-reclosing follows, the circuit breaker remains open. This is called final trip or definite trip.

Shot initiation

In some applications, the `START` signal is used for initiating or blocking autoreclose shots, in other applications the `OPERATE` command is needed. In its simplest, the auto-reclose function is initiated after the protection has detected a fault, issued a trip and opened the breaker. One input is enough for initiating the function.

The function consists of six individual initiation lines `INIT_1, INIT_2 .. INIT_6` and delayed initiation lines `DEL_INIT_x`. The user can use as many of the initiation lines as required. Using only one line makes setting easier, whereas by using multiple lines, higher functionality can be achieved. Basically, there are no differences between the initiation lines, except that the lines 2, 3 and 4 have the delayed initiation `DEL_INIT` inputs, and lines 1, 5 and 6 do not.

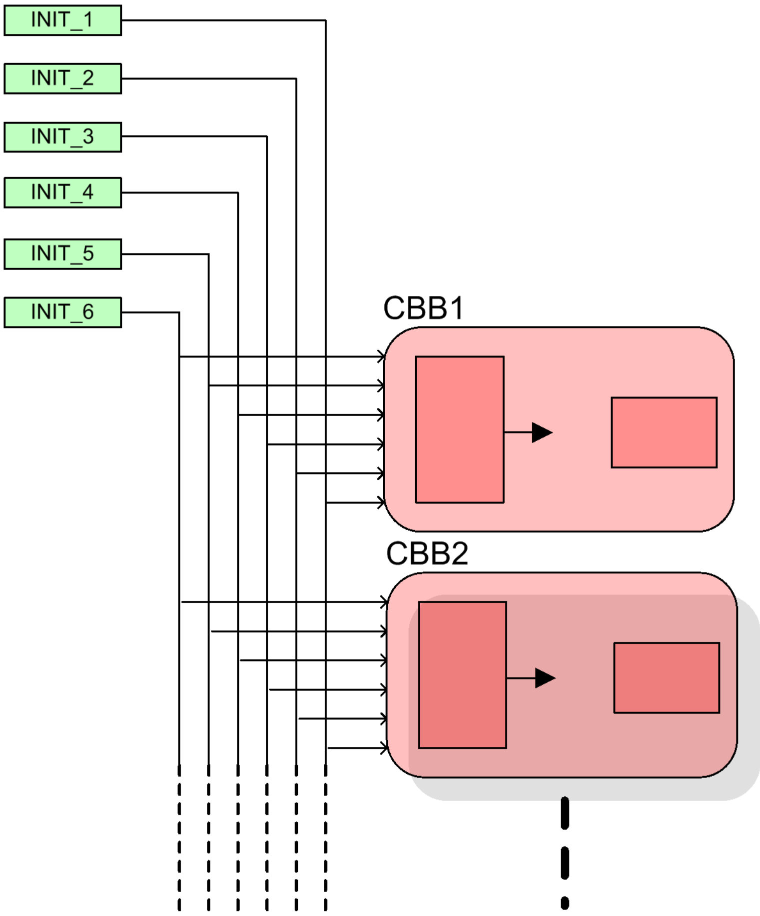


Figure 221: Simplified CBB initiation diagram

INIT_1...6	initiation lines
CBB1...CBB2	first two cycle building blocks

The operation of a CBB consists of two parts: initiation and execution. In the initiation part, the status of the initiation lines is compared to the CBB settings. In order to allow the initiation at any of the initiation line activation, the corresponding switch in the *Init signals CBB_* parameter must be set to TRUE. In order to block the initiation, the corresponding switch in the *Blk signals CBB_* parameter must be set to TRUE.

If any of the initiation lines set with the *Init signals CBB_* parameter is active and no initiation line causes blocking, the CBB requests for execution.

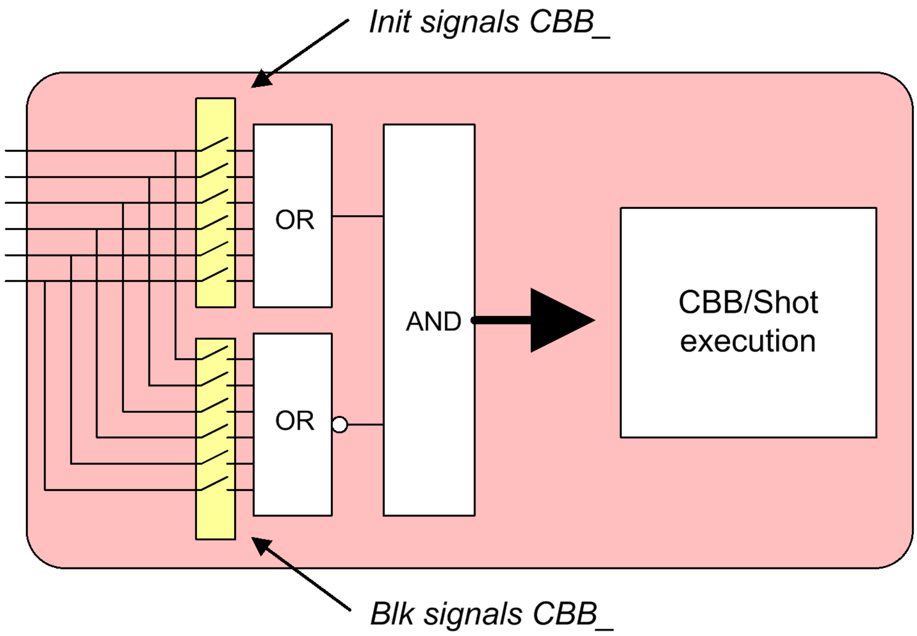


Figure 222: Simplified CBB diagram

Each CBB has individual *Init signals CBB_* and *Blk signals CBB_* settings. Therefore, each initiation line can be used for both initiating and blocking any or all auto-reclose shots.

Other conditions that must be fulfilled before any CBB can be initiated are, for example, the closed position of the circuit breaker.

Sequence

The auto reclose sequence is implemented by using CBBs. The highest possible amount of CBBs is seven. If the user wants to have, for example, a sequence of three shots, only the first three CBBs are needed. Using building blocks instead of fixed shots gives enhanced flexibility, allowing multiple and adaptive sequences.

Each CBB is identical. The *Shot number CBB_* setting defines at which point in the auto-reclose sequence the CBB should be performed, that is, whether the particular CBB is going to be the first, second, third, fourth or fifth shot.

During the initiation of a CBB, the conditions of initiation and blocking are checked. This is done for all CBBs simultaneously. Each CBB that fulfils the initiation conditions requests an execution.

The function also keeps track of shots already performed, that is, at which point the auto-reclose sequence is from shot 1 to lockout. For example, if shots 1 and 2 have already been performed, only shots 3 to 5 are allowed.

Additionally, the *Enable shot jump* setting gives two possibilities:

- Only such CBBs that are set for the next shot in the sequence can be accepted for execution. For example, if the next shot in the sequence should be shot 2, a request from CBB set for shot 3 is rejected.
- Any CBB that is set for the next shot or any of the following shots can be accepted for execution. For example, if the next shot in the sequence should be shot 2, also CBBs that are set for shots 3, 4 and 5 are accepted. In other words, shot 2 can be ignored.

In case there are multiple CBBs allowed for execution, the CBB with the smallest number is chosen. For example, if CBB2 and CBB4 request an execution, CBB2 is allowed to execute the shot.

The auto-reclose function can perform up to five auto-reclose shots or cycles.

Configuration examples

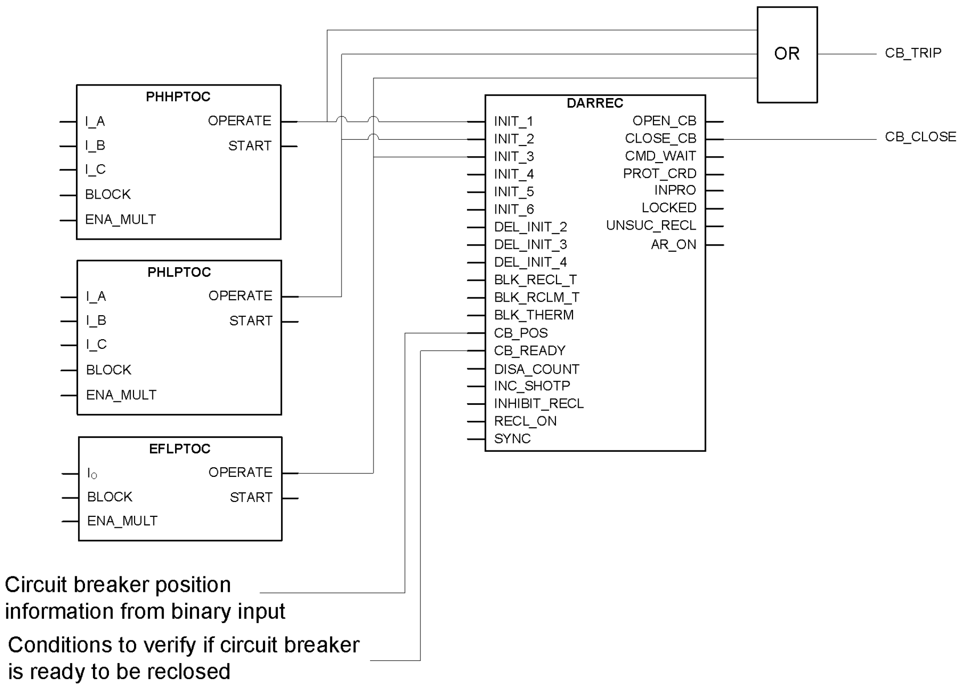


Figure 223: Example connection between protection and autoreclose functions in IED configuration

It is possible to create several sequences for a configuration.

Autoreclose sequences for overcurrent and non-directional earth-fault protection applications where high speed and delayed autoreclosings are needed can be as follows:

Example 1.

The sequence is implemented by two shots which have the same reclosing time for all protection functions, namely I>>, I> and Io>. The initiation of the shots is done by activating the operating signals of the protection functions.

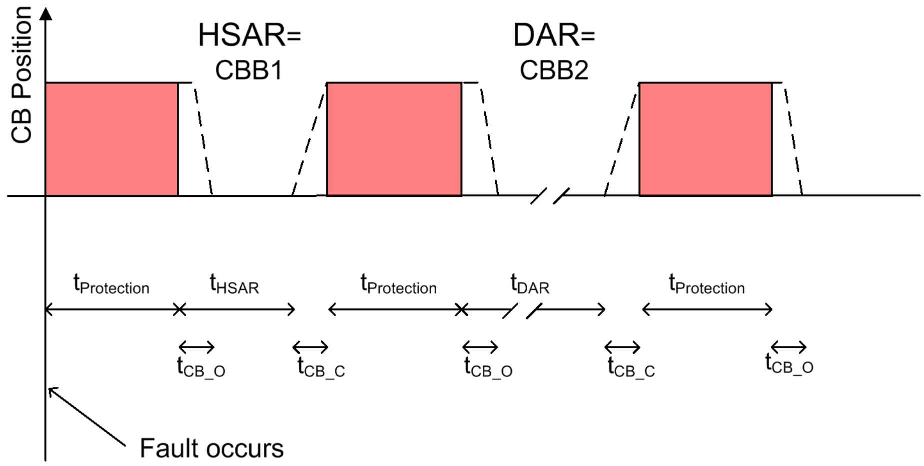


Figure 224: Autoreclose sequence with two shots

t_{HSAR}	Time delay of high-speed autoreclosing, here: *First reclose time*
t_{DAR}	Time delay of delayed autoreclosing, here: *Second reclose time*
$t_{Protection}$	Operating time for the protection stage to clear the fault
t_{CB_O}	Operating time for opening the circuit breaker
t_{CB_C}	Operating time for closing the circuit breaker

In this case, the sequence needs two CBBs. The reclosing times for shot 1 and shot 2 are different, but each protection function initiates the same sequence. The CBB sequence is as follows:

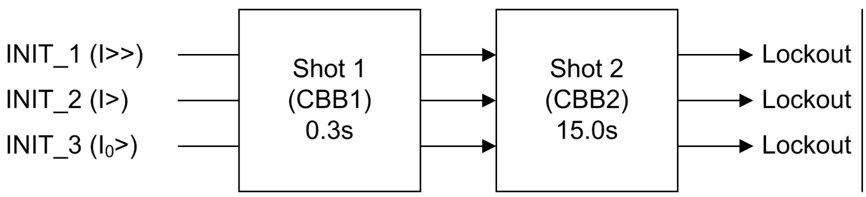


Figure 225: Two shots with three initiation lines

Table 366: Settings for configuration example 1

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	7 (lines 1,2 and 3 = 1+2+4 = 7)
First reclose time	0.3s (an example)
Shot number CBB2	2
Init signals CBB2	7 (lines 1,2 and 3 = 1+2+4 = 7)
Second reclose time	15.0s (an example)

Example 2

There are two separate sequences implemented with three shots. Shot 1 is implemented by CBB1 and it is initiated with the high stage of the overcurrent protection (I>>). Shot 1 is set as a high-speed autoreclosing with a short time delay. Shot 2 is implemented with CBB2 and meant to be the first shot of the autoreclose sequence initiated by the low stage of the overcurrent protection (I>) and the low stage of the non-directional earth-fault protection (Io>). It has the same reclosing time in both situations. It is set as a high-speed autoreclosing for corresponding faults. The third shot, which is the second shot in the autoreclose sequence initiated by I> or Io>, is set as a delayed autoreclosing and executed after an unsuccessful high-speed autoreclosing of a corresponding sequence.

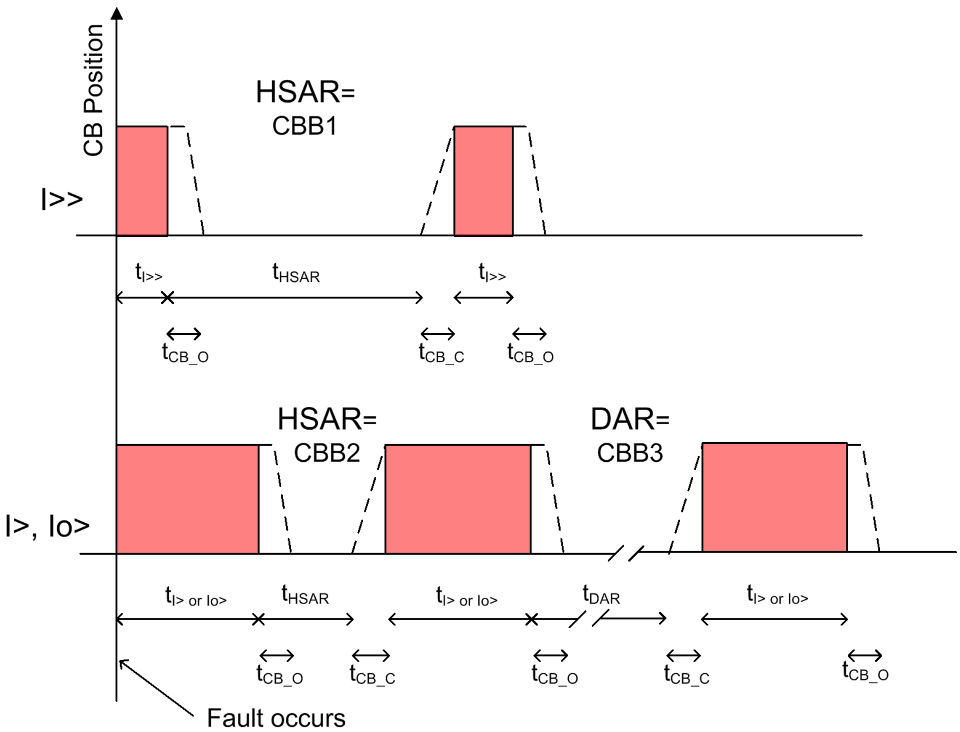


Figure 226: Autoreclose sequence with two shots with different shot settings according to initiation signal

t_{HSAR}	Time delay of high-speed autoreclosing, here: *First reclose time*
t_{DAR}	Time delay of delayed autoreclosing, here: *Second reclose time*
$t_{I>>}$	Operating time for the I>> protection stage to clear the fault
$t_{I>}$ or $_{Io>}$	Operating time for the I> or Io> protection stage to clear the fault
t_{CB_O}	Operating time for opening the circuit breaker
t_{CB_C}	Operating time for closing the circuit breaker

In this case, the number of needed CBBs is three, that is, the first shot's reclosing time depends on the initiation signal. The CBB sequence is as follows:

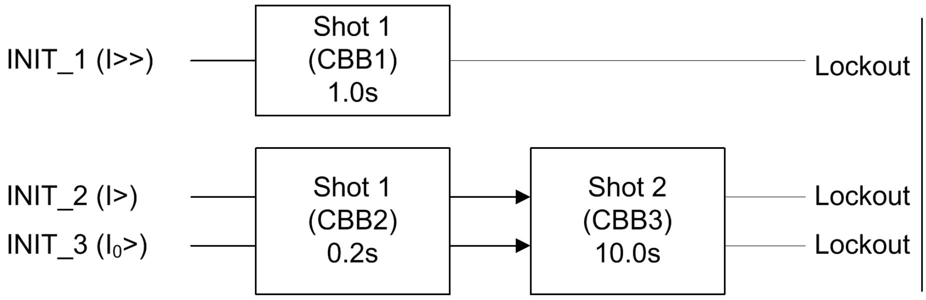


Figure 227: Three shots with three initiation lines

If the sequence is initiated from the `INIT_1` line, that is, the overcurrent protection high stage, the sequence is one shot long. On the other hand, if the sequence is initiated from the `INIT_2` or `INIT_3` lines, the sequence is two shots long.

Table 367: Settings for configuration example 2

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	1 (line 1)
First reclose time	0.0s (an example)
Shot number CBB2	1
Init signals CBB2	6 (lines 2 and 3 = 2+4 = 6)
Second reclose time	0.2s (an example)
Shot number CBB3	2
Init signals CBB3	6 (lines 2 and 3 = 2+4 = 6)
Third reclose time	10.0s

Delayed initiation lines

The auto-reclose function consists of six individual auto-reclose initiation lines `INIT_1...INIT 6` and three delayed initiation lines:

- DEL_INIT_2
- DEL_INIT_3
- DEL_INIT_4

DEL_INIT_2 and INIT_2 are connected together with an OR-gate, as are inputs 3 and 4. Inputs 1, 5 and 6 do not have any delayed input. From the auto-reclosing point of view, it does not matter whether INIT_x or DEL_INIT_x line is used for shot initiation or blocking.

The auto-reclose function can also open the circuit breaker from any of the initiation lines. It is selected with the *Tripping line* setting. As a default, all initiation lines activate the OPEN_CB output.

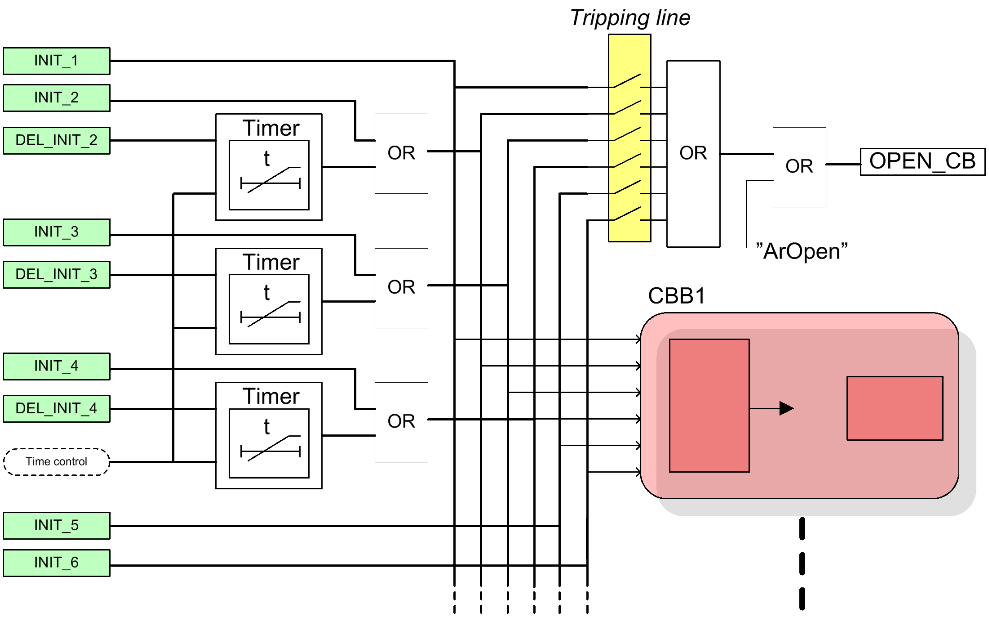


Figure 228: Simplified logic diagram of initiation lines

Each delayed initiation line has four different time settings:

Table 368: Settings for delayed initiation lines

Setting name	Description and purpose
Str x delay shot 1	Time delay for the DEL_INIT_x line, where x is the number of the line 2, 3 or 4. Used for shot 1.
Str x delay shot 2	Time delay for the DEL_INIT_x line, used for shot 2.
Str x delay shot 3	Time delay for the DEL_INIT_x line, used for shot 3.
Str x delay shot 4	Time delay for the DEL_INIT_x line, used for shots 4 and 5. Optionally, can also be used with SOTF.

Shot initiation from protection start signal

In it simplest, all auto-reclose shots are initiated by protection trips. As a result, all trip times in the sequence are the same. This is why using protection trips may not be the optimal solution. Using protection start signals instead of protection trips for initiating shots shortens the trip times.

Example 1

When a two-shot-sequence is used, the start information from the protection function is routed to the `DEL_INIT 2` input and the operate information to the `INIT_2` input. The following conditions have to apply:

- protection operate time = 0.5s
- *Str 2 delay shot 1* = 0.05s
- *Str 2 delay shot 2* = 60s
- *Str 2 delay shot 3* = 60s

Operation in a permanent fault:

1. Protection starts and activates the `DEL_INIT 2` input.
2. After 0.05 seconds, the first autoreclose shot is initiated. The function opens the circuit breaker: the `OPEN_CB` output activates. The total trip time is the protection start delay + 0.05 seconds + the time it takes to open the circuit breaker.
3. After the first shot, the circuit breaker is reclosed and the protection starts again.
4. Because the delay of the second shot is 60 seconds, the protection is faster and trips after the set operation time, activating the `INIT 2` input. The second shot is initiated.
5. After the second shot, the circuit breaker is reclosed and the protection starts again.
6. Because the delay of the second shot is 60 seconds, the protection is faster and trips after the set operation time. No further shots are programmed after the final trip. The function is in lockout and the sequence is considered unsuccessful.

Example 2

The delays can be used also for fast final trip. The conditions are the same as in Example 1, with the exception of *Str 2 delay shot 3* = 0.10 seconds.

The operation in a permanent fault is the same as in Example 1, except that after the second shot when the protection starts again, *Str 2 delay shot 3* elapses before the protection operate time and the final trip follows. The total trip time is the protection start delay + 0.10 seconds + the time it takes to open the circuit breaker.

Fast trip in Switch on to fault

The *Str _ delay shot 4* parameter delays can also be used to achieve a fast and accelerated trip with SOTF. This is done by setting the *Fourth delay in SOTF* parameter to "1" and connecting the protection start information to the corresponding `DEL_INIT_` input.

When the function detects a closing of the circuit breaker, that is, any other closing except the reclosing done by the function itself, it always prohibits shot initiation for the time set with the *Reclaim time* parameter. Furthermore, if the *Fourth delay in SOTF* parameter is "1", the *Str _ delay shot 4* parameter delays are also activated.

Example 1

The protection operation time is 0.5 seconds, the *Fourth delay in SOTF* parameter is set to "1" and the *Str 2 delay shot 4* parameter is 0.05 seconds. The protection start signal is connected to the DEL_INIT_2 input.

If the protection starts after the circuit breaker closes, the fast trip follows after the set 0.05 seconds. The total trip time is the protection start delay + 0.05 seconds + the time it takes to open the circuit breaker.

9.6.5.2 Signals

Table 369: DARREC Input signals

Name	Type	Default	Description
INIT_1	BOOLEAN	0=False	AR initialization / blocking signal 1
INIT_2	BOOLEAN	0=False	AR initialization / blocking signal 2
INIT_3	BOOLEAN	0=False	AR initialization / blocking signal 3
INIT_4	BOOLEAN	0=False	AR initialization / blocking signal 4
INIT_5	BOOLEAN	0=False	AR initialization / blocking signal 5
INIT_6	BOOLEAN	0=False	AR initialization / blocking signal 6
DEL_INIT_2	BOOLEAN	0=False	Delayed AR initialization / blocking signal 2
DEL_INIT_3	BOOLEAN	0=False	Delayed AR initialization / blocking signal 3
DEL_INIT_4	BOOLEAN	0=False	Delayed AR initialization / blocking signal 4
BLK_RECL_T	BOOLEAN	0=False	Blocks and resets reclose time
BLK_RCLM_T	BOOLEAN	0=False	Blocks and resets reclaim time
BLK_THERM	BOOLEAN	0=False	Blocks and holds the reclose shot from the thermal overload
CB_POS	BOOLEAN	0=False	Circuit breaker position input
CB_READY	BOOLEAN	1=True	Circuit breaker status signal
INC_SHOTP	BOOLEAN	0=False	A zone sequence coordination signal
INHIBIT_RECL	BOOLEAN	0=False	Interrupts and inhibits reclosing sequence
RECL_ON	BOOLEAN	0=False	Level sensitive signal for allowing (high) / not allowing (low) reclosing
SYNC	BOOLEAN	0=False	Synchronizing check fulfilled

Table 370: DARREC Output signals

Name	Type	Description
OPEN_CB	BOOLEAN	Open command for circuit breaker
CLOSE_CB	BOOLEAN	Close (reclose) command for circuit breaker
CMD_WAIT	BOOLEAN	Wait for master command
INPRO	BOOLEAN	Reclosing shot in progress, activated during dead time
LOCKED	BOOLEAN	Signal indicating that AR is locked out
PROT_CRD	BOOLEAN	A signal for coordination between the AR and the protection
UNSUC_RECL	BOOLEAN	Indicates an unsuccessful reclosing sequence
AR_ON	BOOLEAN	Autoreclosing allowed
READY	BOOLEAN	Indicates that the AR is ready for a new sequence

9.6.5.3 Settings

Table 371: DARREC Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off/On
Reclosing operation	1=Off 2=External Ctl 3=On			1=Off	Reclosing operation (Off, External Ctl / On)
Manual close mode	0=False 1=True			0=False	Manual close mode
Wait close time	50...10000	ms	50	250	Allowed CB closing time after reclose command
Max wait time	100...1800000	ms	100	10000	Maximum wait time for haltDeadTime release
Max trip time	100...10000	ms	100	10000	Maximum wait time for deactivation of protection signals
Close pulse time	10...10000	ms	10	200	CB close pulse time
Max Thm block time	100...1800000	ms	100	10000	Maximum wait time for thermal blocking signal deactivation
Cut-out time	0...1800000	ms	100	10000	Cutout time for protection coordination
Reclaim time	100...1800000	ms	100	10000	Reclaim time
Dsr time shot 1	0...10000	ms	100	0	Discrimination time for first reclosing
Dsr time shot 2	0...10000	ms	100	0	Discrimination time for second reclosing
Dsr time shot 3	0...10000	ms	100	0	Discrimination time for third reclosing
Dsr time shot 4	0...10000	ms	100	0	Discrimination time for fourth reclosing
Terminal priority	1=None 2=Low (follower) 3=High (master)			1=None	Terminal priority
Synchronisation set	0...127			0	Selection for synchronizing requirement for reclosing
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Auto wait time	0...60000	ms	10	2000	Wait time for reclosing condition fullfilling
Auto lockout reset	0=False 1=True			1=True	Automatic lockout reset
Protection crd limit	1...5			1	Protection coordination shot limit
Protection crd mode	1=No condition 2=AR inoperative 3=CB close manual 4=AR inop, CB man 5=Always			4=AR inop, CB man	Protection coordination mode
Auto initiation cnd	1=Not allowed 2=When sync fails 3=CB doesn't close 4=Both			2=When sync fails	Auto initiation condition
Tripping line	0...63			0	Tripping line, defines INIT inputs which cause OPEN_CB activation
Control line	0...63			63	Control line, defines INIT inputs which are protection signals
Enable shot jump	0=False 1=True			1=True	Enable shot jumping
CB closed Pos status	0=False 1=True			1=True	Circuit breaker closed position status
Fourth delay in SOTF	0=False 1=True			0=False	Sets 4th delay into use for all DEL_INIT signals during SOTF
First reclose time	0...300000	ms	10	5000	Dead time for CBB1
Second reclose time	0...300000	ms	10	5000	Dead time for CBB2
Third reclose time	0...300000	ms	10	5000	Dead time for CBB3
Fourth reclose time	0...300000	ms	10	5000	Dead time for CBB4
Fifth reclose time	0...300000	ms	10	5000	Dead time for CBB5
Sixth reclose time	0...300000	ms	10	5000	Dead time for CBB6
Seventh reclose time	0...300000	ms	10	5000	Dead time for CBB7
Init signals CBB1	0...63			0	Initiation lines for CBB1
Init signals CBB2	0...63			0	Initiation lines for CBB2
Init signals CBB3	0...63			0	Initiation lines for CBB3
Init signals CBB4	0...63			0	Initiation lines for CBB4
Init signals CBB5	0...63			0	Initiation lines for CBB5
Init signals CBB6	0...63			0	Initiation lines for CBB6
Init signals CBB7	0...63			0	Initiation lines for CBB7
Blk signals CBB1	0...63			0	Blocking lines for CBB1
Blk signals CBB2	0...63			0	Blocking lines for CBB2
Blk signals CBB3	0...63			0	Blocking lines for CBB3
Blk signals CBB4	0...63			0	Blocking lines for CBB4
Blk signals CBB5	0...63			0	Blocking lines for CBB5
Blk signals CBB6	0...63			0	Blocking lines for CBB6
Blk signals CBB7	0...63			0	Blocking lines for CBB7
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Shot number CBB1	0...5			0	Shot number for CBB1
Shot number CBB2	0...5			0	Shot number for CBB2
Shot number CBB3	0...5			0	Shot number for CBB3
Shot number CBB4	0...5			0	Shot number for CBB4
Shot number CBB5	0...5			0	Shot number for CBB5
Shot number CBB6	0...5			0	Shot number for CBB6
Shot number CBB7	0...5			0	Shot number for CBB7
Str 2 delay shot 1	0...300000	ms	10	0	Delay time for start2, 1st reclose
Str 2 delay shot 2	0...300000	ms	10	0	Delay time for start2 2nd reclose
Str 2 delay shot 3	0...300000	ms	10	0	Delay time for start2 3rd reclose
Str 2 delay shot 4	0...300000	ms	10	0	Delay time for start2, 4th reclose
Str 3 delay shot 1	0...300000	ms	10	0	Delay time for start3, 1st reclose
Str 3 delay shot 2	0...300000	ms	10	0	Delay time for start3 2nd reclose
Str 3 delay shot 3	0...300000	ms	10	0	Delay time for start3 3rd reclose
Str 3 delay shot 4	0...300000	ms	10	0	Delay time for start3, 4th reclose
Str 4 delay shot 1	0...300000	ms	10	0	Delay time for start4, 1st reclose
Str 4 delay shot 2	0...300000	ms	10	0	Delay time for start4 2nd reclose
Str 4 delay shot 3	0...300000	ms	10	0	Delay time for start4 3rd reclose
Str 4 delay shot 4	0...300000	ms	10	0	Delay time for start4, 4th reclose
Frq Op counter limit	0...250			0	Frequent operation counter lockout limit
Frq Op counter time	1...250	min		1	Frequent operation counter time
Frq Op recovery time	1...250	min		1	Frequent operation counter recovery time
Auto init	0...63			0	Defines INIT lines that are activated at auto initiation

9.6.5.4 Monitored data

Table 372: DARREC Monitored data

Name	Type	Values (Range)	Unit	Description
DISA_COUNT	BOOLEAN	0=False 1=True		Signal for counter disabling
FRQ_OPR_CNT	INT32	0...2147483647		Frequent operation counter
FRQ_OPR_AL	BOOLEAN	0=False 1=True		Frequent operation counter alarm
STATUS	Enum	-2=Unsuccessful -1=Not defined 1=Ready 2=In progress 3=Successful		AR status signal for IEC61850
ACTIVE	BOOLEAN	0=False 1=True		Reclosing sequence is in progress
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
INPRO_1	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 1
INPRO_2	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 2
INPRO_3	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 3
INPRO_4	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 4
INPRO_5	BOOLEAN	0=False 1=True		Reclosing shot in progress, shot 5
DISCR_INPRO	BOOLEAN	0=False 1=True		Signal indicating that discrimination time is in progress
CUTOUT_INPRO	BOOLEAN	0=False 1=True		Signal indicating that cut-out time is in progress
SUC_RECL	BOOLEAN	0=False 1=True		Indicates a successful reclosing sequence
UNSUC_CB	BOOLEAN	0=False 1=True		Indicates an unsuccessful CB closing
CNT_SHOT1	INT32	0...2147483647		Resetable operation counter, shot 1
CNT_SHOT2	INT32	0...2147483647		Resetable operation counter, shot 2
CNT_SHOT3	INT32	0...2147483647		Resetable operation counter, shot 3
CNT_SHOT4	INT32	0...2147483647		Resetable operation counter, shot 4
CNT_SHOT5	INT32	0...2147483647		Resetable operation counter, shot 5
COUNTER	INT32	0...2147483647		Resetable operation counter, all shots
SHOT_PTR	INT32	0...6		Shot pointer value
MAN_CB_CL	BOOLEAN	0=False 1=True		Indicates CB manual closing during reclosing sequence
SOTF	BOOLEAN	0=False 1=True		Switch-onto-fault
DARREC	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

9.6.5.5 Technical data

Table 373: DARREC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

9.6.5.6 Technical revision history

Table 374: Technical revision history

Technical revision	Change
B	PROT_DISA output removed and removed the related settings

Section 10 General function block features

10.1 Definite time characteristics

10.1.1 Definite time operation

The DT mode is enabled when the *Operating curve type* setting is selected either as "ANSI Def. Time" or "IEC Def. Time". In the DT mode, the `OPERATE` output of the function is activated when the time calculation exceeds the set *Operate delay time*.

The user can determine the reset in the DT mode with the *Reset delay time* setting, which provides the delayed reset property when needed.

The *Type of reset curve* setting has no effect on the reset method when the DT mode is selected, but the reset is determined solely with the *Reset delay time* setting.

The purpose of the delayed reset is to enable fast clearance of intermittent faults, for example self-sealing insulation faults, and severe faults which may produce high asymmetrical fault currents that partially saturate the current transformers. It is typical for an intermittent fault that the fault current contains so called drop-off periods, during which the fault current falls below the set start current, including hysteresis. Without the delayed reset function, the operate timer would reset when the current drops off. In the same way, an apparent drop-off period of the secondary current of the saturated current transformer can also reset the operate timer.

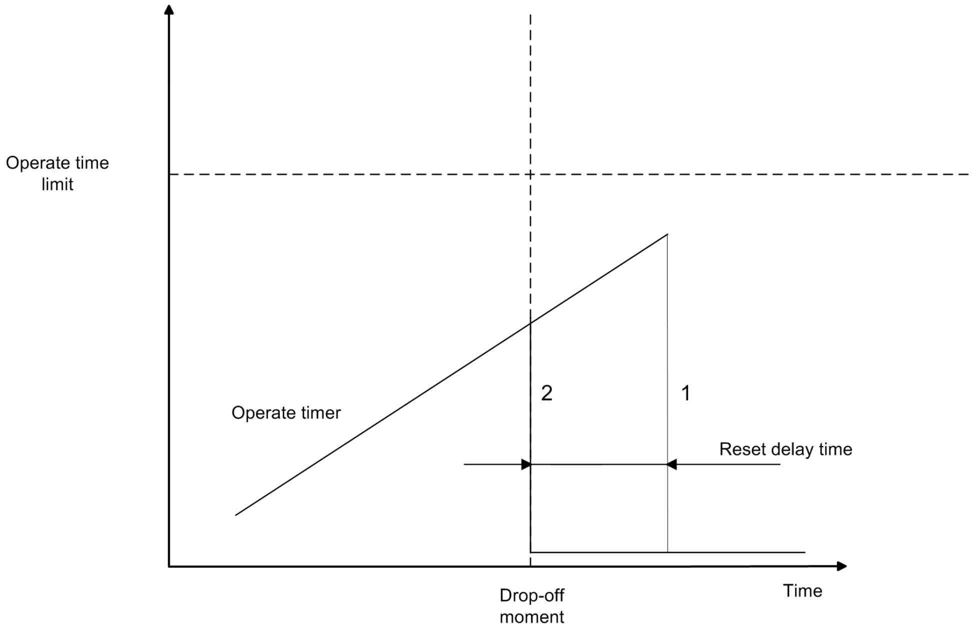


Figure 229: Operation of the counter in drop-off

In case 1, the reset is delayed with the *Reset delay time* setting and in case 2, the counter is reset immediately, because the *Reset delay time* setting is set to zero.

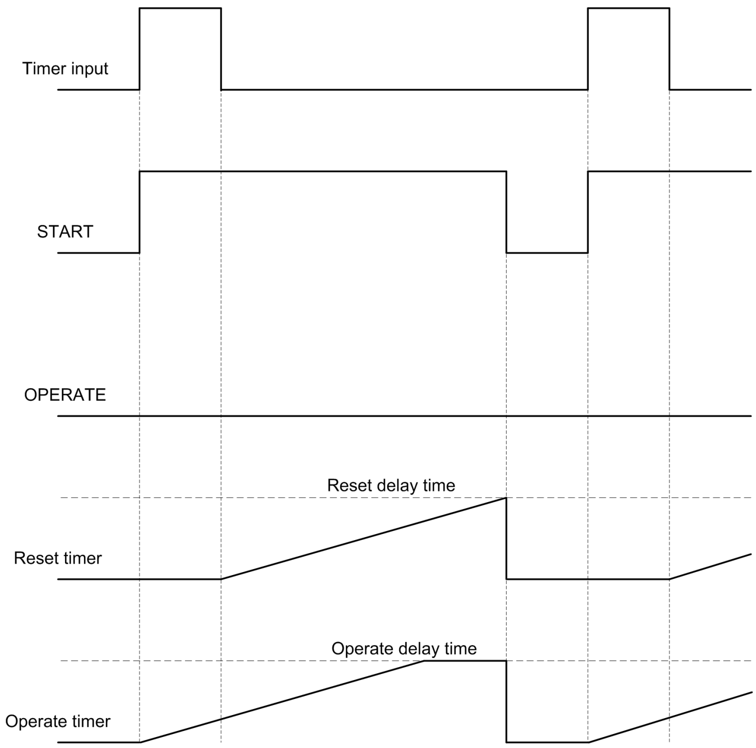


Figure 230: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 230, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Start value*. The input signal is inactive when the current is below the set *Start value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the START output and the operate timer starts elapsing. The reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. When the reset (drop-off) timer elapses, the operate timer is reset. Since this happens before another start occurs, the OPERATE output is not activated.

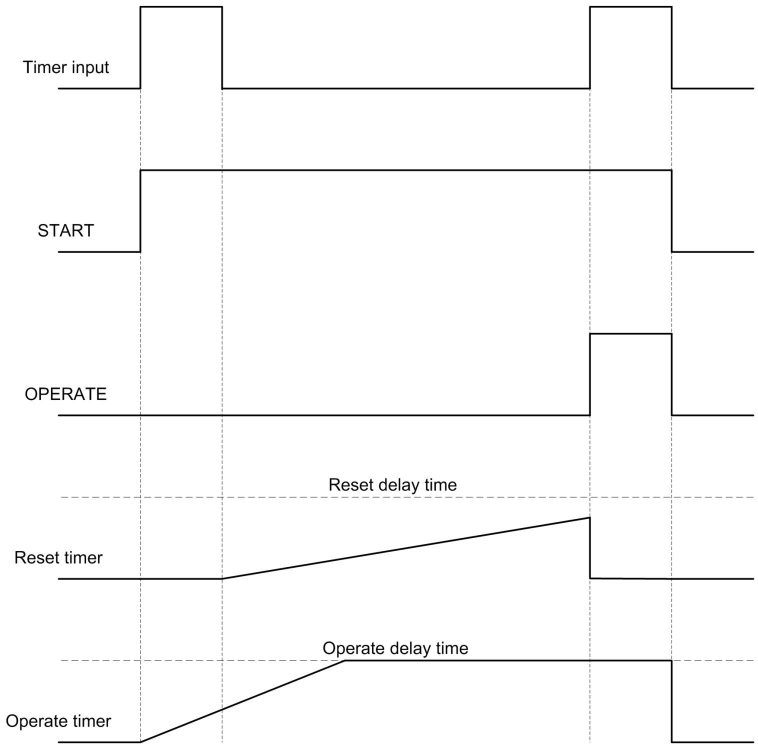


Figure 231: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 231, the input signal for the definite timer (here: timer input) is active, provided that the current is above the set *Start value*. The input signal is inactive when the current is below the set *Start value* and the set hysteresis region. The timer input rises when a fault current is detected. The definite timer activates the START output and the operate timer starts elapsing. The Reset (drop-off) timer starts when the timer input falls, that is, the fault disappears. Another fault situation occurs before the reset (drop-off) timer has elapsed. This causes the activation of the OPERATE output, since the operate timer already has elapsed.

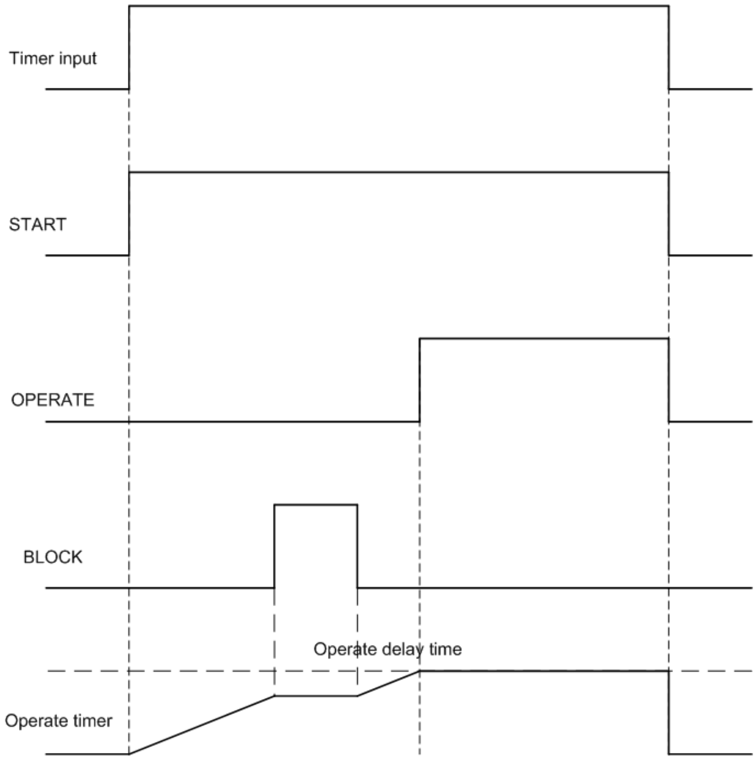


Figure 232: Operating effect of the `BLOCK` *input when the selected blocking mode is "Freeze timer"*

If the `BLOCK` input is activated when the operate timer is running, as described in Figure 232, the timer is frozen during the time `BLOCK` remains active. If the timer input is not active longer than specified by the *Reset delay time* setting, the operate timer is reset in the same way as described in Figure 230, regardless of the `BLOCK` input .

The selected blocking mode is "Freeze timer".

10.2 Current based inverse definite minimum time characteristics

10.2.1 IDMT curves for overcurrent protection

In inverse-time modes, the operate time depends on the momentary value of the current: the higher the current, the faster the operate time. The operate time calculation or integration starts immediately when the current exceeds the set *Start value* and the `START` output is activated.

The OPERATE output of the component is activated when the cumulative sum of the integrator calculating the overcurrent situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum operate time* setting defines the minimum operate time for the IDMT mode, that is, it is possible to limit the IDMT based operate time for not becoming too short. For example:

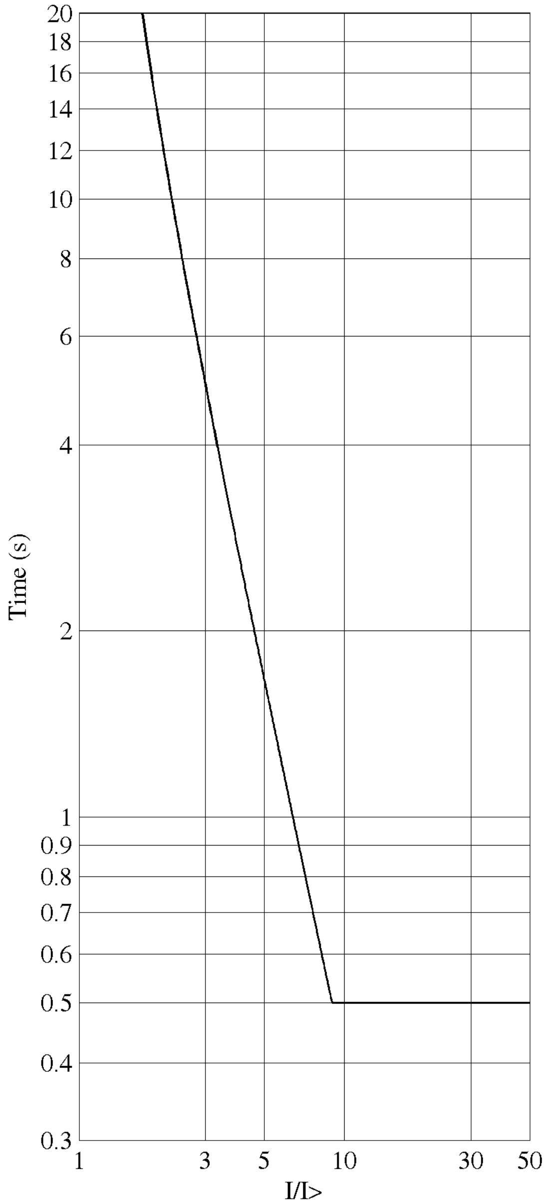


Figure 233: Operate time curves based on IDMT characteristic with the value of the Minimum operate time setting = 0.5 second

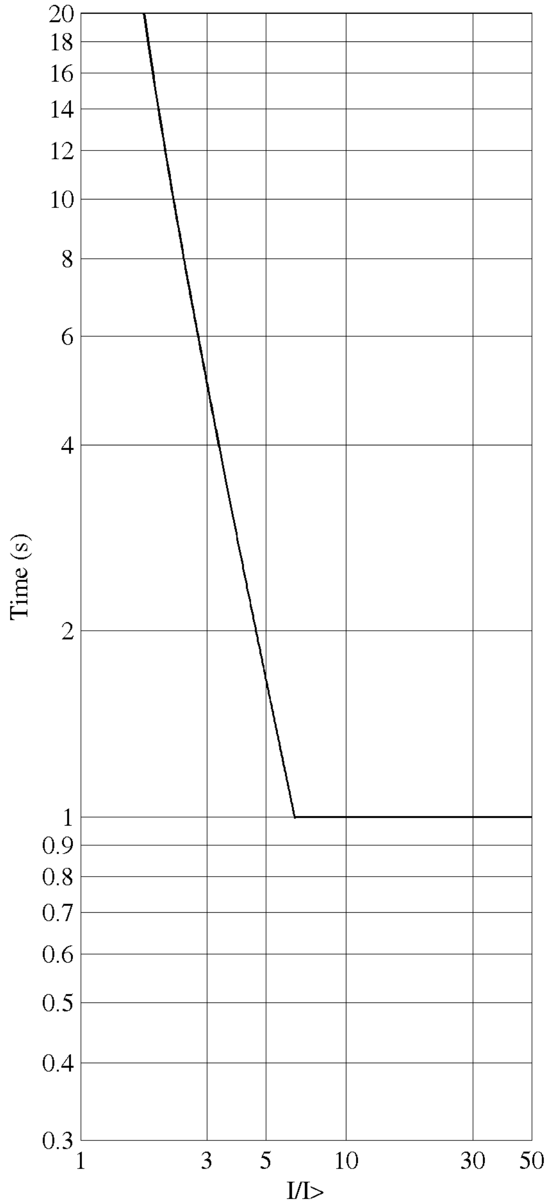


Figure 234: Operate time curves based on IDMT characteristic with the value of the Minimum operate time setting = 1 second

10.2.1.1 Standard inverse-time characteristics

For inverse-time operation, both IEC and ANSI/IEEE standardized inverse-time characteristics are supported.

The operate times for the ANSI and IEC IDMT curves are defined with the coefficients A, B and C.

The values of the coefficients can be calculated according to the formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>} \right)^{C} - 1} + B \right) \cdot k$$

(Equation 44)

t[s] Operate time in seconds

I measured current

I> set *Start value*

k set *Time multiplier*

Table 375: Curve parameters for ANSI and IEC IDMT curves

Curve name	A	B	C
(1) ANSI Extremely Inverse	28.2	0.1217	2.0
(2) ANSI Very Inverse	19.61	0.491	2.0
(3) ANSI Normal Inverse	0.0086	0.0185	0.02
(4) ANSI Moderately Inverse	0.0515	0.1140	0.02
(6) Long Time Extremely Inverse	64.07	0.250	2.0
(7) Long Time Very Inverse	28.55	0.712	2.0
(8) Long Time Inverse	0.086	0.185	0.02
(9) IEC Normal Inverse	0.14	0.0	0.02
(10) IEC Very Inverse	13.5	0.0	1.0
(11) IEC Inverse	0.14	0.0	0.02
(12) IEC Extremely Inverse	80.0	0.0	2.0
(13) IEC Short Time Inverse	0.05	0.0	0.04
(14) IEC Long Time Inverse	120	0.0	1.0

The maximum guaranteed measured current is 50 x In for the current protection. When the set *Start value* exceeds 1.00 x In, the turn point where the theoretical IDMT characteristics are levelling out to the definite time can be calculated with a formula:

$$Turn\ point = \frac{50 \times In}{Start\ value}$$

(Equation 45)

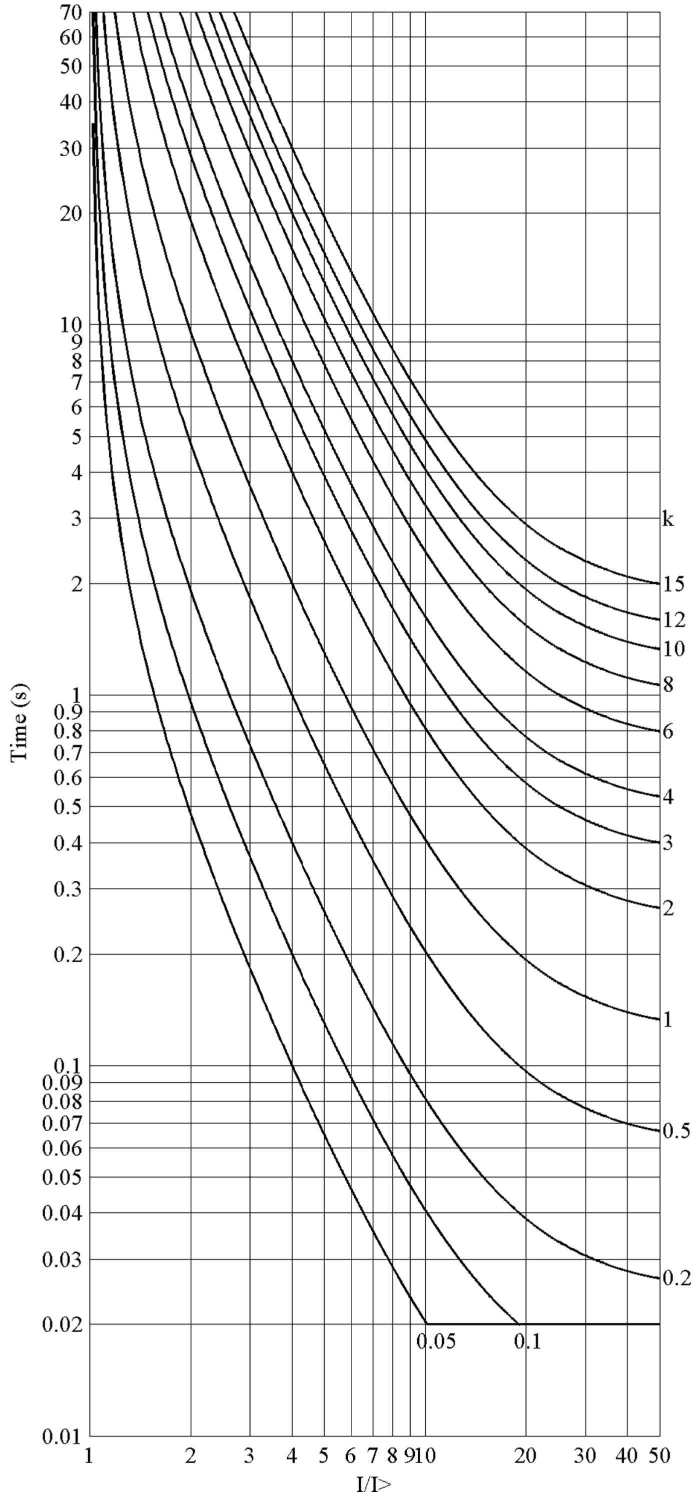


Figure 235: ANSI extremely inverse-time characteristics

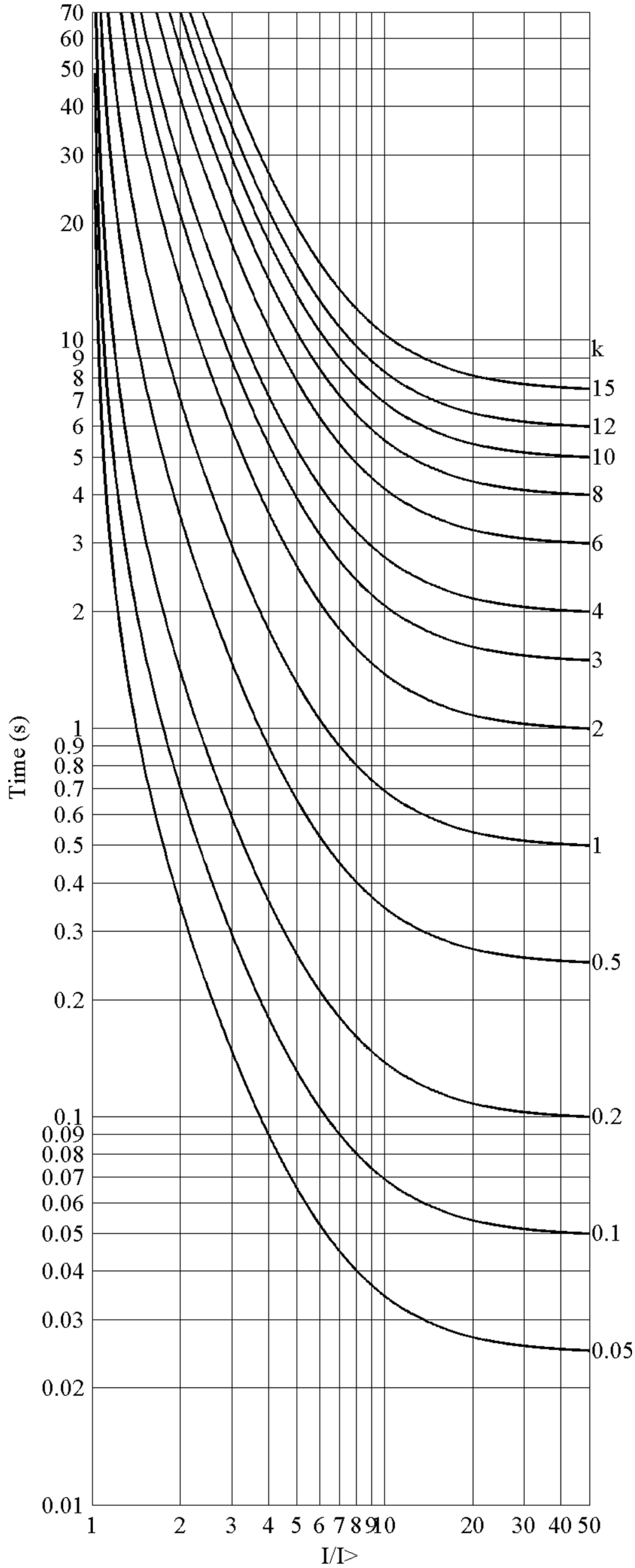


Figure 236: ANSI very inverse-time characteristics

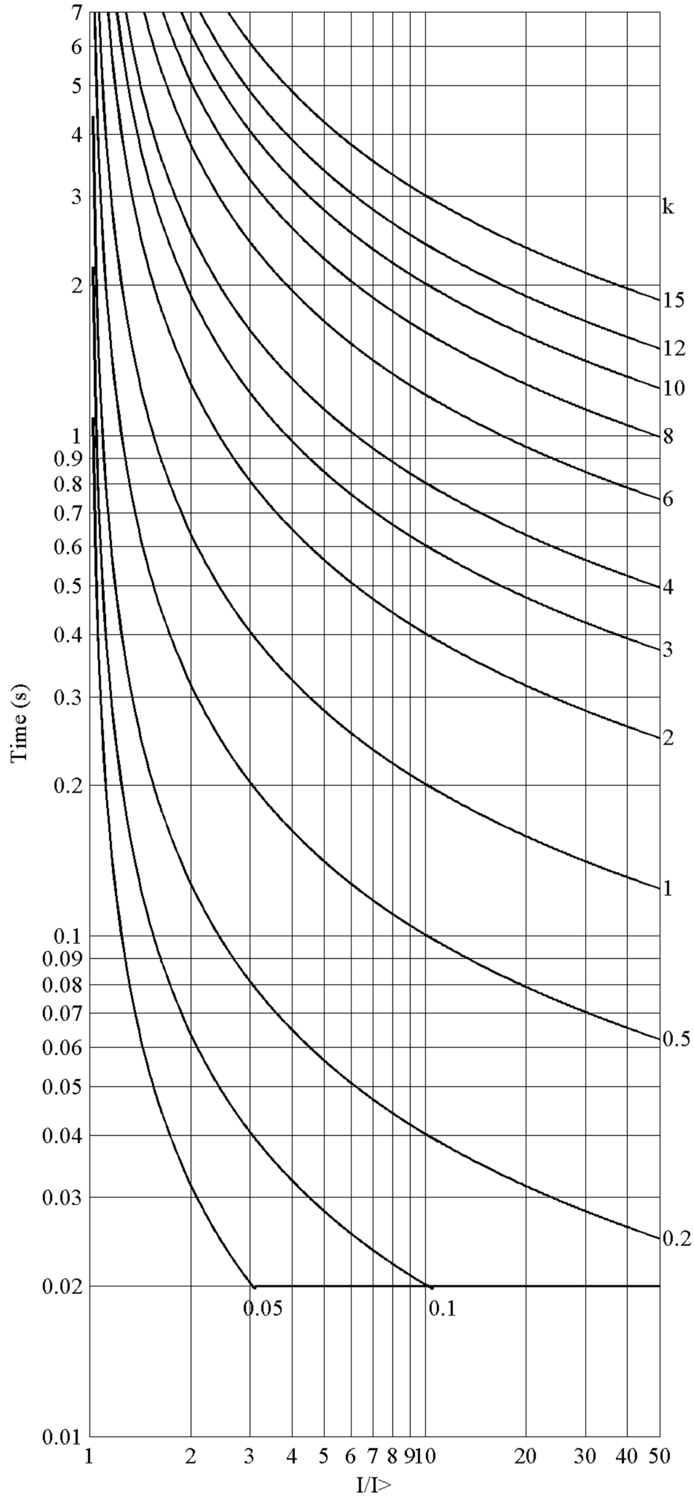


Figure 237: ANSI normal inverse-time characteristics

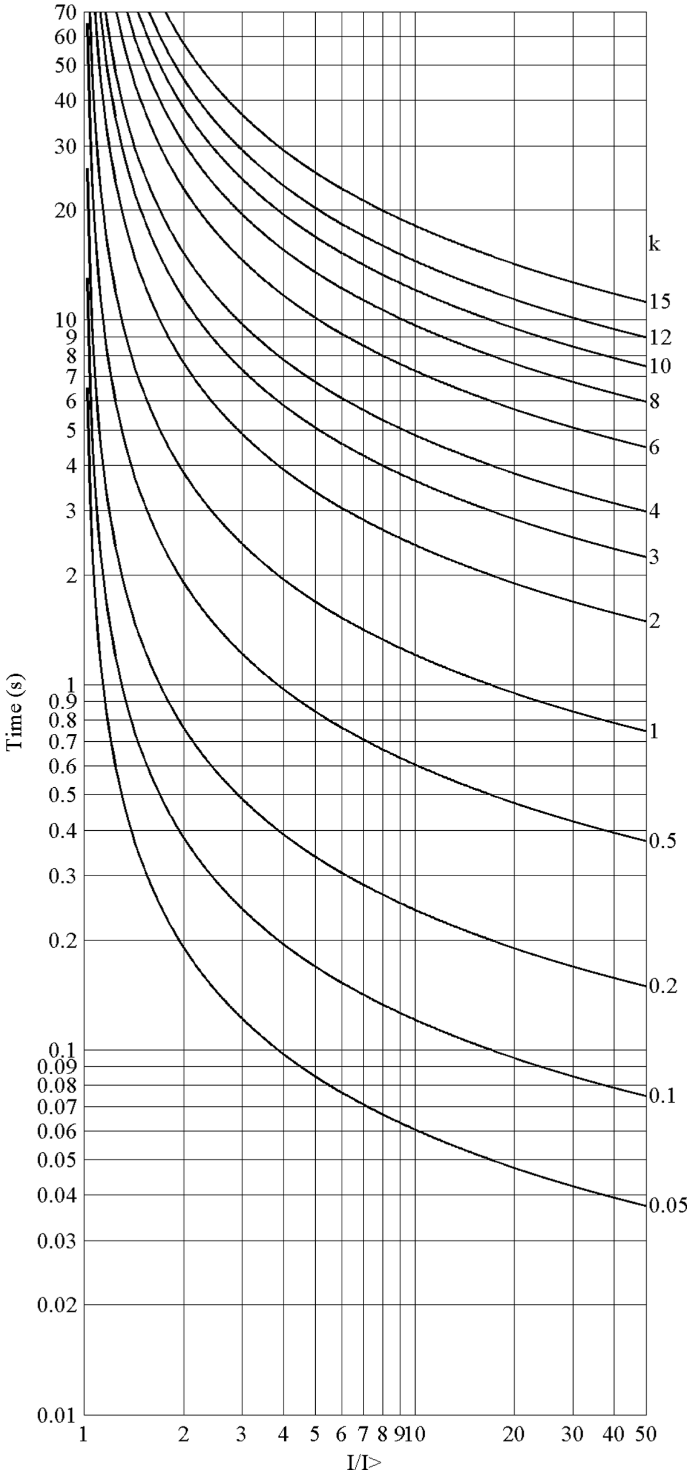


Figure 238: ANSI moderately inverse-time characteristics

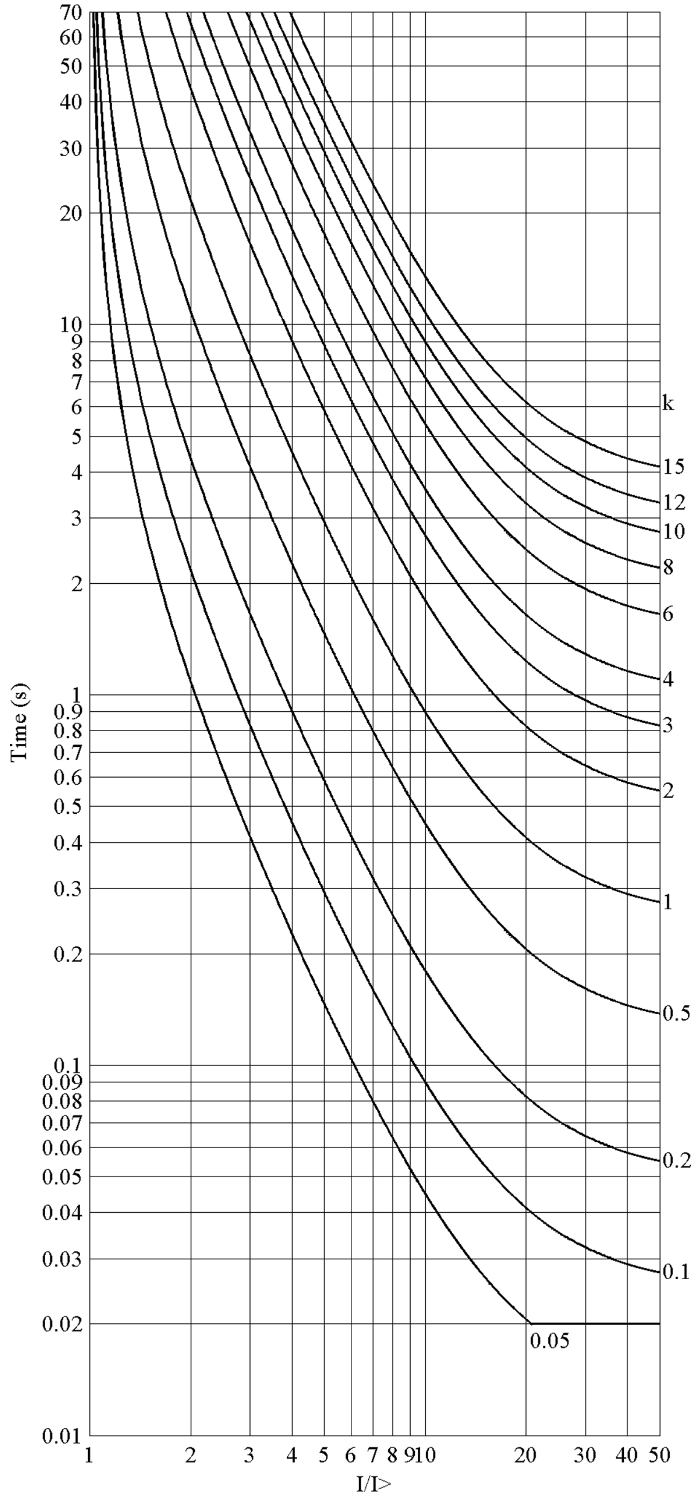


Figure 239: ANSI long-time extremely inverse-time characteristics

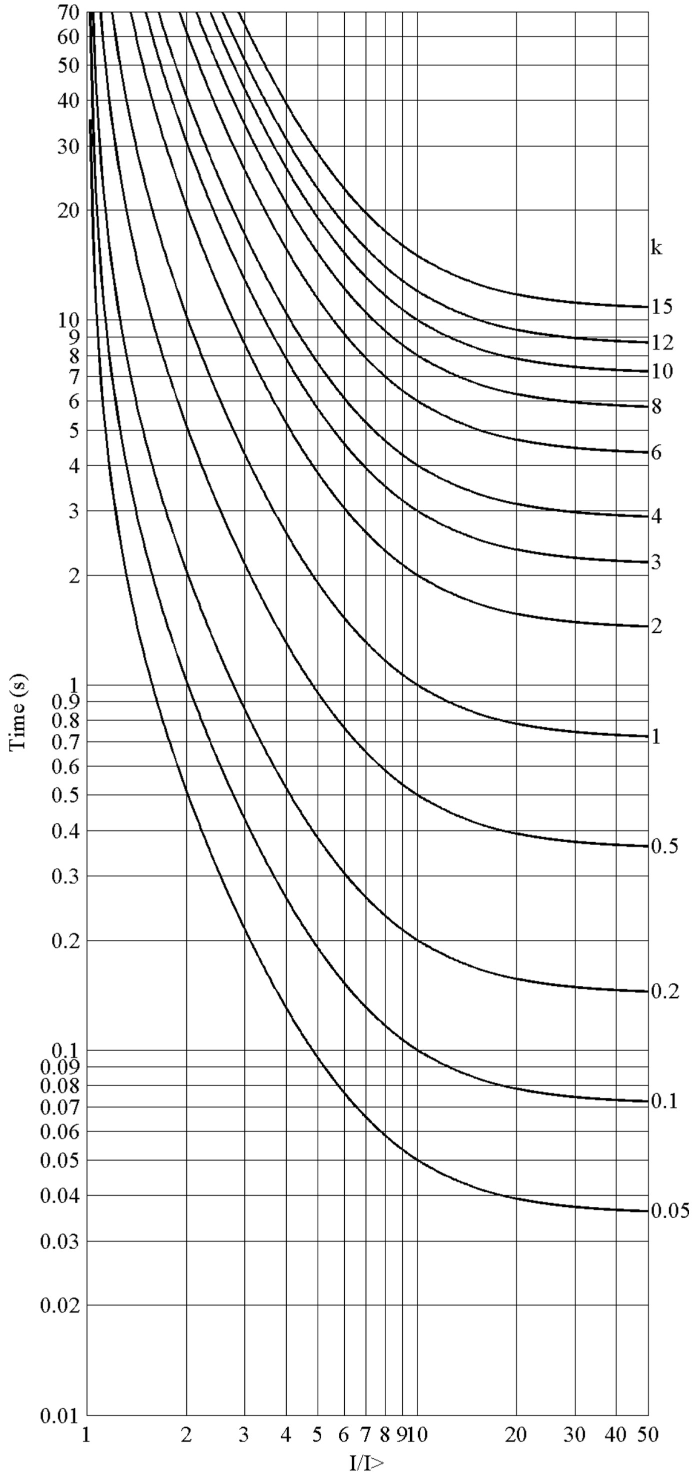


Figure 240: ANSI long-time very inverse-time characteristics

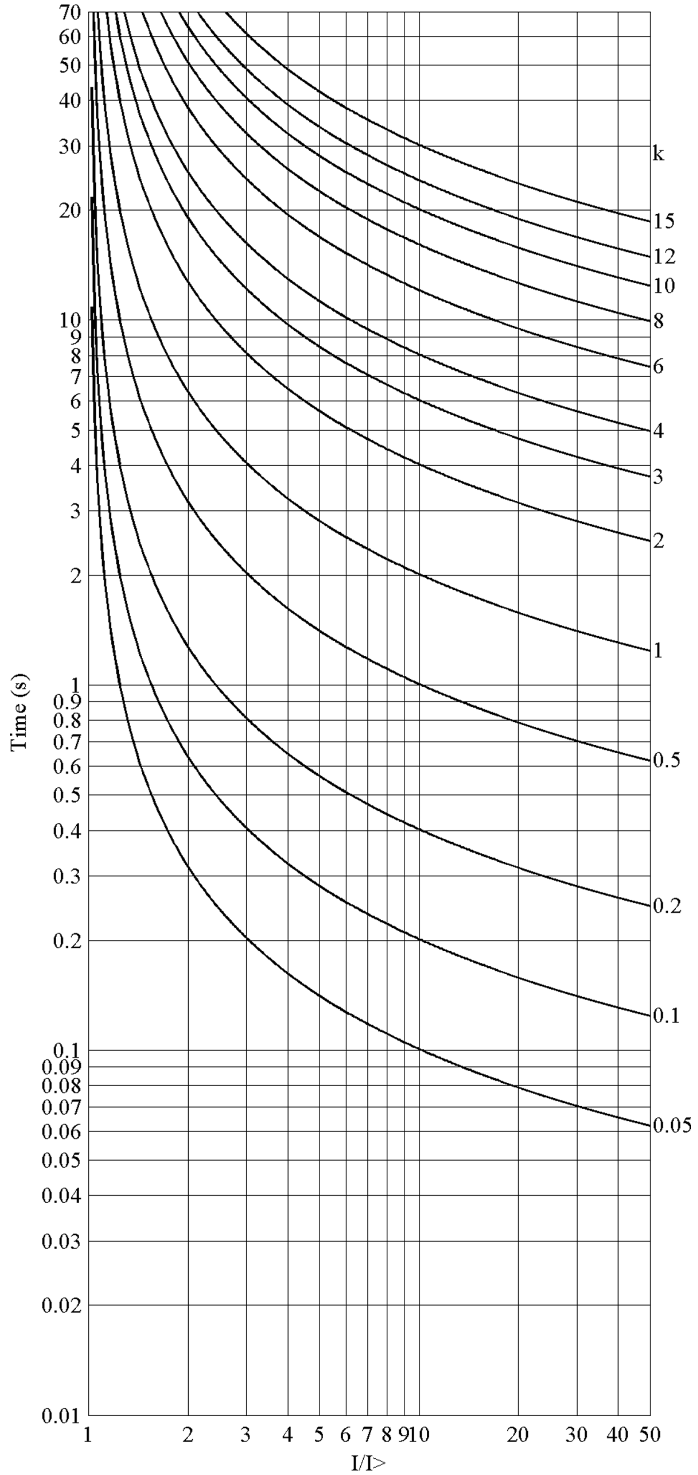


Figure 241: ANSI long-time inverse-time characteristics

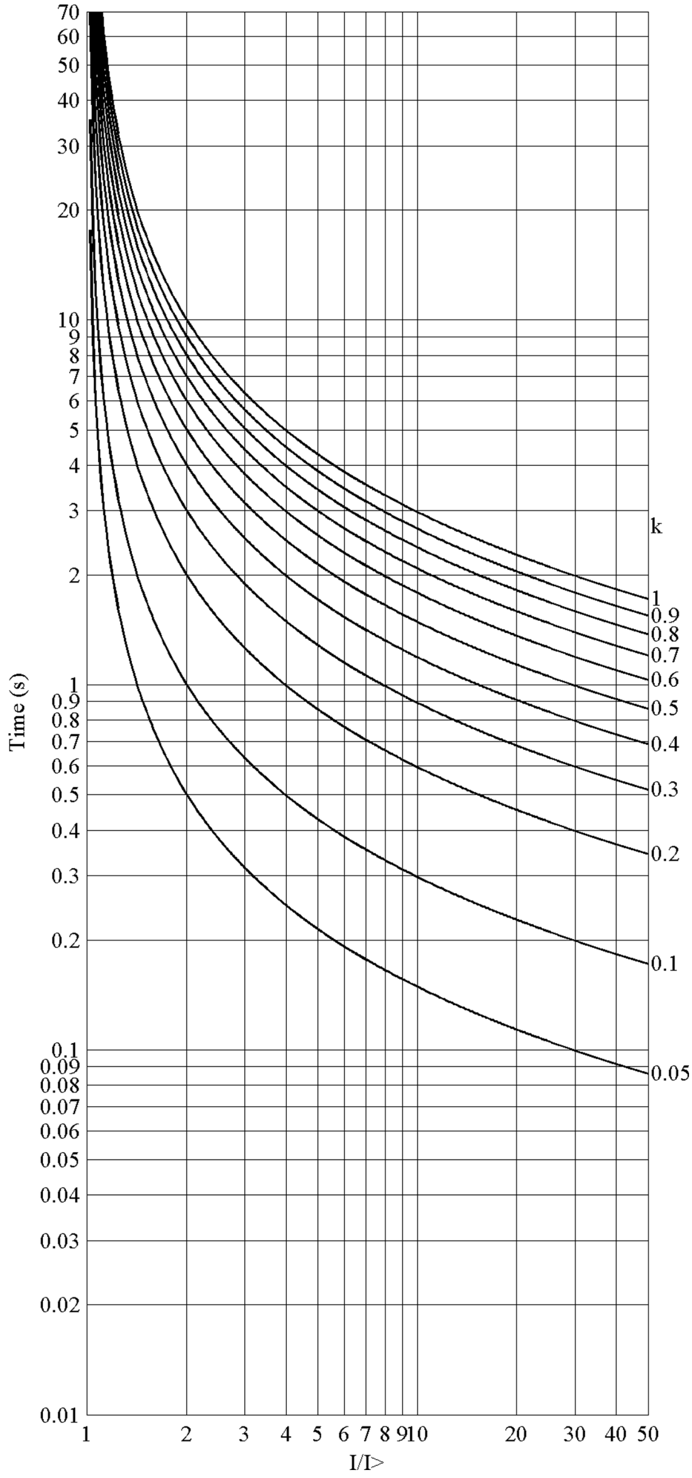


Figure 242: IEC normal inverse-time characteristics

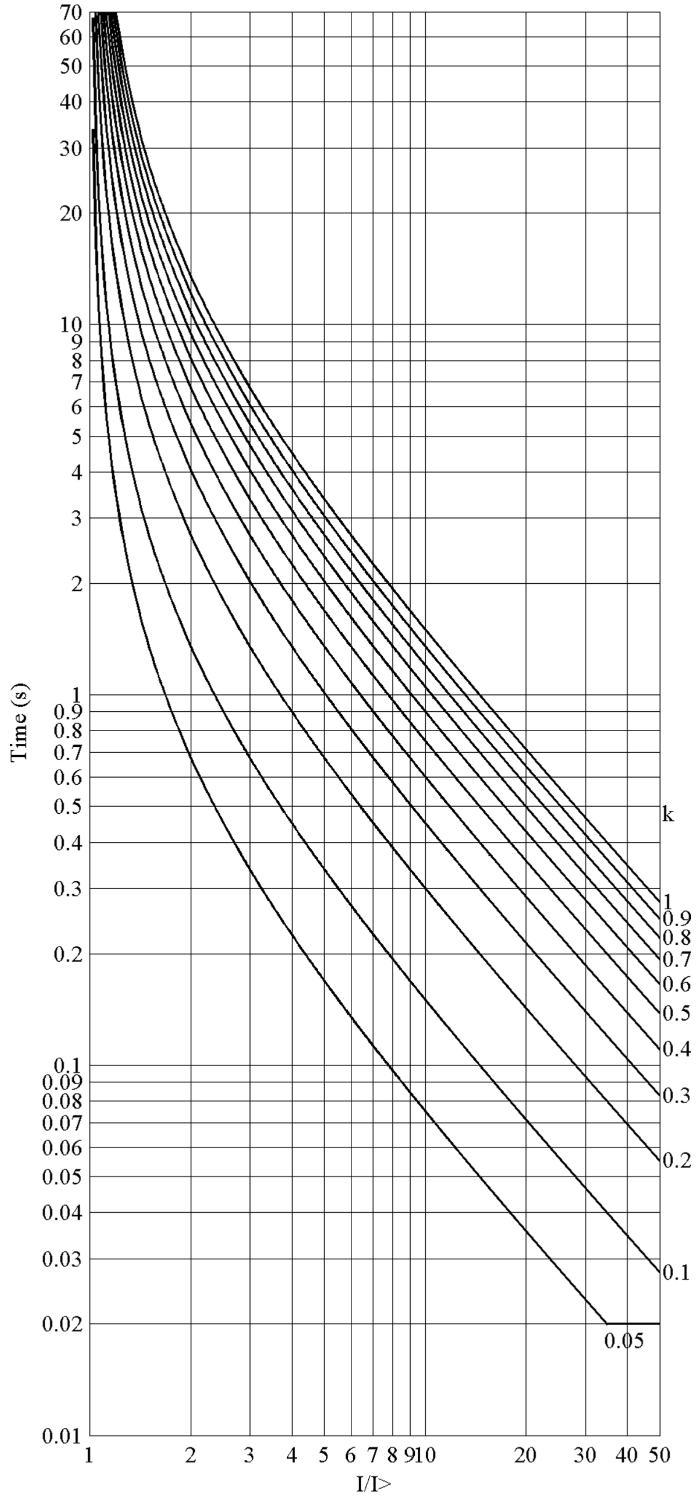


Figure 243: IEC very inverse-time characteristics

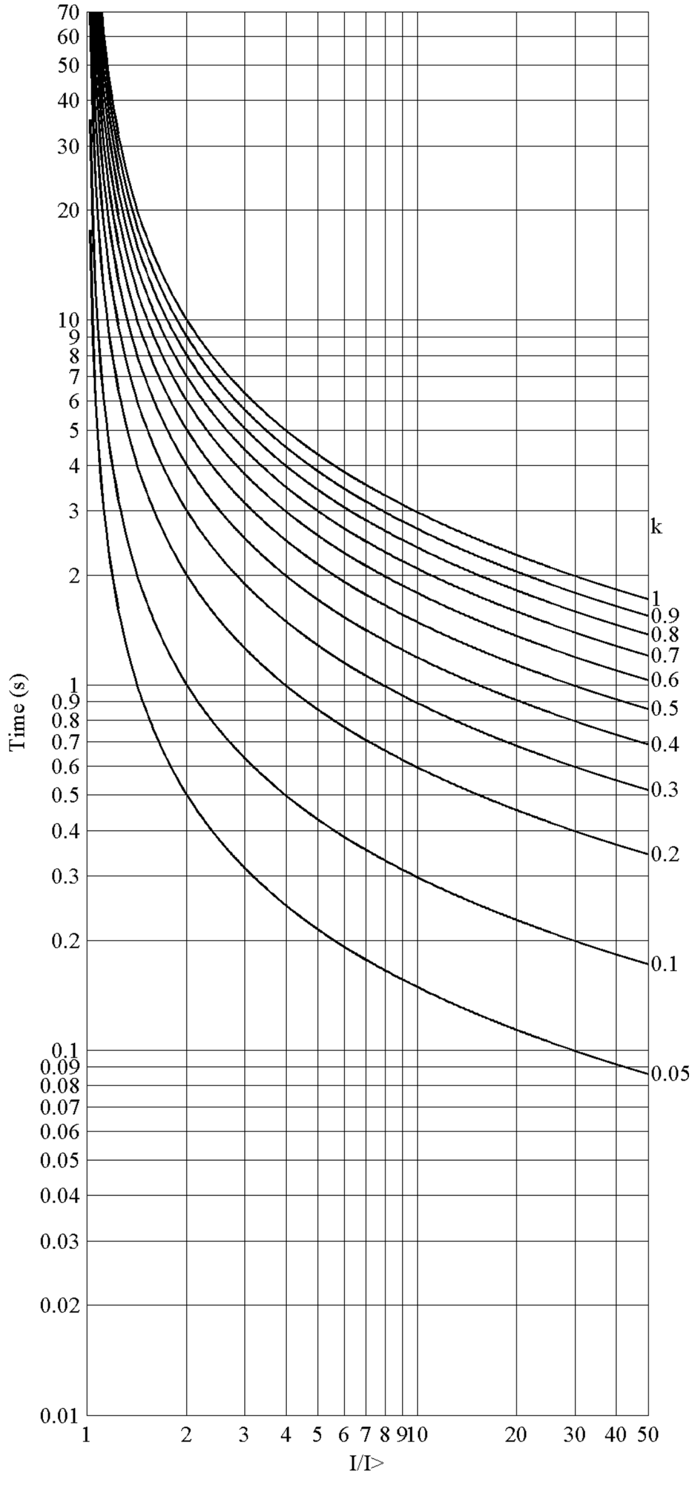


Figure 244: IEC inverse-time characteristics

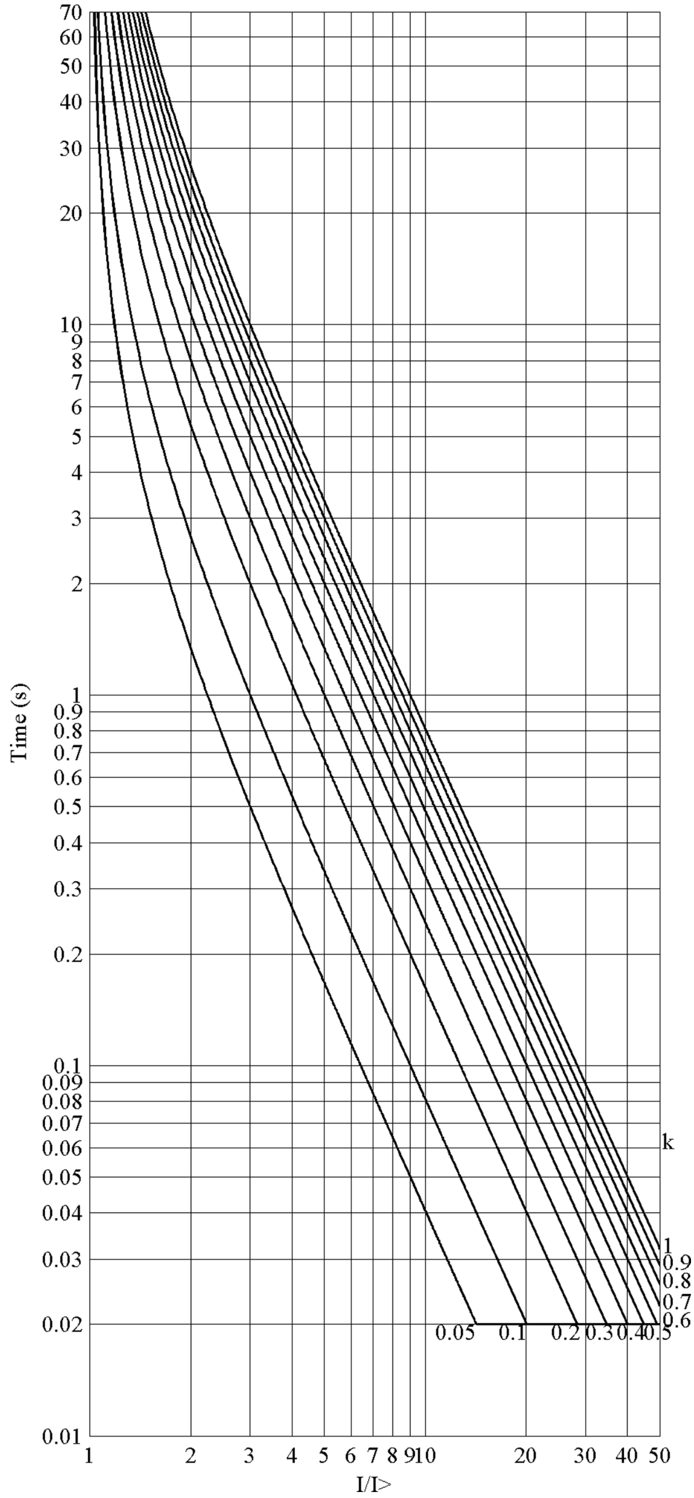


Figure 245: IEC extremely inverse-time characteristics

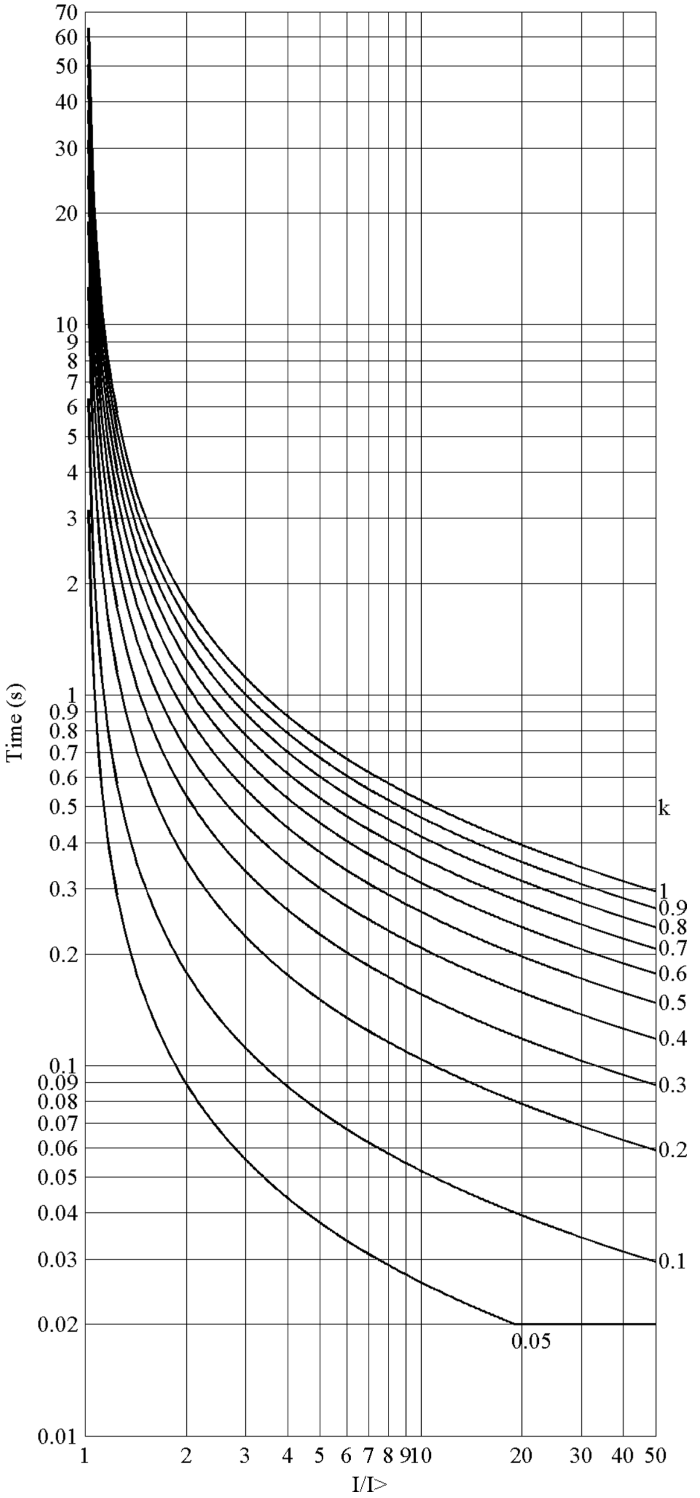


Figure 246: IEC short-time inverse-time characteristics

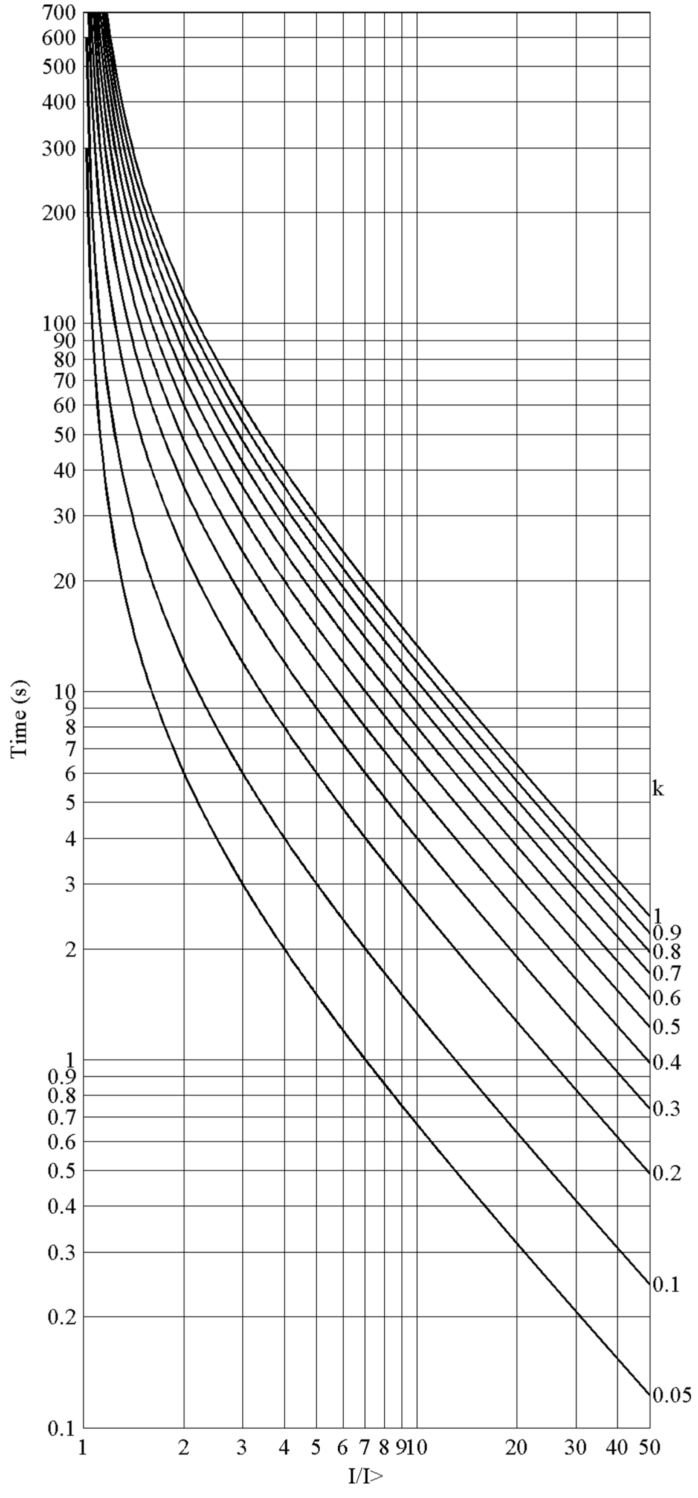


Figure 247: IEC long-time inverse-time characteristics

10.2.1.2 User-programmable inverse-time characteristics

The user can define curves by entering parameters into the following standard formula:

$$t[s] = \left(\frac{A}{\left(\frac{I}{I>} \right)^{C} - E} + B \right) \cdot k$$

(Equation 46)

t[s]	Operate time (in seconds)
A	set *Curve parameter A*
B	set *Curve parameter B*
C	set *Curve parameter C*
E	set *Curve parameter E*
I	Measured current
I>	set *Start value*
k	set *Time multiplier*

10.2.1.3 RI and RD-type inverse-time characteristics

The RI-type simulates the behavior of electromechanical relays. The RD-type is an earth-fault specific characteristic.

The RI-type is calculated using the formula

$$t[s] = \left(\frac{k}{0.339 - 0.236 \times \frac{I>}{I}} \right)$$

(Equation 47)

The RD-type is calculated using the formula

$$t[s] = 5.8 - 1.35 \times \text{In}\left(\frac{I}{k \times I>} \right)$$

(Equation 48)

t[s] Operate time (in seconds)

k set *Time multiplier*

I Measured current

I> set *Start value*

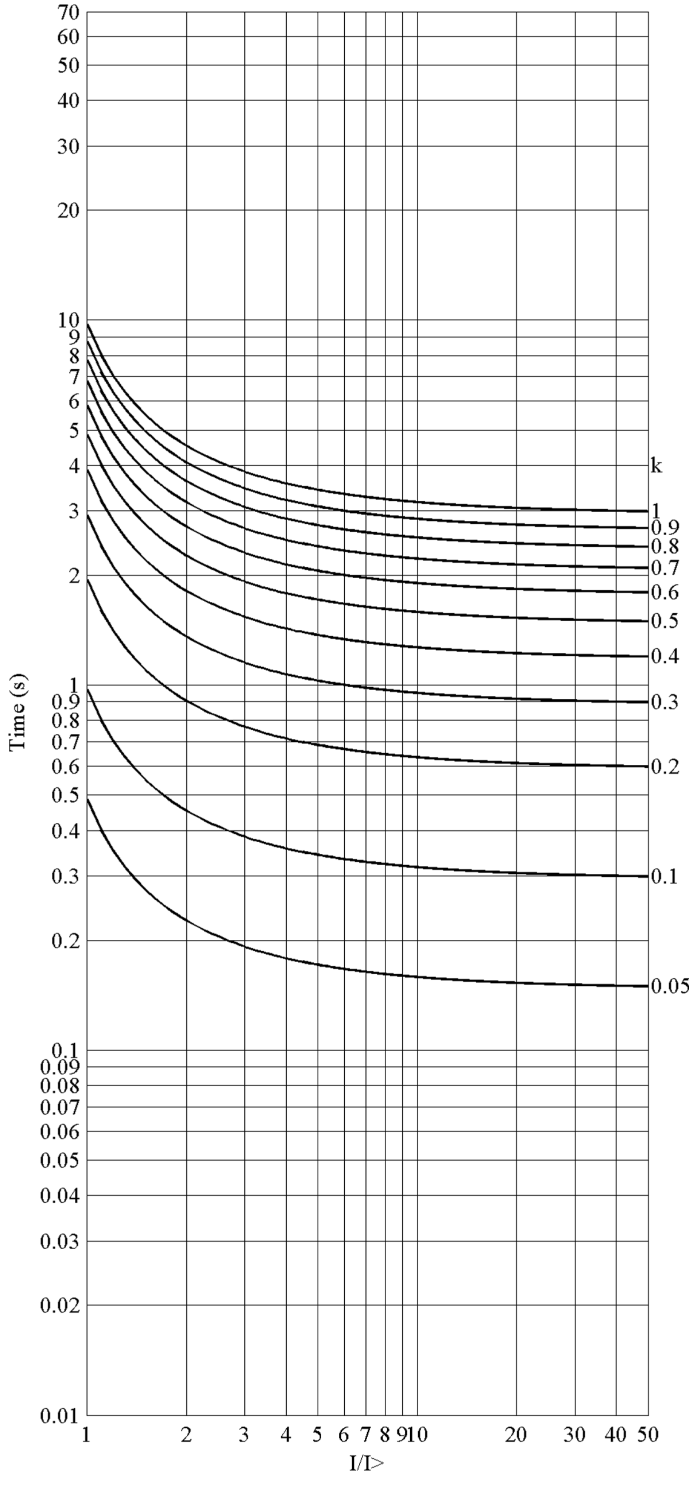


Figure 248: RI-type inverse-time characteristics

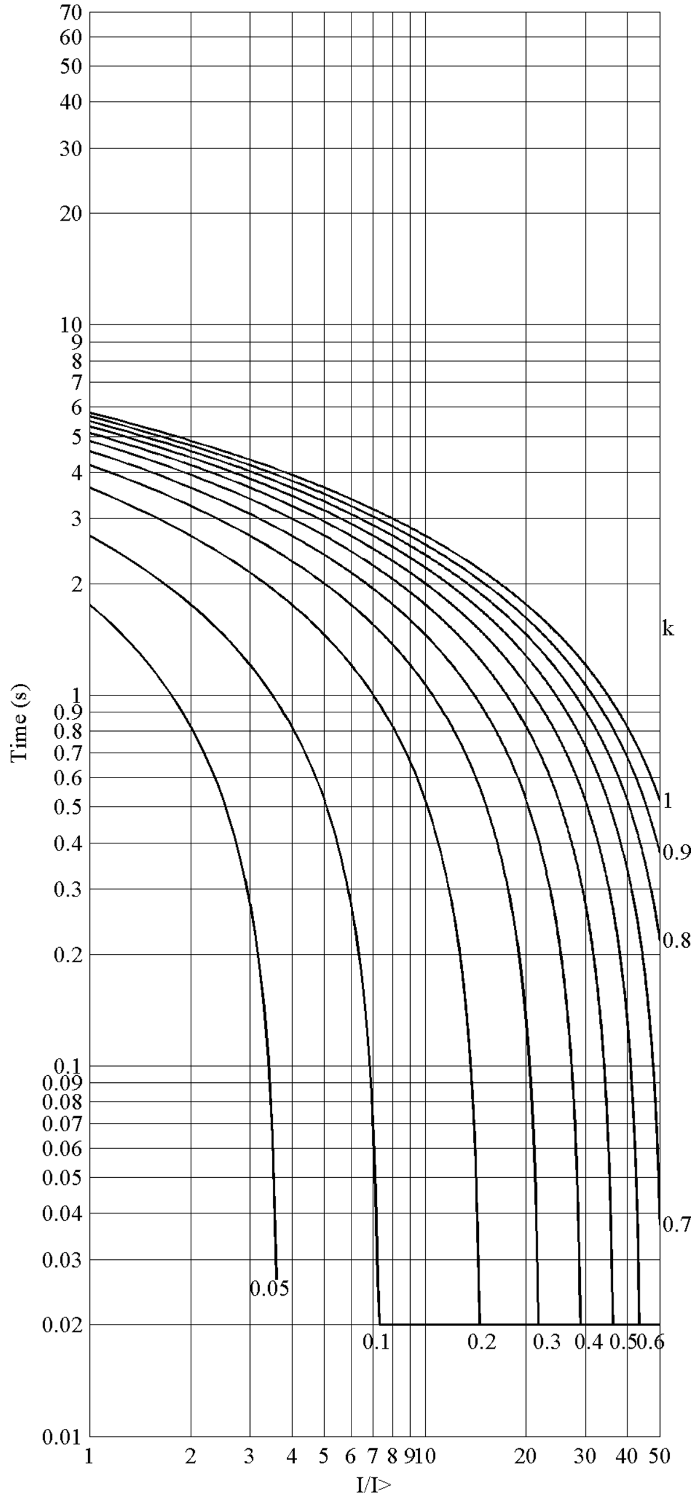


Figure 249: RD-type inverse-time characteristics

10.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting as follows:

Table 376: Values for reset mode

Setting name	Possible values
Type of reset curve	1=Immediate 2=Def time reset 3=Inverse reset

Immediate reset

If the *Type of reset curve* setting in a drop-off case is selected as "Immediate", the inverse timer resets immediately.

Definite time reset

The definite type of reset in the inverse-time mode can be achieved by setting the *Type of reset curve* parameter to “Def time reset”. As a result, the operate inverse-time counter is frozen for the time determined with the *Reset delay time* setting after the current drops below the set *Start value*, including hysteresis.The integral sum of the inverse-time counter is reset, if another start does not occur during the reset delay.

If the *Type of reset curve* setting is selected as “Def time reset”, the current level has no influence on the reset characteristic.

Inverse reset

Inverse reset curves are available only for ANSI and user-programmable curves. If you use other curve types, immediate reset occurs.

Standard delayed inverse reset

The reset characteristic required in ANSI (IEEE) inverse-time modes is provided by setting the *Type of reset curve* parameter to “Inverse reset”. In this mode, the time delay for reset is given with the following formula using the coefficient D, which has its values defined in the table below.

$$t[s] = \left(\frac{D}{\left(\frac{I}{I>}\right)^2 - 1} \right) \cdot k$$

(Equation 49)

t[s] Reset time (in seconds)

k set *Time multiplier*

I Measured current

I> set *Start value*

Table 377: Coefficients for ANSI delayed inverse reset curves

Curve name	D
(1) ANSI Extremely Inverse	29.1
(2) ANSI Very Inverse	21.6
(3) ANSI Normal Inverse	0.46
(4) ANSI Moderately Inverse	4.85
(6) Long Time Extremely Inverse	30
(7) Long Time Very Inverse	13.46
(8) Long Time Inverse	4.6

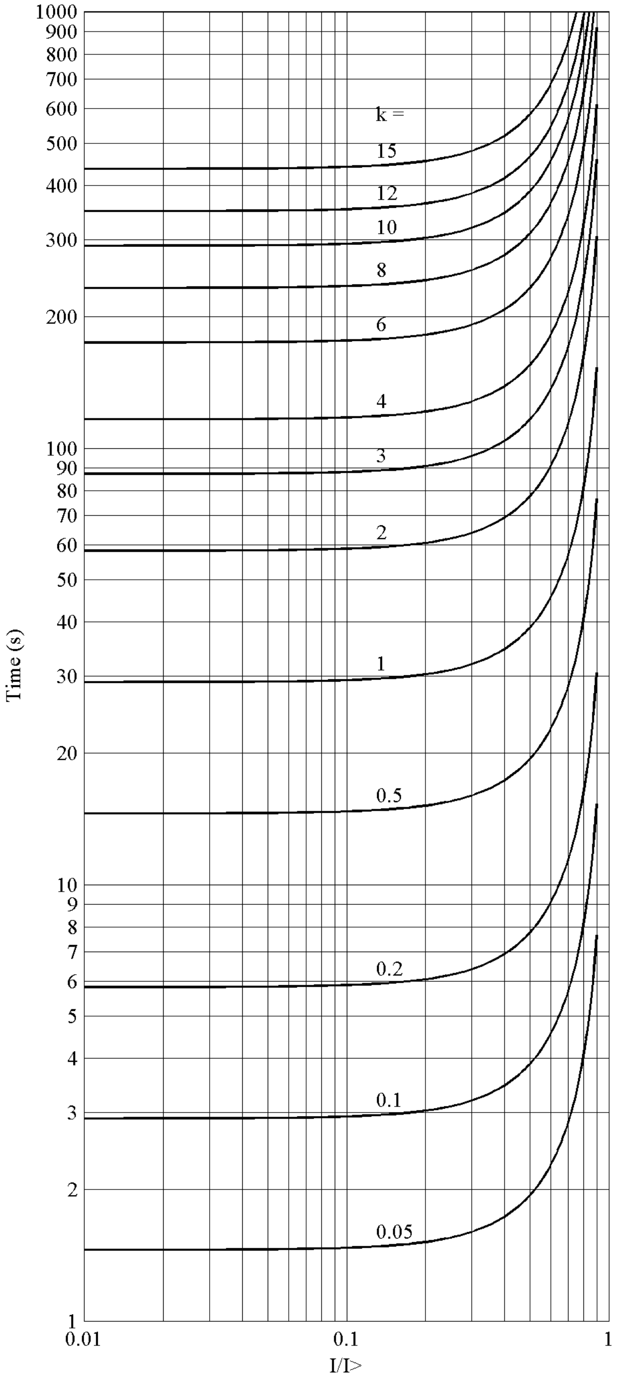


Figure 250: ANSI extremely inverse reset time characteristics

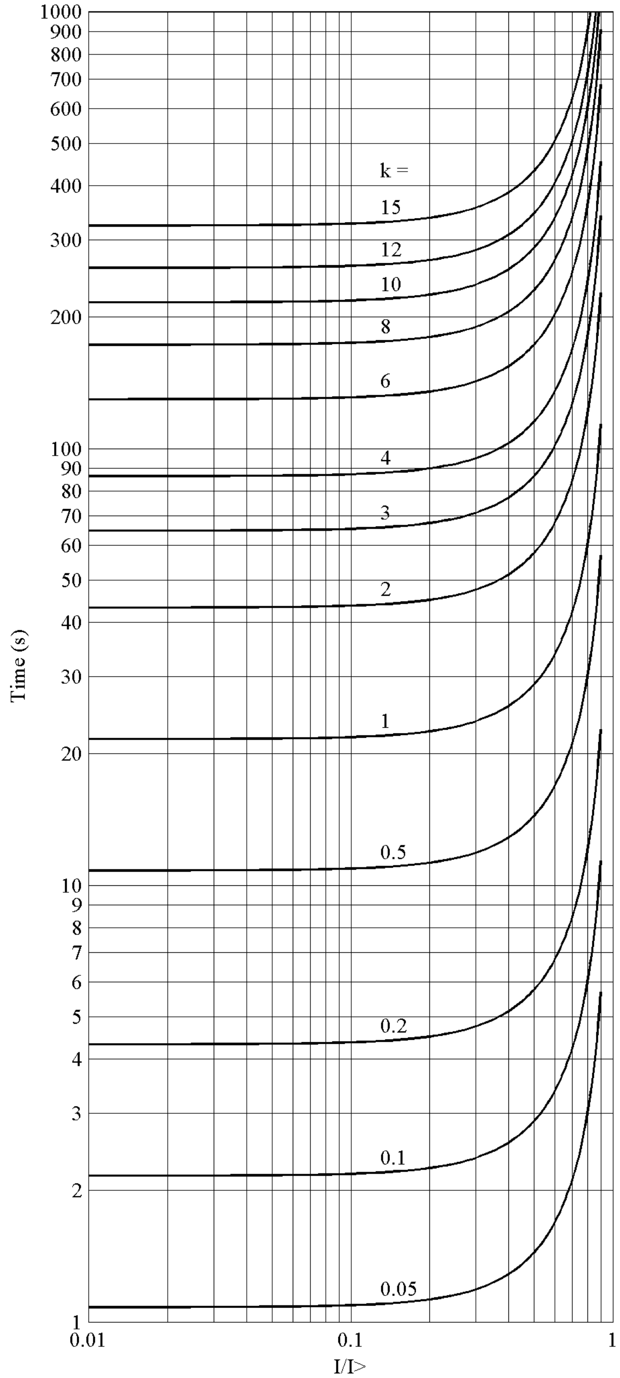


Figure 251: ANSI very inverse reset time characteristics

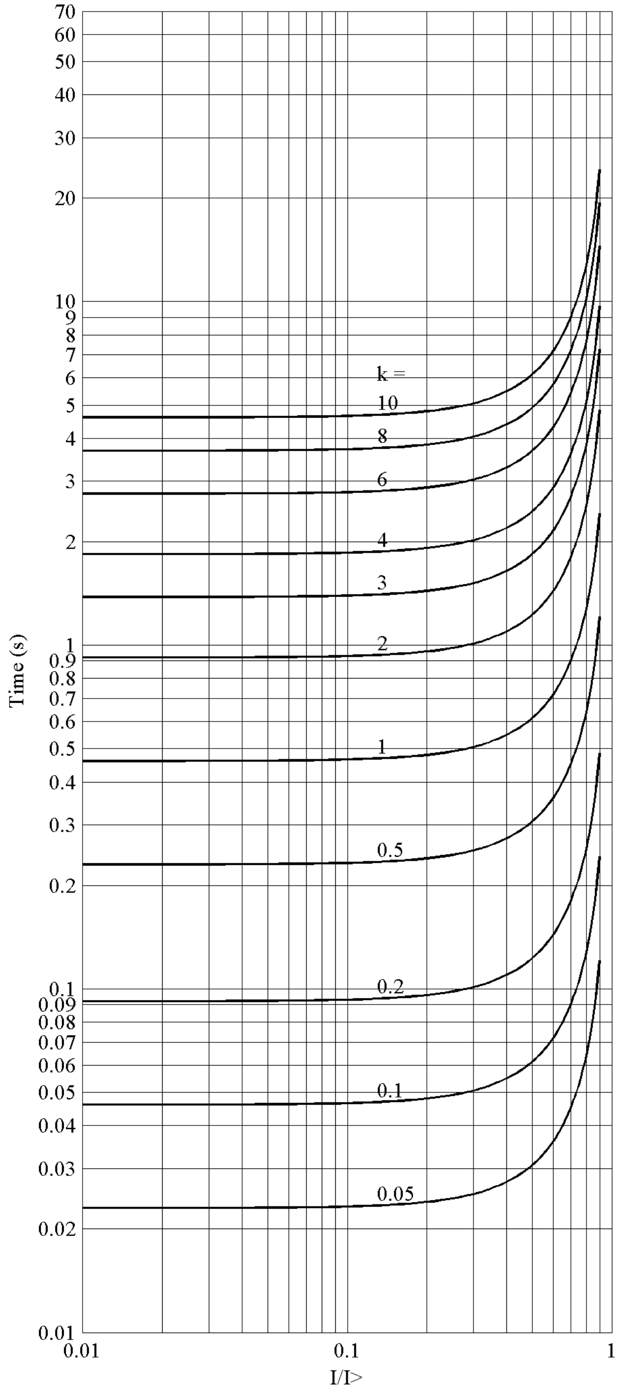


Figure 252: ANSI normal inverse reset time characteristics

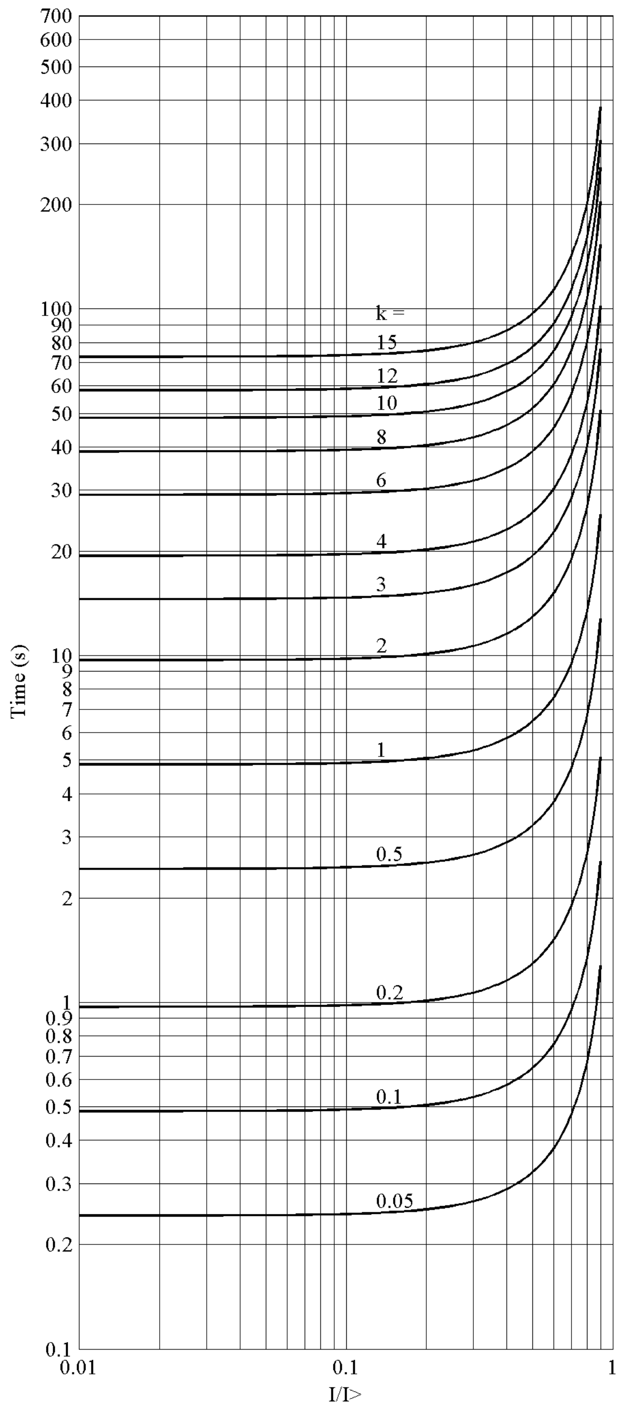


Figure 253: ANSI moderately inverse reset time characteristics

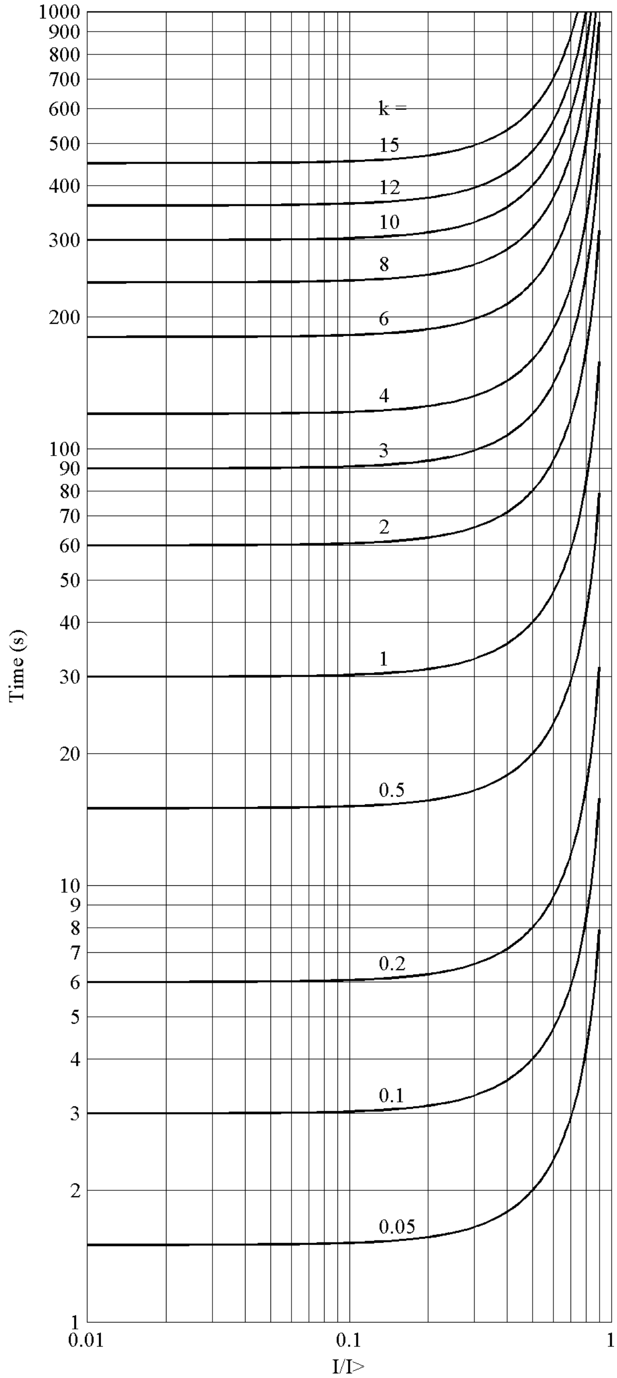


Figure 254: ANSI long-time extremely inverse reset time characteristics

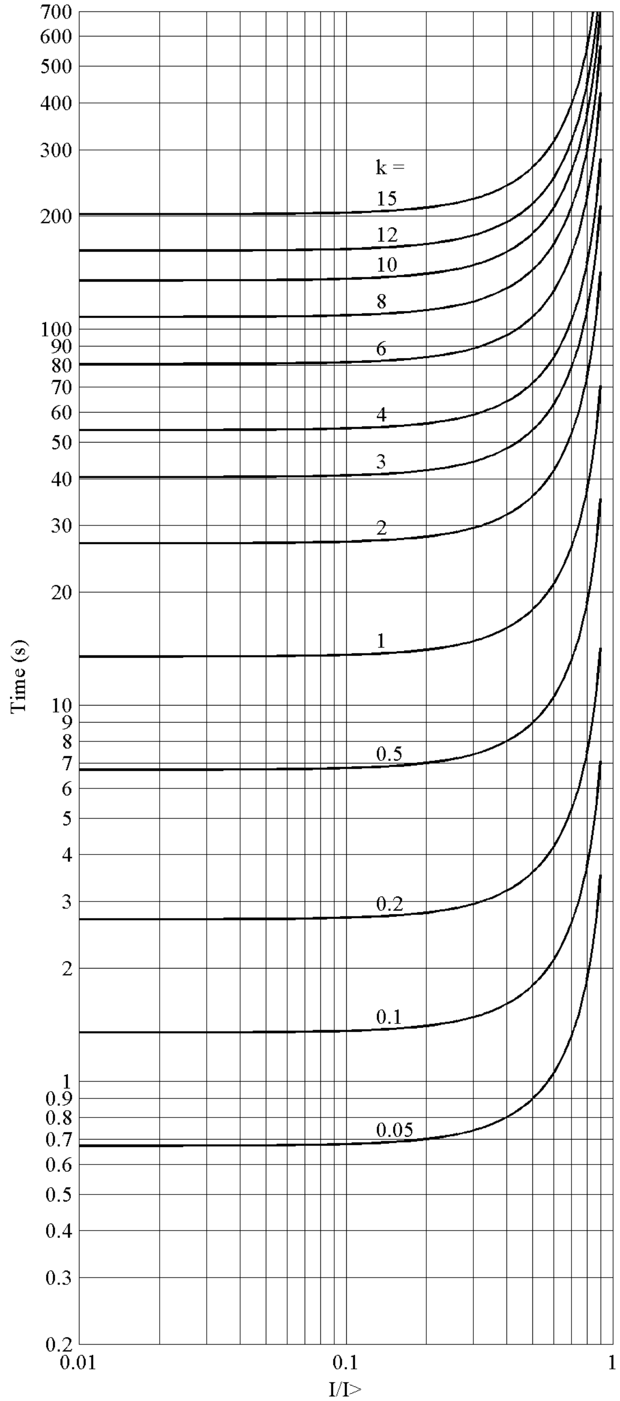


Figure 255: ANSI long-time very inverse reset time characteristics

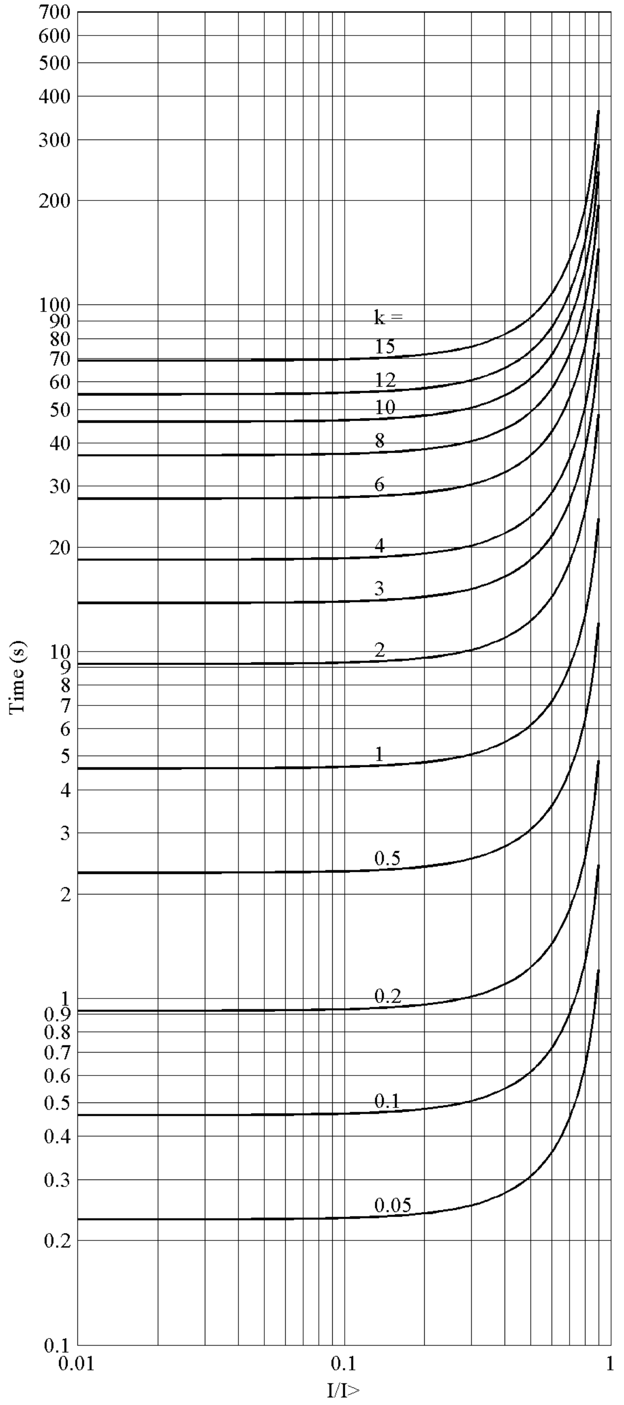


Figure 256: ANSI long-time inverse reset time characteristics

The delayed inverse-time reset is not available for IEC-type inverse time curves.

User-programmable delayed inverse reset

The user can define the delayed inverse reset time characteristics with the following formula using the set *Curve parameter D*.

$$t[s] = \left(\frac{D}{\left(\frac{I}{I>}\right)^2 - 1} \right) \cdot k$$

(Equation 50)

t[s]	Reset time (in seconds)
k	set *Time multiplier*
D	set *Curve parameter D*
I	Measured current
I>	set *Start value*

10.2.3 Inverse-timer freezing

When the BLOCK input is active, the internal value of the time counter is frozen at the value of the moment just before the freezing. Freezing of the counter value is chosen when the user does not wish the counter value to count upwards or to be reset. This may be the case, for example, when the inverse-time function of an IED needs to be blocked to enable the definite-time operation of another IED for selectivity reasons, especially if different relaying techniques (old and modern relays) are applied.

The selected blocking mode is "Freeze timer".

The activation of the BLOCK input also lengthens the minimum delay value of the timer.

Activating the BLOCK input alone does not affect the operation of the START output. It still becomes active when the current exceeds the set *Start value*, and inactive when the current falls below the set *Start value* and the set *Reset delay time* has expired.

10.3 Voltage based inverse definite minimum time characteristics

10.3.1 IDMT curves for overvoltage protection

In inverse-time modes, the operate time depends on the momentary value of the voltage, the higher the voltage, the faster the operate time. The operate time calculation or integration starts immediately when the voltage exceeds the set value of the *Start value* setting and the `START` output is activated.

The `OPERATE` output of the component is activated when the cumulative sum of the integrator calculating the overvoltage situation exceeds the value set by the inverse time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum operate time* setting defines the minimum operate time for the IDMT mode, that is, it is possible to limit the IDMT based operate time for not becoming too short. For example:

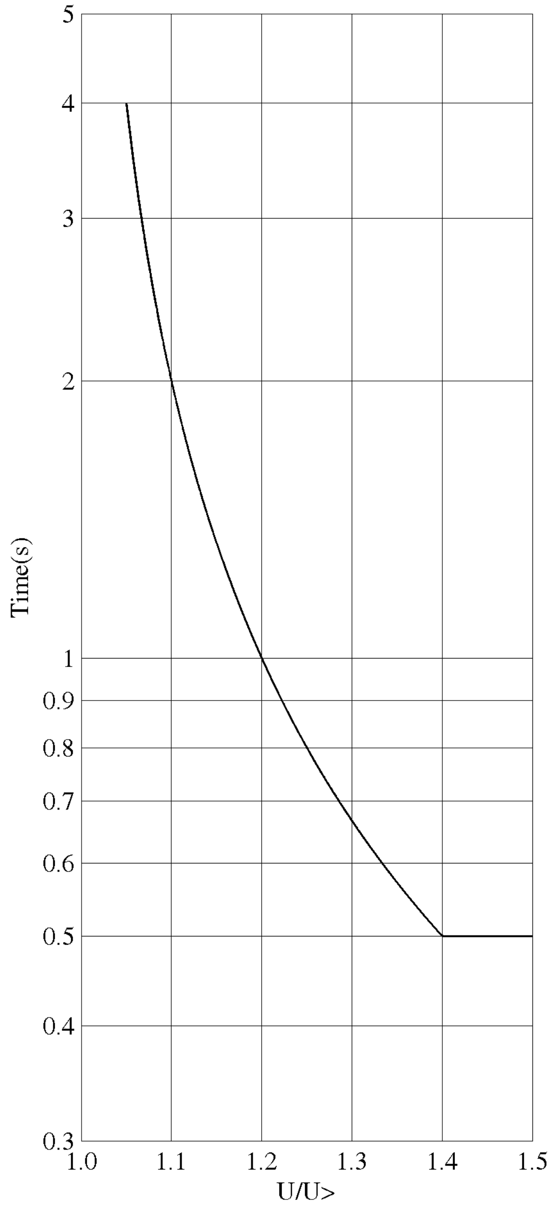


Figure 257: Operate time curve based on IDMT characteristic with Minimum operate time set to 0.5 second

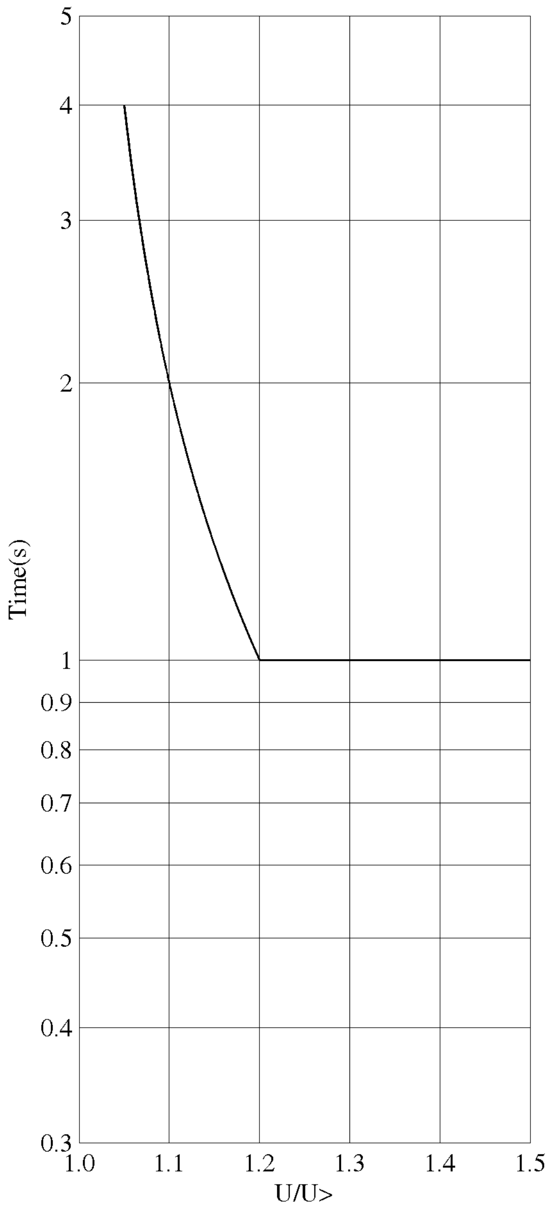


Figure 258: Operate time curve based on IDMT characteristic with Minimum operate time set to 1 second

10.3.1.1 Standard inverse-time characteristics for overvoltage protection

The operate times for the standard overvoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse operate time can be calculated with the formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{U - U>}{U>} - C\right)^{E}} + D$$

(Equation 51)

t [s] operate time in seconds

U measured voltage

U> the set value of *Start value*

k the set value of *Time multiplier*

Table 378: Curve coefficients for standard overvoltage IDMT curves

Curve name	A	B	C	D	E
(17) Inverse Curve A	1	1	0	0	1
(18) Inverse Curve B	480	32	0.5	0.035	2
(19) Inverse Curve C	480	32	0.5	0.035	3

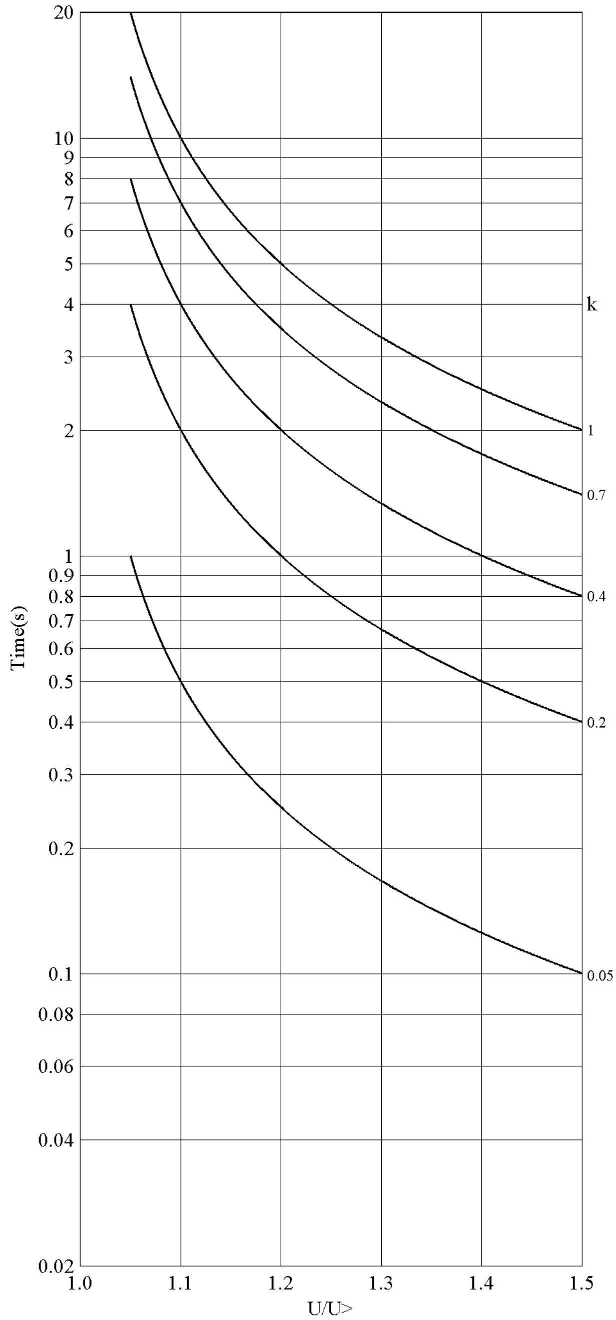


Figure 259: Inverse curve A characteristic of overvoltage protection

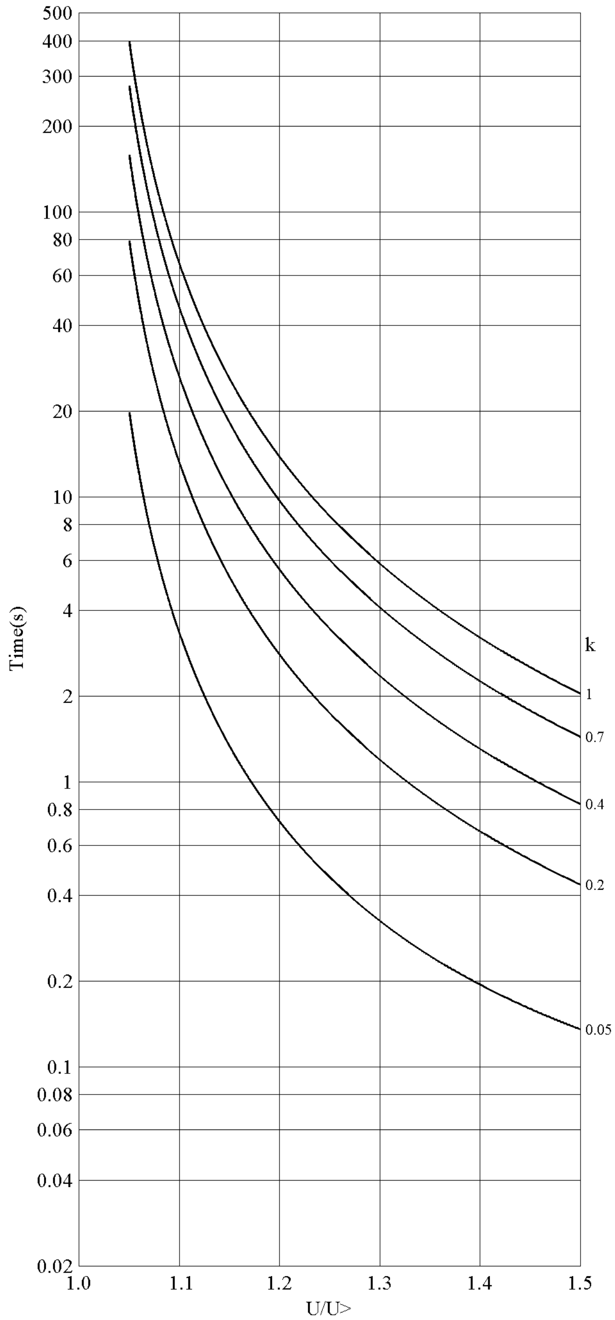


Figure 260: Inverse curve B characteristic of overvoltage protection

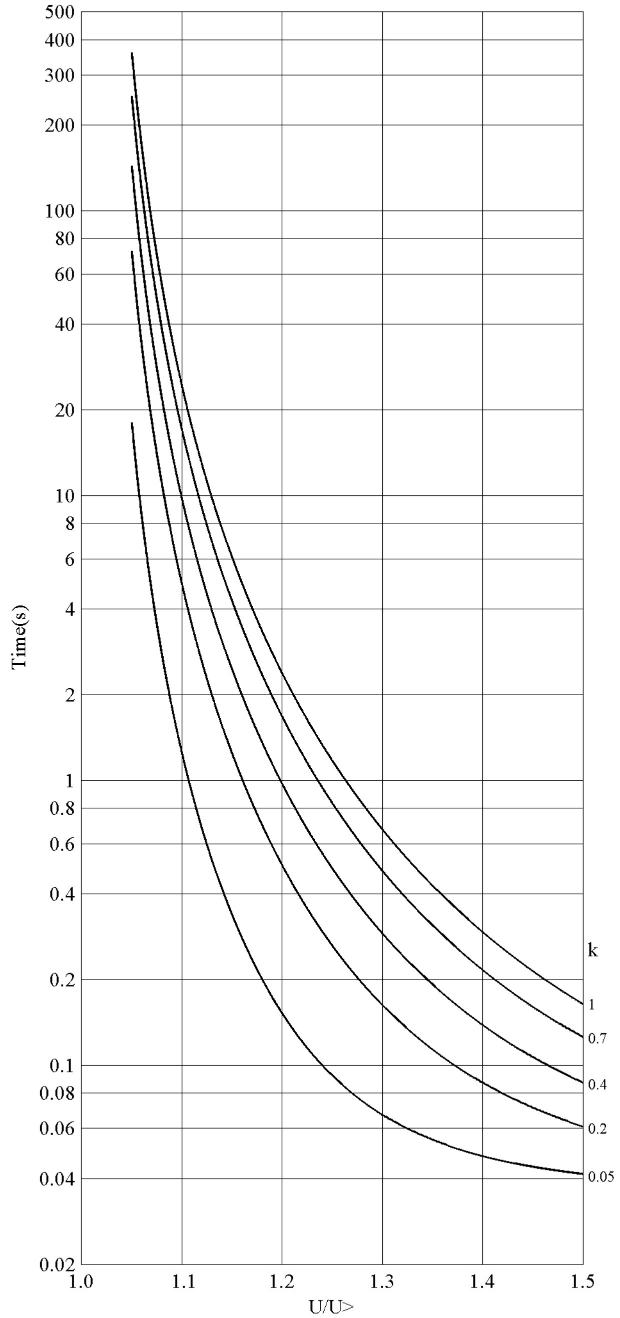


Figure 261: Inverse curve C characteristic of overvoltage protection

10.3.1.2 User programmable inverse-time characteristics for overvoltage protection

The user can define the curves by entering the parameters using the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{U - U>}{U>} - C\right)^{E}} + D$$

(Equation 52)

t[s]	operate time in seconds
A	the set value of *Curve parameter A*
B	the set value of *Curve parameter B*
C	the set value of *Curve parameter C*
D	the set value of *Curve parameter D*
E	the set value of *Curve parameter E*
U	measured voltage
U>	the set value of *Start value*
k	the set value of *Time multiplier*

10.3.1.3 IDMT curve saturation of overvoltage protection

For the overvoltage IDMT mode of operation, the integration of the operate time does not start until the voltage exceeds the value of *Start value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared to *Start value*. For example, due to the curve equation B and C, the characteristics equation output is saturated in such a way that when the input voltages are in the range of *Start value* to *Curve Sat Relative* in percent over *Start value*, the equation uses *Start value* * (1.0 + *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio U/U> exceeds the unity, *Curve Sat Relative* is also set for it. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning the discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum operate time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

10.3.2 IDMT curves for undervoltage protection

In the inverse-time modes, the operate time depends on the momentary value of the voltage, the lower the voltage, the faster the operate time. The operate time calculation or integration starts immediately when the voltage goes below the set value of the *Start value* setting and the `START` output is activated.

The `OPERATE` output of the component is activated when the cumulative sum of the integrator calculating the undervoltage situation exceeds the value set by the inverse-time mode. The set value depends on the selected curve type and the setting values used. The user determines the curve scaling with the *Time multiplier* setting.

The *Minimum operate time* setting defines the minimum operate time possible for the IDMT mode. For setting a value for this parameter, the user should carefully study the particular IDMT curve.

10.3.2.1 Standard inverse-time characteristics for undervoltage protection

The operate times for the standard undervoltage IDMT curves are defined with the coefficients A, B, C, D and E.

The inverse operate time can be calculated with the formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \times \frac{U< - U}{U<} - C\right)^{E}} + D$$

(Equation 53)

t [s]	operate-time in seconds
U	measured voltage
U<	The set value of the *Start value* setting
k	The set value of the *Time multiplier* setting

Table 379: Curve coefficients for standard undervoltage IDMT curves

Curve name	A	B	C	D	E
(21) Inverse Curve A	1	1	0	0	1
(22) Inverse Curve B	480	32	0.5	0.055	2

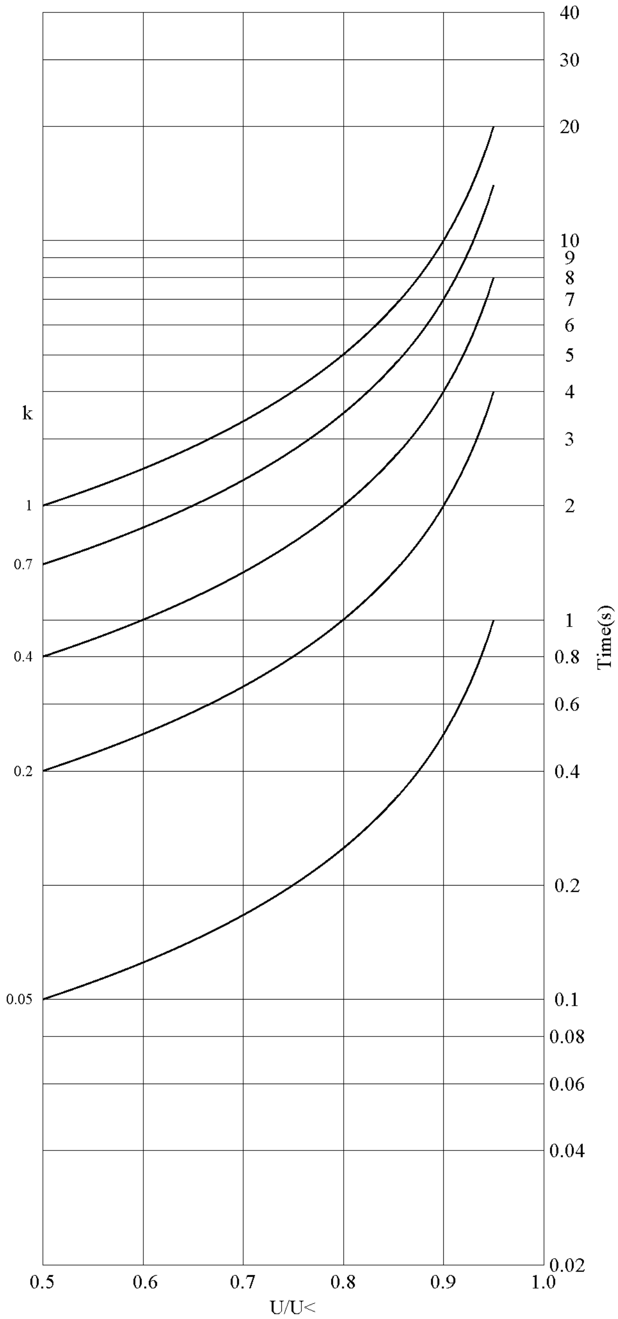


Figure 262: : Inverse curve A characteristic of undervoltage protection

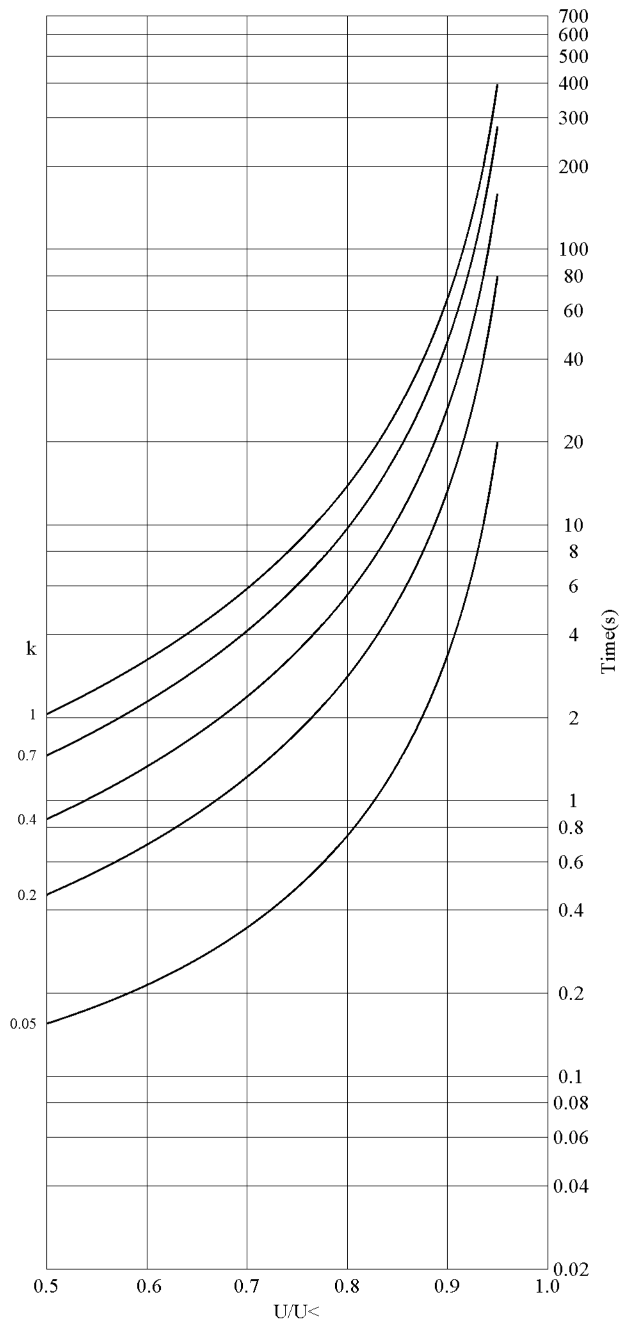


Figure 263: Inverse curve B characteristic of undervoltage protection

10.3.2.2 User-programmable inverse-time characteristics for undervoltage protection

The user can define curves by entering parameters into the standard formula:

$$t[s] = \frac{k \cdot A}{\left(B \times \frac{U< - U}{U<} - C\right)^{E}} + D$$

(Equation 54)

t[s]	operate time in seconds
A	the set value of *Curve parameter A*
B	the set value of *Curve parameter B*
C	the set value of *Curve parameter C*
D	the set value of *Curve parameter D*
E	the set value of *Curve parameter E*
U	measured voltage
U<	the set value of *Start value*
k	the set value of *Time multiplier*

10.3.2.3 IDMT curve saturation of undervoltage protection

For the undervoltage IDMT mode of operation, the integration of the operate time does not start until the voltage falls below the value of *Start value*. To cope with discontinuity characteristics of the curve, a specific parameter for saturating the equation to a fixed value is created. The *Curve Sat Relative* setting is the parameter and it is given in percents compared with *Start value*. For example, due to the curve equation B, the characteristics equation output is saturated in such a way that when input voltages are in the range from *Start value* to *Curve Sat Relative* in percents under *Start value*, the equation uses *Start value* * (1.0 - *Curve Sat Relative* / 100) for the measured voltage. Although, the curve A has no discontinuities when the ratio U/U> exceeds the unity, *Curve Sat Relative* is set for it as well. The *Curve Sat Relative* setting for curves A, B and C is 2.0 percent. However, it should be noted that the user must carefully calculate the curve characteristics concerning also discontinuities in the curve when the programmable curve equation is used. Thus, the *Curve Sat Relative* parameter gives another degree of freedom to move the inverse curve on the voltage ratio axis and it effectively sets the maximum operate time for the IDMT curve because for the voltage ratio values affecting by this setting, the operation time is fixed, that is, the definite time, depending on the parameters but no longer the voltage.

10.4 Measurement modes

In many current or voltage dependent function blocks, there are four alternative measuring principles:

- RMS
- DFT which is a numerically calculated fundamental component of the signal
- Peak-to-peak
- Peak-to-peak with peak backup

Consequently, the measurement mode can be selected according to the application.

In extreme cases, for example with high overcurrent or harmonic content, the measurement modes function in a slightly different way. The operation accuracy is defined with the frequency range of f/fn=0.95...1.05. In peak-to-peak and RMS measurement modes, the harmonics of the phase currents are not suppressed, whereas in the fundamental frequency measurement the suppression of harmonics is at least -50 dB at the frequency range of f= n x fn, where n = 2, 3, 4, 5,...

RMS

The RMS measurement principle is selected with the *Measurement mode* setting using the value "RMS". RMS consists of both AC and DC components. The AC component is the effective mean value of the positive and negative peak values. RMS is used in applications where the effect of the DC component must be taken into account.

RMS is calculated according to the formula:

$$I_{RMS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_i^2}$$

(Equation 55)

n the number of samples in a calculation cycle

I_i the current sample value

DFT

The DFT measurement principle is selected with the *Measurement mode* setting using the value "DFT". In the DFT mode, the fundamental frequency component of the measured signal is numerically calculated from the samples. In some applications, for example, it can be difficult to accomplish sufficiently sensitive settings and accurate operation of the low stage, which may be due to a considerable amount of harmonics on the primary side currents. In such a case, the operation can be based solely on the fundamental frequency component of the current. In addition, the DFT mode has slightly higher CT requirements than the peak-to-peak mode, if used with high and instantaneous stages.

Peak-to-peak

The peak-to-peak measurement principle is selected with the *Measurement mode* setting using the value "Peak-to-Peak". It is the fastest measurement mode, in which the measurement quantity is made by calculating the average from the positive and negative peak values. The DC component is not included. The retardation time is short. The damping of the harmonics is quite low and practically determined by the characteristics of the anti-aliasing filter of the IED inputs. Consequently, this mode is usually used in conjunction with high and instantaneous stages, where the suppression of harmonics is not so important. In addition, the peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.

Peak-to-peak with peak backup

The peak-to-peak with peak backup measurement principle is selected with the *Measurement mode* setting using the value "P-to-P+backup". It is similar to the peak-to-peak mode, with the exception that it has been enhanced with the peak backup. In the peak-to-peak with peak backup mode, the function starts with two conditions: the peak-to-peak value is above the set start current or the peak value is above two times the set *Start value*. The peak backup is enabled only when the function is used in the DT mode in high and instantaneous stages for faster operation.

Section 11 Requirements for measurement transformers

11.1 Measuring and protection in eVD4

eVD4 integrates the RBX615 IED based on the Relion® technology with the combined current and voltage sensors [1] mounted on the medium-voltage circuit breaker contact arms, enabling to measure the current and voltage [2] applied to each pole.

The combined current and voltage sensor is used for conversion, insulation and protection. The sensor converts excessive current and voltage in the primary circuit of the network to an appropriate signal for secondary circuit equipment, for example, the protective IED. The sensor insulates the primary and secondary circuits from each other. The sensor protects the secondary equipment from the harmful effects of large currents during a short circuit in the network.

The current sensor consists of a Rogowski coil: a uniform winding on a non-ferromagnetic core, enclosing the current-leading contact arm. The voltage induced in the winding is directly proportional to the variation in the primary current.

The current sensors are characterized by the absence of the saturation, no hysteresis phenomena, negligible power losses, extremely low temperature rise in operation and by measuring the precision for the fault currents up to the maximum setting value for the protection thresholds.

The voltage sensor consists of a capacitive divider moulded in the sensor and facing the circuit breaker bushing. The output signal is a voltage directly proportional to the primary voltage.

The voltage sensors are characterized by the absence of the ferroresonance phenomena, thus providing a high level of safety, and they are non-sensitive to DC voltages.

[1] According to the IEC 60044-8 and IEC 60044-7 standards, the proper names are electronic current transformers and electronic voltage transformers
[2] Voltage measure is available when the combined voltage and current sensors (combisensor) are mounted on eVD4, depending on the protection functions and license level required. As an alternative, for a basic current protection features scope, only current sensors and relevant current measure are available.

Figure 264: eVD4 device

Used current and voltage sensing technology within a single combined sensor introduces safe and reliable devices without any possibility for dangerous states or connection of secondary circuits. These combined sensors are designed especially for the application with the circuit breaker. To provide the best performance and highest level of safety, their shape, size and ratings are fully optimized.

Due to the built-in sensor selection (only three types/sizes are needed to cover continuous thermal currents from 1250 A up to 2500 A), driven between these three types by the circuit breaker rated current, a fast and reliable short circuit and overcurrent protection can be enabled, thus disregarding the saturated CT phenomena and a delayed relay operation that can endanger; selectivity and co-ordination of protection.

Major properties of sensors:

- Linearity: A sensor is linear over a wide range of currents or voltages. One single current sensor can be used, for example, for switchgear rated from 40 A to 1250 A and one voltage sensor can be used for primary rated voltages from 7.2 kV to 17.5 kV. Order-specific calculation and design for various primary currents is not necessary.
- No saturation: The linearity extends up to the highest values of currents or voltages. Calculation of accuracy limit factor (or instrument security factor) for various applications is not necessary.
- No accuracy versus burden calculation: eVD4 sensors are tested and delivered including all the specific signal cable connections to the IED analog input. The impedance of the protection and control IED is high enough to have no significant influence on the accuracy of the sensor. No additional wires are

needed to connect the sensors as well as no interconnection and wiring work is required for proper sensor operation.

- Transmitted signal: The nominal value of the transmitted signal is low enough to be harmless to the secondary equipment and people, even when the highest currents and voltages occur on the primary side. A broken circuit or short circuit in the signal cable causes no hazards or damage, thus providing highest level of safety.
- Overvoltage and disturbance withstand: Voltage sensors do not need to be disconnected for voltage testing at power frequency on the switchgear. Due to the absence of iron, no saturation occurs. Current sensors provide a low and safe output even during the short circuit currents. Both sensing elements are capable to provide a reliable and accurate response to transients.

Sensors are designed, manufactured and tested by ABB according to the latest international standards in the field when they are applicable.

Table 380: Different standards used

Instruments	Standards
Voltage sensors	IEC 60044-7 (1999-12)
Instrument transformers	Part 7: electronic voltage transformers
Current sensors	IEC 60044-8 (2002-07)
Instrument transformers	Part 8: electronic current transformers

11.2 Power connection diagram

As an example, Figure 265 shows the typical connection diagram of the phase current and phase voltage sensors (with an integrated temperature measurement) and of the optional residual current transformer for a generic feeder.

All analog signal connections from current and voltage sensors are tested on eVD4 during the factory routine tests, verifying sensor ratio and the wiring all the way through from the primary system to the IED.

Dotted lines refer to the customer installation. Therefore, the residual current CT must be connected in accordance with the terminal diagram provided with the IED, with respect to both phases and polarity, to the dedicated pins in the switchgear socket installation.

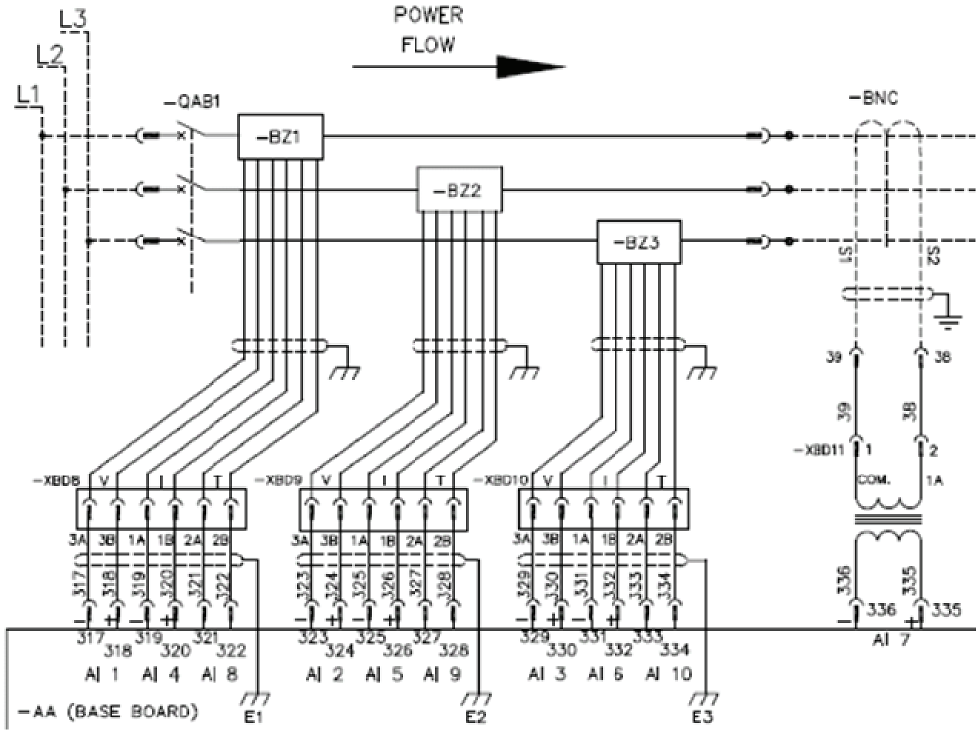


Figure 265: Power connection diagram

See the schematic drawings 1VCD400106 for the withdrawable version and 1VCD400137 for the fixed version.

11.3 Current sensor accuracy class and accuracy limit factor

The eVD4 current sensor is capable to fulfill the requirements for both metering and protection purposes by one single unit. Therefore, the current sensors are designed for the accuracy class 1/5P. Accuracy class 1 is for measurement functions - current metering, power metering, and so on. 5P is for protection functions.

Table 381: Current error limits specified by IEC 60044-8 for measuring purposes

Accuracy class	± Percentage current (ratio) error at the percentage of the rated current shown below				± Phase error at the percentage of the rated current shown below							
					Minutes				Centiradians			
	5	20	100	120	5	20	100	120	5	20	100	120
1.0	3.0	1.5	1.0	1.0	180	90	60	60	5.4	2.7	1.8	1.8

Table 382: Current error limits specified by IEC 60044-8 for protection purposes

Accuracy class	Current error at the rated primary current %	Phase error at the rated primary current		Composite error at the rated accuracy limit primary current (%)	At accuracy limit condition Maximum peak instantaneous error %
		Minutes	Centiradians		
5 P	±1	±60	±1.8	5	-

For the measuring electronic current transformers, the accuracy class is designated by the highest permissible percentage current error at a rated current prescribed for the accuracy class concerned, that is, 1 percent current error up to 120 percent of the rated current (or nominal primary current I_{1n}).

For the protective electronic current transformers, the accuracy class is designed with a highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection), that is, 5 percent composite (phase and current) error up to the rated accuracy limit primary current In case of eCB sensors, the accuracy is measured up to the rated accuracy limit primary current 7.5 kA and the sensors reached an accuracy well below the limit values.

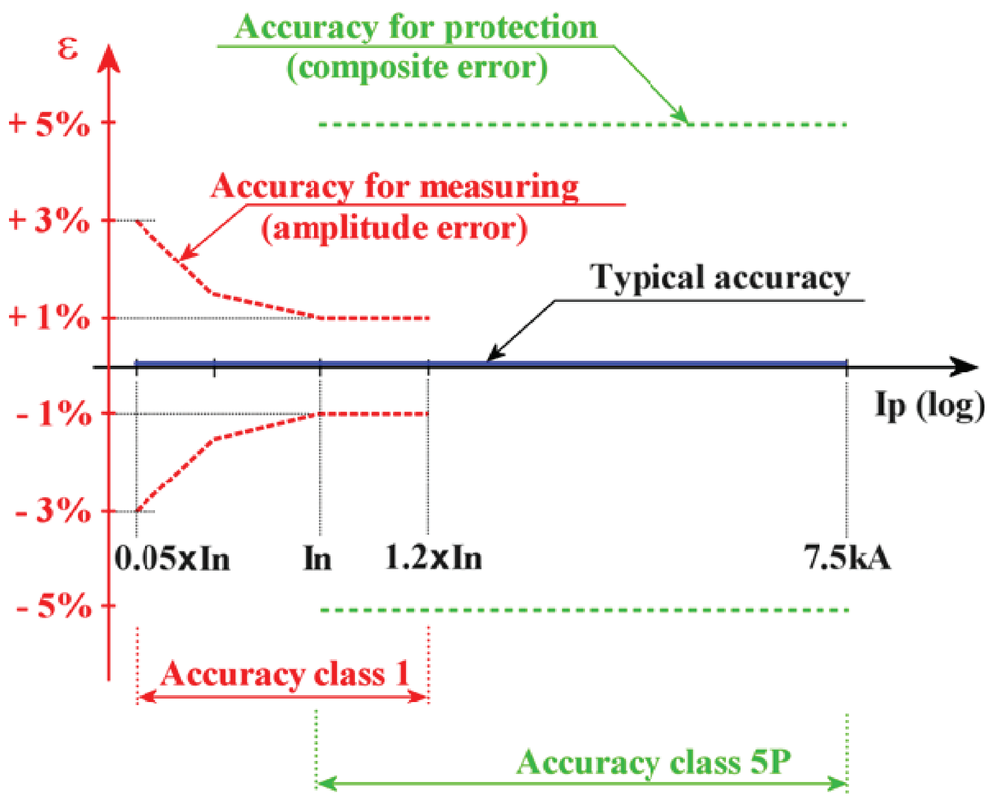


Figure 266: Current accuracy limits for class 1/5P

Correction factor: The amplitude error of current sensors is in practice constant and independent of the primary current. Hence, due to the possibility of correcting the error to 0 percent to reach an accuracy at the rated conditions much better than the required, the error is corrected in the IED by using a correction factor, measured separately for every sensor during routine tests, and stored in the IED in the eVD4 assembly process.

11.4 Voltage sensor accuracy class

Similar to the current sensor, the eVD4 current voltage sensor is capable to fulfill the requirements for both metering and protection purposes by one single unit. Therefore, the voltage sensors are designed for an accuracy class 1/3P. Accuracy class 1 is for measurement functions - voltage metering, power metering, and so on. 3P is for voltage protection functions.

Table 383: Voltage error limits specified by IEC 60044-7 for measuring purposes

Accuracy class	ε_u Percentage voltage (ratio) error ±	φ_e Phase error ±	
		Minutes	Centiradians
1.0	1.0	40	1.2

Table 384: Voltage error limits specified by IEC 60044-7 for protection purposes

Accuracy class	U_p/U_{pn} %								
	2			5			x 1)		
	ε_u ±	φ_e ±	φ_e ±	ε_u ±	φ_e ±	φ_e ±	ε_u ±	φ_e ±	φ_e ±
3 P	6	240	7	3	120	3.5	3	120	3.5

1) x is the rated voltage factor multiplied by 100.

For the measuring electronic voltage transformers, the accuracy class is designated with the highest permissible percentage voltage error at the rated voltage prescribed for the accuracy class concerned, that is, 1 percent voltage error up to 120 percent of the rated voltage. The voltage error and phase displacement at the rated frequency shall not exceed the values given above at any voltage between 80 percent to 120 percent of the rated voltage.

For the protective electronic voltage transformers, the accuracy class is designated by the highest permissible voltage error from 2 or 5 percent of the rated voltage up to the voltage corresponding to the rated voltage factor prescribed for the accuracy class concerned and followed by the letter "P" (meaning protection), that is, 3 percent voltage error up to the upper voltage limit, that is, the voltage corresponding to the rated voltage factor 1.9.

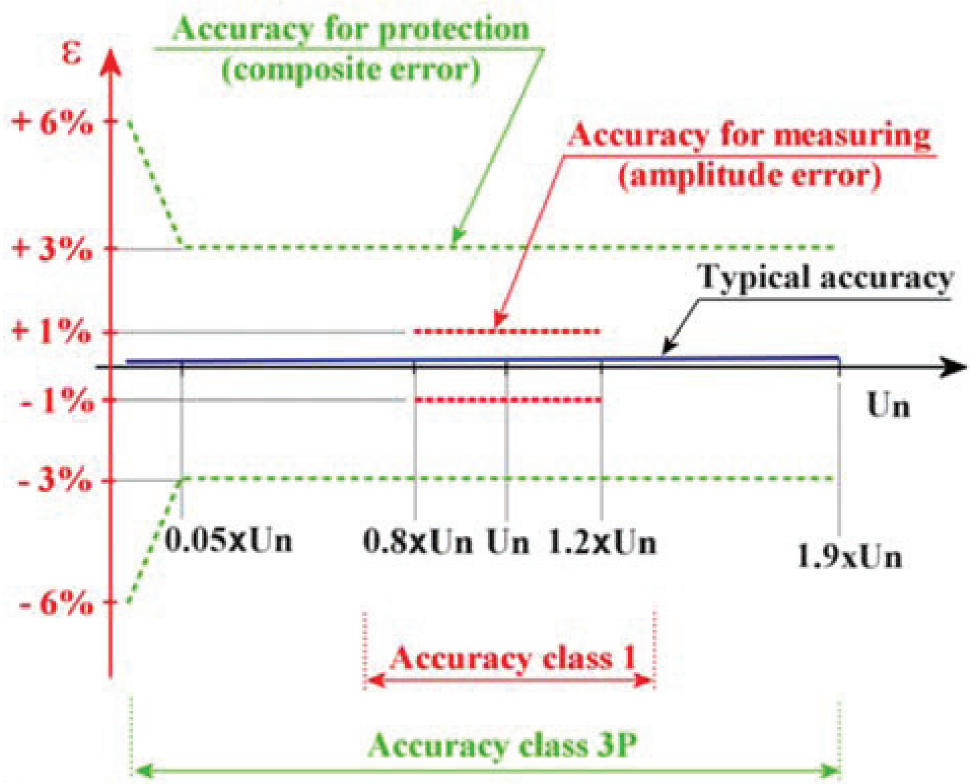


Figure 267: Voltage accuracy limits for class 1/3P

The voltage measurement provided by the voltage divider depends on the temperature of the sensor. The IED acquires the temperature of the voltage sensor (capacitive voltage divider) by an integrated temperature sensor. The temperature value of each of the three voltage dividers is used to increase the precision of the voltage measurement on the basis of the thermal characteristic of the voltage sensor itself.

Correction factor: The amplitude error of the voltage sensors is in practice constant and independent of the primary voltage. Hence, due to the possibility of correcting the error down to 0 percent to reach an accuracy at the rated conditions much better than the required, the error is corrected in the IED by using a correction factor measured separately for every sensor during routine tests and stored in the IED in the eVD4 assembly process.

11.5 Residual current transformer accuracy class

eVD4 enables the residual current measuring and protection functions either based on internal computation [3] from the measured phase currents or from the direct measurement supported by an optional residual current transformer.

The latter method is preferred when a higher accuracy is required as in networks with a high-resistance, compensated or isolated neutral point where low-amplitude earth-fault currents occur and an earth-fault start current setting may be needed in a few amperes range.

When the residual current transformer is used, the CT has to be chosen carefully to avoid distortion of the secondary current due to a saturated CT, which can endanger; selectivity and coordination of protection.

Due attention is needed to ensure that the residual CT polarity is according to the connection diagram so that the direction of the secondary current flow is correct for a given direction of the primary current flow. This is essential for the proper operation of the directional function, protection and measurement in the IED. See the schematic drawing 1VCD400106 for the withdrawable version and 1VCD400137 for the fixed version.

If the residual CT secondary circuit is accidentally opened when a primary current is flowing, a high voltage appears at the secondary terminals. The voltage can break the insulation and is dangerous to personnel. In general, open circuit of the secondary terminals is considered as a serious accident.

In the withdrawable eVD4 execution, the XB connector sectionalizes the residual CT (-BNC dedicated pins 38, 39) secondary circuit only when the CB is in the withdrawn position [4] and the primary circuit is sectionalized. In the fixed eVD4 execution, care is provided to ensure the XB connector cannot be sectionalized if the CB is not open and the primary circuit is sectionalized, to avoid a potentially dangerous high voltage at the secondary terminals.

[3] Residual or earth-fault current is calculated from the vectorial sum of the three-phase currents. This can be done in networks with low-resistance neutral earthing in which large zero-sequence currents occur.

[4] ABB switchgear as UniGear and PowerBox provide a safety mechanical interlock to prevent the XB connector operation with CB in the service position.

Table 385: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at the rated accuracy limit primary current (%)	Ratio error at 5 percent of the rated primary current (%)
		Minutes	Centiradians		
5 P	±1	±60	±1.8	5	-
10 P	±3	-	-	10	-

The accuracy classes 5P and 10P are suitable for residual current protection. The 5P class provides a better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering and so on) of the IED.

The accuracy limit factor is the ratio of the rated accuracy limit primary current to the rated primary current (or nominal primary current I_{1n}). For example, a protective current transformer of the type 5P10 has the accuracy class 5P and the accuracy limit factor 10.

The CT accuracy limit primary current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it can have severe effects on the performance of the protection relay. As residual CTs are used when the earth-fault current is low, saturation cannot be the case.

More important is the behavior of the residual CT during the high-current three-phase faults that may induce saturation due to cable positioning and cause a false earth-fault indication. Cable positioning and the choice of the CT must be careful to avoid such a case.

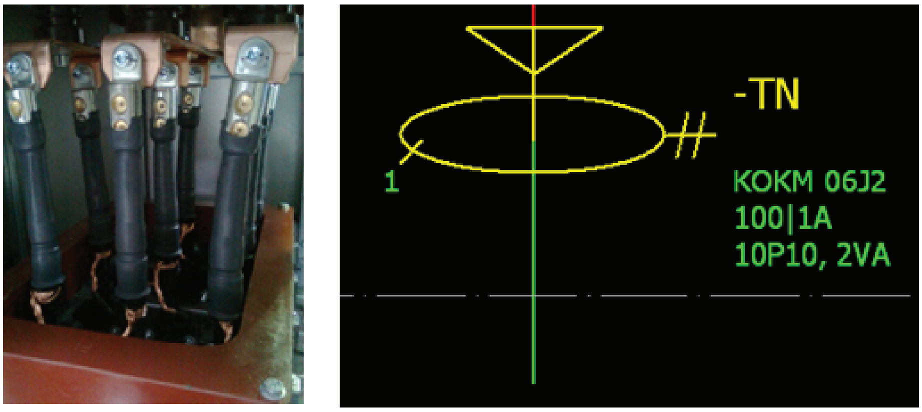


Figure 268: Behavior of the residual current transformer

Residual CT may be chosen out of ABB range "**CABLE CURRENT TRANSFORMERS KOKM 1_ /KOKM 06 J_ /KOKU 072 G4/ KOLA 06 J2" Catalogue 1YMA699100-en**

11.6 Analog value measurement

The high-precision IED analog input channels allow the acquisition and processing of three-phase currents through the current sensors fitted on the circuit breaker contact arms and a residual current (if an optional residual current transformer is present). Current sensor output is proportional to the frequency, but the IED processes the amplitude of the signals as a function of mV/Hz, that is, independently from the rated network frequency.

In applications where voltage functions are needed, combined current and voltage sensors provide the additional three-phase voltage signals.

All protection functions are based on at least one of the four alternative measurement modes: "RMS" including all harmonic contents, "DFT" is based on the network frequency only, "Peak-to-Peak" and "P-to-P + backup". The measurement mode is selected with the *Measurement mode* setting in a specific protection setting.

In eVD4, due to the high sensor linearity, the actual operational limit is given by the saturation of the IED signal dynamic that occurs well above 40 times the sensor nominal primary current I_{1n}, that is, above the maximum settable start current value for current protections.

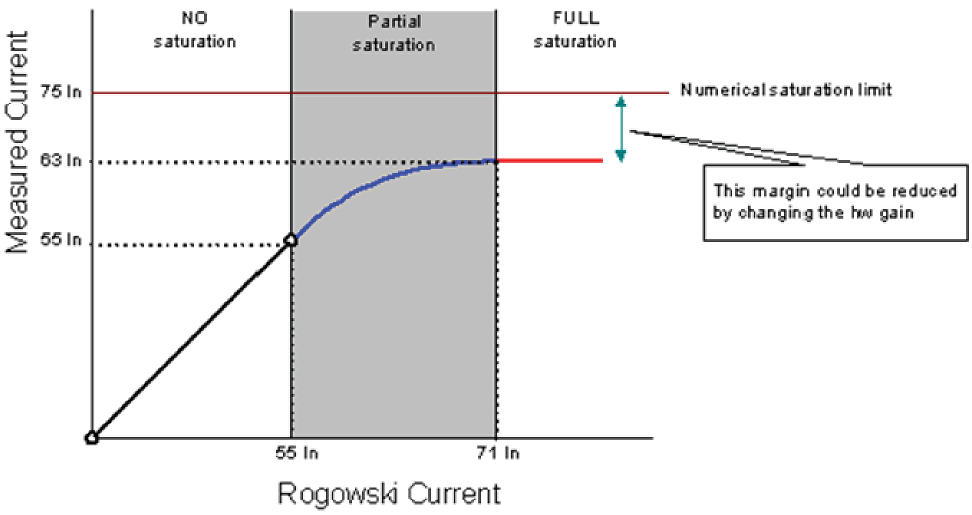


Figure 269: Measured current versus Rogowski current

The saturation effect of the IED signal dynamic occurs well above the maximum settable start current value and therefore does not affect the current protection functionality. It can affect the trip value recorded at the protection operation if the value exceeds the "no saturation" area.

The IED signal dynamic depends on the quantity "Nominal Current" In, that is, the load current for a feeder. Such a parameter is set in the IED at a commissioning based on the feeder application and the IED dynamic is automatically scaled to provide best accuracy of the measurement chain from 5 percent of In to above 40 times the value of In.

When In is smaller than the sensor rated current, it is not possible to use all the setting range for the settable start current value. It is then suggested to use maximum settable start current value (40 In) less than the sensor nominal primary current (40 I_{1n}), or the operation may enter the saturation area. Such a limitation has no significant influence on the operational condition as 40 times the rated load current setting for a feeder covers all possible fault conditions.

11.7 Example for overcurrent, overvoltage and earth-fault protection

The protection is implemented as:

- three-stage definite time non-directional overcurrent protection.
- two-stage definite time earth-fault non-directional overcurrent protection.
- one-stage definite time overvoltage protection.

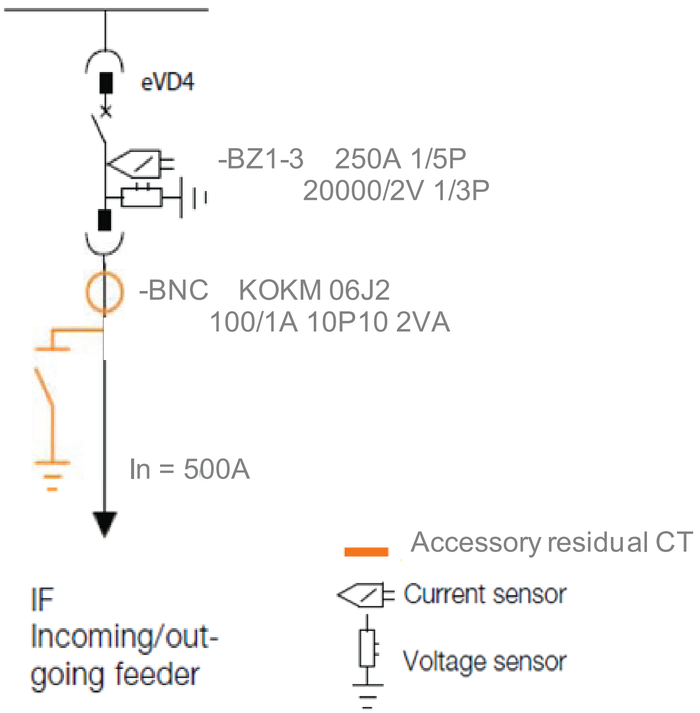


Figure 270: A typical medium-voltage feeder in a 10kV network

The maximum three-phase fault current is 15.7 kA and the minimum three-phase short circuit current is 10.8 kA [5] , depending on the fault location in the protected system.

The network is managed with a compensated neutral point, so minimum earth-fault current is 4 A and maximum is 200 A when the system compensation is "Off" and returns to the insulated neutral point operation.

Overvoltage protection is set to avoid unsafe operational condition due to the voltage fluctuations on the long supplying distribution line. Maximum overvoltage can be expected at 13kV.

The start current setting for the low-set stage (3I>) is selected to be more than twice the nominal current In of the cable. The operate time is selected so that it is selective with the next relay.

The settings for the high-set stage and instantaneous stage are defined so that the coordination is ensured with the downstream protection.

In addition, the start current settings have to be defined so that the IED operates with the minimum fault current and it does not operate with the maximum load current.

Table 386: Settings for all stages

	Start value	Multiplier to rated value In, Un	-BZ1-2-3		-BNC
I1n, U1n			250A	20000/2V	100A
accuracy			1/5P	1/3P	10P
3I>	1200A	2.4	4.8		
3I>>	1800A	3.6	7.2		
3I>>	3500A	7	14		
3V>	12000/sqrt(3)	1.2		0.6	
I0>	2A				0.02
I0>>	140A				1.4
min fault I	10,8kA	21.6	43.2		
max fault I	15,7kA	31.4	62.8		
max fault V	13kV	1.3		0.65	

From the application, the suitable setting for the instantaneous stage (I>>>) in this example is 3500 A (14 x I_{1n} primary sensor current), that is, seven times the rated

[5] With a nominal primary sensor current I_{1n} = 250 A the 40 times maximum settable start current range covers up to 10 kA, that is, it is possible to set a protection stage right below the minimum three-phase short circuit value of 10.8 kA. With the feeder load current, that is, "Nominal Current" In, at 500 A the IED signal dynamic exceeds 40 In above 20 kA, so both minimum and maximum three-phase short circuit value of 10.8 kA and 15.7 kA are in the "no saturation" area and correctly measured at a trip.

feeder current In. Therefore, it needs the fastest possible clearance and still less than the minimum fault current level foreseen in the system.

Section 12 IED physical connections

All external circuits are connected to the terminals on the IED through the circuit-breaker plug. Connect all terminals with 1 mm^2 wires, except the residual earth CT connections which require 2,5 mm^2 wires.

12.1 Communication connections

The front communication connection is an RJ-45-type connector used mainly for configuring and setting. There are three available rear communication connections.

- Galvanic RJ-45 Ethernet connection
- Optical LC Ethernet connection
- EIA-485 serial connection

12.1.1 Ethernet RJ-45 front connection

The connector is mainly for configuration and setting purposes. The interface on the PC side has to be configured in a way that it obtains the IP address automatically. There is a DHCP server inside IED for the front interface only.

The events and setting values and all input data such as memorized values and disturbance records can be read via the front communication port.

Only one of the possible clients can be used for parametrization at a time.

- PCM600
- LHMI

The default IP address of the IED through this port is 192.168.0.254.

The front port supports TCP/IP protocol. A standard Ethernet CAT 5 crossover cable is used with the front port.

12.1.2 Ethernet rear connections

The Ethernet communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection. The communication channels can be accessed from the plug of the circuit breaker. A shielded twisted-pair cable CAT 5e is used with the RJ-45 connector and an optical multi-mode cable (≤ 2 km) with the LC type connector.

The IED's default IP address through this port is 192.168.2.10 with the TCP/IP protocol. The data transfer rate is 100 Mbps.

12.1.3 EIA-485 serial rear connection

The EIA-485 communication module follows the TIA/EIA-485 standard and is intended to be used in a daisy-chain bus wiring scheme with 2-wire half-duplex or 4-wire full-duplex, multi-point communication.

The maximum number of devices (nodes) connected to the bus where the IED is used is 32, and the maximum length of the bus is 1200 meters.

12.1.4 Communication interfaces and protocols

Table 387: Supported station communication interfaces and protocols

Interfaces/Protocols	Ethernet		Serial
	100BASE-TX RJ-45	100BASE-FX LC	EIA-232/EIA-485
IEC 61850	●	●	-
MODBUS RTU/ASCII	-	-	●
MODBUS TCP/IP	●	●	-
DNP3 (serial)	-	-	-
DNP3 TCP/IP	-	-	-
IEC 60870-5-103	-	-	-
● = Supported			

12.1.5 Recommended industrial Ethernet switches

ABB recommends three third-party industrial Ethernet switches.

- RuggedCom RS900
- RuggedCom RS1600
- RuggedCom RSG2100

Section 13 Technical data

Table 388: HMI dimensions

Description	Value
Width	223 mm
Height	180 mm
Depth	34.5 mm
Weight	1.05 kg

Table 389: Power supply

Description	High voltage	Low voltage
U_{aux}nominal	110, 125, 220, 250 V DC	48, 60 V DC
U_{aux}variation	75...110% of U_n (82.5...275 V DC)	75...110% of U_n (38.4...66 V DC)
Start-up threshold		38.4 V DC (48 V DC * 80%)
Burden of auxiliary voltage supply under quiescent (P_q)/ operating condition	DC < 15 W (nominal)/< 150 W (max)	DC < 15 W (nominal)/< 150 W (max)
Ripple in the DC auxiliary voltage	Max 12% of the DC value (at frequency of 100 Hz)	
Maximum interruption time in the auxiliary DC voltage without resetting the IED	110 V DC: 50 ms	48 V DC: 50 ms

Table 390: Binary inputs

Description	Value
Operating range	±20% of the rated voltage
Rated voltage	48...250 V DC
Current drain	1.6...1.9 mA
Power consumption	31.0...570.0 mW
Threshold voltage	36...176 V DC
Reaction time	10 ms

Table 391: Signal outputs and IRF output

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A

Table continues on next page

Description	Value
Make and carry 0.5 s	15 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 392: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front (on the LHMI)	TCP/IP protocol	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s
Rear (on the plug)	TCP/IP protocol	Shielded twisted pair CAT 5e cable with RJ-45 connector	100 MBits/s

Table 393: Degree of protection of the LHMI

Description	Value
Front side	IP 20

Table 394: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)[1)]
Relative humidity	<93%, non-condensing
Atmospheric pressure	86...106 kPa
Transport and storage temperature range	-40...+85ºC

1) Degradation in MTBF and HMI performance outside the temperature range of -25...+55ºC

Table 395: Environmental tests

Description	Type test value	Reference
Dry heat test (humidity <50%)	• 16 h at +55ºC • 16 h at +70ºC	IEC 60068-2-2
Dry cold test	• 24 h at -30ºC	IEC 60068-2-1 ANSI C37.09
Damp heat test, cyclic	• 96 h at +40°C, humidity >85% • 48 h at +40°C, humidity >96%	IEC 60068-2-78

Section 14 IED and functionality tests

Table 396: Electromagnetic compatibility tests

Description	Type test value	Reference
1 MHz/100 kHz burst disturbance test: • Common mode • Differential mode	 2.5 kV 1 kV	IEC 61000-4-18 IEC 60255-22-1, class III
Electrostatic discharge test: • Contact discharge • Air discharge	 8 kV (IED) 6 kV (HMI) 15 kV (IED) 8 kV (HMI)	IEC 61000-4-2 IEC 60255-22-2
Radio frequency interference tests: • Conducted, common mode • Radiated, amplitude-modulated	 10 V (rms) f=150 kHz-80 MHz 10 V/m (rms) f=80-3000 MHz	 IEC 61000-4-6 IEC 60255-22-6, class III IEC 61000-4-3 IEC 60255-22-3, class III
Fast transient disturbance tests: • Communication port • Remaining port	 2 kV 4 kV	 IEC 61000-4-4 IEC 60255-22-4, level 3 IEC 61000-4-4 IEC 60255-22-4, level 4
Surge immunity test: • Binary inputs • Communication • Other ports	 4 kV, line-to-earth 2 kV, line-to-line 2 kV, line-to-earth 4 kV, line-to-earth 2 kV, line-to-line	IEC 61000-4-5 IEC 60255-22-5, level 4/3
Power frequency (50 Hz) magnetic field: • Continuous • 1s short duration	 100 A/m 1000 A/m	IEC 61000-4-8, level 5
Voltage dips and short interruptions	100%/100 ms	IEC 61000-4-11
Power frequency immunity test: • Common mode	 30 V rms continuous 300 V rms 1 s	IEC 61000-4-16 IEC 60255-22-7, level 4/3

Table continues on next page

Description	Type test value	Reference
• Differential mode	15 Hz-150 kHz 1 V-10 V	
Emission tests: • Conducted, RF-emission (mains terminal) 0.15-0.50 MHz 0.5-30 MHz • Radiated, RF-emission 30-230 MHz 230-1000 MHz	 < 79 dB(μV) quasi peak < 66 dB(μV) average < 73 dB(μV) quasi peak < 60 dB(μV) average < 50 dB(μV/m) quasi peak, measured at 3 m distance < 57 dB(μV/m) quasi peak, measured at 3 m distance	EN 55011 CISPR 11, Group 1, Class A

Table 397: Insulation tests

Description	Type test value	Reference
Dielectric tests • Test voltage	 2 kV, 50 Hz, 1 min 500 V, 50 Hz, 1 min, communication	IEC 60255-5 and IEC 60255-27
Impulse voltage test • Test voltage	 5 kV, 1.2/50 μs, 0.5 J 1 kV, 1.2/50 μs, 0.5 J, communication	IEC 60255-5 and IEC 60255-27

Table 398: EMC compliance

Description	Reference
EMC directive	2004/108/EC
Standard	EN 50263 (2000) EN 60255-26 (2007)

Section 15 Applicable standards and regulations

EN 50263

EN 60255-26

EN 60255-27

EMC council directive 2004/108/EC

EU directive 2002/96/EC/175

IEC 60255

Low-voltage directive 2006/95/EC

IEC 62271–1

IEC 61850

Section 16 Glossary

100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
CAT 5	A twisted pair cable type designed for high signal integrity
CAT 5e	An enhanced version of CAT 5 that adds specifications for far end crosstalk
CBB	Cycle building block
CT	Current transformer
DFT	Discrete Fourier transform
DHCP	Dynamic Host Configuration Protocol
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DT	Definite time
EIA-232	Serial communication standard according to Electronics Industries Association
EIA-485	Serial communication standard according to Electronics Industries Association
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
Firmware	System software or hardware that has been written and stored in a device's memory that controls the device
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
IDMT	Inverse definite minimum time
IEC 60870-5-103	Communication standard for protective equipment; A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IED	Intelligent electronic device
IP	Internet protocol

IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
LAN	Local area network
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
NPS	Negative phase sequence
PC	Personal computer; Polycarbonate
PCM600	Protection and Control IED Manager
Peak-to-peak	The amplitude of a waveform between its maximum positive value and its maximum negative value; A measurement principle where the measurement quantity is made by calculating the average from the positive and negative peak values without including the DC component. The peak-to-peak mode allows considerable CT saturation without impairing the performance of the operation.
Peak-to-peak with peak backup	A measurement principle similar to the peak-to-peak mode but with the function starting on two conditions: the peak-to-peak value is above the set start current or the peak value is above two times the set start value
R/L	Remote/Local
RCA	Also known as MTA or base angle. Characteristic angle.
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
SBO	Select-before-operate
SCL	XML-based substation description configuration language defined by IEC 61850
SD	Secure digital
SLD	Single-line diagram
SMT	Signal Matrix tool in PCM600
SNTP	Simple Network Time Protocol
SOTF	Switch on to fault

TCP/IP	Transmission Control Protocol/Internet Protocol
VI	Vacuum interrupter
WAN	Wide area network
WHMI	Web human-machine interface

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