RELION® PROTECTION AND CONTROL

REX610

Technical Manual

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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 protection relays. The installation and commissioning personnel must have a basic knowledge in handling electronic equipment.

1.3 Product documentation

1.3.1 Product documentation set

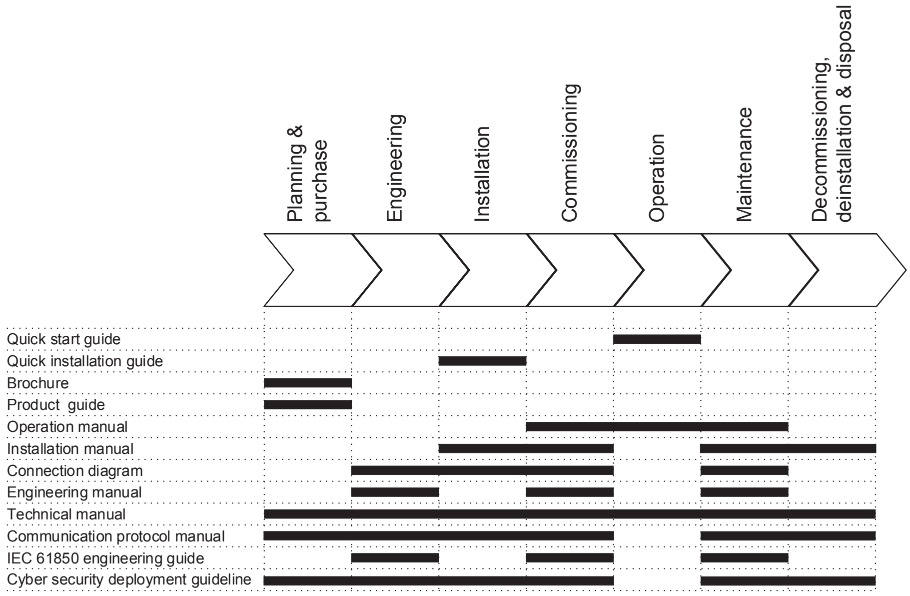

Figure 1: The intended use of documents during the product life cycle

1.3.2 Document revision history

Document revision/date	Product version	History
A/2022-04-21	1.0	First release
B/2022-06-29	1.0	Content updated

1.3.3 Related documentation

Download the latest documents from the ABB Web site 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 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 .
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile 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".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.
- Values of quantities are expressed with a number and an SI unit. The corresponding imperial units may be given in parentheses.

- This document assumes that the parameter setting visibility is "Advanced".
- A functional earth terminal is indicated in figures with the symbol ⏚.
- Equipment protected throughout by double insulation or reinforced insulation (equivalent to class II of IEC 61140) is indicated in figures with the symbol ⧈.

1.4.3 Functions, codes and symbols

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

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
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
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67P/51P-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67P/51P-2
Non-directional earth-fault protection, low stage	EFLPTOC	Io>	51G/51N-1
Non-directional earth-fault protection, high stage	EFHPTOC	Io>>	51G/51N-2
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	Io>>>	50G/50N
Directional earth-fault protection, low stage	DEFLPDEF	Io> ->	67G/N-1 51G/N-1
Directional earth-fault protection, high stage	DEFHPDEF	Io>> ->	67G/N-1 51G/N-2
Three-phase inrush detector	INRPHAR	3I2f>	68HB
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	3Ith>F	49F
Negative-sequence overcurrent protection	NSPTOC	I2>M	46M
Phase discontinuity / Single phasing protection for motor	PDNSPTOC	I2/I1>	46PD
Loss of phase, undercurrent	PHPTUC	3I<	37
Three-phase undervoltage protection	PHPTUV	3U<	27
Three-phase overvoltage protection	PHPTOV	3U>	59

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Residual overvoltage protection	ROVPTOV	Uo>	59G/59N
Circuit breaker failure protection	CCBRBRF	3I>/Io>BF	50BF
Master trip	TRPPTRC	Master Trip	94/86
Multipurpose protection	MAPGAPC	MAP	MAP
Control			
Circuit-breaker control	CBXCBR	I <-> O CB	52
Disconnector position indication	DCSXSWI	I <-> O DC	29DS
Earthing switch position indication	ESSXSWI	I <-> O ES	29GS
Autoreclosing	DARREC	O -> I	79
Condition monitoring and supervision			
Trip circuit supervision	TCSSCBR	TCS	TCM
Fuse failure supervision	SEQSPVC	FUSEF	VCM, 60
Circuit-breaker condition monitoring	SSCBR	CBCM	52CM
Current circuit supervision	CCSPVC	MCS 3I	CCM
Measurement			
Three-phase current measurement	CMMXU	3I	IA, IB, IC
Residual current measurement	RESCMMXU	Io	IG
Sequence current measurement	CSMSQI	I1, I2, I0	I1, I2, I0
Three-phase voltage measurement	VMMXU	3U	VA, VB, VC
Residual voltage measurement	RESVMMXU	Uo	VG/VN
Traditional LED indication			
Programmable LED control	LED	LED	LED
Logging functions			
Disturbance recorder (common functionality)	RDRE	DR	DFR
Disturbance recorder, analog channels 1…8	A1RADR	A1RADR	A1RADR
Disturbance recorder, binary channels 1...32	B1RBDR	B1RBDR	B1RBDR
Communication protocols			
IEC 61850-8-1 MMS	MMSLPRT	MMSLPRT	MMSLPRT
IEC 61850-8-1 GOOSE	GSELPRT	GSELPRT	GSELPRT
Modbus protocol	MBSLPRT	MBSLPRT	MBSLPRT

Section 2 REX610 overview

2.1 Overview

REX610 is a freely configurable all-in-one protection relay that covers the full range of basic power distribution applications, without forgoing simplicity. The small number of variants translates into easy ordering, setup, use and maintenance. Although rich in functionality, REX610 represents a cost-effective choice. The fully modular hardware, unlocking all available functionality, and continuous access to new developments allow easy and flexible customization, modification and adaptation to changing protection and communication requirements at any time.

REX610 is a member of the renowned Relion® protection and control family of relays, building on ABB’s strong heritage of freely configurable multifunctional relays and many proven protection algorithms.

2.1.1 Product version history

Product version	Product history
1.0	Product released

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.11 or later
- REX610 Connectivity Package Ver.1.0 or later

Download connectivity packages from the ABB Web site abb.com/mediumvoltage or directly with Update Manager in PCM600.

2.2 Relay hardware

The relay has mandatory and optional slots. A mandatory slot always contains a module but an optional slot may be empty, depending on the composition variant ordered.

Table 2: Module slots

Module	Slot A1	Slot A2	Slot B	Slot C1	Slot C2	Slot D1	Slot D2
AIC2001				o			
AIC2002				o			
AIU2001							o
COM2001		●					
DIO2001			●				
PSU2001	●						
● = Mandatory to have the modules in the slot o = Optional to have one of the allocated modules in the slot							

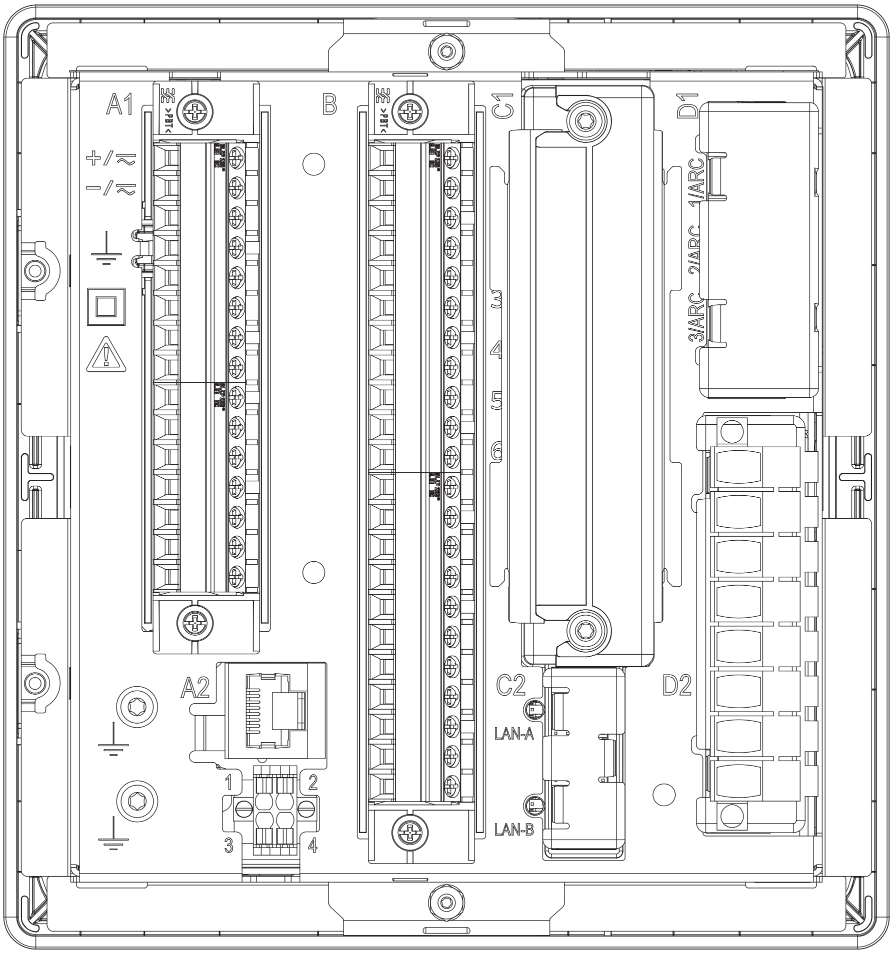

Figure 2: Hardware module slot overview of the REX610 relay

Table 3: Module description

Module	Description
AIU2001	Analog input 4 × VT compression
AIC2001	Analog input 4 × CT compression
AIC2002	Analog input 4 × CT ring lug
PSU2001	24...250 VDC / 48...240 VAC + 2 × PO
DIO2001	Digital I/O 6 × BI + 4 × SO
COM2001	1 × RJ-45 + 1 × RS-485
PO = Power Output SO = Signal Output	

The relay has a nonvolatile memory which does not need any periodical maintenance. The nonvolatile memory stores all events, recordings and logs to a memory which retains data if the relay loses its auxiliary supply.

2.3 Local HMI

The LHMI is used for setting, monitoring and controlling the protection relay. The LHMI comprises the display, buttons, LED indicators and communication port.

Figure 3: Example of the LHMI

2.3.1 Display

The LHMI includes a graphical display 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 4: Display

Character size 1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20

1) Depending on the selected language

The display view is divided into four basic areas.

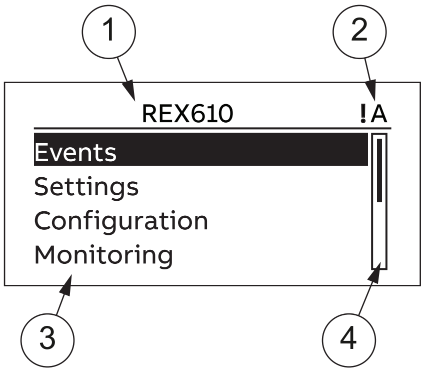

Figure 4: Display layout

1 Header

2 Icon

3 Content

4 Scroll bar (displayed when needed)

2.3.2 LEDs

The LHMI includes three protection indicators in the upper-right corner: Ready, Start and Trip.

There are 10 matrix programmable LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI or PCM600.

2.3.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. Using the push buttons, open or close commands can be given to objects in the primary circuit, for example, a circuit breaker. The push buttons are also used to acknowledge alarms and reset indications.

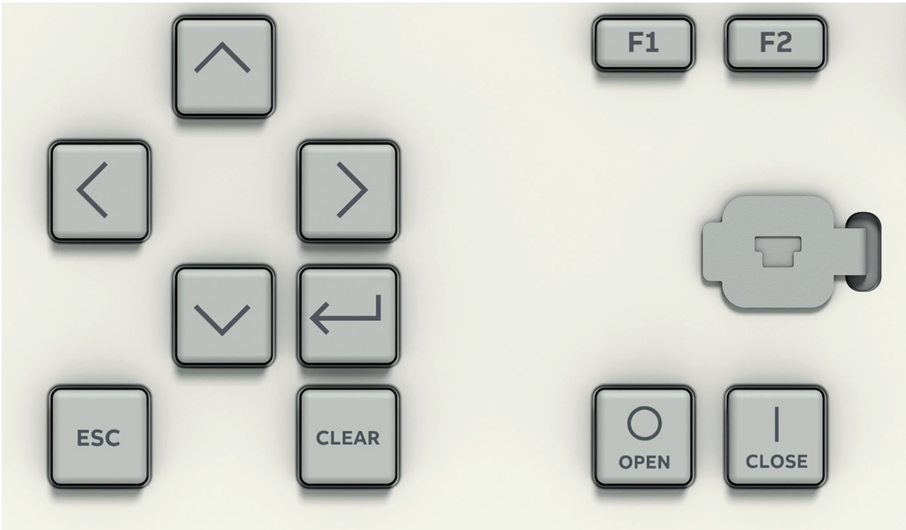

Figure 5: LHMI keypad with object control, navigation and command push buttons and USB communication port

2.4 Authorization

Four factory default user accounts have been predefined, each with different rights and default passwords. The roles for these four user accounts are the same as the username.

- VIEWER
- OPERATOR
- ENGINEER
- ADMINISTRATOR

The default passwords in the protection relay delivered from the factory can be changed with Administrator user rights or by the users themselves.

Each protection relay supports four roles and eight user accounts. Each user can be mapped to only one role.

IED Users in PCM600 is used to manage the local user accounts.

- User accounts can be created under any role.
- Administrator needs to share the default password generated for the user account by the tool with the users and recommend the user to change the password.
- The user accounts' password can be changed by the users from IED Users or from the LHMI.
- Administrator can reset the user passwords.

The user account information is written to the protection relay from IED Users in PCM600. The user account information is securely maintained in a local database in the protection relay.

Any user logging into the protection relay from LHMI or PCM600 (FTPS/USB) is authenticated based on the user account information and this user's rights are defined by the user's role.

Table 5: Default user roles

Role	Description
VIEWER	Viewing what objects are present in the logical device
OPERATOR	Viewing what objects are present in the logical device Performing control operations such as opening or closing the circuit breaker
ENGINEER	Viewing what objects are present in the logical device Making parameter setting and configuration changes in addition to having full access to the data sets and files
ADMINISTRATOR	Superset of all the roles

Table 6 describes the default mapping of all the user rights associated with all the roles in the protection relay. This mapping can be modified according to the user requirements.

Table 6: Default roles-to-rights mapping

Rights/Roles	ADMINISTRATOR	ENGINEER	OPERATOR	VIEWER
Settings & Configuration	Read/Write	Read/Write	Read	Read
Settings Group Handling	Read/Write	Read	Read/Write	Read
Control Operations	Read/Write	Read	Read/Write	Read
Record Handling	Read/Write	Read/Write	Read	Read
Test Mode	Read/Write	Read/Write	Read	Read
System Update	Read/Write	Read	Read	Read
User Management	Read/Write	Read	Read	Read

User account information can be exported from IED Users in PCM600 to an encrypted file which can be imported into another protection relay.

User authorization is disabled by default for LHMI.

For user authorization for PCM600, see PCM600 documentation.

The Administrator user shall not be allowed to delete the last ADMINISTRATOR user and itself. FTP/FTPS logins are done by entering the username and password; there is no role selection required. The highest role for the username is automatically selected by the protection relay. Performing the Restore Factory settings operation in IED Users in PCM600 restores user accounts to the factory user accounts.

2.4.1 Audit trail

The protection relay offers a large set of event-logging functions. Critical system and protection relay security-related events are logged to a separate nonvolatile audit trail for the administrator.

Audit trail is a chronological record of system activities that allows the reconstruction and examination of the sequence of system and security-related events and changes in the protection relay. Both audit trail events and process related events can be examined and analyzed in a consistent method with the help of Event List in LHMI and Event Viewer in PCM600.

The protection relay stores 2048 audit trail events to the nonvolatile audit trail. Additionally, 1024 process events are stored in a nonvolatile event list. Both the audit trail and event list work according to the FIFO principle. Nonvolatile memory is based on a memory type which does not need battery backup nor regular component change to maintain the memory storage.

Audit trail events related to user authorization (login, logout) are defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined user names or user categories. The user audit trail events are accessible from Event Viewer in PCM600.

Table 7: Audit trail events

Event ID	Audit trail event	Description
1110	Login	Successful login from LHMI and PCM600
1210	Logout	Successful logout from LHMI, PCM600 or IEC 61850
1130	Login failure	Login failed for using the wrong user credentials
13200	Configuration transfer	Configuration transferred successfully to the device
1380	Parameter change	Parameter changed successfully
1460	Parameter change fail	Parameter change failed

Table continues on next page

Event ID	Audit trail event	Description
1520	Software update	Software updated successfully
1610	Software update fail	Software update failed
2210	Password change	User password changed successfully
2220	Password change fail	User password change failed
5270	System startup	Software reset
6110	Test on	Test mode started
6120	Test off	Test mode ended
6130	Control operation	Control operation performed successfully
5120	Reset trips	Latched trips reset

PCM600 Event Viewer can be used to view the audit trail events and process related events. Audit trail events are visible through dedicated Security events view. Since only the administrator has the right to read audit trail, authorization must be used in PCM600. The audit trail cannot be reset, but PCM600 Event Viewer can filter data.

2.5 Station communication

Operational information and controls are available through a wide range of communication protocols including IEC 61850 and Modbus®. Full communication capabilities, for example, horizontal communication between the relays, are only enabled by IEC 61850.

The IEC 61850 protocol is a core part of the relay as the protection and control application is fully based on standard modelling. The relay supports Edition 2 version of the standard. With Edition 2 support, the relay has the latest functionality modelling for substation applications and the best interoperability for modern substations.

2.6 Modification Sales

Modification Sales is a concept that provides modification support for already delivered relays. Under Modification Sales it is possible to add protection functions by adding a hardware module. The same options are available as when a new relay variant is configured and ordered from the factory: it is possible to add new hardware modules into empty slots or change the type of the existing modules within the slots.

Section 3 Basic functions

3.1 General parameters

Table 8: Authorization Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Remote override	0=False 1=True			1=True	Disable authority
Local override	0=False 1=True			1=True	Disable authority

Table 9: Authorization Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Change password				0	Change user password

Table 10: IO-modules Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 hysteresis

Table 11: Ethernet-rear-port Non group settings (Basic)

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 12: System Non group settings (Basic)

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				REX610	Bay name in system

Table 13: System Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
IDMT Sat point	10...50	I/I>	1	50	Overcurrent IDMT saturation point
Enable USB	0=False 1=True			0=False	Enable USB connection

Table 14: HMI Non group settings (Basic)

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			2=Main menu	LHMI default view
Backlight timeout	1...60	min	1	3	LHMI backlight timeout
Autoscroll delay	0...30	s	1	0	Autoscroll delay for Measurements view

Table 15: IEC-61850-8-1-MMS Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset counters	0=False 1=True			0=False	Reset MMS counters

Table 16: MODBUS Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Port	1=COM 1 3=Ethernet - TCP 1			3=Ethernet - TCP 1	Port selection for this protocol instance. Select between serial and Ethernet based communication.
Address	1...254		1	1	Unit address
Write authority	0=Read only 1=Disable 0x write 2=Full access			2=Full access	Selects the control authority scheme
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Client1 IP				0.0.0.0	Sets the IP address of the client1. If set to zero, connection from any client is accepted.
ControlStructPWd 1				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
ControlStructPWd 2				****	Password for control operations using Control Struct mechanism, which is available on 4x memory area.
Parity	0=none 1=odd 2=even			2=even	Parity for the serial connection.
Operation	1=on 5=off			5=off	Enable or disable this protocol instance
Client2 IP				0.0.0.0	Sets the IP address of the client2. If set to zero, connection from any client is accepted.
Reset counters	0=False 1=True			0=False	Reset counters

Table 17: MODBUS Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
TCP port	1...65535		1	502	Defines the listening port for the Modbus TCP server. Default

3.2 Communication

The protection relay supports communication protocols including IEC 61850, Modbus® over TCP and serial RS-485. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices (so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile. Furthermore, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard.

The protection relay can support three simultaneous clients. If PCM600 reserves one client connection, only two client connections are left, for example, for IEC 61850 and Modbus.

3.2.1 Secure communication

The protection relay supports secure communication for file transfer protocol using Transport Layer Security protocol. File transfer client must use explicit FTPS to communicate to the relay.

FTPS is always enabled by default but the relay also supports FTP communication. PCM600 always uses FTPS to communicate with the relay.

It is recommended to always use FTPS communication.

3.2.2 Communication services

3.2.2.1 Ethernet ports

The protection relay allows the use of a rear port IP address for the station ports on the communication module.

The rear port IP network is assigned to a single Ethernet port and it can be used to make separate networks for different communication protocols or, for example, a separate service network for configuration purposes. Multicast station/bus communication, such as GOOSE, is supported on this interface.

The parameters for setting the rear port IP network are located under **Configuration/Communication/Ethernet/Rear port(s)**.

Table 18: Default rear port IP address parameters

Parameter	Option	Default	Description
Configuration/ Communication/ Ethernet/Rear Port{s)/IP address	0.0.0.0	192.168.2.10	IP address for rear port(s)
Configuration/ Communication/ Ethernet/Rear Port{s)/ Subnet mask	0.0.0.0	255.255.255.0	Subnet mask for rear port(s)
Configuration/ Communication/ Ethernet/Rear Port{s)/Mac address	XX-XX-XX-XX-XX-XX	XX-XX-XX-XX-XX-XX	Mac address for rear port(s)

3.2.2.2 USB port (front port)

The protection relay supports the use of a front port (USB port) for device configuration and powering up the relay.

USB communication over the USB port is disabled by default. The *Enable USB* parameter must be set to "True" via **Configuration/System** to enable the USB communication. The authorization for USB communication can be enabled by setting the *Remote Override* parameter to "False" via **Configuration/Authorization/passwords**.

When the device is powered by the USB port, protection functions are disabled.

Device can powered by USB even when the configuration parameter *Enable USB* is set to "False".

When *Remote override* is set to "False", the user is asked to enter username and password on the LHMI when connecting to the relay's front USB port.

Table 19:

Parameter	Option	Default	Description
Configuration/Authorization/passwords/Remote override	True / False	TRUE	Disable authority
Configuration/System/Enable USB	True / False	FALSE	Enable or Disable Communication

3.2.3 Serial port supervision SERLCCH

3.2.3.1 Function block

Figure 6: Function block

3.2.3.2 Functionality

The serial port supervision function SERLCCH represents one serial communication port driver. The device hardware supports one galvanic (RS-485) UART-based communication port. The protection relay uses the port for serial communication protocol links.

The relay supports one serial communication COM1 which corresponds to function block SERLCCH. The COM port driver has its own setting parameters on the HMI under **Configuration/Communication/COM1**.

Output `LNKxLIV` is active (TRUE) whenever characters are received on the serial interface. Output `CHxLIV` is active (TRUE) while complete link frames are received. Both outputs go to FALSE state after 15 seconds of inactivity on the port.

3.2.3.3 Signals

Table 20: SERLCCH Output signals

Name	Type	Description
CH1LIV	BOOLEAN	Communication channel live
LNK1LIV	BOOLEAN	Link status

3.2.3.4 Settings

Table 21: SERLCCH Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Baudrate	1=300 2=600 3=1200 4=2400 5=4800 6=9600[1)] 7=19200[1)] 8=38400 9=57600 10=115200			6=9600	Baudrate
Serial mode	1=RS485 2Wire			1=RS485 2Wire	Serial mode
Reset counters	0=False 1=True			0=False	Resets counters

1) Recommended baud rate for optimum performance

3.2.3.5 Monitored data

Table 22: SERLCCH Monitored data

Name	Type	Values (Range)	Unit	Description
Characters received	UINT32	0...2147483646		Characters received
Parity errors	UINT32	0...2147483646		Number of parity errors
Overrun errors	UINT32	0...2147483646		Number of overrun errors
Framing errors	UINT32	0...2147483646		Number of framing errors

3.2.4 Physical locations of the serial channels

The relay's communication interfaces are located on the lower left side of the protection relay when viewing it from the rear.

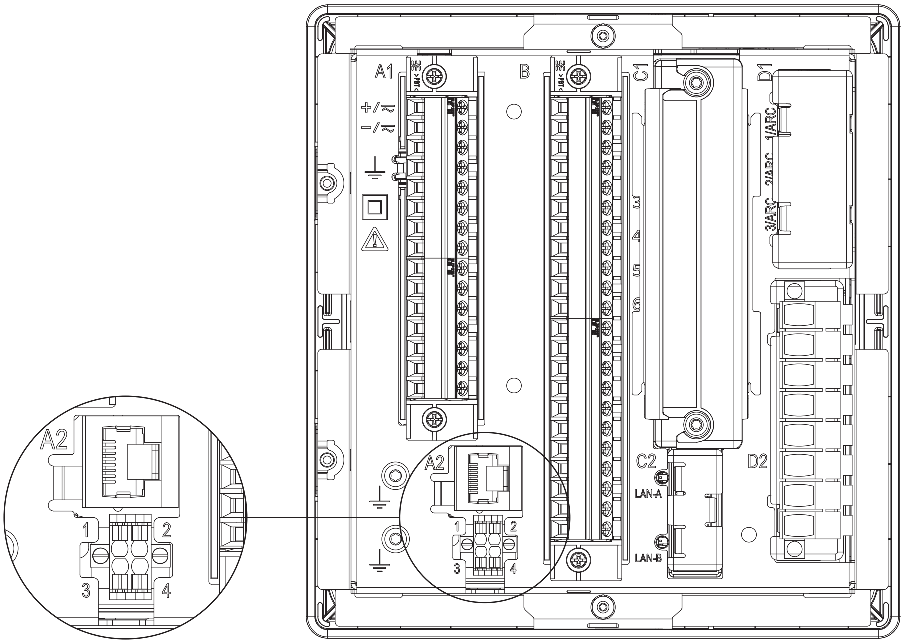

Figure 7: RS-485 4-pin terminal

Table 23: RS-485 connector pins

Pin	RS-485 connector pin signal type
1	A_485 Data signal A (normal)
2	B_485 Data signal B (inverted)
3	SHIELD AC coupled shield pin
4	GND_485 Common pin for A/B

3.2.5 RS-485 bias and termination settings

The isolated RS-485 interface is available at a 3-pin compression type connector X102. It features a bidirectional balanced communication bus (A and B) and a connection for the shield wire/ground reference. Typical connection is through a shielded twisted pair (STP) cable. The RS-485 connection is compliant with TIA/EIA-485. Bus termination can be activated or deactivated though a jumper on the PSU module. Jumper X3 on PSU PCBA provides a user installable termination option. Total termination is 120 Ω if jumper X3 is inserted.

See the installation manual for instructions on how to change termination configuration.

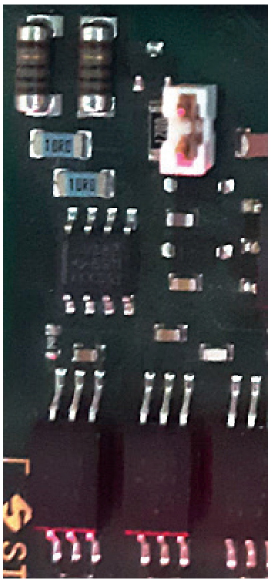

Figure 8: Serial termination jumper

3.2.6 Serial link diagnostics and monitoring

Serial communication diagnostics and monitoring is divided between the serial link driver and the serial communication protocol. The lower level physical and protocol-independent aspects of the UART-based serial communication are monitored in the serial link driver. Diagnostic counters and monitoring values are found via the LHMI in **Monitoring/Communication/COM1**.

Table 24: Setting parameters

Parameter	Description
Serial mode	Used for galvanic RS-485 mode, 2-wire
Baudrate	Communication speed used

Table 25: Monitoring data for COM channel

Parameter or counter	Description
LNKxLIV	TRUE whenever characters are received on the serial interface
CHxLIV	TRUE while complete link frames are received
Characters received	Counts all incoming non-erroneous characters. This counter operates regardless of whether the serial driver is set to detect a whole protocol link frame or just separate characters.
Parity errors	Counts the number of parity errors detected in characters received

Table continues on next page

Parameter or counter	Description
Overrun errors	Counts the number of overrun errors detected in characters received
Framing errors	Counts the number of framing errors detected in characters received
Reset counter	Resets all counters to zero

3.2.7 Modbus protocol MBSLPRT

3.2.7.1 Function block

Figure 9: Function block

3.2.7.2 Functionality

The function block represents a Modbus server protocol instance in the protection relay. Function block settings include communication interface assignment for the instance, that is, Ethernet/TCP or serial.

A Modbus server protocol instance is activated if the function block instance is added to the application configuration. The setting *Operation* should be "On" and setting *Port* should have the communication interface assignment.

The STATUS output of the function block is active if Modbus client requests have been received on the communication interface within 15 seconds.

By default no Modbus data is mapped to the protocol interface. Protocol data has to be created using Communication Management in PCM600. There is only one mapping set provided. Several Modbus protocol instances can point to the same mapping set.

For more information on the Modbus server protocol, see the Modbus communication protocol manual.

3.3 Self-supervision

The protection relay's extensive self-supervision system continuously supervises the relay’s software, hardware and certain external circuits. It handles the run-time fault situation and informs the user about a fault via the LHMI, the relay's main unit power module Ready LED and through the communication channels. The target of the self-supervision is to safeguard the relay’s reliability by increasing both dependability and security. The dependability can be described as the relay’s ability to operate when required. The security can be described as the relay scheme’s ability to refrain from operating when not required. The dependability is increased by letting the system operators know about the problem, giving them a chance to take the necessary actions as soon as possible. The security is increased by preventing the relay from making false decisions, such as issuing false control commands.

There are two types of fault indications.

- Internal faults
- Warnings

Warnings are indications of less severe situations which can also be caused by external reasons such as a missing relay configuration.

The self-supervision page is available under **Main menu/Monitoring/Self-supervision node**. The self-supervision page has the Internal fault and Warning indications. In normal operation, `ALL OK` is displayed for the Internal fault and Warning indications. The self-supervision also controls the status of IRF output relay. The IRF output relay is energized under normal conditions and de-energized under internal fault conditions.

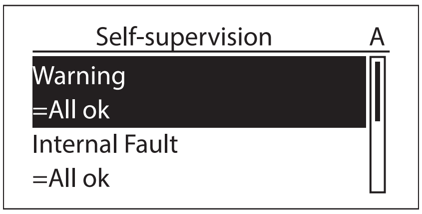

Figure 10: Relay self-supervision status on local HMI

In addition, the boot reason is available in the audit trail events in Event Viewer in PCM600 under the Security events.

3.3.1 Internal faults

When an internal relay fault is detected, relay protection operation is disabled, the green Ready LED begins to flash and the self-supervision output contact is activated.

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.

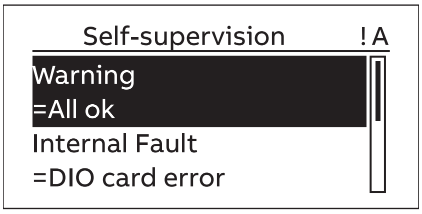

Figure 11: Internal fault in LHMI self-supervision page

If an internal fault disappears, the green Ready LED stops flashing and the protection relay returns to the normal service state. The fault indication message remains on the display until manually cleared.

The self-supervision signal output operates on the closed-circuit principle.

- Normal conditions with empty application configuration
  - DIO2001 pins 16 and 17 are closed, pins 16 and 18 are open.
- Normal conditions with application configuration
  - DIO2001 pins 16 and 17 are open, pins 16 and 18 are closed.
- USB powered with or without application configuration
  - DIO2001 pins 16 and 18 are closed, pins 16 and 17 are open.

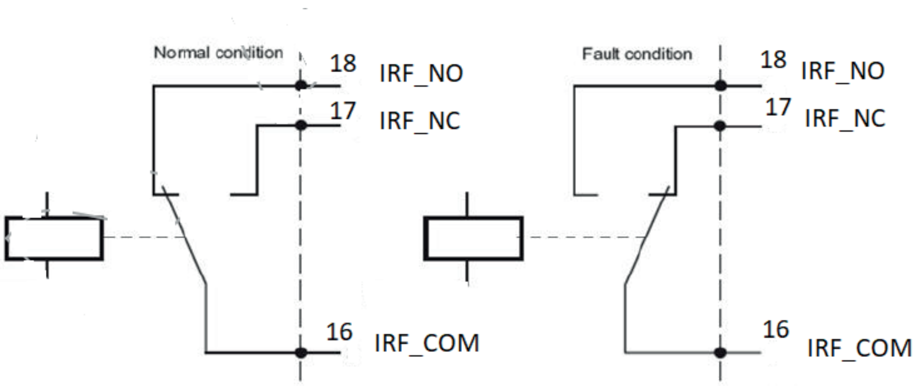

Figure 12: Output contact

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

The display code format for internal faults is `aa.bb.cc.ddd.ee`.

- `aa`: Reserved for future
- `bb`: Error domain
  - `1`: HW error
  - `2`: Runtime error
  - `3`: Communication error
- `cc`: Component
  - Range 0...11
- `ddd`: Error category
- `ee`: Offset
  - Range 0...255

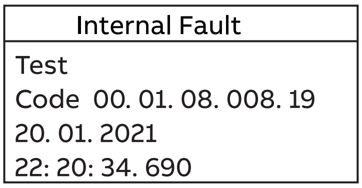

Figure 13: Fault indication

Table 26: Internal fault indications and codes

Fault indication	Error category	Additional information
File system error	7	A file system error has occurred
Test	8	Internal fault test activated by the user
USB powered	12	Device powered with USB
RAM error	80[1]	Memory error
ROM error	81	Failure in internal NV memory
PSU traceability invalid	160	Invalid PSU card traceability data
DIO traceability invalid	161	Invalid DIO card traceability data
AIU traceability invalid	162	Invalid AIU card traceability data
AIC traceability invalid	163	Invalid AIC card traceability data
HMI traceability invalid	164	Invalid HMI card traceability data
Product traceability invalid	165	Invalid product traceability data
LHMI LCD error	166	Failure in LCD detection
AIU card error	171	Error in the AIU card
DIO card error	172	Error in the DIO card
AIC card error	173	Error in the AIC card
Firmware update error	175[1]	Software update failed
CPU exception	176[1]	CPU exception

Table continues on next page

Fault indication	Error category	Additional information
HW config mismatch	177	Mismatch between the HW configuration and the HW cards connected to the relay
System Boot up failure	179[1)]	Error during system bootup
HMI Card error	181	Error in the HMI card
RTC Error	182	Error in the RTC
Device Resource error	183	IRF triggered One of the mandatory files missing
COM failure	184[1)]	COM failure
ADC Error	185[1)]	Analog samples missing

1) Used for software simulation

For further information on internal fault indications, see the operation manual.

3.3.2 Warnings

In case of a warning, the protection relay continues to operate except for those protection functions possibly affected by the fault, and the green Ready LED remains lit as during normal operation.

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.

The display code format for the warning codes is `aa.bb.cc.ddd.ee`.

- `aa`: Reserved for future
- `bb`: Error domain
  - `1`: HW error
  - `2`: Runtime error
  - `3`: Communication error
- `cc`: Component
  - Range 0...11
- `ddd`: Warning category
- `ee`: Offset
  - Range 0...255

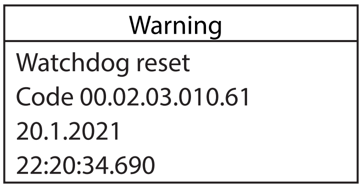

Figure 14: Warning

Table 27: Warning indications and codes

Warning indication	Warning category	Additional information
System	2	Error in file operations
Watchdog reset	10	Watch dog reset has occurred
Power down det.	11	Auxiliary supply voltage dropped too low
Modbus warning	21	Error in Modbus communication
Dataset error	24	Error in data set(s)
Report cont. Error	25[1]	IEC report error
SCL config error	27	Error in SCL configuration file or the file is missing
Logic warning	28	Too many connections in the configuration
SMT connect error	29	Error in SMT connections
GOOSE input warning	30[1]	Error in GOOSE connections
ACT Config. mismatch	37	Configuration mismatch
SDcard mount Warn	156	SD card mount error
PSU.data.invalid	160[1]	PSU traceability warning
DIO.data.invalid	161[1]	DIO traceability warning
AIU.data.invalid	162[1]	AIU traceability warning
AIC.data.invalid	163[1]	AIC traceability warning
HMI.data.invalid	164[1]	HMI traceability warning
LHMI keyscan error	169[1]	Keyscan error
GOOSE receive error	170	Error in GOOSE message receiving
GOOSE publish error	171[1]	Error in GOOSE publish
SDcard memory full	172	SD card memory is full
Device Cert. Expired	173	Device certificate expired
SDcard error	174	Error in SD card
SNTP error	175	Error in the SNTP module
Internal voltage error	176[1]	Voltage error detected
Inter. humidity sensor error	177	Error in internal humidity sensor
Inter. temp. sensor error	178	Error in internal temperature sensor
Access Errx	179	Setting write failure
Table continues on next page		

Warning indication	Warning category	Additional information
Config. not available	181	Error in ACT connections/ACT Configuration not available
SCL validation warning	182	Failure in SCL file validation
MMS report warning	183[1)]	MMS report warning
MMS service warning	184[1)]	MMS service warning

1) Used for software simulation

For further information on warning indications, see the operation manual.

3.4 Programmable LEDs

3.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE identification
Programmable LEDs	LED	LED	LED

3.4.2 Function block

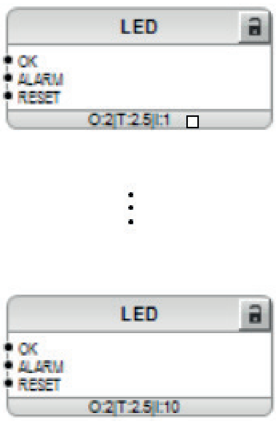

Figure 15: Function block

3.4.3 Functionality

The programmable LEDs reside on the right side of the display on the protection relay.

Figure 16: Programmable LEDs on the right side of the display

All the programmable LEDs in the HMI of the protection relay have two colors, green and red. For each LED, the different colors are individually controllable.

Each LED has two control inputs, ALARM and OK. The color setting is common for all the LEDs. It is controlled with the *Alarm colour* setting, the default value being "Red". The OK input corresponds to the color that is available, with the default value being "Green".

Changing the *Alarm colour* setting to "Green" changes the color behavior of the OK inputs to red.

The ALARM input has a higher priority than the OK input.

Each LED is seen in the Application Configuration tool as an individual function block. Each LED has user-editable description text for event description. The state ("None", "OK", "Alarm") of each LED can also be read under a common monitored data view for programmable LEDs.

The LED status also provides a means for resetting the individual LED via communication. The LED can also be reset from configuration with the RESET input.

The resetting and clearing function for all LEDs is under the **Clear** menu.

The menu structure for the programmable LEDs is presented in Figure 17. The common color selection setting *Alarm colour* for all ALARM inputs is in the **General** menu, while the LED-specific settings are under the LED-specific menu nodes.

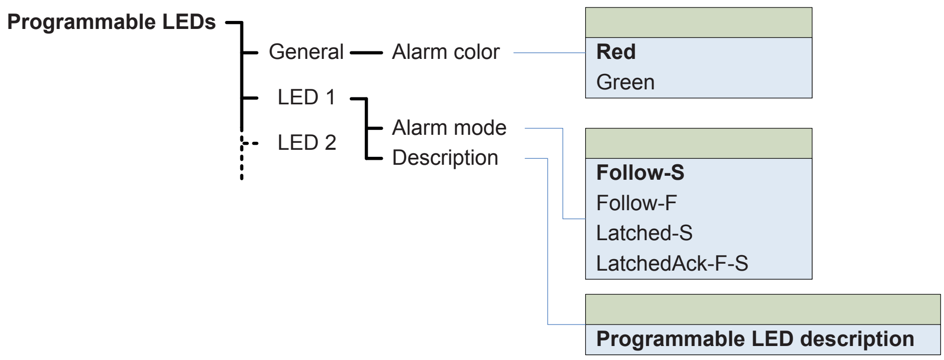

Figure 17: Menu structure

Alarm mode alternatives

The ALARM input behavior can be selected with the alarm mode settings from the alternatives "Follow-S", "Follow-F", "Latched-S" and "LatchedAck-F-S". The OK input behavior is always according to "Follow-S". The alarm input latched modes can be cleared with the reset input in the application logic.

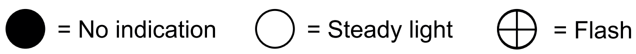

Figure 18: Symbols used in the sequence diagrams

"Follow-S": Follow Signal, ON

In this mode ALARM follows the input signal value, Non-latched.

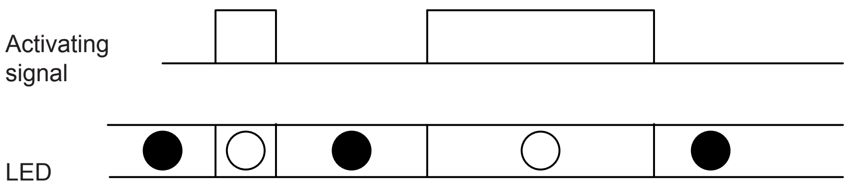

Figure 19: Operating sequence "Follow-S"

"Follow-F": Follow Signal, Flashing

Similar to "Follow-S", but instead the LED is flashing when the input is active, Non-latched.

"Latched-S": Latched, ON

This mode is a latched function. At the activation of the input signal, the alarm shows a steady light. After acknowledgement by the local operator pressing any key on the keypad, the alarm disappears.

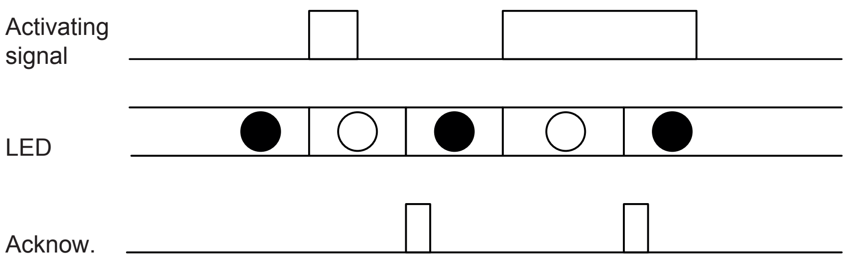

Figure 20: Operating sequence "Latched-S"

"LatchedAck-F-S": Latched, Flashing-ON

This mode is a latched function. At the activation of the input signal, the alarm starts flashing. After acknowledgement, the alarm disappears if the signal is not present and gives a steady light if the signal is present.

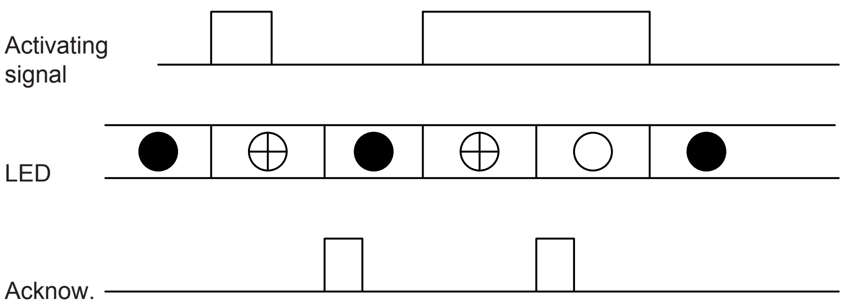

Figure 21: Operating sequence "LatchedAck-F-S"

3.4.4 Signals

Table 28: Input signals

Name	Type	Default	Description
OK	BOOLEAN	0=False	Ok input for LED 1
ALARM	BOOLEAN	0=False	Alarm input for LED 1
RESET	BOOLEAN	0=False	Reset input for LED 1
Table continues on next page			

Name	Type	Default	Description
OK	BOOLEAN	0=False	Ok input for LED 2
ALARM	BOOLEAN	0=False	Alarm input for LED 2
RESET	BOOLEAN	0=False	Reset input for LED 2
OK	BOOLEAN	0=False	Ok input for LED 3
ALARM	BOOLEAN	0=False	Alarm input for LED 3
RESET	BOOLEAN	0=False	Reset input for LED 3
OK	BOOLEAN	0=False	Ok input for LED 4
ALARM	BOOLEAN	0=False	Alarm input for LED 4
RESET	BOOLEAN	0=False	Reset input for LED 4
OK	BOOLEAN	0=False	Ok input for LED 5
ALARM	BOOLEAN	0=False	Alarm input for LED 5
RESET	BOOLEAN	0=False	Reset input for LED 5
OK	BOOLEAN	0=False	Ok input for LED 6
ALARM	BOOLEAN	0=False	Alarm input for LED 6
RESET	BOOLEAN	0=False	Reset input for LED 6
OK	BOOLEAN	0=False	Ok input for LED 7
ALARM	BOOLEAN	0=False	Alarm input for LED 7
RESET	BOOLEAN	0=False	Reset input for LED 7
OK	BOOLEAN	0=False	Ok input for LED 8
ALARM	BOOLEAN	0=False	Alarm input for LED 8
RESET	BOOLEAN	0=False	Reset input for LED 8
OK	BOOLEAN	0=False	Ok input for LED 9
ALARM	BOOLEAN	0=False	Alarm input for LED 9
RESET	BOOLEAN	0=False	Reset input for LED 9
OK	BOOLEAN	0=False	Ok input for LED 10
ALARM	BOOLEAN	0=False	Alarm input for LED 10
RESET	BOOLEAN	0=False	Reset input for LED 10

3.4.5 Settings

Table 29: LED settings

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm colour	1=Green 2=Red			2=Red	Colour for the alarm state of the LED
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 1
Description				Programmable LEDs	Programmable LED description
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 2
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 3
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 4
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 5
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 6
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 7
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 8
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 9
Description				Programmable LEDs	Programmable LED description
Alarm mode	0=Follow-S 1=Follow-F 2=Latched-S 3=LatchedAck-F-S			0=Follow-S	Alarm mode for programmable LED 10
Description				Programmable LEDs	Programmable LED description

3.4.6 Monitored data

Table 30: Monitored data

Name	Type	Values (Range)	Unit	Description
Programmable LED 1	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 1
Programmable LED 2	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 2
Programmable LED 3	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 3
Programmable LED 4	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 4
Programmable LED 5	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 5
Programmable LED 6	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 6
Programmable LED 7	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 7
Programmable LED 8	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 8
Programmable LED 9	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 9
Programmable LED 10	Enum	0=None 1=Ok 3=Alarm		Status of programmable LED 10

Table 31: IEC 61850 mapping

LED instance in Application Configuration	Mapping in IEC 61850 data model (ALARM and OK signals)
LED1...LED10	LEDGGIO1.Alm1...LEDGGIO1.Alm10
	LEDGGIO1.Ind1...LEDGGIO1.Ind10

3.5 Time synchronization

3.5.1 Time master supervision GNRLLTMS

3.5.1.1 Function block

Figure 22: Function block

3.5.1.2 Functionality

The protection relay has a disciplined RTC in hardware with a resolution of one millisecond. The clock can be either free-running or synchronized to an external source. The RTC is used to time-stamp events, recorded data, disturbance recordings, sampled measured values and various other system services.

The protection relay supports SNTP to synchronize the RTC. The accuracy is ±5 ms with SNTP.

Real-time clock at power off

During power off, the system time is kept in a separate capacitor-backed RTC. This RTC provides a millisecond resolution and digital temperature compensation for the crystal oscillator. Typical accuracy is 10 ppm which means the time may drift maximum 1 second per day. This RTC runs on a stored charge in a supercapacitor at least for 48 hours. After the capacitor has been discharged, the time is lost.

Real-time clock at power-up

At startup, the initial system time is recovered from the capacitor-backed RTC or set to 01-01-2010 if the RTC time was lost. The clock is free-running until the selected synchronization source becomes available. The first synchronization message sets the time to an accurate value and later synchronization messages additionally discipline the clock so that the time drift between synchronization messages is minimized. If the synchronization source is lost, the drift can be 0.25 ppm if the external clock source was a high-quality clock and the surrounding temperature is constant.

The setting *Synch source* determines the method for synchronizing the RTC. If it is set to "None", the clock is free-running and the settings *Date* and *Time* can be used to set the time manually. In this mode the typical accuracy is 10 ppm and the time may drift maximum 1 second per day.

Other setting values activate a communication protocol that provides the time synchronization.

SNTP

The relay 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 relay tries to switch back to the primary server on every SNTP request attempt to the primary server. If both SNTP servers are offline, event time stamps have the time invalid status.

If one SNTP server is used, it is recommended to set *IP SNTP secondary* as "0.0.0.0". This disables the server redundancy scheme and prevents the IED from attempting to access a non-existing secondary server.

The time is requested from the SNTP server every 60 seconds. Supported SNTP versions are 3 and 4. SNTP requires a high-performance server to meet the performance expectations.

3.5.1.3 Signals

Table 32: GNRLLTMS Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm status for clock synchronization Always FALSE with *Synch source* set to "None"
WARNING	BOOLEAN	Warning status for clock synchronization Always FALSE with *Synch source* set to "None"

Table 33: SNTP Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm status for clock synchronization TRUE if the connection to both primary and secondary SNTP servers has been lost. FALSE if the connection to the secondary SNTP server is detected.
WARNING	BOOLEAN	Warning status for clock synchronization TRUE if the connection to SNTP primary server has been lost. Otherwise FALSE.

Table 34: Time Output signals

Name	Type	Description
ALARM	BOOLEAN	Alm
WARNING	BOOLEAN	Wrn

3.5.1.4 Settings

Table 35: Time format Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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

Table 36: Time Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Synch source	0=None 1=SNTP			1=SNTP	Time synchronization source
Date				0	Date
Time				0	Time
Local time offset	-840...840	min	1	0	Local time offset in minutes
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 in use	0=False 1=True			1=True	DST in use setting
DST on time (hours)	0...23	h	1	2	Daylight saving time on, time (hh)
DST on time (minutes)	0...59	min	1	0	Daylight saving time on, time (mm)
DST on date (day)	1...31		1	1	Daylight saving time on, date (dd:mm)
DST on date (month)	1=January 2=February 3=March 4=April 5=May 6=June 7=July 8=August 9=September 10=October 11=November 12=December			5=May	Daylight saving time on, date (dd:mm)

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
DST on day (weekday)	0=reserved 1=Monday 2=Tuesday 3=Wednesday 4=Thursday 5=Friday 6=Saturday 7=Sunday			0=reserved	Daylight saving time on, day of week
DST off time (hours)	0...23	h	1	2	Daylight saving time off, time (hh)
DST off time (minutes)	0...59	min	1	0	Daylight saving time off, time (mm)
DST off date (day)	1...31		1	25	Daylight saving time off, date (dd:mm)
DST off date (month)	1=January 2=February 3=March 4=April 5=May 6=June 7=July 8=August 9=September 10=October 11=November 12=December			9=September	Daylight saving time off, date (dd:mm)
DST off day (weekday)	0=reserved 1=Monday 2=Tuesday 3=Wednesday 4=Thursday 5=Friday 6=Saturday 7=Sunday			0=reserved	Daylight saving time off, day of week
DST offset	-720...720	min	1	60	Daylight saving time offset

3.5.1.5 Monitored data

Table 37: Monitored data

Name	Type	Values (Range)	Unit	Description
Synch source	Enum	0=Not defined 1=SNTP primary 2=SNTP secondary 99=Free running		Time synchronization source
Synch status	Bool	0=Down 1=Up		Time synchronization status
Synch accuracy	Int	0...128		Time synchronization accuracy. Number of the significant bits in fraction of second.

Table 38: Time Monitored data

Name	Type	Values (Range)	Unit	Description
Synch source	Enum	0=Not defined 1=SNTP primary 2=SNTP secondary 99=Free running, locally generated		Current time source
Synch status	BOOLEAN	0=Down 1=Up		Time channel status (up/down)

3.6 Generic protection control PROTECTION

3.6.1 Function block

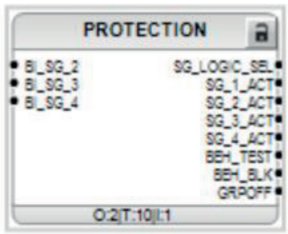

Figure 23: Function block

3.6.2 Functionality

Setting group control

The protection relay supports four setting groups. Each setting group contains parameters categorized as group settings inside application functions. The customer can change the active setting group at run time.

The active setting group can be changed by a parameter or via binary inputs depending on the mode selected with the **Configuration/Setting Group/SG operation mode** setting.

The default value of all inputs is FALSE, which makes it possible to use only the required number of inputs and leave the rest disconnected. The setting group selection is not dependent on the `SG_x_ACT` outputs.

Table 39: Optional operation modes for setting group selection

SG operation mode	Description
Operator (Default)	Setting group can be changed with the setting **Settings/Setting group/Active group**. Value of the `SG_LOGIC_SEL` output is FALSE.
Logic mode 1	Setting group can be changed with binary inputs (`BI_SG_2...BI_SG_4`). The highest `TRUE` binary input defines the active setting group. Value of the `SG_LOGIC_SEL` output is TRUE.

Table 40: SG operation mode = "Logic mode 1"

Input			
BI_SG_2	BI_SG_3	BI_SG_4	Active group
FALSE	FALSE	FALSE	1
TRUE	FALSE	FALSE	2
any	TRUE	FALSE	3
any	any	TRUE	4

Setting group 1 can be copied to any other or all groups from HMI (Copy group 1).

Test mode

The function has two outputs, `BEH_TST` and `BEH_BLK`, which are activated in test mode according to Table 41.

Table 41: Test mode

Test mode	Description	Protection BEH_BLK	Protection BEH_TST
Normal mode	Normal operation	FALSE	FALSE
IED blocked	Protection works as in “Normal mode” but the ACT configuration can be used to block physical outputs to process. Control function commands are blocked.	TRUE	FALSE
IED test	Protection works as in “Normal mode” but protection functions work in parallel with test parameters.	FALSE	TRUE
IED test and blocked	Protection works as in “Normal mode” but protection functions work in parallel with the test parameter. The ACT configuration can be used to block physical outputs to process. Control function command is blocked.	TRUE	TRUE

For more information, see the Test mode section in this manual.

Special function block outputs

The function block has a few outputs dedicated for special purposes.

Table 42: Special function block outputs

Output	Description
CNF_CHANGE	Any setting change in the protection relay activates this output for a short period of time (100...200 ms).
GRPOFF	Some application function blocks do now allow unconnected analog inputs. In such a case, `GRPOFF` must be connected to such an input.
DEV_WARN	A protection relay's internal warning activates this output. For more information, see Warnings under the Self-supervision section.

3.6.3 Signals

Table 43: PROTECTION Input signals

Name	Type	Default	Description
BI_SG2	BOOLEAN	0	Setting group 2 is active
BI_SG3	BOOLEAN	0	Setting group 3 is active
BI_SG4	BOOLEAN	0	Setting group 4 is active
MOD_TEST	BOOLEAN	0	Activation of test mode
MOD_BLK	BOOLEAN	0	Block test mode

Table 44: PROTECTION Output signals

Name	Type	Description
SG_LOGIC_SEL	BOOLEAN	Logic selection for setting group
SG_1_ACT	BOOLEAN	Setting group 1 is active
SG_2_ACT	BOOLEAN	Setting group 2 is active
SG_3_ACT	BOOLEAN	Setting group 3 is active
SG_4_ACT	BOOLEAN	Setting group 4 is active
CNF_CHANGE	BOOLEAN	Active after any setting change
BEH_TEST	BOOLEAN	Logical device LD0 test status

Table continues on next page

Name	Type	Description
BEH_BLK	BOOLEAN	Logical device LD0 block status
GRPOFF	Group signal	Group off signal for function blocks
DEV_WARN	BOOLEAN	Protection relay internal warning

3.6.4 Settings

Table 45: PROTECTION Settings

Parameter	Values (Range)	Unit	Step	Default	Description
SG operation mode	1=Operator 2=Logic mode 1			1=Operator	Operation mode for setting group change

3.7 Local/Remote control CONTROL

3.7.1 Function block

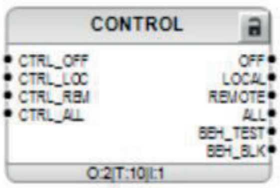

Figure 24: Function block

3.7.2 Functionality

Depending on the relay configuration, the selection of the local/remote mode can be made via a binary input or it can be setting based. The control via binary input can be enabled by setting the value of the *LR control* setting to "Binary input". The binary input control requires that the CONTROL function is instantiated in the product configuration. The control via setting can be enabled by setting *LR control* to "Setting based", and L/R control is realized by setting the value of *Control authority*.

In binary input control, the actual Local/Remote control state is evaluated by the priority scheme on the function block inputs. If more than one input is active, the input with the highest priority is selected. The priority order is “off”, “local”, “remote”, “all”.

The actual state is reflected on the CONTROL function outputs. Only one output is active at a time.

Table 46: Truth table for CONTROL

Input				Output
CTRL_OFF	CTRL_LOC	CTRL_REM	CTRL_ALL	
TRUE	N/A	N/A	N/A	OFF = TRUE
FALSE	TRUE	N/A	N/A	LOCAL = TRUE
FALSE	FALSE	TRUE	TRUE	REMOTE = TRUE
FALSE	FALSE	FALSE	TRUE	ALL = TRUE
FALSE	FALSE	FALSE	FALSE	OFF = TRUE

3.7.3 L/R control access

Only one Local/Remote access scenario is possible: "L,R, L+R".

Control access can be simultaneously permitted from local or remote location. Simultaneous local or remote control operation is not allowed as only one client and location at a time can access controllable objects, and they remain reserved until the previously started control operation is first completed by the client. Control access with IEC 61850 originator category station is interpreted as remote access.

The present control status can be monitored in the HMI or PCM600 via **Monitoring/Control command** with the *LR state* parameter or from the IEC 61850 data object CTRL.LLN0. LocKeyHMI.

IEC 61850 command originator category is always set by the IEC 61850 client.

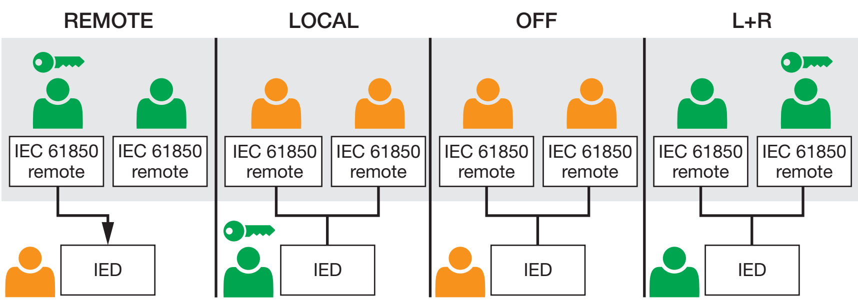

Figure 25: LR control access "L, R, L+R"

Table 47: LR control access "L,R,L+R" using R/L button

Setting based control	L/R Control status	Control access	
Control authority	L/R state CTRL.LLN0.LocKeyHMI	Local user	IEC 61850 client
Local	1	x	
Remote	2		x
Local + Remote	4	x	x
Off	0		

3.7.4 Control mode

The function has two outputs `BEH_TST` and `BEH_BLK` which are activated in test mode according to Table 48.

Table 48: Control mode

Control mode	Description	Control BEH_BLK
On	Normal operation	FALSE
Blocked	Control function commands blocked	TRUE
Off	Control functions disabled	FALSE

For more information, see the Test mode chapter in this manual.

3.7.5 Signals

Table 49: CONTROL Input signals

Name	Type	Default	Description
CTRL_OFF	BOOLEAN	0	Control input OFF
CTRL_LOC	BOOLEAN	0	Control input Local
CTRL_REM	BOOLEAN	0	Control input Remote
CTRL_ALL	BOOLEAN	0	Control input All

Table 50: CONTROL Output signals

Name	Type	Description
OFF	BOOLEAN	Control output OFF
LOCAL	BOOLEAN	Control output Local
REMOTE	BOOLEAN	Control output Remote

Table continues on next page

Name	Type	Description
ALL	BOOLEAN	Control output All
BEH_BLK	BOOLEAN	Logical device CTRL block status
BEH_TST	BOOLEAN	Logical device CTRL test status

3.7.6 Settings

Table 51: Control Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
LR control	2=Binary input 3=Setting based			3=Setting based	LR control based on setting or binary input
Control authority	1=OFF 2=LOCAL 3=REMOTE 4=LOCAL + REMOTE			1=OFF	Setting based control selection

Table 52: Control Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Control mode	1=On 2=Blocked 5=Off			1=On	Enabling and disabling control

3.7.7 Monitored data

Table 53: Control Monitored data

Name	Type	Values (Range)	Unit	Description
Command response	Enum	0=No commands 1=Select open 2=Select close 3=Operate open 4=Operate close 5=Direct open 6=Direct close 7=Cancel 8=Position reached 9=Position timeout 10=Object status only 11=Object direct 12=Object select 13=RL local allowed 14=RL remote allowed 15=RL off 16=Function off 17=Function blocked 18=Command progress 19=Select timeout 20=Missing authority 21=Close not enabled 22=Open not enabled 23=Internal fault 24=Already close 25=Wrong client 26=RL station allowed 27=RL change 28=Abortion by trip 29=Reed not closed 30=Motor blocked 31=Motor wrong direction		Latest command response
LR state	Enum	0=Off 1=Local 2=Remote 4=L+R		LR state monitoring

3.8 Nonvolatile memory

The relay does not include any battery backup power. If the auxiliary power is lost, critical information such as relay configuration and settings, events, disturbance recordings and other critical data are saved to the relay's nonvolatile memory. The relay's real-time clock keeps running via a 48-hour capacitor backup.

- Up to 1024 events are stored. The stored events are visible in HMI and Event viewer tool in PCM600.
- Circuit breaker condition monitoring
- Latched alarm and trip LEDs' statuses
- Trip circuit lockout
- Counter values

3.9 SD card

SD card can be used to store the disturbance records available in the relay by using the *Disturbance recorder* setting.

Table 54: SD Card Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Disturbance recorder	0=Cancel 1=Transfer			0=Cancel	Transfer disturbance recorder

Table 55: SD Card Monitored data

Name	Type	Values (Range)	Unit	Description
Memory remaining	FLOAT32	0...64000	MB	SD card memory remaining
Safe removal	BOOLEAN	0=No 1=Yes		SD card safe removable indication
Mounted	BOOLEAN	0=No 1=Yes		SD card mounted status indication

3.10 Analog measurement channels

The maximum number of physical analog measurement channels is eight. This can be achieved with two analog input modules. In addition to the local channels, a certain number of numerical channels is always calculated from physical measurements. This number also depends on the connection type of the TVTR function block

Table 56: TVTR/TCTR connection types and numerical channels

Connection type	Function block	Physical channels	Numerical channels
ULx × 1	ULxTVTR	1	0
URES	ULxTVTR	1	0
ULx × 2 (Wye/Delta)	ULxTVTR	2	4
ULx × 2 + URES (Wye/Delta)	ULxTVTR	3	4
ULx × 3 (Delta)	ULxTVTR	3	3
ULx × 3 (Wye)	ULxTVTR	3	4
ILx × 3	ILxTCTR	3	1
IRES	RESxTCTR	1	0

The maximum number of measurement channels is 19. This can be calculated by adding physical and numerical channels together.

In REX610 relays, the UTVTR functions automatically calculate missing signals if enough information is available. If measured Uo is needed for calculations but it is not provided, it is assumed to be zero. Table 57 shows possible voltage connections and outcome of the UTVTR function. A three-phase current connection in the ILTCTR function always provides a calculated Io channel.

Table 57: Calculated voltages for different connection types

Voltage connection	Phase-to-phase voltages (Ph-Ph)	Phase-to-neutral voltages (Ph-n)	Residual voltage Uo
3 × ph-n	yes, calculated	yes	yes, calculated
3 × ph-n + Uo	yes, calculated	yes	yes
2 × ph-n	yes, calculated[1)]	yes, missing ph-n calculated[1)]	no
2 × ph-n + Uo	yes, calculated	yes, missing ph-n calculated	yes
3 × ph-ph	yes	yes, calculated[1)]	no
3 × ph-ph + Uo	yes	yes, calculated	yes
2 × ph-ph	yes, missing ph-ph calculated	yes, calculated[1)]	no
2 × ph-ph + Uo	yes, missing ph-ph calculated	yes, calculated	yes

1) Uo assumed zero

3.11 Binary inputs

The binary inputs are mainly assembled in groups of two inputs that have one common connection. The binary inputs are bipolar so the common connection can be tied to ground or to supply voltage. Input groups are isolated from each other and from the secondary side.- For more information, see the Module diagrams section in this manual.

Every binary input has an oxide-burn feature, that is, wetting current. The oxide-burn feature can be disabled only on binary input 14 that can be used as a pulse counter input.

The pulse counter input is enabled by setting the parameter *Input 14 counter-mode* in **Configuration/I/O modules/Slot #/Input filtering**. When enabled, the pulse counter input has dedicated *Input counter threshold voltage* and *Input counter threshold hysteresis* settings.

3.11.1 Binary input threshold voltage

The parameter *Input threshold voltage* is used to set the threshold level of the binary inputs. *Input threshold voltage* determines the voltage level for the activation of the inputs. The threshold can be set for every module or slot specifically depending on the *Slot specific threshold* setting. Binary inputs are configurable to both AC and DC voltage type.

Table 58: Input threshold voltage parameters

Parameter		Values	Default
Slot specific threshold		0=False 1=True	0=False
Input threshold voltage	DC voltage	16…176 V	16 V
	AC voltage	34...168 V	34 V

3.11.2 Threshold hysteresis

Threshold hysteresis is used to determine the deactivation threshold for the binary inputs in case of voltage drops in the auxiliary voltage supply. Threshold hysteresis value determines how low the deactivation voltage is compared to the activation voltage as a percentage. Hysteresis can be set for every module or slot specifically depending on the *Slot specific hysteresis* setting.

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 de-blocked (the status is valid) and an event is generated.

Binary inputs always deactivate when the voltage level drops below 14 V.

Table 59: Threshold hysteresis parameters

Parameter	Values	Default
Slot specific hysteresis	0=False 1=True	0=False
Input threshold hysteresis	10…50%	10%
OSC.level	2...50 events	30 events
OSC.hyst	2...50 events	10 events

3.11.3 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 protection relay.

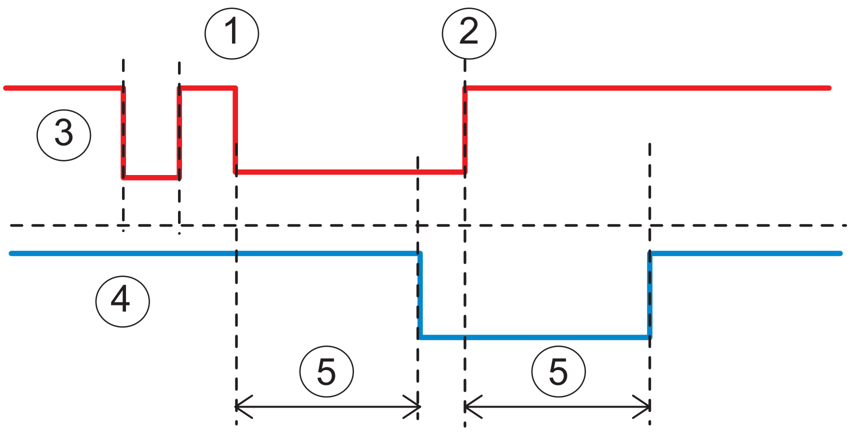

Figure 26: Binary input filtering

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 60: Input filter parameter values

Parameter	Values	Default
Input # filter time	10...100 ms	10 ms

3.11.4 Binary input inversion

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

Table 61: Binary input states

Control voltage	Input # invert	State of binary input
No	0	FALSE (0)
Yes	0	TRUE (1)
No	1	TRUE (1)
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.

3.11.5 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.

Table 62: Oscillation parameters

Parameter	Value	Default
Input osc. level	2...50 events/s	30 events/s
Input osc. hyst	2...50 events/s	10 events/s

3.12 Binary outputs

The protection relay provides a number of binary outputs used for tripping, executing local or remote control actions of a breaker or a disconnector, and for connecting the protection relay to external annunciation equipment for indicating, signaling and recording. The contacts used for external signaling, recording, and indicating the signal outputs need to adjust to smaller currents but they can require a minimum current (burden) to ensure a guaranteed operation.

The binary outputs are implemented by software-controlled mechanical relays. At power-up (cold boot), all relays are OFF through power-on reset of the micro-controller. In case of a warm boot, the relays remain in the state they are. They can be forced into OFF state by activating the RESET of the micro-controller. The micro-controller controls the relays through logic control lines. To improve robustness, control and switching functions in the relay driver are double mainly to prevent a single error from tripping the binary output relay. All contacts are freely programmable, except for the internal fault output IRF.

Table 63: Binary outputs

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A (normal BO) and 15 A (SO1 type)
Make and carry for 0.5 s	15 A/30 A (SO1 type)
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC	IEC: 1 A/0.25 A/0.15 A UL: According to component manufacturer's claim
Contact operating time	<7 ms
Channel to channel isolation	BOs shall be isolated from each other so that they can be connected freely to external potentials.

3.12.1 Power outputs

The protection relay contains two binary power outputs. These power outputs connect externally to circuit breakers and are normally used for energizing the breaker closing coil and trip coil. The binary power outputs (also called TRIP relays) are implemented by software controlled mechanical relays. At power-up (cold boot), all relays are OFF through power-on reset of the micro-controller. In case of a warm boot, the relays remain in the state they are. They can be forced into OFF state by activating the RESET of the micro-controller. The micro-controller is located on the DIO module and controls the relays on the PSU module through logic control lines. To improve robustness, control and switching functions in the relay driver are double mainly to prevent a single error from tripping the power binary output relay.

Table 64: Power binary outputs with TCS functionality

Description		Value
Rated voltage		250 V AC/DC
Continuous contact carry		8 A
Make and carry for 3.0 s		15 A
Make and carry for 0.5 s		30 A
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC (two contacts connected in series for double pole power outputs)		5 A/3 A/1 A
Contact operating time		<10 ms
Trip-circuit supervision (TCS)	Control voltage range	20...250 V AC/DC
	Current drain through the supervision circuit	~1.5 mA
	Minimum voltage over the TCS contact	20 V AC/DC (15...20 V)
Channel to channel isolation		BOs shall be isolated from each other so that they can be connected freely to external potentials. In addition to all the type tests, fully isolated outputs must pass dielectric isolation test requirements as mentioned in the type test guidelines.

3.13 Preprocessing blocks

3.13.1 Phase current preprocessing ILTCTR

3.13.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase current preprocessing	ILTCTR	ILTCTR	ILTCTR

3.13.1.2 Function block

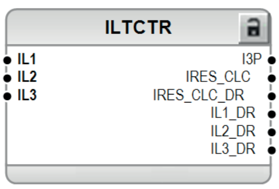

Figure 27: Function block

3.13.1.3 Functionality

The phase current preprocessing function ILTCTR is used for setting up the three phase current measurement channels. The input channels for ILTCTR are from physical hardware. The output `I3P` channel of ILTCTR can be connected to different applications which require 3 phase current and positive- and negative-sequence current. The output `IRES_CLC` can be connected to functions using the calculated residual current.

The CT's primary rated current can be set using *Primary current* setting. The setting *Secondary current* defines the nominal current of the CT's secondary winding. This is used as a reference to scale the measurements accordingly. These settings also affect the scaling of the calculated residual current.

Current magnitude correction of an external CT can be made using settings *Amplitude Corr A*, *Amplitude Corr B* and *Amplitude Corr C*.

Current angle correction of an external CT can be made using settings *Angle Corr A*, *Angle Corr B* and *Angle Corr C*.

Reverse polarity setting is used to reverse the polarity of phase CTs.

All three phases must be always connected.

3.13.1.4 Signals

Table 65: ILTCTR Input signals

Name	Type	Default	Description
IL1	SIGNAL	-	Analog input
IL2	SIGNAL	-	Analog input
IL3	SIGNAL	-	Analog input

Table 66: ILTCTR Output signals

Name	Type	Description
I3P	SIGNAL	Three-phase currents
IRES_CLC	SIGNAL	Residual current, calculated
IRES_CLC_DR	SIGNAL	Residual current, calculated, for disturbance recorder
IL1_DR	SIGNAL	Phase current IL1 for disturbance recorder
IL2_DR	SIGNAL	Phase current IL2 for disturbance recorder
IL3_DR	SIGNAL	Phase current IL3 for disturbance recorder

3.13.1.5 Settings

Table 67: ILTCTR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Primary current	1.0...15000.0	A	0.1	100.0	Rated primary current
Amplitude Corr A	0.9000...1.1000		0.0001	1.0000	Phase A amplitude correction factor
Amplitude Corr B	0.9000...1.1000		0.0001	1.0000	Phase B amplitude correction factor
Amplitude Corr C	0.9000...1.1000		0.0001	1.0000	Phase C amplitude correction factor
Angle Corr A	-8.0000...8.0000	deg	0.0001	0.0000	Phase A angle correction factor
Angle Corr B	-8.0000...8.0000	deg	0.0001	0.0000	Phase B angle correction factor
Angle Corr C	-8.0000...8.0000	deg	0.0001	0.0000	Phase C angle correction factor
Secondary current	0.10...10.00	A	0.01	1.00	Rated secondary current

Table 68: ILTCTR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the phase CTs

3.13.2 Residual current preprocessing RESTCTR

3.13.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual current preprocessing	RESTCTR	RESTCTR	RESTCTR

3.13.2.2 Function block

Figure 28: Function block

3.13.2.3 Functionality

The residual current preprocessing function RESTCTR is used for setting up the residual current measurement channels. Input channels for RESTCTR are from physical hardware. The output `IRES_MEAS` channel of RESTCTR can be connected to different applications which require measured residual current.

The residual CTs' primary rated current can be set using *Primary current* setting. The setting *Secondary current* defines the nominal current of the CT's secondary winding. This is used as a reference to scale measurements accordingly.

Residual current magnitude correction of an external CT can be made using the *Amplitude Corr* setting.

Residual current angle correction of an external CT can be made using the *Angle correction* setting.

The *Reverse polarity* setting is used to reverse the polarity of the residual CT.

3.13.2.4 Signals

Table 69: RESTCTR Input signals

Name	Type	Default	Description
IRES	SIGNAL	-	Residual current

Table 70: RESTCTR Output signals

Name	Type	Description
IRES_MEAS	SIGNAL	Residual current, measured
IRES_MEAS_DR	SIGNAL	Residual current, measured, for disturbance recorder

3.13.2.5 Settings

Table 71: RESTCTR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Primary current	1.0...6000.0	A	0.1	100.0	Primary current
Secondary current	0.10...10.00	A	0.01	1.00	Secondary current
Amplitude Corr	0.9000...1.1000		0.0001	1.0000	Amplitude correction
Angle correction	-8.0000...8.0000	deg	0.0001	0.0000	Angle correction factor

Table 72: RESTCTR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reverse polarity	0=False 1=True			0=False	Reverse the polarity of the residual CT

3.13.3 Phase and residual voltage preprocessing UTVTR

3.13.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase and residual voltage preprocessing	UTVTR	UTVTR	UTVTR

3.13.3.2 Function block

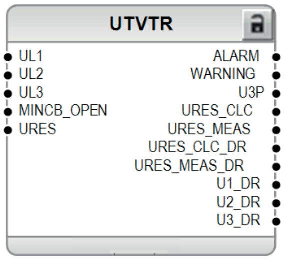

Figure 29: Function block

3.13.3.3 Functionality

The phase and residual voltage preprocessing function UTVTR is used for setting up the three phase voltage measurement channels and residual voltage measurement. The input channels for UTVTR are from physical hardware.

The output channel `U3P` of UTVTR can be connected to different applications which require phase voltage, positive and negative sequence.

Outputs `URES_MEAS` and `URES_CLC` can be connected to different applications which require measured residual voltage or calculated residual voltage (from phase voltages), respectively.

If only two phase-to-earth/phase-to-phase voltages are available, then the third phase-to-earth/phase-to-phase voltage can be calculated without `URES` input connected (assumed to be zero in that case). Positive- and negative-sequence components are also calculated using these voltages. The accuracy of the calculated values is affected if the actual residual voltage is not zero.

The VTs' primary rated voltage can be set using *Primary voltage* setting. The setting *Secondary voltage* defines the nominal voltage of the VT's secondary winding. This is used as a reference to scale the measurements accordingly.

The Voltage (Uo) residual voltage settings are also used for scaling the calculated residual voltage in comparison to the measured residual voltage.

The Voltage (Uo) settings must be set for output URES_MEAS and URES_CLC scaling. If the residual voltage is not connected to UTVTR, Voltage (Uo) settings must be set only for the calculated residual voltage URES_CLC scaling.

If the residual voltage is not connected to UTVTR, the **Voltage (Uo)/*Primary voltage*** cannot be set smaller than 1/√3 times **Voltage (3U)/*Primary voltage***.

Voltage magnitude correction can be made using settings *Amplitude Corr A*, *Amplitude Corr B* and *Amplitude Corr C* for an external three-phase VT and *Amplitude Corr* setting for an external residual VT.

Voltage angle correction can be made using settings *Angle Corr A*, *Angle Corr B* and *Angle Corr C* for an external three-phase VT and *Angle correction* setting for an external residual VT.

The VT connection can be set using *VT connection*. For three phase-to-earth voltage measurements, *VT connection* can be set to "Wye", and for three phase-to-phase voltage measurements, *VT connection* can be set to "Delta".

The MINCB_OPEN input signal is connected through a relay binary input to the NC auxiliary contact of the MCB protecting the VT secondary circuit. The MINCB_OPEN signal receives information about the MCB open state. When MINCB_OPEN is active, the outputs ALARM and WARNING are activated.

Output WARNING is always internally active whenever output ALARM is active.

3.13.3.4 Reference angle calculation

If only Voltage Preprocessing (UTVTR) is available, or if both Voltage Preprocessing (UTVTR) and Current Preprocessing (ILTCTR) are available, the voltage angle is taken as a reference for angle calculation.

If only Current Preprocessing (ILTCTR) is available, the current angle is taken as a reference for angle calculation.

In measurement functions CMMXU, VMMXU, RESVMMXU and RESCMMXU, the execution order of UTVTR should be set to a lower value (O:1 or lower execution number) for the voltage angle to be taken as reference. If lower execution order is not set, voltage angle from the previous execution round is taken as a reference for the measurement angle calculation. The execution order can be set as illustrated in Figure 30.

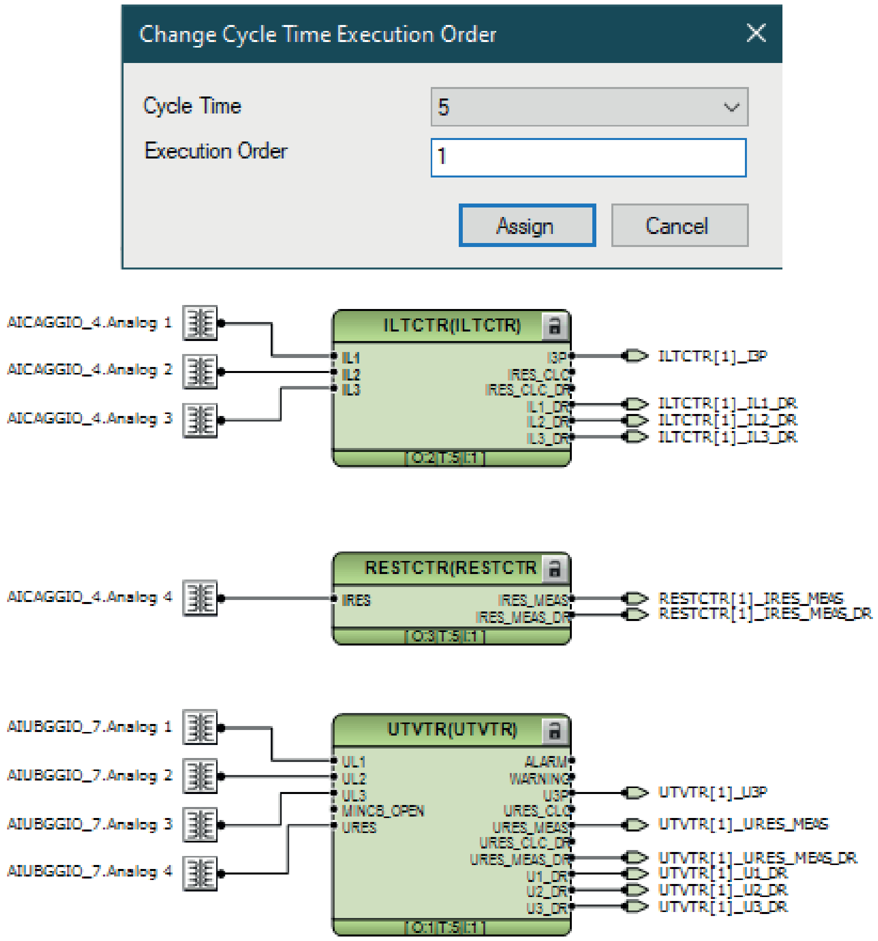

Figure 30: Execution order example

3.13.3.5 Residual voltage scaling

Calculated U_0 is scaled to the same level as measured U_0. The scaling is determined by the ratio of ULTVTR primary voltage and RESTVTR primary voltage within one UTVTR instance. The assumption is open-delta U_0 measurement type.

Typical markings of an open-delta U_0 transformer in a 20 kV network can be: **20kV/sqrt(3) :100V/sqrt(3) :100V/3**. In case of a solid earth fault, this transformer gives 100 V output which corresponds to 11.547 kV. If ULTVTR primary voltage is set to 20 kV and RESTVTR primary voltage is set to 11.547 kV when this transformer is used, `URES_CLC` and `URES_MEAS` output equal amplitude.

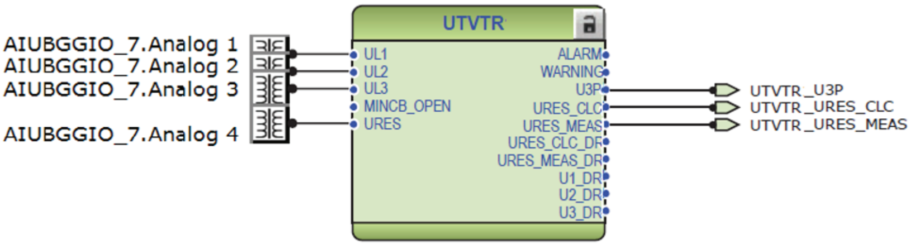

Figure 31: UTVTR1 configured with both measured and calculated U_0

The VT connection mode must be "WYE".

In this case, ROVPTOV1 and ROVPTOV2 in Figure 32 can both use the same U_0 reference level in their settings. `URES_CLC` and `URES_MEAS` in Figure 31 are scaled to the same level.

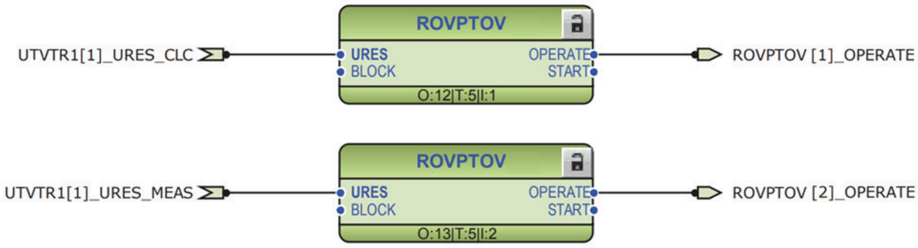

Figure 32: Two ROVPTOV instances, one using calculated U_0 and the other measured U_0

3.13.3.6 Signals

Table 73: UTVTR Input signals

Name	Type	Default	Description
UL1	SIGNAL	-	Analog input
UL2	SIGNAL	-	Analog input
UL3	SIGNAL	-	Analog input
MINCB_OPEN	BOOLEAN	0=False	Active when external MCB opens protected voltage circuit
URES	SIGNAL	-	Residual voltage

Table 74: UTVTR Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm
WARNING	BOOLEAN	Warning
U3P	SIGNAL	Three-phase voltages
URES_CLC	SIGNAL	Residual voltage, calculated

Table continues on next page

Name	Type	Description
URES_MEAS	SIGNAL	Residual voltage, measured
URES_CLC_DR	SIGNAL	Residual voltage, calculated, for disturbance recorder
URES_MEAS_DR	SIGNAL	Residual voltage, measured, for disturbance recorder
U1_DR	SIGNAL	Phase voltage U1 for disturbance recorder
U2_DR	SIGNAL	Phase voltage U2 for disturbance recorder
U3_DR	SIGNAL	Phase voltage U3 for disturbance recorder

3.13.3.7 Settings

Table 75: UTVTR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Primary voltage	0.100...440.000	kV	0.001	20.000	Primary rated voltage
Secondary voltage	57...250	V	1	100	Secondary rated voltage
VT connection	1=Wye 2=Delta			2=Delta	Voltage transducer measurement connection
Amplitude Corr A	0.9000...1.1000		0.0001	1.0000	Phase A Voltage phasor magnitude correction of an external voltage transformer
Amplitude Corr B	0.9000...1.1000		0.0001	1.0000	Phase B Voltage phasor magnitude correction of an external voltage transformer
Amplitude Corr C	0.9000...1.1000		0.0001	1.0000	Phase C Voltage phasor magnitude correction of an external voltage transformer
Angle Corr A	-8.0000...8.0000	deg	0.0001	0.0000	Phase A Voltage phasor angle correction of an external voltage transformer
Angle Corr B	-8.0000...8.0000	deg	0.0001	0.0000	Phase B Voltage phasor angle correction of an external voltage transformer
Angle Corr C	-8.0000...8.0000	deg	0.0001	0.0000	Phase C Voltage phasor angle correction of an external voltage transformer
Secondary voltage	57...250	V	1	100	Secondary voltage
Primary voltage	0.100...440.000	kV	0.001	11.547	Primary voltage
Amplitude Corr	0.9000...1.1000		0.0001	1.0000	Amplitude correction
Angle correction	-8.0000...8.0000	deg	0.0001	0.0000	Angle correction factor

3.13.3.8 Monitored data

Table 76: UTVTR Monitored data

Name	Type	Values (Range)	Unit	Description
ALARM	BOOLEAN	0=False 1=True		Alarm
WARNING	BOOLEAN	0=False 1=True		Warning
MINCB_OPEN	BOOLEAN	0=False 1=True		Active when external MCB opens protected voltage circuit

3.14 GOOSE function blocks

Common signals

The VALID output indicates the validity of received GOOSE data, which means in case of valid, that the GOOSE communication is working and received data quality bits (if configured) indicate good process data. Invalid status is caused either by bad data quality bits or GOOSE communication failure. See IEC 61850 engineering guide for details.

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

Settings

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

3.14.1 Received GOOSE binary information GOOSERCV_BIN

3.14.1.1 Function block

Figure 33: Function block

3.14.1.2 Functionality

The received GOOSE binary information function GOOSERCV_BIN is used to connect the GOOSE binary inputs to the application.

3.14.1.3 Signals

Table 77: GOOSERCV_BIN Input signals

Name	Type	Default	Description
IN	BOOLEAN	0	Input signal

Table 78: GOOSERCV_BIN Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
VALID	BOOLEAN	Output signal

3.14.2 Received GOOSE measured value information GOOSERCV_MV

3.14.2.1 Function block

Figure 34: Function block

3.14.2.2 Functionality

The received GOOSE measured value information function GOOSERCV_MV is used to connect the GOOSE measured value inputs to the application.

3.14.2.3 Signals

Table 79: GOOSERCV_MV Input signals

Name	Type	Default	Description
IN	FLOAT32	0	Input signal

Table 80: GOOSERCV_MV Output signals

Name	Type	Description
OUT	FLOAT32	Output signal
VALID	BOOLEAN	Output signal

3.14.3 Received GOOSE interlocking information GOOSERCV_INTL

3.14.3.1 Function block

Figure 35: Function block

3.14.3.2 Functionality

The received GOOSE interlocking information function GOOSERCV_INTL is used to connect the GOOSE double binary input to the application and extracting single binary position signals from the double binary position signal.

The `OP` output signal indicates that the position is open. Default value (0) is used if `VALID` output indicates invalid status.

The `CL` output signal indicates that the position is closed. Default value (0) is used if `VALID` output indicates invalid status.

The `OK` output signal indicates that the position is neither in faulty or intermediate state. The default value (0) is used if `VALID` output indicates invalid status.

3.14.3.3 Signals

Table 81: GOOSERCV_INTL Input signals

Name	Type	Default	Description
IN	Dbpos	00	Input signal

Table 82: GOOSERCV_INTL Output signals

Name	Type	Description
OP	BOOLEAN	Position open output signal
CL	BOOLEAN	Position closed output signal
OK	BOOLEAN	Position OK output signal
VALID	BOOLEAN	Output signal

3.15 Type conversion function blocks

3.15.1 Good signal quality QTY_GOOD

3.15.1.1 Function block

Figure 36: Function block

3.15.1.2 Functionality

The good signal quality function QTY_GOOD evaluates the quality bits of the input signal and passes it as a Boolean signal for the application.

The `IN` input can be connected to any logic application signal (except preprocessing block). Due to application logic quality bit propagation, each (simple and even combined) signal has quality which can be evaluated.

The `OUT` output indicates quality good of the input signal. Input signals that have no quality bits set or only test bit is set, will indicate quality good status.

3.15.1.3 Signals

Table 83: QTY_GOOD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 84: QTY_GOOD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.15.2 Bad signal quality QTY_BAD

3.15.2.1 Function block

Figure 37: Function block

3.15.2.2 Functionality

The bad signal quality function QTY_BAD evaluates the quality bits of the input signal and passes it as a Boolean signal for the application.

The IN input can be connected to any logic application signal (except preprocessing block). Due to application logic quality bit propagation, each (simple and even combined) signal has quality which can be evaluated.

The OUT output indicates quality bad of the input signal. Input signals that have any other than test bit set, will indicate quality bad status.

3.15.2.3 Signals

Table 85: QTY_BAD Input signals

Name	Type	Default	Description
IN	Any	0	Input signal

Table 86: QTY_BAD Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

3.16 Configurable logic blocks

3.16.1 Minimum pulse timer

3.16.1.1 Minimum pulse timer, two channels TPGAPC (ANSI 62TP)

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum pulse timer, two channels	TPGAPC	TP	62TP

Function block

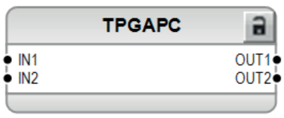

Figure 38: Function block

Functionality

The minimum pulse timer, two channels, function TPGAPC contains two independent timers. The function has a settable pulse length (in milliseconds). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated, the output is set for a specific duration using the *Pulse time* setting. Both timers use the same setting parameter.

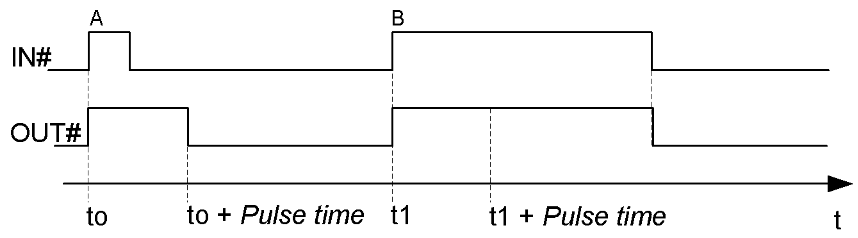

Figure 39: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

Signals

Table 87: TPGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2

Table 88: TPGAPC Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

Settings

Table 89: TPGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...60000	ms	1	150	Minimum pulse time

Monitored data

Table 90: TPGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
OUT1	BOOLEAN	0=False 1=True		Output 1 status
OUT2	BOOLEAN	0=False 1=True		Output 2 status
IN1	BOOLEAN	0=False 1=True		Input 1
IN2	BOOLEAN	0=False 1=True		Input 2

3.16.1.2 Minimum pulse timer second resolution, two channels TPSGAPC (ANSI 62TPS)

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum pulse timer second resolution, two channels	TPSGAPC	TPS	62TPS

Function block

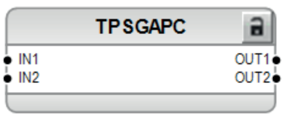

Figure 40: Function block

Functionality

The minimum pulse timer second resolution, two channels, function TPSGAPC contains two independent timers. The function has a settable pulse length (in seconds). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated, the output is set for a specific duration using the *Pulse time* setting. Both timers use the same setting parameter.

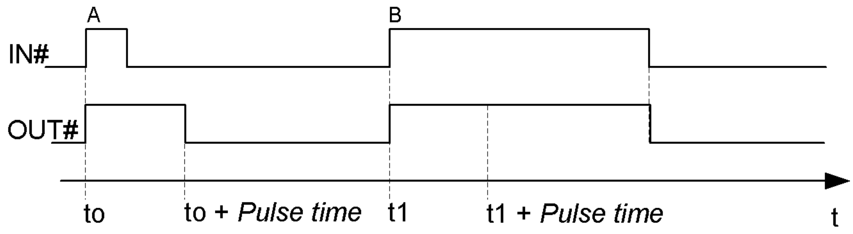

Figure 41: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

Signals

Table 91: TPSGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2

Table 92: TPSGAPC Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

Settings

Table 93: TPSGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	s	1	0	Minimum pulse time

Monitored data

Table 94: TPSGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
OUT1	BOOLEAN	0=False 1=True		Output 1 status
OUT2	BOOLEAN	0=False 1=True		Output 2 status
IN1	BOOLEAN	0=False 1=True		Input 1
IN2	BOOLEAN	0=False 1=True		Input 2

3.16.1.3 Minimum pulse timer minutes resolution, two channels TPMGAPC (ANSI 62TPM)

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Minimum pulse timer minutes resolution, two channels	TPMGAPC	TPM	62TPM

Function block

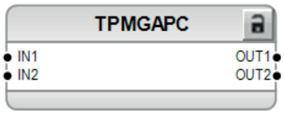

Figure 42: Function block

Functionality

The minimum pulse timer minutes resolution, two channels, function TPMGAPC contains two independent timers. The function has a settable pulse length (in minutes). The timers are used for setting the minimum pulse length for example, the signal outputs. Once the input is activated, the output is set for a specific duration using the *Pulse time* setting. Both timers use the same setting parameter.

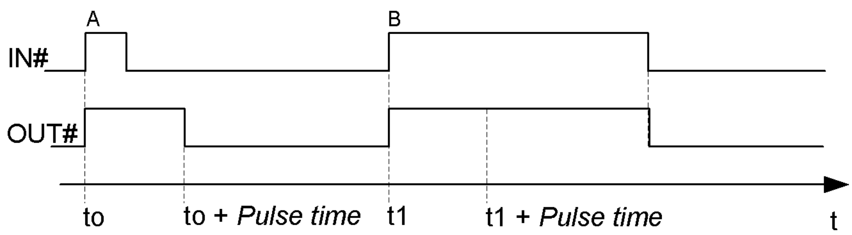

Figure 43: A = Trip pulse is shorter than Pulse time setting, B = Trip pulse is longer than Pulse time setting

Signals

Table 95: TPMGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2

Table 96: TPMGAPC Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1 status
OUT2	BOOLEAN	Output 2 status

Settings

Table 97: TPMGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Pulse time	0...300	min	1	0	Minimum pulse time

Monitored data

Table 98: TPMGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
OUT1	BOOLEAN	0=False 1=True		Output 1 status
OUT2	BOOLEAN	0=False 1=True		Output 2 status
IN1	BOOLEAN	0=False 1=True		Input 1
IN2	BOOLEAN	0=False 1=True		Input 2

3.16.2 Time delay off, eight channels TOFGAPC (ANSI 62TOF)

3.16.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time delay off, eight channels	TOFGAPC	TOF	62TOF

3.16.2.2 Function block

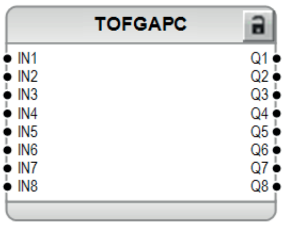

Figure 44: Function block

3.16.2.3 Functionality

The time delay off, eight channels, function TOFGAPC can be used, for example, for a drop-off-delayed output related to the input signal. The function contains eight independent timers. There is a settable delay in the timer. Once the input is activated, the output is set immediately. When the input is cleared, the output stays on until the time set with the *Off delay time* setting has elapsed.

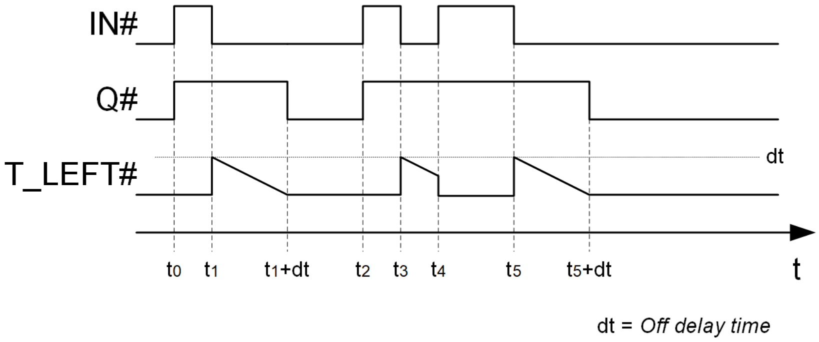

Figure 45: Timer operation

3.16.2.4 Signals

Table 99: TOFGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1 status
IN2	BOOLEAN	0=False	Input 2 status
IN3	BOOLEAN	0=False	Input 3 status
IN4	BOOLEAN	0=False	Input 4 status
IN5	BOOLEAN	0=False	Input 5 status
IN6	BOOLEAN	0=False	Input 6 status
IN7	BOOLEAN	0=False	Input 7 status
IN8	BOOLEAN	0=False	Input 8 status

Table 100: TOFGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1 status
Q2	BOOLEAN	Output 2 status
Q3	BOOLEAN	Output 3 status
Q4	BOOLEAN	Output 4 status
Q5	BOOLEAN	Output 5 status
Q6	BOOLEAN	Output 6 status
Q7	BOOLEAN	Output 7 status
Q8	BOOLEAN	Output 8 status

3.16.2.5 Settings

Table 101: TOFGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Off delay time 1	0...3600000	ms	10	0	Off delay time
Off delay time 2	0...3600000	ms	10	0	Off delay time
Off delay time 3	0...3600000	ms	10	0	Off delay time
Off delay time 4	0...3600000	ms	10	0	Off delay time
Off delay time 5	0...3600000	ms	10	0	Off delay time
Off delay time 6	0...3600000	ms	10	0	Off delay time
Off delay time 7	0...3600000	ms	10	0	Off delay time
Off delay time 8	0...3600000	ms	10	0	Off delay time

3.16.2.6 Monitored data

Table 102: TOFGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
Q1	BOOLEAN	0=False 1=True		Output 1 status
Q2	BOOLEAN	0=False 1=True		Output 2 status
Q3	BOOLEAN	0=False 1=True		Output 3 status
Q4	BOOLEAN	0=False 1=True		Output 4 status
Q5	BOOLEAN	0=False 1=True		Output 5 status
Q6	BOOLEAN	0=False 1=True		Output 6 status
Q7	BOOLEAN	0=False 1=True		Output 7 status
Q8	BOOLEAN	0=False 1=True		Output 8 status
IN1	BOOLEAN	0=False 1=True		Input 1 status
IN2	BOOLEAN	0=False 1=True		Input 2 status
IN3	BOOLEAN	0=False 1=True		Input 3 status
IN4	BOOLEAN	0=False 1=True		Input 4 status
IN5	BOOLEAN	0=False 1=True		Input 5 status

Table continues on next page

Name	Type	Values (Range)	Unit	Description
IN6	BOOLEAN	0=False 1=True		Input 6 status
IN7	BOOLEAN	0=False 1=True		Input 7 status
IN8	BOOLEAN	0=False 1=True		Input 8 status

3.16.2.7 Technical data

Table 103: TOFGAPC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±40 ms

3.16.3 Time delay on, eight channels TONGAPC (ANSI 62TON)

3.16.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time delay on, eight channels	TONGAPC	TON	62TON

3.16.3.2 Function block

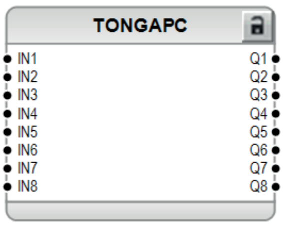

Figure 46: Function block

3.16.3.3 Functionality

The time delay on, eight channels, function TONGAPC can be used, for example, for time-delaying the output related to the input signal. TONGAPC contains eight independent timers. The timer has a settable time delay. Once the input is activated, the output is set after the time set by the *On delay time* setting has elapsed.

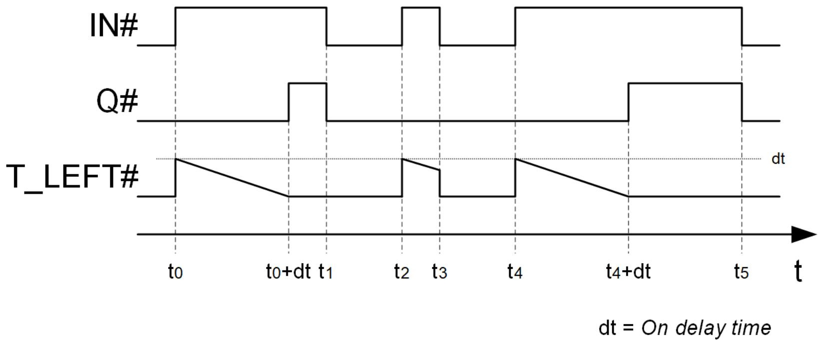

Figure 47: Timer operation

3.16.3.4 Signals

Table 104: TONGAPC Input signals

Name	Type	Default	Description
IN1	BOOLEAN	0=False	Input 1
IN2	BOOLEAN	0=False	Input 2
IN3	BOOLEAN	0=False	Input 3
IN4	BOOLEAN	0=False	Input 4
IN5	BOOLEAN	0=False	Input 5
IN6	BOOLEAN	0=False	Input 6
IN7	BOOLEAN	0=False	Input 7
IN8	BOOLEAN	0=False	Input 8

Table 105: TONGAPC Output signals

Name	Type	Description
Q1	BOOLEAN	Output 1
Q2	BOOLEAN	Output 2
Q3	BOOLEAN	Output 3
Q4	BOOLEAN	Output 4
Q5	BOOLEAN	Output 5
Q6	BOOLEAN	Output 6
Q7	BOOLEAN	Output 7
Q8	BOOLEAN	Output 8

3.16.3.5 Settings

Table 106: TONGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
On delay time 1	0...3600000	ms	10	0	On delay time
On delay time 2	0...3600000	ms	10	0	On delay time
On delay time 3	0...3600000	ms	10	0	On delay time
On delay time 4	0...3600000	ms	10	0	On delay time
On delay time 5	0...3600000	ms	10	0	On delay time
On delay time 6	0...3600000	ms	10	0	On delay time
On delay time 7	0...3600000	ms	10	0	On delay time
On delay time 8	0...3600000	ms	10	0	On delay time

3.16.3.6 Monitored data

Table 107: TONGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
Q1	BOOLEAN	0=False 1=True		Output 1
Q2	BOOLEAN	0=False 1=True		Output 2
Q3	BOOLEAN	0=False 1=True		Output 3
Q4	BOOLEAN	0=False 1=True		Output 4
Q5	BOOLEAN	0=False 1=True		Output 5
Q6	BOOLEAN	0=False 1=True		Output 6
Q7	BOOLEAN	0=False 1=True		Output 7
Q8	BOOLEAN	0=False 1=True		Output 8
IN1	BOOLEAN	0=False 1=True		Input 1
IN2	BOOLEAN	0=False 1=True		Input 2
IN3	BOOLEAN	0=False 1=True		Input 3
IN4	BOOLEAN	0=False 1=True		Input 4
IN5	BOOLEAN	0=False 1=True		Input 5

Table continues on next page

Name	Type	Values (Range)	Unit	Description
IN6	BOOLEAN	0=False 1=True		Input 6
IN7	BOOLEAN	0=False 1=True		Input 7
IN8	BOOLEAN	0=False 1=True		Input 8

3.16.3.7 Technical data

Table 108: TONGAPC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±40 ms

3.16.4 Programmable buttons FKEYGGIO (ANSI FKEY)

3.16.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Programmable buttons (2 buttons)	FKEYGGIO	FKEY	FKEY

3.16.4.2 Function block

Figure 48: Function block

3.16.4.3 Functionality

The programmable buttons function FKEYGGIO is a simple interface between the panel and the application. The user input from the buttons available on the front panel is transferred to the assigned functionality and the corresponding LED is ON or OFF for indication. The behavior of each function key in the specific application is configured by connection with other application functions. This gives the maximum flexibility.

3.16.4.4 Operation principle

L1 and L2 represent the LEDs on the protection relay's LHMI. When an input is set to TRUE, the corresponding LED is lit. When a function key on LHMI is pressed, the corresponding output, K1 or K2, is set to TRUE.

3.16.4.5 Signals

Table 109: FKEYGGIO Input signals

Name	Type	Default	Description
L1	BOOLEAN	0=False	LED 1
L2	BOOLEAN	0=False	LED 2

Table 110: FKEYGGIO Output signals

Name	Type	Description
K1	BOOLEAN	KEY 1
K2	BOOLEAN	KEY 2

3.16.4.6 Monitored data

Table 111: FKEYGGIO Monitored data

Name	Type	Values (Range)	Unit	Description
L1	BOOLEAN	0=False 1=True		LED 1
L2	BOOLEAN	0=False 1=True		LED 2
K1	BOOLEAN	0=False 1=True		KEY 1
K2	BOOLEAN	0=False 1=True		KEY 2

3.17 Standard logic operators

3.17.1 OR gate with two inputs OR, six inputs OR6 and twenty inputs OR20

3.17.1.1 Function block

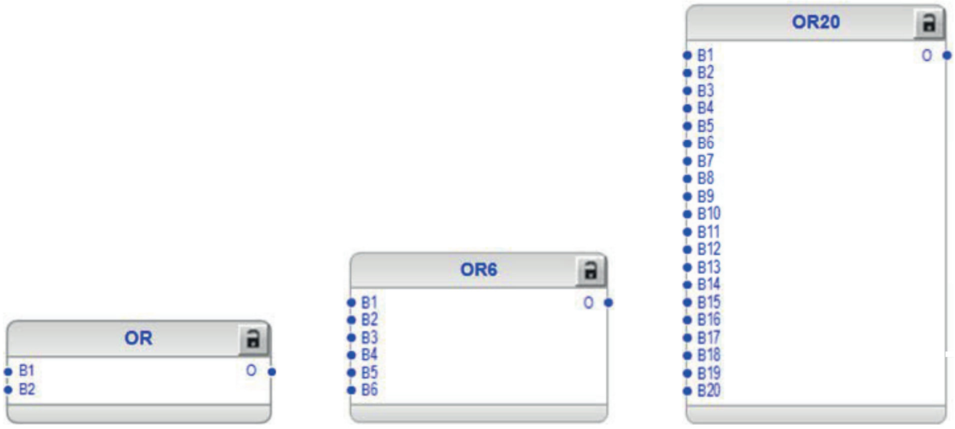

Figure 49: Function blocks

3.17.1.2 Functionality

OR, OR6 and OR20 are used to form general combinatory expressions with boolean variables.

The O output is activated when at least one input has the value TRUE. The default value of all inputs is FALSE, which makes it possible to use only the required number of inputs and leave the rest disconnected.

OR has two inputs, OR6 six and OR20 twenty inputs.

3.17.1.3 Signals

Table 112: OR Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2

Table 113: OR6 Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2
B3	BOOLEAN	0	Input signal 3
B4	BOOLEAN	0	Input signal 4
B5	BOOLEAN	0	Input signal 5
B6	BOOLEAN	0	Input signal 6

Table 114: Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2
B3	BOOLEAN	0	Input signal 3
B4	BOOLEAN	0	Input signal 4
B5	BOOLEAN	0	Input signal 5
B6	BOOLEAN	0	Input signal 6
B7	BOOLEAN	0	Input signal 7
B8	BOOLEAN	0	Input signal 8
B9	BOOLEAN	0	Input signal 9
B10	BOOLEAN	0	Input signal 10
B11	BOOLEAN	0	Input signal 11
B12	BOOLEAN	0	Input signal 12
B13	BOOLEAN	0	Input signal 13
B14	BOOLEAN	0	Input signal 14
B15	BOOLEAN	0	Input signal 15
B16	BOOLEAN	0	Input signal 16
B17	BOOLEAN	0	Input signal 17
B18	BOOLEAN	0	Input signal 18
B19	BOOLEAN	0	Input signal 19
B20	BOOLEAN	0	Input signal 20

Table 115: OR Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 116: OR6 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 117: OR20 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 118: OR20 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

3.17.1.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.2 AND gate with two inputs AND, six inputs AND6 and twenty inputs AND20

3.17.2.1 Function block

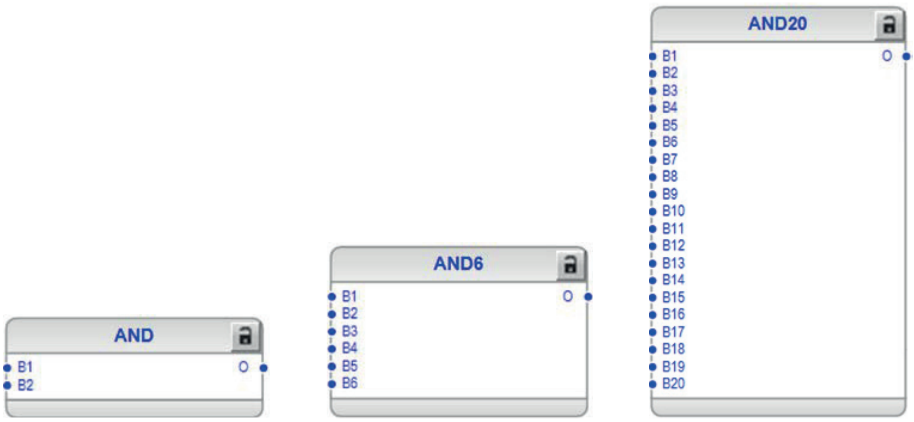

Figure 50: Function blocks

3.17.2.2 Functionality

AND, AND6 and AND20 are used to form general combinatory expressions with boolean variables.

The default value in all inputs is logical TRUE, which makes it possible to use only the required number of inputs and leave the rest disconnected.

AND has two inputs, AND6 six inputs and AND20 twenty inputs.

3.17.2.3 Signals

Table 119: AND Input signals

Name	Type	Default	Description
B1	BOOLEAN	1	Input signal 1
B2	BOOLEAN	1	Input signal 2

Table 120: AND6 Input signals

Name	Type	Default	Description
B1	BOOLEAN	1	Input signal 1
B2	BOOLEAN	1	Input signal 2
B3	BOOLEAN	1	Input signal 3
B4	BOOLEAN	1	Input signal 4
B5	BOOLEAN	1	Input signal 5
B6	BOOLEAN	1	Input signal 6

Table 121: AND20 Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2
B3	BOOLEAN	0	Input signal 3
B4	BOOLEAN	0	Input signal 4
B5	BOOLEAN	0	Input signal 5
B6	BOOLEAN	0	Input signal 6
B7	BOOLEAN	0	Input signal 7
B8	BOOLEAN	0	Input signal 8
B9	BOOLEAN	0	Input signal 9
B10	BOOLEAN	0	Input signal 10
B11	BOOLEAN	0	Input signal 11
B12	BOOLEAN	0	Input signal 12
B13	BOOLEAN	0	Input signal 13
B14	BOOLEAN	0	Input signal 14
B15	BOOLEAN	0	Input signal 15
B16	BOOLEAN	0	Input signal 16
B17	BOOLEAN	0	Input signal 17
B18	BOOLEAN	0	Input signal 18
B19	BOOLEAN	0	Input signal 19
B20	BOOLEAN	0	Input signal 20

Table 122: AND Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 123: AND6 Output signals

Name	Type	Description
O	BOOLEAN	Output signal

Table 124: AND20 output signals

Name	Type	Description
O	BOOLEAN	Output signal

3.17.2.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.3 XOR gate with two inputs XOR

3.17.3.1 Function block

Figure 51: Function block

3.17.3.2 Functionality

The exclusive OR function XOR is used to generate combinatory expressions with boolean variables.

The output signal is TRUE if the input signals are different and FALSE if they are equal.

3.17.3.3 Signals

Table 125: XOR Input signals

Name	Type	Default	Description
B1	BOOLEAN	0	Input signal 1
B2	BOOLEAN	0	Input signal 2

Table 126: XOR Output signal

Name	Type	Description
O	BOOLEAN	Output signal

3.17.3.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.4 NOT gate NOT

3.17.4.1 Function block

Figure 52: Function block

3.17.4.2 Functionality

NOT is used to generate combinatory expressions with boolean variables.

NOT inverts the input signal.

3.17.4.3 Signals

Table 127: NOT Input signals

Name	Type	Default	Description
I	BOOLEAN	0	Input signal

Table 128: NOT Output signal

Name	Type	Description
O	BOOLEAN	Output signal

3.17.4.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.5 Rising edge detector R_TRIG

3.17.5.1 Function block

Figure 53: Function block

3.17.5.2 Functionality

R_TRIG is used as a rising edge detector.

R_TRIG detects the transition from FALSE to TRUE at the CLK input. When the rising edge is detected, the element assigns the output to TRUE. At the next execution round, the output is returned to FALSE despite the state of the input.

3.17.5.3 Signals

Table 129: R_TRIG Input signals

Name	Type	Default	Description
CLK	BOOLEAN	0	Input signal

Table 130: R_TRIG Output signals

Name	Type	Description
Q	BOOLEAN	Output signal

3.17.5.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.6 Falling edge detector F_TRIG

3.17.6.1 Function block

Figure 54: Function block

3.17.6.2 Functionality

F_TRIG is used as a falling edge detector.

The function detects the transition from TRUE to FALSE at the CLK input. When the falling edge is detected, the element assigns the Q output to TRUE. At the next execution round, the output is returned to FALSE despite the state of the input.

3.17.6.3 Signals

Table 131: F_TRIG Input signals

Name	Type	Default	Description
CLK	BOOLEAN	0	Input signal

Table 132: F_TRIG Output signals

Name	Type	Description
Q	BOOLEAN	Output signal

3.17.6.4 Settings

The function does not have any parameters available in the LHMI or in PCM600.

3.17.7 SR flip-flop, volatile SR

3.17.7.1 Function block

Figure 55: Function block

3.17.7.2 Functionality

The SR flip-flop output `Q` can be set or reset from the `S` or `R` inputs. `S` input has a higher priority over the `R` input. Output `NOTQ` is the negation of output `Q`.

The statuses of outputs `Q` and `NOTQ` are not retained in the nonvolatile memory.

Table 133: Truth table for SR flip-flop

S	R	Q
0	0	0[1)]
0	1	0
1	0	1
1	1	1

1) Keep state/no change

3.17.7.3 Signals

Table 134: SR Input signals

Name	Type	Default	Description
S	BOOLEAN	0=False	Set Q output when set
R	BOOLEAN	0=False	Resets Q output when set

Table 135: SR Output signals

Name	Type	Description
Q	BOOLEAN	Q status
NOTQ	BOOLEAN	NOTQ status

3.17.8 RS flip-flop, volatile RS

3.17.8.1 Function block

Figure 56: Function block

3.17.8.2 Functionality

The RS flip-flop output `Q` can be set or reset from the `S` or `R` inputs. `R` input has a higher priority over the `S` input. Output `NOTQ` is the negation of output `Q`.

The statuses of outputs `Q` and `NOTQ` are not retained in the nonvolatile memory.

Table 136: Truth table for RS flip-flop

S	R	Q
0	0	0[1)]
0	1	0
1	0	1
1	1	0

1) Keep state/no change

3.17.8.3 Signals

Table 137: RS Input signals

Name	Type	Default	Description
S	BOOLEAN	0=False	Set Q output when set
R	BOOLEAN	0=False	Resets Q output when set

Table 138: RS Output signals

Name	Type	Description
Q	BOOLEAN	Q status
NOTQ	BOOLEAN	NOTQ status

3.18 Factory settings restoration

In case of configuration data loss or any other file system error that prevents the protection relay from working properly, the whole file system can be restored to the original factory state. All default settings and configuration files stored in the factory are restored. As the relay has no configuration, a warning message `Config. not available` is displayed.

For further information on restoring factory settings, see the operation manual.

3.19 Ethernet channel supervision functions

The protection relay offers a bandwidth rate limiting functionality to limit the Ethernet/TCP network traffic. The main purpose of this feature is the possibility to divide network segments for different multicast frame types and also to limit the network congestion and traffic towards the protection relay processing during network attacks (such as a Denial of Service attack) or in case of network configuration issues.

The Ethernet rate limiter is configured for 1000 packets per second. The Ethernet filter only allows the subscribed GOOSE packets.

3.19.1 Ethernet channel supervision SCHLCCH

3.19.1.1 Function block

Figure 57: Function block

3.19.1.2 Functionality

Ethernet channel supervision SCHLCCH represents the rear LAN Ethernet channel.

An unused Ethernet port can be set "Off" with the setting **Configuration/ Communication/Ethernet/Rear port/Port Mode**. This setting closes the port from software, disabling the Ethernet communication in that port. Closing an unused Ethernet port enhances the cyber security of the relay.

3.19.1.3 Signals

Table 139: SCHLCCH Output signals

Name	Type	Description
CH1LIV	BOOLEAN	Ethernet channel live
LNK1LIV	BOOLEAN	Ethernet port 1 link status

3.19.1.4 Settings

Table 140: SCHLCCH Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Port mode	0=Off 1=On			1=On	Ethernet port mode

3.19.1.5 Monitored data

Table 141: SCHLCCH Monitored data

Name	Type	Values (Range)	Unit	Description
CH1LIV	BOOLEAN	0=False 1=True		Ethernet channel live
LNK1LIV	BOOLEAN	0=False 1=True		Ethernet port 1 link status

Section 4 Protection functions

4.1 Three-phase current protection

4.1.1 Three-phase non-directional overcurrent protection PHxPTOC (ANSI 51P-1, 51P-2, 50P)

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

4.1.1.2 Function block

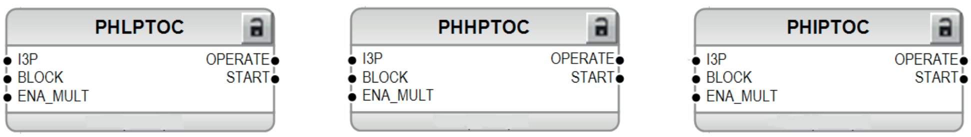

Figure 58: Function block

4.1.1.3 Functionality

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

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.

4.1.1.4 Analog input configuration

PHxPTOC has one analog group input which must be properly configured.

Table 142: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.1.1.5 Operation principle

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

The operation of PHxPTOC can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

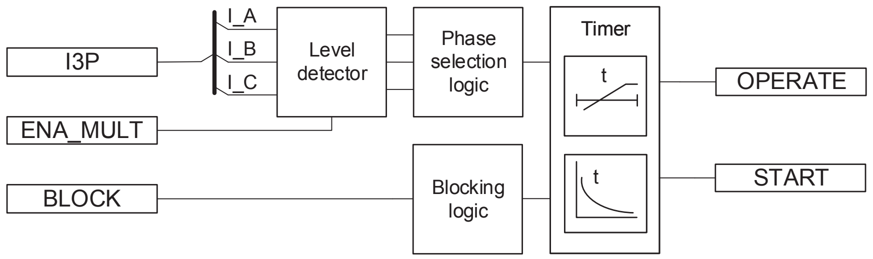

Figure 59: Functional module diagram

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 protection relay 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.

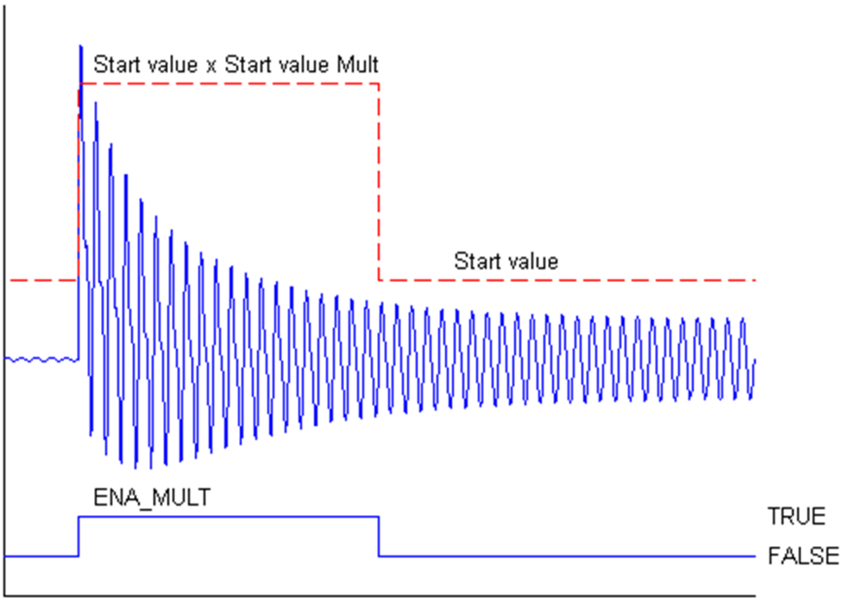

Figure 60: Start value behavior with ENA_MULT *input activated*

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.

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 operation 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 and the value of START_DUR. The `START` output is deactivated when the reset timer has elapsed.

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 IDMT curves for overcurrent protection 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 operating time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the `OPERATE` output is not deactivated when blocking is activated. 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.

4.1.1.6 Measurement modes

The function operates on four alternative measurement modes: "RMS", "DFT", "Peak-to-Peak" and "P-to-P + backup". Additionally, there is “Wide P-to-P” measurement mode in some products variants. The measurement mode is selected with the setting *Measurement mode*.

Table 143: Measurement modes supported by PHxPTOC stages

Measurement mode	PHLPTOC	PHHPTOC	PHIPTOC
RMS	x	x	
DFT	x	x	
Peak-to-Peak	x	x	
P-to-P + backup			x
Wide P-to-P	x		

For a detailed description of the measurement modes, see the Measurement modes section in this manual.

4.1.1.7 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 protection 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 DT characteristics can be chosen by selecting the *Operating curve type* values "ANSI Def. Time" or "IEC Def. Time". The functionality is identical in both cases.

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

Table 144: Timer characteristics supported by different stages

Operating curve type	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

Table continues on next page

Operating curve type	PHLPTOC	PHHPTOC
(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	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 145: Reset time characteristics supported by different stages

Reset curve type	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.

4.1.1.8 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
- Backup 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 backup 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 overcurrent protection

The purpose of transformer overcurrent protection is to operate as main protection, when differential protection is not used. It can also be used as coarse back-up protection for differential protection in faults inside the zone of protection, that is, faults occurring in incoming or outgoing feeders, in the region of transformer terminals and tank cover. This means that the magnitude range of the fault current can be very wide. The range varies from $6xI_n$ to several hundred times I_n, depending on the impedance of the transformer and the source impedance of the feeding network. From this point of view, it is clear that the operation must be both very fast and selective, which is usually achieved by using coarse current settings.

The purpose is also to protect the transformer from short circuits occurring outside the protection zone, that is through-faults. Transformer overcurrent protection also provides protection for the LV-side busbars. In this case the magnitude of the fault current is typically lower than $12xI_n$ depending on the fault location and transformer impedance. Consequently, the protection must operate as fast as possible taking into account the selectivity requirements, switching-in currents, and the thermal and mechanical withstand of the transformer and outgoing feeders.

Traditionally, overcurrent protection of the transformer has been arranged as shown in Figure 61. The low-set stage PHLPTOC operates time-selectively both in transformer and LV-side busbar faults. The high-set stage PHHPTOC operates instantaneously making use of current selectivity only in transformer HV-side faults. If there is a possibility, that the fault current can also be fed from the LV-side up to the HV-side, the transformer must also be equipped with LV-side overcurrent protection. Inrush current detectors are used in start-up situations to multiply the current start value setting in each particular protection relay where the inrush current can occur. The overcurrent and contact based circuit breaker failure protection CCBRBRF is used to confirm the protection scheme in case of circuit breaker malfunction.

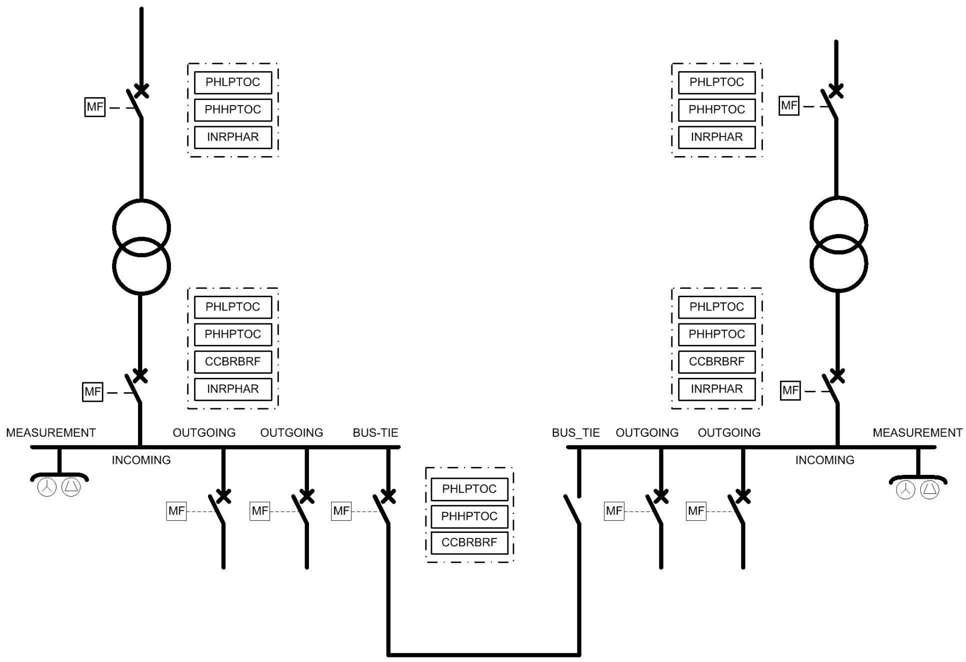

Figure 61: Example of traditional time selective transformer overcurrent protection

The operating times of the main and backup overcurrent protection of the above scheme become quite long, this applies especially in the busbar faults and also in the transformer LV-terminal faults. In order to improve the performance of the above scheme, a multiple-stage overcurrent protection with reverse blocking is proposed. Figure 62 shows this arrangement.

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 backup 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 62 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 146: Proposed functionality of numerical transformer and busbar overcurrent 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 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.

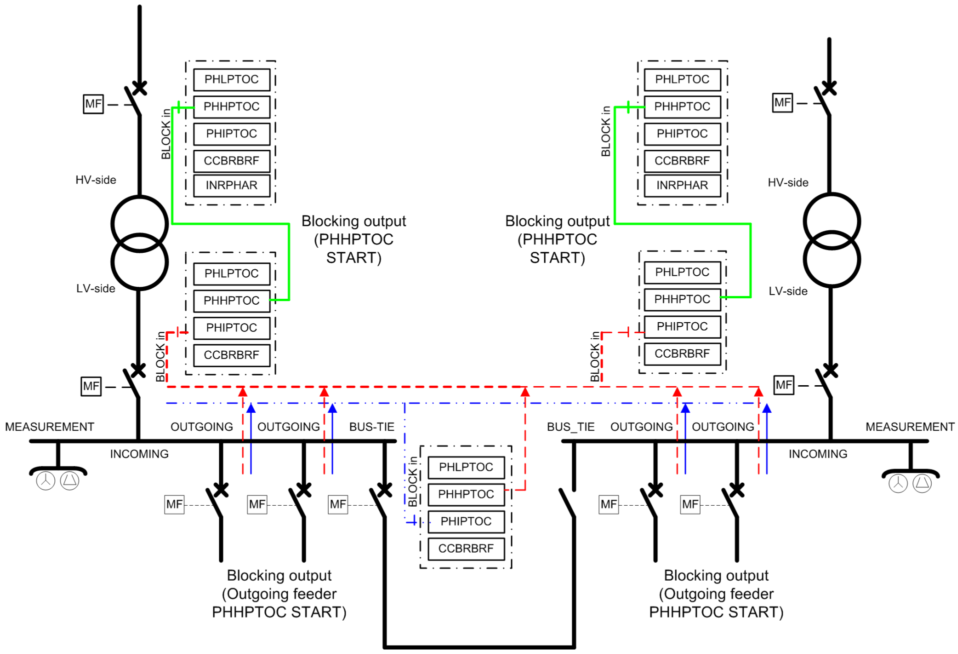

Figure 62: Numerical overcurrent protection functionality for a typical sub-transmission/distribution substation (feeder protection not shown). Blocking output = digital output signal from the start of a protection stage, Blocking in = digital input signal to block the operation of a protection stage

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 very low. Also, the effects of switching inrush currents on the setting values can be reduced by using the protection relay's 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, see the Measurement modes chapter in this 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 multiple-stage overcurrent units. Figure 63 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 overcurrent 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.

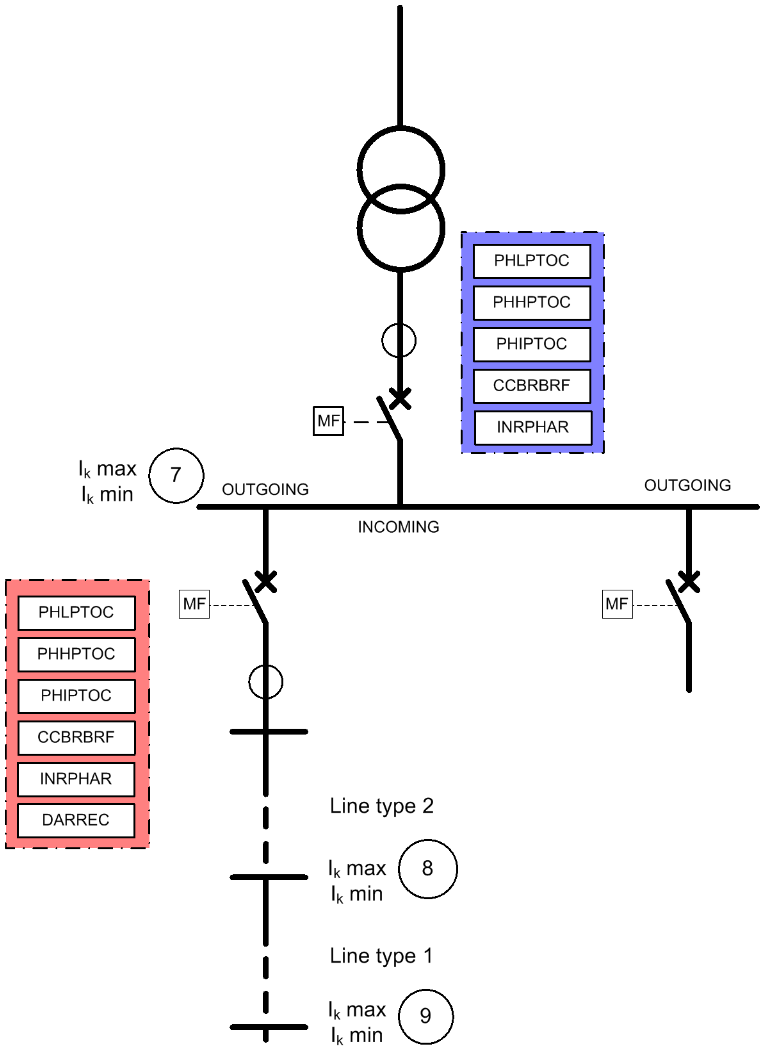

Figure 63: Functionality of numerical multiple-stage overcurrent protection

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 simultaneously in a coordination plan. In Figure 64, the coordination plan shows an example of operation characteristics in the LV-side incoming feeder and radial outgoing feeder.

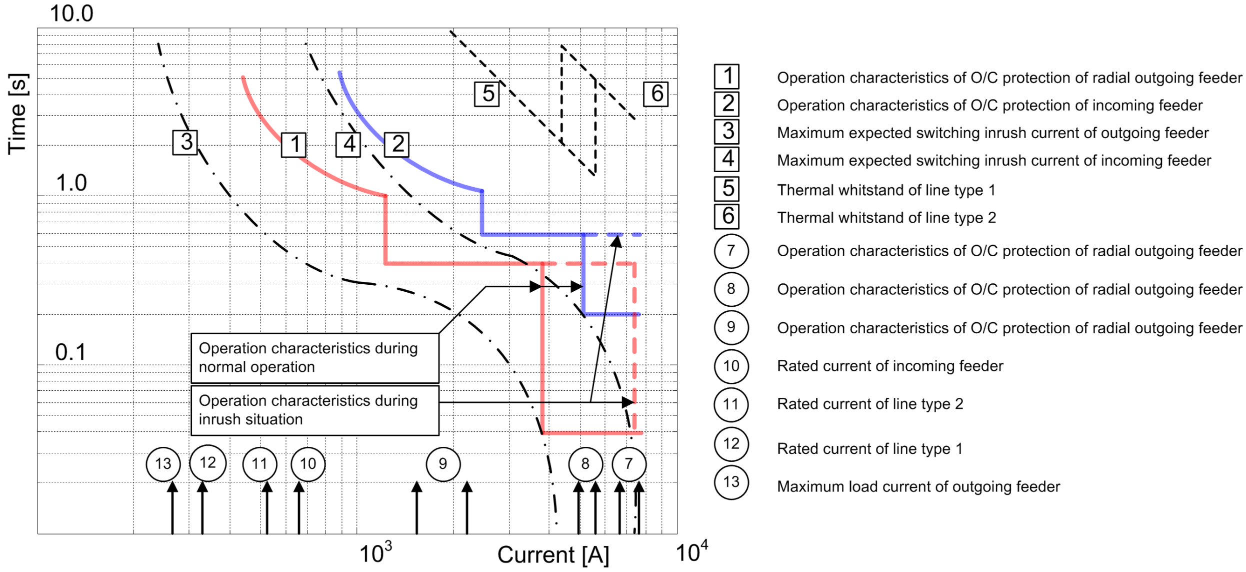

Figure 64: Example coordination of numerical multiple-stage overcurrent protection

4.1.1.9 Signals

Table 147: PHLPTOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 148: PHHPTOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 149: PHIPTOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 150: PHLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 151: PHHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 152: PHIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.1.10 Settings

Table 153: PHLPTOC Non group settings (Basic)

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
Curve parameter A	0.0086...50000.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...6.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 154: PHLPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
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
Operate delay time	40...300000	ms	10	40	Operate delay time

Table 155: PHLPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak 5=Wide P-to-P			2=DFT	Selects used measurement mode
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

Table 156: PHLPTOC Group settings (Advanced)

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

Table 157: PHHPTOC Non group settings (Basic)

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
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 158: PHHPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
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
Operate delay time	40...300000	ms	10	40	Operate delay time

Table 159: PHHPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
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

Table 160: PHHPTOC Group settings (Advanced)

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

Table 161: PHIPTOC Non group settings (Basic)

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

Table 162: PHIPTOC Group settings (Basic)

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...300000	ms	10	20	Operate delay time

Table 163: PHIPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.1.11 Monitored data

Table 164: PHLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHLPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 165: PHHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHHPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 166: PHIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHIPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.1.12 Technical data

Table 167: PHxPTOC Technical data

Characteristic		Value		
Operation accuracy	PHLPTOC	Depending on the frequency of current measured: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × I_n[1)] ±1.5% of the set value or ±0.007 × I_n[2)]		
	PHHPTOC and PHIPTOC	±1.5% of the set value or ±0.002 × I_n[1)] ±1.5% of the set value or ±0.007 × I_n[2)] (at currents in the range of 0.1…10 × I_n) ±5% of the set value (at currents in the range of 10…40 × I_n)		
Start time[3)4)]		Minimum	Typical	Maximum
	PHIPTOC: I_{Fault} = 2 × set *Start value* I_{Fault} = 10 × set *Start value*	12ms 8 ms	20 ms 13 ms	38 ms 31 ms
	PHHPTOC and PHLPTOC: I_{Fault} = 2 × set *Start value*	25 ms	35 ms	48 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms[5)]		
Suppression of harmonics		RMS: No suppression DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression P-to-P+backup: No suppression		

1) *Measurement mode* = "RMS", "DFT" and "Peak-Peak" mode with CT secondary >0.2 A
2) *Measurement mode* = "Peak-to-peak", CT Secondary <0.2 A
3) *Measurement mode* = default (depends on the stage), current before fault = 0.0 × 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
4) Includes the delay of the signal output contact (SO)
5) Maximum *Start value* = 2.5 × I_n, *Start value* multiples in the range of 1.5...20

4.1.2 Three-phase directional overcurrent protection DPHxPDOC (ANSI 67P/51P-1, 67P/51P-2)

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> ->	67P/51P-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67P/51P-2

4.1.2.2 Function block

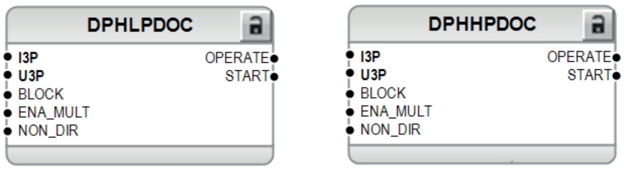

Figure 65: Function block

4.1.2.3 Functionality

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

DPHxPDOC starts up 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.

4.1.2.4 Analog channel configuration

DPHxPDOC has two analog group inputs which must be properly configured.

Table 168: Analog inputs

Input	Description
I3P	Three-phase currents
U3P	Three-phase voltages

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 169: Special conditions

Condition	Description
U3P connected to real measurements	The function can work with any two phase voltage channels connected but it is recommended to connect all three voltage channels.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.1.2.5 Operation principle

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

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

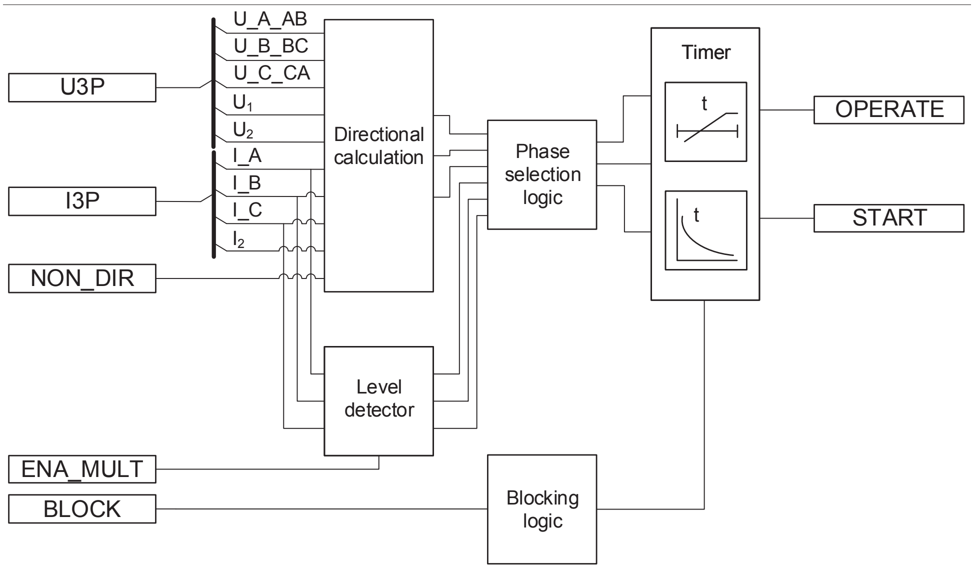

Figure 66: Functional module diagram

Directional calculation

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

Table 170: 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. The user can select either "Non-directional", "Forward" or "Reverse" operation. 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 protection relay 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 a voltage memory arises and these are kept frozen until the time set with *Voltage Mem time* elapses.

The value for the *Min operate voltage* setting should be carefully selected since the accuracy in low signal levels is strongly affected by the measuring device accuracy.

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.

DPHxPDOC can be forced to the non-directional operation with the `NON_DIR` input. When the `NON_DIR` input is active, DPHxPDOC operates as a non-directional overcurrent protection, regardless of the *Directional mode* setting.

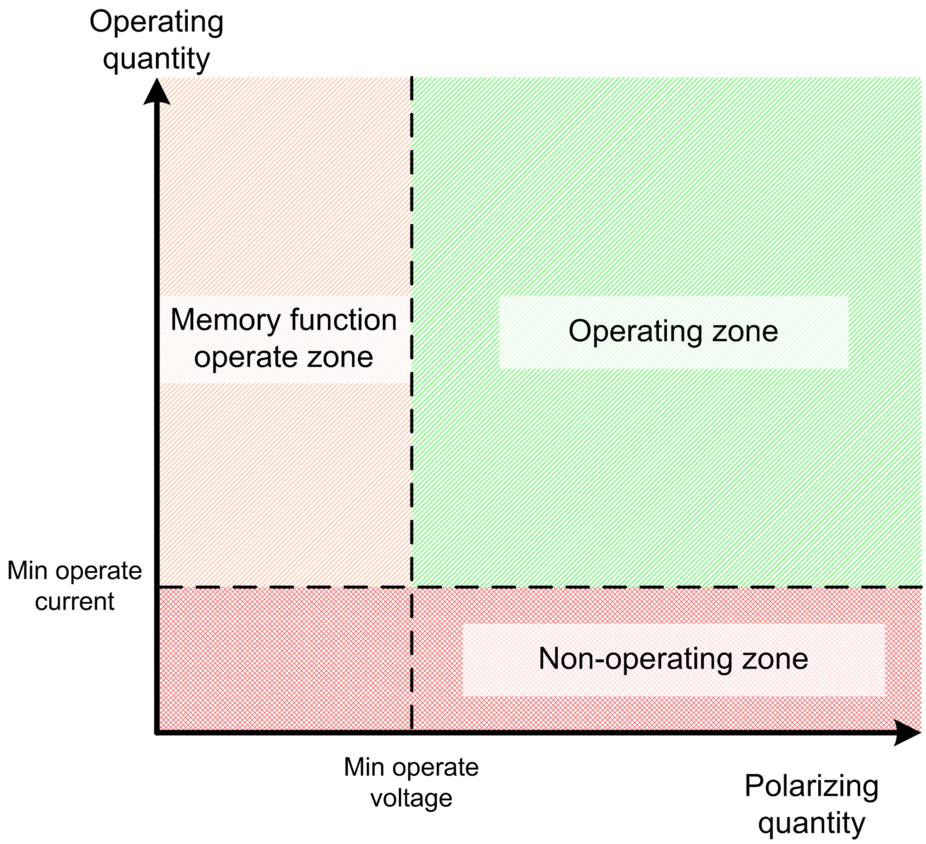

Figure 67: Operating zones at minimum magnitude levels

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 protection relay 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.

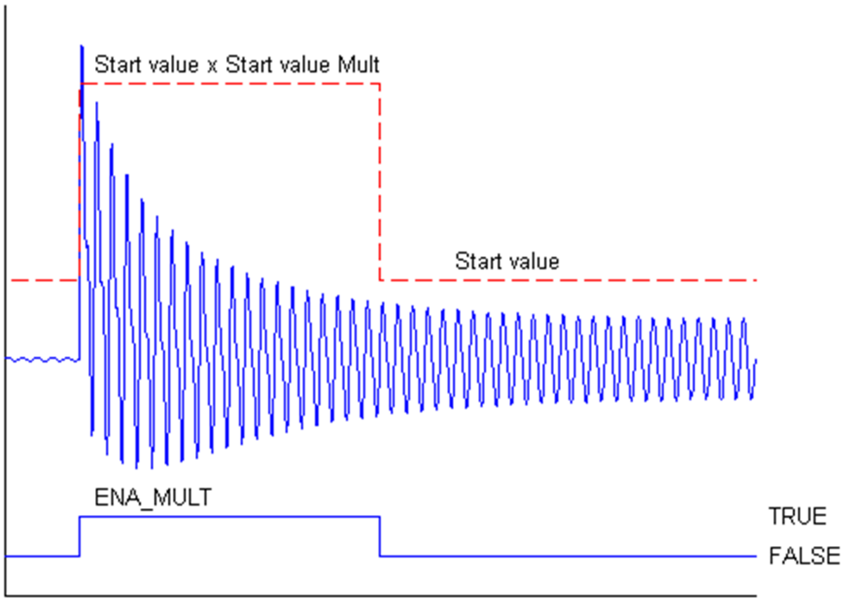

Figure 68: Start value behavior with `ENA_MULT` *input activated*

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 operation 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 and the value of START_DUR. The `START` output is deactivated when the reset timer has elapsed.

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 IDMT curves for overcurrent protection 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 operating time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the `OPERATE` output is not deactivated when blocking is activated. 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.

4.1.2.6 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 171: Measurement modes supported by DPHxPDOC stages

Measurement mode	DPHLPDOC	DPHHPDOC
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

4.1.2.7 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 backward operation area, the *Max reverse angle* setting gives the counterclockwise sector and the *Min reverse angle* setting gives the corresponding clockwise sector, a measurement from the *Characteristic angle* setting that has been rotated 180 degrees.

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.

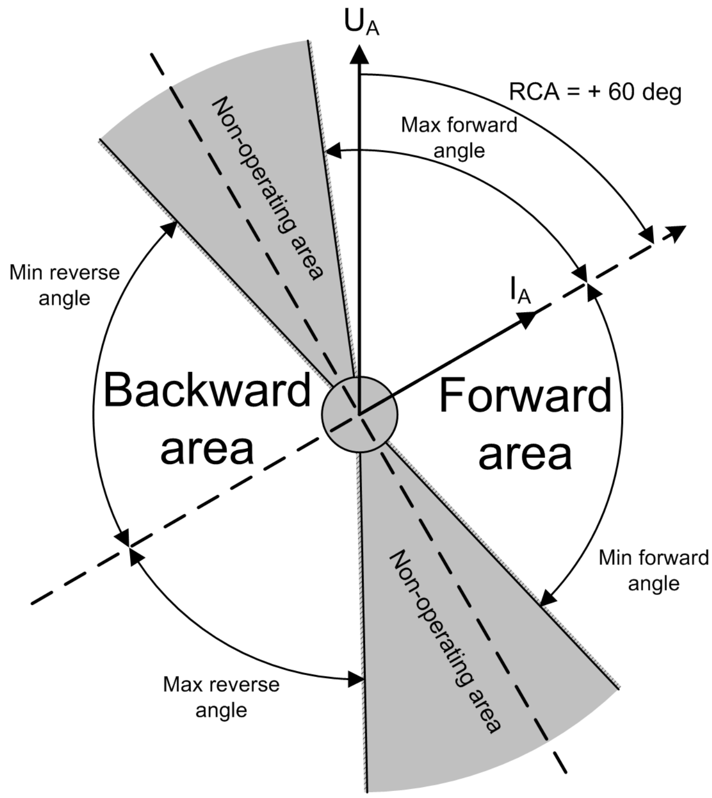

Figure 69: Configurable operating sectors

Table 172: 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)	-1 = both

Table 173: 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

Self-polarizing as polarizing method

Table 174: Equations for calculating angle difference for self-polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{U}_A$	$ANGLE\_A = \varphi(\underline{U}_A) - \varphi(\underline{I}_A) - \varphi_{RCA}$ (Equation 1)
B	$\underline{I}_B$	$\underline{U}_B$	$ANGLE\_B = \varphi(\underline{U}_B) - \varphi(\underline{I}_B) - \varphi_{RCA}$ (Equation 2)
C	$\underline{I}_C$	$\underline{U}_C$	$ANGLE\_C = \varphi(\underline{U}_C) - \varphi(\underline{I}_C) - \varphi_{RCA}$ (Equation 3)
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{U}_{AB}$	$ANGLE\_A = \varphi(\underline{U}_{AB}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA}$ (Equation 4)
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{U}_{BC}$	$ANGLE\_B = \varphi(\underline{U}_{BC}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA}$ (Equation 5)
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{U}_{CA}$	$ANGLE\_C = \varphi(\underline{U}_{CA}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA}$ (Equation 6)

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.

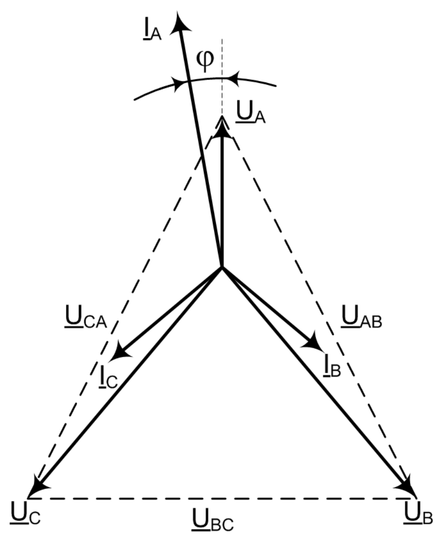

Figure 70: Single-phase earth fault, phase A

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.

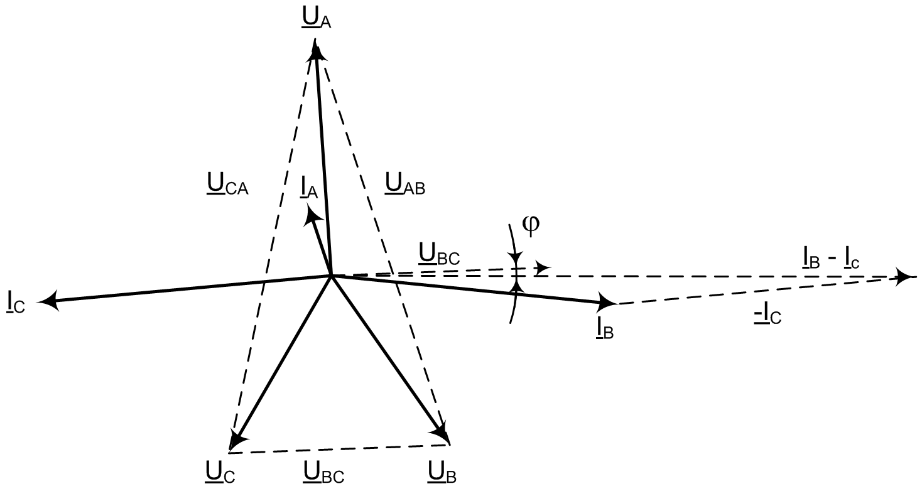

Figure 71: Two-phase short circuit, short circuit is between phases B and C

Cross-polarizing as polarizing quantity

Table 175: Equations for calculating angle difference for cross-polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{U}_{BC}$	$$ANGLE\_A = \varphi(\underline{U}_{BC}) - \varphi(\underline{I}_A) - \varphi_{RCA} + 90^o$$ (Equation 7)
B	$\underline{I}_B$	$\underline{U}_{CA}$	$$ANGLE\_B = \varphi(\underline{U}_{CA}) - \varphi(\underline{I}_B) - \varphi_{RCA} + 90^o$$ (Equation 8)
C	$\underline{I}_C$	$\underline{U}_{AB}$	$$ANGLE\_C = \varphi(\underline{U}_{AB}) - \varphi(\underline{I}_C) - \varphi_{RCA} + 90^o$$ (Equation 9)
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{U}_{BC}$ - $\underline{U}_{CA}$	$$ANGLE\_A = \varphi(\underline{U}_{BC} - \underline{U}_{CA}) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 90^o$$ (Equation 10)
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{U}_{CA}$ - $\underline{U}_{AB}$	$$ANGLE\_B = \varphi(\underline{U}_{CA} - \underline{U}_{AB}) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} + 90^o$$ (Equation 11)
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{U}_{AB}$ - $\underline{U}_{BC}$	$$ANGLE\_C = \varphi(\underline{U}_{AB} - \underline{U}_{BC}) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 90^o$$ (Equation 12)

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.

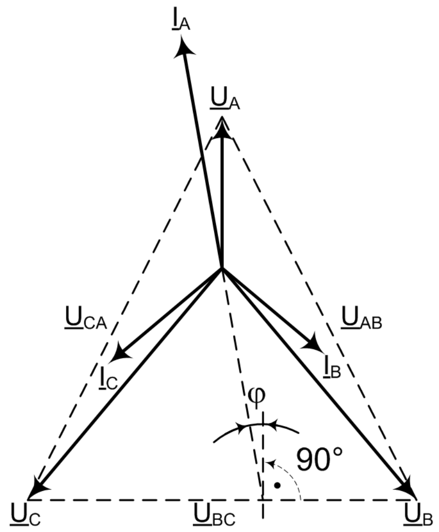

Figure 72: Single-phase earth fault, phase A

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.

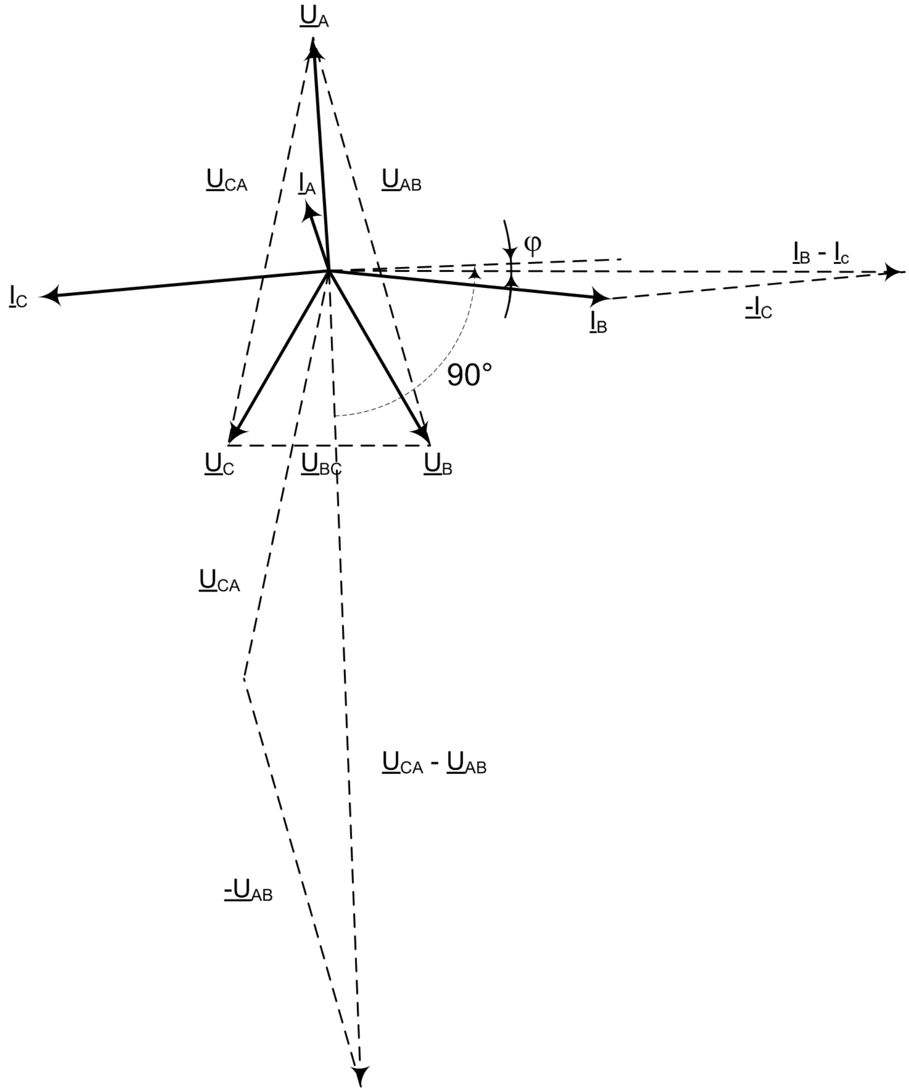

Figure 73: Two-phase short circuit, short circuit is between phases B and C

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 13)

This means that the actuating polarizing quantity is -$\underline{U}_2$.

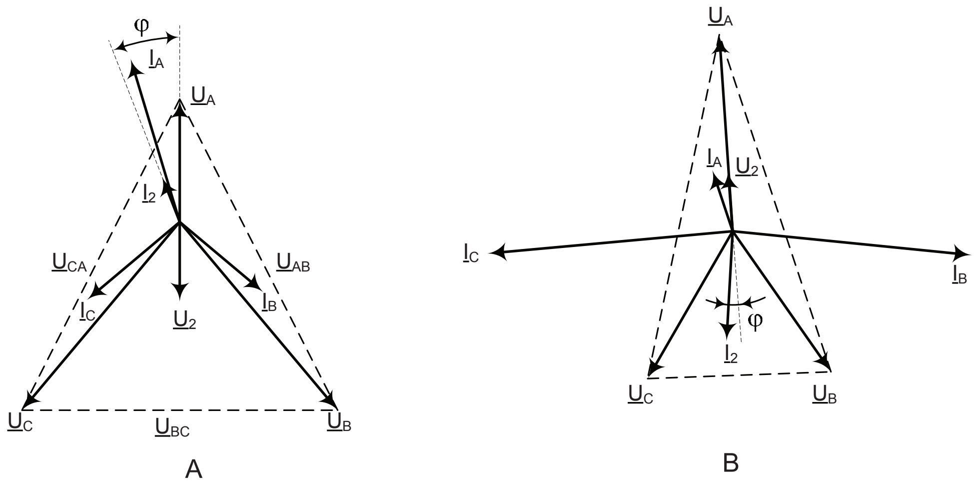

Figure 74: Phasors in a single-phase earth fault, phases A-N, and two-phase short circuit, phases B and C, when the actuating polarizing quantity is the negative-sequence voltage -U2

Positive sequence voltage as polarizing quantity

Table 176: Equations for calculating angle difference for positive-sequence quantity polarizing method

Faulted phases	Used fault current	Used polarizing voltage	Angle difference
A	$\underline{I}_A$	$\underline{U}_1$	$ANGLE\_A = \varphi(\underline{U}_1) - \varphi(\underline{I}_A) - \varphi_{RCA}$ (Equation 14)
B	$\underline{I}_B$	$\underline{U}_1$	$ANGLE\_B = \varphi(\underline{U}_1) - \varphi(\underline{I}_B) - \varphi_{RCA} - 120^\circ$ (Equation 15)
C	$\underline{I}_C$	$\underline{U}_1$	$ANGLE\_C = \varphi(\underline{U}_1) - \varphi(\underline{I}_C) - \varphi_{RCA} + 120^\circ$ (Equation 16)
A - B	$\underline{I}_A$ - $\underline{I}_B$	$\underline{U}_1$	$ANGLE\_A = \varphi(\underline{U}_1) - \varphi(\underline{I}_A - \underline{I}_B) - \varphi_{RCA} + 30^\circ$ (Equation 17)
B - C	$\underline{I}_B$ - $\underline{I}_C$	$\underline{U}_1$	$ANGLE\_B = \varphi(\underline{U}_1) - \varphi(\underline{I}_B - \underline{I}_C) - \varphi_{RCA} - 90^\circ$ (Equation 18)
C - A	$\underline{I}_C$ - $\underline{I}_A$	$\underline{U}_1$	$ANGLE\_C = \varphi(\underline{U}_1) - \varphi(\underline{I}_C - \underline{I}_A) - \varphi_{RCA} + 150^\circ$ (Equation 19)

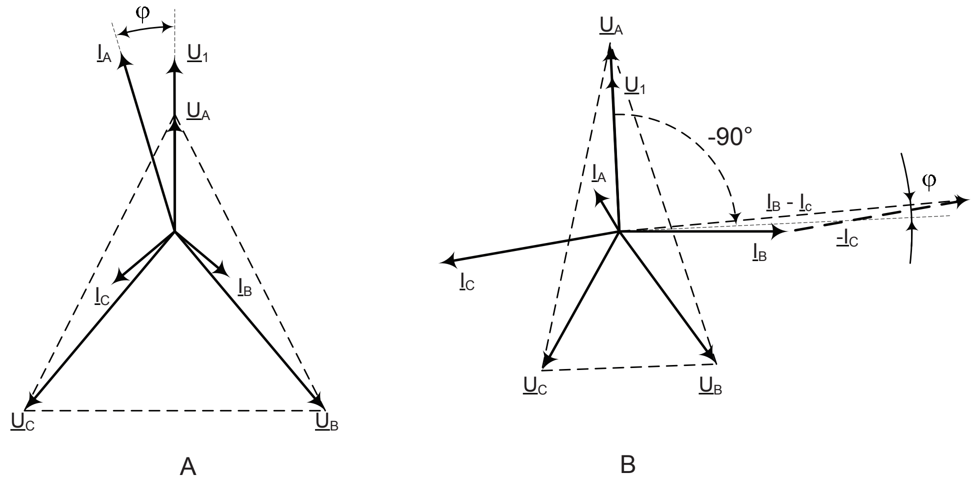

Figure 75: Phasors in a single-phase earth fault, phase A to ground, and a two-phase short circuit, phases B-C, are short-circuited when the polarizing quantity is the positive-sequence voltage U_1

Network rotation 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 protection relay using the parameter in the HMI menu **Configuration/System/Phase rotation**. The default parameter value is "ABC".

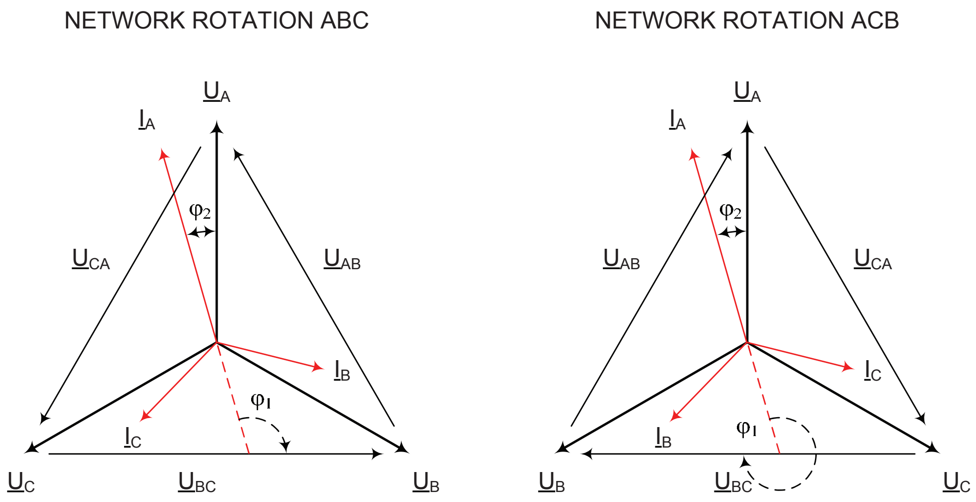

Figure 76: Examples of network rotating direction

4.1.2.8 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, phase overcurrent protection 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 protection 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 protection 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 protection 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.

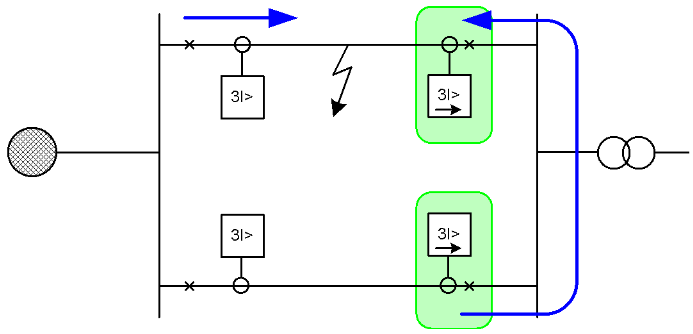

Figure 77: Overcurrent protection of parallel lines using directional protection relays

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.

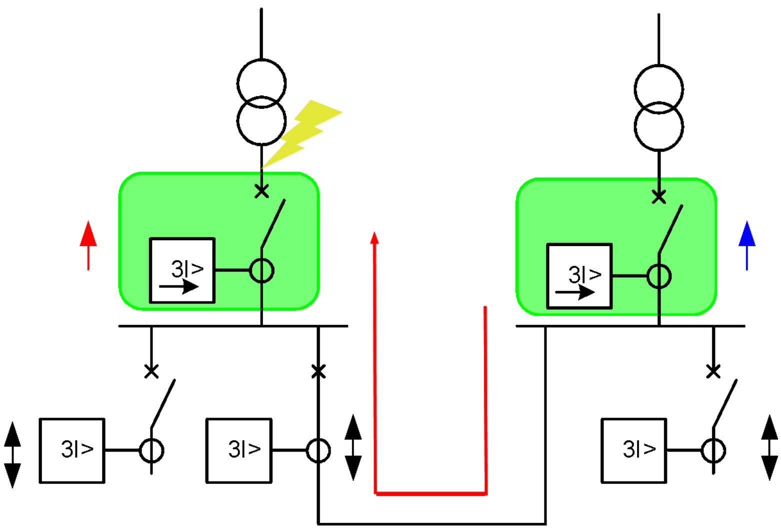

Figure 78: Overcurrent protection of parallel operating transformers

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 protection 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.

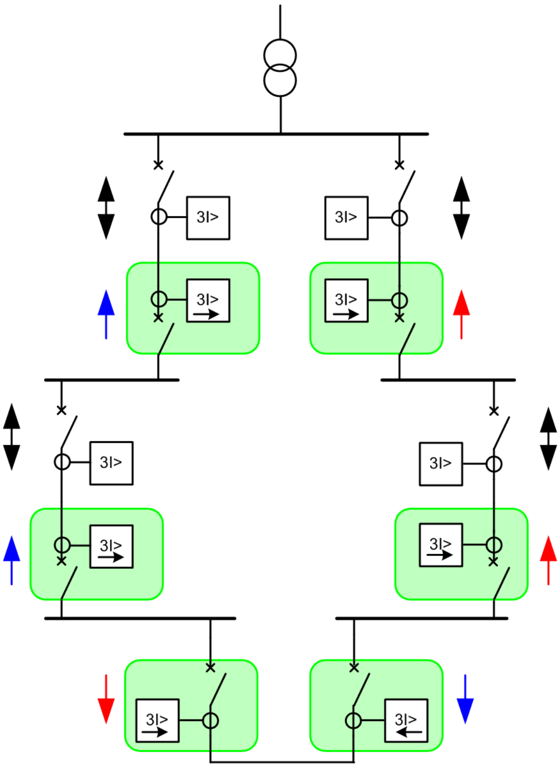

Figure 79: Closed ring network topology where feeding lines are protected with directional overcurrent protection relays

4.1.2.9 Signals

Table 177: DPHLPDOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
U3P	SIGNAL	-	Three-phase voltages
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 178: DPHHPDOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
U3P	SIGNAL	-	Three-phase voltages
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier
NON_DIR	BOOLEAN	0=False	Forces protection to non-directional

Table 179: DPHLPDOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 180: DPHHPDOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.1.2.10 Settings

Table 181: DPHLPDOC Non group settings (Basic)

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
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 182: *DPHLPDOC Group settings (Basic)*

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
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
Operate delay time	40...300000	ms	10	40	Operate delay 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

Table 183: *DPHLPDOC Non group settings (Advanced)*

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
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
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 184: DPHLPDOC Group settings (Advanced)

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
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Pol quantity	1=Self pol 4=Neg. seq. volt. 5=Cross pol 7=Pos. seq. volt.			5=Cross pol	Reference quantity used to determine fault direction

Table 185: DPHHPDOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	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

Table 186: DPHHPDOC Group settings (Basic)

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		0.01	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
Operate delay time	40...300000	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

Table 187: DPHHPDOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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

Table 188: DPHHPDOC Group settings (Advanced)

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
Voltage Mem time	0...3000	ms	1	40	Voltage memory time
Pol quantity	1=Self pol 4=Neg. seq. volt. 5=Cross pol 7=Pos. seq. volt.			5=Cross pol	Reference quantity used to determine fault direction

4.1.2.11 Monitored data

Table 189: 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
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
DIR_A	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase B
DIR_C	Enum	0=unknown 1=forward 2=backward -1=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
VMEM_USED	BOOLEAN	0=False 1=True		Voltage memory in use status
DPHLPDOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 190: DPHHPDOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
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
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 -1=both		Direction phase A
DIR_B	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase B

Table continues on next page

Name	Type	Values (Range)	Unit	Description
DIR_C	Enum	0=unknown 1=forward 2=backward -1=both		Direction phase C
VMEM_USED	BOOLEAN	0=False 1=True		Voltage memory in use status
DPHHPDOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.2.12 Technical data

Table 191: DPHxPDOC Technical data

Characteristic		Value		
Operation accuracy	DPHLPDOC	Depending on the frequency of the measured current: f_n ±2 Hz		
		Current: ±1.5% of the set value or ±0.002 × I_n1) ±1.5% of the set value or ±0.007 × I_n2) Voltage: ±1.5% of the set value or ±0.002 × U_n Phase angle: ±2°		
	DPHHPDOC	Current: ±1.5% of the set value or ±0.002 × I_n1) ±1.5% of the set value or ±0.007 × I_n2) (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n) Voltage: ±1.5% of the set value or ±0.002 × U_n Phase angle: ±2°		
Start time3)4)		Minimum	Typical	Maximum
	I_{Fault} = 2 × set *Start value*	28 ms	35 ms	42 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms5)		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Measurement mode* = "RMS", "DFT" and "Peak-Peak" mode with CT secondary >0.2 A
2) *Measurement mode* = "Peak-to-peak", CT Secondary <0.2 A
3) *Measurement mode* and *Pol quantity* = default, current before fault = 0.0 × I_n, voltage before fault = 1.0 × 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
4) Includes the delay of the signal output contact
5) Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20

4.1.3 Three-phase thermal protection for feeders, cables and distribution transformers T1PTTR (ANSI 49F)

4.1.3.1 Identification

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

4.1.3.2 Function block

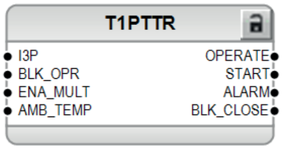

Figure 80: Function block

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 three-phase thermal protection for feeders, cables and distribution transformers 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 Analog channel configuration

T1PTTR has one analog group input which must be properly configured.

Table 192: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.1.3.5 Operation principle

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

The operation of T1PTTR can be described using a module diagram. All the modules in the diagram are explained in the next sections.

The function uses ambient temperature which can be measured locally or remotely. Local measurement is done by the protection relay. Remote measurement uses analog GOOSE to connect `AMB_TEMP` input.

If the quality of remotely measured temperature is invalid or communication channel fails the function uses ambient temperature set in *Env temperature Set*.

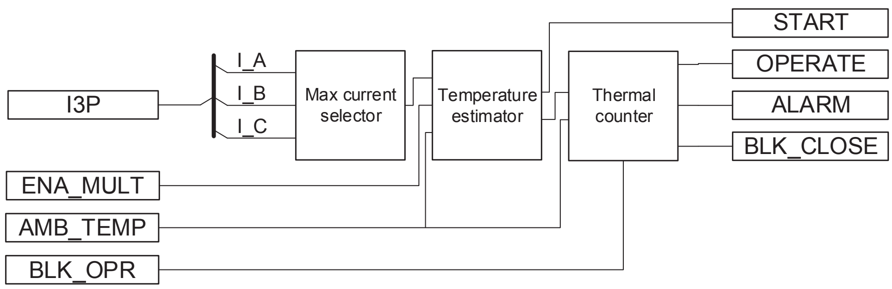

Figure 81: Functional module diagram

Max current selector

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

Temperature estimator

The final temperature rise is calculated from the highest of the three-phase currents according to the expression:

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

(Equation 20)

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

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

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 21)

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 or it can be measured. 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 22)

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 two 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 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 23)

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 ambient temperature can be directly connected through the AMB_TEMP input of T1PTTR using GOOSE connection.

The *Env temperature Set* setting is used to define the ambient temperature if the ambient temperature measurement value is not connected to the AMB_TEMP input. The *Env temperature Set* setting is also used when the ambient temperature measurement connected to T1PTTR is set to “Not in use” in the RTD function.

The temperature calculation is initiated from the value defined with the *Initial temperature* setting parameter. This is done in case the protection relay is powered up, 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 protection relay is restarted.

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

T1PTTR thermal model complies with the IEC 60255-149 standard.

4.1.3.6 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.

4.1.3.7 Signals

Table 193: T1PTTR Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLK_OPR	BOOLEAN	0=False	Block signal for operate outputs
ENA_MULT	BOOLEAN	0=False	Enable Current multiplier
AMB_TEMP	FLOAT32	0	The ambient temperature used in the calculation

Table 194: T1PTTR Output signals

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

4.1.3.8 Settings

Table 195: T1PTTR Non group settings (Basic)

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

Table 196: T1PTTR Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Time constant	60...60000	s	1	2700	Time constant of the line in seconds.
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
Env temperature Set	-50...100	°C	1	40	Ambient temperature used when no external temperature measurement available
Alarm value	20.0...150.0	°C	0.1	80.0	Temperature level for start (alarm)
Maximum temperature	20.0...200.0	°C	0.1	90.0	Temperature level for operate
Reclose temperature	20.0...150.0	°C	0.1	70.0	Temperature for reset of block reclose after operate

Table 197: T1PTTR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Initial temperature	-50.0...100.0	°C	0.1	0.0	Temperature raise above ambient temperature at startup

Table 198: T1PTTR Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Current multiplier	1...5		1	1	Current multiplier when function is used for parallel lines

4.1.3.9 Monitored data

Table 199: 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...60000	s	Estimated time to operate
T_ENA_CLOSE	INT32	0...60000	s	Estimated time to deactivate BLK_CLOSE
TEMP_AMB	FLOAT32	-99...999	°C	The ambient temperature used in the calculation
T1PTTR1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.3.10 Technical data

Table 200: T1PTTR Technical data

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

1) Overload current > 1.2 × Operate level temperature

4.1.4 Loss of phase, undercurrent PHPTUC (ANSI 37)

4.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loss of phase, undercurrent	PHPTUC	3I<	37

4.1.4.2 Function block

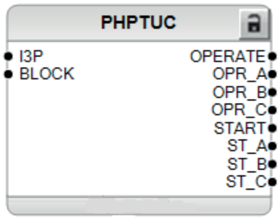

Figure 82: Function block

4.1.4.3 Functionality

The phase undercurrent protection function PHPTUC is used to detect an undercurrent that is considered as a fault condition.

PHPTUC starts when the current is less than the set limit. Operation time characteristics are according to definite time (DT).

The function contains a blocking functionality. It is possible to block function outputs and reset the definite timer.

4.1.4.4 Analog input configuration

PHPTUC has one analog group input which must be properly configured.

Table 201: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.1.4.5 Operation principle

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

The operation of PHPTUC can be described with a module diagram. All the modules in the diagram are explained in the next sections.

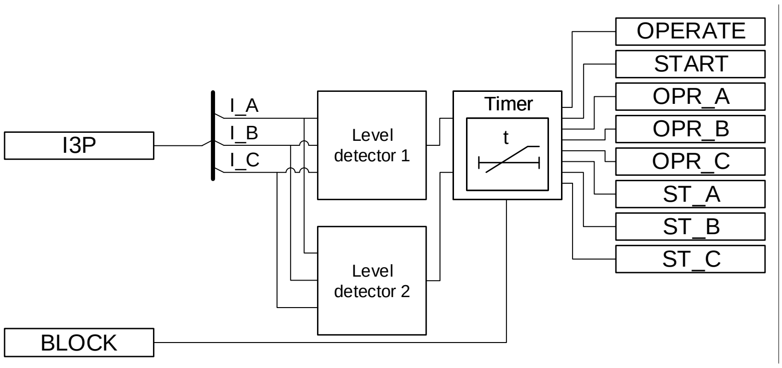

Figure 83: Functional module diagram

Level detector 1

This module compares the phase currents (RMS value) to the *Start value* setting. The *Operation mode* setting can be used to select the "3-phase" or "1-phase" mode.

If in the "3-phase" mode all the phase current values are less than the value of the *Start value* setting, the 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* value of the element.

If in the "1-phase" mode any of the phase current values are less than the value of the *Start value* setting, the condition is detected and an enable signal is sent to the timer. This signal is disabled after all the phase currents have exceeded the set *Start value* value of the element.

The protection relay does not accept the *Start value* to be smaller than *Current block value*.

Level detector 2

This is a low-current detection module that monitors the de-energized condition of the protected object. The module compares the phase currents (RMS value) to the *Current block value* setting. If all the phase current values are less than the *Current block value* setting, a signal is sent to block the operation of the timer.

Timer

Once activated, the timer activates the `START` output and the phase-specific `ST_X` output. The time characteristic is according to DT. When the operation timer has reached the value set by *Operate delay time*, the `OPERATE` output and the phase-specific `OPR_X` output are 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 operating time. The value is available through the monitored data view.

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

4.1.4.6 Application

In some cases, smaller distribution power transformers are used where the high-side protection involves only power fuses. When one of the high-side fuses blows in a single-phase condition, knowledge of it on the secondary side is lacking. The resulting negative-sequence current leads to a premature failure due to excessive heating and breakdown of the transformer insulation. Knowledge of this condition when it occurs allows for a quick fuse replacement and saves the asset.

The *Current block value* setting can be set to zero to not block PHPTUC with a low three-phase current. However, this results in an unnecessary event sending when the transformer or protected object is disconnected.

Phase-specific start and operate can give a better picture about the evolving faults when one phase has started first and another follows.

PHPTUC is meant to be a general protection function, so that it could be used in other cases too.

4.1.4.7 Signals

Table 202: PHPTUC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block all binary outputs by resetting timers

Table 203: PHPTUC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
OPR_A	BOOLEAN	Operate phase A
OPR_B	BOOLEAN	Operate phase B
OPR_C	BOOLEAN	Operate phase C
START	BOOLEAN	Start
ST_A	BOOLEAN	Start phase A
ST_B	BOOLEAN	Start phase B
ST_C	BOOLEAN	Start phase C

4.1.4.8 Settings

Table 204: PHPTUC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operation mode	1=Three Phase 2=Single Phase			1=Three Phase	Number of phases needed to start

Table 205: PHPTUC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.01...1.00	xIn	0.01	0.50	Current setting to start
Operate delay time	50...200000	ms	10	2000	Operate delay time
Current block value	0.00...0.50	xIn	0.01	0.10	Low current setting to block internally

Table 206: PHPTUC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.1.4.9 Monitored data

Table 207: PHPTUC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTUC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.1.4.10 Technical data

Table 208: PHPTUC Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × I_n
Start time	Typically <65 ms
Reset time	Typically 40 ms
Reset ratio	Typically 1.04
Retardation time	<45 ms
Operate time accuracy	±1.0% of the set value or ±40 ms

4.2 Earth-fault protection

4.2.1 Non-directional earth-fault protection EFxPTOC (ANSI 51G/51N-1, 51G/51N-2, 50G/50N)

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	Io>	51G/51N-1
Non-directional earth-fault protection, high stage	EFHPTOC	Io>>	51G/51N-2
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	Io>>>	50G/50N

4.2.1.2 Function block

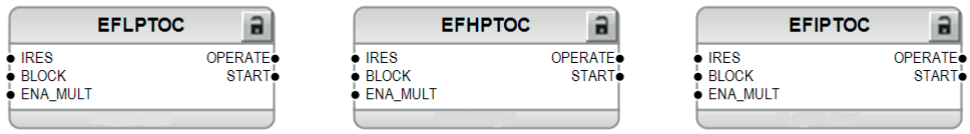

Figure 84: Function block

4.2.1.3 Functionality

The non-directional earth-fault protection 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.

4.2.1.4 Analog channel configuration

EFxPTOC has one analog group input which must be properly configured.

Table 209: Analog inputs

Input	Description
IRES	Residual current (measured or calculated)

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 210: Special conditions

Condition	Description
IRES	If connected to IRES_MEAS (function RESTCTR), the residual channel saturation limit is 19 A and 55 A for secondary current setting range of 0.1...3 A and 3...10 A respectively. This should be considered when setting *Start value* for the function.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.2.1.5 Operation principle

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

The operation of EFxPTOC can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

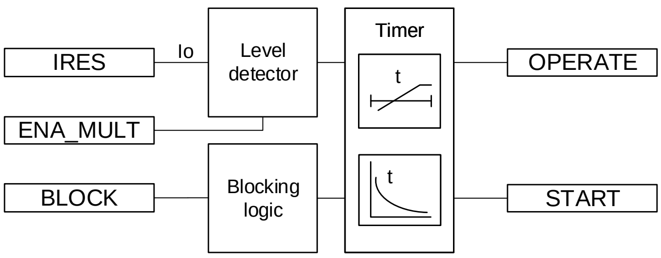

Figure 85: Functional module diagram

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 enable-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 protection relay 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.

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 operation 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 and the value of START_DUR. The START output is deactivated when the reset timer has elapsed.

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 IDMT curves for overcurrent protection 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 operating time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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.

4.2.1.6 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 211: Measurement modes supported by EFxPTOC stages

Measurement mode	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 Measurement modes section in this manual.

4.2.1.7 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 protection 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 212: Timer characteristics supported by different stages

Operating curve type	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 213: Reset time characteristics supported by different stages

Reset curve type	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.

4.2.1.8 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 backup 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.

4.2.1.9 Signals

Table 214: EFLPTOC Input signals

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

Table 215: EFHPTOC Input signals

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

Table 216: EFIPTOC Input signals

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

Table 217: EFLPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 218: EFHPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 219: EFIPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.1.10 Settings

Table 220: EFLPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 221: EFLPTOC Group settings (Basic)

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
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...300000	ms	10	40	Operate delay time

Table 222: EFLPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
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

Table 223: EFLPTOC Group settings (Advanced)

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

Table 224: EFHPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 225: EFHPTOC Group settings (Basic)

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
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Operate delay time	40...300000	ms	10	40	Operate delay time

Table 226: EFHPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT 3=Peak-to-Peak			2=DFT	Selects used measurement mode
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

Table 227: EFHPTOC Group settings (Advanced)

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

Table 228: EFIPTOC Non group settings (Basic)

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

Table 229: EFIPTOC Group settings (Basic)

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...300000	ms	10	20	Operate delay time

Table 230: EFIPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.2.1.11 Monitored data

Table 231: EFLPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFLPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 232: EFHPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFHPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 233: EFIPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
EFIPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.1.12 Technical data

Table 234: EFxPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the current measured: f_n ±2 Hz		
	EFLPTOC	±1.5% of the set value or ±0.002 × I_n		
	EFHPTOC and EFIPTOC	±1.5% of the set value or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n)		
Start time [1)2)]		Minimum	Typical	Maximum
	EFIPTOC: I_{Fault} = 2 × set *Start value* I_{Fault} = 10 × set *Start value*	22 ms 13 ms	27 ms 18 ms	37 ms 34 ms
	EFHPTOC and EFLPTOC: I_{Fault} = 2 × set *Start value*	20 ms	30 ms	42 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms [3)]		
Suppression of harmonics		RMS: No suppression DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression		

1) *Measurement mode* = default (depends on the stage), current before fault = 0.0 × 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 (SO)
3) Maximum *Start value* = 2.5 × I_n, *Start value* multiples in the range of 1.5...20

4.2.2 Directional earth-fault protection DEFxPDEF (ANSI 67G/N-1 51G/N-1, 67G/N-1 51G/N-2)

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	Io> ->	67G/N-1 51G/N-1
Directional earth-fault protection, high stage	DEFHPDEF	Io>> ->	67G/N-1 51G/N-2

4.2.2.2 Function block

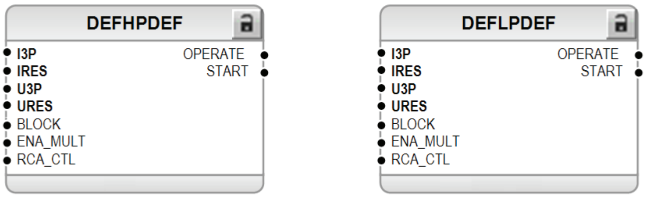

Figure 86: Function block

4.2.2.3 Functionality

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

The function starts and operates when the operating quantity (current) and polarizing quantity (voltage) 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.

4.2.2.4 Analog channel configuration

DEFxPDEF has four analog group inputs which must be properly configured.

Table 235: Analog inputs

Input	Description
I3P[1)]	Three-phase currents Necessary when *Pol quantity* is set to "Neg. seq. volt."
IRES	Residual current (measured or calculated)
U3P[1)]	Three-phase voltages Necessary when *Pol quantity* is set to "Neg. seq. volt."
URES[2)]	Residual voltage (measured or calculated) Necessary when *Pol quantity* is set to "Zero seq. volt."

1) Can be connected to `GRPOFF` if *Pol quantity* is set to "Zero seq. volt" or *Directional mode* is set to "Non-directional"
2) Can be connected to `GRPOFF` if *Pol quantity* is set to "Neg. seq. volt" or *Directional mode* is set to "Non-directional"

See the preprocessing function blocks in this document for the possible signal sources. The GRPOFF signal is available in the function block called Protection.

There are a few special conditions which must be noted with the configuration.

Table 236: Special conditions

Condition	Description
IRES	If connected to IRES_MEAS (function RESTCTR), the residual channel saturation limit is 19 A and 55 A for secondary current setting range of 0.1...3 A and 3...10 A respectively. This should be considered when setting *Start value* for the function.
U3P connected real measurements	All three phase voltage channels need to be connected.
URES calculated	Setting *VT connection* must be "Wye" in that particular UTVTR.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.2.2.5 Operation principle

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

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

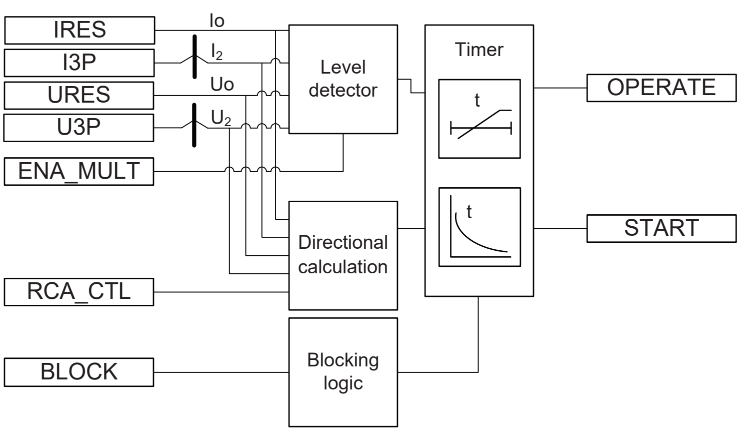

Figure 87: Functional module diagram

Level detector

The magnitude of the operating quantity is compared to the set *Start value* and the magnitude of the polarizing quantity is compared to the set *Voltage start value*. If both the 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 operating quantity. If the `ENA_MULT` input is active, the *Start value* setting is multiplied by the *Start value Mult* setting.

If the *Enable voltage limit* setting is set to "True", the magnitude of the polarizing quantity is checked even if the *Directional mode* was set to "Non-directional" or *Allow Non Dir* to "True". The protection relay does not accept the *Start value* or *Start value Mult* setting if the product of these settings exceeds the *Start value* setting range.

Typically, the `ENA_MULT` input is connected to the inrush detection function INRHPAR. In case of inrush, INRPHAR activates the `ENA_MULT` input, which multiplies *Start value* by the *Start value Mult* setting.

Directional calculation

The directional calculation module monitors the angle between the polarizing quantity and operating quantity. Depending on the *Pol quantity* setting, the polarizing quantity can be the residual voltage (measured or calculated) or the negative sequence voltage. When the angle is in the operation sector, the module sends the enabling signal to the timer module.

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

If *Pol quantity* is set to "Zero seq. volt.", the residual current and residual voltage are used for directional calculation.

If *Pol quantity* is set to "Neg. seq. volt.", the negative sequence current and negative sequence voltage are used for directional calculation.

In the phasor diagrams representing the operation of DEFxPDEF, the polarity of the polarizing quantity (Uo or U2) is reversed, that is, the polarizing quantity in the phasor diagrams is either -Uo or -U2. Reversing is done by switching the polarity of the residual current measuring channel (see the connection in the Protection relay's physical connections section). Similarly the polarity of the calculated Io and I_2 is also switched.

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

Table 237: 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 |Io| x sin (ANGLE) has a positive value and "reverse" when the value is negative. ANGLE is the angle difference between -Uo and Io.
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.

Polarizing quantity selection "Neg. seq. volt." is available only in the "Phase angle" operation mode.

The directional operation can be selected with the *Directional mode* setting. The alternatives are "Non-directional", "Forward" and "Reverse" operation. The operation criterion is selected with the *Operation mode* setting. By setting *Allow Non Dir* to "True", non-directional operation is allowed when the directional information is invalid, that is, when the magnitude of the polarizing quantity is less than the value of the *Min operate voltage* setting.

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 equation for calculating the negative sequence voltage component need to be changed. The network rotating direction is defined with a system parameter *Phase rotation*. The calculation of the component is affected but the angle difference calculation remains the same. When the residual voltage is 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 protection relay using the parameter in the HMI menu: **Configuration/System/Phase rotation**.
The default parameter value is "ABC".

If the *Enable voltage limit* setting is set to "True", the magnitude of the polarizing quantity is checked even if *Directional mode* is set to "Non-directional" or *Allow Non Dir* to "True".

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. RCA_CTL affects the *Characteristic angle* setting.

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

The polarity of the polarizing quantity can be reversed by setting the *Pol reversal* to "True", which turns the polarizing quantity by 180 degrees.

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

The DIRECTION monitored data indicates on which operating sector the operating quantity is measured. The FAULT_DIR monitored data indicates in which operation sector the fault current is measured. The monitored data is operational once the function is started.

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

Table 238: Monitored data values

Monitored data values	Description
ANGLE	Also called operating angle, shows the angle difference between the polarizing quantity (Uo, U_2) and operating quantity (Io, I_2).
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 or calculated residual current. If the *Operation mode* setting is "IoSin", I_OPER is calculated as follows I_OPER = Io x sin(ANGLE). If the *Operation mode* setting is "IoCos", I_OPER is calculated as follows I_OPER = Io x cos(ANGLE).

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 operation 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, 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 and the value of START_DUR. The `START` output is deactivated when the reset timer has elapsed.

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 IDMT curves for overcurrent protection 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 operating time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's program. The influence of the `BLOCK` signal activation is preselected with the global setting *Blocking mode*.

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The *Blocking mode* setting has three blocking methods. In the "Freeze timer" mode, the operation timer is frozen to the prevailing value, but the `OPERATE` output is not deactivated when blocking is activated. 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.

4.2.2.6 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 Io into account. This is done by comparing the phase angle of the operating and polarizing quantity.

Relay characteristic angle

The *Characteristic angle* setting, 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 the 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

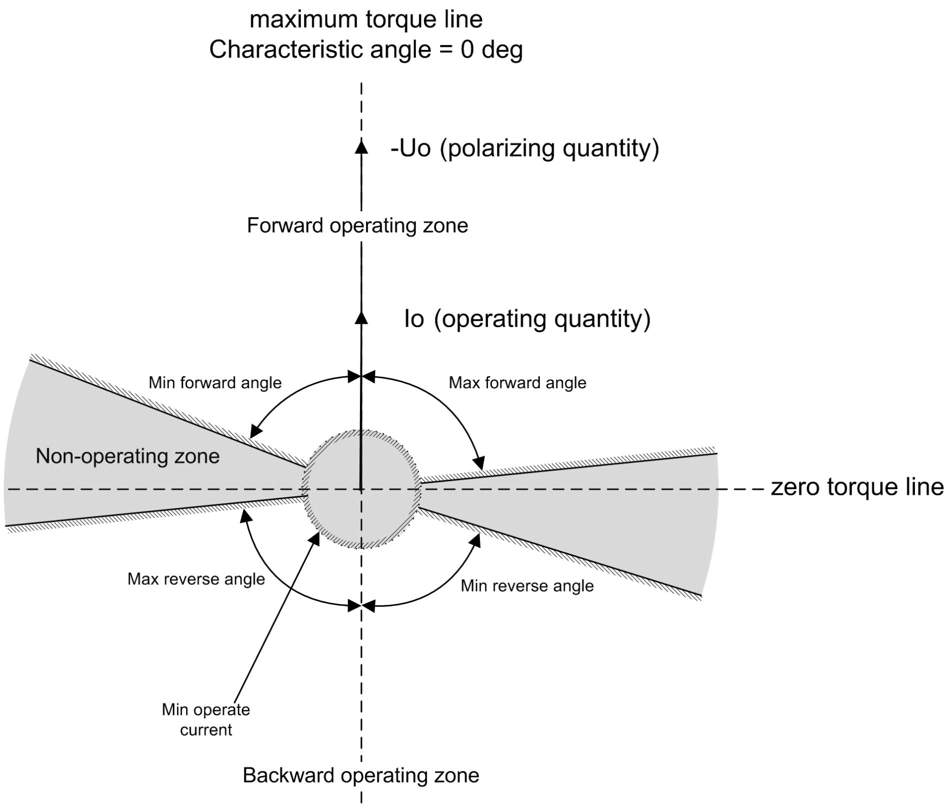


Figure 88: Definition of the relay characteristic angle, RCA=0 degrees in a compensated network

Example 2

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

=> *Characteristic angle* = +60 deg

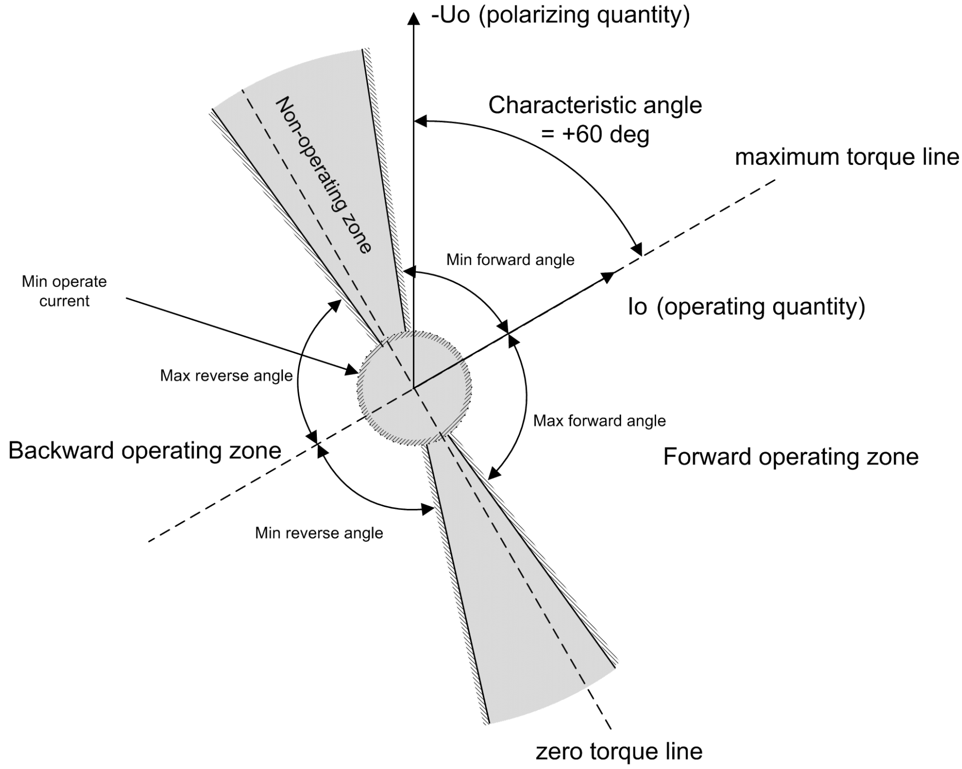


Figure 89: Definition of the relay characteristic angle, RCA=+60 degrees in a solidly earthed network

Example 3

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

=> *Characteristic angle* = -90 deg

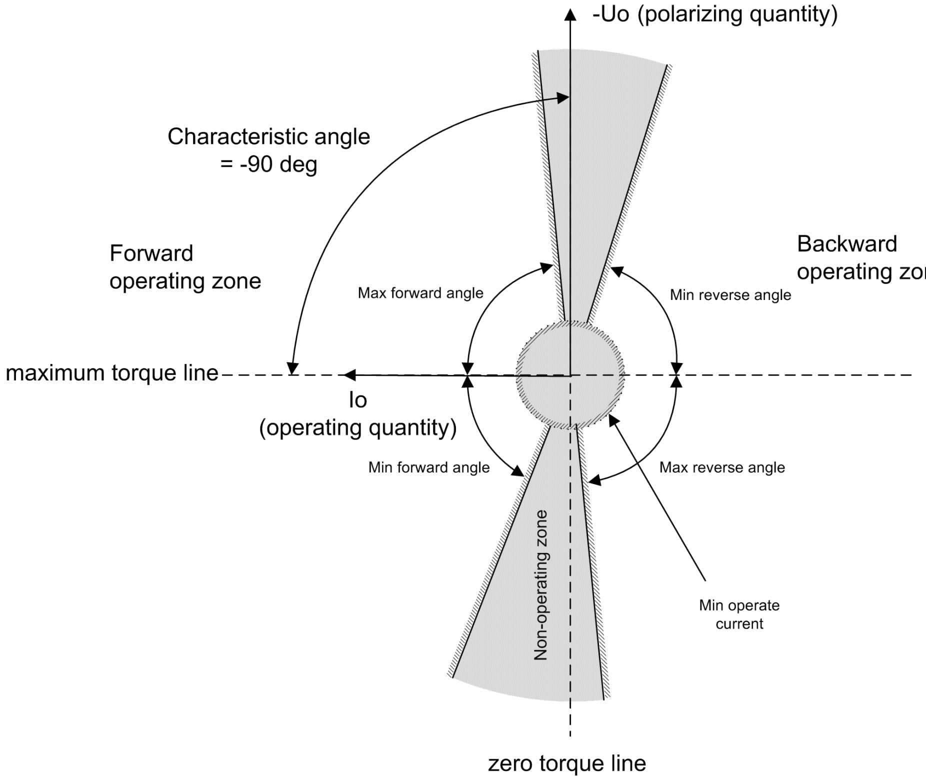


Figure 90: Definition of the relay characteristic angle, RCA=–90 degrees in an isolated network

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 phase-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 polarizing voltage. Consequently, the relay characteristic angle (RCA) should be set to -90 degrees and the operation criteria to "IoSin" 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*. Figure 91 illustrates a simplified equivalent circuit for an unearthed network with an earth fault in phase C.

For definitions of different directional earth-fault characteristics, see Directional earth-fault characteristics.

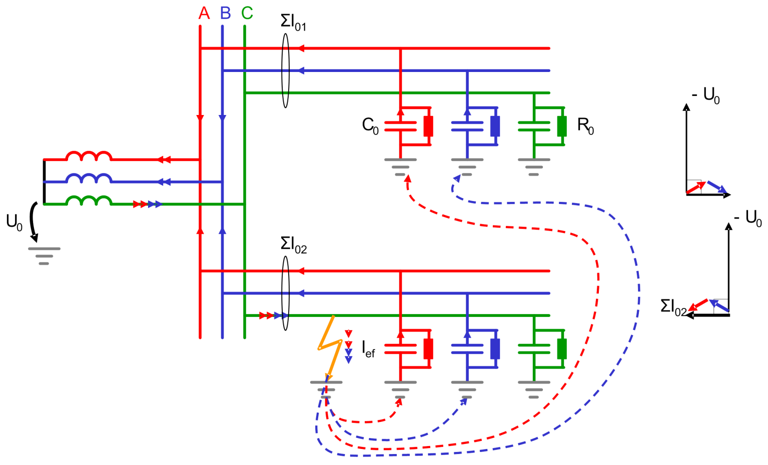


Figure 91: Earth-fault situation in an isolated network

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 protection 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 *Operation mode* should be set to "Phase angle" and the relay characteristic angle (RCA) should be set to 0 degrees. Alternatively, the *Operation mode* can be set to "IoCos". Figure 92 illustrates a simplified equivalent circuit for a compensated network with an earth fault in phase C.

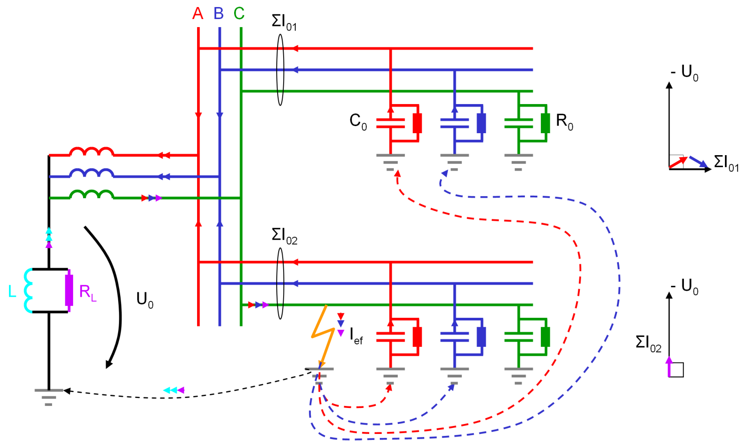


Figure 92: Earth-fault situation in a compensated network

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 can be 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. 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 operation criteria as described in Table 239 and Table 240.

Table 239: Relay characteristic angle control in Iosin(φ) and Iocos(φ) operation criteria

Operation mode setting:	RCA_CTL = FALSE	RCA_CTL = TRUE
Iosin	Actual operation mode: Iosin	Actual operation mode: Iocos
Iocos	Actual operation mode: Iocos	Actual operation mode: Iosin

Table 240: Characteristic angle control in phase angle operation mode

Characteristic angle setting	RCA_CTL = FALSE	RCA_CTL = TRUE
-90°	φ_{RCA} = -90°	φ_{RCA} = 0°
0°	φ_{RCA} = 0°	φ_{RCA} = -90°

Use of the extended phase angle characteristic

The traditional method of adapting the directional earth-fault protection function to the prevailing neutral earthing conditions is done with the *Characteristic angle* setting. In an unearthed network, *Characteristic angle* is set to -90 degrees and in a compensated network *Characteristic angle* is set to 0 degrees. In case the earthing method of the network is temporarily changed from compensated to unearthed due to the disconnection of the arc suppression coil, the *Characteristic angle* setting should be modified correspondingly. This can be done using the setting groups or the RCA_CTL input. Alternatively, the operating sector of the directional earth-fault protection function can be extended to cover the operating sectors of both neutral earthing principles. Such characteristic is valid for both unearthed and compensated network and does not require any modification in case the neutral earthing changes temporarily from the unearthed to compensated network or vice versa.

The extended phase angle characteristic is created by entering a value of over 90 degrees for the *Min forward angle* setting; a typical value is 170 degrees (*Min reverse angle* in case *Directional mode* is set to "Reverse"). The *Max forward angle* setting should be set to cover the possible measurement inaccuracies of current and voltage transformers; a typical value is 80 degrees (*Max reverse angle* in case *Directional mode* is set to "Reverse").

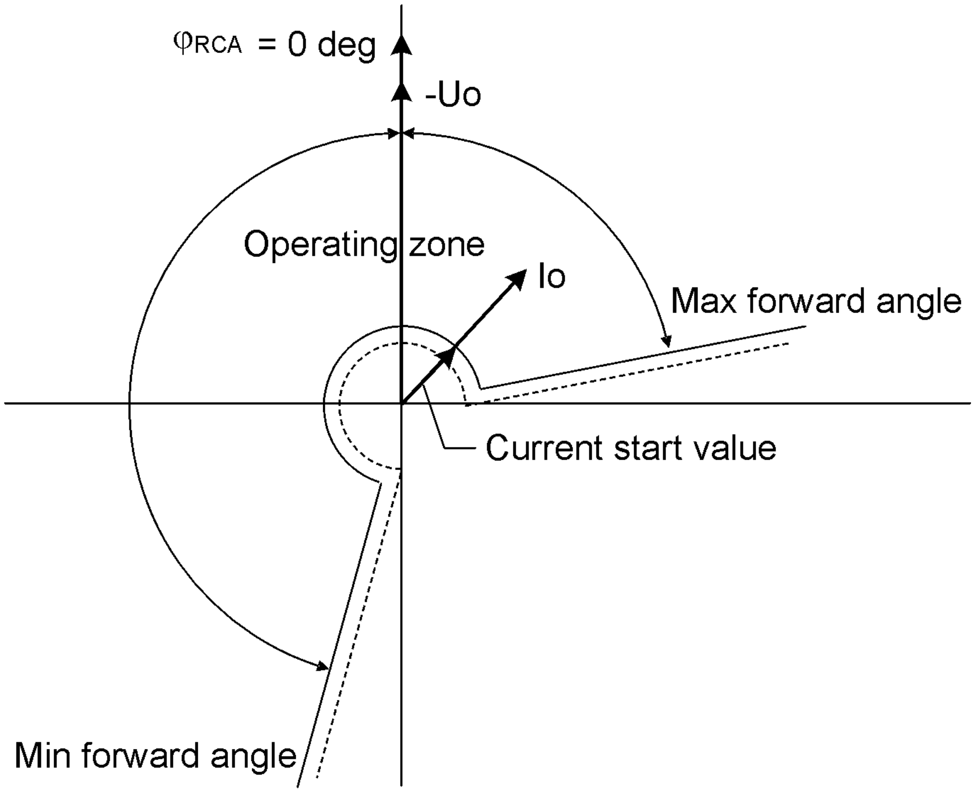


Figure 93: Extended operation area in directional earth-fault protection

4.2.2.7 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 241: Measurement modes supported by DEFxPDEF stages

Measurement mode	DEFLPDEF	DEFHPDEF
RMS	x	x
DFT	x	x
Peak-to-Peak	x	x

For a detailed description of the measurement modes, see the Measurement modes section in this manual.

4.2.2.8 Timer characteristics

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

The protection 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 242: Timer characteristics supported by different stages

Operating curve type	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 243: Reset time characteristics supported by different stages

Reset curve type	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

4.2.2.9 Directional earth-fault characteristics

Phase angle characteristic

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 DIRECTION monitored data indicates on which operating sector the operating quantity is measured. The FAULT_DIR monitored data indicates in which operation sector the fault current is measured. The monitored data is operational once the function is started.

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 counterclockwise 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 counterclockwise 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.

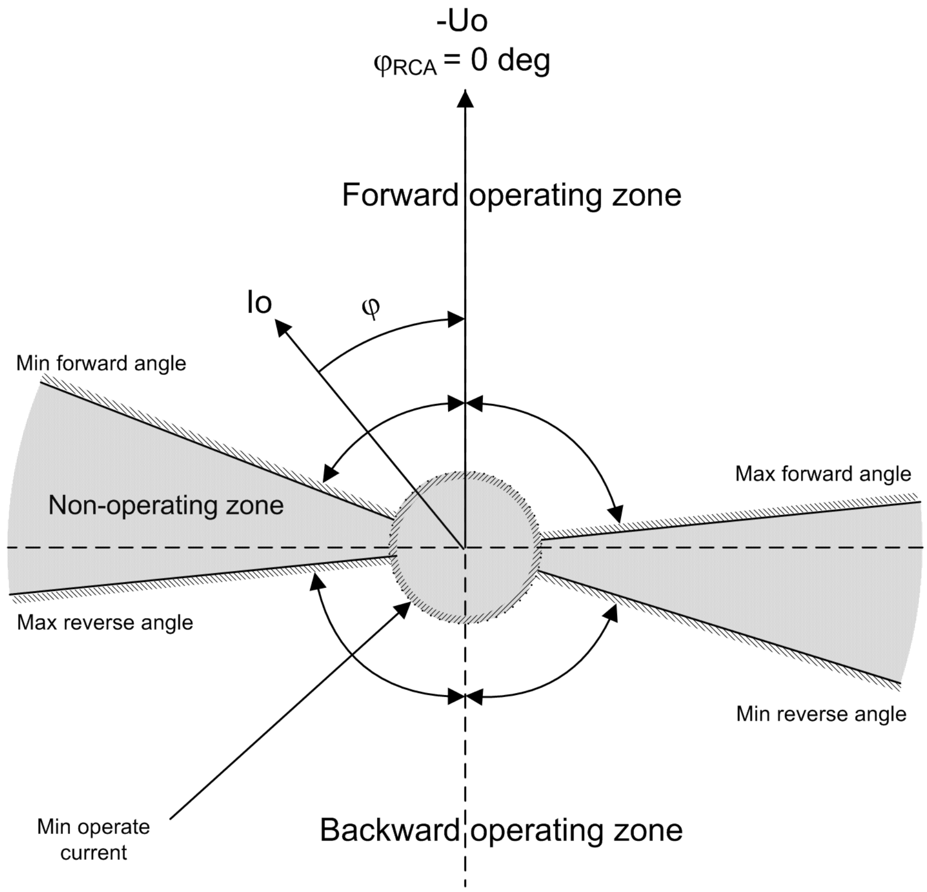


Figure 94: Configurable operating sectors in phase angle characteristic

Table 244: 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

If the *Allow Non Dir* setting is "False", the directional operation (forward, reverse) is not allowed when the measured polarizing or operating quantities are invalid, 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 monitored data 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.

Iosin(φ) and Iocos(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 Iosin(φ) characteristics is used in an isolated network, measuring the reactive component of the fault current caused by the earth capacitance. The Iocos(φ) characteristics is used in a compensated network, measuring the active component of the fault current.

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

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

Table 245: Relay characteristic angle control in the IoSin and IoCos operation criteria

Operation mode:	RCA_CTL = "False"	RCA_CTL = "True"
IoSin	Actual operation criterion: Iosin(φ)	Actual operation criterion: Iocos(φ)
IoCos	Actual operation criterion: Iocos(φ)	Actual operation criterion: Iosin(φ)

When the Iosin(φ) or Iocos(φ) criterion is used, the component indicates a forward- or reverse-type fault through the FAULT_DIR and DIRECTION monitored data, 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 monitored data 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 Iosin(φ) or Iocos(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.

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

Example 1.

Iosin(φ) criterion selected, forward-type fault

```
=> FAULT_DIR = 1
```

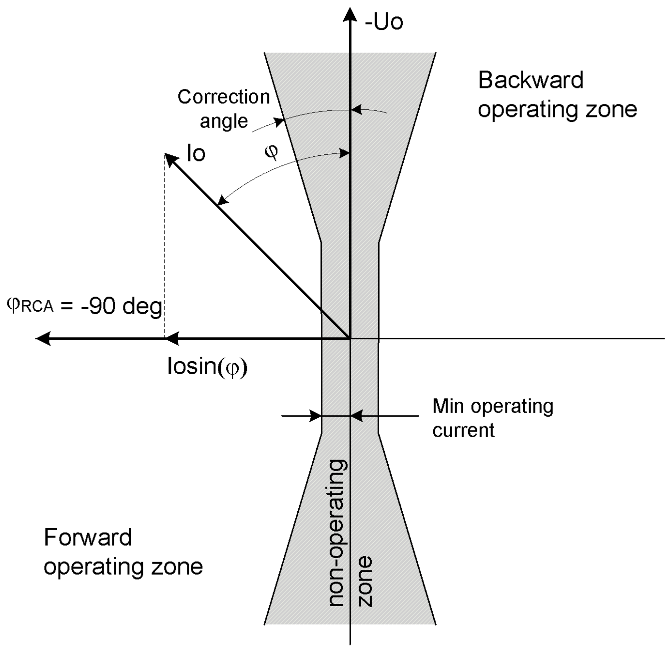


Figure 95: Operating characteristic Iosin(φ) in forward fault

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

Example 2.

Iosin(φ) criterion selected, reverse-type fault

```
=> FAULT_DIR = 2
```

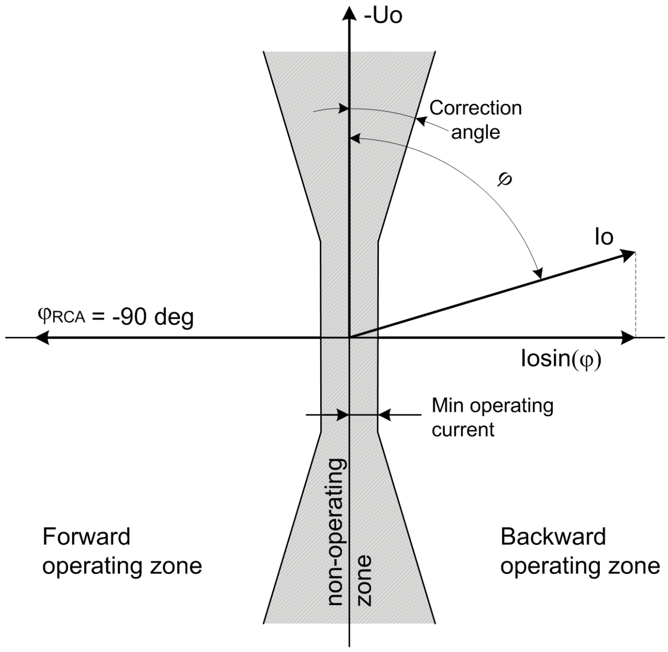


Figure 96: Operating characteristic Iosin(φ) in reverse fault

Example 3.

Iocos(φ) criterion selected, forward-type fault

`=> FAULT_DIR = 1`

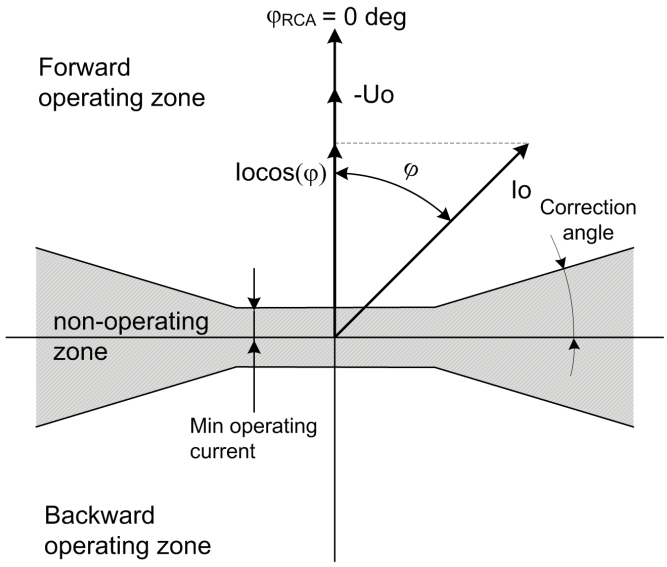


Figure 97: Operating characteristic Iocos(φ) in forward fault

Example 4.

Iocos(φ) criterion selected, reverse-type fault

=> FAULT_DIR = 2

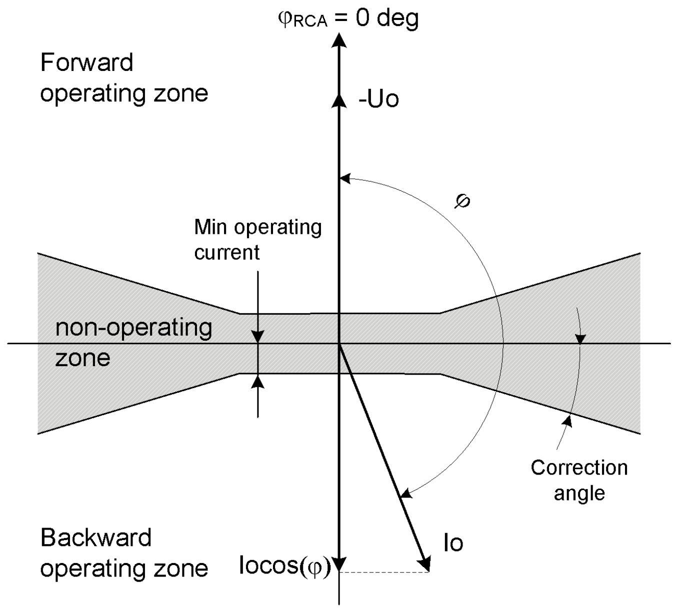


Figure 98: Operating characteristic Iocos(φ) in reverse fault

Phase angle 80

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

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

- The *Max forward angle* and *Max reverse angle* settings cannot be set but they 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.

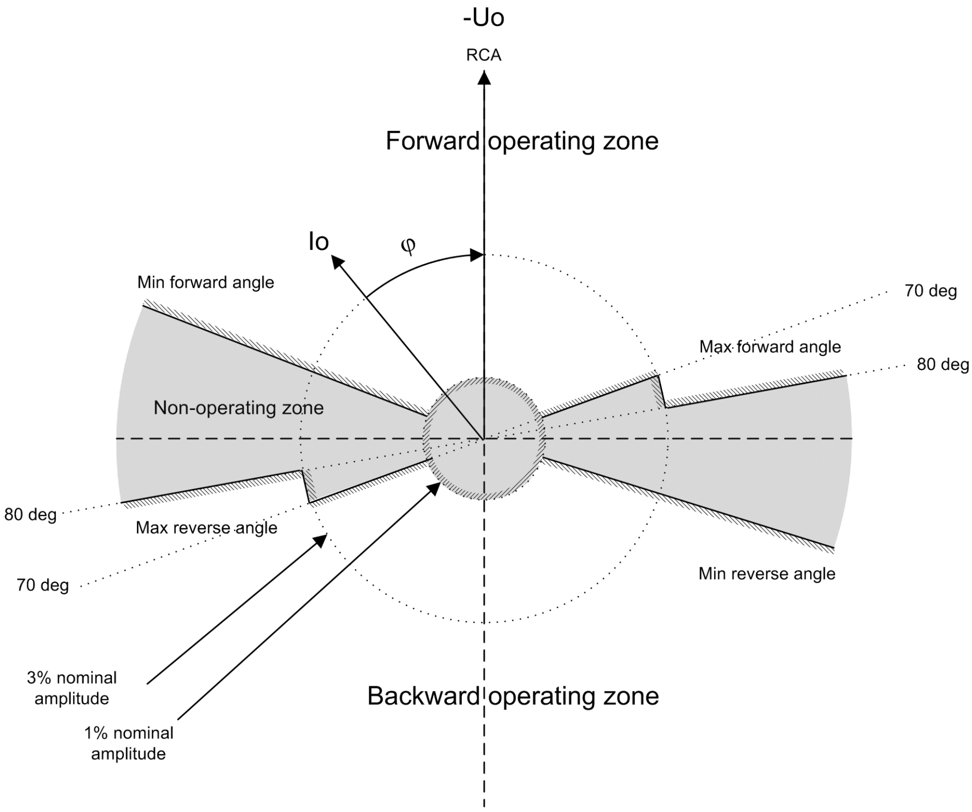


Figure 99: Operating characteristic for phase angle 80

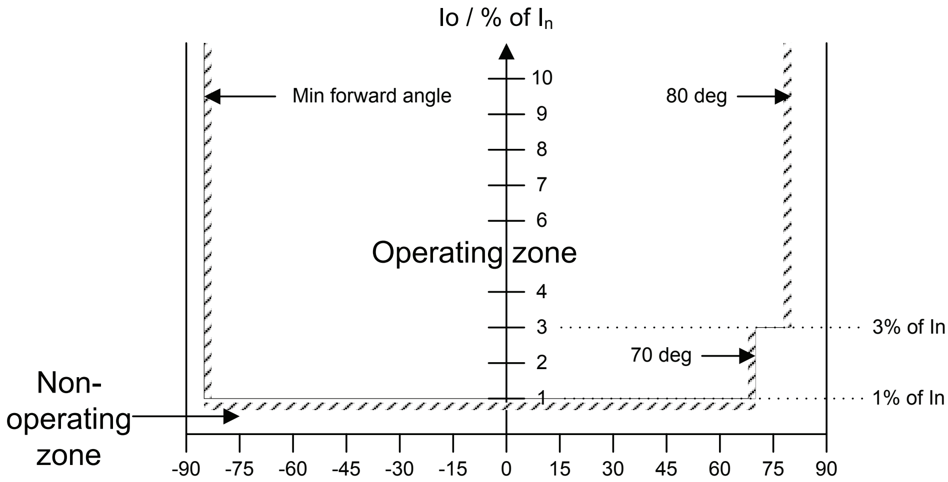


Figure 100: Phase angle 80 amplitude (Directional mode = Forward)

Phase angle 88

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

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

- The *Max forward angle* and *Max reverse angle* settings cannot be set but they have a fixed value of 88 degrees
- The sector limits of the fixed sectors are rounded.

Sector rounding in the phase angle 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 20...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.

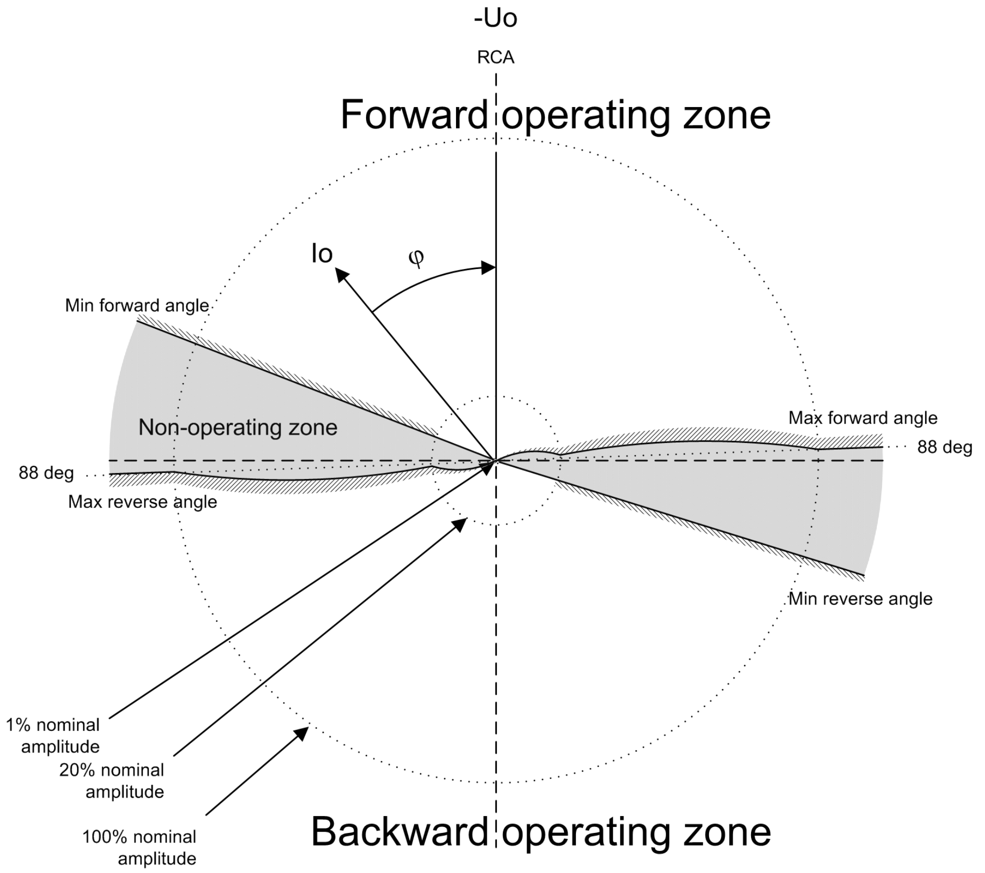


Figure 101: Operating characteristic for phase angle 88

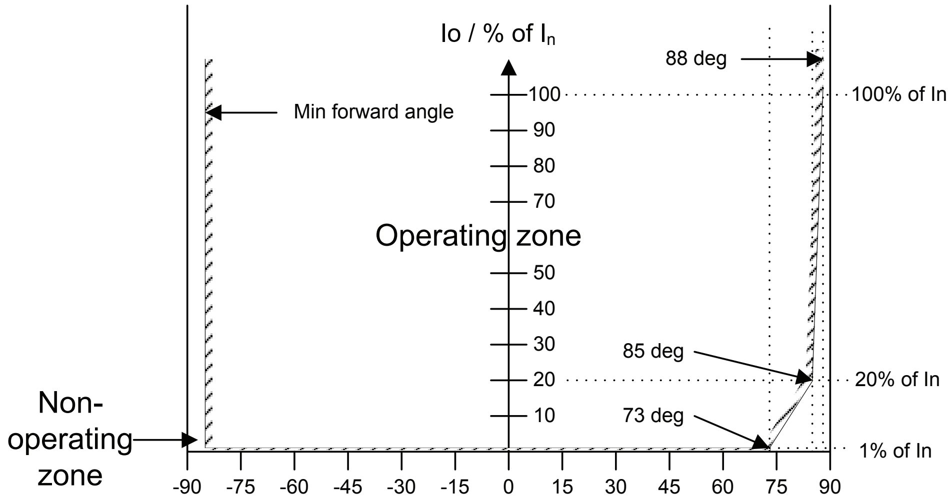


Figure 102: Phase angle 88 amplitude (Directional mode = Forward)

4.2.2.10 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 protection relay.

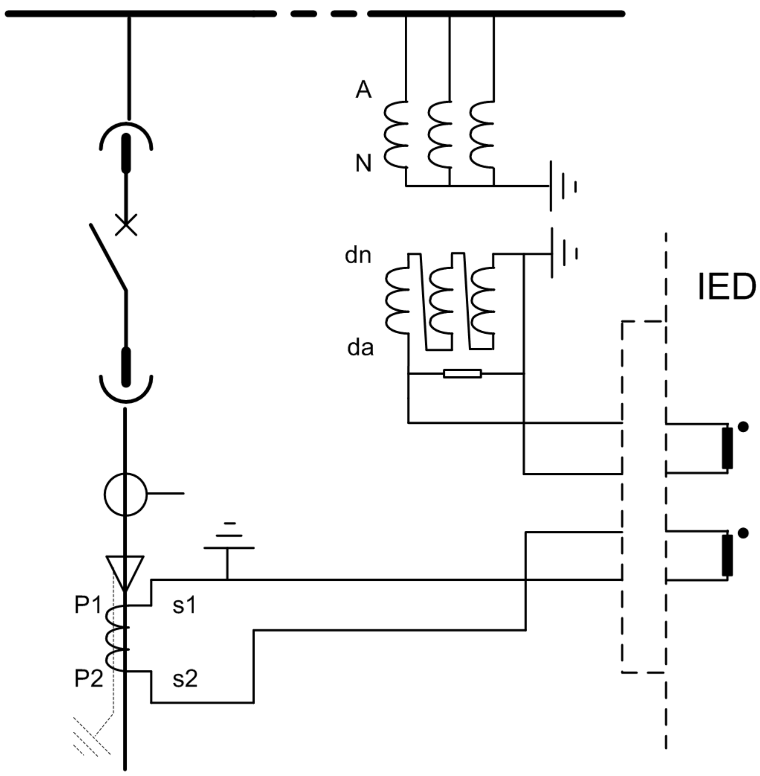


Figure 103: Connection of measuring transformers

4.2.2.11 Signals

Table 246: DEFLPDEF Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
IRES	SIGNAL	-	Residual current
U3P	SIGNAL	-	Three-phase voltages
URES	SIGNAL	-	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 247: DEFHPDEF Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
IRES	SIGNAL	-	Residual current
U3P	SIGNAL	-	Three-phase voltages
URES	SIGNAL	-	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 248: DEFLPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

Table 249: DEFHPDEF Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.2.2.12 Settings

Table 250: DEFLPDEF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 251: DEFLPDEF Group settings (Basic)

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		0.01	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
Operate delay time	50...300000	ms	10	50	Operate delay time
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	80	Minimum phase angle in reverse direction
Voltage start value	0.010...1.000	xUn	0.001	0.010	Voltage start value

Table 252: DEFLPDEF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	50...60000	ms	1	50	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

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Correction angle	0.0...10.0	deg	0.1	0.0	Characteristic correction angle in IoCos and IoSin mode
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Pol quantity	3=Zero seq. volt. 4=Neg. seq. volt.			3=Zero seq. volt.	Reference quantity used to determine fault direction

Table 253: DEFLPDEF Group settings (Advanced)

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
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

Table 254: DEFHPDEF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 255: DEFHPDEF Group settings (Basic)

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		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
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
Operate delay time	40...300000	ms	10	40	Operate delay time
Characteristic angle	-179...180	deg	1	-90	Characteristic angle
Max forward angle	0...180	deg	1	80	Maximum phase angle in forward direction
Max reverse angle	0...180	deg	1	80	Maximum phase angle in reverse direction
Min forward angle	0...180	deg	1	80	Minimum phase angle in forward direction
Min reverse angle	0...180	deg	1	80	Minimum phase angle in reverse direction
Voltage start value	0.010...1.000	xUn	0.001	0.010	Voltage start value

Table 256: DEFHPDEF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time
Minimum operate time	40...60000	ms	1	40	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	Characteristic correction angle in IoCos and IoSin mode
Pol reversal	0=False 1=True			0=False	Rotate polarizing quantity
Pol quantity	3=Zero seq. volt. 4=Neg. seq. volt.			3=Zero seq. volt.	Reference quantity used to determine fault direction

Table 257: DEFHPDEF Group settings (Advanced)

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
Operation mode	1=Phase angle 2=IoSin 3=IoCos 4=Phase angle 80 5=Phase angle 88			1=Phase angle	Operation criteria
Enable voltage limit	0=False 1=True			1=True	Enable voltage limit

4.2.2.13 Monitored data

Table 258: 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	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
I_OPER	FLOAT32	0.00...40.00	xIn	Calculated operating current
DEFLPDEF1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Table 259: 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	FLOAT32	-180.00...180.00	deg	Angle between polarizing and operating quantity
ANGLE_RCA	FLOAT32	-180.00...180.00	deg	Angle between operating angle and characteristic angle
I_OPER	FLOAT32	0.00...40.00	xIn	Calculated operating current
DEFHPDEF1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.2.2.14 Technical data

Table 260: DEFxPDEF Technical data

Characteristic		Value		
Operation accuracy	DEFLPDEF	Depending on the frequency of the measured current: f_n ±2 Hz		
		Current: ±1.5% of the set value or ±0.002 × I_n Voltage: ±1.5% of the set value or ±0.002 × U_n Phase angle: ±2°		
	DEFHPDEF	Current: ±1.5% of the set value or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% of the set value (at currents in the range of 10…40 × I_n) Voltage: ±1.5% of the set value or ±0.002 × U_n Phase angle: ±2°		
Start time 1)2)		Minimum	Typical	Maximum
	DEFHPDEF I_{Fault} = 2 × set *Start value*	36 ms	50 ms	88 ms
	DEFLPDEF I_{Fault} = 2 × set *Start value*	40 ms	50 ms	73 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms 3)		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Measurement mode* = default (depends on the stage), current before fault = 0.0 × 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 × I_n, *Start value* multiples in range of 1.5...20

4.3 Unbalance protection

4.3.1 Negative-sequence overcurrent protection NSPTOC (ANSI 46M)

4.3.1.1 Identification

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

4.3.1.2 Function block

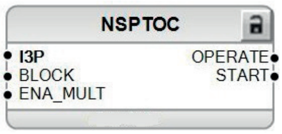


Figure 104: Function block

4.3.1.3 Functionality

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

NSPTOC can also be used for detecting broken conductors.

The function is based on the measurement of the negative sequence current. In a fault situation, the function starts when the negative 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.

4.3.1.4 Analog channel configuration

NSPTOC has one analog group input which must be properly configured.

Table 261: Analog signals

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.3.1.5 Operation principle

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

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

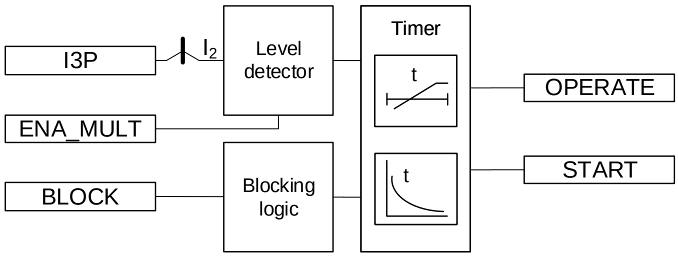


Figure 105: Functional module diagram

Level detector

The measured negative-sequence current is compared to the set *Start value*. If the measured value exceeds the set *Start value*, 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*.

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

Timer

Once activated, 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 operation 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 and the value of START_DUR. The START output is deactivated when the reset timer has elapsed.

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 IDMT curves for overcurrent protection 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 operating time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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.

4.3.1.6 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.

The most common application for the negative sequence overcurrent protection is probably rotating machines, where negative sequence current quantities indicate unbalanced loading conditions (unsymmetrical voltages). Unbalanced loading normally causes extensive heating of the machine and can result in severe damages even over a relatively short time period.

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

4.3.1.7 Signals

Table 262: NSPTOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_MULT	BOOLEAN	0=False	Enable signal for current multiplier

Table 263: NSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.1.8 Settings

Table 264: NSPTOC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Curve parameter A	0.0086...120.0000		0.0001	28.2000	Parameter A for customer programmable curve
Curve parameter B	0.0000...0.7120		0.0001	0.1217	Parameter B for customer programmable curve
Curve parameter C	0.02...2.00		0.01	2.00	Parameter C for customer programmable curve
Curve parameter D	0.46...30.00		0.01	29.10	Parameter D for customer programmable curve
Curve parameter E	0.0...1.0		0.1	1.0	Parameter E for customer programmable curve

Table 265: NSPTOC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
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
Operate delay time	40...200000	ms	10	40	Operate delay time

Table 266: NSPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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

Table 267: NSPTOC Group settings (Advanced)

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

4.3.1.9 Monitored data

Table 268: NSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
NSPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.1.10 Technical data

Table 269: NSPTOC Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × I_n		
Start time 1)2)		Minimum	Typical	Maximum
	I_{Fault} = 2 × set *Start value*	22 ms	32 ms	52 ms
	I_{Fault} = 10 × set *Start value*	14 ms	24 ms	40 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±7.0% of the theoretical value or ±50 ms 3)		
Suppression of harmonics		DFT: -50 dB at f = n × 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 × I_n, *Start value* multiples in range of 1.5...20

4.3.2 Phase discontinuity / Single phasing protection for motor PDNSPTOC (ANSI 46PD)

4.3.2.1 Identification

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

4.3.2.2 Function block

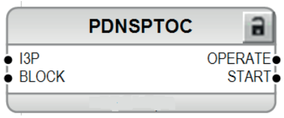


Figure 106: Function block

4.3.2.3 Functionality

The phase discontinuity / single phasing protection for motor function 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.

4.3.2.4 Analog channel configuration

PDNSPTOC has one analog group input which must be properly configured.

Table 270: Analog signals

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.3.2.5 Operation principle

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

The operation of PDNSPTOC can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

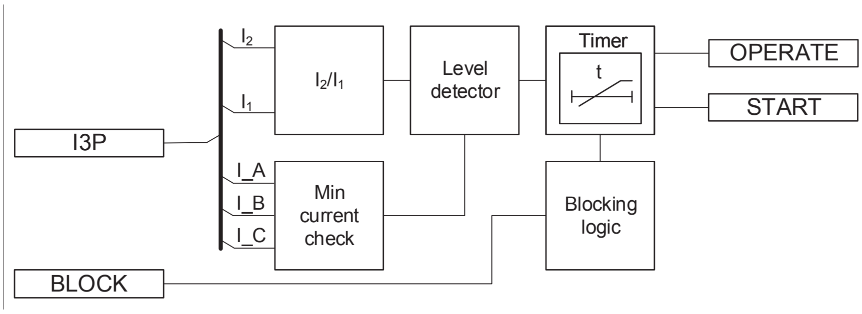


Figure 107: Functional module diagram

I_2/I_1

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

Level detector

The level detector compares the calculated ratio of the negative- and positive-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 value of *Min phase current*, the level detector reports the exceeding of the value to the timer.

Min current check

The min current check module checks whether 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 operation time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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.

4.3.2.6 Application

In three-phase distribution and subtransmission network applications the phase discontinuity in one phase can cause an 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 the positive-sequence and negative-sequence currents. This gives a better sensitivity and stability compared to plain negative-sequence current protection since the calculated ratio of positive-sequence and negative-sequence currents is relatively constant during load variations.

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

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

(Equation 24)

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

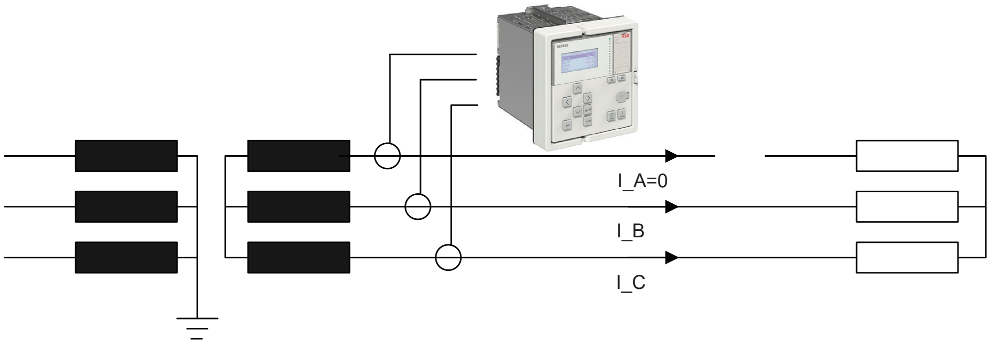


Figure 108: Broken conductor fault situation in phase A in a distribution or subtransmission feeder

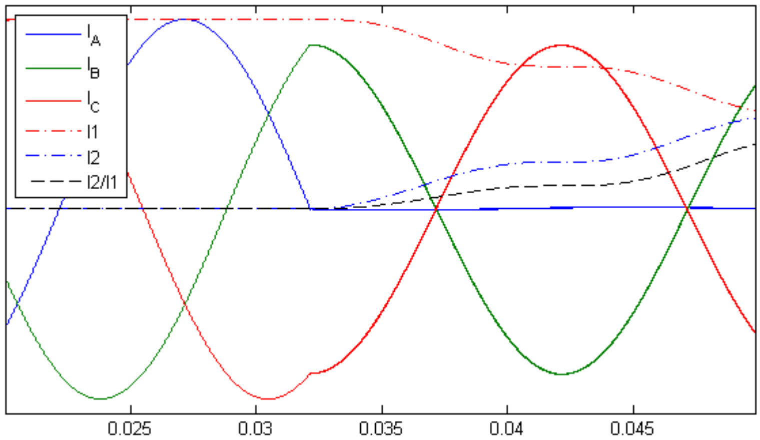


Figure 109: Three-phase current quantities during the broken conductor fault in phase A with the ratio of negative-sequence and positive-sequence currents

4.3.2.7 Signals

Table 271: PDNSPTOC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 272: PDNSPTOC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.3.2.8 Settings

Table 273: PDNSPTOC Non group settings (Basic)

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

Table 274: PDNSPTOC Group settings (Basic)

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 275: PDNSPTOC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Min phase current	0.05...0.30	xIn	0.01	0.10	Minimum phase current
Reset delay time	0...60000	ms	1	20	Reset delay time

4.3.2.9 Monitored data

Table 276: 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
PDNSPTOC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.3.2.10 Technical data

Table 277: PDNSPTOC Technical data

Characteristic	Value
Operate time accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±2.5% of the set value
Start time	<80 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Table continues on next page	

Characteristic	Value
Retardation time	<45 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±40 ms
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

4.4 Voltage protection

4.4.1 Three-phase overvoltage protection PHPTOV (ANSI 59)

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

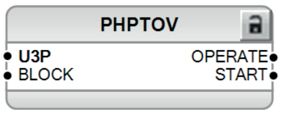


Figure 110: Function block

4.4.1.3 Functionality

The three-phase overvoltage protection function 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.

4.4.1.4 Analog channel configuration

PHPTOV has one analog group input which must be properly configured.

Table 278: Analog inputs

Input	Description
U3P	Three-phase voltages

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 279: Special conditions

Condition	Description
U3P connected to real measurements	The function can work with one voltage channel connected if *Num of start phases* is set to "1 out of 3". Otherwise, all three voltage channels must be connected.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.4.1.5 Operation principle

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

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

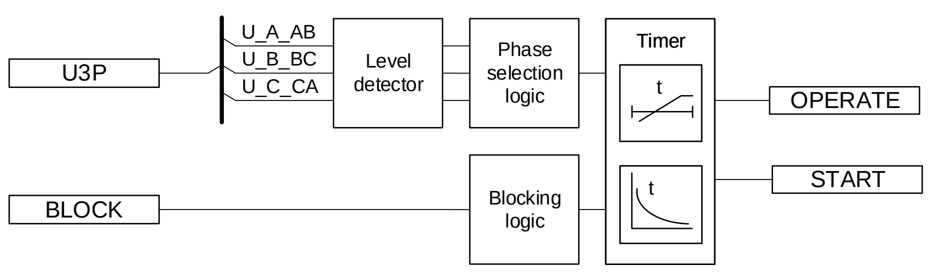


Figure 111: Functional module diagram

Level detector

The fundamental frequency component of the measured three-phase voltages are compared phase-wise 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 IDMT curve saturation of overvoltage protection 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 match 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 IDMT curves for overvoltage protection 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*, *Type of time reset* and *Reset delay time* settings.

Table 280: Reset time functionality when IDMT operation time curve selected

Reset functionality		Setting Type of reset curve	Setting Type of time reset	Setting Reset delay time
Instantaneous reset	Operation timer is "Reset instantaneously" when drop-off occurs	"Immediate"	Setting has no effect	Setting has no effect
Frozen timer	Operation timer is frozen during drop-off	"Def time reset"	"Freeze Op timer"	Operate timer is reset after the set *Reset delay time* has elapsed
Linear decrease	Operation timer value linearly decreases during the drop-off situation	"Def time reset"	"Decrease Op timer"	Operate timer is reset after the set *Reset delay time* has elapsed

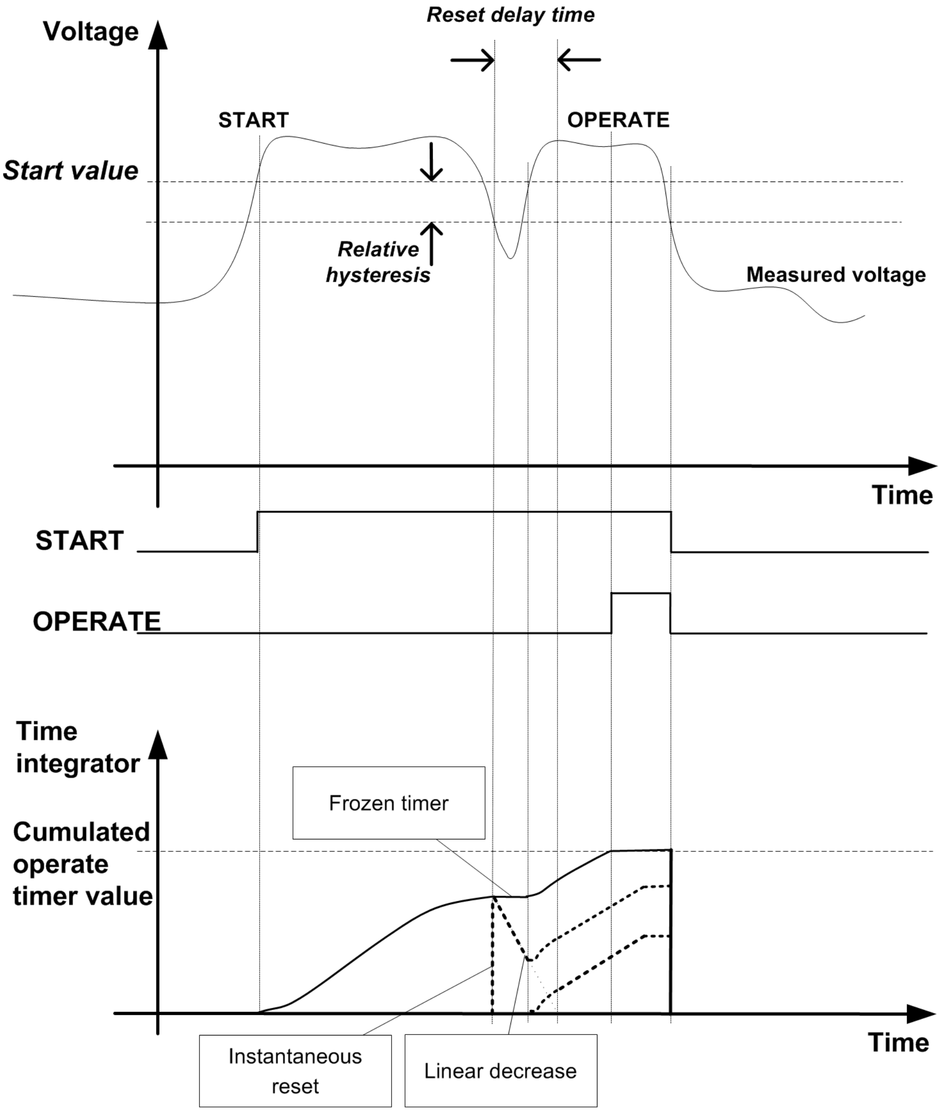


Figure 112: Behavior of different IDMT reset modes. Operate signal is based on settings Type of reset curve = "Def time reset" and Type of time reset= "Freeze Op timer". The effect of other reset modes is also presented

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 IDMT curves for overvoltage protection 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 operation time. The value is available in the Monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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 timer” mode of blocking has no effect during the inverse reset mode.

4.4.1.6 Timer characteristics

The operating curve types supported by PHPTOV are:

Table 281: 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

4.4.1.7 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 relay's 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.

4.4.1.8 Signals

Table 282: PHPTOV Input signals

Name	Type	Default	Description
U3P	SIGNAL	-	Three-phase voltages
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 283: PHPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.1.9 Settings

Table 284: PHPTOV Non group settings (Basic)

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
Curve parameter A	0.005...200.000		0.001	1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00		0.01	1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0		0.1	0.0	Parameter C for customer programmable curve

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter D	0.000...60.000		0.001	0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000		0.001	1.000	Parameter E for customer programmable curve
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages

Table 285: PHPTOV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Start value	0.05...1.60	xUn	0.01	1.10	Start value
Operate delay time	40...300000	ms	10	40	Operate delay time

Table 286: PHPTOV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 Sat Relative	0.0...10.0		0.1	0.0	Tuning parameter to avoid curve discontinuities
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

Table 287: PHPTOV Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset			1=Immediate	Selection of reset curve type
Type of time reset	1=Freeze Op timer 2=Decrease Op timer			1=Freeze Op timer	Selection of time reset

4.4.1.10 Monitored data

Table 288: PHPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTOV1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.1.11 Technical data

Table 289: PHPTOV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 × set *Start value*	18 ms	31 ms	42 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 × U_n, Voltage before fault = 0.9 × 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 × U_n, *Start value* multiples in range of 1.20...2.00

4.4.2 Three-phase undervoltage protection PHPTUV (ANSI 27)

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

4.4.2.2 Function block

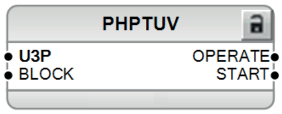


Figure 113: Function block

4.4.2.3 Functionality

The three-phase undervoltage protection function 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.

4.4.2.4 Analog channel configuration

PHPTUV has one analog group input which must be properly configured.

Table 290: Analog inputs

Input	Description
U3P	Three-phase voltages

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 291: Special conditions

Condition	Description
U3P connected to real measurements	The function can work with one voltage channel connected if *Num of start phases* is set to "1 out of 3" but the other two channels must be fed with high values (considerably above *Start value*). For other values of *Num of start phases*, all three voltage channels must be connected.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.4.2.5 Operation principle

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

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

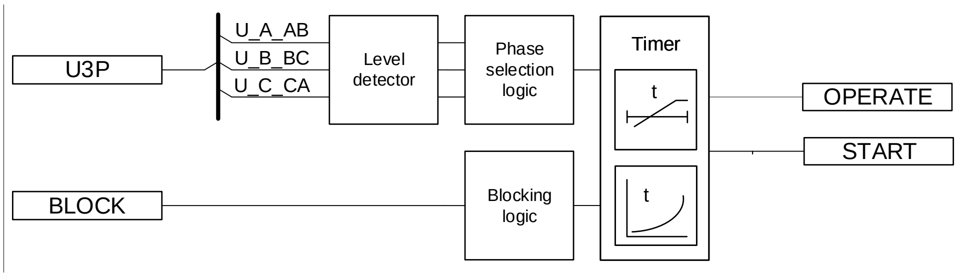


Figure 114: Functional module diagram

Level detector

The fundamental frequency component of the measured three phase voltages are compared phase-wise 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 back 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 more detailed description on IDMT curves and usage of *Curve Sat Relative* setting, see the IDMT curves for undervoltage protection 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 unnecessary starts and operates are wanted to avoid 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 match 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 IDMT curves for undervoltage protection 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*, *Type of time reset* and *Reset delay time* settings.

Table 292: Reset time functionality when IDMT operation time curve selected

Reset functionality		Setting Type of reset curve	Setting Type of time reset	Setting Reset delay time
Instantaneous reset	Operation timer is “Reset instantaneously” when drop-off occurs	“Immediate”	Setting has no effect	Setting has no effect
Frozen timer	Operation timer is frozen during drop-off	“Def time reset”	“Freeze Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed
Linear decrease	Operation timer value linearly decreases during the drop-off situation	“Def time reset”	“Decrease Op timer”	Operate timer is reset after the set *Reset delay time* has elapsed

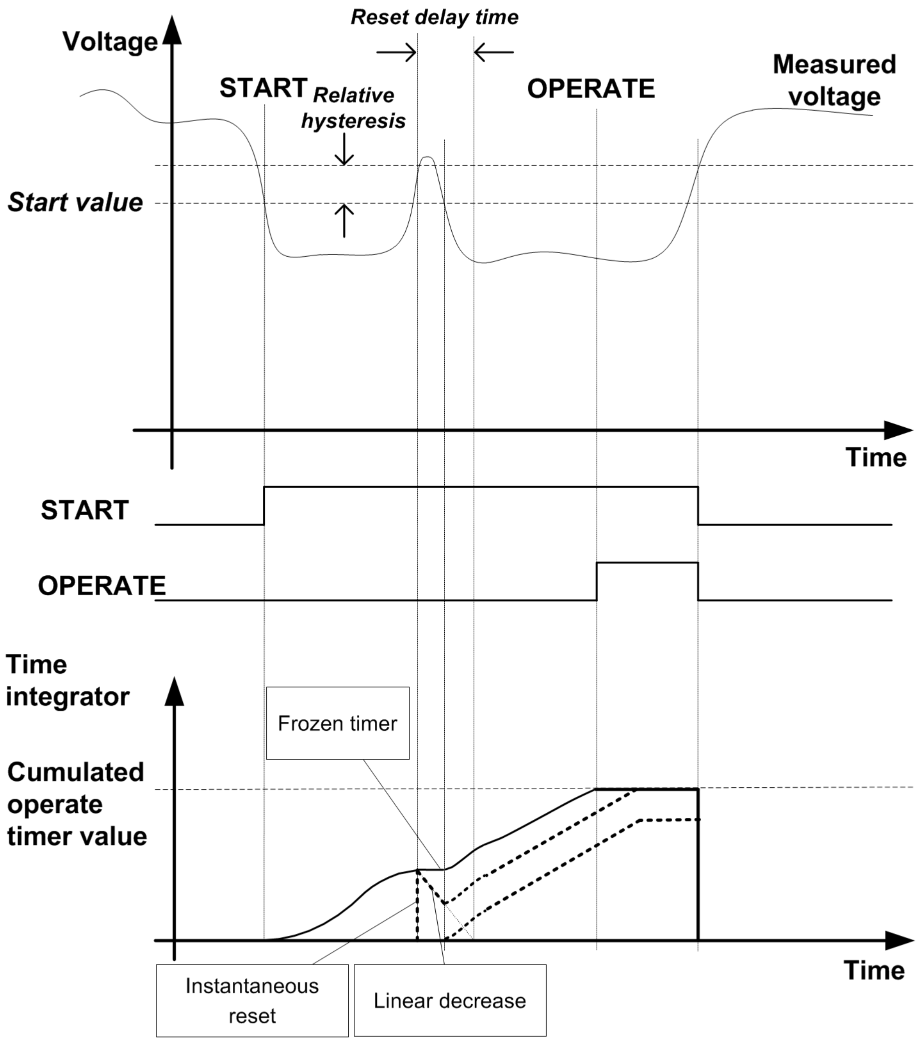


Figure 115: Behavior of different IDMT reset modes. Operate signal is based on settings Type of reset curve = "Def time reset" and Type of time reset= "Freeze Op timer". The effect of other reset modes is also presented

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 IDMT curves for undervoltage protection 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 operation time. The value is available in the Monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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 timer” mode of blocking has no effect during the “Inverse reset” mode.

4.4.2.6 Timer characteristics

The operating curve types supported by PHPTUV are:

Table 293: 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

4.4.2.7 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. 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.

4.4.2.8 Signals

Table 294: PHPTUV Input signals

Name	Type	Default	Description
U3P	SIGNAL	-	Three-phase voltages
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 295: PHPTUV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.2.9 Settings

Table 296: PHPTUV Non group settings (Basic)

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
Curve parameter A	0.005...200.000		0.001	1.000	Parameter A for customer programmable curve
Curve parameter B	0.50...100.00		0.01	1.00	Parameter B for customer programmable curve
Curve parameter C	0.0...1.0		0.1	0.0	Parameter C for customer programmable curve
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Curve parameter D	0.000...60.000		0.001	0.000	Parameter D for customer programmable curve
Curve parameter E	0.000...3.000		0.001	1.000	Parameter E for customer programmable curve
Voltage selection	1=phase-to-earth 2=phase-to-phase			2=phase-to-phase	Parameter to select phase or phase-to-phase voltages

Table 297: PHPTUV Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
Time multiplier	0.05...15.00		0.01	1.00	Time multiplier in IEC/ANSI IDMT curves
Start value	0.05...1.20	xUn	0.01	0.90	Start value
Operate delay time	60...300000	ms	10	60	Operate delay time

Table 298: PHPTUV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 Sat Relative	0.0...10.0		0.1	0.0	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
Relative hysteresis	1.0...5.0	%	0.1	4.0	Relative hysteresis for operation

Table 299: PHPTUV Group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Type of reset curve	1=Immediate 2=Def time reset			1=Immediate	Selection of reset curve type
Type of time reset	1=Freeze Op timer 2=Decrease Op timer			1=Freeze Op timer	Selection of time reset

4.4.2.10 Monitored data

Table 300: PHPTUV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
PHPTUV1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.2.11 Technical data

Table 301: PHPTUV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 0.9 × set *Start value*	58 ms	70 ms	82 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<45 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±40 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±50 ms[3)]		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) *Start value* = 1.0 × U_n, Voltage before fault = 1.1 × 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...0.20

4.4.3 Residual overvoltage protection ROVPTOV (ANSI 59G/ 59N)

4.4.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual overvoltage protection	ROVPTOV	Uo>	59G/59N

4.4.3.2 Function block

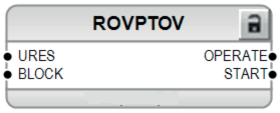


Figure 116: Function block

4.4.3.3 Functionality

The residual overvoltage protection function ROVPTOV is used in distribution networks where the residual overvoltage can reach non-acceptable levels in, for example, 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.

4.4.3.4 Analog channel configuration

ROVPTOV has one analog group input which must be properly configured.

Table 302: Analog inputs

Input	Description
URES	Residual voltage (measured or calculated)

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 303: Special conditions

Condition	Description
URES calculated	The function requires that all three voltage channels are connected to calculate residual voltage. Setting *VT connection* must be "Wye" in that particular UTVTR.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

4.4.3.5 Operation principle

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

The operation of ROVPTOV can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

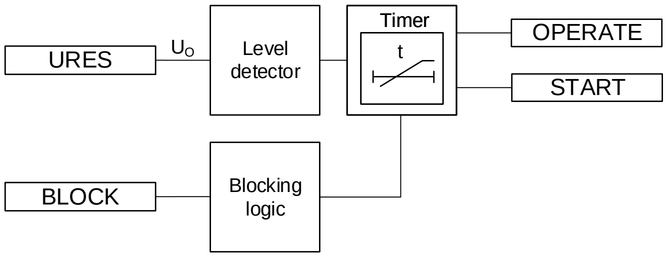


Figure 117: Functional module diagram

Level detector

The residual voltage is compared to the set *Start value*. If the value exceeds the set *Start value*, the level detector sends an enable 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 operation time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the `BLOCK` input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the `OPERATE` output is not deactivated when blocking is activated. 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.

4.4.3.6 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 the back-up protection of feeders for busbar protection when a 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-to-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 the 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.

4.4.3.7 Signals

Table 304: ROVPTOV Input signals

Name	Type	Default	Description
URES	SIGNAL	-	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode

Table 305: ROVPTOV Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.4.3.8 Settings

Table 306: ROVPTOV Non group settings (Basic)

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

Table 307: ROVPTOV Group settings (Basic)

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 308: ROVPTOV Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

4.4.3.9 Monitored data

Table 309: ROVPTOV Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
ROVPTOV1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.4.3.10 Technical data

Table 310: ROVPTOV Technical data

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or ±0.002 × U_n		
Start time[1)2)]		Minimum	Typical	Maximum
	U_{Fault} = 2 × set *Start value*	39 ms	50 ms	64 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<45 ms		
Operate time accuracy		±1.0% of the set value or ±40 ms		
Suppression of harmonics		DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…		

1) Residual voltage before fault = 0.0 × 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

4.5 Multipurpose protection MAPGAPC (ANSI MAP)

4.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Multipurpose protection	MAPGAPC	MAP	MAP

4.5.2 Function block

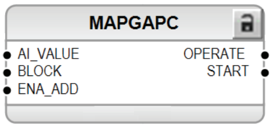


Figure 118: Function block

4.5.3 Functionality

The multipurpose protection function MAPGAPC is used as a general protection with many possible application areas as it has flexible measuring and setting facilities. The function can be used as an under- or overprotection with a settable absolute hysteresis limit. The function 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.

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 MAPGAPC can be described using a module diagram. All the modules in the diagram are explained in the next sections.

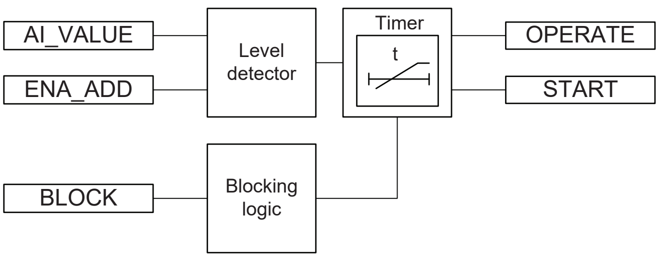


Figure 119: Functional module diagram

Level detector

Level detector compares AI_VALUE to the *Start value* setting. The *Operation mode* setting defines the direction of the level detector.

Table 311: Operation mode types

Operation mode	Description
Under	If the input signal AI_VALUE is lower than the set value of the *Start value* setting, the level detector enables the timer module.
Over	If the input signal AI_VALUE exceeds the set value of the *Start value* setting, the level detector enables the timer module.

The *Absolute hysteresis* setting can be used for preventing unnecessary oscillations if the input signal is slightly 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. If the ENA_ADD input is activated, the threshold value of the internal comparator is the sum of the *Start value Add* and *Start value* settings. The resulting threshold value for the comparator can be increased or decreased depending on the sign and value of the *Start value Add* setting.

Timer

Once activated, 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 starting condition disappears before the module operates, the reset timer is activated. If the reset timer reaches the value set by *Reset delay time*, the operation 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 operation time. The value is available in the monitored data view.

Blocking logic

There are three operation modes in the blocking function. The operation modes are controlled by the BLOCK input and the global setting in **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 protection relay's 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 timer" mode, the operation timer is frozen to the prevailing value, but the OPERATE output is not deactivated when blocking is activated. 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.

4.5.5 Application

The function block can be used for any general analog signal protection, either underprotection or overprotection. The setting range is wide, allowing various protection schemes for the function. Thus, the absolute hysteresis can be set to a value that suits the application.

The temperature protection using GOOSERCV_MV can be done using the function block. The measured temperature can be fed from GOOSERCV_MV to the function input that detects too high temperatures in the motor bearings or windings, for example. When the ENA_ADD input is enabled, the threshold value of the internal comparator is the sum of the *Start value Add* and *Start value* settings. This allows a temporal increase or decrease of the level detector depending on the sign and value of the *Start value Add* setting, for example, when the emergency start is activated. If, for example, *Start value* is 100, *Start value Add* is 20 and the ENA_ADD input is active, the input signal needs to rise above 120 before MAPGAPC operates.

4.5.6 Signals

Table 312: MAPGAPC Input signals

Name	Type	Default	Description
AI_VALUE	FLOAT32	0.0	Analogue input value
BLOCK	BOOLEAN	0=False	Block signal for activating the blocking mode
ENA_ADD	BOOLEAN	0=False	Enable start added

Table 313: MAPGAPC Output signals

Name	Type	Description
OPERATE	BOOLEAN	Operate
START	BOOLEAN	Start

4.5.7 Settings

Table 314: MAPGAPC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operation mode	1=Over 2=Under			1=Over	Operation mode

Table 315: MAPGAPC Group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	-10000.0...10000.0		0.1	0.0	Start value
Operate delay time	0...200000	ms	100	0	Operate delay time
Start value Add	-100.0...100.0		0.1	0.0	Start value Add

Table 316: MAPGAPC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	100	0	Reset delay time
Absolute hysteresis	0.01...100.00		0.01	0.10	Absolute hysteresis for operation

4.5.8 Monitored data

Table 317: MAPGAPC Monitored data

Name	Type	Values (Range)	Unit	Description
START_DUR	FLOAT32	0.00...100.00	%	Ratio of start time / operate time
MAPGAPC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

4.5.9 Technical data

Table 318: MAPGAPC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±40 ms

Section 5 Protection related functions

5.1 Three-phase inrush detector INRPHAR (ANSI 68HB)

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase inrush detector	INRPHAR	3I2f>	68HB

5.1.2 Function block

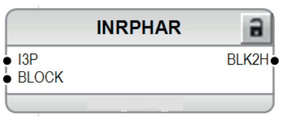


Figure 120: Function block

5.1.3 Functionality

The three-phase inrush detector function INRPHAR is used to detect 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 Analog channel configuration

INRPHAR has one analog group input which must be properly configured.

Table 319: Analog signals

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

5.1.5 Operation principle

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

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

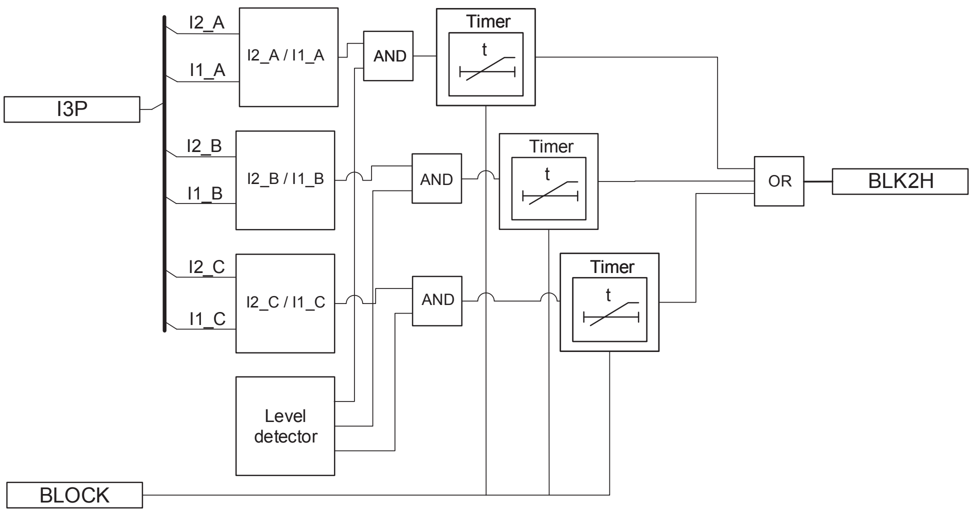


Figure 121: Functional module diagram

I_2H/I_1H

These modules calculate the ratio of the second harmonic (I_2H) and fundamental frequency (I_1H) of the 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, Timer runs until the set *Operate delay time* value is exceeded. The time characteristics 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 up counting, 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.

5.1.6 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 the second harmonic component to the fundamental component exceeds the set value.

Other applications of this function include the detection of inrush in lines connected to a transformer.

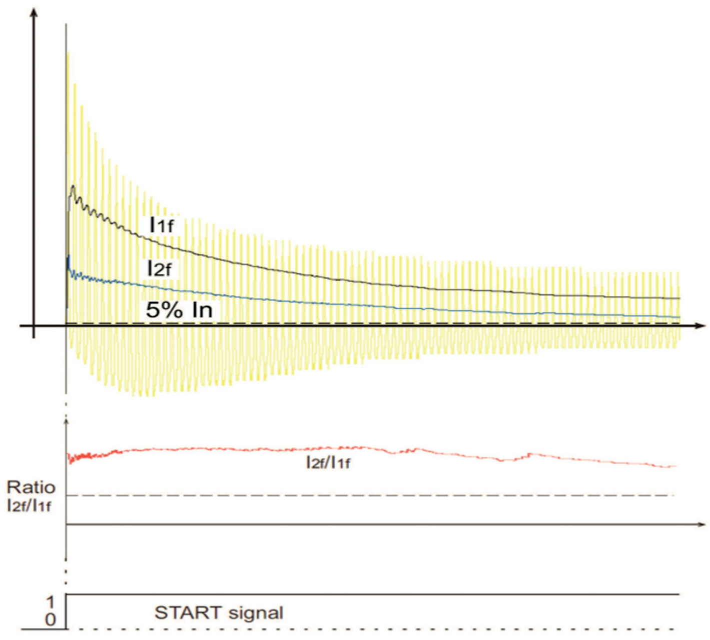


Figure 122: Inrush current in transformer

It is recommended to use the second harmonic and the waveform-based inrush blocking from the transformer differential protection function TR2PTDF if available.

5.1.7 Signals

Table 320: INRPHAR Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block input status

Table 321: INRPHAR Output signals

Name	Type	Description
BLK2H	BOOLEAN	Second harmonic based block

5.1.8 Settings

Table 322: INRPHAR Non group settings (Basic)

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

Table 323: INRPHAR Group settings (Basic)

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 324: INRPHAR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	0...60000	ms	1	20	Reset delay time

5.1.9 Monitored data

Table 325: INRPHAR Monitored data

Name	Type	Values (Range)	Unit	Description
INRPHAR1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.1.10 Technical data

Table 326: INRPHAR Technical data

Characteristic	Value
Operation accuracy	At the frequency f = f_n
	Current measurement: ±1.5% of the set value or ±0.002 × I_n Ratio I2f/I1f measurement: ±5.0% of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typically 0.96
Operate time accuracy	+35 ms / -0 ms

5.2 Circuit breaker failure protection CCBRBRF (ANSI 50BF)

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	50BF

5.2.2 Function block

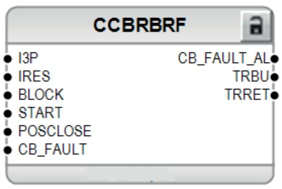


Figure 123: Function block

5.2.3 Functionality

The circuit breaker failure protection function CCBRBRF is activated by trip commands from the protection functions or through binary inputs. CCBRBRF includes a conditional or unconditional re-trip function, and also a conditional back-up trip function.

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 which can be used to block the function outputs.

5.2.4 Analog channel configuration

CCBRBRF has two analog group inputs which must be properly configured.

Table 327: Analog inputs

Input	Description
I3P[1)]	Three-phase currents Necessary when *CB failure mode* is set other than "Breaker status"
IRES[1)]	Residual current (measured or calculated) Necessary when *CB failure mode* is set other than "Breaker status"

1) Can be connected to GRPOFF if *CB failure mode* is set to "Breaker status" and *CB fail retrip mode* is not set to "Current check"

See the preprocessing function blocks in this document for the possible signal sources. The GRPOFF signal is available in the function block called Protection.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

5.2.5 Operation principle

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

The operation of CCBRBRF can be described using a module diagram. All the modules 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.

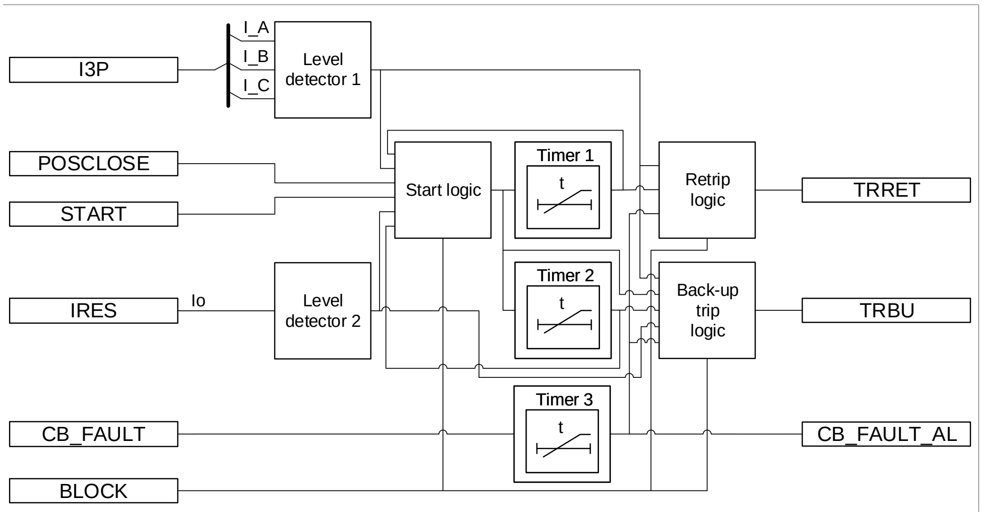


Figure 124: Functional module diagram

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 start, retrip and backup trip logics. The parameter should be set low enough so that breaker failure situations with 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 start and backup trip logics. In high-impedance earthed systems, the residual current at phase-to-earth faults is 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 current setting should be chosen in accordance with the setting of the sensitive earth-fault protection.

Start logic

Start logic is used to manage the starting of Timer 1 and Timer 2. It also resets the function after the circuit breaker failure is handled. On the rising edge of the `START` input, the enabling signal is sent to Timer 1 and Timer 2. Typically, the `START` input is activated when any protection function operates and trips the circuit breaker.

The Start logic module is reset depending on the settings *CB failure mode* and *CB failure trip mode* as shown in Table 328. In all cases in Table 328, however, the resetting is possible only after 150 ms from the activation of Start logic. This time is for ensuring correct operation in case of oscillation in the starting signal.

Table 328: Start logic operation

<table>
<tr><th>Value of setting CB failure mode</th><th>Value of setting CB failure trip mode</th><th>Start logic reset condition</th></tr>
<tr><td rowspan="3">Current</td><td>1 out of 3</td><td>All phase currents drop below Current value setting.</td></tr>
<tr><td>1 out of 4</td><td>All phase currents drop below Current value setting and the residual current drops below Current value Res setting.</td></tr>
<tr><td>2 out of 4</td><td>Either of the following is true:
• All phase currents drop below Current value setting.
• The residual current drops below Current value Res setting and (at least) two phases are below Current value setting.</td></tr>
<tr><td>Breaker status</td><td>1 out of 3
1 out of 4
2 out of 4</td><td>CB is in open position.</td></tr>
<tr><td rowspan="3">Both(AND)</td><td>1 out of 3</td><td>Either of the following is true:
• CB is in open position.
• All phase currents drop below Current value setting.</td></tr>
<tr><td>1 out of 4</td><td>Either of the following is true:
• CB is in open position.
• All phase currents drop below Current value setting and the residual current drops below Current value Res setting.</td></tr>
<tr><td>2 out of 4</td><td>One of the following is true:
• CB is in open position.
• All phase currents drop below Current value setting.
• The residual current drops below Current value Res setting and (at least) two phases are below Current value setting.</td></tr>
<tr><td rowspan="3">Both(OR)</td><td>1 out of 3</td><td>CB is in open position and all phase currents drop below Current value setting.</td></tr>
<tr><td>1 out of 4</td><td>CB is in open position and all phase currents drop below Current value setting and the residual current drops below Current value Res setting.</td></tr>
<tr><td>2 out of 4</td><td>CB is in open position and either of the following is true:
• All phase currents drop below Current value setting.
• The residual current drops below Current value Res setting and (at least) two phases are below Current value setting.</td></tr>
</table>

In addition, the function is immediately reset if:

- *Start latching mode* is set to "Level sensitive", and the `START` signal is deactivated. The recommended setting value is "Rising edge".
- The `BLOCK` input is activated.

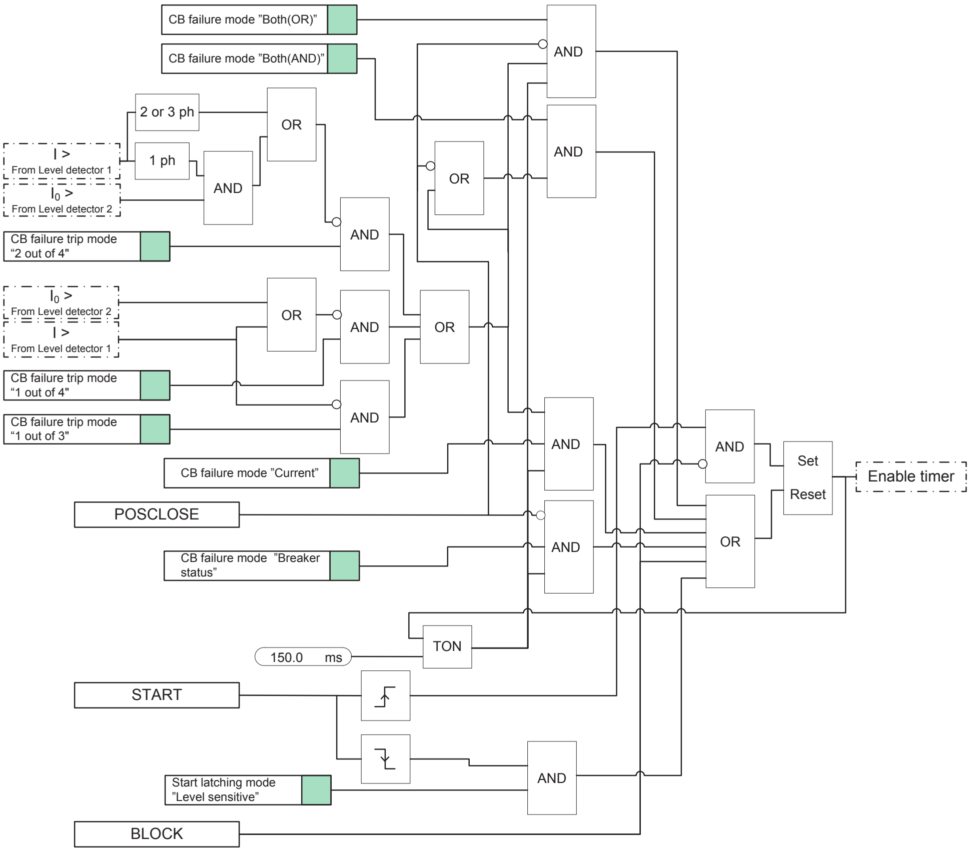


Figure 125: Start logic

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 value set with *Retrip time*, the retrip logic 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 backup trip logic 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 CB failure delay can be estimated as:

$$CBfailuredelay \geq Retriptime + t_{cbopen} + t_{BFP\_reset} + t_{margin}$$

(Equation 25)

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.

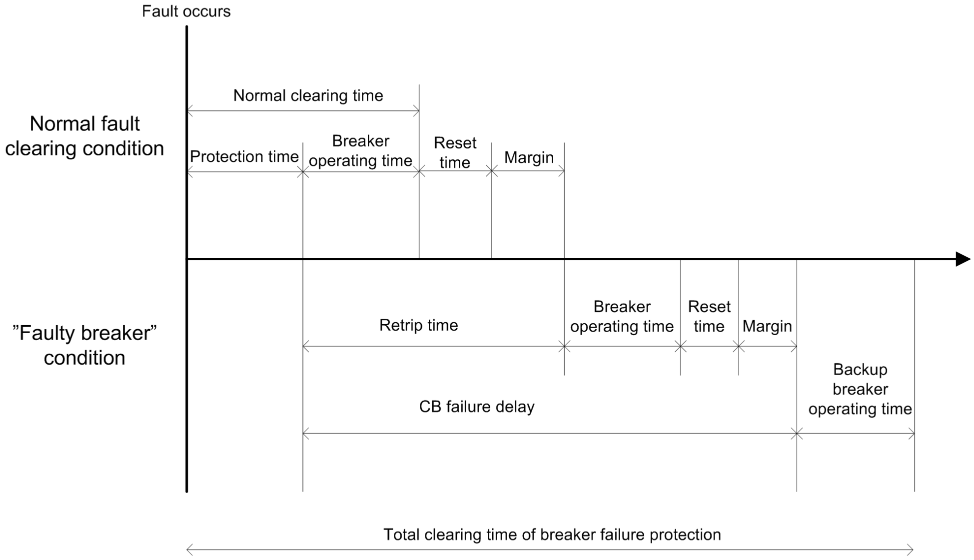


Figure 126: Timeline of the breaker failure protection

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 *CB fault delay*, the `CB_FAULT_AL` output is activated. After the set time, an alarm is given so that the circuit breaker can be repaired. A typical value is 5 s.

Retrip logic

Timer 1 activates Retrip logic, which can be used to give a retrip signal `TRRET` for the main circuit breaker. The operation of Retrip logic depends on the settings *CB failure mode* and *CB fail retrip mode* as shown in Table 329.

Table 329: Retrip logic operation

Value of setting CB fail retrip mode	Value of setting CB failure mode	Retrip functionality
Off	Current Breaker status Both(AND) Both(OR)	Retrip functionality switched off. TRRET is not activated.
Without Check	Current Breaker status Both(AND) Both(OR)	TRRET is activated after Timer 1 elapses.
Current check	Current	TRRET is activated after Timer 1 elapses and any phase current exceeds *Current value* setting.
	Breaker status	TRRET is activated after Timer 1 elapses and CB is in closed position.
	Both(AND)	TRRET is activated after Timer 1 elapses and CB is in closed position and any phase current exceeds *Current value* setting.
	Both(OR)	TRRET is activated after Timer 1 elapses and either of the following is true: • CB is in closed position. • Any phase current exceeds *Current value* setting.

TRRET activation is blocked if either CB_FAULT_AL output (from Timer 3) is active or the BLOCK input is activated.

Once activated, TRRET remains active for the set *Trip pulse time* or until the reasons for activation are reset. TRRET is also reset if CB_FAULT_AL or BLOCK is activated.

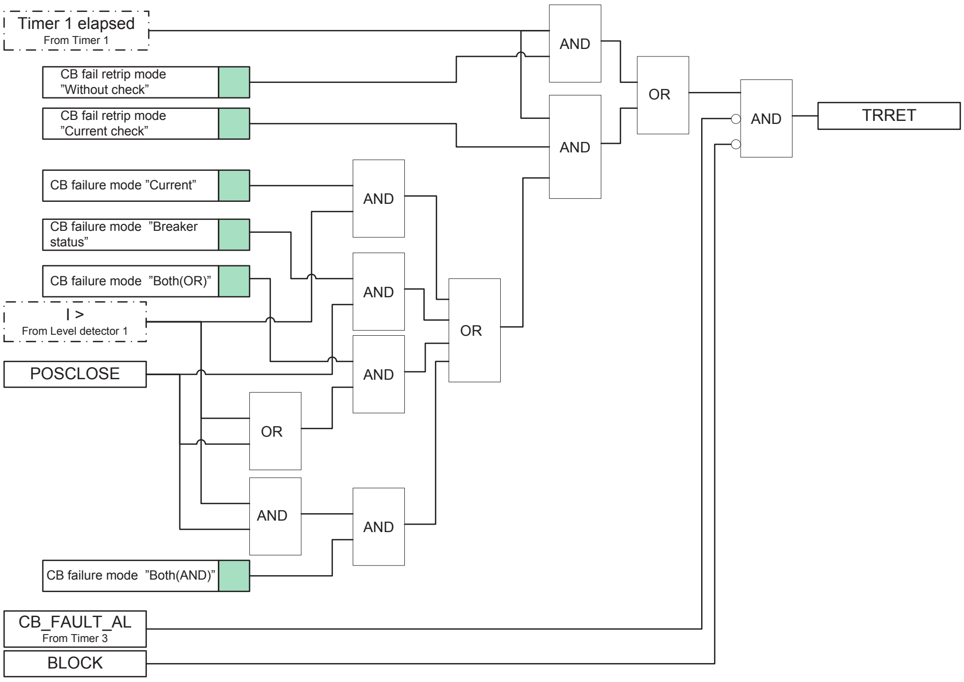


Figure 127: Retrip logic

Backup trip logic

Timer 2 activates Backup trip logic, which gives a backup trip TRBU for the upstream circuit breaker if the main circuit breaker fails to clear the fault. Backup trip logic is also activated if the timer-enabling signal from the Start logic module (rising edge of the START input detected) and CB_FAULT_AL are both active.

The operation of Backup trip logic depends on the settings *CB failure mode* and *CB failure trip mode* as shown in Table 330.

Table 330: Backup trip logic operation

<table>
<tr><th>Value of setting CB failure mode</th><th>Value of setting CB failure trip mode</th><th>Conditions for activating Backup trip logic</th></tr>
<tr><td rowspan="3">Current</td><td>1 out of 3</td><td>Any phase current exceeds Current value setting.</td></tr>
<tr><td>1 out of 4</td><td>Either of the following is true:
• Any phase current exceeds Current value setting.
• The residual current exceeds Current value Res setting.</td></tr>
<tr><td>2 out of 4</td><td>Either of the following is true:
• Any phase current exceeds Current value setting and the residual current exceeds Current value Res setting.
• Two or three phase currents exceed Current value setting.</td></tr>
<tr><td>Breaker status</td><td>1 out of 3
1 out of 4
2 out of 4</td><td>CB is in closed position.</td></tr>
<tr><td rowspan="3">Both(AND)</td><td>1 out of 3</td><td>CB is in closed position and any phase current exceeds Current value setting.</td></tr>
<tr><td>1 out of 4</td><td>CB is in closed position and either of the following is true:
• Any phase current exceeds Current value setting.
• The residual current exceeds Current value Res setting.</td></tr>
<tr><td>2 out of 4</td><td>CB is in closed position and either of the following is true:
• Any phase current exceeds Current value setting and the residual current exceeds Current value Res setting.
• Two or three phase currents exceed Current value setting.</td></tr>
<tr><td colspan="3">Table continues on next page</td></tr>
</table>

Value of setting CB failure mode	Value of setting CB failure trip mode	Conditions for activating Backup trip logic
Both(OR)	1 out of 3	Either of the following is true: • CB is in closed position. • Any phase current exceeds *Current value* setting.
	1 out of 4	One of the following is true: • CB is in closed position. • Any phase current exceeds *Current value* setting. • The residual current exceeds *Current value Res* setting.
	2 out of 4	One of the following is true: • CB is in closed position. • Any phase current exceeds *Current value* setting and the residual current exceeds *Current value Res* setting. • Two or three phase currents exceed *Current value* setting.

Once activated, TRBU remains active until the set *Trip pulse time* or until the reasons for activation are reset. TRRET is also reset if BLOCK is activated.

In most applications, "1 out of 3" is sufficient.

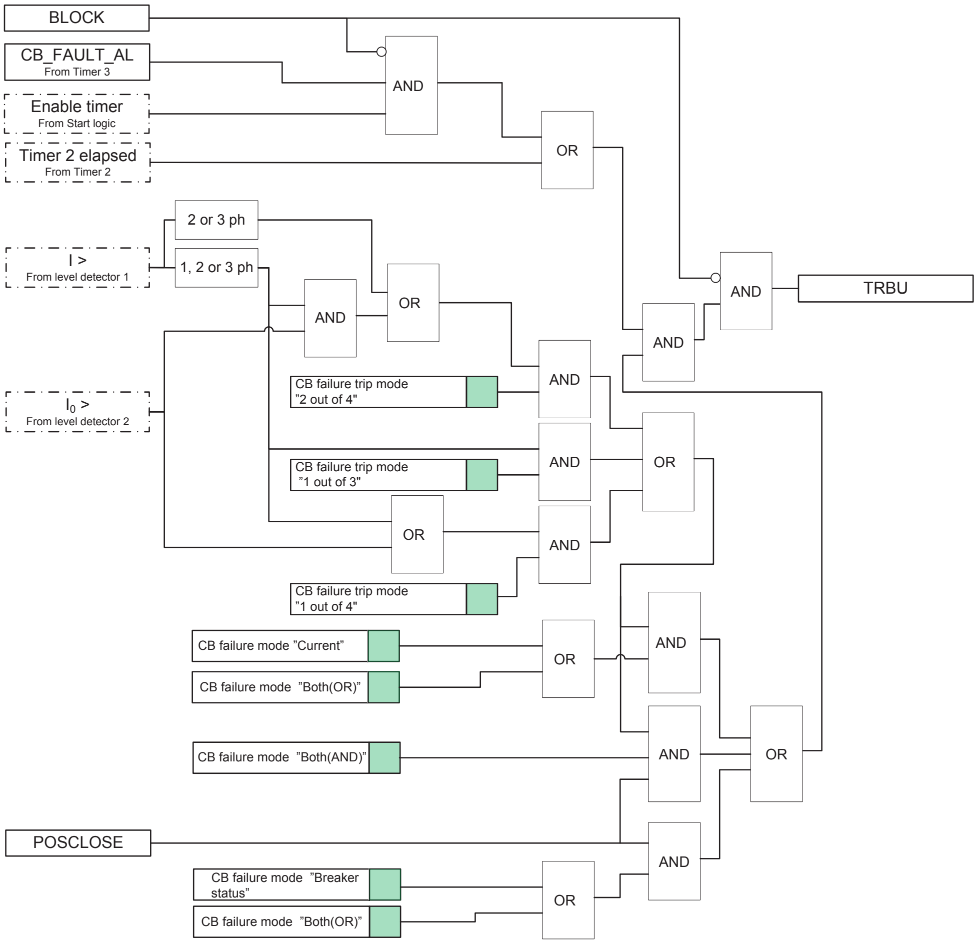


Figure 128: Backup trip logic

5.2.6 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 backup trip command to up-stream 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 backup tripping of several breakers in case mistakes occur during protection relay maintenance and tests.

CCBRBRF is initiated by operating different protection functions or digital logics inside the protection relay. 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.

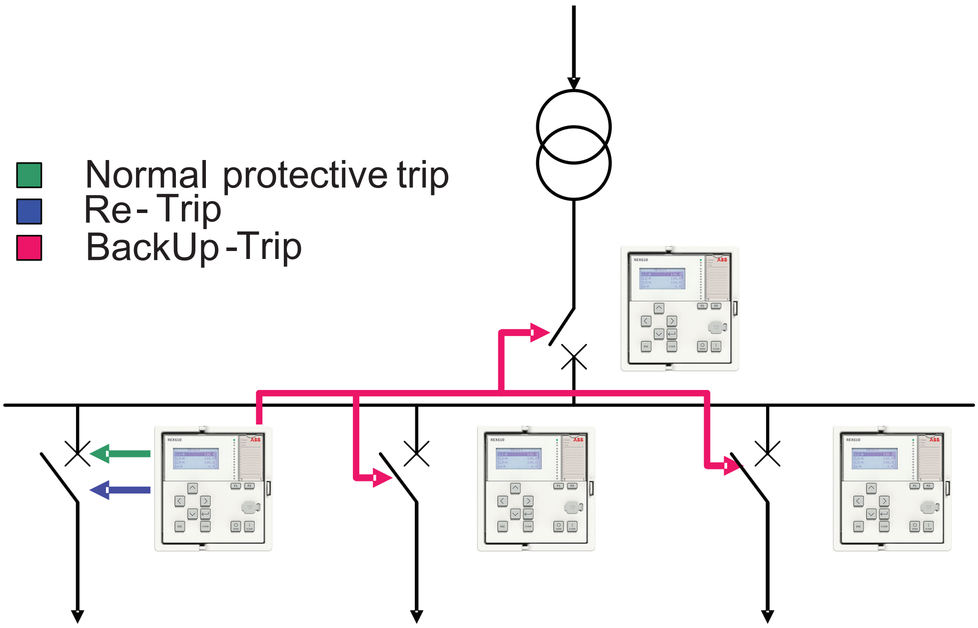


Figure 129: Typical breaker failure protection scheme in distribution substations

5.2.7 Signals

Table 331: CCBRBRF Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
IRES	SIGNAL	-	Residual current
BLOCK	BOOLEAN	0=False	Block CBFP operation
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

Table 332: CCBRBRF Output signals

Name	Type	Description
CB_FAULT_AL	BOOLEAN	Delayed CB failure alarm
TRBU	BOOLEAN	Backup trip
TRRET	BOOLEAN	Retrip

5.2.8 Settings

Table 333: CCBRBRF Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Current value	0.05...2.00	xIn	0.01	0.30	Operating phase current
Current value Res	0.05...2.00	xIn	0.01	0.30	Operating residual current
CB failure trip mode	1=2 out of 4 2=1 out of 3 3=1 out of 4			2=1 out of 3	Backup trip current check mode
CB failure mode	1=Current 2=Breaker status 3=Both (AND) -1=Both (OR)			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	120	Delay timer for retrip
CB failure delay	0...60000	ms	10	240	Delay timer for backup trip
Operation	1=on 5=off			1=on	Operation Off / On

Table 334: CCBRBRF Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
CB fault delay	0...60000	ms	10	5000	Circuit breaker faulty delay
Measurement mode	2=DFT 3=Peak-to-Peak			3=Peak-to-Peak	Phase current measurement mode of function
Trip pulse time	0...60000	ms	10	200	Pulse length of retrip and backup trip outputs
Start latching mode	1=Rising edge 2=Level sensitive			1=Rising edge	Start reset delayed or immediately

5.2.9 Monitored data

Table 335: CCBRBRF Monitored data

Name	Type	Values (Range)	Unit	Description
CCBRBRF1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

5.2.10 Technical data

Table 336: CCBRBRF Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × I_n
Operate time accuracy	±1.0% of the set value or ±40 ms
Reset time	Typically 40 ms
Retardation time	<45 ms

5.3 Master trip TRPPTRC (ANSI 94/86)

5.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Master trip	TRPPTRC	Master Trip	94/86

5.3.2 Function block

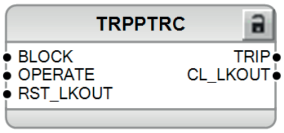


Figure 130: Function block

5.3.3 Functionality

The master trip 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 minimum trip pulse length can be set 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 Operation principle

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 intended to go through the function to the circuit breaker trip coil are blocked.

The operation of TRPPTRC can be described with a module diagram. All the modules in the diagram are explained in the next sections.

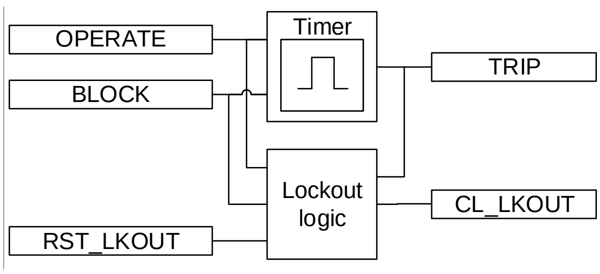


Figure 131: Functional module diagram

Timer

The duration of the `TRIP` output signal from TRPPTRC can be adjusted 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 protection relay, or from external protection functions via one or more of the protection relay's binary inputs. The function has a single trip output TRIP for connecting the function to one or more of the protection relay's binary outputs, and also to other functions within the protection relay 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 be 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 337: Operation modes for the TRPPTRC trip output

Mode	Operation
Non-latched	The *Trip pulse time* 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 application of the 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, TRPPTRC can block the CBXCBR closing.

TRPPTRC 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 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 protection relay, for example when starting the breaker failure protection.

TRPPTRC is used for simple three-phase tripping applications.

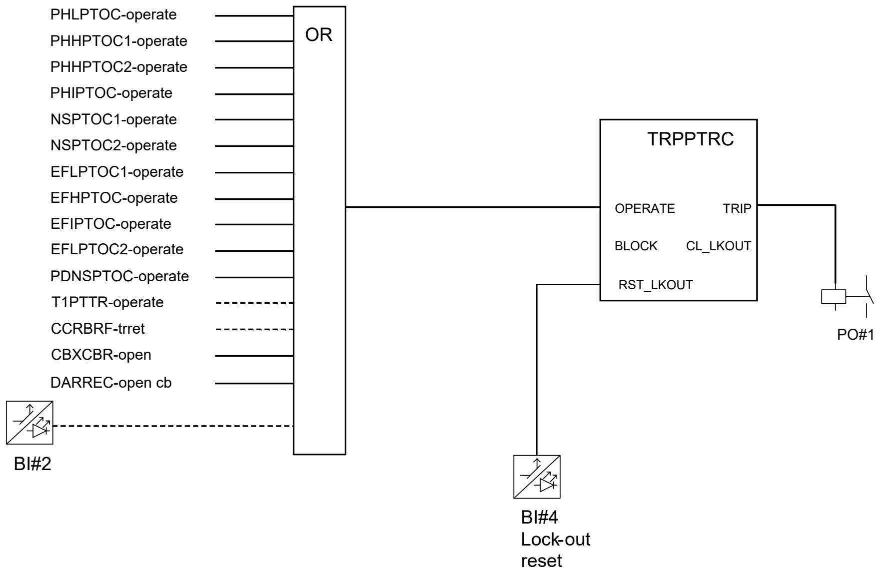


Figure 132: Typical TRPPTRC connection

5.3.6 Signals

Table 338: TRPPTRC Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0=False	Block of function
OPERATE	BOOLEAN	0=False	Operate
RST_LKOUT	BOOLEAN	0=False	Input for resetting the circuit breaker lockout function

Table 339: 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 340: TRPPTRC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Trip pulse time	20...60000	ms	1	250	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 341: TRPPTRC Monitored data

Name	Type	Values (Range)	Unit	Description
TRPPTRC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

Section 6 Supervision functions

6.1 Trip circuit supervision TCSSCBR (ANSI TCM)

6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip circuit supervision	TCSSCBR	TCS	TCM

6.1.2 Function block

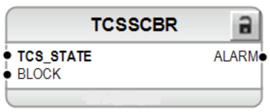


Figure 133: Function block

6.1.3 Functionality

The trip circuit supervision function TCSSCBR is designed to supervise the control circuit of the circuit breaker. The invalidity of a control circuit is detected by using a dedicated output contact that contains the supervision functionality. The failure of a circuit is reported to the corresponding function block in the relay configuration.

The function starts and operates when TCSSCBR detects a trip circuit failure. The operating time characteristic for the function is DT. 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 TCSSCBR can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

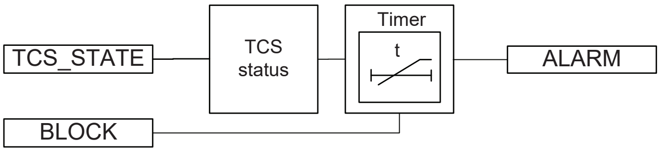


Figure 134: Functional module diagram

TCS status

This module receives the trip circuit status from the hardware. A detected failure in the trip circuit activates the timer.

Timer

Once activated, the timer runs until the set value of *Operate delay time* has elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the `ALARM` output is activated.

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.

6.1.5 Application

TCSSCBR detects faults in the electrical control circuit of the circuit breaker. The function can supervise both open and closed coil circuits. This supervision is necessary to find out the vitality of the control circuits continuously.

Figure 135 shows an application of the trip circuit supervision function use.

The best solution is to connect an external R_{ext} shunt resistor in parallel with the circuit breaker internal contact. Although the circuit breaker internal contact is open, TCS can see the trip circuit through R_{ext}. The R_{ext} resistor should have such a resistance that the current through the resistance remains small, that is, it does not harm or overload the circuit breaker's trip coil.

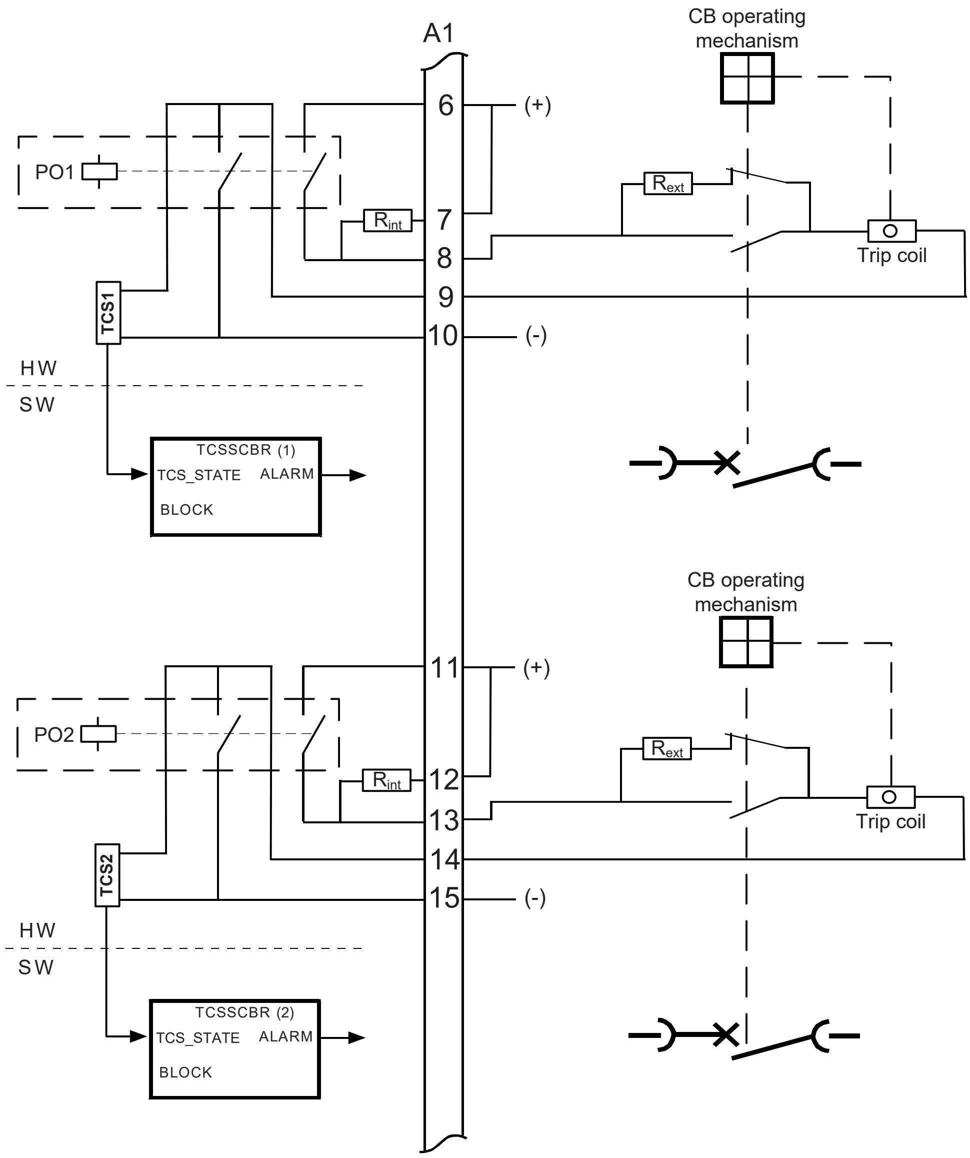


Figure 135: Operating principle of the trip circuit supervision with an external resistor. The TCSSCBR blocking switch is not required since the external resistor is used.

If TCS is required only in a closed position, the external shunt resistance can be omitted. When the circuit breaker is in the open position, TCS sees the situation as a faulty circuit. One way to avoid TCS operation in this situation is to block the supervision function whenever the circuit breaker is open.

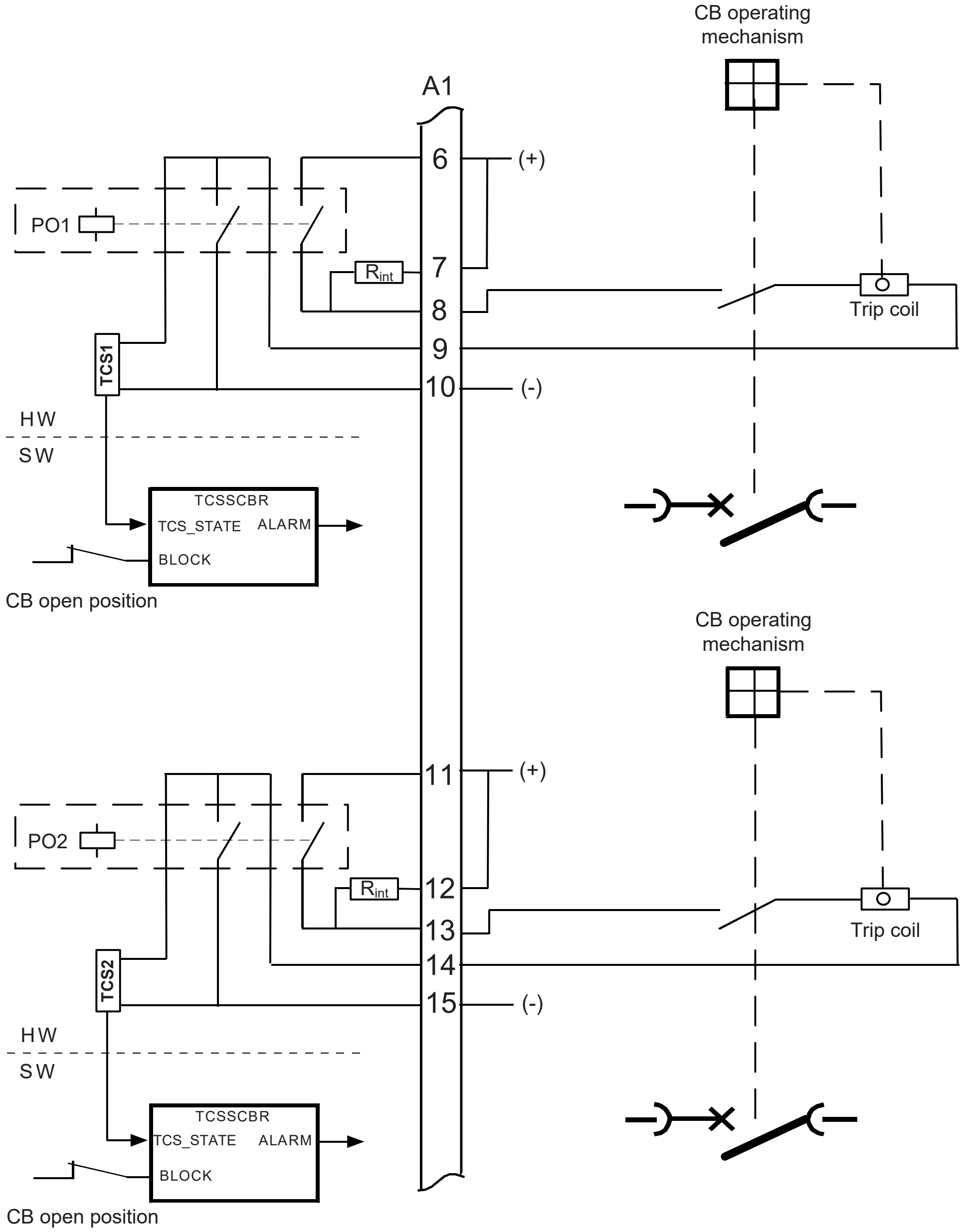


Figure 136: Operating principle of the trip circuit supervision without an external resistor. The circuit breaker open indication is set to block TCSSCBR when the circuit breaker is open.

Trip circuit supervision and other trip contacts

It is typical that the trip circuit contains more than one trip contact in parallel, for example in transformer feeders where the trip of a Buchholz relay is connected in parallel with the feeder terminal and other relays involved. The supervising current cannot detect if one or all the other contacts connected in parallel are not connected properly.

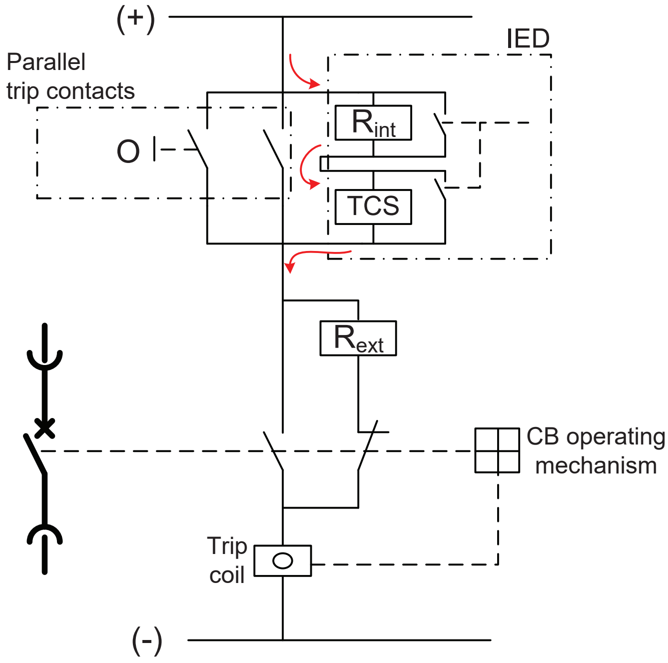


Figure 137: Constant test current flow in parallel trip contacts and trip circuit supervision

In case of parallel trip contacts, the recommended way to do the wiring is that the TCS test current flows through all wires and joints.

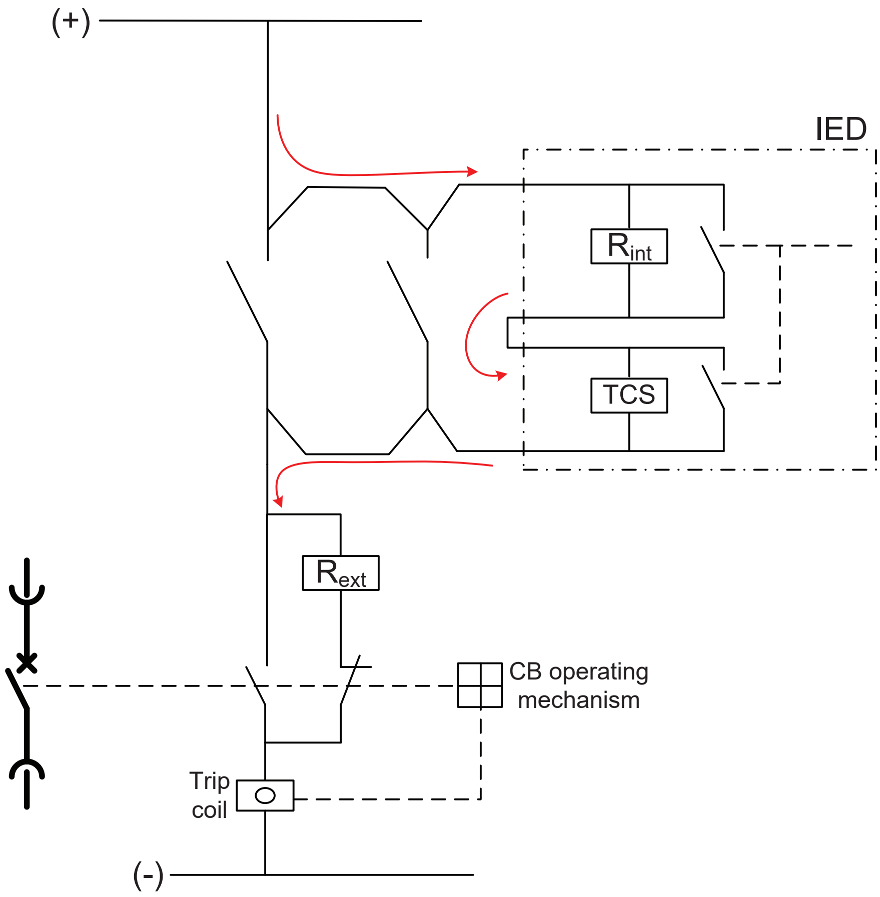


Figure 138: Improved connection for parallel trip contacts where the test current flows through all wires and joints

Several trip circuit supervision functions parallel in circuit

Not only does the trip circuit often have parallel trip contacts, but it is also possible that the circuit has multiple TCS circuits in parallel. Each TCS circuit causes its own supervising current to flow through the monitored coil and the actual coil current is a sum of all TCS currents. This must be considered when determining the resistance of R_{ext}.

Setting the TCS function in a protection relay not-in-use does not typically affect the supervising current injection.

Trip circuit supervision with auxiliary relays

Many retrofit projects are carried out partially, that is, the old electromechanical relays are replaced with new ones but the circuit breaker is not replaced. This creates a problem that the coil current of an old type circuit breaker can be too high for the protection relay trip contact to break.

The circuit breaker coil current is normally cut by an internal contact of the circuit breaker. In case of a circuit breaker failure, there is a risk that the protection relay trip contact is destroyed since the contact is obliged to disconnect high level of electromagnetic energy accumulated in the trip coil.

An auxiliary relay can be used between the protection relay trip contact and the circuit breaker coil. This way the breaking capacity question is solved, but the TCS circuit in the protection relay monitors the healthy auxiliary relay coil, not the circuit breaker coil. The separate trip circuit supervision relay is applicable for this to supervise the trip coil of the circuit breaker.

Dimensioning of the external resistor

Under normal operating conditions, the applied external voltage is divided between the relay's internal circuit and the external trip circuit so that at the minimum 20 V (15...20 V) remains over the relay's internal circuit. Should the external circuit's resistance be too high or the internal circuit's too low, for example due to welded relay contacts, a fault is detected.

Mathematically, the operation condition can be expressed as:

$$U_C - (R_{ext} + R_{\text{int}} + R_s) \cdot I_C \geq 20V \quad AC / DC$$

(Equation 26)

U_c	Operating voltage over the supervised trip circuit
I_c	Measuring current through the trip circuit, approx. 1.5 mA (0.99...1.72 mA)
R_{ext}	External shunt resistance
R_{int}	Internal shunt resistance, 1 kΩ
R_s	Trip coil resistance

If the external shunt resistance is used, it has to be calculated not to interfere with the functionality of the supervision or the trip coil. Too high a resistance causes too high a voltage drop, jeopardizing the requirement of at least 20 V over the internal circuit, while too low a resistance can enable false operations of the trip coil.

Table 342: Values recommended for the external resistor R_{ext}

Operating voltage U_c	Shunt resistor R_{ext}
48 V AC/DC	1.2 kΩ, 5 W
60 V AC/DC	5.6 kΩ, 5 W
110 V AC/DC	22 kΩ, 5 W
220 V AC/DC	33 kΩ, 5 W

Due to the requirement that the voltage over the TCS contact must be 20 V or higher, correct operation is not guaranteed with auxiliary operating voltages lower than 48 V DC because of the voltage drop in R_{int}, R_{ext} and the operating coil or even voltage drop of the feeding auxiliary voltage system which can cause too low voltage values over the TCS contact. In this case, erroneous alarming can occur.

At lower (<48 V DC) auxiliary circuit operating voltages, it is recommend to use the circuit breaker position to block unintentional operation of TCS.

Using power output contacts without trip circuit supervision

If TCS is not used but the contact information of the corresponding power outputs is required, the internal resistor can be bypassed. The output can then be used as a normal power output. When bypassing the internal resistor, the wiring between the terminals of the corresponding output PO1 (X100:8-7) or PO2 (X100:13-12) can be disconnected. The internal resistor is required if the complete TCS circuit is used.

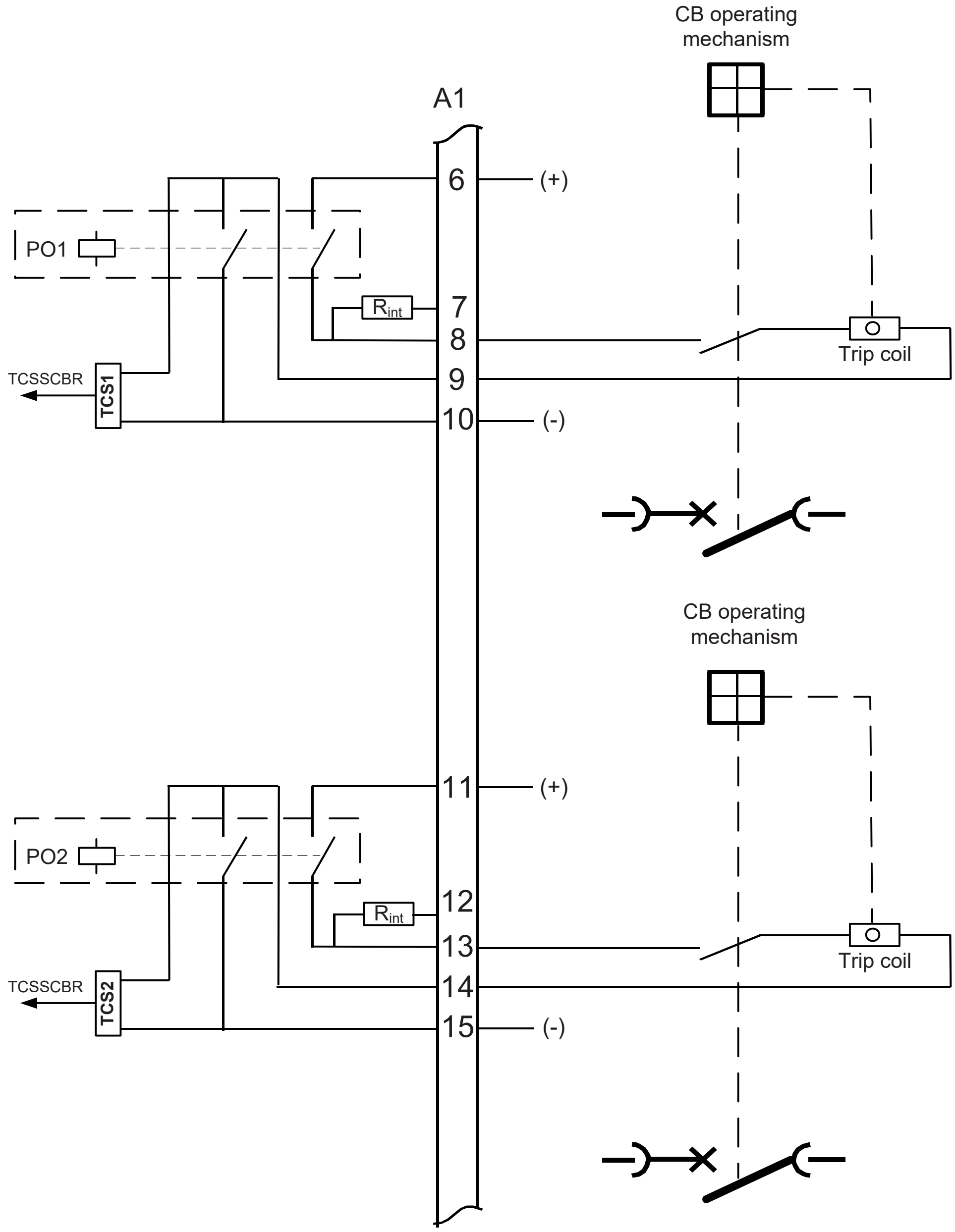


Figure 139: Connection of a power output when TCS is not used and the internal resistor is disconnected

Incorrect connections and use of trip circuit supervision

Although the TCS circuit consists of two separate contacts, those are designed to be used as series connected to guarantee the breaking capacity given in the technical manual of the protection relay. Besides the weak breaking capacity, the internal resistor is not dimensioned to withstand current without a TCS circuit. As a result, this kind of incorrect connection causes immediate burning of the internal resistor when the circuit breaker is in the close position and the voltage is applied to the trip circuit. Figure 140 shows incorrect usage of a TCS circuit when only one of the contacts is used.

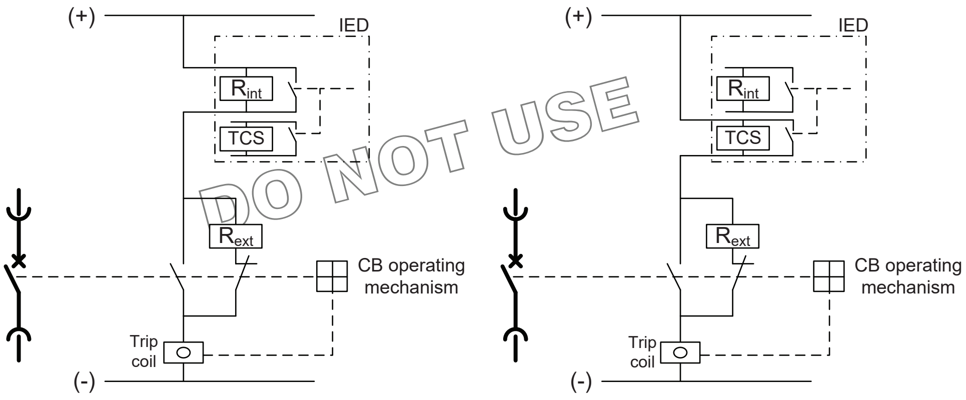
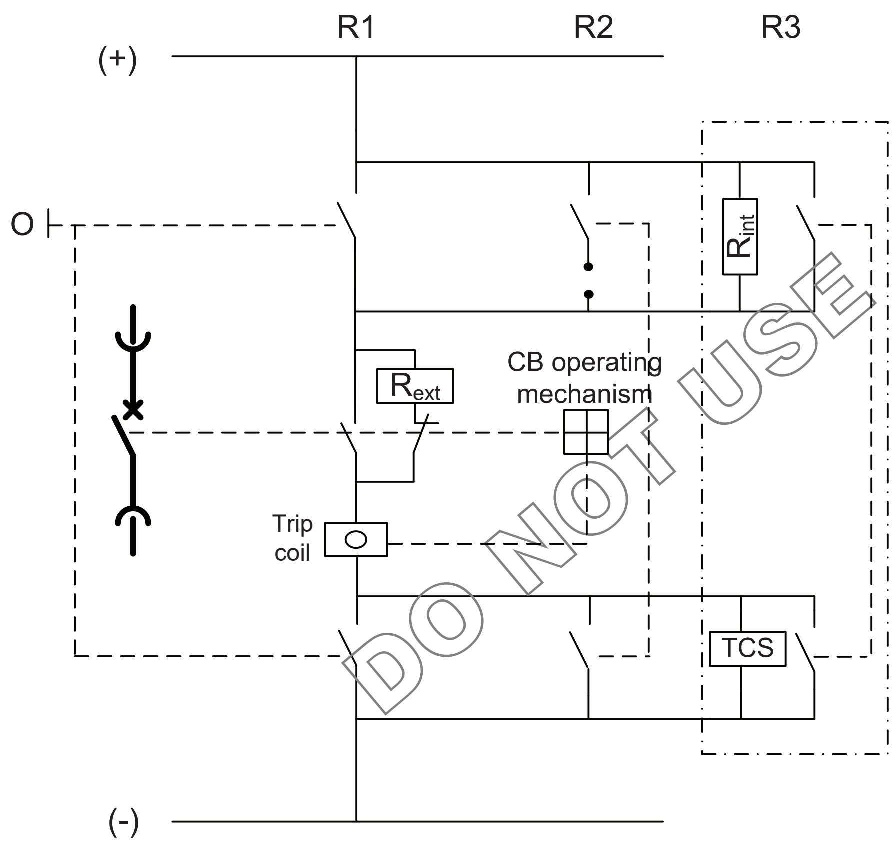


Figure 140: Incorrect connection of trip circuit supervision

A connection of three protection relays with a double pole trip circuit is shown in Figure 141. Only protection relay R3 has an internal TCS circuit. In order to test the operation of protection relay R2, but not to trip the circuit breaker, the upper trip contact of protection relay R2 is disconnected while the lower contact is still connected. When protection relay R2 operates, the coil current starts to flow through the internal resistor of protection relay R3 and the resistor burns immediately. As proven with the previous examples, both trip contacts must operate together. Attention should also be paid to correct usage of the trip circuit supervision while, for example, testing the protection relay.



DO NOT USE

Figure 141: Incorrect testing of protection relays

6.1.6 Signals

Table 343: TCSSCBR Input signals

Name	Type	Default	Description
TCS_STATE	BOOLEAN	0=False	Trip circuit supervision status
BLOCK	BOOLEAN	0=False	Block input status

Table 344: TCSSCBR Output signals

Name	Type	Description
ALARM	BOOLEAN	Alarm output

6.1.7 Settings

Table 345: TCSSCBR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Operate delay time	1000...300000	ms	1000	3000	Operate delay time

Table 346: TCSSCBR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Reset delay time	1000...60000	ms	1000	1000	Reset delay time

6.1.8 Monitored data

Table 347: TCSSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
TCSSCBR1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.2 Current circuit supervision CCSPVC (ANSI CCM)

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current circuit supervision	CCSPVC	MCS 3I	CCM

6.2.2 Function block

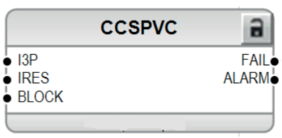


Figure 142: Function block

6.2.3 Functionality

The current circuit supervision function CCSPVC is used for monitoring current transformer secondary circuits.

CCSPVC 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 protection relay.

CCSPVC 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 Analog channel configuration

CCSPVC has two analog group inputs which must be properly configured.

Table 348: Analog inputs

Input	Description
I3P	Three-phase currents
IRES	Residual current (measured)

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 349: Special conditions

Condition	Description
IRES measured	In case IRES needs to be derived, the function requires that all CT cores, except for the one used for phase current measurement, must be used and summed externally.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

6.2.5 Operation principle

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

The operation of CCSPVC can be described with a module diagram. All the modules in the diagram are explained in the next sections.

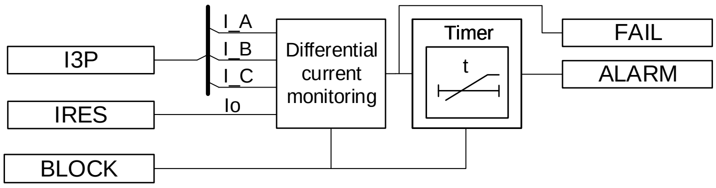


Figure 143: Functional module diagram

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 × In, the differential current limit is defined with *Start value*. When the highest phase current is more than 1.0 × In, the differential current limit is calculated with the equation.

$$MAX(I\_A, I\_B, I\_C) \cdot Start\ value$$

(Equation 27)

The differential current is limited to 1.0 × In.

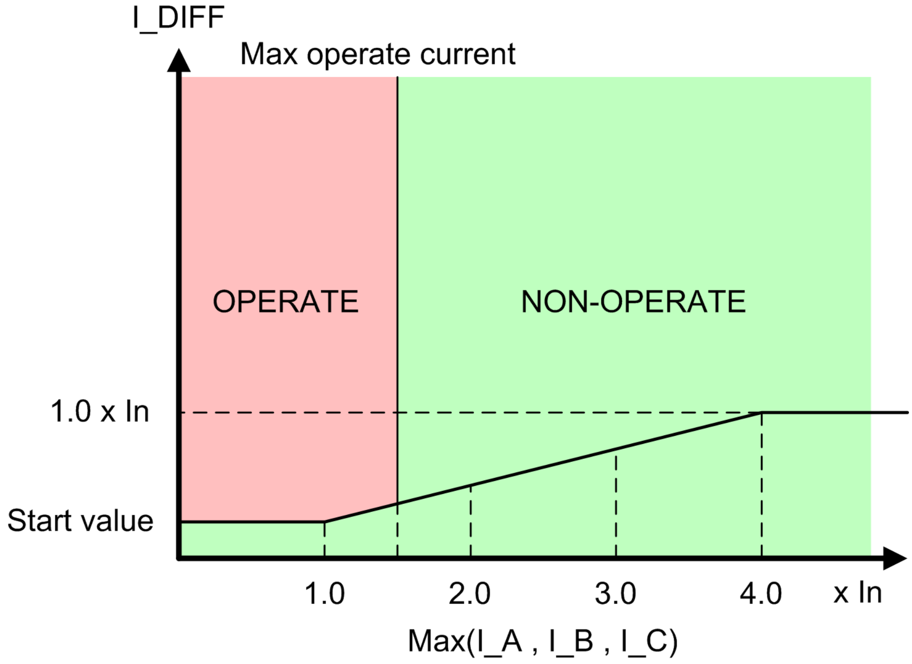


Figure 144: CCSPVC operating characteristics

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 in the monitored data view on the LHMI or through other communication tools. The value is calculated with the equation.

$$I\_DIFF = \left| \overline{I\_A} + \overline{I\_B} + \overline{I\_C} \right| - \left| \overline{I\_REF} \right|$$

(Equation 28)

The *Start value* setting is given in units of ×In 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 deactivates 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 deactivates immediately. However, the ALARM output deactivates after a fixed delay of three seconds.

The function resets when the differential current is below the start value and the highest phase current is more than 5 percent of the nominal current (0.05 × In).

If the current falls to zero when the FAIL or ALARM outputs are active, the deactivation of these outputs is prevented.

The activation of the BLOCK input deactivates the ALARM output.

6.2.6 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 can result in differences in the secondary currents from the two CT cores. An unwanted blocking of protection functions during the transient stage must then be avoided.

The supervision function must be sensitive and have a short operation time 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 protection relay, 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 core-balanced current transformer

CCSPVC compares the sum of phase currents to the current measured with the core-balanced CT.

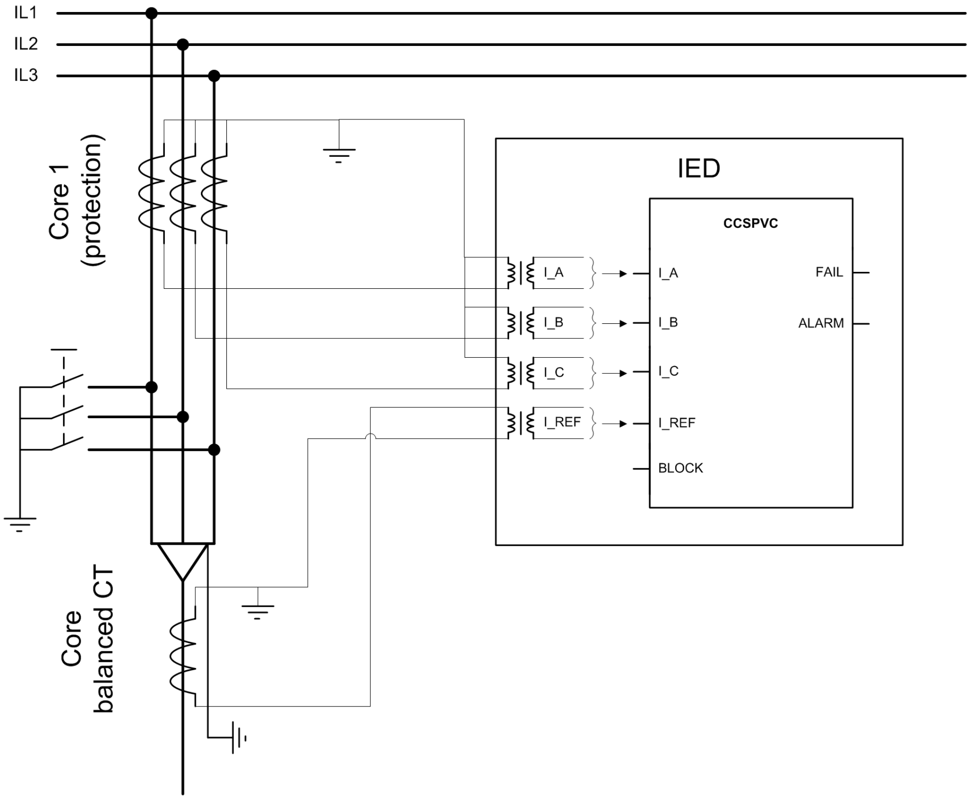


Figure 145: Connection diagram for reference current measurement with core-balanced current transformer

Current measurement with two independent three-phase sets of CT cores

Figure 146 and Figure 147 show diagrams of connections where the reference current is measured with two independent three-phase sets of CT cores.

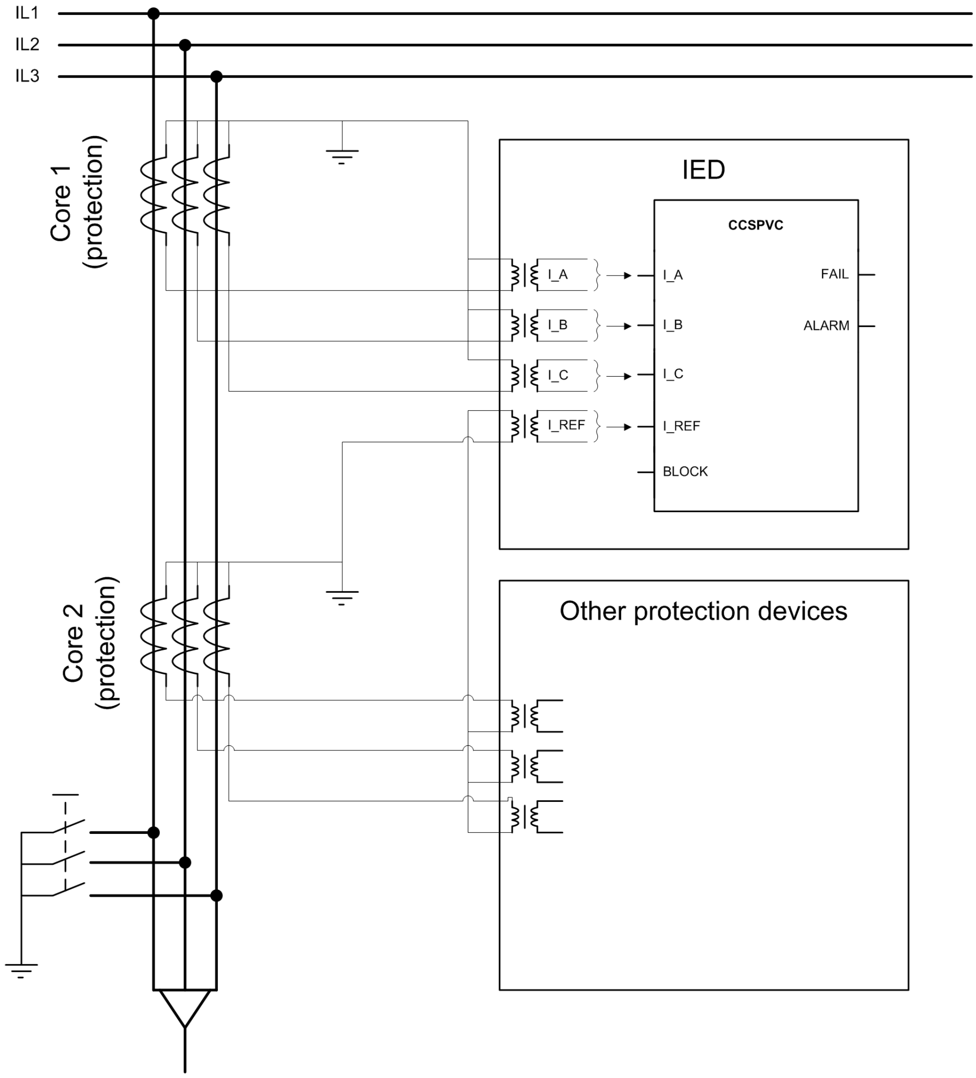


Figure 146: Connection diagram for current circuit supervision with two sets of three-phase current transformer protection cores

When using the measurement core for reference current measurement, it should be noted that the saturation level of the measurement core is much lower than with the protection core. This should be taken into account when setting the current circuit supervision function.

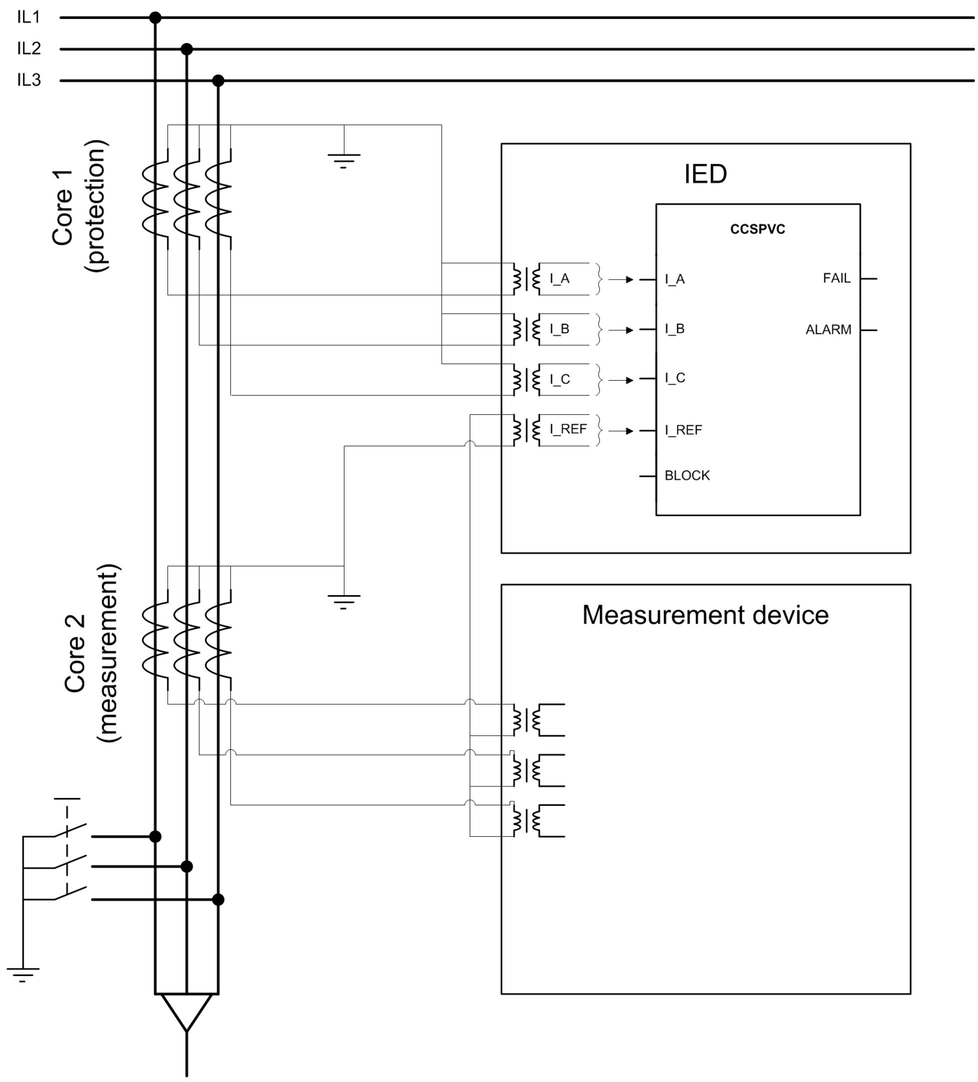


Figure 147: Connection diagram for current circuit supervision with two sets of three-phase current transformer cores (protection and measurement)

Example of incorrect connection

The currents must be measured with two independent cores, that is, the phase currents must be measured with a different core than the reference current. A connection diagram shows an example of a case where the phase currents and the reference currents are measured from the same core.

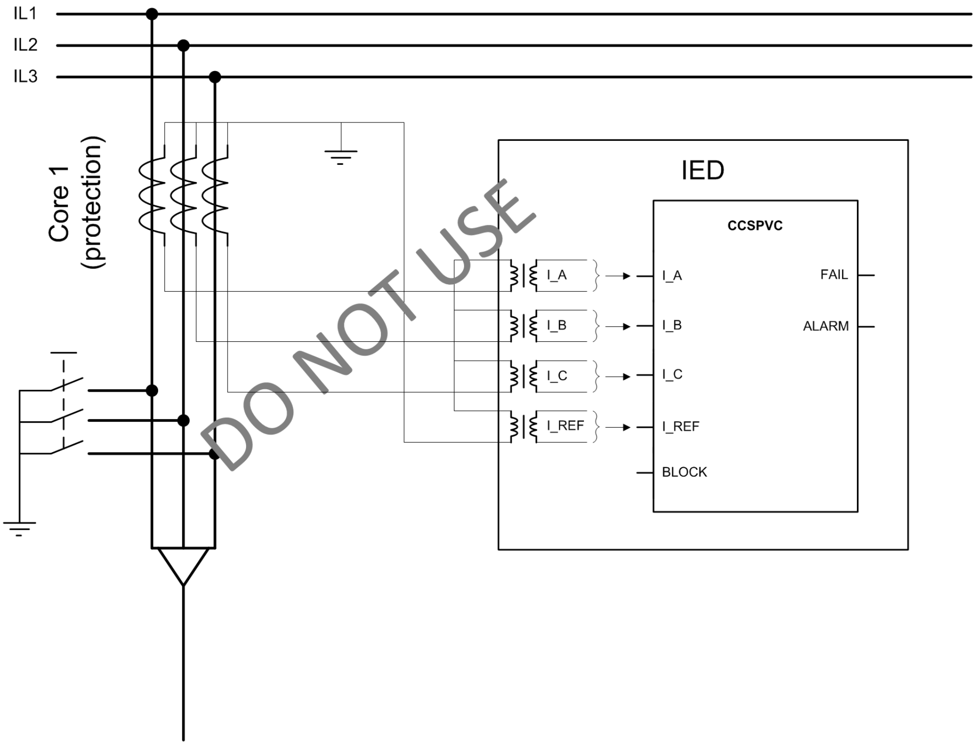


Figure 148: Example of incorrect reference current connection

6.2.7 Signals

Table 350: CCSPVC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
IRES	SIGNAL	-	Residual current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 351: CCSPVC Output signals

Name	Type	Description
FAIL	BOOLEAN	Fail output
ALARM	BOOLEAN	Alarm output

6.2.8 Settings

Table 352: CCSPVC Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Start value	0.05...0.20	xIn	0.01	0.05	Minimum operate current differential level
Operation	1=on 5=off			1=on	Operation On / Off

Table 353: CCSPVC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Max operate current	1.00...5.00	xIn	0.01	1.50	Block of the function at high phase current

6.2.9 Monitored data

Table 354: CCSPVC Monitored data

Name	Type	Values (Range)	Unit	Description
IDIFF	FLOAT32	0.00...40.00	xIn	Differential current
CCSPVC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.2.10 Technical data

Table 355: CCSPVC Technical data

Characteristic	Value
Operate time [1)]	<30 ms

1) Including the delay of the output contact

6.3 Fuse failure supervision SEQSPVC (ANSI VCM, 60)

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fuse failure supervision	SEQSPVC	FUSEF	VCM, 60

6.3.2 Function block

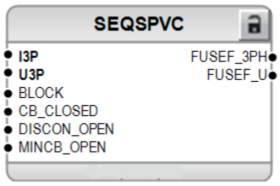


Figure 149: Function block

6.3.3 Functionality

The fuse failure supervision function SEQSPVC is used to block the voltage-measuring functions when failure occurs in the secondary circuits between the voltage transformer (or combi sensor or voltage sensor) and protection relay to avoid misoperations of the voltage protection functions.

SEQSPVC has two algorithms, a negative sequence-based algorithm and a 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 Analog channel configuration

SEQSPVC has two analog group inputs which all must be properly configured.

Table 356: Analog inputs

Input	Description
I3P	Three-phase currents
U3P	Three-phase voltages

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 357: Special conditions

Condition	Description
U3P connected to real measurements	The function can work with any two voltage channels connected but it is recommended to connect all three voltage channels.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

6.3.5 Operation principle

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

The operation of SEQSPVC can be described with a module diagram. All the modules in the diagram are explained in the next sections.

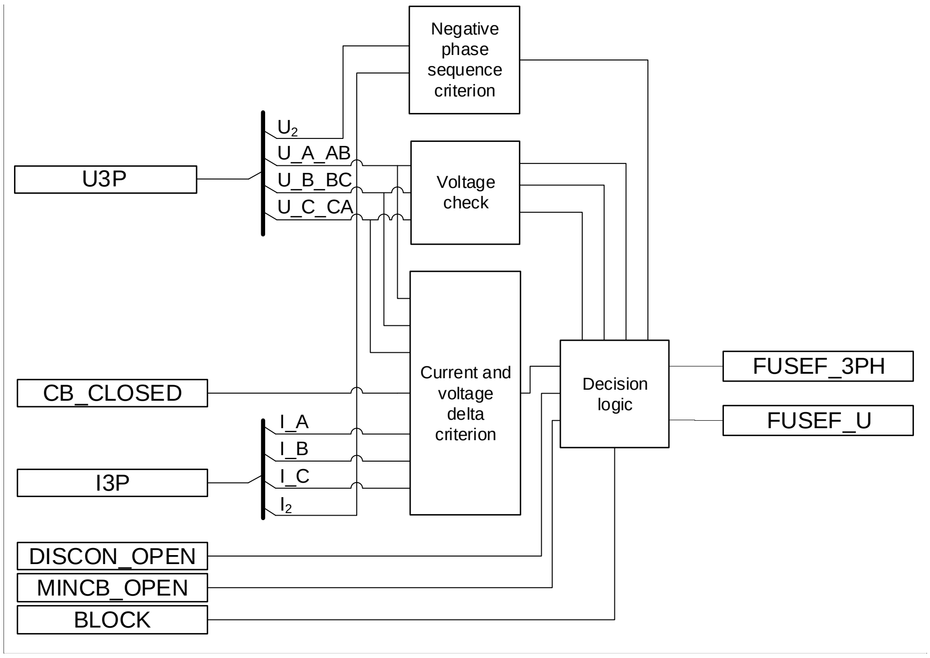


Figure 150: Functional module diagram

Negative phase-sequence criterion

A fuse failure based on the negative-sequence criterion is detected if the measured negative-sequence voltage exceeds the set *Neg Seq voltage Lev* value and the measured negative-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. If 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 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 dU/dt exceeds the corresponding value of the *Voltage change rate* setting and magnitude of dI/dt is below the value of the *Current change rate* setting in any phase at the same time due to the closure of the circuit breaker (`CB_CLOSED` = TRUE).
- The magnitude of dU/dt exceeds the value of the *Voltage change rate* setting and the magnitude of dI/dt is below the *Current change rate* setting in any phase at the same time and the magnitude of the phase current in the same phase exceeds the *Min Op current delta* 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 SEQSPVC with an open breaker. If this is considered to be an important disadvantage, the `CB_CLOSED` input is to be connected to FALSE. In this way only the second criterion can activate the delta function.

The second condition requires the delta criterion to be fulfilled in one phase together with a 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

If voltages are Wye-connected, it is recommended to scale the default values of voltage-based settings with 1/sqrt(3) because the default setting values apply for Delta-connected settings.

The fuse failure detection outputs FUSEF_U and FUSEF_3PH are controlled according to the detection criteria or external signals.

Table 358: Fuse failure output control

Fuse failure detection criterion	Conditions and function response
Negative-sequence criterion	If a fuse failure is detected based on the negative 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 "True", the function activates the FUSEF_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 "True", the function activates the FUSEF_3PH output signal.
External fuse failure detection	The MINCB_OPEN input signal is supposed to be connected through a protection relay 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 a protection relay 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 "True". 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.

6.3.6 Application

Some protection functions operate on the basis of the measured voltage value in the protection relay point. These functions can fail if there is a fault in the measuring circuits between the voltage transformer (or combi sensor or voltage sensor) and protection relay.

A fault in the voltage-measuring circuit is called 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.

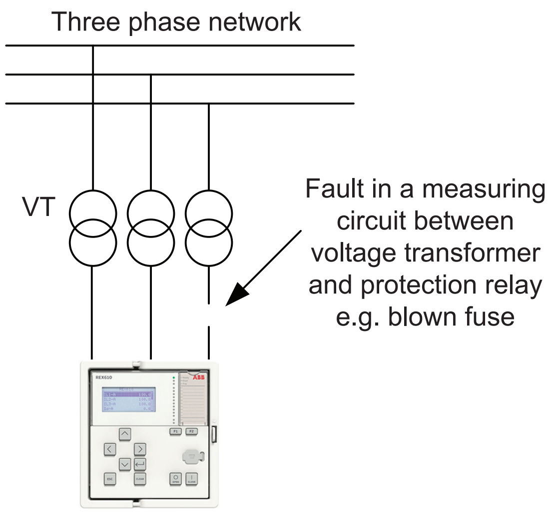


Figure 151: Fault in a circuit from the voltage transformer to the protection relay

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 be intact. 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, SEQSPVC has two outputs for this purpose.

6.3.7 Signals

Table 359: SEQSPVC Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
U3P	SIGNAL	-	Three-phase voltages
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 360: SEQSPVC Output signals

Name	Type	Description
FUSEF_3PH	BOOLEAN	Three-phase start of function
FUSEF_U	BOOLEAN	General start of function

6.3.8 Settings

Table 361: SEQSPVC Non group settings (Basic)

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

Table 362: SEQSPVC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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	0.25...0.90	xUn	0.01	0.40	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	0.50	Minimum operate level of phase voltage for delta calculation
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Min Op current delta	0.01...1.00	xIn	0.01	0.10	Minimum operate level of phase current for delta calculation
Seal in voltage	0.01...1.00	xUn	0.01	0.50	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

6.3.9 Monitored data

Table 363: SEQSPVC Monitored data

Name	Type	Values (Range)	Unit	Description
SEQSPVC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

6.3.10 Technical data

Table 364: SEQSPVC Technical data

Characteristic		Value	
Operate time1)	NPS function	U_{Fault} = 1.1 × set *Neg Seq voltage Lev*	<38 ms
		U_{Fault} = 5.0 × set *Neg Seq voltage Lev*	<24 ms
	Delta function	ΔU = 1.1 × set *Voltage change rate*	<35 ms
		ΔU = 2.0 × set *Voltage change rate*	<28 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

Section 7 Condition monitoring functions

7.1 Circuit-breaker condition monitoring SSCBR (ANSI 52CM)

7.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit-breaker condition monitoring	SSCBR	CBCM	52CM

7.1.2 Function block

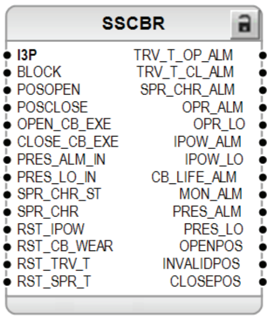


Figure 152: Function block

7.1.3 Functionality

The circuit-breaker condition monitoring function SSCBR is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. The energy is calculated from the measured input currents as a sum of $I^y t$ values. Alarms are generated when the calculated values exceed the threshold settings.

The function contains a blocking functionality which can be used to block the function outputs.

7.1.4 Analog input configuration

SSCBR has one analog group input which must be properly configured.

Table 365: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

7.1.5 Operation principle

The circuit-breaker condition monitoring function includes different metering and monitoring subfunctions. The functions can be enabled and disabled with the *Operation* setting. The corresponding parameter values are “On” and “Off”. The operation counters are cleared when *Operation* is set to “Off”.

The operation of SSCBR can be described with a module diagram. All the modules in the diagram are explained in the next sections.

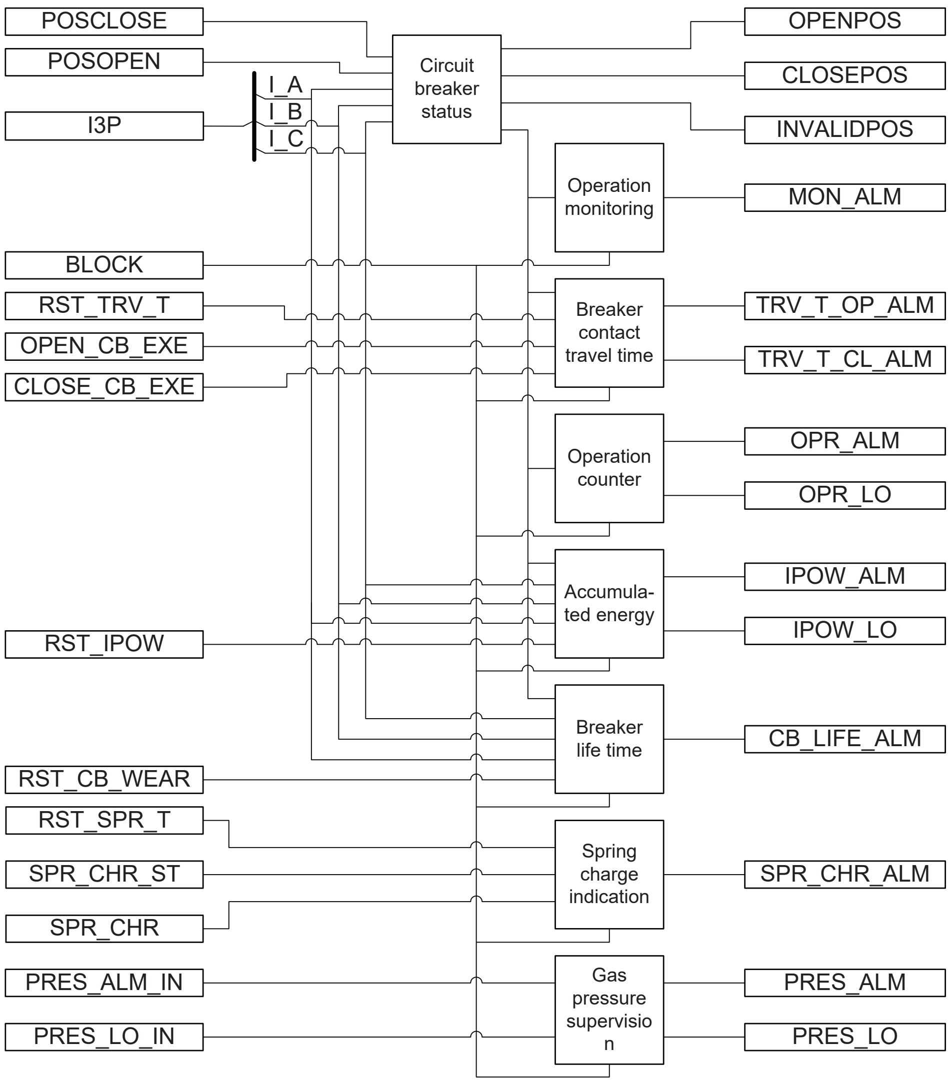


Figure 153: Functional module diagram

Some of the operation features, Circuit breaker operation monitoring, Breaker contact travel time, Remaining life of circuit breaker, are related to time and require time synchronization. If time synchronization is not working, these operation features may not work correctly. For more information, see Time master supervision GNRLLTMS.

7.1.5.1 Circuit breaker status

The Circuit breaker status subfunction monitors the position of the circuit breaker, that is, whether the breaker is in open, closed or invalid position. The operation of the breaker status monitoring can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

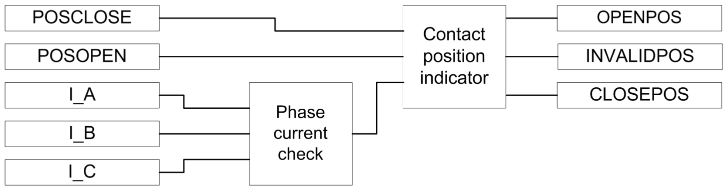


Figure 154: Functional module diagram for monitoring circuit breaker status

Phase current check

This module compares the three phase currents to the setting *Acc stop current*. If the current in a phase exceeds the set level, information about the phase is reported to the contact position indicator module.

Contact position indicator

The OPENPOS output is activated when the auxiliary input contact POSCLOSE is FALSE, the POSOPEN input is TRUE and all the phase currents are below the setting *Acc stop current*.

The CLOSEPOS output is activated when the auxiliary POSOPEN input is FALSE and the POSCLOSE input is TRUE.

The INVALIDPOS output is activated when both the auxiliary contacts have the same value, that is, both are in the same logical level, or if the auxiliary input contact POSCLOSE is FALSE and the POSOPEN input is TRUE and any of the phase currents exceed the setting *Acc stop current*.

The status of the breaker is indicated by the binary outputs OPENPOS, INVALIDPOS and CLOSEPOS for open, invalid and closed position respectively.

7.1.5.2 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.

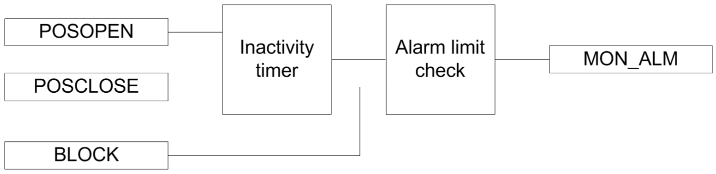


Figure 155: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

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 is 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

When the inactive days exceed the limit value defined with the *Inactive Alm days* setting, the MON_ALM alarm is initiated. The time in hours at which this alarm is activated can be set with the *Inactive Alm hours* parameter as coordinates of UTC. The alarm signal MON_ALM can be blocked by activating the binary input BLOCK.

7.1.5.3 Breaker contact travel time

The Breaker contact travel time module calculates the breaker contact travel time for the closing and opening operation. 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.

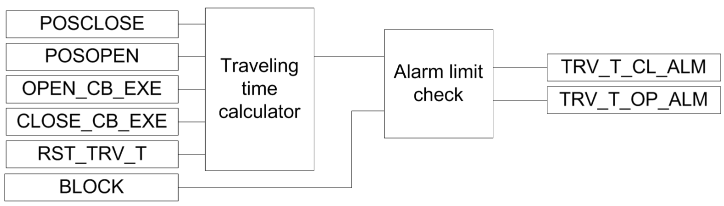


Figure 156: Functional module diagram for breaker contact travel time

Traveling time calculator

The travel time can be calculated using two different methods based on the setting *Travel time Clc mode*.

When the setting *Travel time Clc mode* is “From Pos to Pos”, the contact travel time of the breaker is calculated from the time between auxiliary contacts' state change. The opening travel time is measured between the opening of the

POSCLOSE auxiliary contact and the closing of the POSOPEN auxiliary contact. The travel time is also measured between the opening of the POSOPEN auxiliary contact and the closing of the POSCLOSE auxiliary contact.

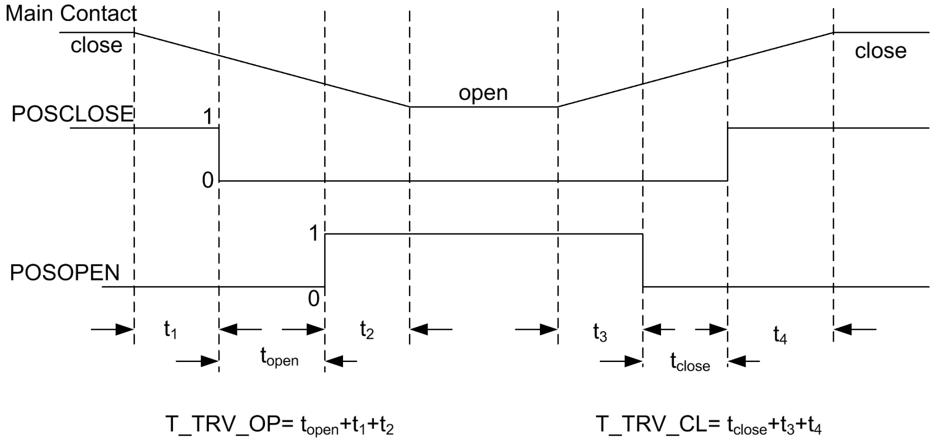


Figure 157: Travel time calculation when Travel time Clc mode is “From Pos to Pos”

There is a time difference t_1 between the start of the main contact opening and the opening of the POSCLOSE auxiliary contact. Similarly, there is a time gap t_2 between the time when the POSOPEN auxiliary contact opens and the main contact is completely open. To incorporate the time $t_1 + t_2$, a correction factor needs to be added with t_{open} to get the actual opening time. This factor is added with the *Opening time Cor* (= $t_1 + t_2$) setting. The closing time is calculated by adding the value set with the *Closing time Cor* ($t_3 + t_4$) setting to the measured closing time.

When the setting *Travel time Clc mode* is “From Cmd to Pos”, the contact travel time of the breaker is calculated from the time between the circuit breaker opening or closing command and the auxiliary contacts’ state change. The opening travel time is measured between the rising edge of the OPEN_CB_EXE command and the POSOPEN auxiliary contact. The closing travel time is measured between the rising edge of the CLOSE_CB_EXEC command and the POSCLOSE auxiliary contact.

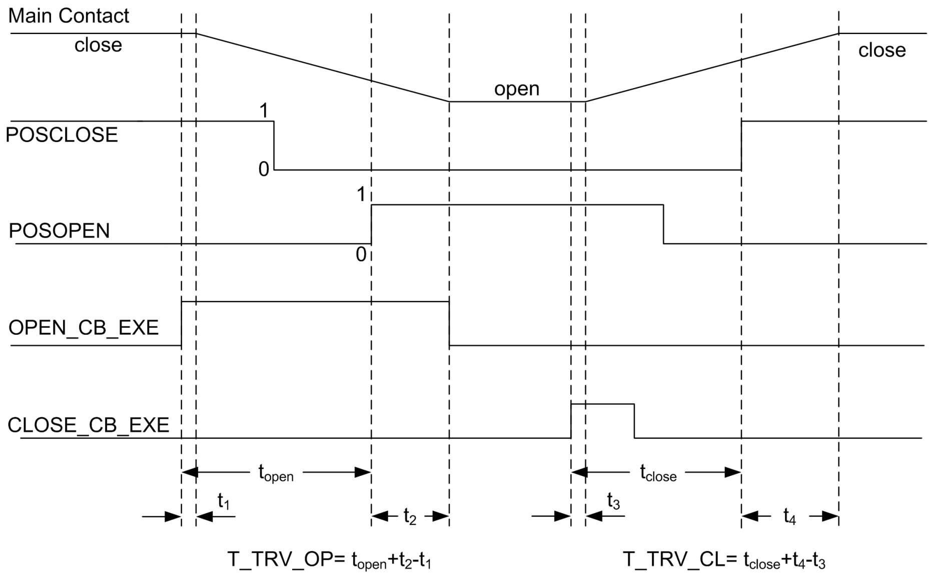


Figure 158: Travel time calculation when Travel time Clc mode is "From Cmd to Pos"

There is a time difference t_1 between the start of the main contact opening and the OPEN_CB_EXE command. Similarly, there is a time gap t_2 between the time when the POSOPEN auxiliary contact opens and the main contact is completely open. Therefore, to incorporate the times t_1 and t_2, a correction factor needs to be added with t_{open} to get the actual opening time. This factor is added with the *Opening time Cor* (= t_2 - t_1) setting. The closing time is calculated by adding the value set with the *Closing time Cor* (t_4 - t_3) setting to the measured closing time.

The last measured opening travel time T_TRV_OP and the closing travel time T_TRV_CL are available in the monitored data view on the LHMI or through tools via communications.

Alarm limit check

When the measured opening travel time is longer than the value set with the *Open alarm time* setting, the TRV_T_OP_ALM output is activated. Respectively, when the measured closing travel time is longer than the value set with the *Close alarm time* setting, the TRV_T_CL_ALM output is activated.

It is also possible to block the TRV_T_CL_ALM and TRV_T_OP_ALM alarm signals by activating the BLOCK input.

7.1.5.4 Operation counter

The operation counter subfunction calculates the number of breaker operation cycles. The opening and closing operations are both included in one operation cycle. The operation counter value is updated after each opening operation.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

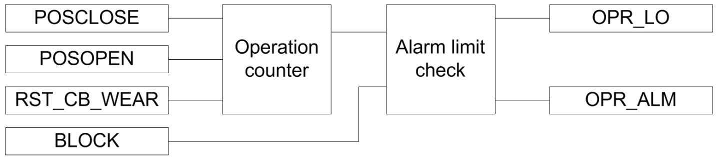


Figure 159: Functional module diagram for counting circuit breaker operations

Operation counter

The operation counter counts the number of operations based on the state change of the binary auxiliary contacts 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 *SSCBR1 rem.life* in the Clear menu from 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.

7.1.5.5 Accumulation of $I^y t$

Accumulation of the $I^y t$ module calculates the accumulated energy.

The operation of the module can be described with a module diagram. All the modules in the diagram are explained in the next sections.

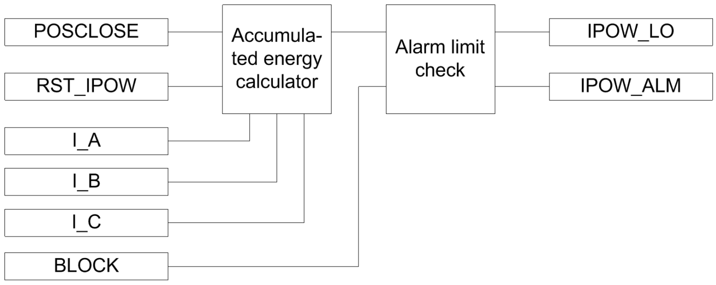


Figure 160: Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

This module calculates the accumulated energy $I^y t$ [$(kA)^y s$]. The factor y is set with the *Current exponent* setting.

The calculation is initiated with the `POSCLOSE` input opening events. It ends when the RMS current becomes lower than the *Acc stop current* setting value.

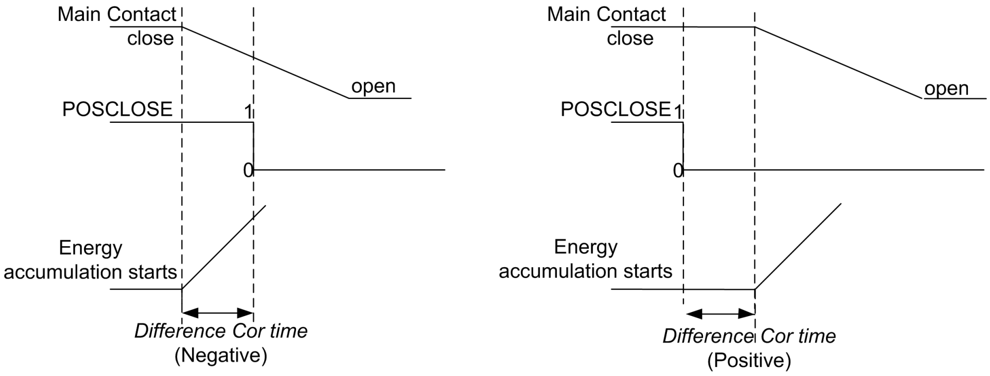


Figure 161: Significance of the Difference Cor time setting

The *Difference Cor time* setting is used instead of the auxiliary contact to accumulate the energy from the time the main contact opens. If the setting is positive, the calculation of energy starts after the auxiliary contact has opened and when the delay is equal to the value set with the *Difference Cor time* setting. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

The accumulated energy outputs `IPOW_A (_B, _C)` are available in the monitored data view on the LHMI or through tools via communications. The values can be reset by setting the parameter *SSCBR1 acc.energy* setting to true in the Clear menu from LHMI.

Alarm limit check

The `IPOW_ALM` alarm is activated when the accumulated energy exceeds the value set with the *Alm Acc currents Pwr* threshold setting. However, when the energy exceeds the limit value set with the *LO Acc currents Pwr* threshold setting, the `IPOW_LO` output is activated.

The `IPOW_ALM` and `IPOW_LO` outputs can be blocked by activating the binary input `BLOCK`.

7.1.5.6 Remaining life of circuit breaker

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. The remaining life is decremented at least with one when the circuit breaker is opened.

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.

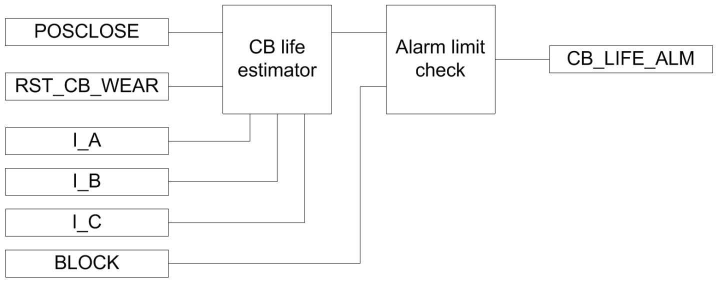


Figure 162: Functional module diagram for estimating the life of the circuit breaker

CB life estimator

CB life estimator module calculates the remaining life of the circuit breaker. The *Op number rated* and *Op number fault* parameters set the number of operations the breaker can perform at the rated current and at the rated fault current. If the tripping current is lower than the rated operating current set with the *Rated Op current* setting, the remaining operation of the breaker reduces by one operation. If the tripping current is higher than the rated fault current set with the *Rated fault current* setting, the remaining operation of the breaker reduces by *Op number rated* divided by *Op number fault*. The remaining life reduction of the tripping current in between these two values is calculated based on the trip curve given by the manufacturer.

$$Directional\ Coef = \frac{\log\left(\frac{Op\ number\ fault}{Op\ number\ rated}\right)}{\log\left(\frac{Rated\ fault\ current}{Rated\ Op\ current}\right)}$$

(Equation 29)

$$\text{Remaining life reduction} = \left(\frac{I_{fault}}{\text{Rated Op current}} \right)^{-\text{Directional Coef}}$$

(Equation 30)

The remaining life is calculated separately for all three phases and it is available as a monitored data value CB_LIFE_A (_B,_C). The values can be cleared by setting the parameter *SSCBR1 rem.life* in the Clear menu from LHMI.

Clearing *SSCBR1 rem.life* 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 *Initial CB Rmn life* parameter and resetting the value via the Clear menu from LHMI.

7.1.5.7 Circuit breaker spring-charged indication

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.

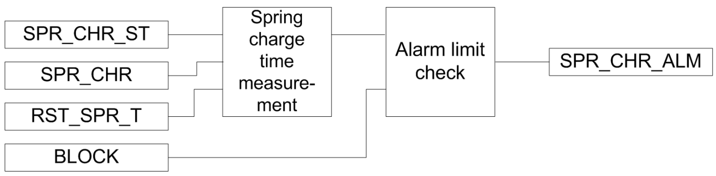


Figure 163: Functional module diagram for circuit breaker spring-charged indication and alarm

Spring charge time measurement

Two binary inputs, SPR_CHR_ST and SPR_CHR, indicate spring charging started and spring charged, respectively. The spring-charging time is calculated from the difference of these two signal timings.

The spring charging time T_SPR_CHR is available in the monitored data view on the LHMI or through tools via communications.

Alarm limit check

If the time taken by the spring to charge is more than the value set with the *Spring charge time* setting, the subfunction generates the SPR_CHR_ALM alarm.

It is possible to block the SPR_CHR_ALM alarm signal by activating the BLOCK binary input.

7.1.5.8 Gas pressure supervision

The gas pressure supervision subfunction monitors the gas pressure inside the arc chamber.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.

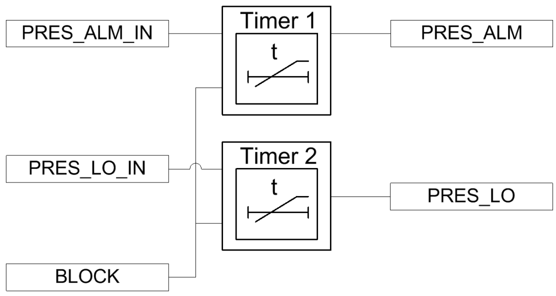


Figure 164: Functional module diagram for circuit breaker gas pressure alarm

The gas pressure is monitored through the binary input signals PRES_LO_IN and PRES_ALM_IN.

Timer 1

When the PRES_ALM_IN binary input is activated, the PRES_ALM alarm is activated after a time delay set with the *Pressure alarm time* setting. The PRES_ALM alarm can be blocked by activating the BLOCK input.

Timer 2

If the pressure drops further to a very low level, the PRES_LO_IN binary input becomes high, activating the lockout alarm PRES_LO after a time delay set with the *Pres lockout time* setting. The PRES_LO alarm can be blocked by activating the BLOCK input.

7.1.6 Application

SSCBR includes different metering 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. The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.

Breaker contact travel time

High traveling times indicate the need for the maintenance of the circuit breaker mechanism. Therefore, detecting excessive traveling 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 contact's and the auxiliary contact's position change.

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.

Accumulation of I^yt

Accumulation of I^yt calculates the accumulated energy ΣI^yt, where the factor y is known as the current exponent. The factor y depends on the type of the circuit breaker. For oil circuit breakers, the factor y is normally 2. In case of a high-voltage system, the factor y can be 1.4...1.5.

Remaining life of the breaker

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 for estimating the remaining life of a circuit breaker

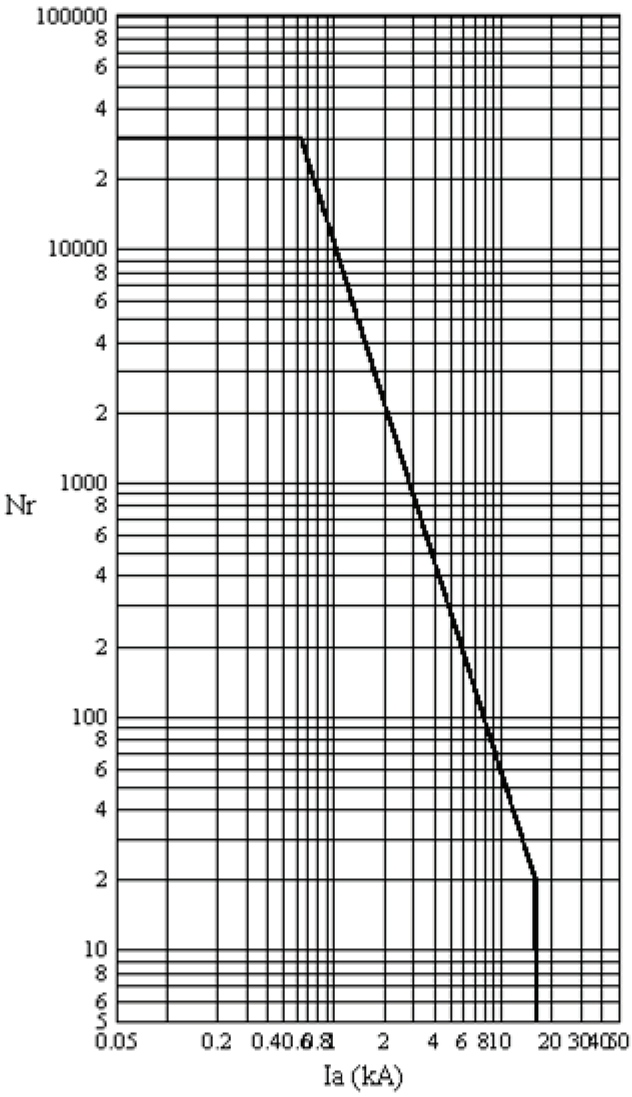


Figure 165: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

Nr	the number of closing-opening operations allowed for the circuit breaker
Ia	the current at the time of tripping of the circuit breaker

Calculation for estimating the remaining life

Figure 165 shows that there are 30,000 possible operations at the rated operating current of 630 A and 20 operations at the rated fault current 16 kA. Therefore, if the tripping current is 10 kA, one operation at 10 kA is equivalent to 30,000/60=500 operations at the rated current. It is also assumed that prior to this tripping, the remaining life of the circuit breaker is 15,000 operations. Therefore, after one operation of 10 kA, the remaining life of the circuit breaker is 15,000-500=14,500 at the rated operating current.

Spring-charged 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.

Gas pressure supervision

The gas pressure supervision monitors the gas pressure inside the arc chamber. When the pressure becomes too low compared to the required value, the circuit breaker operations are locked. A binary input is available based on the pressure levels in the function, and alarms are generated based on these inputs.

7.1.7 Signals

Table 366: SSCBR Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block input status
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for closeposition of apparatus from I/O
OPEN_CB_EXE	BOOLEAN	0=False	Signal for open command to coil
CLOSE_CB_EXE	BOOLEAN	0=False	Signal for close command to coil
PRES_ALM_IN	BOOLEAN	0=False	Binary pressure alarm input
PRES_LO_IN	BOOLEAN	0=False	Binary pressure input for lockout indication
SPR_CHR_ST	BOOLEAN	0=False	CB spring charging started input
SPR_CHR	BOOLEAN	0=False	CB spring charged input
RST_IPOW	BOOLEAN	0=False	Reset accumulation energy
RST_CB_WEAR	BOOLEAN	0=False	Reset input for CB remaining life and operation counter
RST_TRV_T	BOOLEAN	0=False	Reset input for CB closing and opening travel times
RST_SPR_T	BOOLEAN	0=False	Reset input for the charging time of the CB spring

Table 367: SSCBR Output signals

Name	Type	Description
TRV_T_OP_ALM	BOOLEAN	CB open travel time exceeded set value
TRV_T_CL_ALM	BOOLEAN	CB close travel time exceeded set value
SPR_CHR_ALM	BOOLEAN	Spring charging time has crossed the set value
OPR_ALM	BOOLEAN	Number of CB operations exceeds alarm limit
OPR_LO	BOOLEAN	Number of CB operations exceeds lockout limit
IPOW_ALM	BOOLEAN	Accumulated currents power (Iyt),exceeded alarm limit

Table continues on next page

Name	Type	Description
IPOW_LO	BOOLEAN	Accumulated currents power (Iyt),exceeded lockout limit
CB_LIFE_ALM	BOOLEAN	Remaining life of CB exceeded alarm limit
MON_ALM	BOOLEAN	CB 'not operated for long time' alarm
PRES_ALM	BOOLEAN	Pressure below alarm level
PRES_LO	BOOLEAN	Pressure below lockout level
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

7.1.8 Settings

Table 368: SSCBR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Operation Off / On
Open alarm time	0...200	ms	1	40	Alarm level setting for open travel time in ms
Close alarm time	0...200	ms	1	40	Alarm level Setting for close travel time in ms
Alarm Op number	0...99999		1	200	Alarm limit for number of operations
Lockout Op number	0...99999		1	300	Lock out limit for number of operations
Current exponent	0.00...2.00		0.01	2.00	Current exponent setting for energy calculation
Alm Acc currents Pwr	0.00...20000.00		0.01	2500.00	Setting of alarm level for accumulated currents power
Spring charge time	0...60000	ms	10	15000	Setting of alarm for spring charging time of CB in ms
Difference Cor time	-10...10	ms	1	5	Corr. factor for time dif in aux. and main contacts open time
Acc stop current	5.00...500.00	A	0.01	10.00	RMS current setting below which engy acm stops
LO Acc currents Pwr	0.00...20000.00		0.01	2500.00	Lockout limit setting for accumulated currents power
Op number rated	1...99999		1	10000	Number of operations possible at rated current
Rated Op current	100.00...5000.00	A	0.01	1000.00	Rated operating current of the breaker
Rated fault current	500.00...75000.00	A	0.01	5000.00	Rated fault current of the breaker
Directional Coef	-3.00...-0.50		0.01	-1.50	Directional coefficient for CB life calculation
Op number fault	1...10000		1	1000	Number of operations possible at rated fault current

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Inactive Alm days	0...9999		1	2000	Alarm limit value of the inactive days counter
Initial CB Rmn life	0...99999		1	5000	Initial value for the CB remaining life
Travel time Clc mode	1=From Cmd to Pos 2=From Pos to Pos			2=From Pos to Pos	Travel time calculation mode selection

Table 369: SSCBR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Opening time Cor	-100...100	ms	1	10	Correction factor for open travel time in ms
Closing time Cor	-100...100	ms	1	10	Correction factor for CB close travel time in ms
Pressure alarm time	0...60000	ms	1	10	Time delay for gas pressure alarm in ms
Life alarm level	0...99999		1	500	Alarm level for CB remaining life
Pres lockout time	0...60000	ms	10	10	Time delay for gas pressure lockout in ms
Counter initial Val	0...99999		1	0	The operation numbers counter initialization value
Ini inactive days	0...9999		1	0	Initial value of the inactive days counter
Inactive Alm hours	0...23	h	1	0	Alarm time of the inactive days counter in hours
Ini Acc currents Pwr	0.00...20000.00		0.01	0.00	Initial value for accumulation energy (Iyt)

7.1.9 Monitored data

Table 370: SSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
T_TRV_OP	FLOAT32	0...60000	ms	Travel time of the CB during opening operation
T_TRV_CL	FLOAT32	0...60000	ms	Travel time of the CB during closing operation
T_SPR_CHR	FLOAT32	0.00...99.99	s	The charging time of the CB spring
NO_OPR	INT32	0...99999		Number of CB operation cycle
INA_DAYS	INT32	0...9999		The number of days CB has been inactive
CB_LIFE_A	INT32	-99999...99999		CB Remaining life phase A
CB_LIFE_B	INT32	-99999...99999		CB Remaining life phase B
CB_LIFE_C	INT32	-99999...99999		CB Remaining life phase C
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
IPOW_A	FLOAT32	0.000...30000.000		Accumulated currents power (Iyt), phase A
IPOW_B	FLOAT32	0.000...30000.000		Accumulated currents power (Iyt), phase B
IPOW_C	FLOAT32	0.000...30000.000		Accumulated currents power (Iyt), phase C
SSCBR1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

7.1.10 Technical data

Table 371: SSCBR Technical data

Characteristic	Value
Current measuring accuracy	±1.5% or ±0.002 × I_n (at currents in the range of 0.1…10 × I_n) ±5.0% (at currents in the range of 10…40 × I_n)
Operate time accuracy	±1.0% of the set value or ±40 ms
Travelling time measurement	±11 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 function CSMSQI is used for monitoring and metering the phase sequence currents.

The information of the measured quantity is available for the operator both locally in LHMI and remotely to a network control center with communication.

If the measured data in LHMI is within parentheses, there are some problems to express the data.

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 *Measurement mode* setting. Depending on the measuring function, if the measurement mode cannot be selected, the measuring mode is "DFT".

Value reporting

The measurement functions are capable of reporting new values for network control center (SCADA system) based on various 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 with the phase-to-phase voltages.

GOOSE is an event based protocol service. Analog GOOSE uses the same event generation functions as vertical SCADA communication for updating the measurement values.

Zero-point clamping

A measured value under the 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 the zero-clamping limit, new values are reported.

Table 372: 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)
Sequence current measurement (CSMSQI)	1% of the nominal (In)

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.

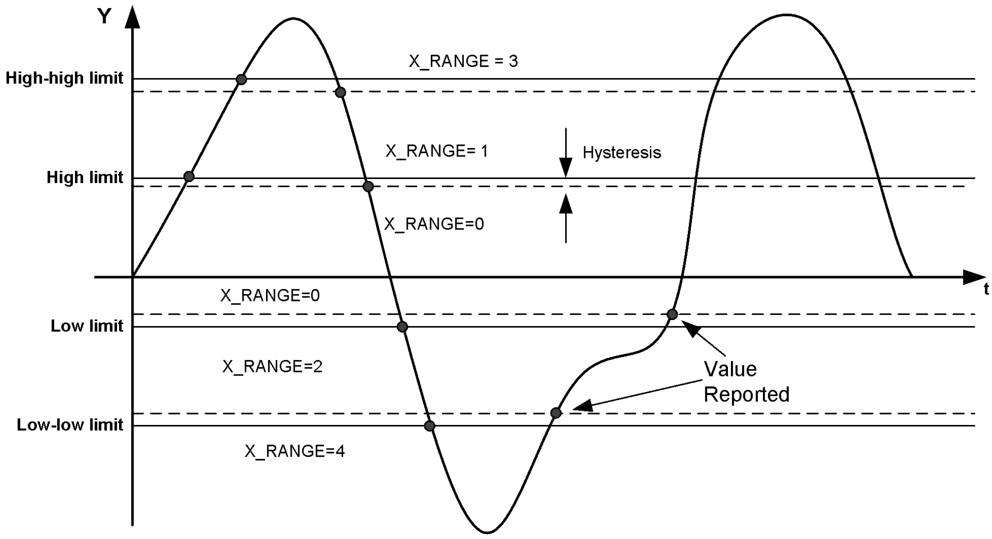


Figure 166: Presentation of operating limits

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.

Table 373: 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	-

Table continues on next page

Function	Settings for limit value supervision	
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

Deadband supervision

The deadband supervision function reports the measured value according to integrated changes over a time period. In Figure 167 the values are reported at points Y1, Y2, Y3 and Y4. There is no value report at the end of |A3 + A4 + A5 + A6 + A7| because the positive and negative areas counteract each other. The integrated changes, |A3 + A4 + A5 + A6 + A7|, equal approximately zero.

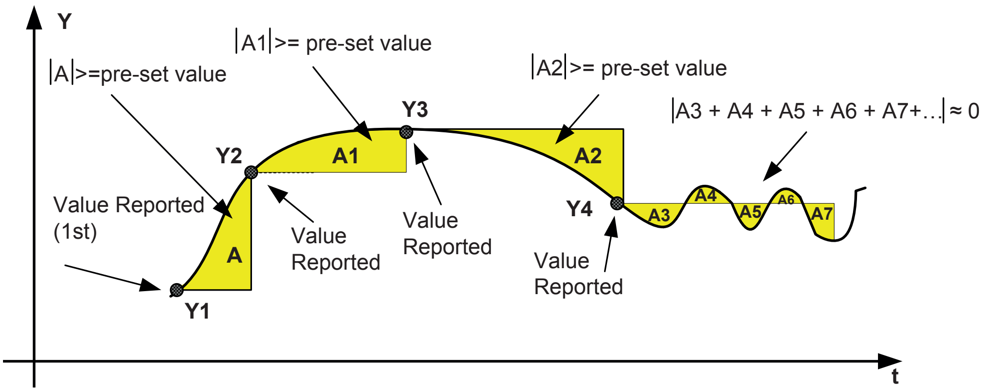


Figure 167: Integral deadband supervision

The deadband value used in the integral calculation is configured with the deadband setting. The value represents the percentage of the difference between the maximum and minimum limit in the units of 0.001 percent x 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 31)

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 374: 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)
Sequence current measurement (CSMSQI)	Ps Seq A deadband, Ng Seq A deadband, Zro A deadband	40/0 (=40xIn)

Sequence components

The phase-sequence components are calculated using the phase currents and phase voltages. More information on calculating the phase-sequence components can be found in Calculated measurements in this manual.

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 currents, voltages 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 protection relays 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 protection relay analog measurement chain can be verified during normal service by a periodic comparison of the measured value from the protection relay 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 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 to keep the communication load to a minimum and yet measurement values are reported frequently enough.

8.1.4 Three-phase current measurement CMMXU (ANSI IA, IB, IC)

8.1.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase current measurement	CMMXU	3I	IA, IB, IC

8.1.4.2 Function block

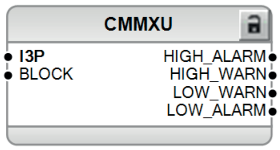


Figure 168: Function block

8.1.4.3 Functionality

The three-phase current measurement function CMMXU provides limit value supervision output (`HIGH_ALARM`, `HIGH_WARN`, `LOW_WARN`, `LOW_ALARM`). The delay of the activation and deactivation of these outputs can be controlled with setting parameters *On delay time* and *Off delay time*.

8.1.4.4 Analog channel configuration

CMMXU has one analog group input which must be properly configured.

Table 375: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

8.1.4.5 Signals

Table 376: CMMXU Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 377: 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

8.1.4.6 Settings

Table 378: CMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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
A high high limit	0.00...40.00	xIn	0.01	1.40	High alarm current limit
A high limit	0.00...40.00	xIn	0.01	1.20	High warning current limit
A low limit	0.00...40.00	xIn	0.01	0.00	Low warning current limit
A low low limit	0.00...40.00	xIn	0.01	0.00	Low alarm current limit
A deadband	100...100000		1	2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)
Operation	1=on 5=off			1=on	Operation Off / On

Table 379: CMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
On delay time	0...1800000	ms	100	0	Delay the activation of the alarm and warning outputs
Off delay time	0...1800000	ms	100	0	Delay the deactivation of the alarm and warning outputs

8.1.4.7 Monitored data

Table 380: CMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
I_INST_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of instantaneous value
I_INST_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of instantaneous value
I_INST_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of instantaneous value
I_DB_A	FLOAT32	0.00...40.00	xIn	IL1 Amplitude, magnitude of reported value
I_RANGE_A	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL1 Amplitude range
I_DB_B	FLOAT32	0.00...40.00	xIn	IL2 Amplitude, magnitude of reported value
I_RANGE_B	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL2 Amplitude range
I_DB_C	FLOAT32	0.00...40.00	xIn	IL3 Amplitude, magnitude of reported value
I_RANGE_C	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		IL3 Amplitude range
I_ANGL_A	FLOAT32	-180.00...180.00	deg	IL1 current angle
I_ANGL_B	FLOAT32	-180.00...180.00	deg	IL2 current angle
I_ANGL_C	FLOAT32	-180.00...180.00	deg	IL3 current angle

8.1.4.8 Technical data

Table 381: CMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±0.6% or ±0.002 × I_n (at currents in the range of 0.01...4.00 × I_n)
Suppression of harmonics	DFT: -50 dB at f = n × f_n , where n = 2, 3, 4, 5,… RMS: No suppression

8.1.5 Three-phase voltage measurement VMMXU (ANSI VA, VB, VC)

8.1.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Three-phase voltage measurement	VMMXU	3U	VA, VB, VC

8.1.5.2 Function block

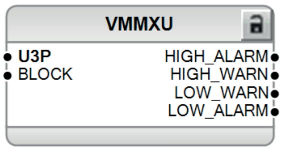


Figure 169: Function block

8.1.5.3 Functionality

The three-phase voltage measurement function VMMXU provides limit value supervision output (HIGH_ALARM, HIGH_WARN, LOW_WARN, LOW_ALARM). Setting parameters *On delay time* and *Off delay time* are used for controlling the activation and the deactivation of alarm and warning outputs.

8.1.5.4 Analog channel configuration

VMMXU has one analog group input which must be properly configured.

Table 382: Analog inputs

Input	Description
U3P	Three-phase voltages

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 383: Special conditions

Condition	Description
U3P connected to real measurements	The function requires that at least one voltage channel is connected if *Num of start phases* is set to "1 out of 3".
	The function requires that at least two voltage channels are connected if *Num of start phases* is set to "2 out of 3".
	The function requires that all three voltage channels are connected if *Num of start phases* is set to "3 out of 3".

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

8.1.5.5 Signals

Table 384: VMMXU Input signals

Name	Type	Default	Description
U3P	SIGNAL	-	Three-phase voltages
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 385: 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

8.1.5.6 Settings

Table 386: VMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
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	0.01	1.40	High alarm voltage limit
V high limit	0.00...4.00	xUn	0.01	1.20	High warning voltage limit
V low limit	0.00...4.00	xUn	0.01	0.00	Low warning voltage limit
V low low limit	0.00...4.00	xUn	0.01	0.00	Low alarm voltage limit
V deadband	100...100000		1	10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)
Operation	1=on 5=off			1=on	Operation Off / On

Table 387: VMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
On delay time	0...1800000	ms	100	0	Delay the activation of the alarm and warning outputs
Off delay time	0...1800000	ms	100	0	Delay the deactivation of the alarm and warning outputs

8.1.5.7 Monitored data

Table 388: VMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
U_INST_AB	FLOAT32	0.00...4.00	xUn	U12 amplitude, magnitude of instantaneous value
U_INST_BC	FLOAT32	0.00...4.00	xUn	U23 amplitude, magnitude of instantaneous value
U_INST_CA	FLOAT32	0.00...4.00	xUn	U31 amplitude, magnitude of instantaneous value
U_INST_A	FLOAT32	0.00...5.00	xUn	UL1 amplitude, magnitude of instantaneous value
U_INST_B	FLOAT32	0.00...5.00	xUn	UL2 amplitude, magnitude of instantaneous value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
U_INST_C	FLOAT32	0.00...5.00	xUn	UL3 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_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_DB_CA	FLOAT32	0.00...4.00	xUn	U31 amplitude, magnitude of reported value
U_RANGE_CA	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		U31 amplitude range
U_ANGL_A	FLOAT32	-180.00...180.00	deg	UL1 angle
U_ANGL_B	FLOAT32	-180.00...180.00	deg	UL2 angle
U_ANGL_C	FLOAT32	-180.00...180.00	deg	UL3 angle
U_ANGL_AB	FLOAT32	-180.00...180.00	deg	U12 angle
U_ANGL_BC	FLOAT32	-180.00...180.00	deg	U23 angle
U_ANGL_CA	FLOAT32	-180.00...180.00	deg	U31 angle

8.1.5.8 Technical data

Table 389: VMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: f_n ±2 Hz at voltages in range 0.01…1.15 × U_n
	±0.6% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.6 Residual current measurement RESCMMXU (ANSI IG)

8.1.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual current measurement	RESCMMXU	Io	IG

8.1.6.2 Function block

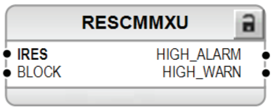


Figure 170: Function block

8.1.6.3 Functionality

The residual current measurement function RESCMMXU provides limit value supervision output (`HIGH_ALARM`, `HIGH_WARN`). Setting parameters *On delay time* and *Off delay time* are used for controlling the activation and, respectively, the deactivation of alarm and warning outputs.

8.1.6.4 Analog channel configuration

RESCMMXU has one analog group input which must be properly configured.

Table 390: Analog inputs

Input	Description
IRES	Residual current (measured or calculated)

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

8.1.6.5 Signals

Table 391: RESCMMXU Input signals

Name	Type	Default	Description
IRES	SIGNAL	-	Residual current
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 392: RESCMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.1.6.6 Settings

Table 393: RESCMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
A Hi high limit res	0.00...40.00	xIn	0.01	0.20	High alarm current limit
A high limit res	0.00...40.00	xIn	0.01	0.05	High warning current limit
A deadband res	100...100000		1	2500	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)
Operation	1=on 5=off			1=on	Operation Off / On

Table 394: RESCMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
On delay time	0...1800000	ms	100	0	Delay the activation of the alarm and warning outputs
Off delay time	0...1800000	ms	100	0	Delay the deactivation of the alarm and warning outputs

8.1.6.7 Monitored data

Table 395: RESCMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
I_INST_RES	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of instantaneous value
I_DB_RES	FLOAT32	0.00...40.00	xIn	Residual current Amplitude, magnitude of reported value
I_RANGE_RES	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual current Amplitude range
I_ANGL_RES	FLOAT32	-180.00...180.00	deg	Residual current angle

8.1.6.8 Technical data

Table 396: RESCMMXU Technical data

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$
	±0.6% or ±0.002 x I_n (at currents in the range of 0.01...4.00 × I_n)
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.7 Residual voltage measurement RESVMMXU (ANSI VG/VN)

8.1.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Residual voltage measurement	RESVMMXU	Uo	VG/VN

8.1.7.2 Function block

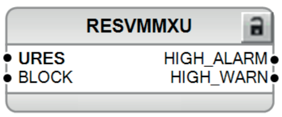


Figure 171: Function block

8.1.7.3 Functionality

The residual voltage measurement function RESVMMXU provides limit value supervision output (HIGH_ALARM, HIGH_WARN). Setting parameters *On delay time* and *Off delay time* are used for controlling the activation and, respectively, the deactivation of alarm and warning outputs.

8.1.7.4 Analog channel configuration

RESVMMXU has one analog group input which must be properly configured.

Table 397: Analog inputs

Input	Description
URES	Residual voltage (measured or calculated)

See the preprocessing function blocks in this document for the possible signal sources.

There are a few special conditions which must be noted with the configuration.

Table 398: Special conditions

Condition	Description
URES calculated	The function requires that all three voltage channels are connected to calculate residual voltage. Setting *VT connection* must be "Wye" in that particular UTVTR.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

8.1.7.5 Signals

Table 399: RESVMMXU Input signals

Name	Type	Default	Description
URES	SIGNAL	-	Residual voltage
BLOCK	BOOLEAN	0=False	Block signal for all binary outputs

Table 400: RESVMMXU Output signals

Name	Type	Description
HIGH_ALARM	BOOLEAN	High alarm
HIGH_WARN	BOOLEAN	High warning

8.1.7.6 Settings

Table 401: RESVMMXU Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
V Hi high limit res	0.00...4.00	xUn	0.01	0.20	High alarm voltage limit
V high limit res	0.00...4.00	xUn	0.01	0.05	High warning voltage limit
V deadband res	100...100000		1	10000	Deadband configuration value for integral calculation. (percentage of difference between min and max as 0,001 % s)
Operation	1=on 5=off			1=on	Operation Off / On

Table 402: RESVMMXU Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Measurement mode	1=RMS 2=DFT			2=DFT	Selects used measurement mode
On delay time	0...1800000	ms	100	0	Delay the activation of the alarm and warning outputs
Off delay time	0...1800000	ms	100	0	Delay the deactivation of the alarm and warning outputs

8.1.7.7 Monitored data

Table 403: RESVMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
U_INST_RES	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of instantaneous value
U_DB_RES	FLOAT32	0.00...4.00	xUn	Residual voltage Amplitude, magnitude of reported value
U_RANGE_RES	Enum	0=normal 1=high 2=low 3=high-high 4=low-low		Residual voltage Amplitude range
U_ANGL_RES	FLOAT32	-180.00...180.00	deg	Residual voltage angle

8.1.7.8 Technical data

Table 404: RESVMMXU Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: $f/f_n = \pm 2$ Hz
	±0.6% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,… RMS: No suppression

8.1.8 Sequence current measurement CSMSQI (ANSI I1, I2, I0)

8.1.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sequence current measurement	CSMSQI	I1, I2, I0	I1, I2, I0

8.1.8.2 Function block

Figure 172: Function block

8.1.8.3 Functionality

The sequence current measurement function CSMSQI provides range outputs (I1_RANGE, I2_RANGE and I0_RANGE) as monitored data.

Instantaneous sequence currents in amperes are available through monitored data I2_INST, I1_INST and I0_INST.

8.1.8.4 Analog channel configuration

CSMSQI has one analog group input which must be properly configured.

Table 405: Analog inputs

Input	Description
I3P	Three-phase currents

See the preprocessing function blocks in this document for the possible signal sources.

Improper analog channel configuration causes a validation error if the analog channels are not completely configured or they do not match with certain settings. For troubleshooting, check the contents of this chapter and also the preprocessing blocks in this document. The configuration can be written to the protection relay once the mismatch is corrected.

8.1.8.5 Signals

Table 406: CSMSQI Input signals

Name	Type	Default	Description
I3P	SIGNAL	-	Three-phase currents

8.1.8.6 Settings

Table 407: CSMSQI Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Ps Seq A Hi high Lim	0.00...40.00	xIn	0.01	1.40	High alarm current limit for positive sequence current
Ps Seq A high limit	0.00...40.00	xIn	0.01	1.20	High warning current limit for positive sequence current
Ps Seq A low limit	0.00...40.00	xIn	0.01	0.00	Low warning current limit for positive sequence current
Ps Seq A low low Lim	0.00...40.00	xIn	0.01	0.00	Low alarm current limit for positive sequence current
Ps Seq A deadband	100...100000		1	2500	Deadband configuration value for positive sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)
Ng Seq A Hi high Lim	0.00...40.00	xIn	0.01	0.20	High alarm current limit for negative sequence current
Ng Seq A High limit	0.00...40.00	xIn	0.01	0.05	High warning current limit for negative sequence current
Ng Seq A low limit	0.00...40.00	xIn	0.01	0.00	Low warning current limit for negative sequence current
Ng Seq A low low Lim	0.00...40.00	xIn	0.01	0.00	Low alarm current limit for negative sequence current
Ng Seq A deadband	100...100000		1	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	0.01	0.20	High alarm current limit for zero sequence current
Zro A High limit	0.00...40.00	xIn	0.01	0.05	High warning current limit for zero sequence current

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Zro A low limit	0.00...40.00	xIn	0.01	0.00	Low warning current limit for zero sequence current
Zro A low low Lim	0.00...40.00	xIn	0.01	0.00	Low alarm current limit for zero sequence current
Zro A deadband	100...100000		1	2500	Deadband configuration value for zero sequence current for integral calculation. (percentage of difference between min and max as 0,001 % s)
Operation	1=on 5=off			1=on	Operation Off / On

8.1.8.7 Monitored data

Table 408: CSMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
I1_INST	FLOAT32	0.00...40.00	xIn	Positive sequence current amplitude, instantaneous value
I2_INST	FLOAT32	0.00...40.00	xIn	Negative sequence current amplitude, instantaneous value
I0_INST	FLOAT32	0.00...40.00	xIn	Zero 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_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_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

Table continues on next page

Name	Type	Values (Range)	Unit	Description
I2_ANGL	FLOAT32	-180.00...180.00	deg	Negative sequence current angle
I1_ANGL	FLOAT32	-180.00...180.00	deg	Positive sequence current angle
I0_ANGL	FLOAT32	-180.00...180.00	deg	Zero sequence current angle

8.1.8.8 Technical data

Table 409: CSMSQI Technical data

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.0% or ±0.002 × I_n at currents in the range of 0.01...4.00 × I_n
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

8.2 Disturbance recorder (common functionality) RDRE (ANSI DFR)

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Disturbance recorder (common functionality)	RDRE	DR	DFR

8.2.2 Function block

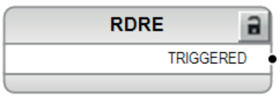


Figure 173: Function block

8.2.3 Functionality

The protection relay is provided with a disturbance recorder featuring up to 8 analog and 32 binary signal channels. The analog channels can be set to record the waveform of the currents and voltages measured and they can 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 either on the rising or the falling edge of the binary signal or on both. By default, the binary channels are set to record external or internal relay signals, for example, the start or trip signals of the relay stages, or external blocking or control signals. Binary relay signals, such as protection start and trip signals, or an external relay control signal via a binary input can be set to trigger the recording. Recorded information is stored in a nonvolatile memory and can be uploaded for subsequent fault analysis.

8.2.3.1 Recorded analog and binary inputs

The relay's analog and binary signals for disturbance recorder can be configured with Application Configuration in PCM600. In addition, each channel of the disturbance recorder can be enabled or disabled by setting the *Operation* parameter of the corresponding channel to "on" or "off".

All channels of the disturbance recorder that are enabled and have a valid signal connected are included in the recording.

8.2.3.2 Triggering alternatives

The recording can be triggered by any of the following alternatives.

- Triggering according to the state change of any of the binary channels of the disturbance recorder. The level sensitivity can be set 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 the Recording started and Recording made events. The Recording made event indicates that the recording has been stored to the nonvolatile 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.

Triggering by binary channels

The input signals for the binary channels of the disturbance recorder can be formed from any of the digital signals. 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, 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 limit values can be set 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. Either high or low analog channel trigger can be disabled by setting the corresponding trigger level parameter to zero.

Manual triggering

The recorder can be triggered manually via the LHMI or via communication by setting the *Trig recording* parameter to "Trig".

Periodic triggering

Periodic triggering means that the recorder automatically makes a recording at certain time intervals. The interval can be adjusted 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 *Periodic trig time* parameter should first be set to zero and then to the new value. The time remaining to the next triggering can be monitored with the Time to trigger monitored data which counts downwards.

8.2.3.3 Length of recordings

The recording length can be defined 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 number of recordings that fit into the available recording memory. This information can be seen with the Rem. amount of rec. monitored data. The fixed memory size allocated to the recorder can fit in 21 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 number of recordings in the memory can be viewed with the Number of recordings monitored data. The 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.

8.2.3.4 Sampling frequencies

The sampling frequency of the disturbance recorder analog channels depends on the set rated frequency. One fundamental cycle always contains the number 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 200 Hz at the rated frequency of 50 Hz and 240 Hz at the rated frequency of 60 Hz.

Table 410: Sampling frequencies of the disturbance recorder analog and binary channels

Storage rate (samples per fundamental cycle)	Recording length	Rated frequency = 50 Hz		Rated frequency = 60 Hz	
		Sampling frequency of analog channels	Sampling frequency of binary channels	Sampling frequency of analog channels	Sampling frequency of binary channels
32	1 · Record length	1600 Hz	200 Hz	1920 Hz	240 Hz
16	2 · Record length	800 Hz	200 Hz	960 Hz	240 Hz
8	4 · Record length	400 Hz	200 Hz	480 Hz	240 Hz

8.2.3.5 Uploading of recordings

The protection relay stores COMTRADE files to the COMTRADE folder. The files can be uploaded with PCM600 or any appropriate computer software that can access the 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.

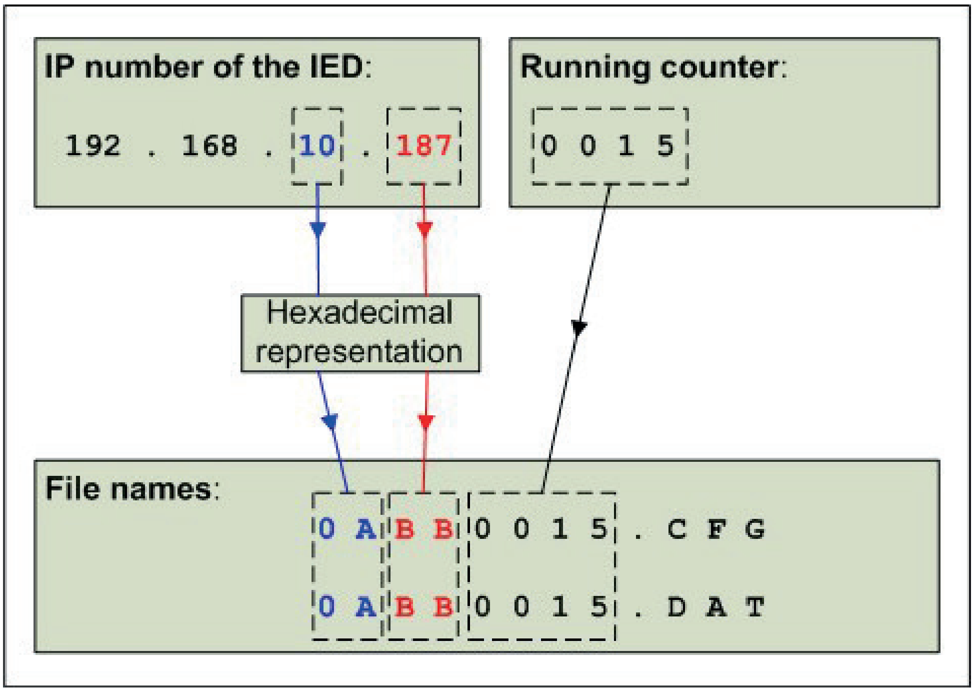


Figure 174: Disturbance recorder file naming

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 protection relay'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.

8.2.3.6 Deletion of recordings

The recordings can be deleted individually or all at once.

Individual disturbance recordings can be deleted with PCM600 or any appropriate computer software, which can access the protection relay's COMTRADE folder. The disturbance recording is not removed from the protection relay's memory until both of the corresponding COMTRADE files, .CFG and .DAT, are deleted. Both file types may need to be deleted separately, depending on the software used.

Deleting all disturbance recordings at once is done either with PCM600 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.

8.2.3.7 Storage mode

The disturbance recorder can capture data in waveform mode. In this mode, the samples are captured according to the *Storage rate* and *Pre-trg length* parameters.

8.2.3.8 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 percentage of the data duration preceding the triggering, that is, the pre-trigger time, can be adjusted with the *Pre-trg length* parameter. The duration of the data following the triggering, that is, the 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.

8.2.3.9 Operation modes

The disturbance recorder has two operation modes: saturation and overwrite mode. The operation mode of the disturbance recorder can be changed 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 Memory full signal state is changed to TRUE. When there is memory available again, the Memory full signal state is changed to FALSE.

Overwrite mode

In the overwrite mode, if 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 Overwrite of rec. signal state is changed to TRUE.

The overwrite mode is recommended if it is 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 modes until the previous recording is completed, but 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 are pre-trigger samples lacking.

8.2.3.10 Exclusion mode

Exclusion mode is on when the value of 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 applies only 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 remaining exclusion time can be monitored with the *Exclusion time rem* parameter (only visible via communication, IEC 61850 data ExclTmRmn) of the corresponding analog or binary channel. The *Exclusion time rem* parameter counts downwards.

8.2.4 Configuration

The disturbance recorder can be configured with PCM600 only

RDRE should always be included in Application Configuration when the disturbance recorder is used.

The disturbance recorder can be enabled or disabled with the *Operation* parameter under **Configuration/Disturbance recorder/General**.

One analog signal type of the protection relay can be mapped to each of the analog channels of the disturbance recorder. The mapping is done in Application Configuration in PCM600. The name of the analog channel is user-configurable. It can be modified by defining a new name to the *Channel id text* parameter of the corresponding analog channel. *Channel id text* can be edited in Application Configuration by selecting the input channel and defining a new *Instance Name* for the channel in the Object Properties pane.

Any external or internal digital signal of the protection relay 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 protection relay. The connection is made with dynamic mapping to the binary channel of the disturbance recorder using, for example, Signal Matrix 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 name of the binary channel can be modified by defining a new name to the *Channel id text* parameter of the corresponding channel. *Channel id text* can be edited in Application Configuration by selecting the input channel and defining a new *Instance Name* for the channel in the Object Properties pane.

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 an analog or a binary channel of the disturbance recorder, the *Operation* parameter of the corresponding analog or binary channel is set to "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 `TRIGGERED` output can be used to control the indication LEDs of the protection relay. The triggering of the disturbance recorder sets the `TRIGGERED` output to TRUE. The output remains in this state until all the data for the corresponding recording has been recorded.

The IP number of the protection relay and the value of the *Bay name* parameter are both included in the COMTRADE configuration file for identification purposes.

8.2.5 Application

The disturbance recorder is used for post-fault analysis and for verifying the correct operation of protection relays 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 protection relay converts the recordings to the COMTRADE format.

COMTRADE is the general standard format used for 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.

8.2.6 Signals

Table 411: RDRE Output signals

Name	Type	Description
TRIGGERED	BOOLEAN	Recording started

8.2.7 Settings

Table 412: RDRE Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Trig recording	0=Cancel 1=Trig			0=Cancel	Manual trigger for the disturbance recorder
Pre-trg length	0...100	%	1	50	Length of recording preceding the triggering in percent
Record length	10...500	cycles	1	50	Record length in fundamental cycles
Operation	1=on 5=off			1=on	Disturbance recorder on / off

Table 413: RDRE Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Periodic trig time	0...604800	s	10	0	Time between periodic triggerings in seconds
Exclusion time	0...1000000	ms	10	0	Time how long triggerings for the same reason are ignored in milliseconds
Operation mode	1=Overwrite 2=Saturation			2=Saturation	Saturation / overwrite
Storage rate	8=8 samples / cycle 16=16 samples / cycle 32=32 samples / cycle			32=32 samples / cycle	Storage rate for waveform recordings in samples per cycle

8.2.8 Monitored data

Table 414: RDRE Monitored data

Name	Type	Values (Range)	Unit	Description
Number of recordings	INT32	0...100		Number of recordings in the memory
Rec. memory used	INT32	0...100	%	How much recording memory is currently used
Rem. amount of rec.	INT32	0...100		Remaining amount of recordings that fit into the available recording memory, when present settings are used
Time to trigger	INT32	0...604800	s	Time remaining to the next periodic triggering

8.3 Disturbance recorder, analog channels 1...8 A1RADR

8.3.1 Function block

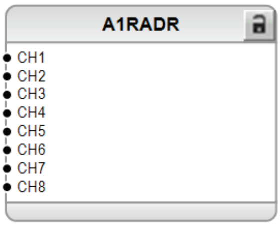


Figure 175: Function block

8.3.2 Signals

The input signal tables for A1RADR are similar except for the channel numbers.

- A1RADR, CH1...CH8

Table 415: A1RADR Input signals

Name	Type	Default	Description
CH1	SIGNAL		Signal for input 1

Values are the same for each input signal. The channel numbers are shown after the parameter name in the LHMI and PCM600.

8.3.3 Settings

Setting tables for all A1RADR channels are similar except for the channel numbers.

Table 416: A1RADR Non group general settings (basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			1=on	Analog channel on / off
Channel id text				Analog ch 1 input	Channel identifier text
High trigger level	0.00...60.00		0.01	10	Over limit
Low trigger level	0.00...2.00		0.01	0	Under limit

8.4 Disturbance recorder, binary channels 1...32 B1RBDR

8.4.1 Function block

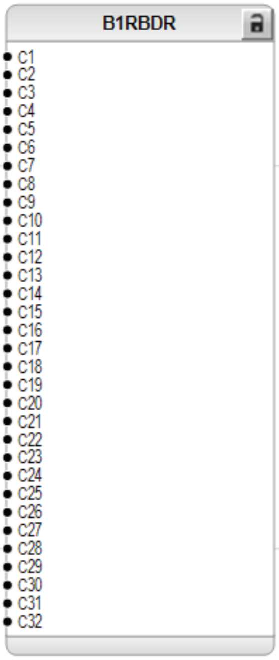


Figure 176: Function block

8.4.2 Signals

The input signal tables for B1RBDR are similar except for the channel numbers.

- B1RBDR, C1...C32

Table 417: B1RBDR Input signals

Name	Type	Default	Description
C1	BOOLEAN	0=False	Signal for input 1

Values are the same for each input signal. The channel numbers are shown after the parameter name in the LHMI and PCM600.

8.4.3 Settings

Setting tables for all B1RBDR channels are similar except for the channel numbers.

Table 418: B1RBDR Non group general settings (basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			5=off	Binary channel on / off
Level trigger mode	1=Positive or Rising 2=Negative or Falling 3=Both 4=Level trigger off			1	Rising / falling / both / trigger off

Table 419: B1RBDR Non group general settings (advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Channel id text				Binary ch 1 input	Channel identifier text

Section 9 Control functions

9.1 Circuit-breaker control CBXCBR (ANSI 52)

9.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit-breaker control	CBXCBR	I <-> O CB	52

9.1.2 Function block

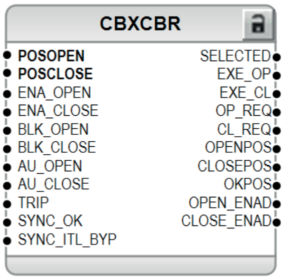


Figure 177: Function block

9.1.3 Functionality

CBXCBR is intended for circuit breaker control and status information purposes. The function executes commands and evaluates block conditions and different time supervision conditions. CBXCBR performs an execution command only if all conditions indicate that a switch operation is allowed. If erroneous conditions occur, the function indicates an appropriate cause value. The function is designed according to the IEC 61850-7-4 standard with logical nodes CILO and CSWI.

The circuit-breaker control function has an operation counter for opening cycles. The counter value can be read and written from the setting *Operation counter*.

9.1.4 Operation principle

Status indication and validity check

The object state is defined by two digital inputs, `POSOPEN` and `POSCLOSE`, which are also available as outputs `OPENPOS` and `CLOSEPOS` together with the `OKPOS` according to Table 420. The debouncing and short disturbances in an input are eliminated by filtering. The binary input filtering time can be adjusted separately for each digital input used by the function block. The validity of the digital inputs that indicate the object state is used as additional information in indications and event logging. The reporting of faulty or intermediate position POSITION (Monitored data) of the apparatus occurs after the *Event delay* setting, assuming that the circuit breaker is still in a corresponding state.

Table 420: Status indication

Input		Status	Output		
POSOPEN	POSCLOSE	POSITION (Monitored data)	OKPOS	OPENPOS	CLOSEPOS
1=True	0=False	1=Open	1=True	1=True	0=False
0=False	1=True	2=Closed	1=True	0=False	1=True
1=True	1=True	3=Faulty/Bad (11)	0=False	0=False	0=False
0=False	0=False	0=Intermediate (00)	0=False	0=False	0=False

Enabling and blocking

CBXCBR has an enabling and blocking functionality for interlocking and synchrocheck purposes.

Circuit-breaker control CBXCBR

Normally, the CB closing is enabled (that is, CLOSE_ENAD signal is TRUE) by activating both ENA_CLOSE and SYNC_OK inputs. Typically, the ENA_CLOSE comes from the interlocking, and SYNC_OK comes from the synchronism and energizing check. The input SYNC_ITL_BYP can be used for bypassing this control. The SYNC_ITL_BYP input can be used to activate CLOSE_ENAD discarding the ENA_CLOSE and SYNC_OK input states. However, the BLK_CLOSE input always blocks the CLOSE_ENAD output.

The CB opening (OPEN_ENAD) logic is the same as CB closing logic, except that SYNC_OK is used only in closing. The SYNC_ITL_BYP input is used in both CLOSE_ENAD and OPEN_ENAD logics.

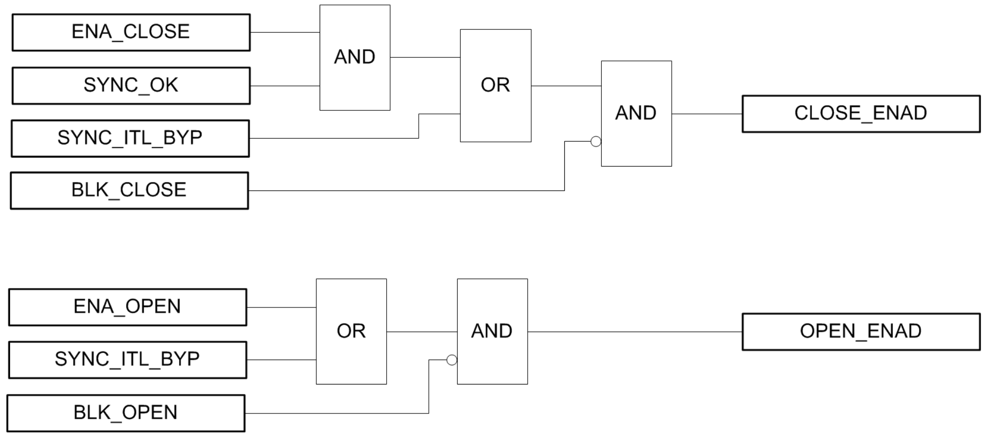


Figure 178: Enabling and blocking logic for CLOSE_ENAD and OPEN_ENAD signals

Opening and closing operations

The opening and closing operations are available via communication, binary inputs or LHMI commands. As a prerequisite for control commands, there are enabling and blocking functionalities for both opening and closing commands (`CLOSE_ENAD` and `OPEN_ENAD` signals). If the control command is executed against the blocking or if the enabling of the corresponding command is not valid, CBXCBR generates an error message.

When close command is given from communication, via LHMI or activating the `AU_CLOSE` input, it is carried out (the `EXE_CL` output) only if `CLOSE_ENAD` is TRUE.

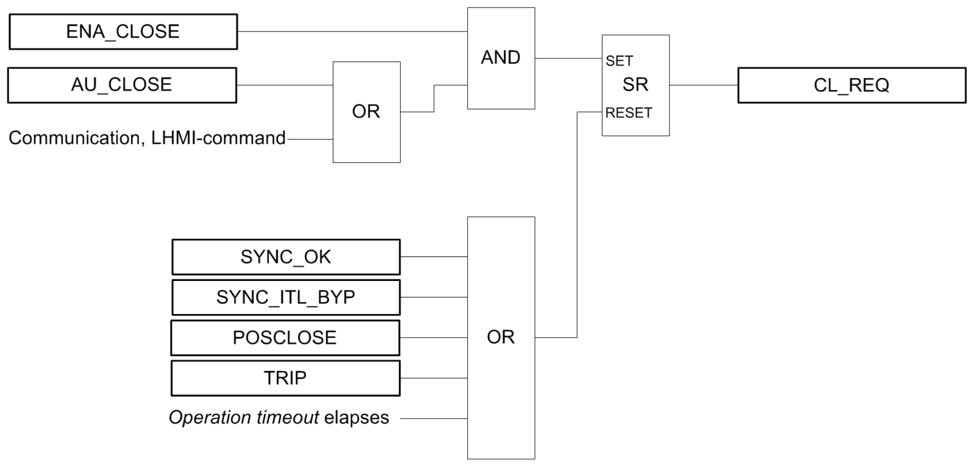


Figure 179: Condition for enabling the close request (CL_REQ) for CBXCBR

When the open command is given from communication, via LHMI or activating the `AU_OPEN` input, it is processed only if `OPEN_ENAD` is TRUE. `OP_REQ` output is also available.

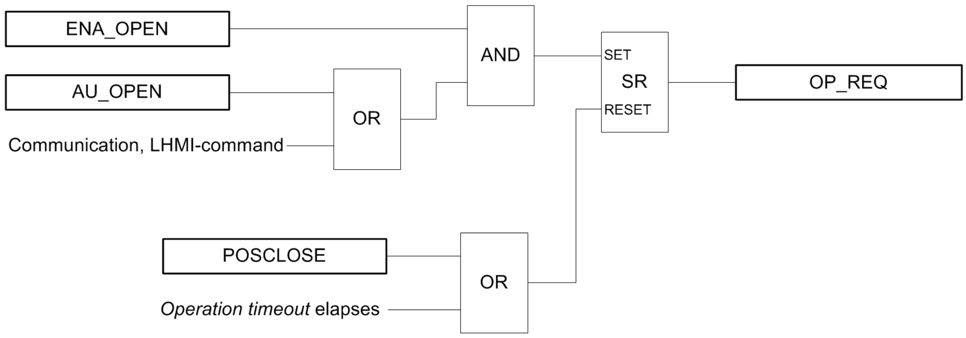


Figure 180: Condition for enabling the open request (OP_REQ) for CBXCBR

OPEN and CLOSE outputs

The EXE_OP output is activated when the open command is given (AU_OPEN, via communication or from LHMI) and OPEN_ENAD signal is TRUE. In addition, the protection trip commands can be routed through the CBXCBR function by using the TRIP input. When the TRIP input is TRUE, the EXE_OP output is activated immediately and bypassing all enabling or blocking conditions.

The EXE_CL output is activated when the close command is given (AU_CLOSE, via communication or from LHMI) and CLOSE_ENAD signal is TRUE. When the TRIP input is TRUE, CB closing is not allowed.

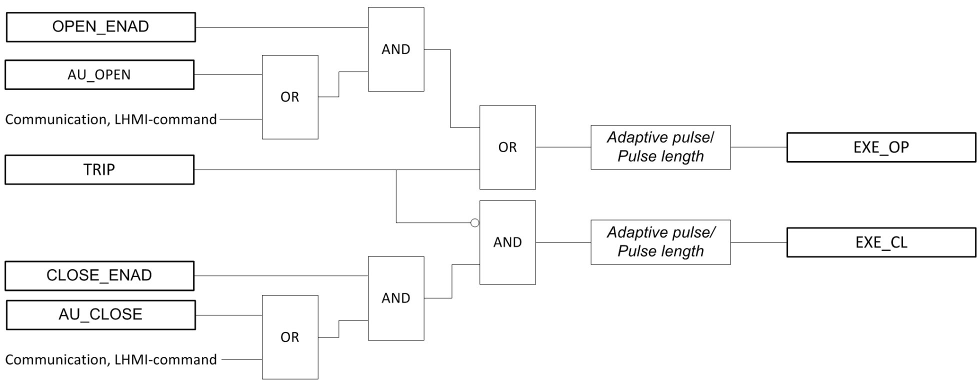


Figure 181: OPEN and CLOSE outputs logic for CBXCBR

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* is set to "True", it causes a variable pulse width, which means that the output pulse is deactivated when the object state shows that the apparatus has entered the correct state. If apparatus fails to enter the correct state, the output pulse is deactivated after the set *Operation timeout* setting, and an error message is displayed. When the *Adaptive pulse* is set to "False", the functions always use 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 apparatus 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, which 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 with a bus. All secured control operations require two-step commands: a selection step and an execution step. The secured object control is responsible for the several tasks.

- 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 direct operation, a single message is used to initiate the control action of a physical device. The direct operation method uses less communication network capacity and bandwidth than the SBO method, because the procedure needs fewer messages for accurate operation.

The “status-only” mode means that control is not possible (non-controllable) via communication or from LHMI.

`AU_OPEN` and `AU_CLOSE` control the object directly regardless of the set *Control model*. These inputs can be used when control is wanted to be implemented purely based on ACT logic and no additional exception handling is needed. However, in case of simultaneous open and close control, the open control is always prioritized.

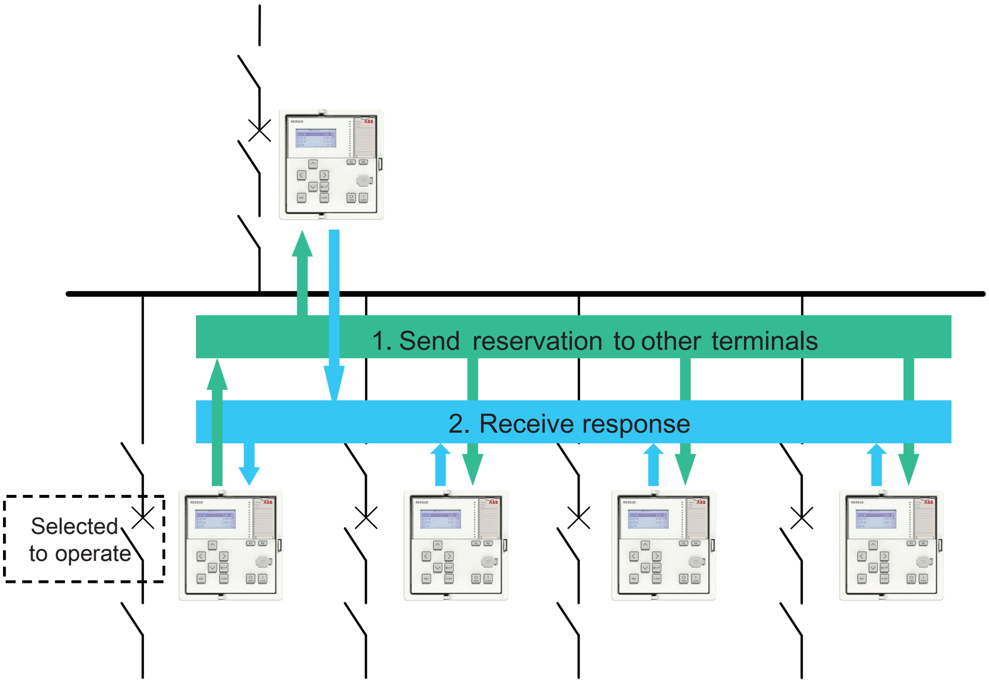


Figure 182: Control procedure in the SBO method

Local/Remote operations

The local/remote selection affects CBXCBR.

- Local: the opening and closing via communication is disabled.
- Remote: the opening and closing via LHMI is disabled.
- `AU_OPEN` and `AU_CLOSE` inputs function regardless of the local/remote selection.

9.1.5 Application

In the field of distribution and sub-transmission automation, reliable control and status indication of primary switching components both locally and remotely is in a significant role. They are needed especially in modern remotely controlled substations.

Control and status indication facilities are implemented in the same package with CBXCBR. When primary components are controlled in the energizing phase, for example, the correct execution sequence of the control commands must be ensured. This can be achieved, for example, with interlocking based on the status indication of the related primary components. The interlocking on the substation level can be applied using the IEC 61850 GOOSE messages between feeders.

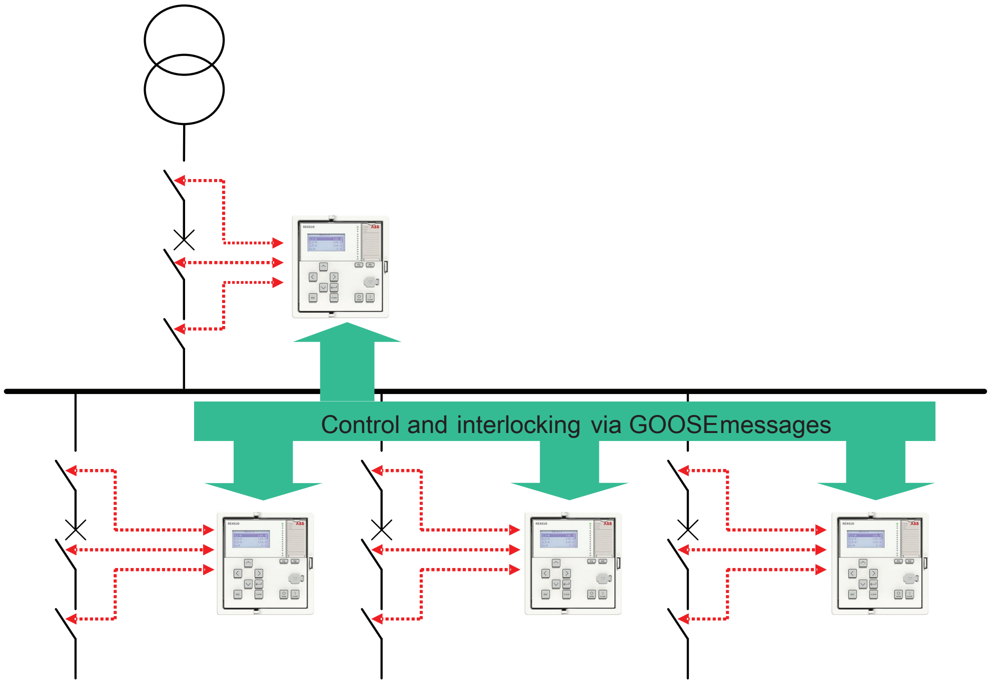


Figure 183: Status indication-based interlocking via the GOOSE messaging

9.1.6 Signals

Table 421: CBXCBR Input signals

Name	Type	Default	Description
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for close position of apparatus from I/O
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
AU_OPEN	BOOLEAN	0=False	Auxiliary open
AU_CLOSE	BOOLEAN	0=False	Auxiliary close
TRIP	BOOLEAN	0=False	Trip signal
SYNC_OK	BOOLEAN	1=True	Synchronism-check OK
SYNC_ITL_BYP	BOOLEAN	0=False	Discards ENA_OPEN and ENA_CLOSE interlocking when TRUE

Table 422: CBXCBR 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
OP_REQ	BOOLEAN	Open request
CL_REQ	BOOLEAN	Close request
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

9.1.7 Settings

Table 423: CBXCBR Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Select timeout	10000...300000	ms	10000	30000	Select timeout in ms
Pulse length	10...60000	ms	1	200	Open and close pulse length
Operation	1=on 5=off			1=on	Operation mode on/off
Control model	0=status-only 1=direct-with-normal-security 4=sbo-with-enhanced-security			4=sbo-with-enhanced-security	Select control model
Operation timeout	10...60000	ms	1	500	Timeout for negative termination
Identification				CBXCBR switch position	Control Object identification

Table 424: CBXCBR Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Operation counter	0...99999		1	0	Nr of opening operations
Adaptive pulse	0=False 1=True			1=True	Deactivate control pulse when apparatus has reached correct position
Event delay	0...10000	ms	1	200	Event delay of the intermediate and faulty position
Vendor				0	External equipment vendor
Serial number				0	External equipment serial number
Model				0	External equipment model

9.1.8 Monitored data

Table 425: CBXCBR Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication
OPEN_CNT	INT32	0...99999		Nr of opening operation count

9.2 Disconnector position indication DCSXSWI and Earthing switch position indication ESSXSWI (ANSI 29DS, 29GS)

9.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Disconnector position indication	DCSXSWI	I <-> O DC	29DS
Earthing switch position indication	ESSXSWI	I <-> O ES	29GS

9.2.2 Function block

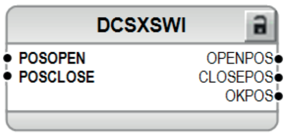


Figure 184: Function block

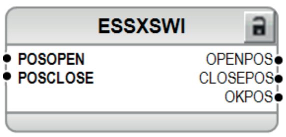


Figure 185: Function block

9.2.3 Functionality

The functions DCSXSWI and ESSXSWI indicate remotely and locally the open, close and undefined states of the disconnector and earthing switch. The functionality of both is identical, but each one is allocated for a specific purpose visible in the function names. For example, the status indication of disconnectors or circuit breaker truck can be monitored with the DCSXSWI function.

The functions are designed according to the IEC 61850-7-4 standard with the logical node XSWI.

9.2.4 Operation principle

Status indication and validity check

The object state is defined by the two digital inputs POSOPEN and POSCLOSE, which are also available as outputs OPENPOS and CLOSEPOS together with the OKPOS according to Table 426. The debounces and short disturbances in an input are eliminated by filtering. The binary input filtering time can be adjusted separately for each digital input used by the function block. The validity of digital inputs that indicate the object state is used as additional information in indications and event logging.

Table 426: Status indication

Input		Status	Output		
POSOPEN	POSCLOSE	POSITION (Monitored data)	OKPOS	OPENPOS	CLOSEPOS
1=True	0=False	1=Open	1=True	1=True	0=False
0=False	1=True	2=Closed	1=True	0=False	1=True
1=True	1=True	3=Faulty/Bad (11)	0=False	0=False	0=False
0=False	0=False	0=Intermediate (00)	0=False	0=False	0=False

9.2.5 Application

In the field of distribution and sub-transmission automation, the reliable control and status indication of primary switching components both locally and remotely is in a significant role. These features are needed especially in modern remote controlled substations. The application area of DCSXSWI and ESSXSWI functions covers remote and local status indication of, for example, disconnectors, air-break switches and earthing switches, which represent the lowest level of power switching devices without short-circuit breaking capability.

9.2.6 Signals

Table 427: DCSXSWI Input signals

Name	Type	Default	Description
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for close position of apparatus from I/O

Table 428: ESSXSWI Input signals

Name	Type	Default	Description
POSOPEN	BOOLEAN	0=False	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0=False	Signal for close position of apparatus from I/O

Table 429: DCSXSWI Output signals

Name	Type	Description
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok

Table 430: ESSXSWI Output signals

Name	Type	Description
OPENPOS	BOOLEAN	Apparatus open position
CLOSEPOS	BOOLEAN	Apparatus closed position
OKPOS	BOOLEAN	Apparatus position is ok

9.2.7 Settings

Table 431: DCSXSWI Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Identification				DCSXSWI switch position	Control Object identification

Table 432: DCSXSWI Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Event delay	0...60000	ms	1	30000	Event delay of the intermediate and faulty position

Table 433: ESSXSWI Non group settings (Basic)

Parameter	Values (Range)	Unit	Step	Default	Description
Identification				ESSXSWI switch position	Control Object identification

Table 434: ESSXSWI Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
Event delay	0...60000	ms	1	30000	Event delay of the intermediate and faulty position

9.2.8 Monitored data

Table 435: DCSXSWI Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication
Vendor	VisString255			External equipment vendor
Serial number	VisString255			External equipment serial number
Model	VisString255			External equipment model

Table 436: ESSXSWI Monitored data

Name	Type	Values (Range)	Unit	Description
POSITION	Dbpos	0=intermediate 1=open 2=closed 3=faulty		Apparatus position indication
Vendor	VisString255			External equipment vendor
Serial number	VisString255			External equipment serial number
Model	VisString255			External equipment model

9.3 Autoreclosing DARREC (ANSI 79)

9.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Autoreclosing	DARREC	O -> I	79

9.3.2 Function block

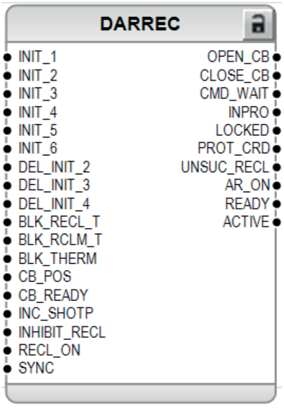


Figure 186: Function block

9.3.3 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 autoreclosing function DARREC can be used with any circuit breaker suitable for autoreclosing. The function provides five programmable autoreclosing shots which can perform one to five successive autoreclosings of desired type and duration, for instance one high-speed and one delayed autoreclosing.

When the reclosing is initiated with starting of the protection function, the autoreclosing 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.

9.3.3.1 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 437: 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).

9.3.3.2 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.

9.3.3.3 Master and slave scheme

With the cooperation between the AR units in the same protection relay or between protection relays, 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.

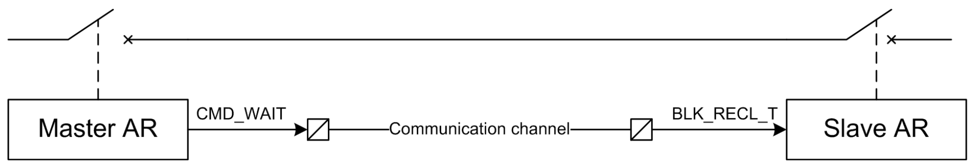


Figure 187: Master and slave scheme

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 autoreclosing shot.

If the terminal priority of the AR unit is set to "none", the AR unit skips all these actions.

9.3.3.4 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 Thm 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.

9.3.4 Operation principle

The function can be enabled and disabled with the *Operation* setting. The corresponding parameter values are "on" and "off". Setting *Operation* to "off" resets non-volatile counters.

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: “On”, “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. AR_ON is activated when reclosing operation is enabled.

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

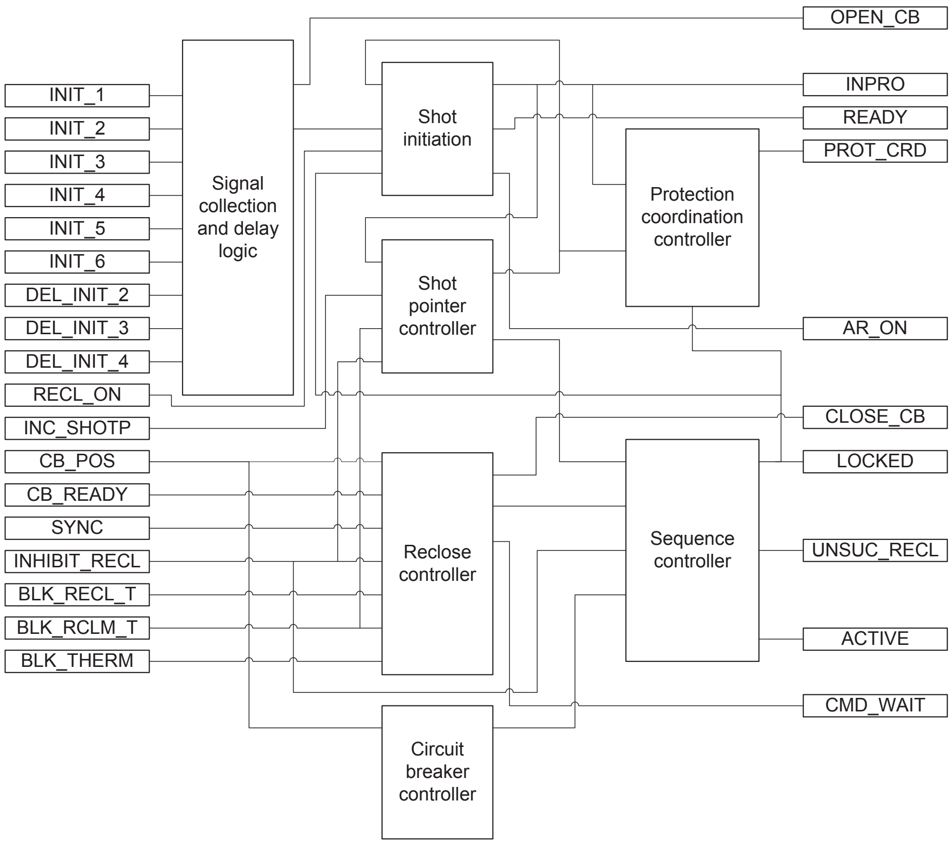


Figure 188: Functional module diagram

Signal collection and delay logic

When the protection trips, the initiation of autoreclosing shots is in most applications executed with the INIT_1...6 inputs. The DEL_INIT_2...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.

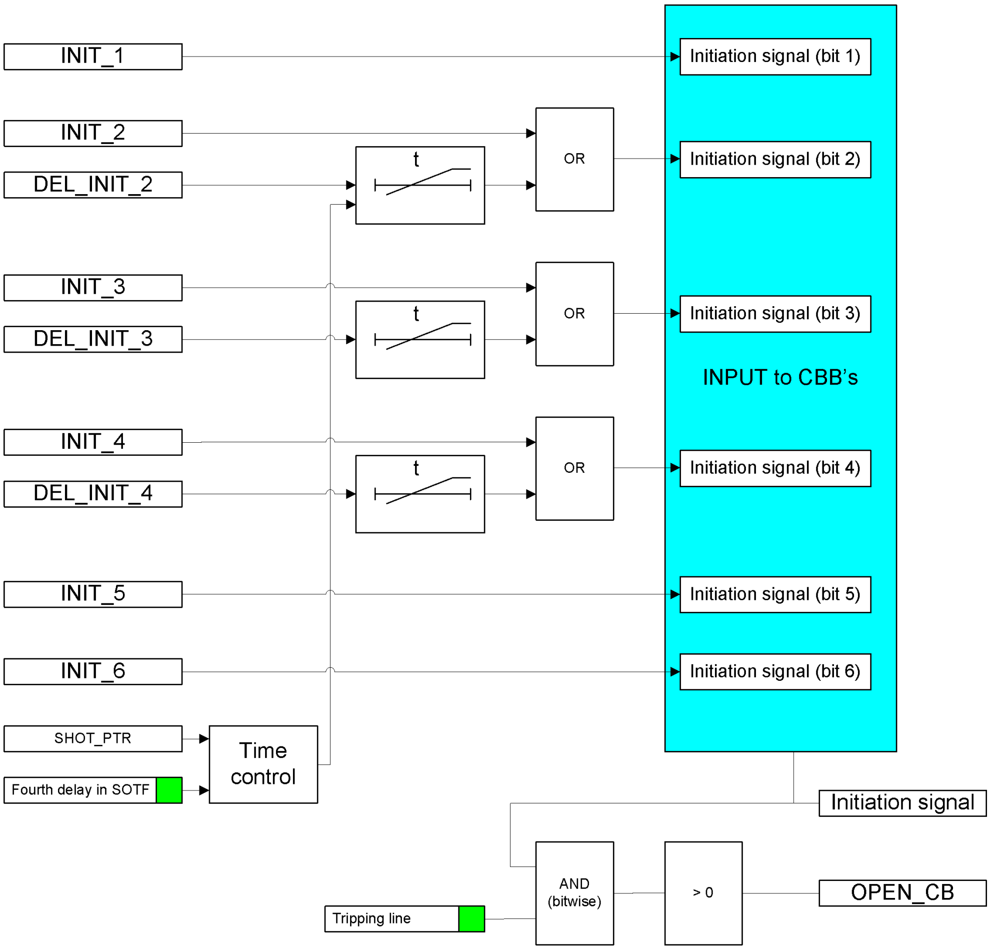


Figure 189: Schematic diagram of delayed initiation input signals

In total, the AR function contains six separate initiation lines used for the initiation or blocking of the autoreclosing 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

- *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

- *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

- *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 reclosing attempts are made. The third and fourth attempts are used to provide the so-called fast final trip to lockout.

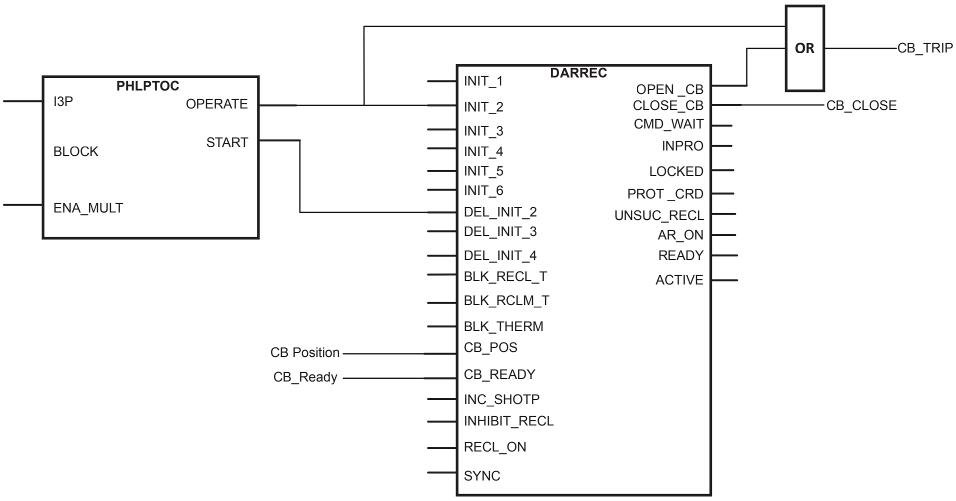


Figure 190: Autoreclosing configuration example

Delayed DEL_INIT_2...4 signals are used only when the autoreclosing shot is initiated with the start signal of a protection stage. After a start delay, the AR function opens the circuit breaker and an autoreclosing 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 autoreclosing 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 autoreclose situation is where one autoreclosing 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 autoreclosing sequence is successful: the reclaim time elapses and no new sequence is started.

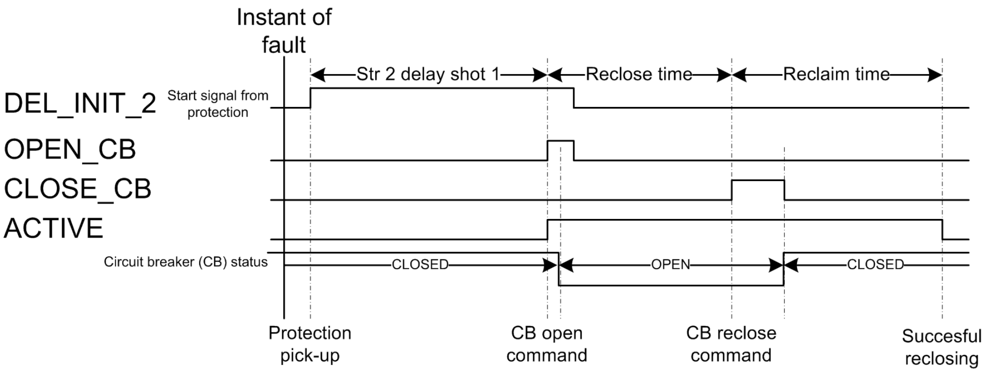


Figure 191: Signal scheme of autoreclosing operation initiated with protection start signal

The autoreclosing shot is initiated with a start signal of the protection function after the start delay time has elapsed. The autoreclosing starts when the *Str 2 delay shot 1* setting elapses.

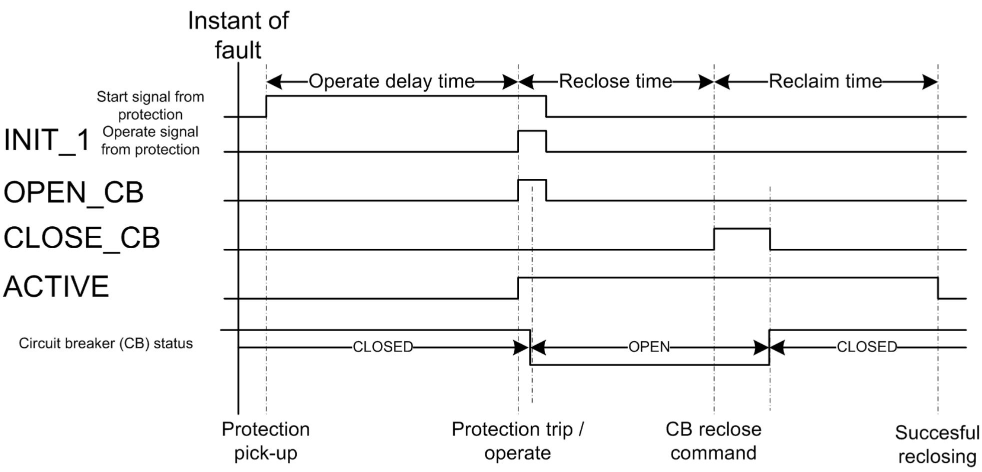


Figure 192: Signal scheme of autoreclosing operation initiated with protection operate signal

The autoreclosing shot is initiated with a trip signal of the protection function. The autoreclosing starts when the protection operate delay time elapses.

Normally, all trip and start signals are used to initiate an autoreclosing shot and trip the circuit breaker. `ACTIVE` output indicates reclosing sequence in progress. 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.

Shot initiation

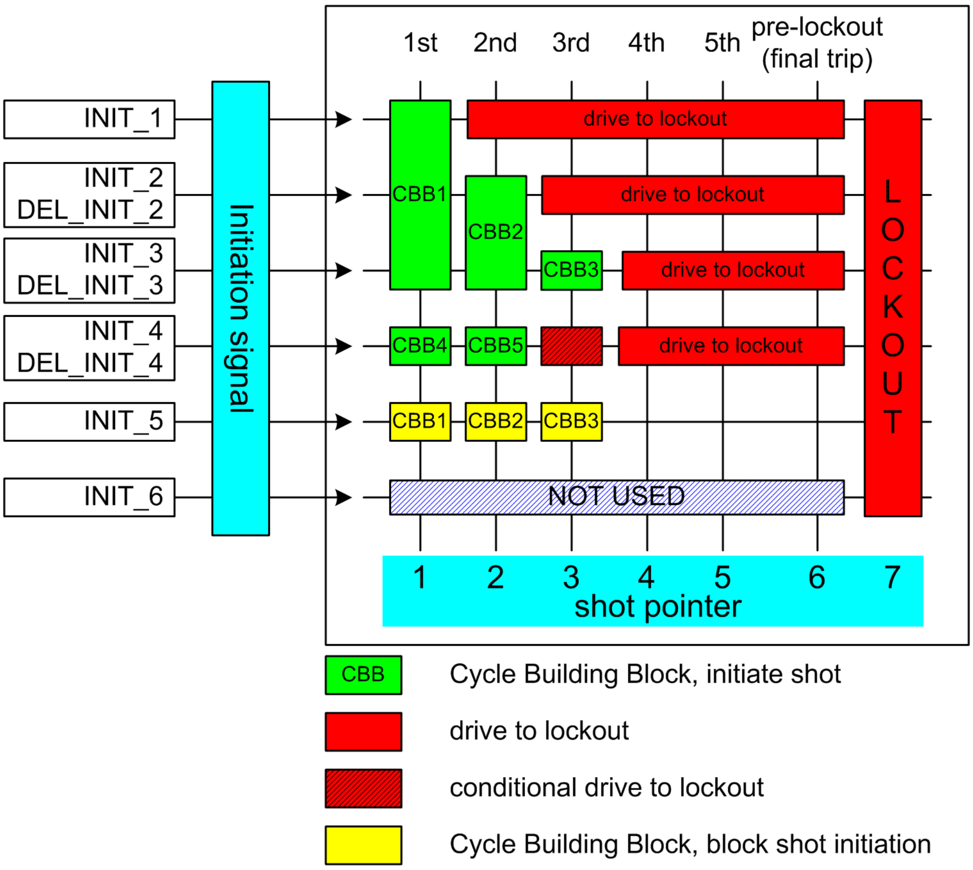


Figure 193: Example of an autoreclosing program with a reclose scheme matrix

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.

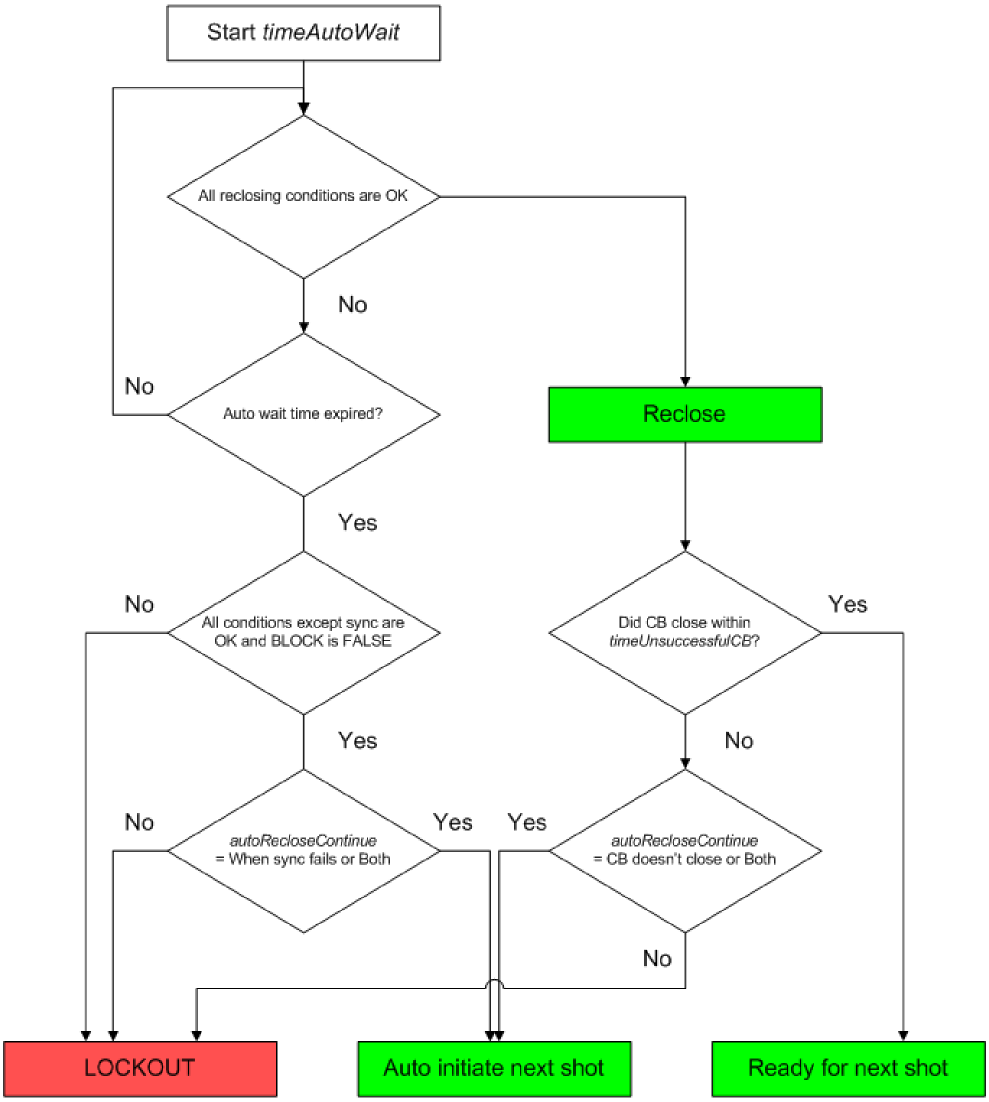


Figure 194: Logic diagram of auto-initiation sequence detection

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.

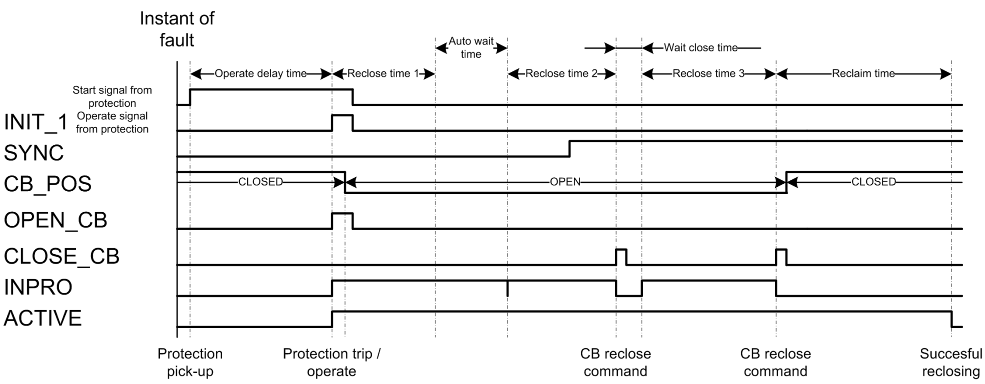


Figure 195: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

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.

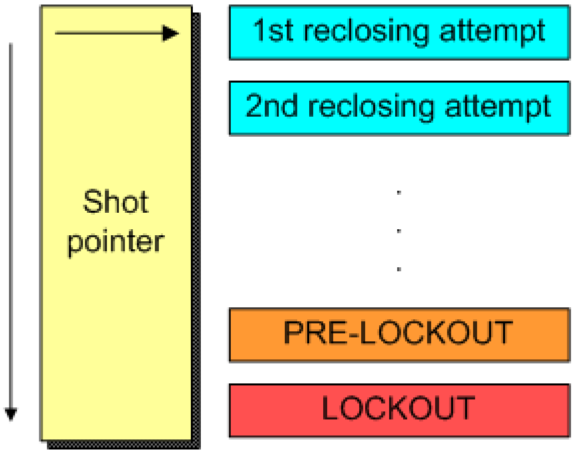


Figure 196: Shot pointer function

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.

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. This is indicated by active READY output.

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.

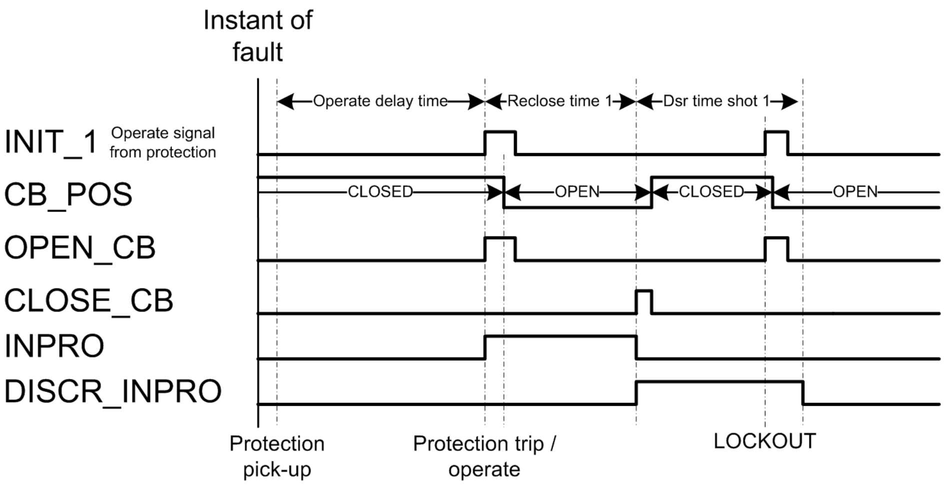


Figure 197: Initiation during discrimination time - AR function goes to lockout

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.

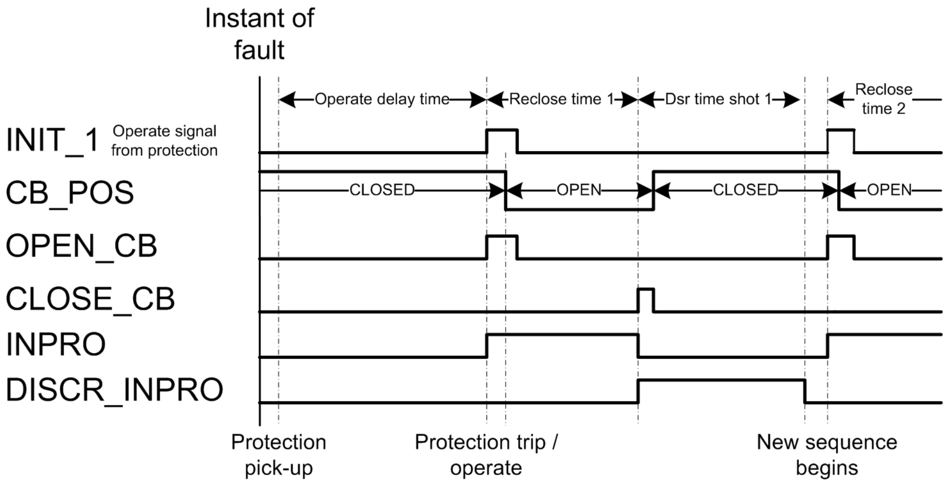


Figure 198: Initiation after elapsed discrimination time - new shot begins

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 *RecRs* parameter. The same functionality can also be found in the Clear menu (DARREC reset).
- 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 *RecRs* 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 autoreclosing sequence and the manual close mode is FALSE.

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

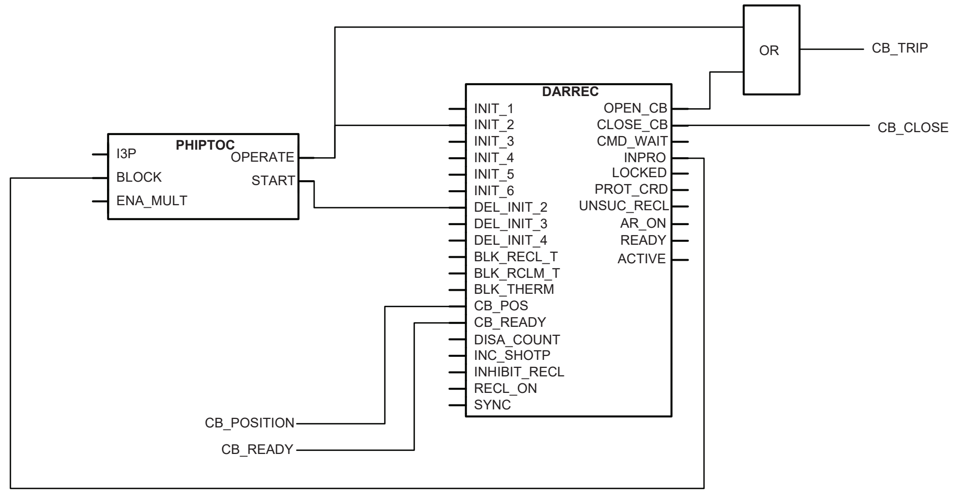


Figure 199: Configuration example of using the `PROT_CRD` output for protection blocking

If the *Protection crd limit* setting has the value "1", the instantaneous three-phase overcurrent protection function PHIPTOC is disabled or blocked after the first shot.

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 autoreclosing function is driven to lockout or, if allowed, an auto-initiation is activated.

The main motivation for autoreclosing 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 autoreclosing 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 autoreclosing 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 autoreclosing 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 autoreclosing function in cases where the fault causes repetitive autoreclosing sequences during a short period of time. For instance, if a tree causes a short circuit and, as a result, there are autoreclosing 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.

9.3.5 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 reclosing command. The counters count the following situations.

- `COUNTER`: counts every reclosing command activation
- `CNT_SHOT1`: counts reclosing commands that are executed from shot 1
- `CNT_SHOT2`: counts reclosing commands that are executed from shot 2
- `CNT_SHOT3`: counts reclosing commands that are executed from shot 3
- `CNT_SHOT4`: counts reclosing commands that are executed from shot 4
- `CNT_SHOT5`: counts reclosing 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 *CntRs* parameter. The same functionality can also be found in the clear menu (DARREC counters).

9.3.6 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 the DARREC autoreclosing function, the implementing method of auto-reclose sequences is patented by ABB.

Table 438: Important definitions related to autoreclosing

Autoreclose shot	An operation where after a preset time the breaker is closed from the breaker tripping caused by protection
Autoreclose 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.

9.3.6.1 Shot initiation

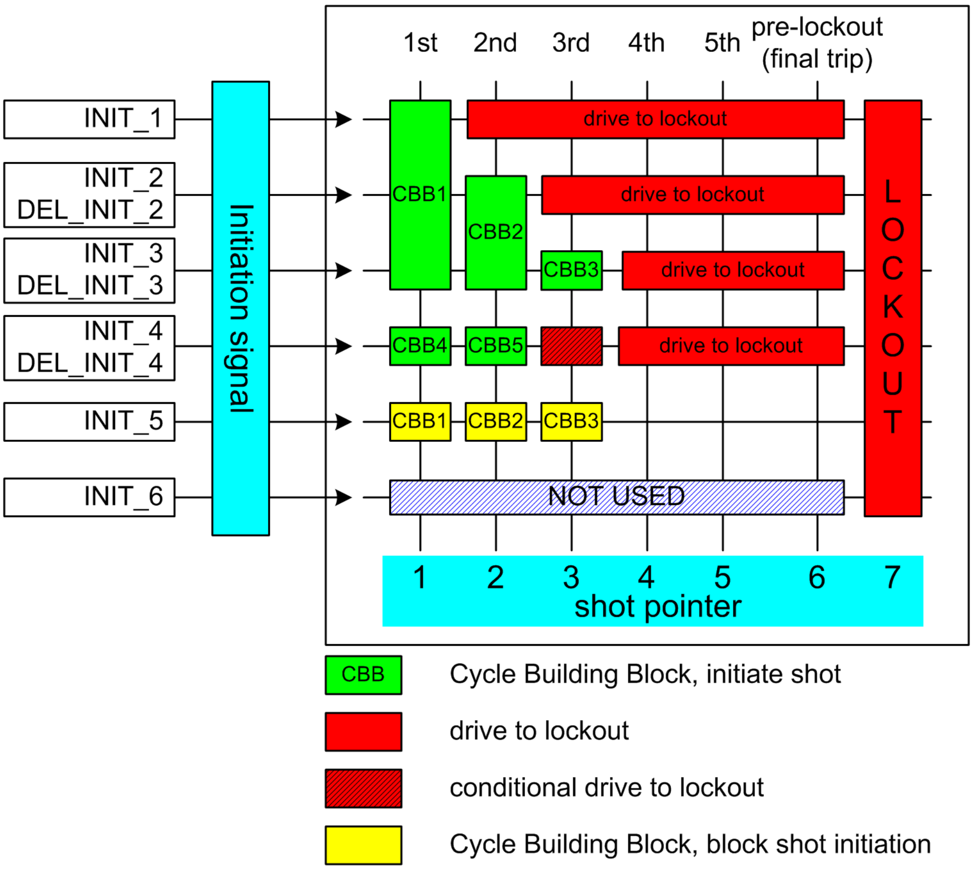


Figure 200: Example of an autoreclosing program with a reclose scheme matrix

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.

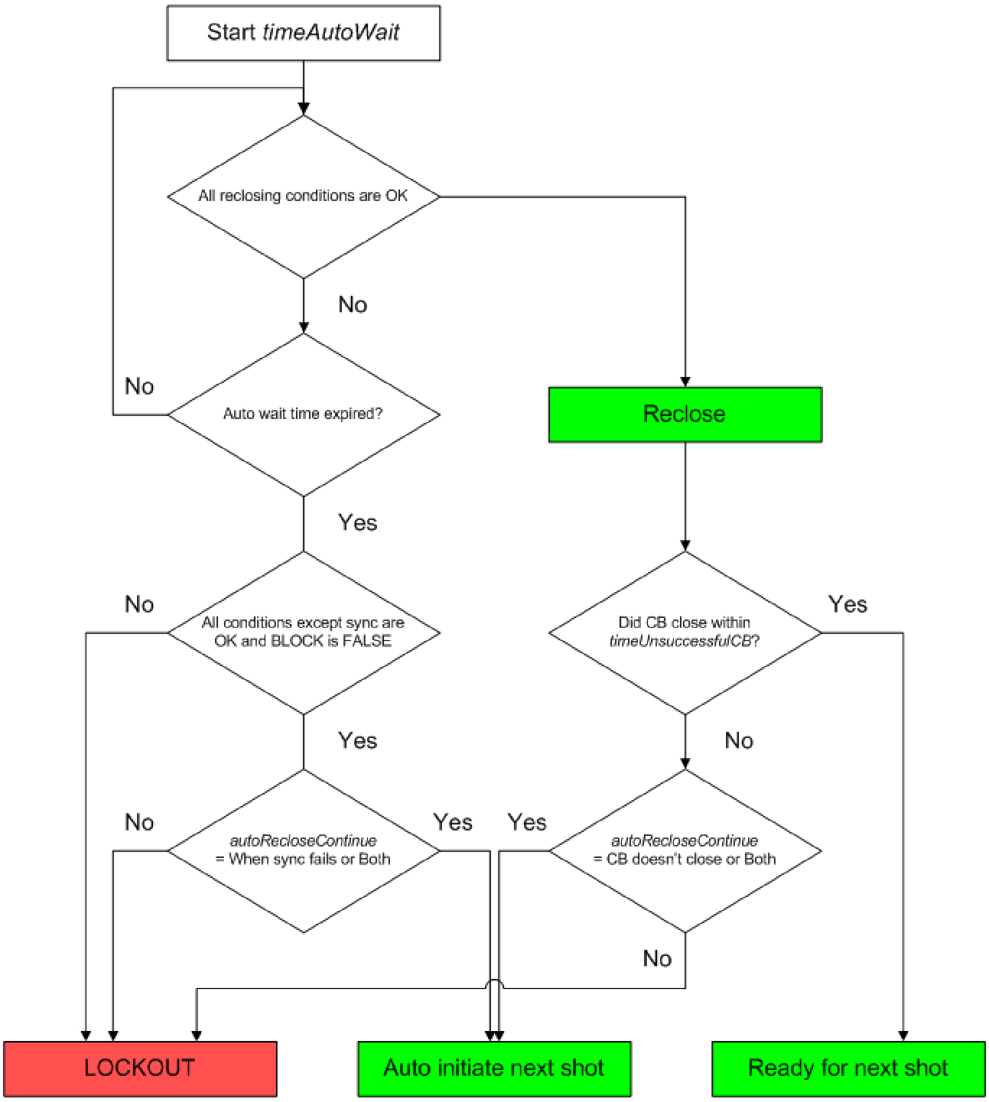


Figure 201: Logic diagram of auto-initiation sequence detection

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.

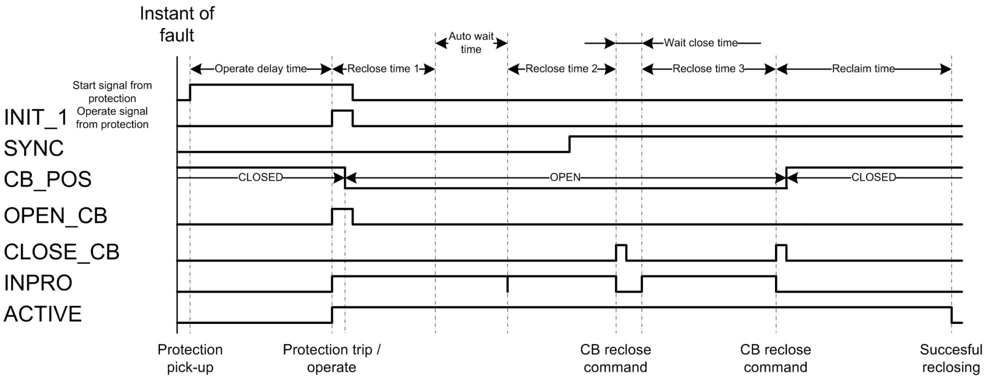


Figure 202: Example of an auto-initiation sequence with synchronization failure in the first shot and circuit breaker closing failure in the second shot

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.

9.3.6.2 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.

9.3.6.3 Configuration examples

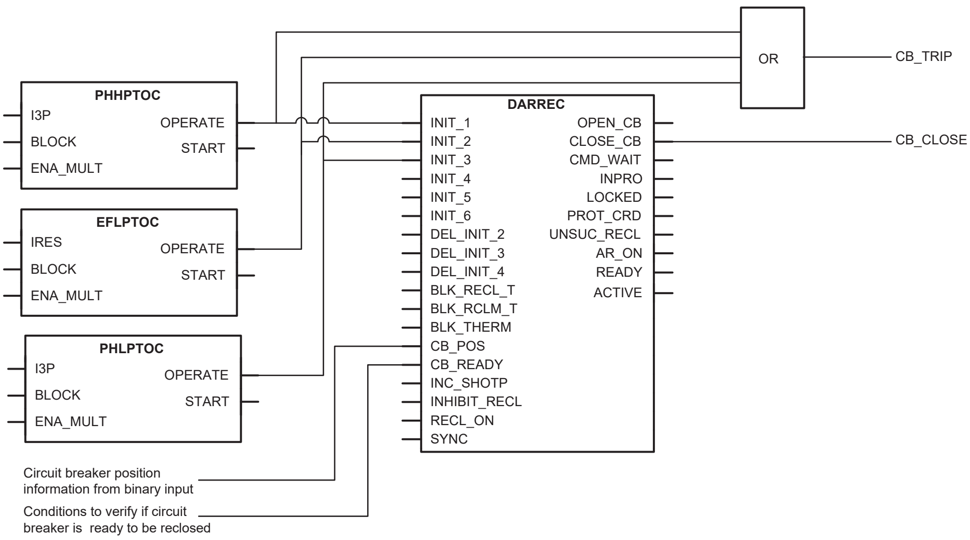


Figure 203: Example connection between protection and autoreclosing functions in protection relay configuration

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.

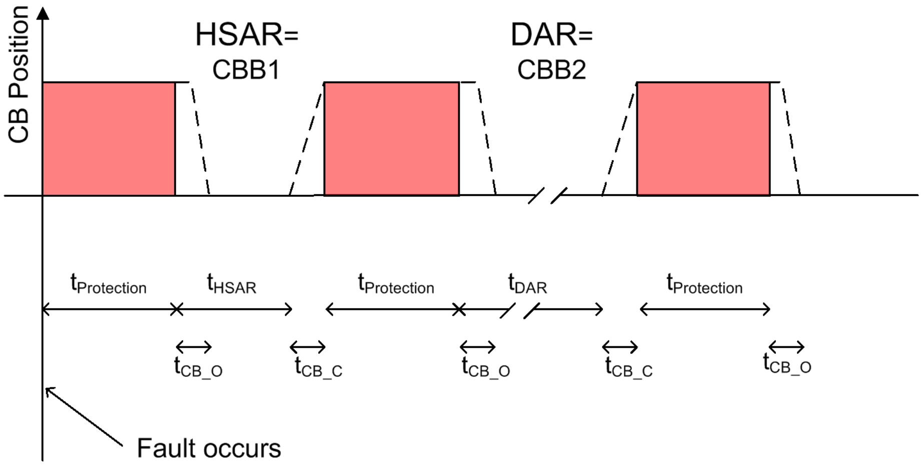


Figure 204: Autoreclosing sequence with two shots

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 described in Table 439 as follows:

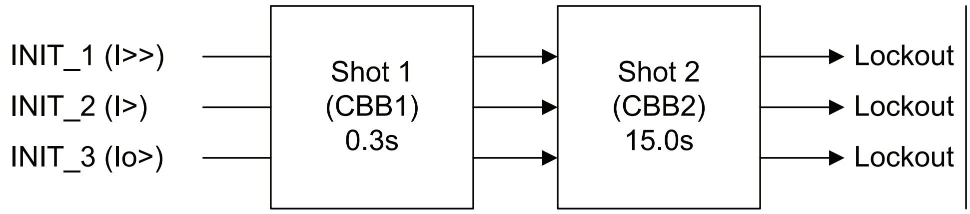


Figure 205: Two shots with three initiation lines

Table 439: 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	0.3 s (an example)
Shot number CBB2	2
Init signals CBB2	7 (lines 1, 2 and 3 = 1+2+4 = 7)
Second reclose time	15.0 s (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.

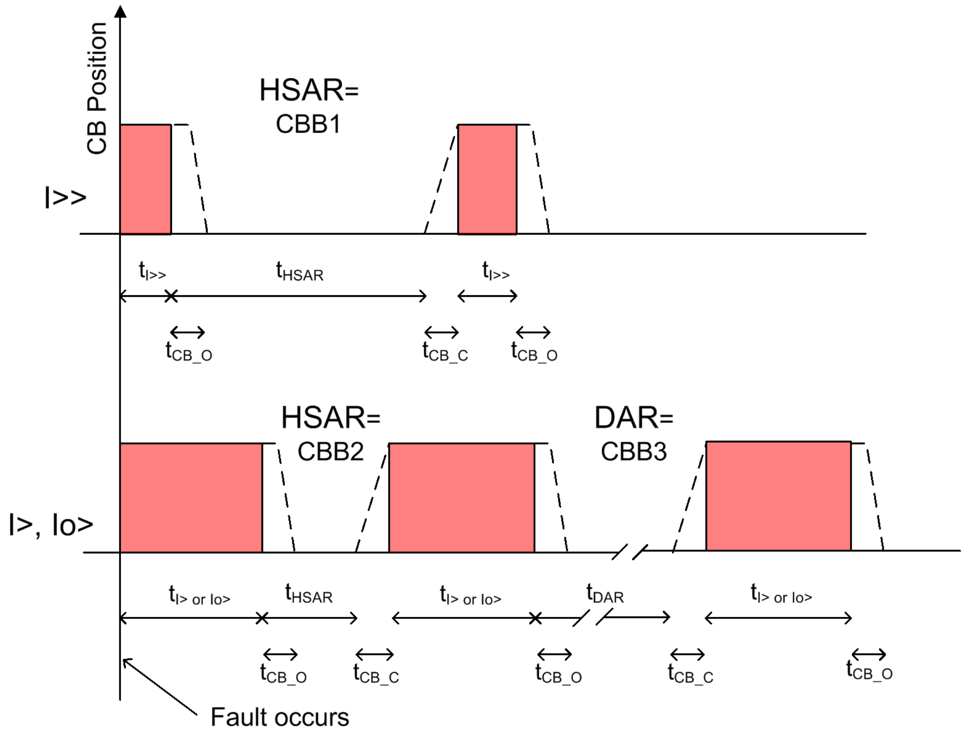


Figure 206: Autoreclosing sequence with two shots with different shot settings according to initiation signal

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.

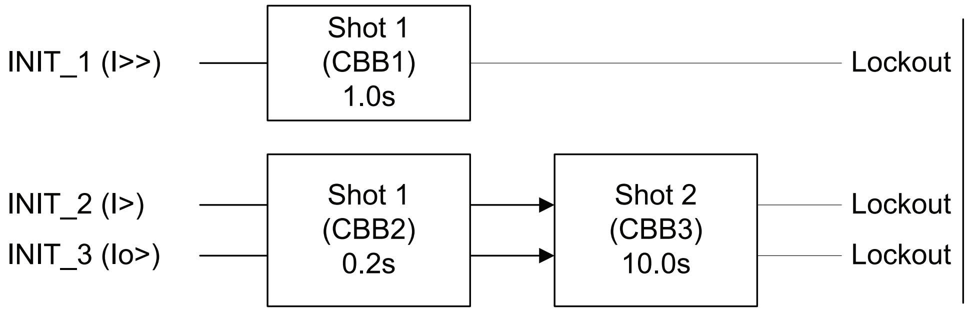


Figure 207: Three shots with three initiation lines

If the sequence is initiated from the INIT_1 line, that is, the overcurrent protection high stage, the sequence is one shot long. If the sequence is initiated from the INIT_2 or INIT_3 lines, the sequence is two shots long.

Table 440: Settings for configuration example 2

Setting name	Setting value
Shot number CBB1	1
Init signals CBB1	1 (line 1)
First reclose time	0.0 s (an example)
Shot number CBB2	1
Init signals CBB2	6 (lines 2 and 3 = 2+4 = 6)
Second reclose time	0.2 s (an example)
Shot number CBB3	2
Init signals CBB3	6 (lines 2 and 3 = 2+4 = 6)
Third reclose time	10.0 s

9.3.6.4 Delayed initiation lines

The autoreclose function consists of six individual autoreclose 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 autoreclosing point of view, it does not matter whether INIT_x or DEL_INIT_x line is used for shot initiation or blocking.

The autoreclose 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.

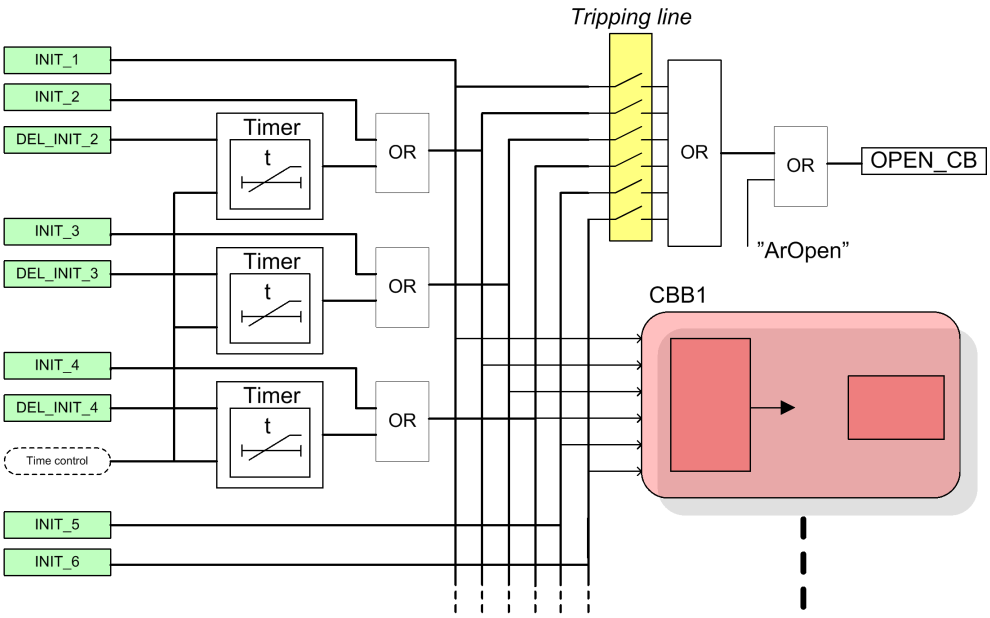


Figure 208: Simplified logic diagram of initiation lines

Each delayed initiation line has four different time settings:

Table 441: 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.

9.3.6.5 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.

9.3.6.6 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.

9.3.7 Signals

Table 442: 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 443: 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

Table continues on next page

Name	Type	Description
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, i.e. the CB_READY input equals TRUE
ACTIVE	BOOLEAN	Reclosing sequence is in progress

9.3.8 Settings

Table 444: DARREC Non group settings (Basic)

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)
Close pulse time	10...10000	ms	10	200	CB close pulse time
Reclaim time	100...1800000	ms	100	10000	Reclaim time
Terminal priority	1=None 2=Low (follower) 3=High (master)			1=None	Terminal priority
Synchronisation set	0...127		1	0	Selection for synchronizing requirement for reclosing
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		1	0	Tripping line, defines INIT inputs which cause OPEN_CB activation
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		1	0	Initiation lines for CBB1
Init signals CBB2	0...63		1	0	Initiation lines for CBB2
Init signals CBB3	0...63		1	0	Initiation lines for CBB3
Init signals CBB4	0...63		1	0	Initiation lines for CBB4
Init signals CBB5	0...63		1	0	Initiation lines for CBB5
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Init signals CBB6	0...63		1	0	Initiation lines for CBB6
Init signals CBB7	0...63		1	0	Initiation lines for CBB7
Shot number CBB1	0...5		1	0	Shot number for CBB1
Shot number CBB2	0...5		1	0	Shot number for CBB2
Shot number CBB3	0...5		1	0	Shot number for CBB3
Shot number CBB4	0...5		1	0	Shot number for CBB4
Shot number CBB5	0...5		1	0	Shot number for CBB5
Shot number CBB6	0...5		1	0	Shot number for CBB6
Shot number CBB7	0...5		1	0	Shot number for CBB7
Frq Op counter limit	0...250		1	0	Frequent operation counter lockout limit
Frq Op counter time	1...250	min	1	1	Frequent operation counter time
Frq Op recovery time	1...250	min	1	1	Frequent operation counter recovery time
Auto init	0...63		1	0	Defines INIT lines that are activated at auto initiation

Table 445: DARREC Non group settings (Advanced)

Parameter	Values (Range)	Unit	Step	Default	Description
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 BLK_RECL_T release
Max trip time	100...10000	ms	100	10000	Maximum wait time for deactivation of protection signals
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
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
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	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
Table continues on next page					

Parameter	Values (Range)	Unit	Step	Default	Description
Control line	0...63		1	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			0=False	Circuit breaker closed position status
Blk signals CBB1	0...63		1	0	Blocking lines for CBB1
Blk signals CBB2	0...63		1	0	Blocking lines for CBB2
Blk signals CBB3	0...63		1	0	Blocking lines for CBB3
Blk signals CBB4	0...63		1	0	Blocking lines for CBB4
Blk signals CBB5	0...63		1	0	Blocking lines for CBB5
Blk signals CBB6	0...63		1	0	Blocking lines for CBB6
Blk signals CBB7	0...63		1	0	Blocking lines 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

9.3.9 Monitored data

Table 446: 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
Table continues on next page				

Name	Type	Values (Range)	Unit	Description
STATUS	Enum	-1=Not defined 1=Ready 2=InProgress 3=Successful 4=WaitingForTrip 5=TripFromProtection 6=FaultDisappeared 7=WaitToComplete 8=CBclosed 9=CycleUnsuccessful 10=Unsuccessful 11=Aborted		AR status signal for IEC61850
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	1...7		Shot pointer value

Table continues on next page

Name	Type	Values (Range)	Unit	Description
MAN_CB_CL	BOOLEAN	0=False 1=True		Indicates CB manual closing during reclosing sequence
SOTF	BOOLEAN	0=False 1=True		Switch-onto-fault
DARREC1	Enum	1=on 2=blocked 3=test 4=test/blocked 5=off		Status

9.3.10 Technical data

Table 447: DARREC Technical data

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±40 ms

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.

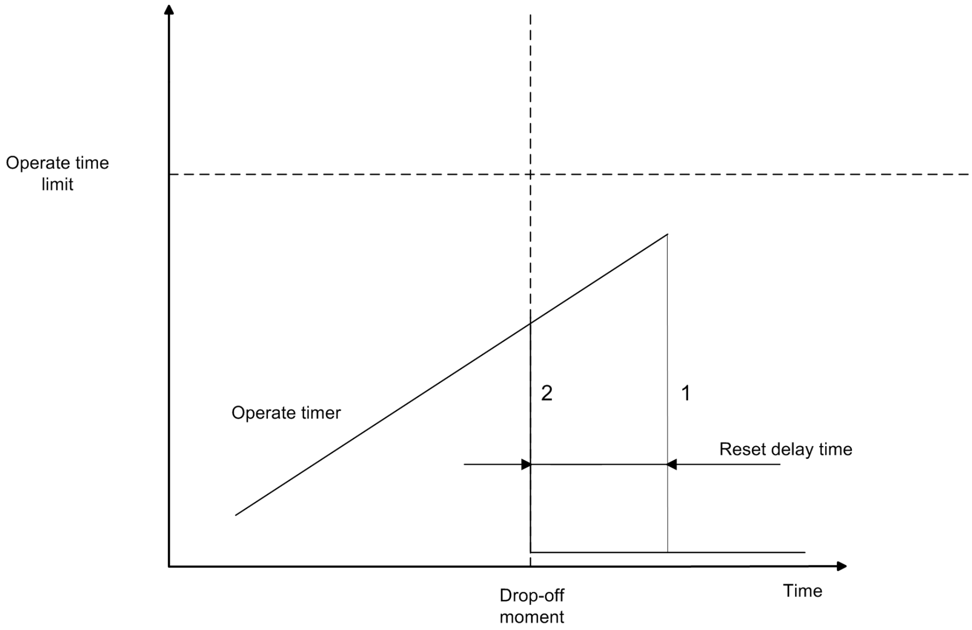


Figure 209: Operation of the counter in drop-off

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.

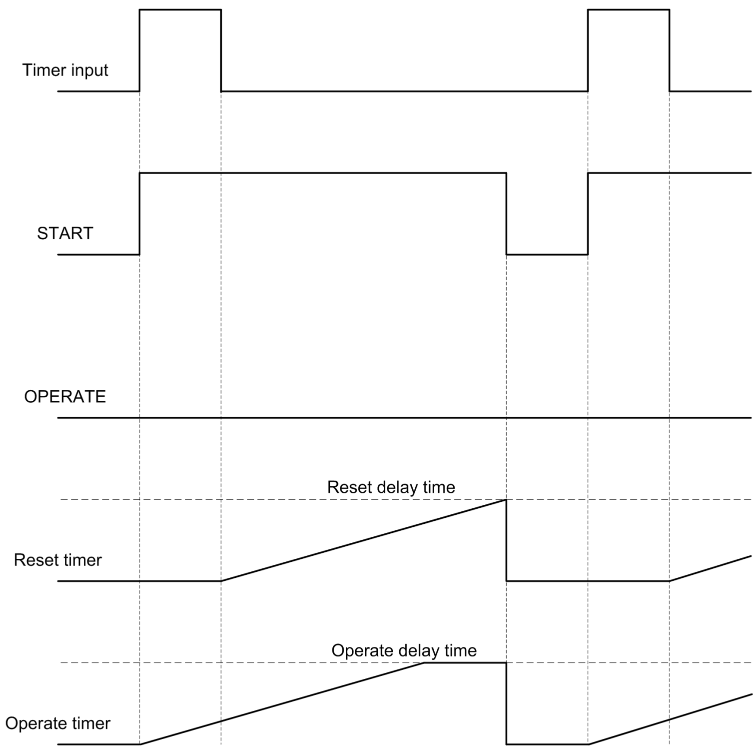


Figure 210: Drop-off period is longer than the set Reset delay time

When the drop-off period is longer than the set *Reset delay time*, as described in Figure 210, 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.

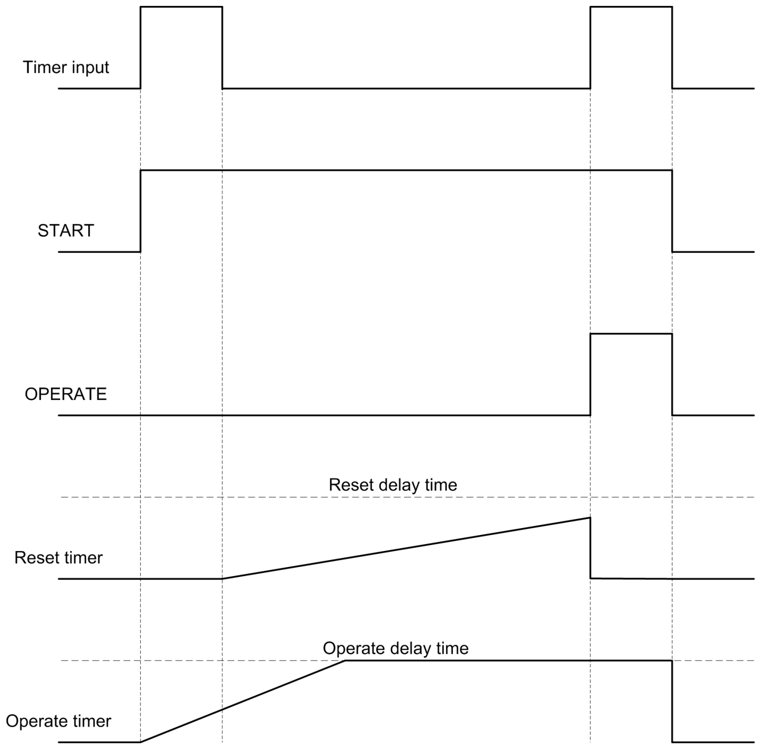


Figure 211: Drop-off period is shorter than the set Reset delay time

When the drop-off period is shorter than the set *Reset delay time*, as described in Figure 211, 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.

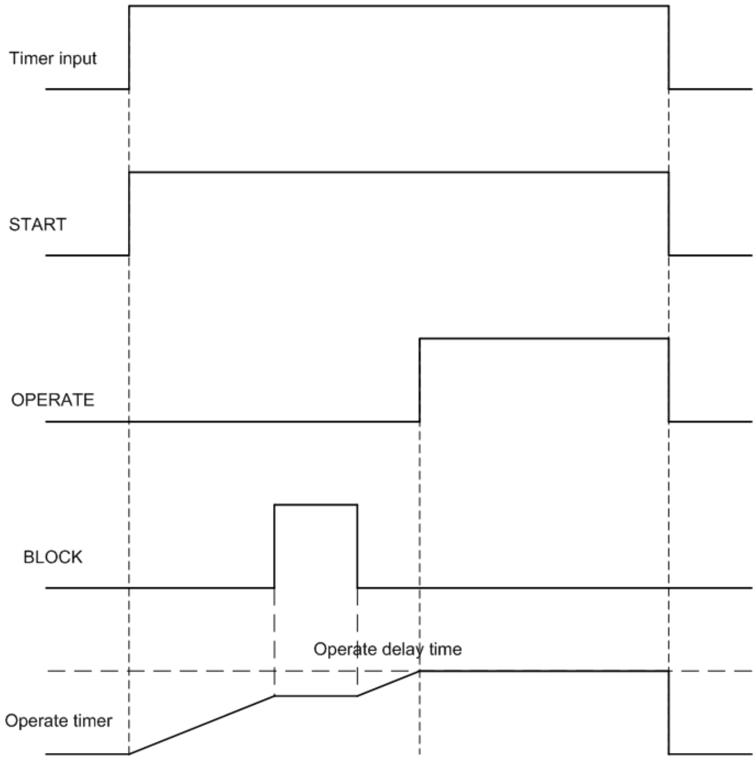


Figure 212: Operating effect of the `BLOCK` *input when the selected blocking mode is "Freeze timer"*

If the `BLOCK` input is activated when the operate timer is running, as described in Figure 212, 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 210, 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 operation time depends on the momentary value of the current: the higher the current, the faster the operation time. The operation 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 curve scaling is determined with the *Time multiplier* setting.

There are two methods to level out the inverse-time characteristic.

- The *Minimum operate time* setting defines the minimum operating time for the IDMT curve, that is, the operation time is always at least the *Minimum operate time* setting.
- Alternatively, the *IDMT Sat point* is used for giving the leveling-out point as a multiple of the *Start value* setting. (Global setting: **Configuration/System/*IDMT Sat point***). The default parameter value is 50. This setting affects only the overcurrent and earth-fault IDMT timers.

IDMT operation time at currents over 50 x In is not guaranteed.

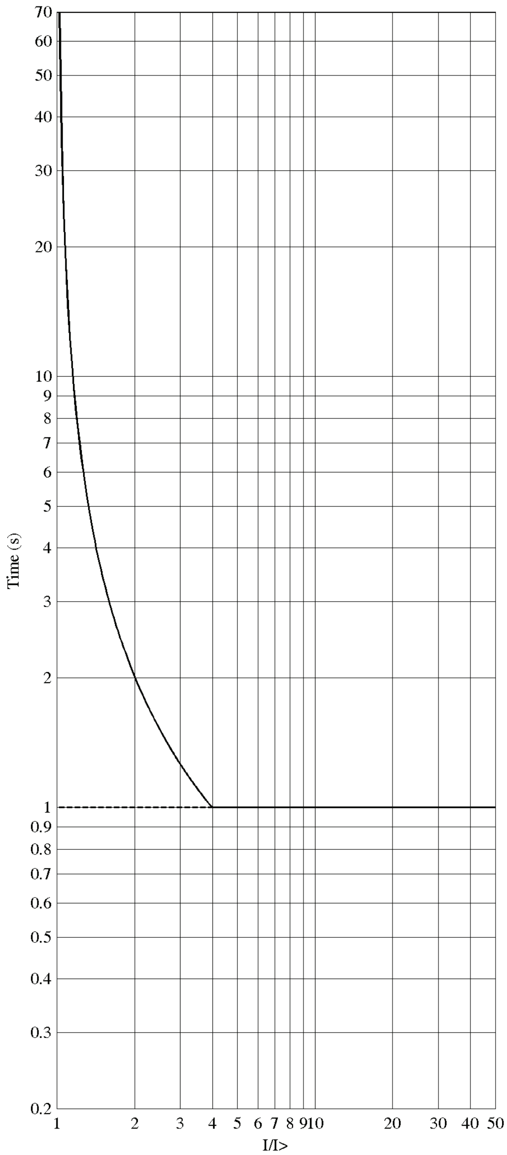


Figure 213: Operation time curve based on the IDMT characteristic leveled out with the Minimum operate time setting is set to 1000 milliseconds (the IDMT Sat point setting is set to maximum).

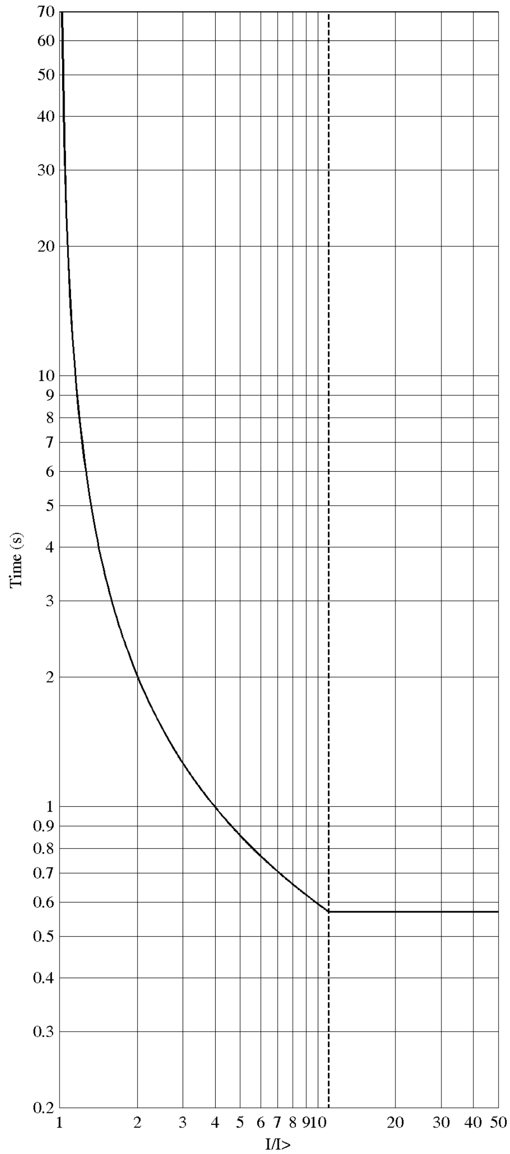


Figure 214: Operation time curve based on the IDMT characteristic leveled out with IDMT Sat point setting value “11” (the Minimum operate time setting is set to minimum).

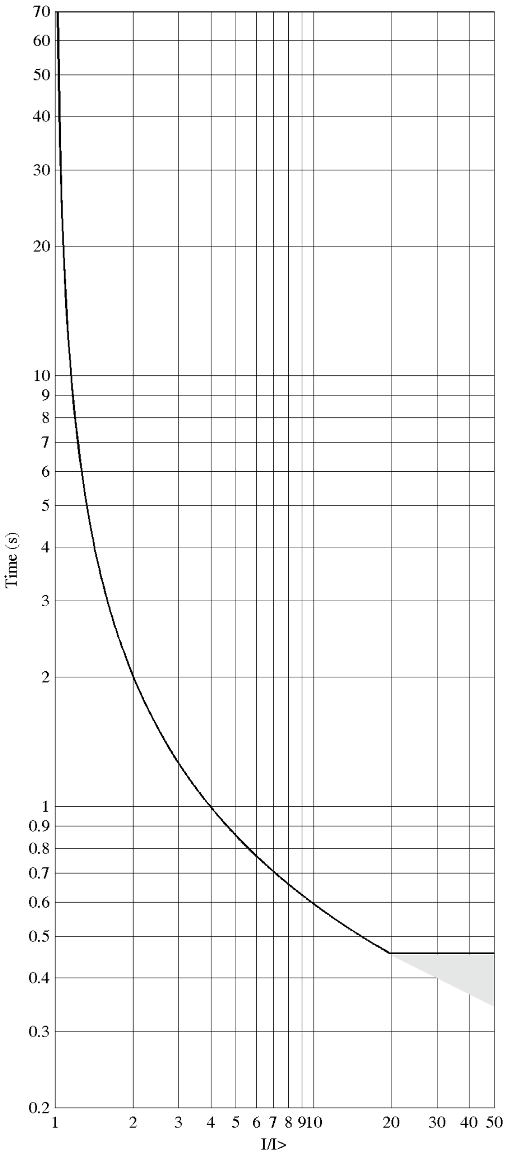


Figure 215: Example of how the inverse time characteristic is leveled out with currents over 50 x In and the Setting Start value setting "2.5 x In". (the IDMT Sat point setting is set to maximum and the Minimum operate time setting is set to minimum).

The grey zone in Figure 215 shows the behavior of the curve in case the measured current is outside the guaranteed measuring range. Also, the maximum measured current of 50 x In gives the leveling-out point 50/2.5 = 20 x I/I>.

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 32)

t[s] Operate time in seconds

I Measured current

I> Set *Start value*

k Set *Time multiplier*

Table 448: 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

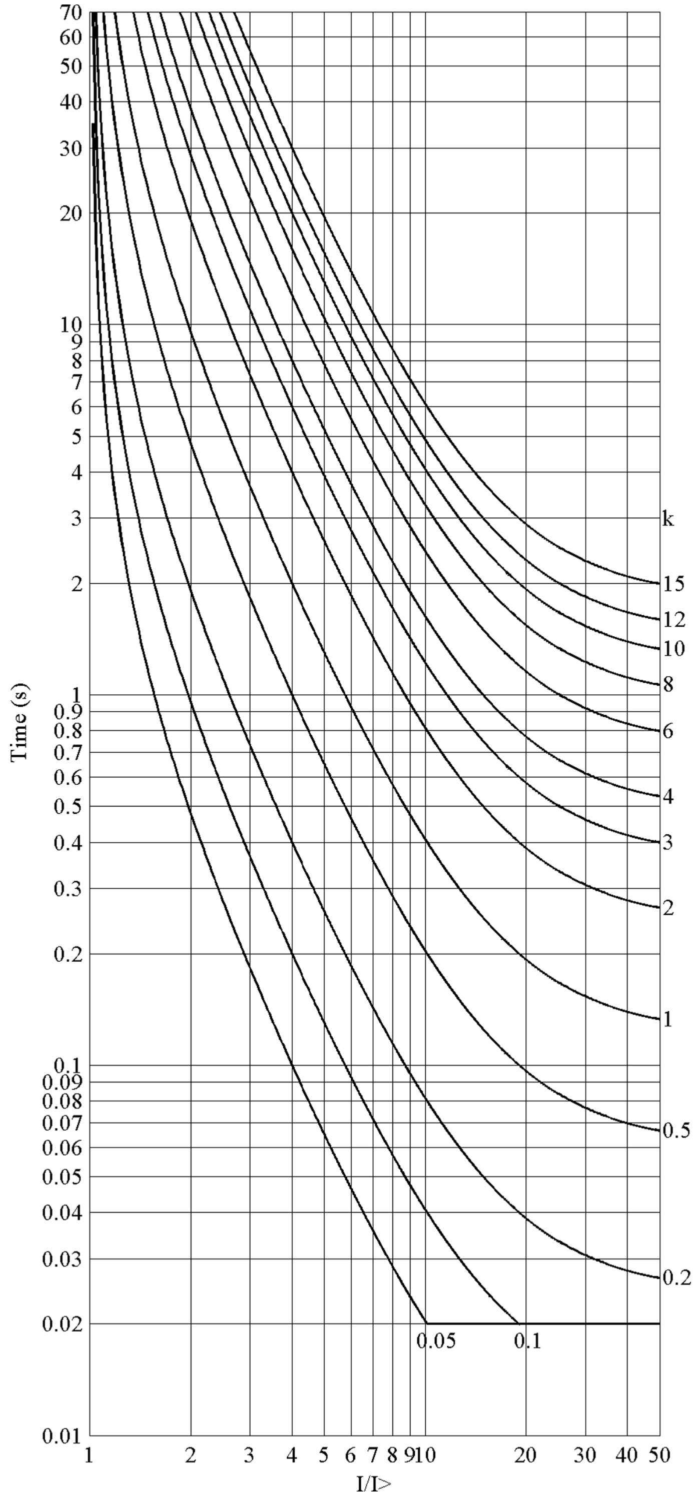


Figure 216: ANSI extremely inverse-time characteristics

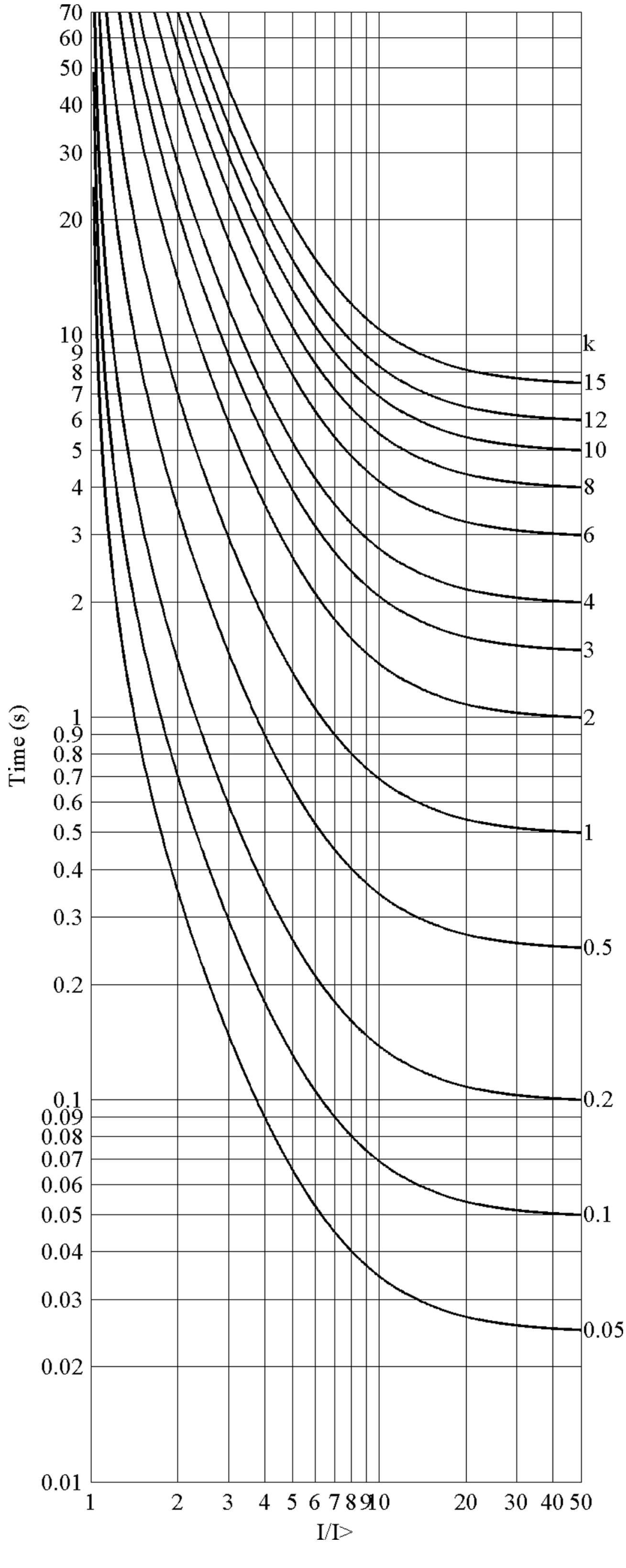


Figure 217: ANSI very inverse-time characteristics

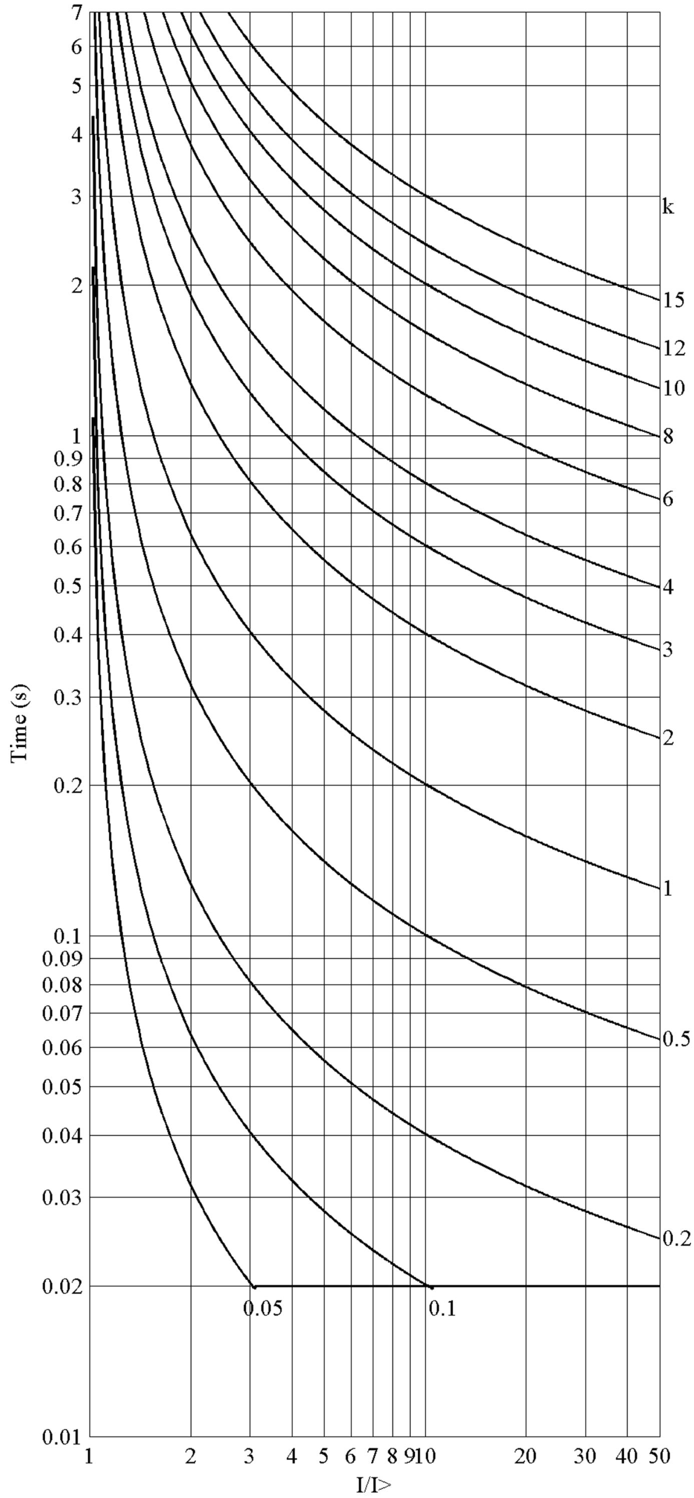


Figure 218: ANSI normal inverse-time characteristics

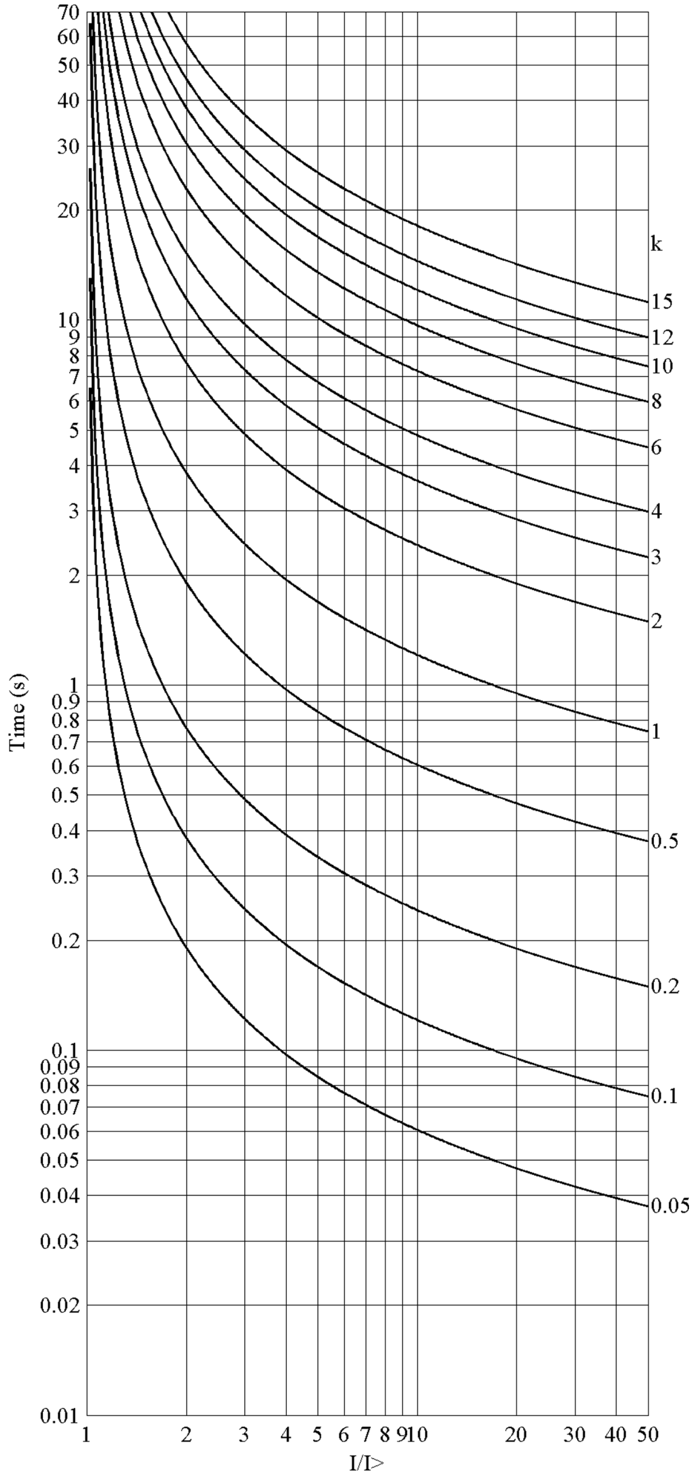


Figure 219: ANSI moderately inverse-time characteristics

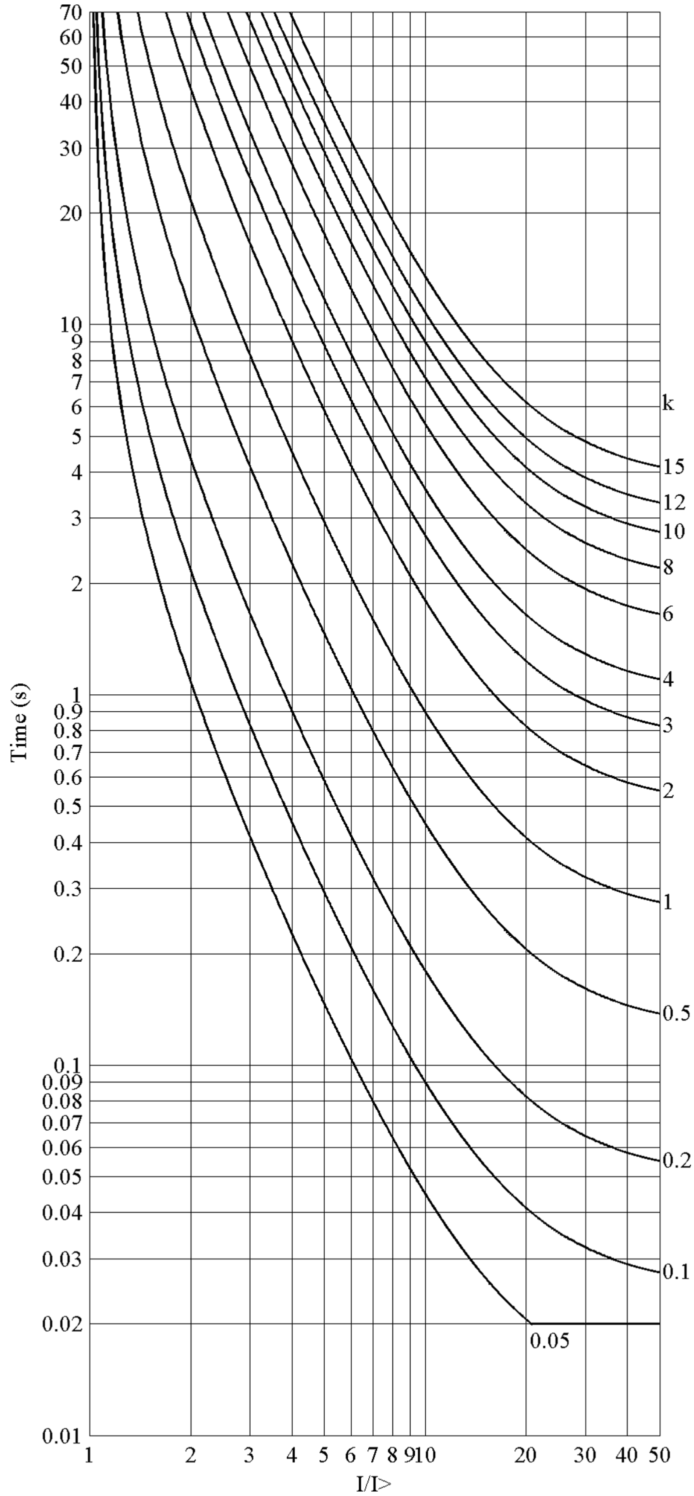


Figure 220: ANSI long-time extremely inverse-time characteristics

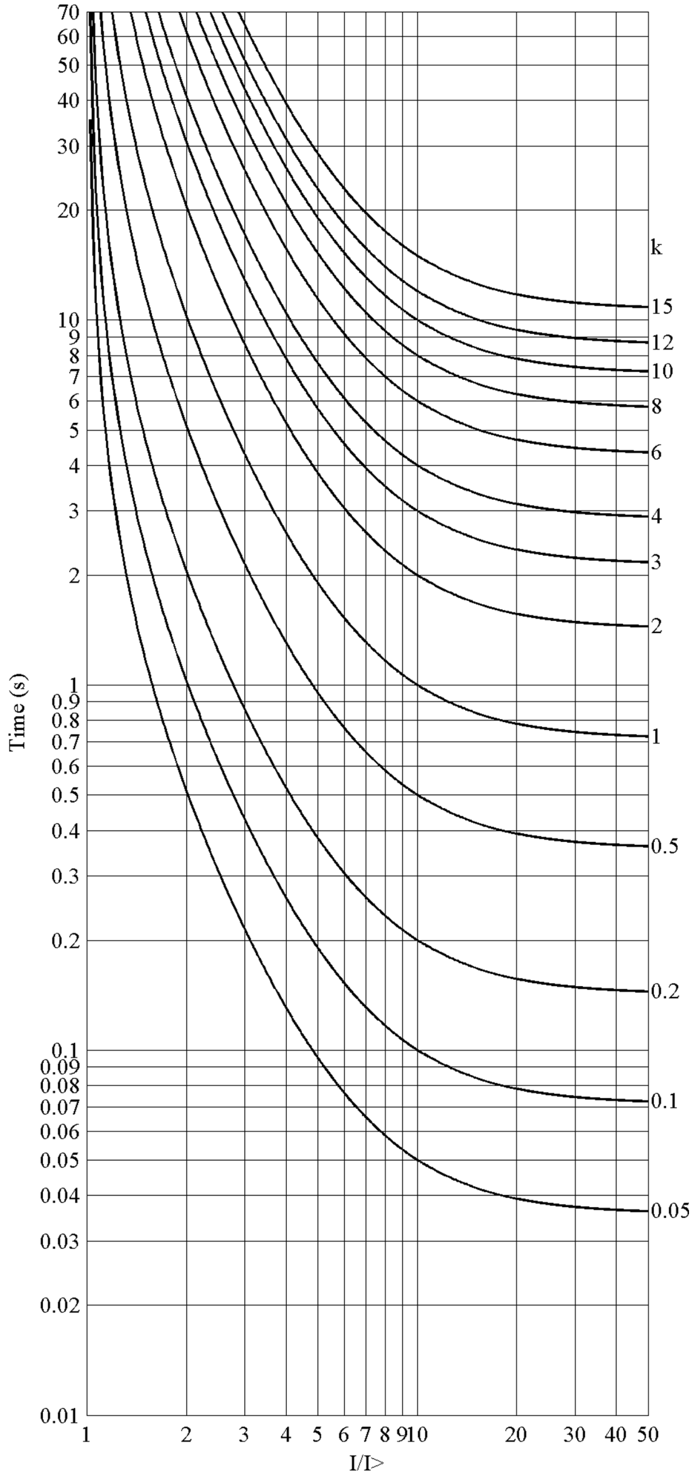


Figure 221: ANSI long-time very inverse-time characteristics

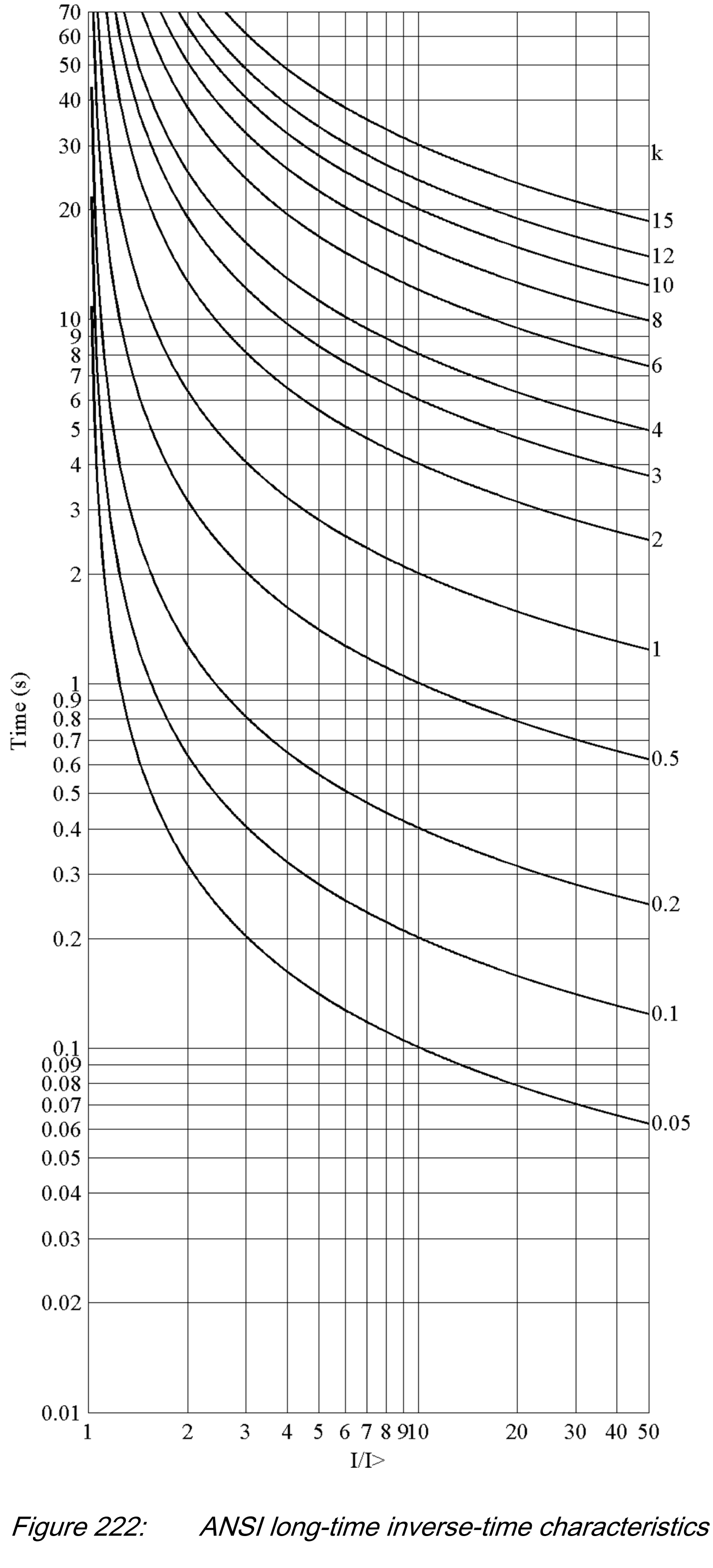


Figure 222: ANSI long-time inverse-time characteristics

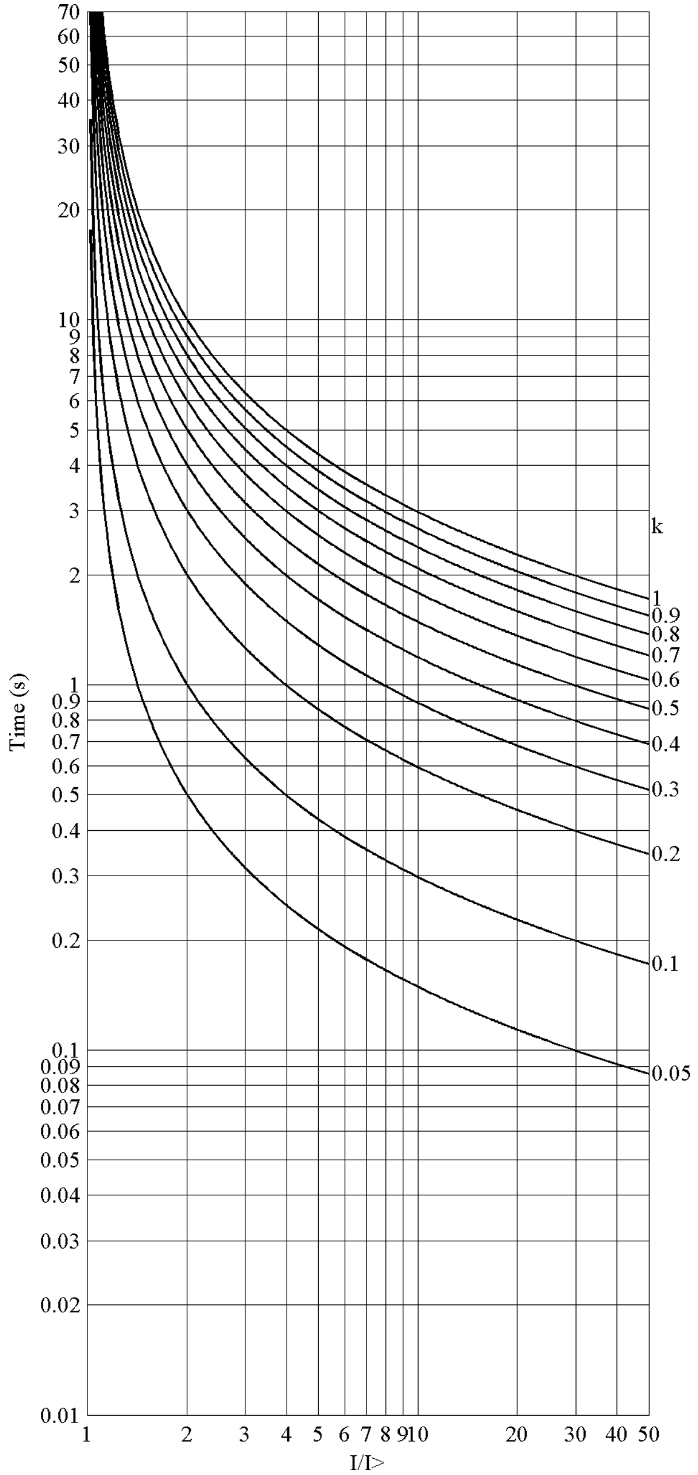


Figure 223: IEC normal inverse-time characteristics

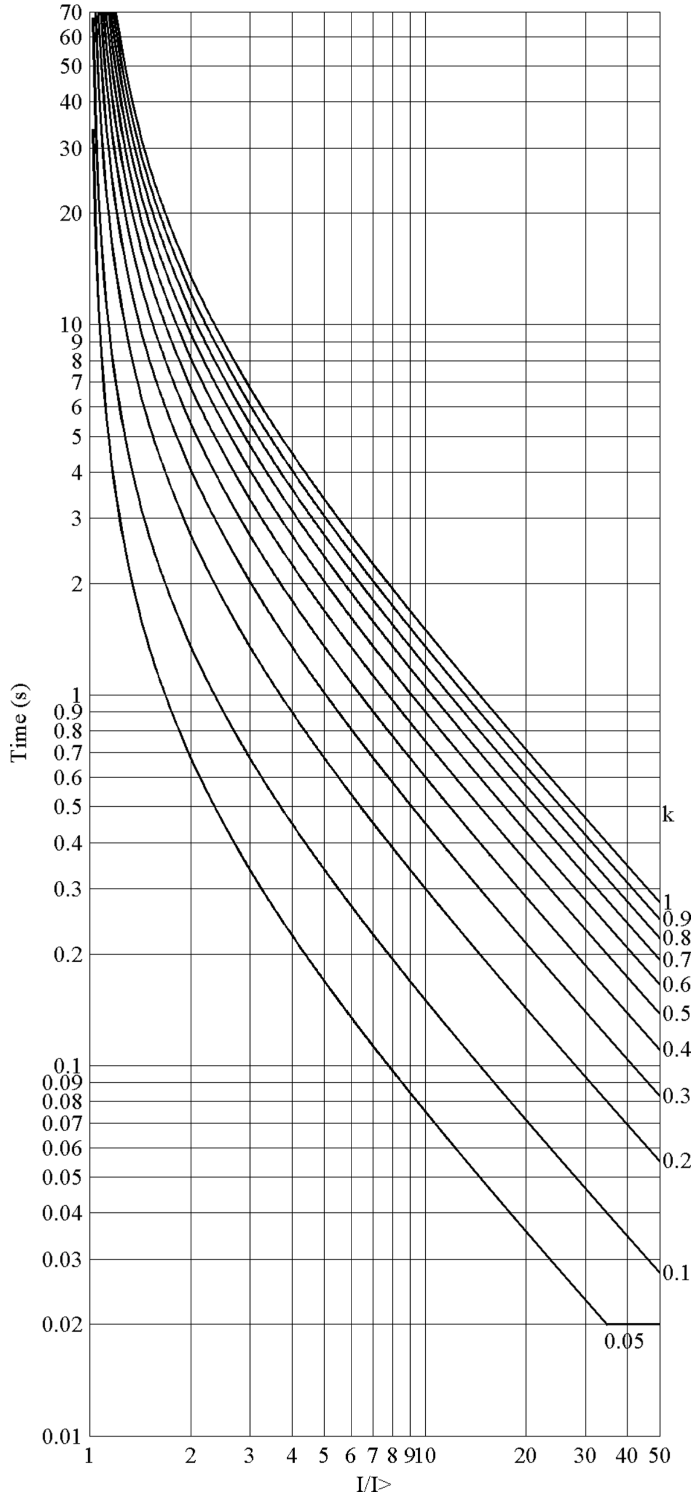


Figure 224: IEC very inverse-time characteristics

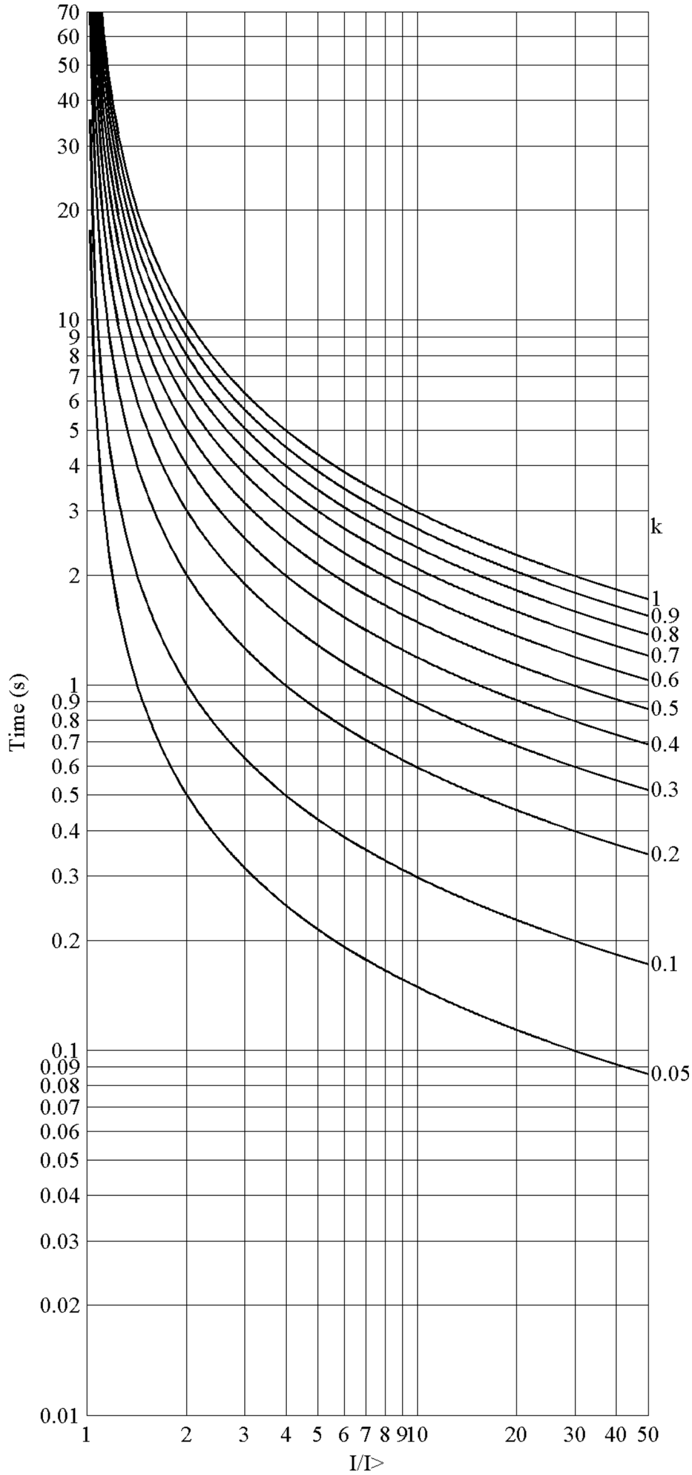


Figure 225: IEC inverse-time characteristics

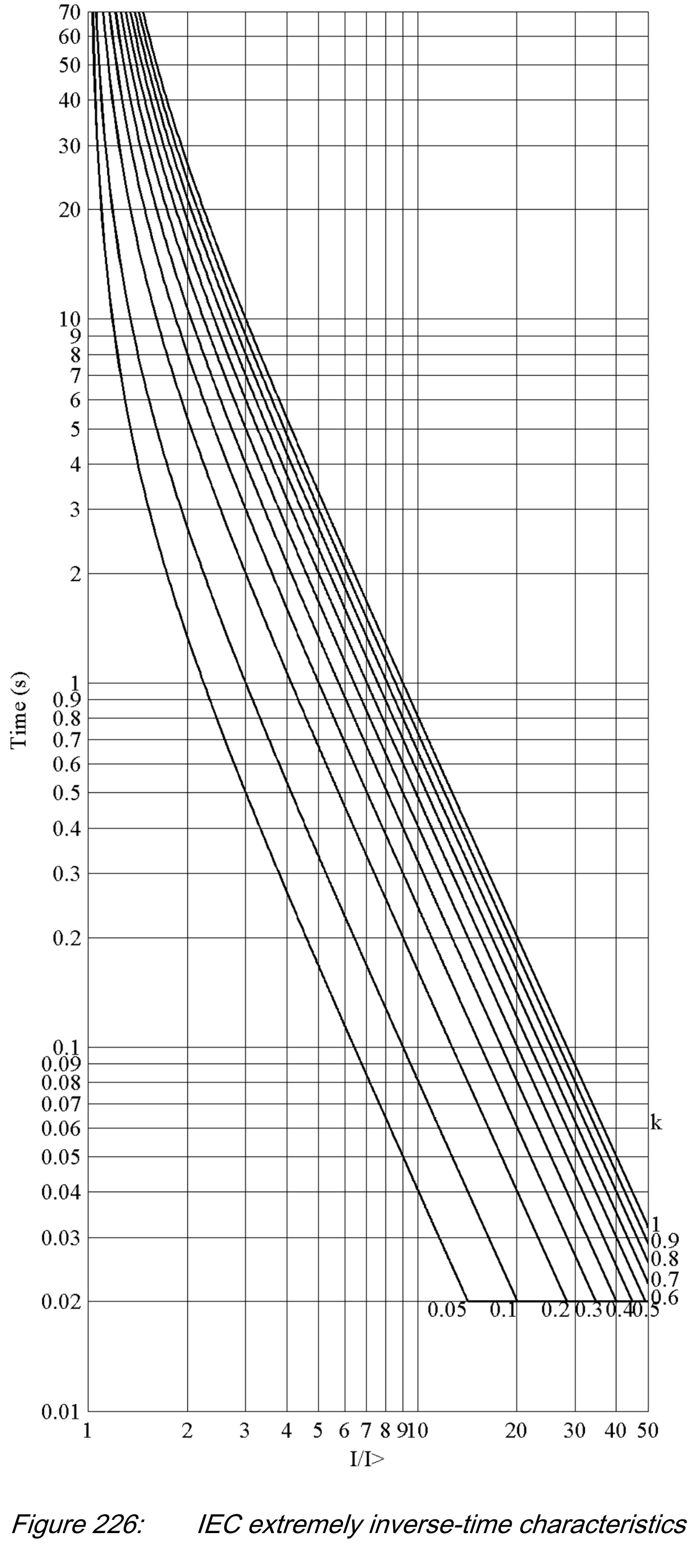


Figure 226: IEC extremely inverse-time characteristics

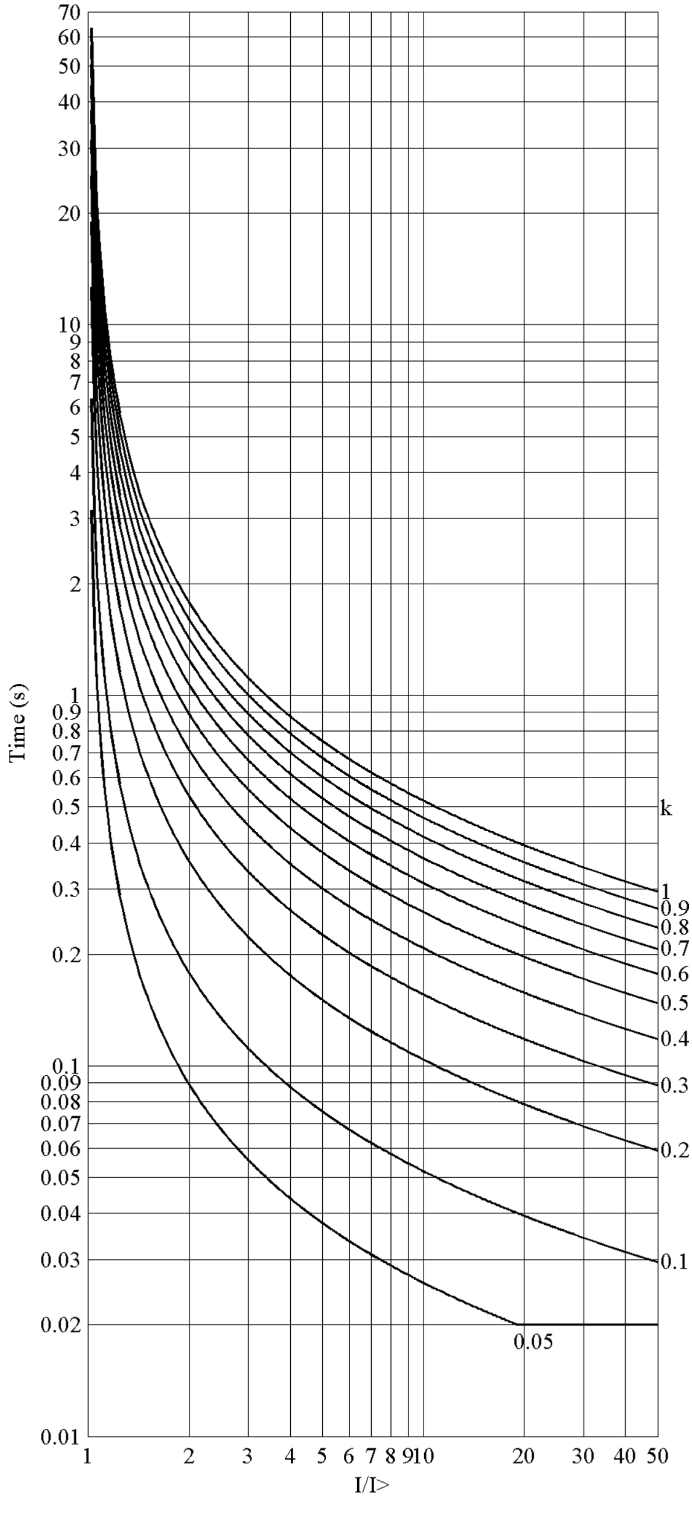


Figure 227: IEC short-time inverse-time characteristics

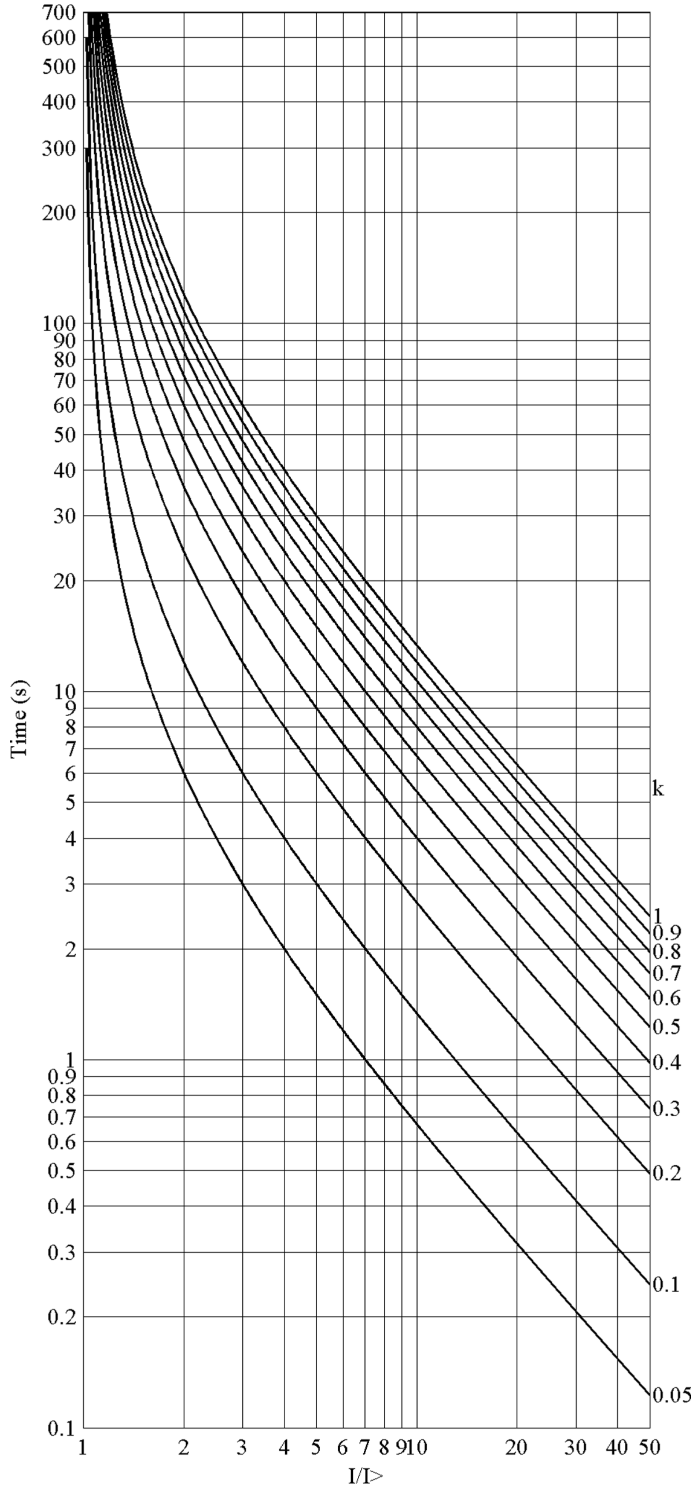


Figure 228: IEC long-time inverse-time characteristics

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 33)

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

$$t[s] = \left(\frac{k}{0.339 - 0.236 \cdot \frac{I>}{I}} \right)$$

(Equation 34)

The RD-type is calculated using the formula

$$t[s] = 5.8 - 1.35 \cdot ln\left(\frac{I}{k \cdot I>} \right)$$

(Equation 35)

t[s]	Operate time (in seconds)
k	Set *Time multiplier*
I	Measured current
I>	Set *Start value*

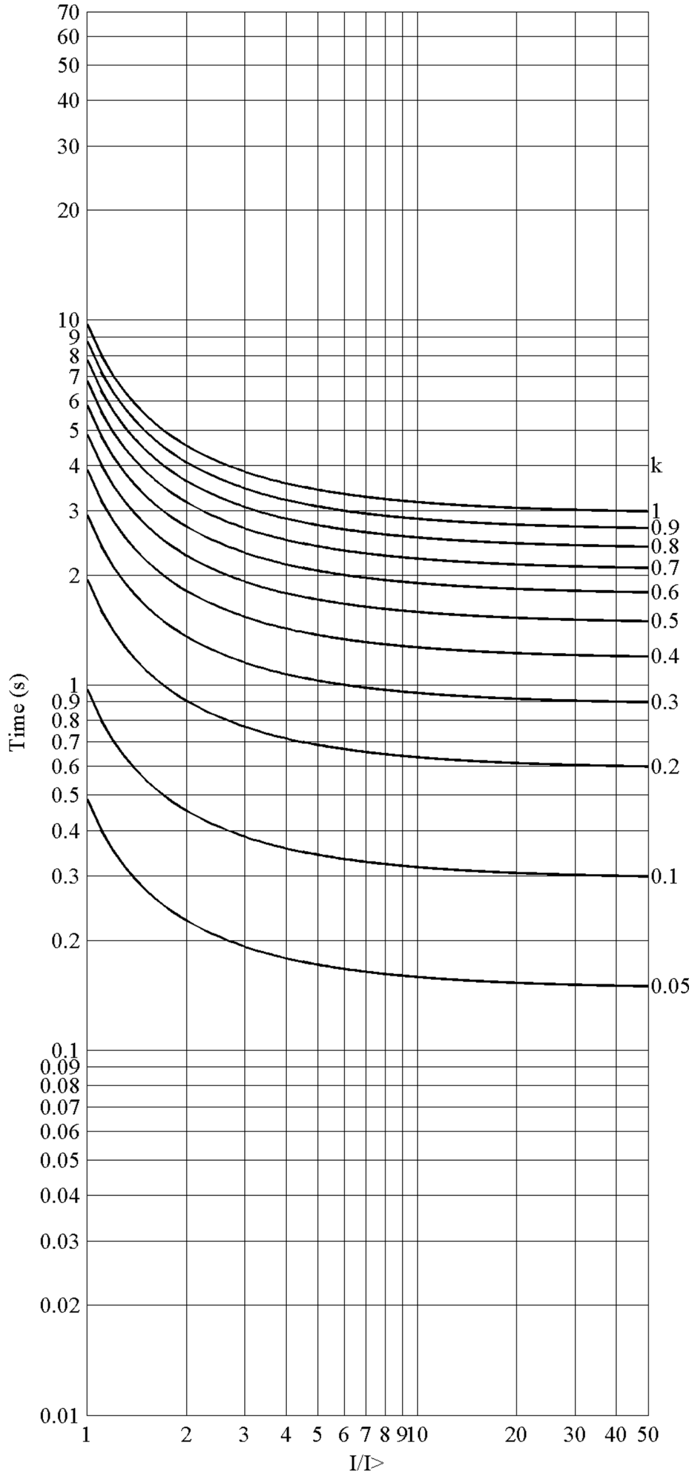


Figure 229: RI-type inverse-time characteristics

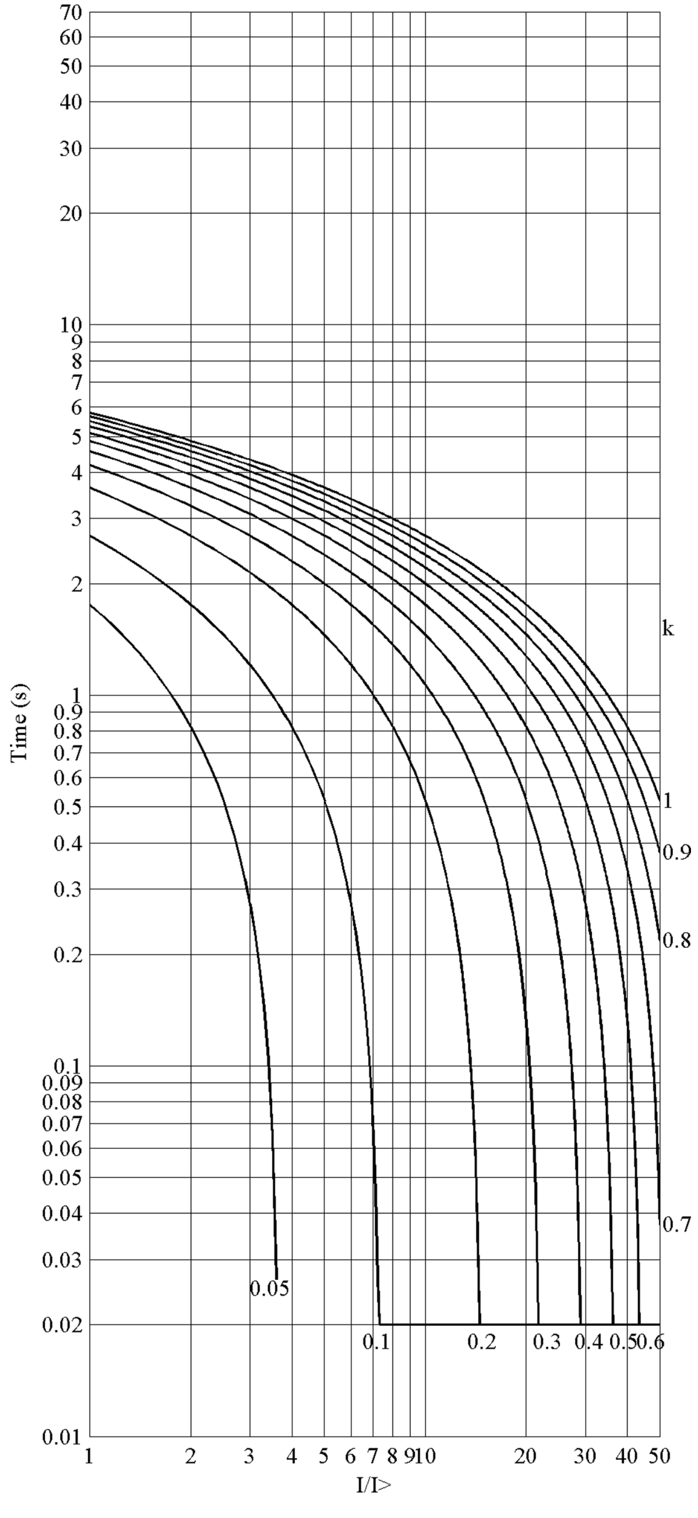


Figure 230: RD-type inverse-time characteristics

10.2.2 Reset in inverse-time modes

The user can select the reset characteristics by using the *Type of reset curve* setting.

Table 449: 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 36)

t[s] Reset time (in seconds)

k Set *Time multiplier*

I Measured current

I> Set *Start value*

Table 450: 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

The delayed inverse reset time depends also on the protection function's start duration value START_DUR. The reset time on the drop-off moment can be calculated by multiplying t[s] with START_DUR.

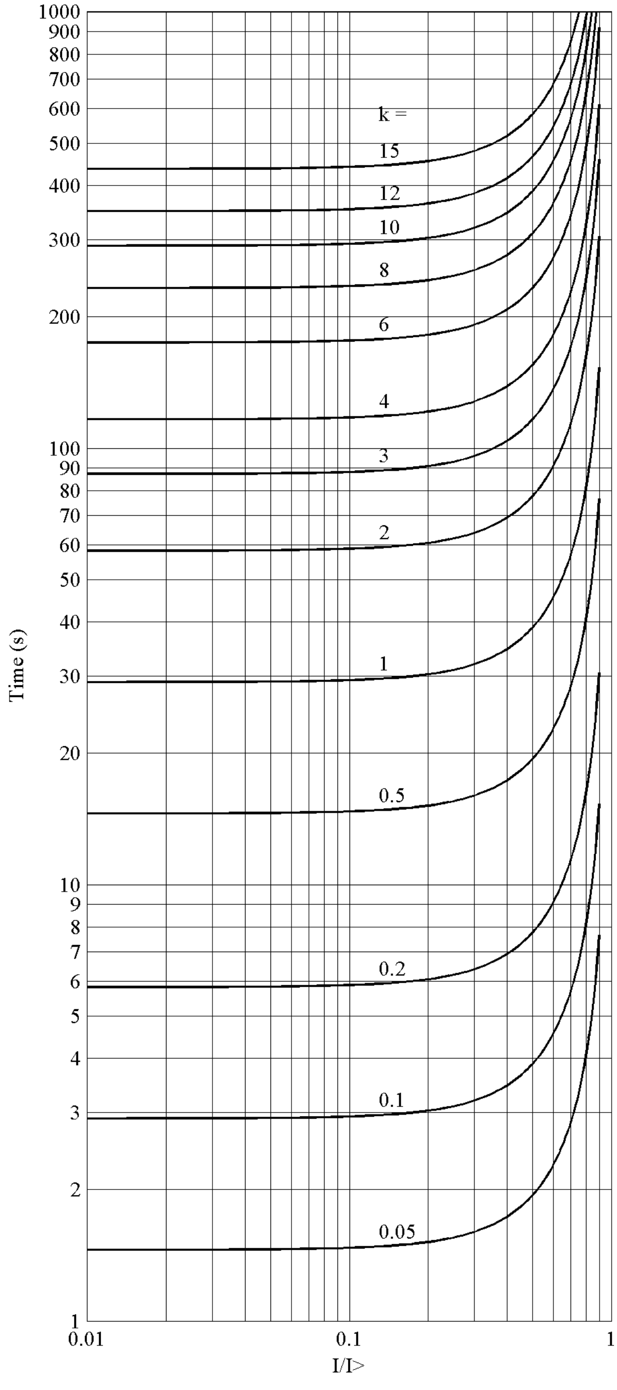


Figure 231: ANSI extremely inverse reset time characteristics

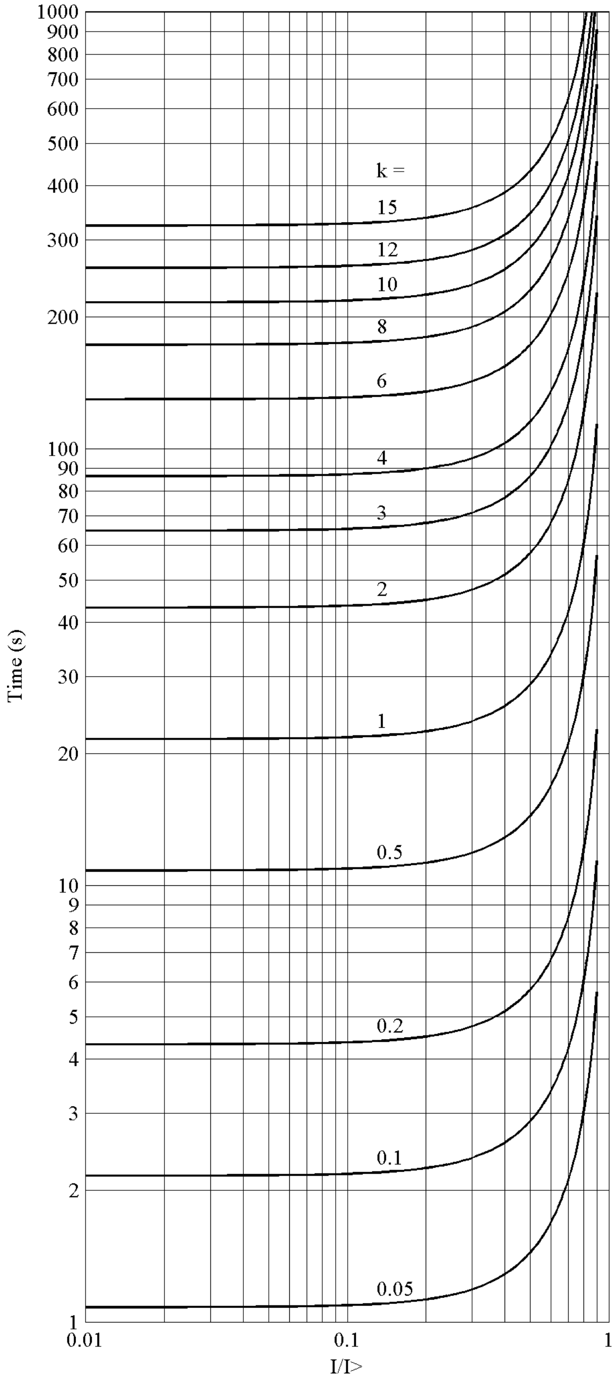


Figure 232: ANSI very inverse reset time characteristics

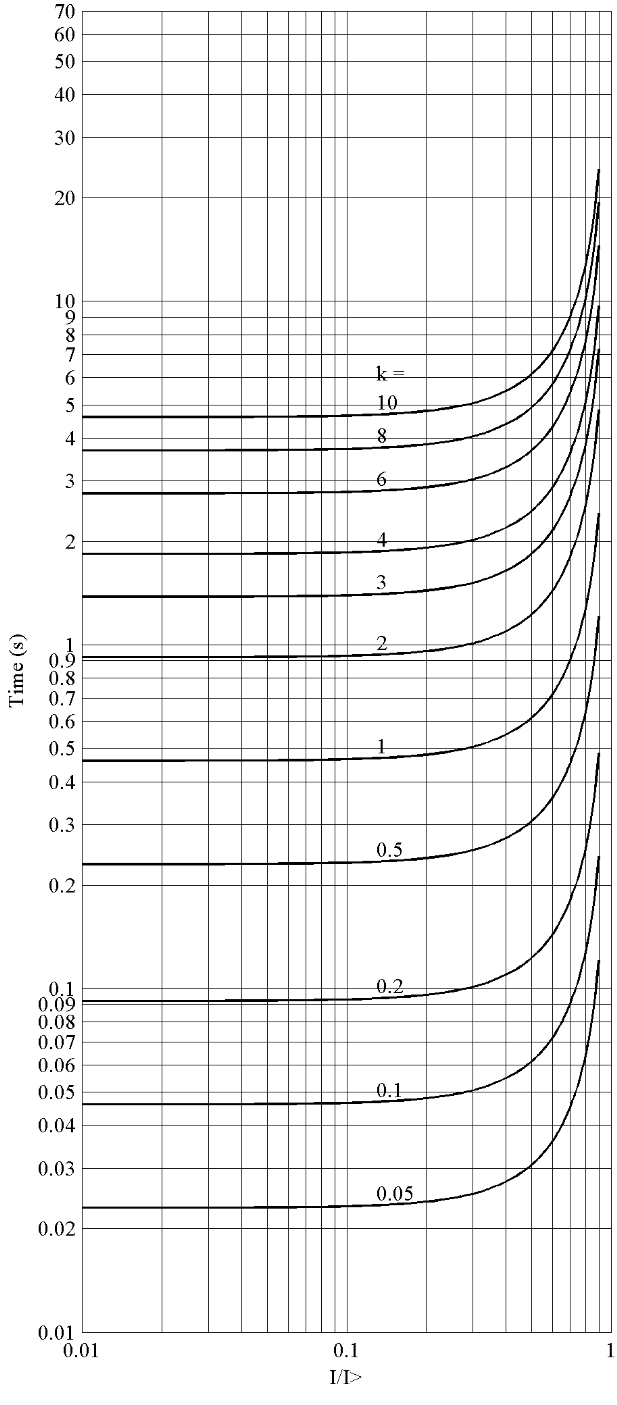


Figure 233: ANSI normal inverse reset time characteristics

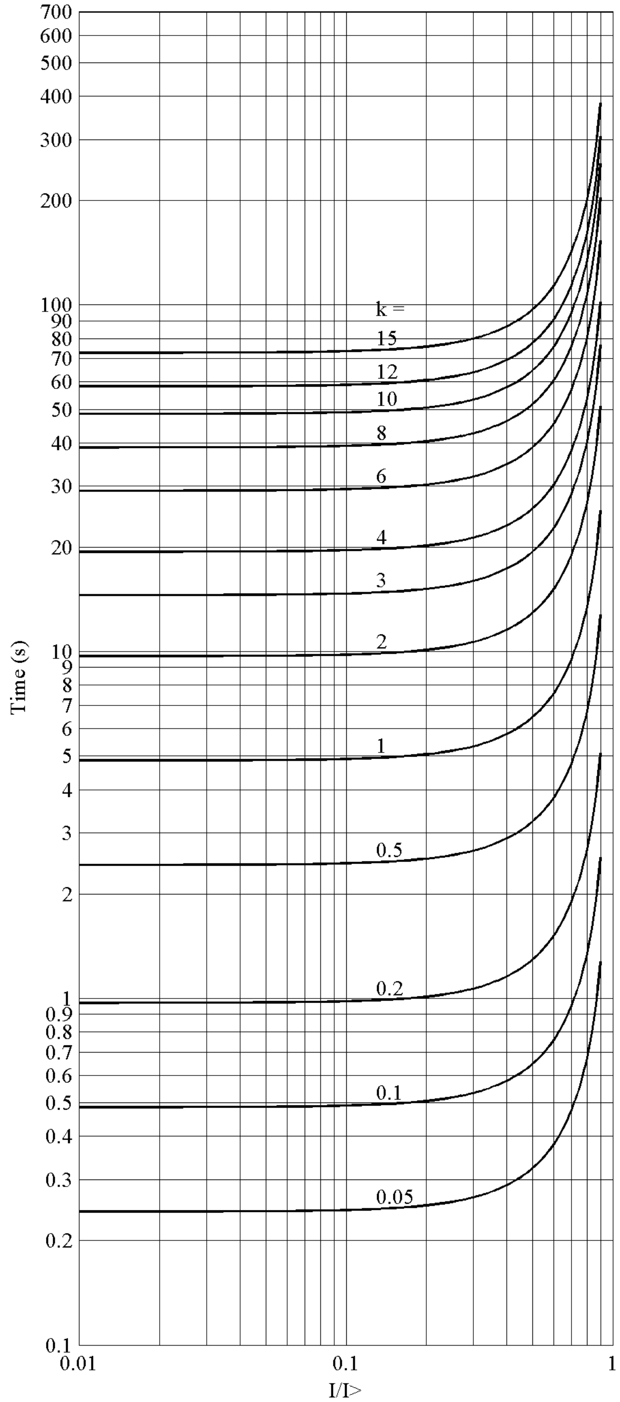


Figure 234: ANSI moderately inverse reset time characteristics

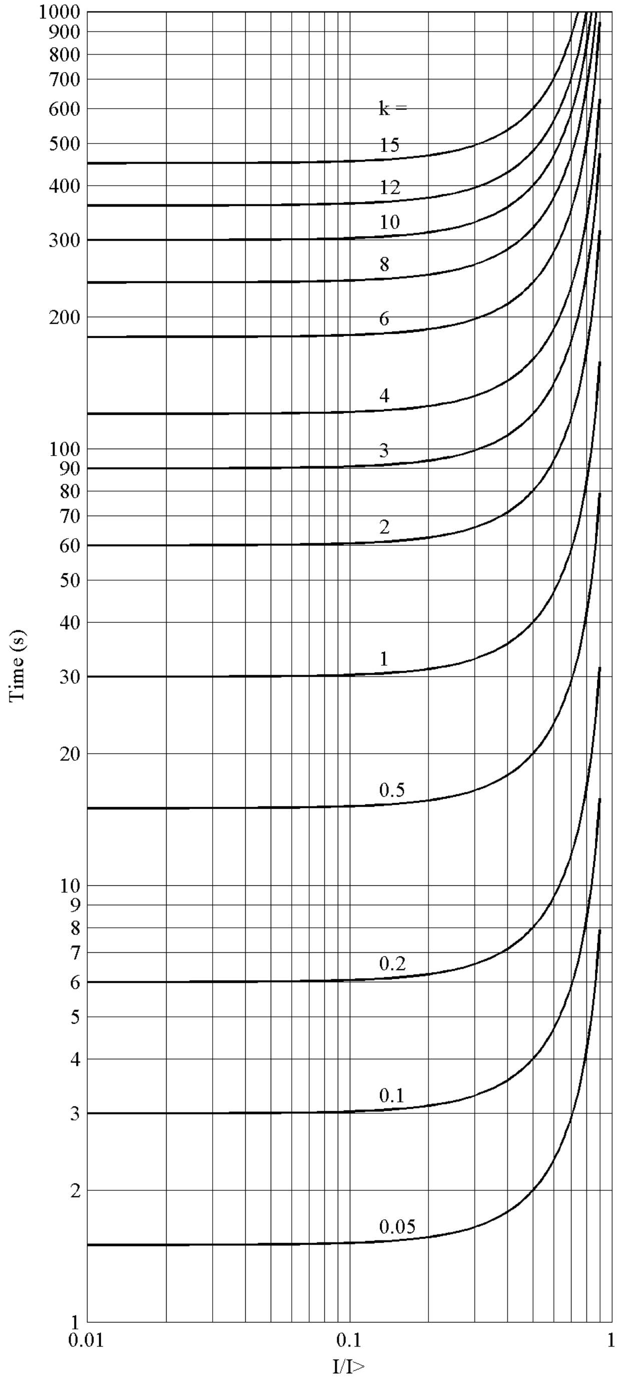


Figure 235: ANSI long-time extremely inverse reset time characteristics

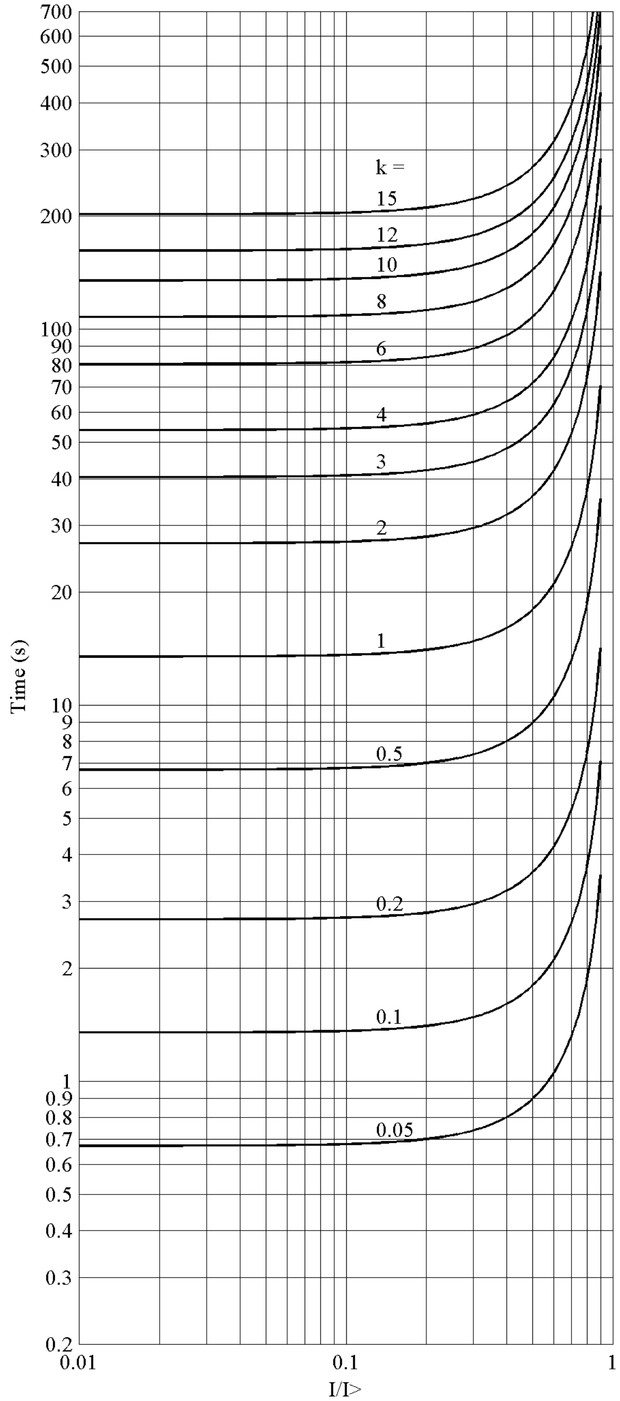


Figure 236: ANSI long-time very inverse reset time characteristics

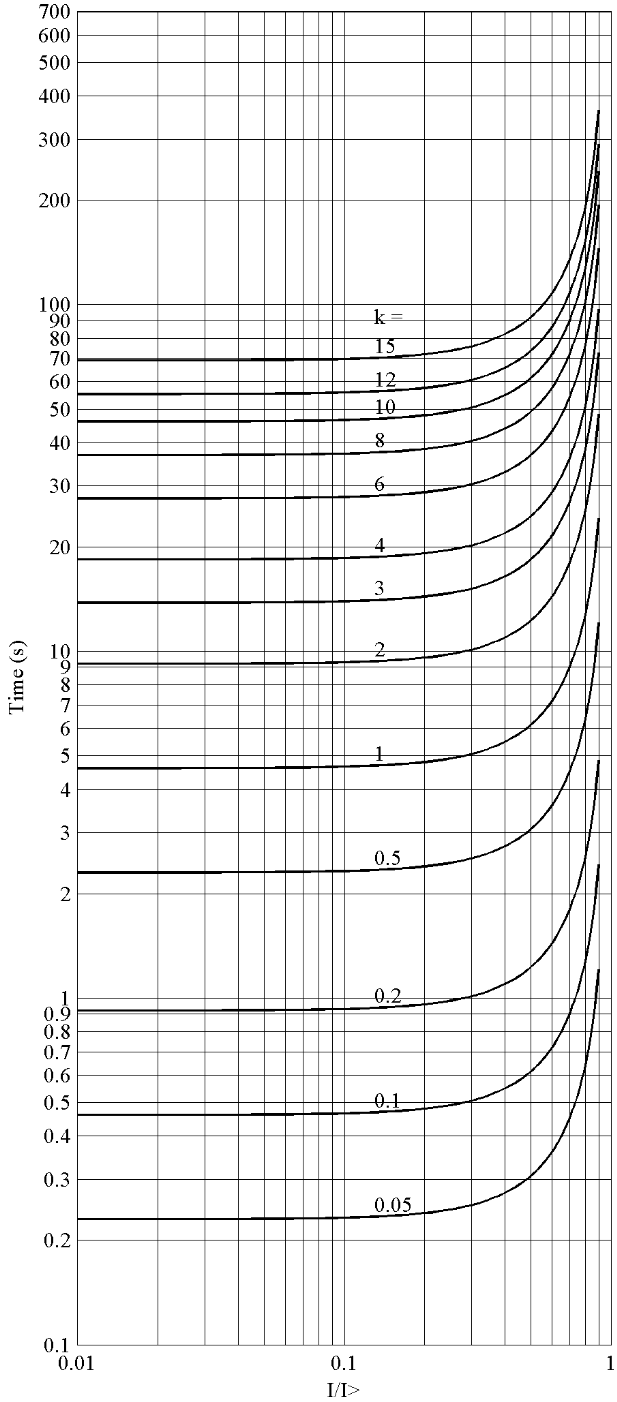


Figure 237: ANSI long-time inverse reset time characteristics

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 37)

The delayed inverse reset time depends also on the protection function's start duration value START_DUR. The reset time on the drop-off moment can be calculated by multiplying t[s] with START_DUR.

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 a protection relay needs to be blocked to enable the definite-time operation of another protection relay 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:

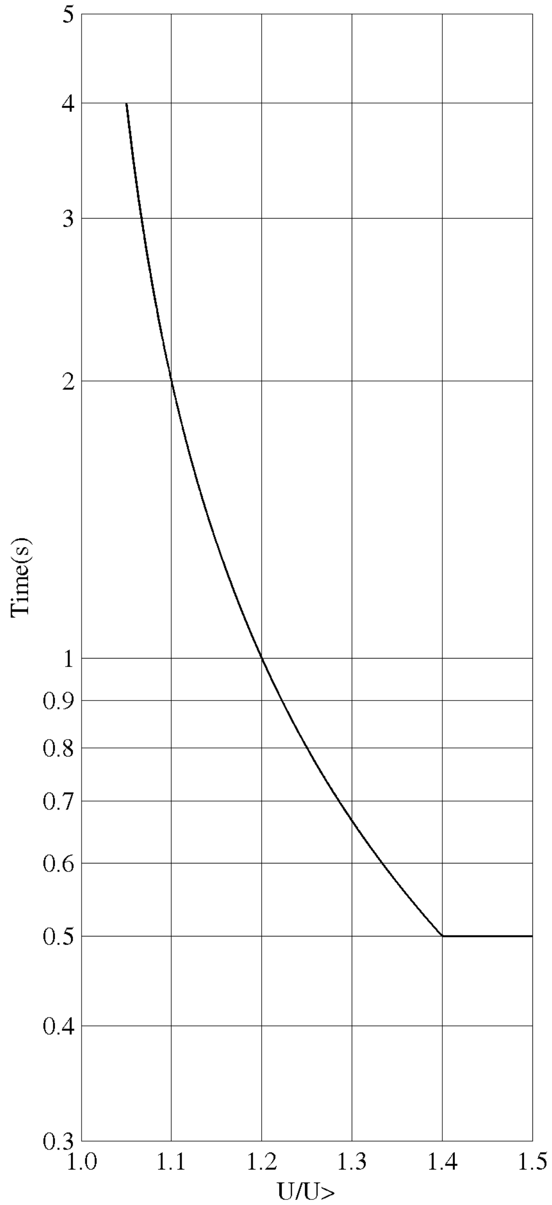


Figure 238: Operate time curve based on IDMT characteristic with Minimum operate time set to 0.5 second

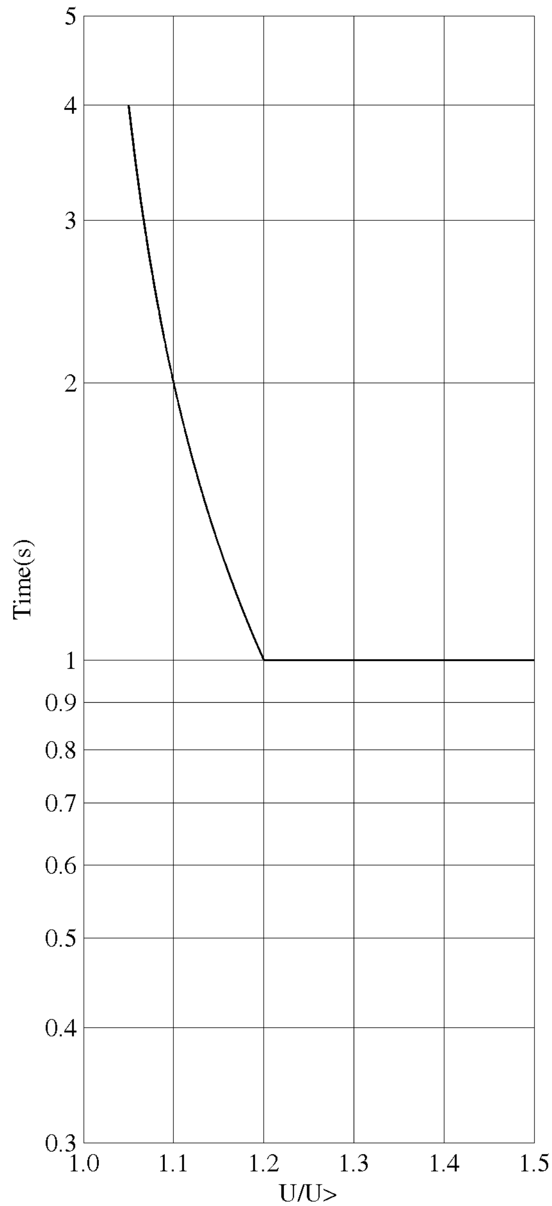


Figure 239: Operate time curve based on IDMT characteristic with Minimum operate time set to 1 second

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:

$$t[s] = \frac{k \cdot A}{\left(B \cdot \frac{U - U>}{U>} - C\right)^{E}} + D$$

(Equation 38)

t [s] Operate time in seconds

U Measured voltage

U> Set value of *Start value*

k Set value of *Time multiplier*

Table 451: Curve coefficients for the 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

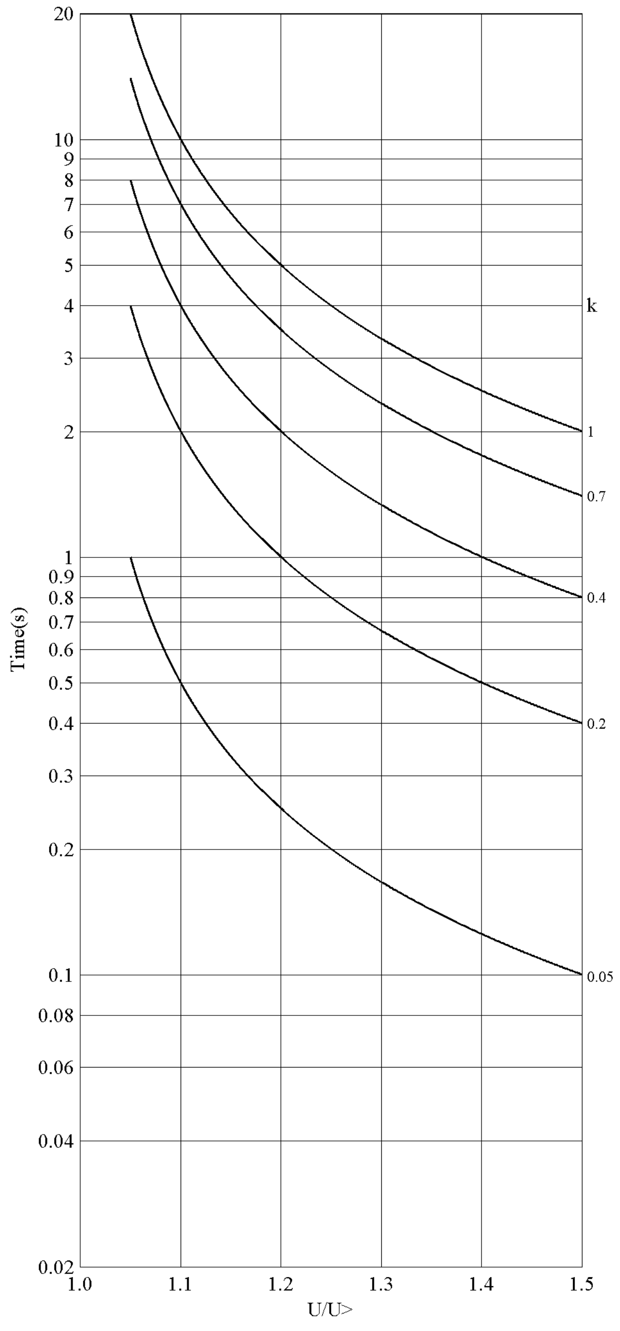


Figure 240: Inverse curve A characteristic of overvoltage protection

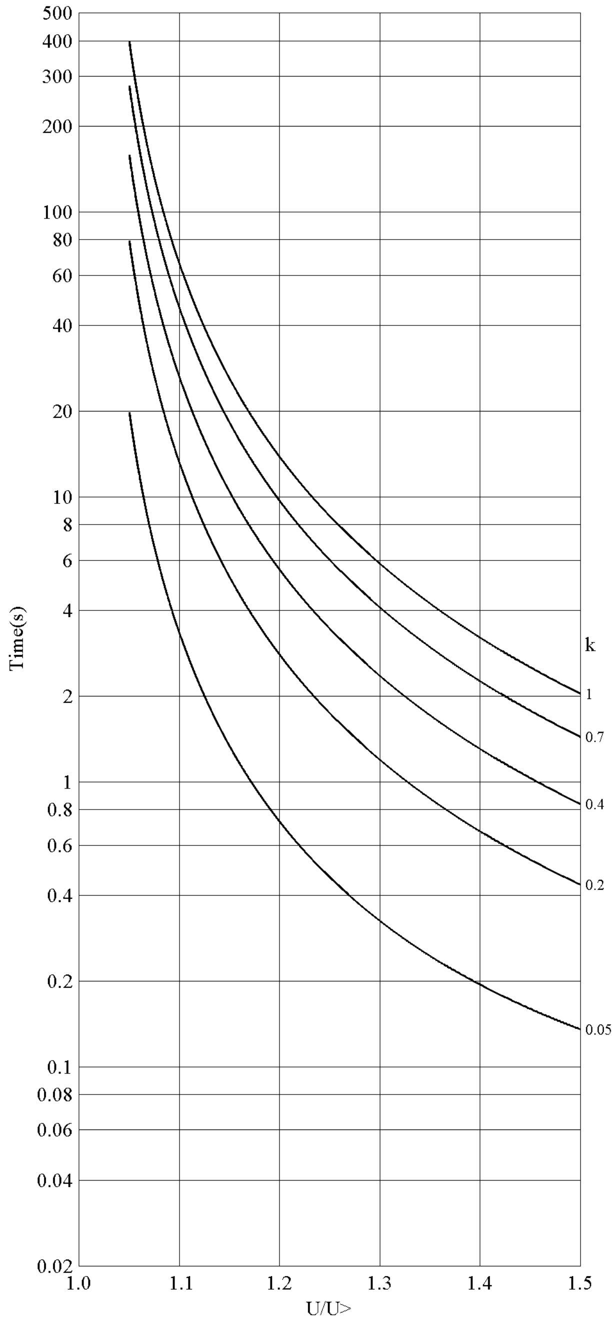


Figure 241: Inverse curve B characteristic of overvoltage protection

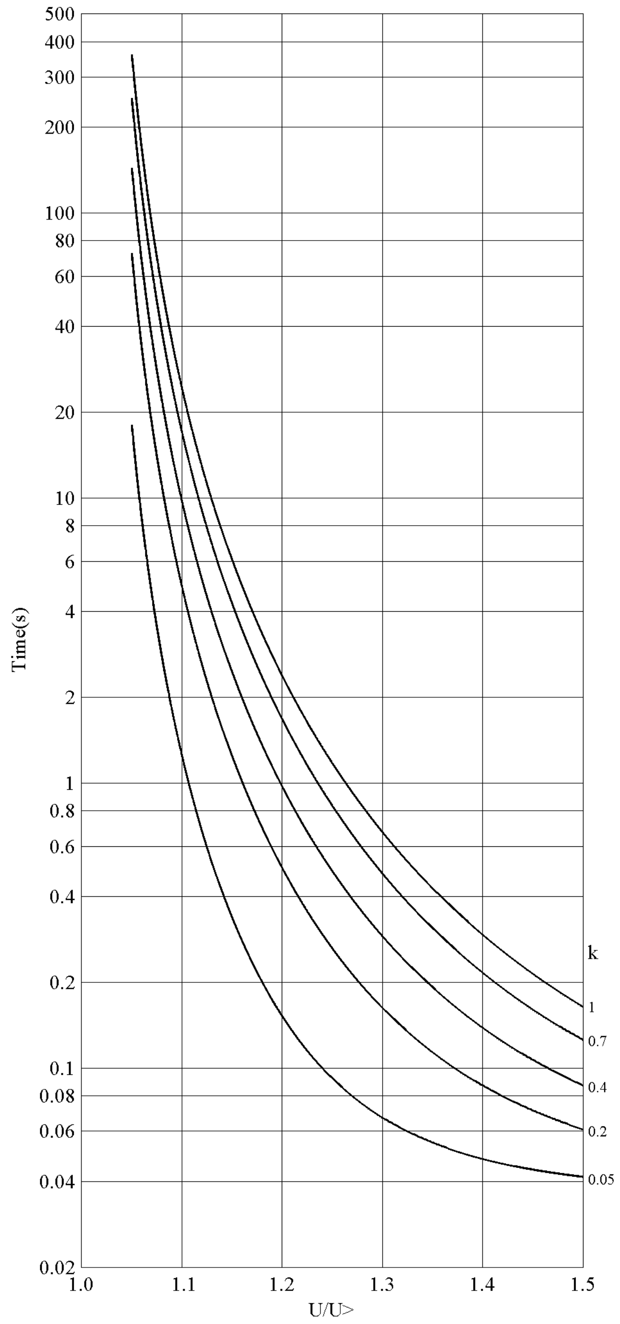


Figure 242: Inverse curve C characteristic of overvoltage protection

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:

$$t[s] = \frac{k \cdot A}{\left(B \cdot \frac{U - U>}{U>} - C\right)^{E}} + D$$

(Equation 39)

t[s]	Operate time in seconds
A	Set value of *Curve parameter A*
B	Set value of *Curve parameter B*
C	Set value of *Curve parameter C*
D	Set value of *Curve parameter D*
E	Set value of *Curve parameter E*
U	Measured voltage
U>	Set value of *Start value*
k	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:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \cdot \frac{U< - U}{U<} - C\right)^{E}} + D$$

(Equation 40)

t [s]	Operate time in seconds
U	Measured voltage
U<	Set value of the *Start value* setting
k	Set value of the *Time multiplier* setting

Table 452: 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

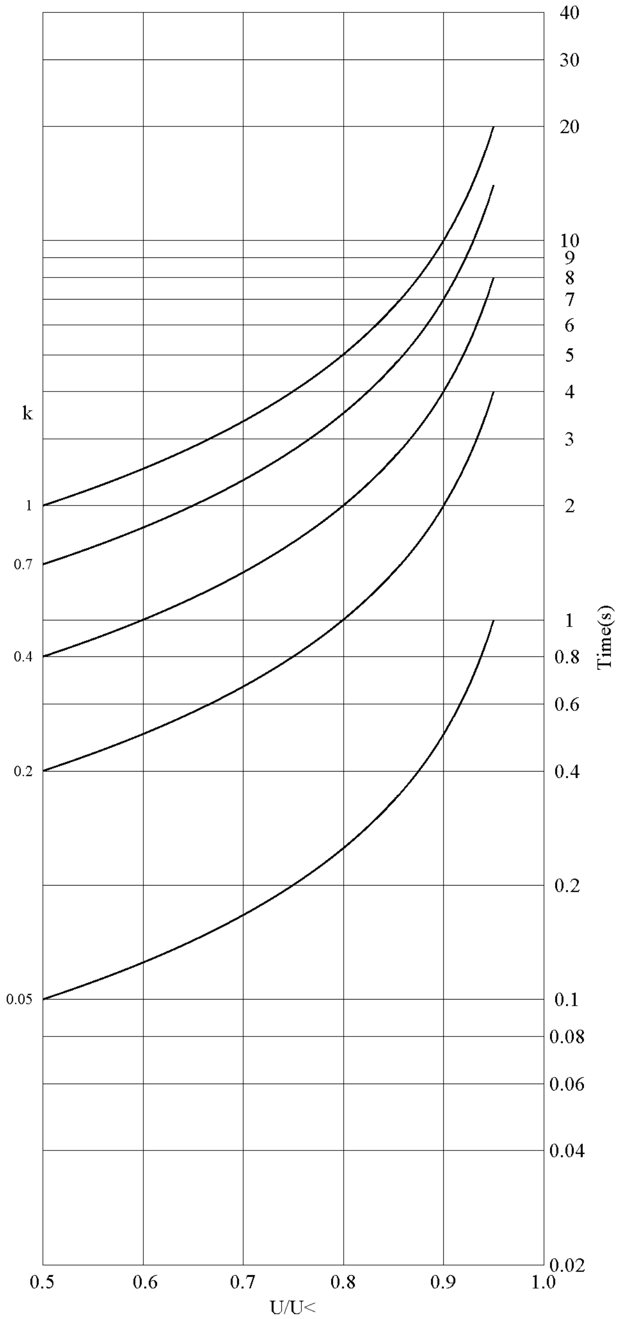


Figure 243: Inverse curve A characteristic of undervoltage protection

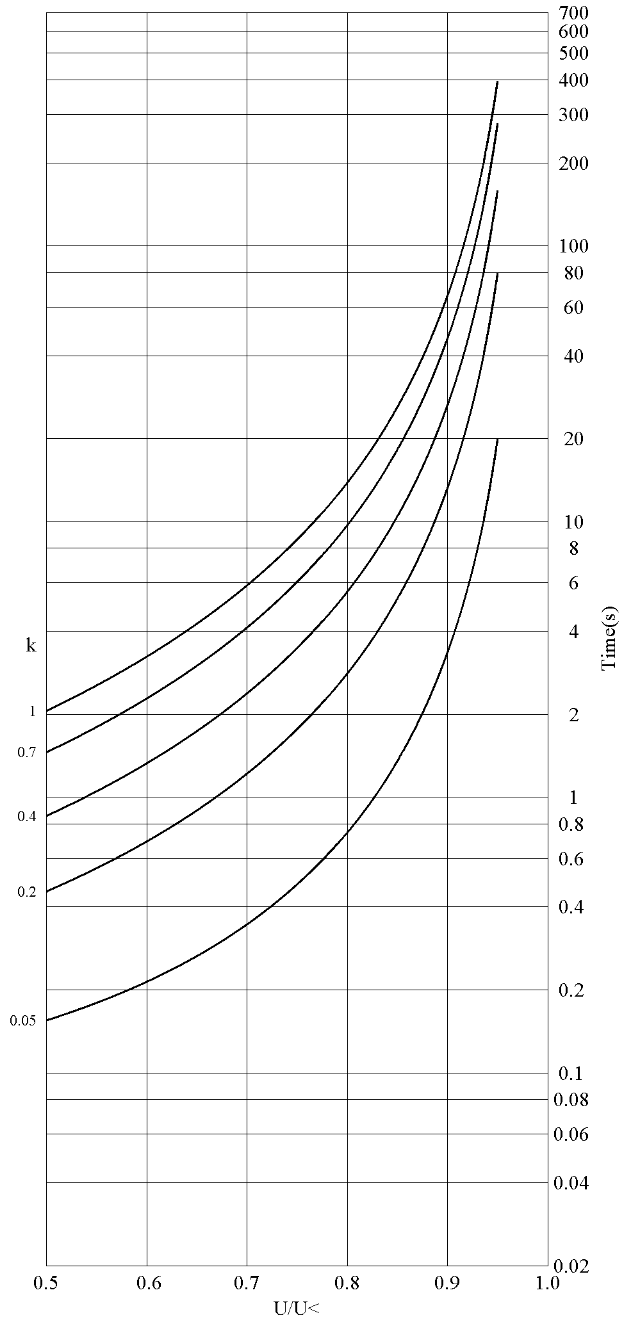


Figure 244: Inverse curve B characteristic of undervoltage protection

10.3.2.2 User-programmable inverse-time characteristics for undervoltage protection

The user can define curves by entering parameters into the standard formula:

$$t\left[s\right] = \frac{k \cdot A}{\left(B \cdot \frac{U< - U}{U<} - C\right)^{E}} + D$$

(Equation 41)

t[s]	Operate time in seconds
A	Set value of *Curve parameter A*
B	Set value of *Curve parameter B*
C	Set value of *Curve parameter C*
D	Set value of *Curve parameter D*
E	Set value of *Curve parameter E*
U	Measured voltage
U<	Set value of *Start value*
k	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 various alternative measuring principles.

- RMS
- DFT which is a numerically calculated fundamental component of the signal
- Peak-to-peak
- Peak-to-peak with peak backup
- Wide peak-to-peak

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 · 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 42)

n Number of samples in a calculation cycle

I_i 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 protection relay 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.

Wide peak-to-peak

The wide peak-to-peak measurement principle is available in products where it is necessary for overcurrent protection to operate already starting from as low frequency as 2 Hz during the generator start-up or shutdown phase. The wide peak-to-peak measurement principle is selected with the *Measurement mode* setting "Wide P-to-P".

The measurement mode calculates the average from the positive and negative peak values over the 500 ms wide measurement window. Retardation and reset times are longer due to the length of the measurement window. The frequency of the fault current affects the operate time. The damping of the harmonics is quite low and practically determined by the characteristics of the anti-aliasing filter of the protection relay current inputs.

When using measurement mode “Wide P-to-P”, the protection relay accepts only *Operate delay time* setting value 800 ms or longer and *Operating curve type* 5=”ANSI Def. Time” or 15=”IEC Def. Time”. These settings should be used for all six setting groups. If the settings are applied only in the active setting group, the validation is not satisfied and the setting commit fails.

Operation accuracy in the frequency range 2...85 Hz is ±1.5% or ±0.003 xI_n.
Operate time accuracy in definite time mode is ±1.0% of the set value or ±60 ms when I_{Fault} = 2 · set *Start value* and the fault current frequency is 10...85 Hz.

10.5 Calculated measurements

Calculated residual current and voltage

The residual current is calculated from the phase currents according to equation:

$$\overline{Io} = -(\bar{I}_A + \bar{I}_B + \bar{I}_C)$$

(Equation 43)

The residual voltage is calculated from the phase-to-earth voltages when the VT connection is selected as “Wye” with the equation:

$$\overline{Uo} = \frac{(\overline{U}_A + \overline{U}_B + \overline{U}_C)}{3}$$

(Equation 44)

Sequence components

The phase-sequence current components are calculated from the phase currents according to:

$$\bar{I}_0 = \frac{(\bar{I}_A + \bar{I}_B + \bar{I}_C)}{3}$$

(Equation 45)

$$\bar{I}_1 = \frac{(\bar{I}_A + a \cdot \bar{I}_B + a^2 \cdot \bar{I}_C)}{3}$$

(Equation 46)

$$\bar{I}_2 = \frac{(\bar{I}_A + a^2 \cdot \bar{I}_B + a \cdot \bar{I}_C)}{3}$$

(Equation 47)

The phase-sequence voltage components are calculated from the phase-to-earth voltages when *VT connection* is selected as “Wye” with the equations:

$$\overline{U}_0 = \frac{(\overline{U}_A + \overline{U}_B + \overline{U}_C)}{3}$$

(Equation 48)

$$\overline{U}_1 = \frac{(\overline{U}_A + a \cdot \overline{U}_B + a^2 \cdot \overline{U}_C)}{3}$$

(Equation 49)

$$\overline{U}_2 = \frac{(\overline{U}_A + a^2 \cdot \overline{U}_B + a \cdot \overline{U}_C)}{3}$$

(Equation 50)

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 equations:

$$\overline{U}_1 = \frac{(\overline{U}_{AB} - a^2 \cdot \overline{U}_{BC})}{3}$$

(Equation 51)

$$\overline{U}_2 = \frac{(\overline{U}_{AB} - a \cdot \overline{U}_{BC})}{3}$$

(Equation 52)

The phase-to-earth voltages are calculated from the phase-to-phase voltages when *VT connection* is selected as "Delta" according to the equations.

$$\overline{U}_A = \overline{U}_0 + \frac{\left(\overline{U}_{AB} - \overline{U}_{CA}\right)}{3}$$

(Equation 53)

$$\overline{U}_B = \overline{U}_0 + \frac{\left(\overline{U}_{BC} - \overline{U}_{AB}\right)}{3}$$

(Equation 54)

$$\overline{U}_C = \overline{U}_0 + \frac{\left(\overline{U}_{CA} - \overline{U}_{BC}\right)}{3}$$

(Equation 55)

If the $\overline{U}_0$ channel is not valid, it is assumed to be zero.

The phase-to-phase voltages are calculated from the phase-to-earth voltages when *VT connection* is selected as "Wye" according to the equations.

$$\overline{U}_{AB} = \overline{U}_A - \overline{U}_B$$

(Equation 56)

$$\overline{U}_{BC} = \overline{U}_B - \overline{U}_C$$

(Equation 57)

$$\overline{U}_{CA} = \overline{U}_C - \overline{U}_A$$

(Equation 58)

10.6 Test mode

10.6.1 Functionality

The mode of all the logical nodes in the relay's IEC 61850 data model can be set with *Test mode*. *Test mode* activation method can be changed via parameter **Main menu/Tests/IED test** in the LHMI. Local/Remote control must be set to "Local" to change *Test mode* via LHMI.

Test mode is also available via IEC 61850 communication. Local/Remote control must be set to "Remote" to change *Test mode* using IEC 61850.

See the CONTROL function block for more details.

Table 453: Test mode

Test mode	Description	Protection BEH_BLK	Protection BEH_TST
Normal mode	Normal operation	FALSE	FALSE
IED blocked	Protection works as in “Normal mode” but the ACT configuration can be used to block physical outputs to process. Control function commands are blocked.	TRUE	FALSE
IED test	Protection works as in “Normal mode” but protection functions work in parallel with test parameters	FALSE	TRUE
IED test and blocked	Protection works as in “Normal mode” but protection functions work in parallel with the test parameter. The ACT configuration can be used to block physical outputs to process. The control function command is blocked.	TRUE	TRUE

See the PROTECTION function block for more details.

The behavior data objects in all logical nodes follow LD0.LLN0.Mod value. If "Normal mode" is selected, the behavior data objects follow the mode (.Mod) data object of the corresponding logical device.

Vertical and horizontal communication is not blocked by the “IED blocked” or “IED test and blocked” modes.

10.6.2 Application configuration and Test mode

The physical outputs from control commands to process are blocked with ”IED blocked” and “IED test and blocked” modes. If physical outputs need to be blocked from the protection, the application configuration must be used to block these signals. The blocking scheme needs to use `BEH_BLK` output of PROTECTION function block.

10.6.3 Control mode

The mode of all logical nodes located under CTRL logical device can be set with *Control mode*. The *Control mode* parameter is available via the LHMI or PCM600 path **Configuration/Control/General**. *Control mode* can be set locally through LHMI if the Local/Remote Control is set to "Local". *Control mode* inherits its value from *Test mode* but *Control mode* values "On", "Blocked" and "Off" can also be set independently. *Control mode* is also available via IEC 61850 communication (CTRL.LLN0.Mod).

Table 454: Control mode

Control mode	Description	Control BEH_BLK
On	Normal operation	FALSE
Blocked	Control function commands blocked	TRUE
Off	Control functions disabled	FALSE

See function block Control for more details.

The behavior data objects under CTRL logical device follow CTRL.LLN0.Mod value. If "On" is selected, the behavior data objects follow the mode of the corresponding logical device.

10.6.4 Application configuration and Control mode

The physical outputs from commands to process are blocked with “Blocked“ mode. If physical outputs need to be blocked totally, meaning also commands from the binary inputs, the application configuration must be used to block these signals. The blocking scheme uses `BEH_BLK` output of CONTROL function block.

10.6.5 Authorization

Test mode and *Control mode* can be changed from the LHMI if the Local/Remote Control is set to "Local". It is possible to write test mode by remote client if it is needed in configuration and if Local/Remote control is set to "Remote". Local and remote control can be selected via setting or via CONTROL function block in application configuration.

10.6.6 LHMI indications

The Ready LED flashes green indicating that one of the test mode options, "IED Test" or "IED test and blocked", is activated. If the test mode option "IED Blocked" is activated, the Start LED flashes red.

Section 11 Requirements for measurement transformers

11.1 Current transformers

11.1.1 Current transformer requirements for overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden. The protection settings of the protection relay should be defined in accordance with the CT performance as well as other factors.

11.1.1.1 Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (F_n) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the 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).

Table 455: 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 rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent 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 protection relay.

The CT accuracy primary limit 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 might have severe effects on the performance of the protection relay.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \cdot \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

(Equation 59)

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

11.1.1.2 Non-directional overcurrent protection

Current transformer selection

Non-directional overcurrent protection does not set high requirements on the accuracy class or on the actual accuracy limit factor (F_a) of the CTs. It is, however, recommended to select a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the protection relay is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$,

I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the protection relay. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to operate, the start current should be set using the formula:

Current start value $< 0.7 \times (I_{kmin} / I_{1n})$

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection relay inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The operate time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a.

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the start current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed protection relay operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive protection relays.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time constant of the DC component of the fault current, when the current is only slightly higher than the starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the operate time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

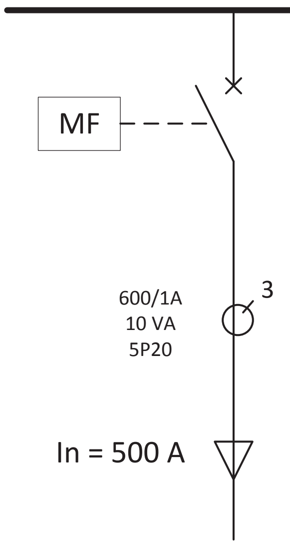
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

$F_a > 20 \cdot \textit{Current start value} / I_{1n}$

The *Current start value* is the primary start current setting of the protection relay.

11.1.1.3 Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three-stage definite time non-directional overcurrent protection.



3I>	1200A 0.75s	2.00 xIn 0.75s
3I>>	1800A 0.50s	3.00 xIn 0.50s
3I>>>	3500A 0.20s	5.83 xIn 0.20s

Figure 245: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 245). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 245.

For the application point of view, the suitable setting for instantaneous stage (I>>>) in this example is 3 500 A (5.83 × I_n). I_n is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 12 Protection relay's physical connections

12.1 Module diagrams

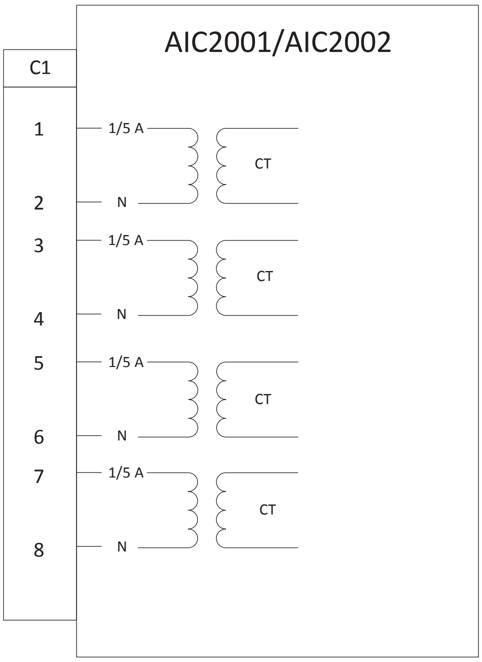


Figure 246: AIC2001/AIC2002 card

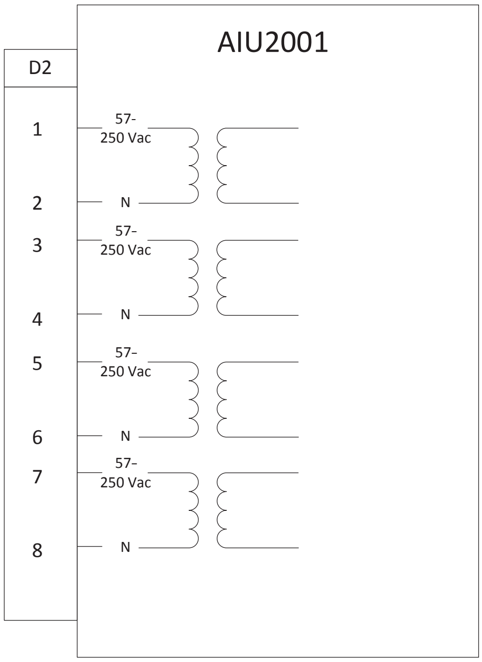


Figure 247: AIU2001 card

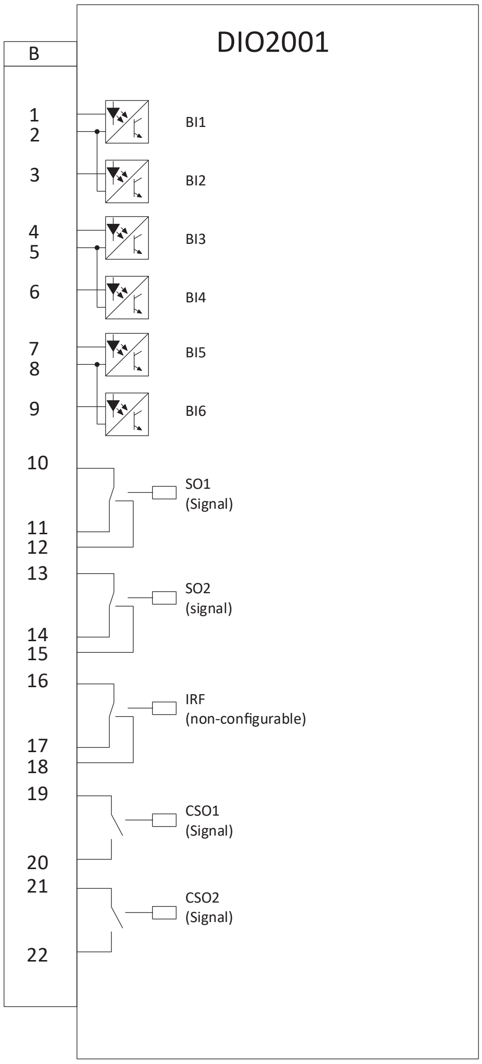


Figure 248: DIO2001 card

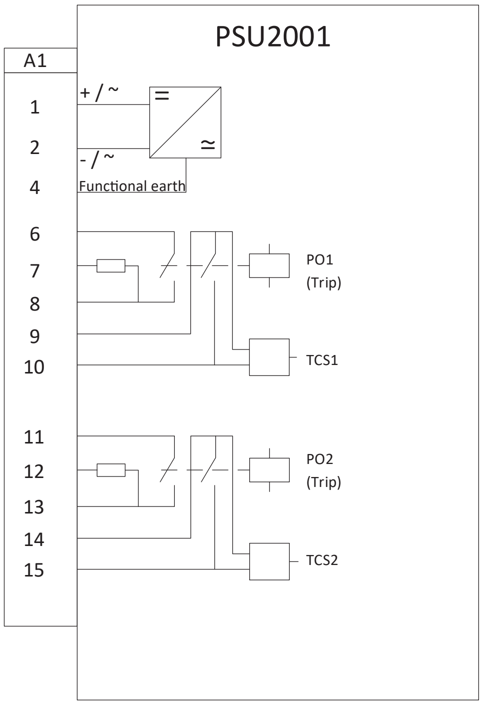


Figure 249: PSU2001 card

Section 13 Technical data

Table 456: Dimensions

Description	Value	
Width	Frame	149.5 mm (5.8858 in)
	Case	127.5 mm (5.0196 in)
Height	Frame	159.5 mm (6.2795 in)
	Case	155.5 mm (6.1220 in)
Depth		202.8 mm (163.6 mm + 39.2 mm) (7.9842 in)
Weight	Protection relay with the four separate connectors	2.5 kg (5.5 lbs)

Table 457: Power supply

Description	Value
Nominal auxiliary voltage U_n	24...250 ⎓ (V DC) 48...240 ∼ (V AC)
Maximum interruption time in the auxiliary DC voltage without resetting the relay	50 ms at U_n
Auxiliary voltage variation	85...110% (AC)
	80...120% (DC)
Start-up threshold	U_n (minimum)
Burden of auxiliary voltage supply under quiescent (P_q)/operating condition	9 W (P_q) 19 W/40 VA (P_{max})
Ripple in the DC auxiliary voltage	<15%
Fuse type	4A 250 ∼ (V AC) fast (+UL DC rated)

Table 458: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz	
Current inputs	Rated current, I_n	1 A	5 A
	Thermal withstand: • Continuous • For 1 s	 4 A 100 A	 20 A 500 A
	Dynamic current withstand: • Half sine wave	 250 A	 1250 A
	Input impedance	<100 mΩ	<20 mΩ
Voltage inputs	Rated voltage	57...250 ∼ (V AC)	
	Voltage withstand: • Continuous • For 10 s	 500 ∼ (V AC) 750 ∼ (V AC)	
	Burden at rated voltage	<0.5 VA	

Table 459: Binary inputs

Description	Value
Operating range	24...250 ⎓ (V DC) 48...240 ∼ (V AC)
Rated voltage	80...120% (DC) 85...110% (AC)
Current drain	Typically 1.6...1.9 mA <2.5 mA
Power consumption	<0.5 W
Threshold voltage, pick-up	Programmable 18...176 ⎓ (V DC) 38...168 ∼ (V AC)
Threshold voltage, drop-off	Programmable 16...176 ⎓ (V DC) 34...168 ∼ (V AC)
Reaction time	<6 ms[1)]
Burden	<0.5 W / 2 VA

1) REX610 cycle time is 5 ms

Adjust the binary input threshold voltage correctly. It is recommended to set the threshold voltage to 70% of the nominal auxiliary voltage. The factory default is 18 V to ensure the binary inputs' operation regardless of the auxiliary voltage used (24, 48, 60, 110, 125, 220 or 250 V DC). However, the default value is not optimal for the higher auxiliary voltages. The binary input threshold voltage should be set as high as possible to prevent any inadvertent activation of the binary inputs due to possible external disturbances. At the same time, the threshold should be set so that the correct operation is not jeopardized in case of undervoltage of the auxiliary voltage.

Table 460: Signal output relays (SO1)

Description		Value
Rated voltage		250 V AC/DC
Continuous contact carry current		5 A
Mechanical endurance	Unloaded operation	10000 cycles
Electrical endurance	Closing operations	1000 cycles
	Opening operations	1000 cycles
Making limits	Limiting making capacity (inductive)	300 W at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Make and carry (resistive) for 3.0 s	15 A (3 s On, 15 Off)
	Make and carry (resistive) for 0.5 s	30 A (0.5 s On, 15 s Off)
Breaking limits	Limiting breaking capacity ≤48 V	1 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 110 V	0.25 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 220 V	0.15 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
Minimum contact load		100 mA

Table 461: IRF and signaling outputs other than SO1

Description		Value
Rated voltage		250 V AC/DC
Continuous contact carry current		5 A
Mechanical endurance	Unloaded operation	10000 cycles
Electrical endurance	Closing operations	1000 cycles
	Opening operations	1000 cycles
Making limits	Limiting making capacity (inductive)	300 W at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Make and carry (resistive) for 3.0 s	10 A (3 s On, 15 Off)
	Make and carry (resistive) for 0.5 s	15 A (0.5 s On, 15 s Off)

Table continues on next page

Description		Value
Breaking limits	Limiting breaking capacity ≤48 V	1 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 110 V	0.25 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 220 V	0.15 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
Minimum contact load		10 mA

Table 462: Tripping output relays (Double-pole power output relays with TCS function)

Description		Value
Rated voltage		250 V AC/DC
Continuous contact carry current		8 A
Mechanical endurance	Unloaded operation	10000 cycles
Electrical endurance	Closing operations	1000 cycles
	Opening operations	1000 cycles
Making limits	Limiting making capacity (inductive)	1000 W at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Make and carry (resistive) for 3.0 s	15 A (3 s On, 15 Off)
	Make and carry (resistive) for 0.5 s	30 A (0.5 s On, 15 s Off)
Breaking limits	Limiting breaking capacity ≤48 V (inductive), two contacts connected in series	5 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 110 V (inductive), two contacts connected in series	3 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
	Limiting breaking capacity 220 V (inductive), two contacts connected in series	1 A at L/R = 40 ms for DC or p.f. = 0.4 for AC
Minimum contact load		100 mA

Table 463: Serial interface

Type	Location	Connector
RS-485	Rear	1=B, 2=A, 3=GND, 4=capacitive shield

Table 464: USB interface, HMI

Type	Location	Connector	Rate
USB, type B	Front	USB 1.x / USB 2.0 compatible	240 Mbits/s (max.)

Table 465: Ethernet interface

Cable	Protocol	Location	Rate
Standard Ethernet CAT 5 STP cable with RJ-45 connector (shielded)	TCP/IP	Rear	100 Mbits/s

Table 466: Degree of protection of the protection relay

Description	Value
Front side	IP 54
Left and right side	IP 20
Top and bottom	IP 20
Case inside[1)]	IP 20

1) Plug-in unit removed

Table 467: Environmental conditions

Description	Value
Operating temperature range	-40...+70ºC
Short-time service temperature range	-40...+85ºC
Relative humidity	5...95% (EN60255)
Atmospheric pressure	86...106 kPa (test reference/EN60255)
Altitude	<2000 m (EN60255)
Transport and storage temperature range	-40...+85ºC

Section 14 Protection relay and functionality tests

Table 468: Electromagnetic compatibility tests

Description	Type test value	Reference
1 MHz/100 kHz burst disturbance test • Common mode • Differential mode	 2.5 kV 2.5 kV	IEC 61000-4-18 IEC 60255-26, class III IEEE C37.90.1-2012
3 MHz, 10 MHz and 30 MHz burst disturbance test • Common mode	 2.5 kV	IEC 61000-4-18
Electrostatic discharge test • Contact discharge • Air discharge	 8 kV 15 kV	IEC 61000-4-2 IEC 60255-26 IEEE C37.90.3-2001
Radio frequency interference test • Conducted RF • Radiated RF	 10 V (rms) f = 150 kHz...80 MHz 10 V/m (rms) f = 80...2700 MHz 20 V/m f = 900 MHz 20 V/m (rms) f = 80...1000 MHz	 IEC 61000-4-6 IEC 60255-26, class III IEC 61000-4-3 IEC 60255-26, class III ENV 50204 IEEE C37.90.2-2004
Fast transient disturbance test • Communication • Other ports	 2 kV 4 kV	IEC 61000-4-4 IEC 60255-26 IEEE C37.90.1-2002
Surge immunity test • Communication • Other ports	 4 kV, line-to-earth 4 kV, line-to-earth 2 kV, line-to-line	IEC 61000-4-5 IEC 60255-26
Power frequency (50 Hz) magnetic field immunity test		IEC 61000-4-8

Table continues on next page

Description	Type test value	Reference
• Continuous • 1...3 s	300 A/m 1000 A/m	
Pulse magnetic field immunity test	1000 A/m 6.4/16 µs	IEC 61000-4-9
Damped oscillatory magnetic field immunity test • Continuous and 2 s	Current oscillation frequency: 100 kHz and 1 MHz Current rise time: 75 ns Repetition frequency: 40 Hz (100 Hz) and 400 Hz (1 MHz) Polarity of first half period: Positive and Negative	IEC 61000-4-10
Voltage dips and short interruptions	30%/10 ms 60%/100 ms 60%/1000 ms >95%/5000 ms	IEC 61000-4-11
Power frequency immunity test • Common mode • Differential mode	Binary inputs only 300 V rms 150 V rms	IEC 61000-4-16 IEC 60255-26, class A
Emission tests		EN 55011, class A IEC 60255-26 CISPR 11 CISPR 22
• Conducted		
0.15...0.50 MHz	<79 dB (µV) quasi peak <66 dB (µV) average	
0.5...30 MHz	<73 dB (µV) quasi peak <60 dB (µV) average	
• Radiated		
30...230 MHz	<40 dB (µV/m) quasi peak, measured at 10 m distance	
230...1000 MHz	<47 dB (µV/m) quasi peak, measured at 10 m distance	
1…3 GHz	<76 dB (µV/m) peak <56 dB (µV/m) average, measured at 3 m distance	
3…6 GHz	<80 dB (µV/m) peak <60 dB (µV/m) average, measured at 3 m distance	

Table 469: Safety-related tests

Description	Type test result	Reference
Overvoltage category	III	IEC 60255-27
Pollution degree	3	IEC 60255-27
Insulation class	Class I	IEC 60255-27
Dielectric tests	2 kV, 50 Hz, 1 min 500 V, 50 Hz, 1 min, communication	IEC 60255-27 IEEE C37.90-2005
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J 1 kV, 1.2/50 μs, 0.5 J, communication	IEC 60255-27 IEEE C37.90-2005
Insulation resistance measurements	>100 MΩ, 500 V DC	IEC 60255-27
Maximum temperature of parts and materials	Tested	IEC 60255-27
Flammability of insulating materials, components and fire enclosures	OK	IEC 60255-1 IEC 60255-27
Single-fault condition	OK	IEC 60255-1 IEC 60255-27

Table 470: Mechanical tests

Description	Type test result	Reference
Vibration tests (sinusoidal)	Class 1	IEC 60068-2-6 (test Fc) IEC 60255-21-1
Shock and bump test	Class 1	IEC 60068-2-27 (test Ea shock) IEC 60068-2-29 (test Eb bump) IEC 60255-21-2
Seismic test	Class 2	IEC 60255-21-3
Drop test	OK	IEC 60068-2-31 ISTA 1A
Mechanical durability test • 200 withdrawals and insertions of the plug-in unit	OK	IEEE C37.90-2005

Table 471: Environmental tests

Description	Type test value	Reference
Dry heat test	• 96 h at +70°C • 16 h at +85°C[1)]	IEC 60068-2-2 IEC60255-1 IEEE C37.90-2005
Dry cold test	• 96 h at -40°C • 16 h at -40°C	IEC 60068-2-1 IEC60255-1 IEEE C37.90-2005
Damped heat cyclic test	• 6 cycles (12 h + 12 h) at +25…+55°C, humidity >93%	IEC 60068-2-30 IEC60255-1
Change of temperature test	• 6 cycles (3 h + 3 h) at -40...+70°C	IEC 60068-2-14 IEC60255-1
Storage test	• 96 h at -40°C • 96 h at +85°C	IEC 60068-2-1 IEC 60068-2-2 IEC60255-1 IEEE C37.90-2005
Damp heat steady state test	10 days at +40°C, 93% RH	IEC 60068-2-78 IEC60255-1
Air quality test	H2S - 10 ppb NO2 - 200 ppb CL2 - 10 ppb SO2 - 200 ppb Temperature - 25°C Relative humidity - 75% Duration - 21 days	IEC 60068-2-60

1) For relays with an LC communication interface, the maximum operating temperature is +70°C.

Table 472: Product safety

Description	Reference
LV directive	EMC Directive 2014/30/EU Low Voltage Directive 2014/35/EU RoHS Directive 2015/863/EU
Standard	EN 60255-27 (2014) EN 60255-1 (2009)

Table 473: EMC compliance

Description	Reference
EMC directive	2014/30/EU
Standard	EN 60255-26 (2013)

Table 474: RoHS compliance

Description
Complies with RoHS Directive 2011/65/EU and the amended EU Directive 2015/863/EU

Section 15 Applicable standards and regulations

EN 60255-1

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 61850

BS EN 60255-26: 2013

BS EN 61000-6-2: 2005

BS EN 61000-6-4: 2019

BS EN 60255-1: 2010

BS EN 60255-27: 2014

Section 16 Glossary

ACT	1. Application Configuration tool in PCM600 2. Trip status in IEC 61850
CAT 5	A twisted pair cable type designed for high signal integrity
CBB	Cycle building block
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
CT	Current transformer
DFT	Discrete Fourier transform
DT	Definite time
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IED	Intelligent electronic device
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IRF	1. Internal fault 2. Internal relay fault
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface

MCB	Miniature circuit breaker
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
NC	Normally closed
PCM600	Protection and Control IED Manager
Peak-to-peak	1. The amplitude of a waveform between its maximum positive value and its maximum negative value 2. 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
PSU	Power supply unit
RCA	Also known as MTA or base angle. Characteristic angle.
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
RS-485	Serial link according to EIA standard RS485
RTC	Real-time clock
SBO	Select-before-operate
SCADA	Supervision, control and data acquisition
SI	Sensor input
SMT	Signal Matrix tool in PCM600
SNTP	Simple Network Time Protocol
SO	Signal output
SOTF	Switch onto fault
STP	Shielded twisted-pair
TCP	Transmission Control Protocol
TCS	Trip-circuit supervision
UART	Universal asynchronous receiver-transmitter

USB	Universal serial bus
UTC	Coordinated universal time
VT	Voltage transformer

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