Relion® 650 series

Line distance protection REL650 Technical Manual

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC).

This conformity is proved by tests conducted by ABB AB in accordance with the generic standard EN 50263 for the EMC directive, and with the standards EN 60255-5 and/or EN 50178 for the low voltage directive.

This product is designed and produced for industrial use.

Table of contents

Section 1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

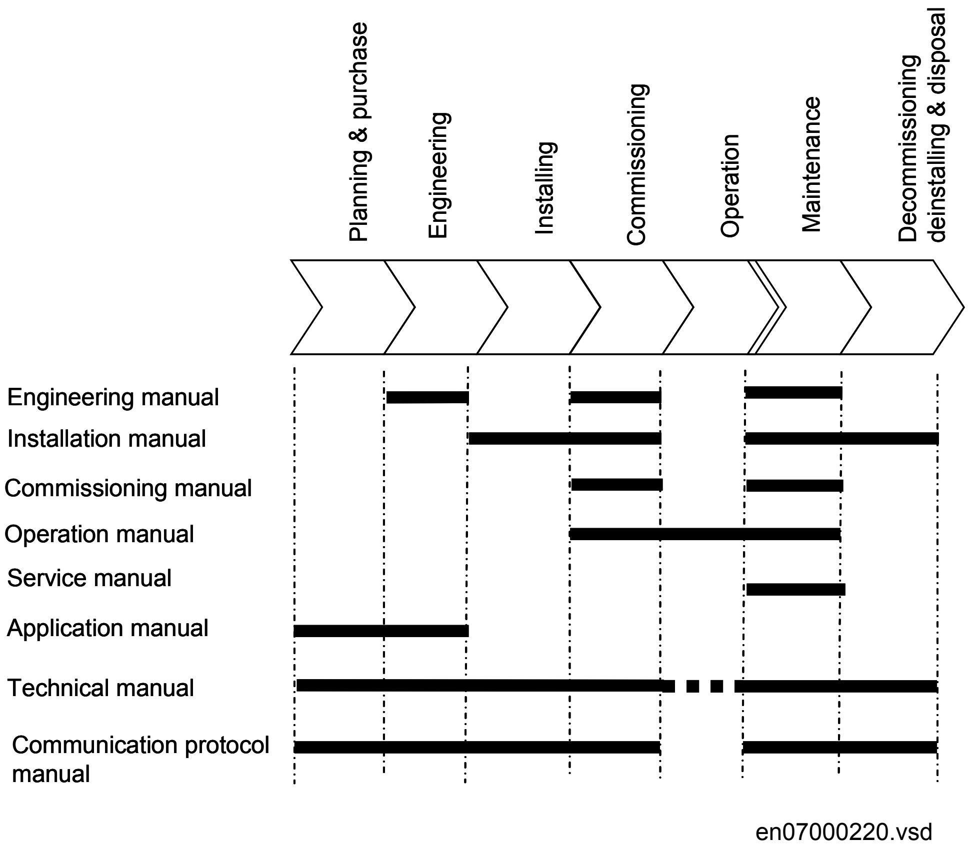


Figure 1: The intended use of manuals in different lifecycles

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and DNP3.

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

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

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

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

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

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

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

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

The service manual is not available yet.

1.3.2 Document revision history

Document revision/date	Product series version	History
-/September 2009	1.0	First release

1.3.3 Related documents

Documents related to REL650	Identity number
Commissioning manual	1MRK 506 307-UEN
Technical manual	1MRK 506 304-UEN
Application manual	1MRK 506 305-UEN

Table continues on next page

Documents related to REL650	Identity number
Product Guide, configured	1MRK 506 308-BEN
Type test certificate	1MRK 506 308-TEN

650 series manuals	Identity number
Operation manual	1MRK 500 088-UEN
Communication protocol manual, DNP3	1MRK 511 224-UEN
Communication protocol manual, IEC 61850	1MRK 511 205-UEN
Engineering manual	1MRK 511 206-UEN
Installation manual	1MRK 514 013-UEN
Point list manual, DNP3	1MRK 511 225-UEN

1.4 Symbols and conventions

1.4.1 Safety indication 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 to 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 should be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Manual conventions

Conventions used in IED manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in Glossary. Glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, for example:
  To navigate between the options, use and .
- HMI menu paths are presented in bold, for example:
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press .
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- The ^ character in front of an input or output signal name in the function block symbol given for a function, indicates that the user can set an own signal name in PCM600.
- The * character after an input or output signal name in the function block symbol given for a function, indicates that the signal must be connected to another function block in the application configuration to achieve a valid application configuration.

Section 2 Available functions

2.1 Main protection functions

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
Impedance protection				
ZQDPDIS	21	Five zone distance protection, quadrilateral characteristic	1	
FDPSPDIS	21	Phase selection with load enchroachment, quadrilateral characteristic	1	
ZMOPDIS	21	Five zone distance protection, mho characteristic		1
FMPSPDIS	21	Faulty phase identification with load enchroachment for mho		1
ZDNRDIR	21	Directional impedance quadrilateral and mho	1	1
PPLPHIZ		Phase preference logic	1	1
ZMRPSB	68	Power swing detection	1	1
ZCVPSOF		Automatic switch onto fault logic, voltage and current based	1	1

2.2 Back-up protection functions

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
Current protection				
PHPIOC	50	Instantaneous phase overcurrent protection	1	1
OC4PTOC	51/67	Four step directional phase overcurrent protection	1	1
EFPIOC	50N	Instantaneous residual overcurrent protection	1	1
EF4PTOC	51N/67N	Four step directional residual overcurrent protection	1	1
SDEPSDE	67N	Sensitive directional residual overcurrent and power protection	1	1
UC2PTUC	37	Time delayed 2-step undercurrent protection	1	1
LPTTR	26	Thermal overload protection, one time constant	1	1
CCRBRF	50BF	Breaker failure protection	1	1
STBPTOC	50STB	Stub protection	1	1

Table continues on next page

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
CCRPLD	52PD	Pole discordance protection	1	1
BRCPTOC	46	Broken conductor check	1	1
GUPPDUP	37	Directional underpower protection	1	1
GOPPDOP	32	Directional overpower protection	1	1
DNSPTOC	46	Negative sequence based overcurrent function	1	1
Voltage protection				
UV2PTUV	27	Two step undervoltage protection	1	1
OV2PTOV	59	Two step overvoltage protection	1	1
ROV2PTOV	59N	Two step residual overvoltage protection	1	1
LOVPTUV	27	Loss of voltage check	1	1
Frequency protection				
SAPTUF	81	Underfrequency function	2	2
SAPTOF	81	Overfrequency function	2	2
SAPFRC	81	Rate-of-change frequency protection	2	2

2.3 Control and monitoring functions

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
Control				
SESRSYN	25	Synchrocheck, energizing check, and synchronizing	1	1
SMBRREC	79	Autorecloser	1	1
QCBAY		Bay control	1	1
LOCREM		Handling of LR-switch positions	1	1
LOCREMCTRL		LHMI control of PSTO	1	1
SLGGIO		Logic Rotating Switch for function selection and LHMI presentation	15	15
VSGGIO		Selector mini switch extension	20	20
DPGGIO		IEC 61850 generic communication I/O functions double point	16	16
SPC8GGIO		Single point generic control 8 signals	5	5
AUTOBITS		AutomationBits, command function for DNP3.0	3	3
Secondary system supervision				
CCSRDIF	87	Current circuit supervision	1	1

Table continues on next page

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
SDDRFUF		Fuse failure supervision	1	1
TCSSCBR		Breaker close/trip circuit monitoring	3	3
Logic				
SMPPTRC	94	Tripping logic	1	1
TMAGGIO		Trip matrix logic	12	12
OR		Configurable logic blocks, OR	283	283
INVERTER		Configurable logic blocks, Inverter	140	140
PULSETIMER		Configurable logic blocks, PULSETIMER	40	40
GATE		Configurable logic blocks, Controllable gate	40	40
XOR		Configurable logic blocks, exclusive OR	40	40
LOOPDELAY		Configurable logic blocks, loop delay	40	40
TimeSet		Configurable logic blocks, timer	40	40
AND		Configurable logic blocks, AND	280	280
SRMEMORY		Configurable logic blocks, set-reset memory	40	40
RSMEMORY		Configurable logic blocks, reset-set memory	40	40
FXDSIGN		Fixed signal function block	1	1
B16I		Boolean 16 to Integer conversion	16	16
B16IFCVI		Boolean 16 to integer conversion with logic node representation	16	16
IB16A		Integer to Boolean 16 conversion	16	16
IB16FCVB		Integer to boolean 16 conversion with logic node representation	16	16
Monitoring				
CVMMXN		Measurements	6	6
CMMXU		Phase current measurement	10	10
VMMXU		Phase-phase voltage measurement	6	6
CMSQI		Current sequence component measurement	6	6
VMSQI		Voltage sequence measurement	6	6
VNMMXU		Phase-neutral voltage measurement	6	6
CNTGGIO		Event counter	5	5
DRPRDRE		Disturbance report	1	1
AxRADR		Analog input signals	1	1
BxRBDR		Binary input signals	1	1
SPGGIO		IEC 61850 generic communication I/O functions	64	64
SP16GGIO		IEC 61850 generic communication I/O functions 16 inputs	16	16
MVGGIO		IEC 61850 generic communication I/O functions	16	16
MVEXP		Measured value expander block	66	66
LMBRFLO		Fault locator	1	1

Table continues on next page

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
SPVNZBAT		Station battery supervision	1	1
SSIMG	63	Insulation gas monitoring function	1	1
SSIML	71	Insulation liquid monitoring function	1	1
SSCBR		Circuit breaker condition monitoring	1	1
Metering				
PCGGIO		Pulse counter logic	16	16
ETPMMTR		Function for energy calculation and demand handling	3	3

2.4 Designed to communicate

IEC 61850	ANSI	Function description	Line Distance	
			REL650 (A01) 3Ph/1CB, quad	REL650 (A05) 3Ph/1CB, mho
Station communication				
		IEC 61850 communication protocol	1	1
		DNP3.0 for TCP/IP communication protocol	1	1
GOOSEINTLKRCV		Horizontal communication via GOOSE for interlocking	59	59
GOOSEBINRCV		GOOSE binary receive	4	4
Scheme communication				
ZCPSCH	85	Scheme communication logic for distance or overcurrent protection	1	1
ZCRWPSCH	85	Current reversal and weak-end infeed logic for distance protection	1	1
ZCLCPLAL		Local acceleration logic	1	1
ECPSCH	85	Scheme communication logic for residual overcurrent protection	1	1
ECRWPSCH	85	Current reversal and weak-end infeed logic for residual overcurrent protection	1	1

2.5 Basic IED functions

IEC 61850	Function description	
Basic functions included in all products		
INTERRSIG	Self supervision with internal event list	1
	Time synchronization	1

Table continues on next page

IEC 61850	Function description	
SETGRPS	Setting group handling	1
ACTVGRP	Parameter setting groups	1
TESTMODE	Test mode functionality	1
CHNGLCK	Change lock function	1
ATHSTAT	Authority status	1
ATHCHCK	Authority check	1

Section 3 Local Human-Machine-Interface LHMI

3.1 Local HMI screen behaviour

3.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Local HMI screen behaviour	SCREEN	-	-

3.1.2 Settings

Table 1: SCREEN Non group settings (basic)

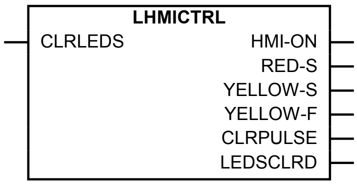
Name	Values (Range)	Unit	Step	Default	Description
DisplayTimeout	10 - 120	Min	10	60	Local HMI display timeout
ContrastLevel	-100 - 100	%	10	0	Contrast level for display
DefaultScreen	0 - 0	-	1	0	Default screen
EvListSrtOrder	Latest on top Oldest on top	-	-	Latest on top	Sort order of event list
AutoIndicationDRP	Off On	-	-	Off	Automatic indication of disturbance report
SubstIndSLD	No Yes	-	-	No	Substitute indication on single line diagram
InterlockIndSLD	No Yes	-	-	No	Interlock indication on single line diagram
BypassCommands	No Yes	-	-	No	Enable bypass of commands

3.2 Local HMI signals

3.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Local HMI signals	LHMICTRL	-	-

3.2.2 Function block



IEC09000320-1-en.vsd

Figure 2: LHMICTRL function block

3.2.3 Signals

Table 2: LHMICTRL Input signals

Name	Type	Default	Description
CLRLEDS	BOOLEAN	0	Input to clear the LCD-HMI LEDs

Table 3: LHMICTRL Output signals

Name	Type	Description
HMI-ON	BOOLEAN	Backlight of the LCD display is active
RED-S	BOOLEAN	Red LED on the LCD-HMI is steady
YELLOW-S	BOOLEAN	Yellow LED on the LCD-HMI is steady
YELLOW-F	BOOLEAN	Yellow LED on the LCD-HMI is flashing
CLRPULSE	BOOLEAN	A pulse is provided when the LEDs on the LCD-HMI are cleared
LEDSCLRD	BOOLEAN	Active when the LEDs on the LCD-HMI are not active

3.3 Basic part for LED indication module

3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Basic part for LED indication module	LEDGEN	-	-
Basic part for LED indication module	GRP1_LED1 - GRP1_LED15 GRP2_LED1 - GRP2_LED15 GRP3_LED1 - GRP3_LED15	-	-

3.3.2 Function block

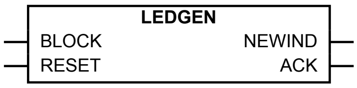


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Figure 3: LEDGEN function block

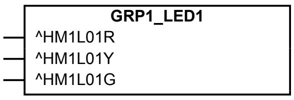

Figure 4: GRP1_LED1 function block

The GRP1_LED1 function block is an example, all 15 LED in each of group 1 - 3 has a similar function block.

3.3.3 Signals

Table 4: LEDGEN Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Input to block the operation of the LEDs
RESET	BOOLEAN	0	Input to acknowledge/reset the indication LEDs

Table 5: GRP1_LED1 Input signals

Name	Type	Default	Description
HM1L01R	BOOLEAN	0	Red indication of LED1, local HMI alarm group 1
HM1L01Y	BOOLEAN	0	Yellow indication of LED1, local HMI alarm group 1
HM1L01G	BOOLEAN	0	Green indication of LED1, local HMI alarm group 1

Table 6: LEDGEN Output signals

Name	Type	Description
NEWIND	BOOLEAN	New indication signal if any LED indication input is set
ACK	BOOLEAN	A pulse is provided when the LEDs are acknowledged

3.3.4 Settings

Table 7: LEDGEN Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
tRestart	0.0 - 100.0	s	0.1	0.0	Defines the disturbance length
tMax	0.0 - 100.0	s	0.1	0.0	Maximum time for the definition of a disturbance

Table 8: GRP1_LED1 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
SequenceType	Follow-S Follow-F LatchedAck-F-S LatchedAck-S-F LatchedColl-S LatchedReset-S	-	-	Follow-S	Sequence type for LED 1, local HMI alarm group 1
LabelOff	0 - 18	-	1	G1L01_OFF	Label string shown when LED 1, alarm group 1 is off
LabelRed	0 - 18	-	1	G1L01_RED	Label string shown when LED 1, alarm group 1 is red
LabelYellow	0 - 18	-	1	G1L01_YELLOW	Label string shown when LED 1, alarm group 1 is yellow
LabelGreen	0 - 18	-	1	G1L01_GREEN	Label string shown when LED 1, alarm group 1 is green

3.4 LCD part for HMI function keys control module

3.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
LCD part for HMI Function Keys Control module	FNKEYMD1 - FNKEYMD5	-	-

3.4.2 Function block

Figure 5: FNKEYMD1 function block

Only the function block for the first button is shown above. There is a similar block for every function button.

3.4.3 Signals

Table 9: FNKEYMD1 Input signals

Name	Type	Default	Description
LEDCTL1	BOOLEAN	0	LED control input for function key

Table 10: FNKEYMD1 Output signals

Name	Type	Description
FKEYOUT1	BOOLEAN	Output controlled by function key

3.4.4 Settings

Table 11: FNKEYMD1 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Mode	Off Toggle Pulsed	-	-	Off	Output operation mode
PulseTime	0.001 - 60.000	s	0.001	0.200	Pulse time for output controlled by LCDFn1
LabelOn	0 - 18	-	1	LCD_FN1_ON	Label for LED on state
LabelOff	0 - 18	-	1	LCD_FN1_OFF	Label for LED off state

Table 12: FNKEYTY1 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Type	Off Menu shortcut Control	-	-	Off	Function key type
MenuShortcut	Menu shortcut for function key				

3.5 Operation principle

3.5.1 Local HMI

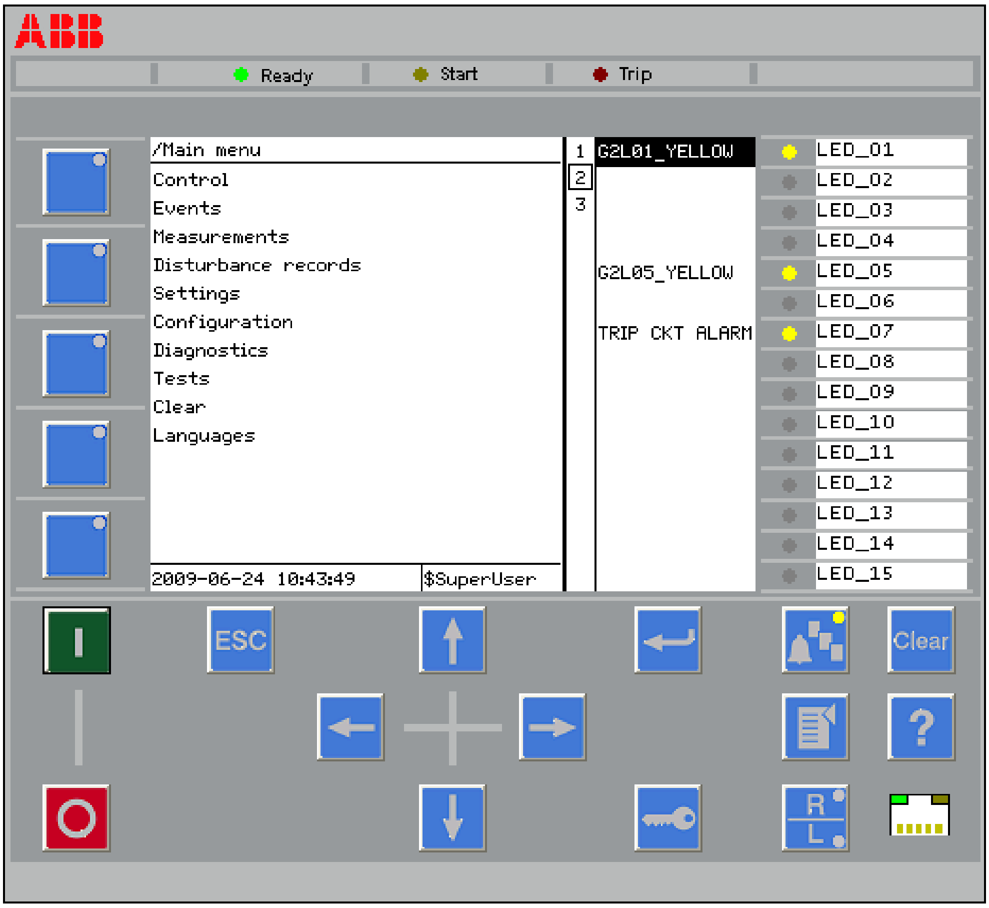

Figure 6: Local human-machine interface

The LHMI of the IED contains the following elements:

- Display (LCD)
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

3.5.1.1 LCD

The LHMI includes a graphical monochrome LCD with a resolution of 320 x 240 pixels. The character size can vary. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

The display view is divided into four basic areas.

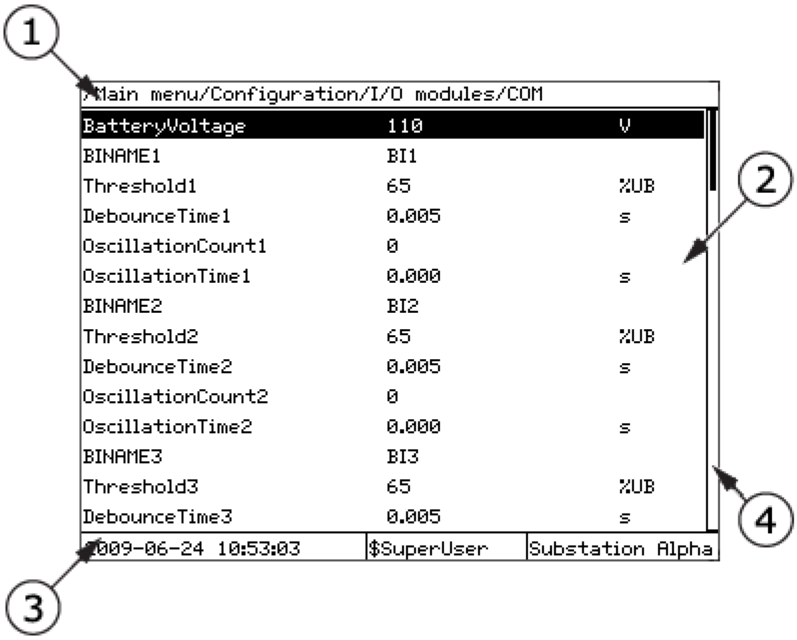

Figure 7: Display layout

1 Path

2 Content

3 Status

4 Scroll bar (appears when needed)

- The path shows the current location in the menu structure. If the path is too long to be shown, it is truncated from the beginning, and the truncation is indicated with three dots.
- The content area shows the menu content.
- The status area shows the current IED time, the user that is currently logged in and the object identification string which is settable via the LHMI or with PCM600.
- If text, pictures or other items do not fit in the display, a vertical scroll bar appears on the right. The text in content area is truncated from the beginning if it does not fit in the display horizontally. Truncation is indicated with three dots.

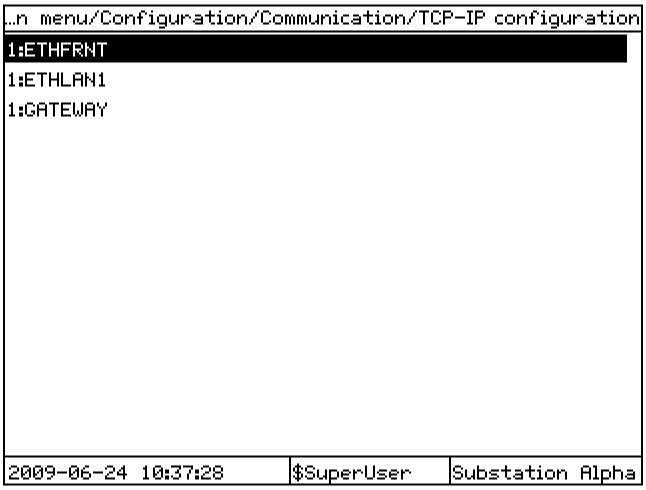

Figure 8: Truncated path

The number before the function instance, for example `1:ETHFRNT`, indicates the instance number.

The function button panel shows on request what actions are possible with the function buttons. Each function button has a LED indication that can be used as a feedback signal for the function button control action. The LED is connected to the required signal with PCM600.

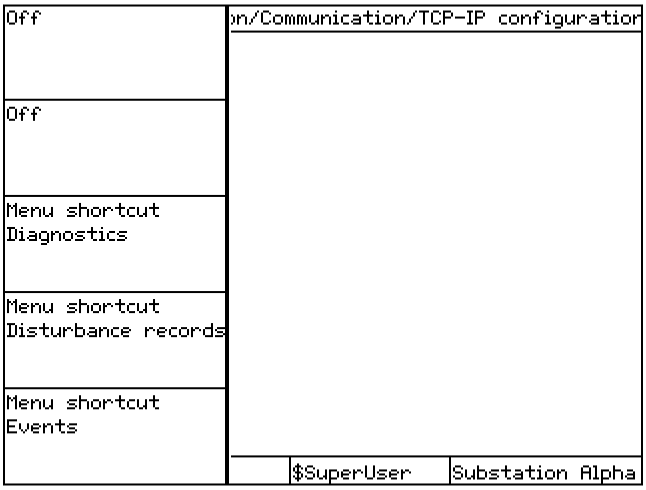

Figure 9: Function button panel

The alarm LED panel shows on request the alarm text labels for the alarm LEDs.

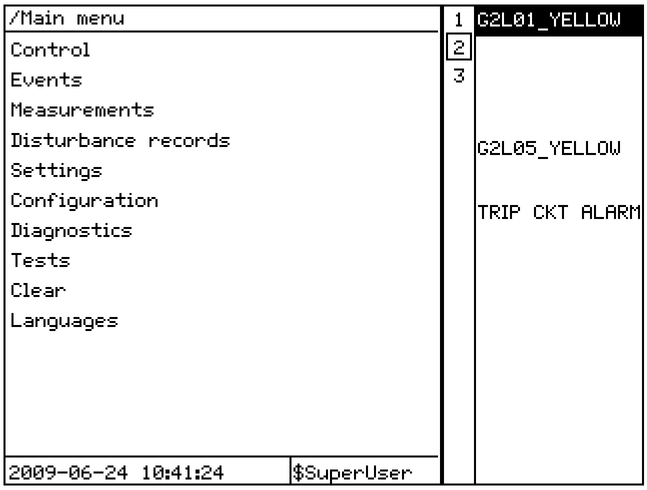

Figure 10: Alarm LED panel

The function button and alarm LED panels are not visible at the same time. Each panel is shown by pressing one of the LCD function buttons or the Multipage button. Pressing the ESC button clears the panel from the display. Both the panels have dynamic width that depends on the label string length that the panel contains.

3.5.1.2 LEDs

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

There are also 15 matrix programmable alarm LEDs on front of the LHMI. Each LED can indicate three states with the colors: green, yellow and red. The alarm texts related to each three-color LED are divided into three pages. The 15 physical three-color LEDs in one LED group can indicate 45 different signals. Altogether, 135 signals can be indicated since there are three LED groups. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI or PCM600.

3.5.1.3 Keypad

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

The keypad also contains programmable push-buttons that can be configured either as menu shortcut or control buttons.

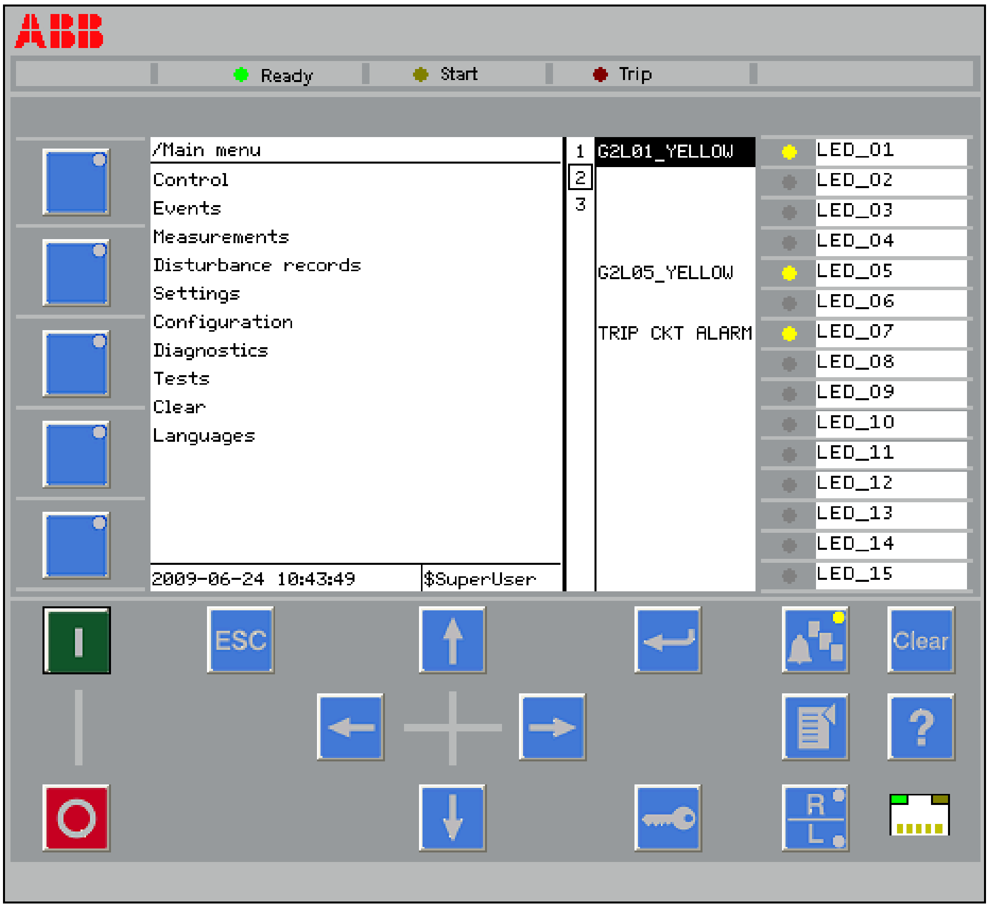

Figure 11: LHMI keypad

3.5.2 LED

3.5.2.1 Functionality

The function blocks LEDGEN and GRP1_LEDx, GRP2_LEDx and GRP3_LEDx (x=1-15) controls and supplies information about the status of the indication LEDs. The input and output signals of the function blocks are configured with PCM600. The input signal for each LED is selected individually using SMT or ACT. Each LED is controlled by a GRP1_LEDx function block, that controls the color and the operating mode.

Each indication LED on local HMI can be set individually to operate in six different sequences; two as follow type and four as latch type. Two of the latching sequence types are intended to be used as a protection indication system, either in collecting or restarting mode, with reset functionality. The other two are intended to be used as signalling system in collecting mode with acknowledgment functionality.

3.5.2.2 Status LEDs

There are three status LEDs above the LCD in the front of the IED, green, yellow and red.

The green LED has a fixed function, while the yellow and red LEDs are user configured. The yellow LED can be used to indicate that a disturbance report is created (steady) or that the IED is in test mode (flashing). The red LED can be used to indicate a trip command.

3.5.2.3 Indication LEDs

Operating modes

Collecting mode

- LEDs, which are used in collecting mode of operation, are accumulated continuously until the unit is acknowledged manually. This mode is suitable when the LEDs are used as a simplified alarm system.

Re-starting mode

- In the re-starting mode of operation each new start resets all previous active LEDs and activates only those, which appear during one disturbance. Only LEDs defined for re- starting mode with the latched sequence type 6 (LatchedReset-S) will initiate a reset and a restart at a new disturbance. A disturbance is defined to end a settable time after the reset of the activated input signals or when the maximum time limit has elapsed.

Acknowledgment/reset

- From local HMI
  - The active indications can be acknowledged/reset manually. Manual acknowledgment and manual reset have the same meaning and is a common signal for all the operating sequences and LEDs. The function is positive edge triggered, not level triggered. The acknowledgment/reset is performed via the 

 button and menus on the LHMI.

- From function input
  - The active indications can also be acknowledged/reset from an input, ACK_RST, to the function. This input can for example be configured to a binary input operated from an external push button. The function is positive edge triggered, not level triggered. This means that even if the button is continuously pressed, the acknowledgment/reset only affects indications active at the moment when the button is first pressed.

- Automatic reset

- The automatic reset can only be performed for indications defined for re-starting mode with the latched sequence type 6 (LatchedReset-S). When the automatic reset of the LEDs has been performed, still persisting indications will be indicated with a steady light.

Operating sequence

The sequences can be of type Follow or Latched. For the Follow type the LED follow the input signal completely. For the Latched type each LED latches to the correspond¬ing input signal until it is reset.

The figures below show the function of available sequences selectable for each LED separately. For sequence 1 and 2 (Follow type), the acknowledgment/reset function is not applicable. Sequence 3 and 4 (Latched type with acknowledgement) are only work¬ing in collecting mode. Sequence 5 is working according to Latched type and collecting mode while sequence 6 is working according to Latched type and re-starting mode. The letters S and F in the sequence names have the meaning S = Steady and F = Flash.

At the activation of the input signal, the indication obtains corresponding color corresponding to the activated input and operates according to the selected sequence diagrams below.

In the sequence diagrams the LEDs have the following characteristics:

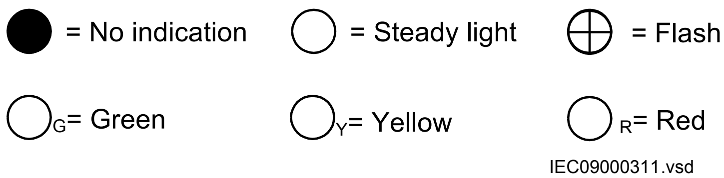

Figure 12: Symbols used in the sequence diagrams

Sequence 1 (Follow-S)

This sequence follows all the time, with a steady light, the corresponding input signals. It does not react on acknowledgment or reset. Every LED is independent of the other LEDs in its operation.

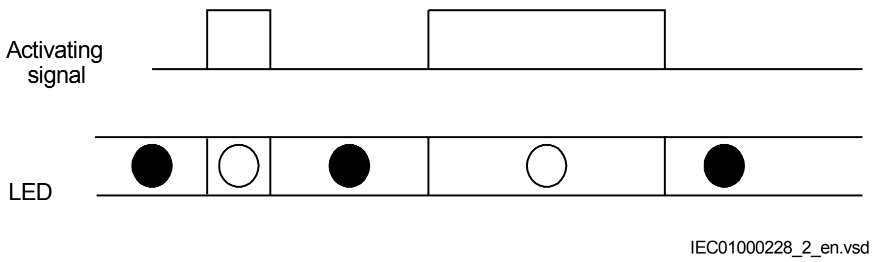

Figure 13: Operating sequence 1 (Follow-S)

If inputs for two or more colors are active at the same time to one LED the priority is as described above. An example of the operation when two colors are activated in parallel is shown in the figure 14.

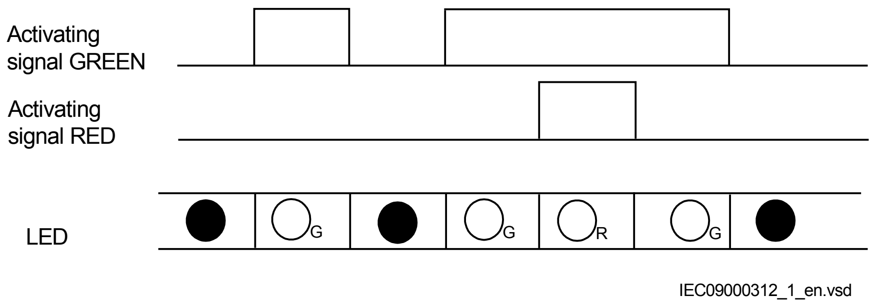

Figure 14: Operating sequence 1, two colors

Sequence 2 (Follow-F)

This sequence is the same as sequence 1, Follow-S, but the LEDs are flashing instead of showing steady light.

Sequence 3 (LatchedAck-F-S)

This sequence has a latched function and works in collecting mode. Every LED is independent of the other LEDs in its operation. At the activation of the input signal, the indication starts flashing. After acknowledgment the indication disappears if the signal is not present any more. If the signal is still present after acknowledgment it gets a steady light.

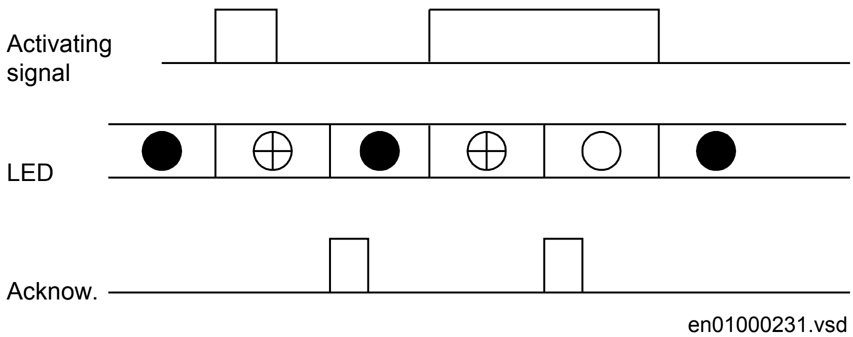

Figure 15: Operating sequence 3 (LatchedAck-F-S)

When an acknowledgment is performed, all indications that appear before the indication with higher priority has been reset, will be acknowledged, independent of if the low priority indication appeared before or after acknowledgment. In Figure 16 it is shown the sequence when a signal of lower priority becomes activated after acknowledgment has been performed on a higher priority signal. The low priority signal will be shown as acknowledged when the high priority signal resets.

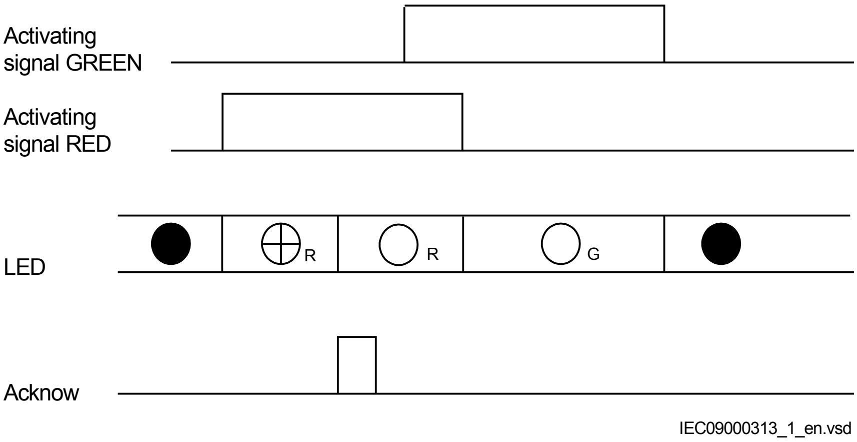

Figure 16: Operating sequence 3, 2 colors involved

If all three signals are activated the order of priority is still maintained. Acknowledgment of indications with higher priority will acknowledge also low priority indications, which are not visible according to figure 17.

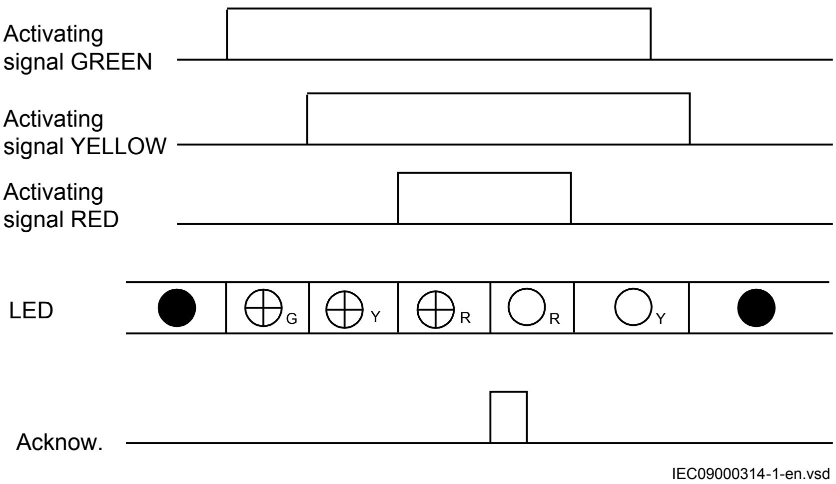

Figure 17: Operating sequence 3, three colors involved, alternative 1

If an indication with higher priority appears after acknowledgment of a lower priority indication the high priority indication will be shown as not acknowledged according to figure 18.

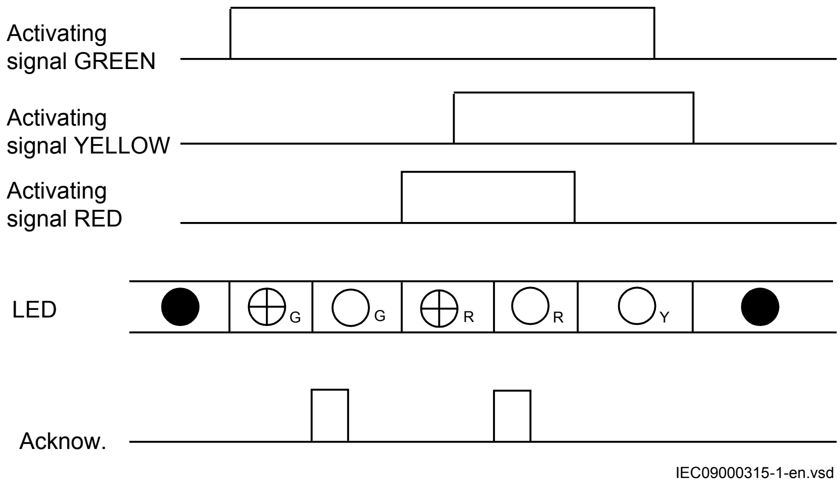

Figure 18: Operating sequence 3, three colors involved, alternative 2

Sequence 4 (LatchedAck-S-F)

This sequence has the same functionality as sequence 3, but steady and flashing light have been alternated.

Sequence 5 (LatchedColl-S)

This sequence has a latched function and works in collecting mode. At the activation of the input signal, the indication will light up with a steady light. The difference to sequence 3 and 4 is that indications that are still activated will not be affected by the reset that is, immediately after the positive edge of the reset has been executed a new reading and storing of active signals is performed. Every LED is independent of the other LEDs in its operation.

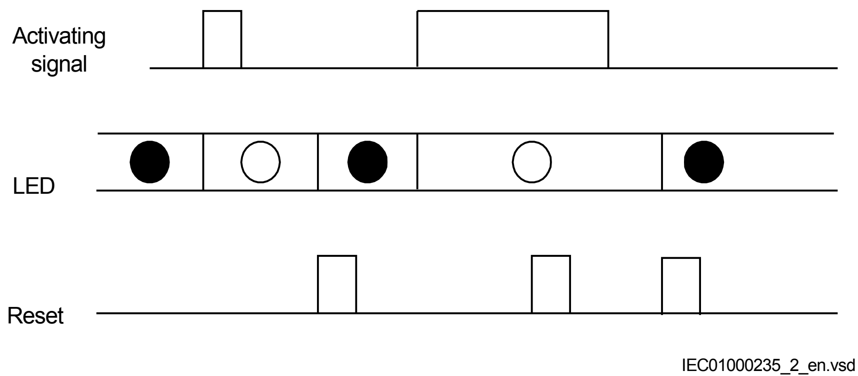

Figure 19: Operating sequence 5 (LatchedColl-S)

That means if an indication with higher priority has reset while an indication with lower priority still is active at the time of reset, the LED will change color according to figure 20.

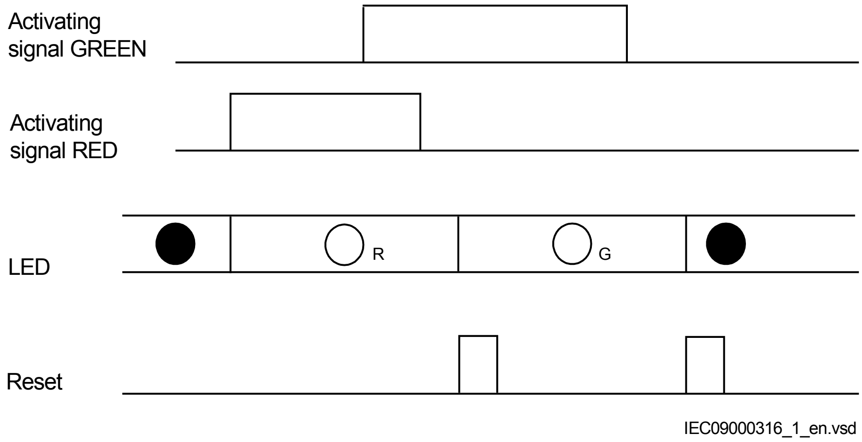

Figure 20: Operating sequence 5, two colors

Sequence 6 (LatchedReset-S)

In this mode all activated LEDs, which are set to sequence 6 (LatchedReset-S), are automatically reset at a new disturbance when activating any input signal for other LEDs set to sequence 6 (LatchedReset-S). Also in this case indications that are still activated will not be affected by manual reset, that is, immediately after the positive edge of that the manual reset has been executed a new reading and storing of active signals is performed. LEDs set for sequence 6 are completely independent in its operation of LEDs set for other sequences.

Timing diagram for sequence 6

Figure 21 shows the timing diagram for two indications within one disturbance.

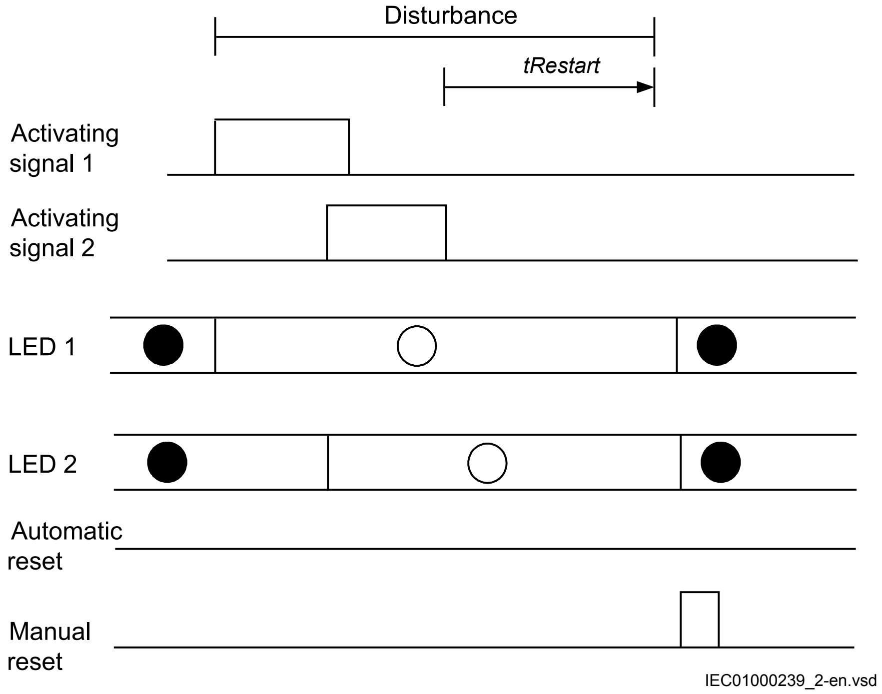

Figure 21: Operating sequence 6 (LatchedReset-S), two indications within same disturbance

Figure 22 shows the timing diagram for a new indication after *tRestart* time has elapsed.

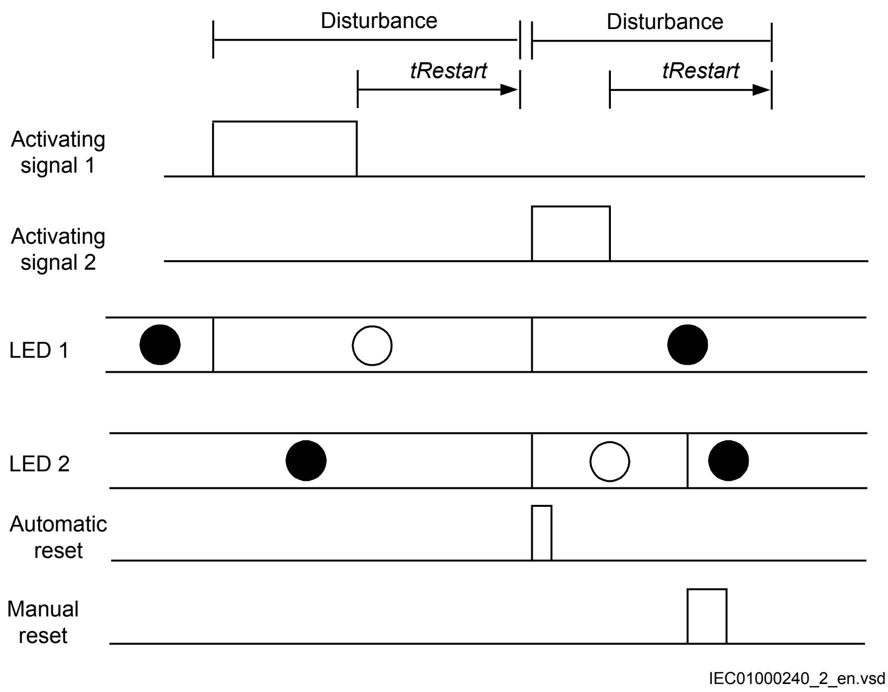

Figure 22: Operating sequence 6 (LatchedReset-S), two different disturbances

Figure 23 shows the timing diagram when a new indication appears after the first one has reset but before *tRestart* has elapsed.

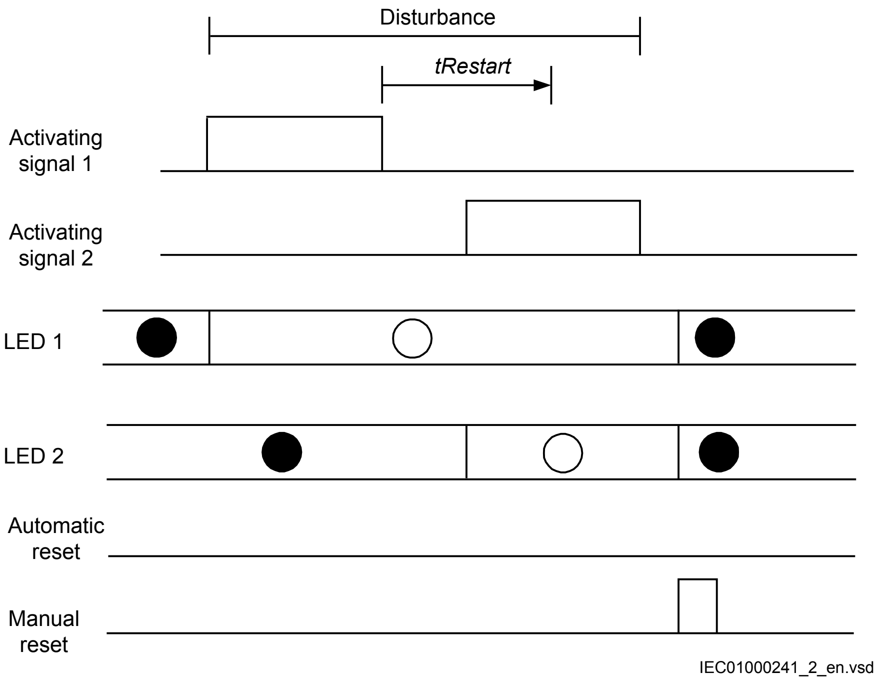

Figure 23: Operating sequence 6 (LatchedReset-S), two indications within same disturbance but with reset of activating signal between

Figure 24 shows the timing diagram for manual reset.

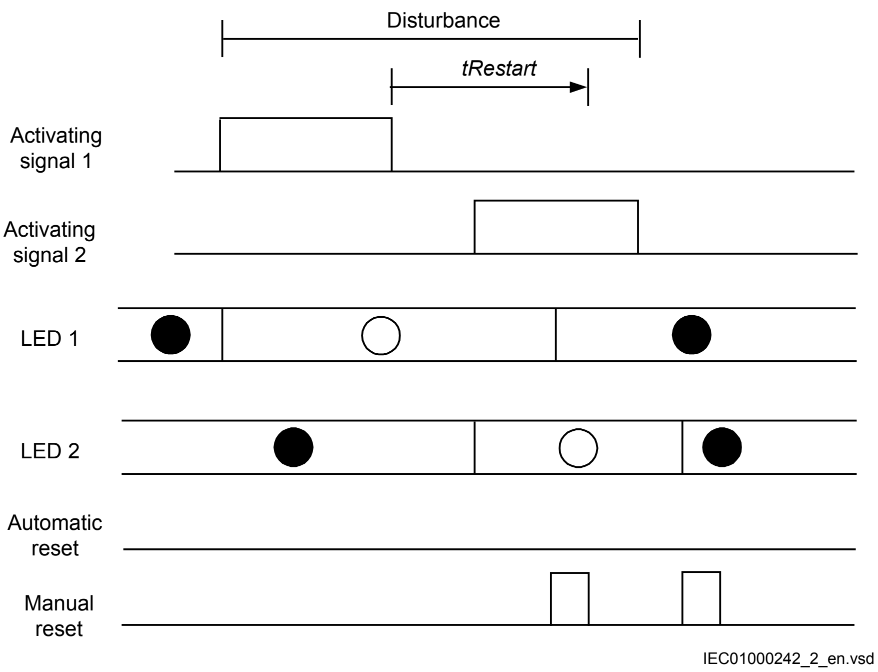

Figure 24: Operating sequence 6 (LatchedReset-S), manual reset

3.5.3 Function keys

3.5.3.1 Functionality

Local Human-Machine-Interface (LHMI) has five function buttons, directly to the left of the LCD, that can be configured either as menu shortcut or control buttons. Each button has an indication LED that can be configured in the application configuration.

When used as a menu shortcut, a function button provides a fast way to navigate between default nodes in the menu tree. When used as a control, the button can control a binary signal.

3.5.3.2 Operation principle

Each output on FNKEYMD1 - FNKEYMD5 function blocks can be controlled from the LHMI function keys. By pressing a function button on the LHMI, the output status of the actual function block will change. These binary outputs can in turn be used to control other function blocks, for example, switch control blocks, binary I/O outputs etc.

FNKEYMD1 - FNKEYMD5 function block also has a number of settings and parameters that controls the behavior of the function block. These settings and parameters are normally set using the PST.

Operating sequence

The operation mode is set individually for each output, either OFF, TOGGLE or PULSED.

Mode 0 (OFF)

This mode always gives the output the value 0 (FALSE). Changes on the IO attribute are ignored.

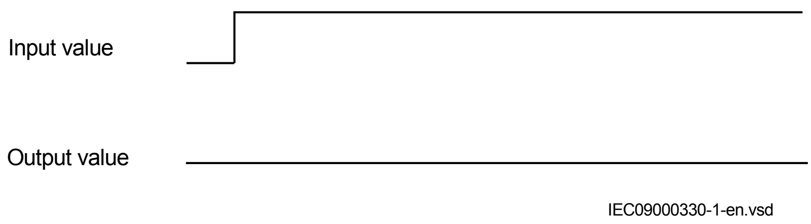

Figure 25: Sequence diagram for Mode 0

Mode 1 (TOGGLE)

In this mode the output toggles each time the function block detects that the input has been written. Note that the input attribute is reset each time the function block executes. The function block execution is marked with a dotted line below.

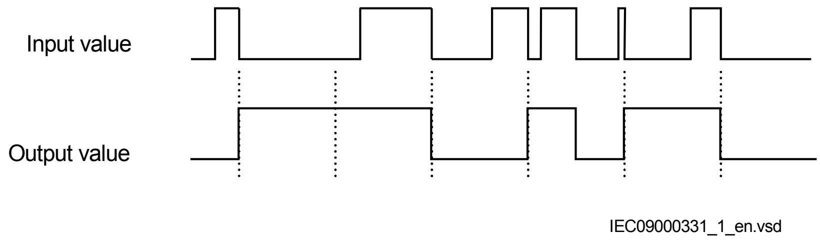

Figure 26: Sequence diagram for Mode 1

Mode 2 (PULSED)

In this mode the output will be high for as long as the setting *pulse time*. After this time the output will go back to 0. The input attribute is reset when the function block detects it being high and there is no output pulse.

Note that the third positive edge on the input attribute does not cause a pulse, since the edge was applied during pulse output. A new pulse can only begin when the output is zero; else the trigger edge is lost.

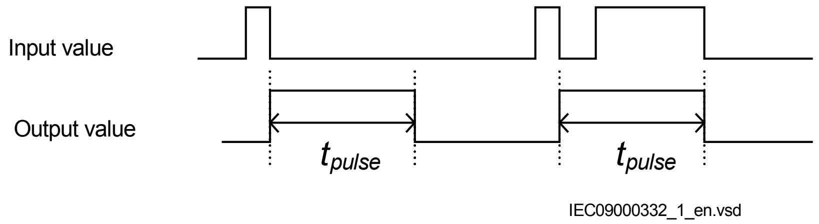

Figure 27: Sequence diagram for Mode 2

Input function

All inputs work the same way: When the LHMI is configured so that a certain function button is of type CONTROL, then the corresponding input on this function block becomes active, and will light the yellow function button LED when high. This functionality is active even if the function block operation setting is set to off.

Section 4 Impedence protection

4.1 Five zone distance protection, quadrilateral characteristic ZQDPDIS

4.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Five zone distance protection, quadrilateral characteristic	ZQDPDIS	Z<	21

4.1.2 Functionality

Five zone distance protection, quadrilateral characteristic (ZQDPDIS) is a five zone full scheme protection with three fault loops for phase-to-phase faults and three fault loops for phase-to-earth fault for each of the independent zones. Individual settings for each zone in resistive and reactive reach gives flexibility for use as back-up protection for transformer connected to overhead lines and cables of different types and lengths.

ZQDPDIS together with phase selection with load enchroachment, FDPSPDIS has functionality for load enchroachment which increases the possibility to detect high resistive faults on heavily loaded lines (see figure 28).

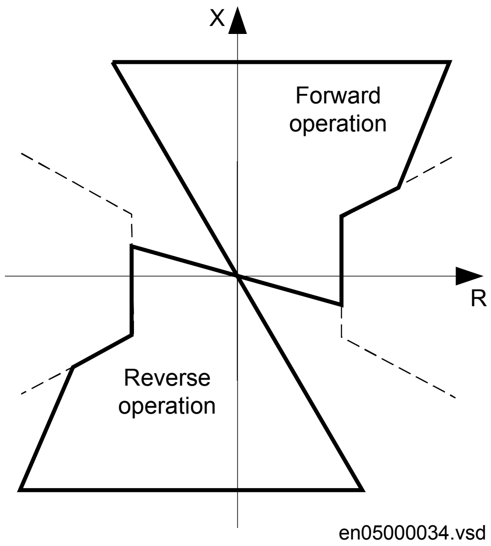

Figure 28: Typical quadrilateral distance protection zone with Phase selection with load encroachment function (FDPSPDIS) activated

Built-in adaptive load compensation algorithm prevents overreaching of zone 1 at phase-to-earth faults on heavily loaded power lines.

The distance protection zones can operate, independent of each other, in directional (forward or reverse) or non-directional mode. This makes them suitable, together with different communication schemes, for the protection of power lines and cables in complex network configurations, such as parallel lines, multi-terminal lines etc.

4.1.3 Function block

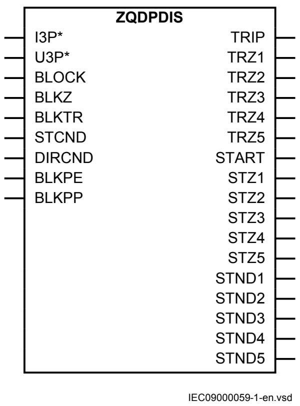

Figure 29: ZQDPDIS function block

4.1.4 Signals

Table 13: ZQDPDIS Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKZ	BOOLEAN	0	Blocks all outputs by fuse failure signal
BLKTR	BOOLEAN	0	Blocks all trip outputs
STCND	INTEGER	0	External start condition (loop enabler)
DIRCND	INTEGER	0	External directional condition
BLKPE	BOOLEAN	0	Blocks all outputs related to phase-to-earth operation
BLKPP	BOOLEAN	0	Blocks all outputs related to phase-to-phase operation

Table 14: ZQDPDIS Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TRZ1	BOOLEAN	Trip zone 1
TRZ2	BOOLEAN	Trip zone 2
TRZ3	BOOLEAN	Trip zone 3
TRZ4	BOOLEAN	Trip zone 4
TRZ5	BOOLEAN	Trip zone 5
START	BOOLEAN	General start signal
STZ1	BOOLEAN	Start zone 1
STZ2	BOOLEAN	Start zone 2
STZ3	BOOLEAN	Start zone 3
STZ4	BOOLEAN	Start zone 4
STZ5	BOOLEAN	Start zone 5
STND1	BOOLEAN	Non-directional start, issued from any phase or loop,zone 1
STND2	BOOLEAN	Non-directional start, issued from any phase or loop, zone 2
STND3	BOOLEAN	Non-directional start, issued from any phase or loop,zone 3
STND4	BOOLEAN	Non-directional start, issued from any phase or loop, zone 4
STND5	BOOLEAN	Non-directional start, issued from any phase or loop, zone 5

4.1.5 Settings

Table 15: ZQDPDIS Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
RFPE1	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, zone 1
RFPE2	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, zone 2
RFPE3	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, zone 3
RFPE4	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, zone 4
RFPE5	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, zone 5
RFPP1	1.00 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, zone 1
RFPP2	1.00 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, zone 2
RFPP3	1.00 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, zone 3
RFPP4	1.00 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, zone 4
RFPP5	1.00 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, zone 5
Z1	0.005 - 3000.000	-	0.001	30	Positive sequence impedance reach for zone 1
Z2	0.005 - 3000.000	-	0.001	30	Positive sequence impedance reach for zone 2
Z3	0.005 - 3000.000	-	0.001	30	Positive sequence impedance reach for zone 3
Z4	0.005 - 3000.000	-	0.001	30	Positive sequence impedance reach for zone 4
Z5	0.005 - 3000.000	-	0.001	30	Positive sequence impedance reach for zone 5
IMinOpPP	10 - 30	%IB	1	20	Minimum operate delta current for Phase-Phase loops
IMinOpPE	10 - 30	%IB	1	20	Minimum operate phase current for Phase-Earth loops
IMinOpIN	5 - 30	%IB	1	5	Minimum operate residual current for Phase-Earth loops
LineAng	0 - 180	Deg	1	80	Line angle for zone 1, 2, 3, 4 and 5
KNMag1	0.00 - 3.00	-	0.01	0.80	Magnitude of earth return compensation factor KN for zone 1
KNMag2	0.00 - 3.00	-	0.01	0.80	Magnitude of earth return compensation factor KN for zone 2, 3, 4 and 5
KNAng1	-180 - 180	Deg	1	0	Angle for earth return compensation factor KN for zone 1

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
KNAng2	-180 - 180	Deg	1	0	Angle for earth return compensation factor for zone 2, 3, 4 and 5
OpModetPE1	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Earth of zone 1
OpModetPP1	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Phase of zone 1
DirMode1	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 1
tPE1	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Earth, zone 1
tPP1	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Phase, zone 1
OpModetPE2	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Earth of zone 2
OpModetPP2	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Phase of zone 2
DirMode2	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 2
tPE2	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Earth, zone 2
tPP2	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Phase zone 2
OpModetPE3	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Earth of zone 3
OpModetPP3	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Phase of zone 3
DirMode3	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 3
tPE3	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Earth, zone 3
tPP3	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Phase zone 3
OpModetPE4	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Earth of zone 4
OpModetPP4	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Phase of zone 4
DirMode4	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 4
tPE4	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Earth, zone 4
tPP4	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Phase, zone 4
OpModetPE5	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Earth of zone 5
OpModetPP5	Off On	-	-	On	Operation mode Off / On of zone timer, Phase-Phase of zone 5
DirMode5	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 5

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
tPE5	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Earth, zone 5
tPP5	0.000 - 60.000	s	0.001	0.000	Time delay to trip, Phase-Phase, zone 5
OpMode1	Disable-Zone Enable Ph-E Enable PhPh Enable Ph-E PhPh	-	-	Enable Ph-E PhPh	Operation mode of zone 1
OpMode2	Disable-Zone Enable Ph-E Enable PhPh Enable Ph-E PhPh	-	-	Enable Ph-E PhPh	Operation mode of zone 2
OpMode3	Disable-Zone Enable Ph-E Enable PhPh Enable Ph-E PhPh	-	-	Enable Ph-E PhPh	Operation mode of zone 3
OpMode4	Disable-Zone Enable Ph-E Enable PhPh Enable Ph-E PhPh	-	-	Enable Ph-E PhPh	Operation mode of zone 4
OpMode5	Disable-Zone Enable Ph-E Enable PhPh Enable Ph-E PhPh	-	-	Enable Ph-E PhPh	Operation mode of zone 5

Table 16: ZQDPDIS Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.1.6 Operation principle

4.1.6.1 Full scheme measurement

The execution of the different fault loops within the IED are of full scheme type, which means that each fault loop for phase-to-earth faults and phase-to-phase faults for forward and reverse faults are executed in parallel.

Figure 30 presents an outline of the different measuring loops for the five, impedance-measuring zones.

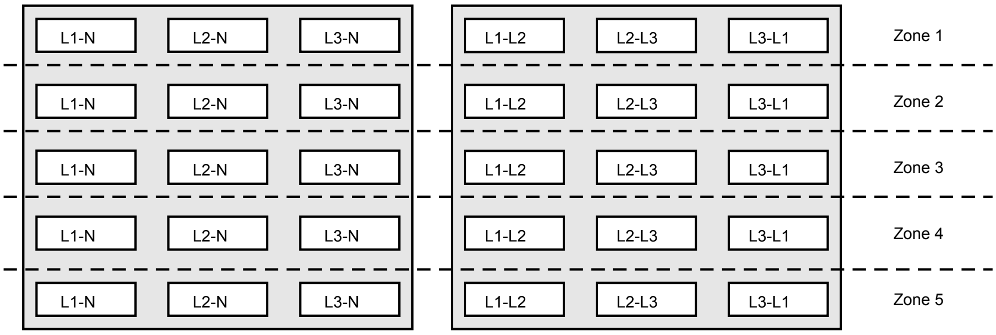

Figure 30: The different measuring loops at phase-to-earth fault and phase-to-phase fault.

The use of full scheme technique gives faster operation time compared to switched schemes which mostly uses a start element to select correct voltages and current depending on fault type. Each distance protection zone performs like one independent distance protection IED with six measuring elements.

4.1.6.2 Impedance characteristic

The distance measuring zone includes six impedance measuring loops; three intended for phase-to-earth faults, and three intended for phase-to-phase as well as, three-phase faults.

The distance measuring zone will essentially operate according to the non-directional impedance characteristics presented in figure 31 and figure 32. The phase-to-earth characteristic is illustrated with the full loop reach while the phase-to-phase characteristic presents the per phase reach.

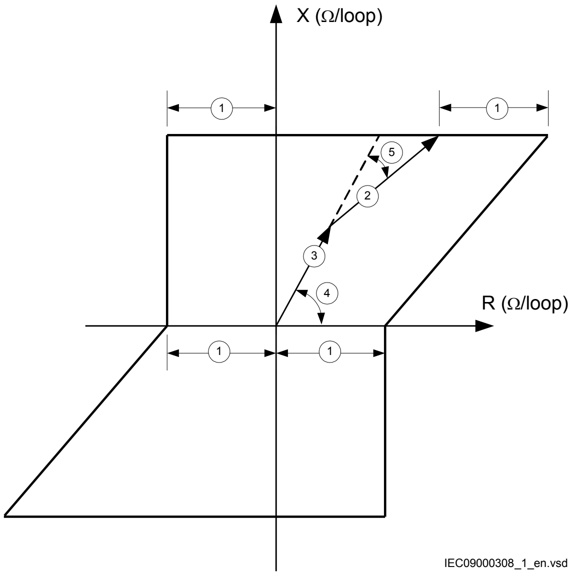

Figure 31: Characteristic for phase-to-earth measuring

1 *RFPE*

2 *KNMag |Z|*
where: *KN·Z*=ZN

3 *|Z|*
where *Z* denotes the positive sequence vector corresponding to the zone reach

4 *LineAng*

5 *KNAng* (negative)

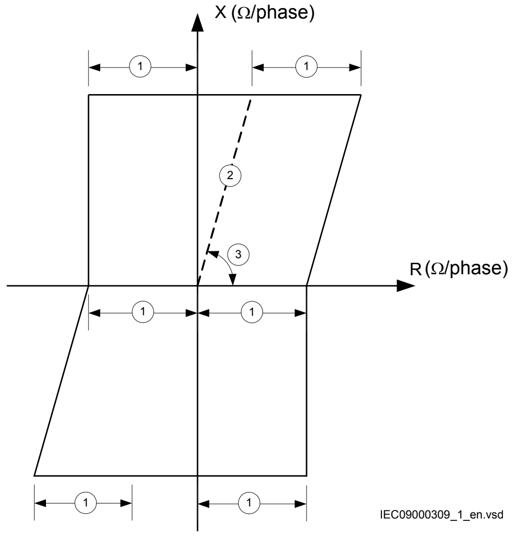

Figure 32: Characteristic for phase-to-phase measuring

1 0.5 · *RFPP*

2 *Z1*

3 *LineAng*

The fault loop reach with respect to each fault type may also be presented as in figure 33. Note in particular the difference in definition regarding the (fault) resistive reach for phase-to-phase faults and three-phase faults.

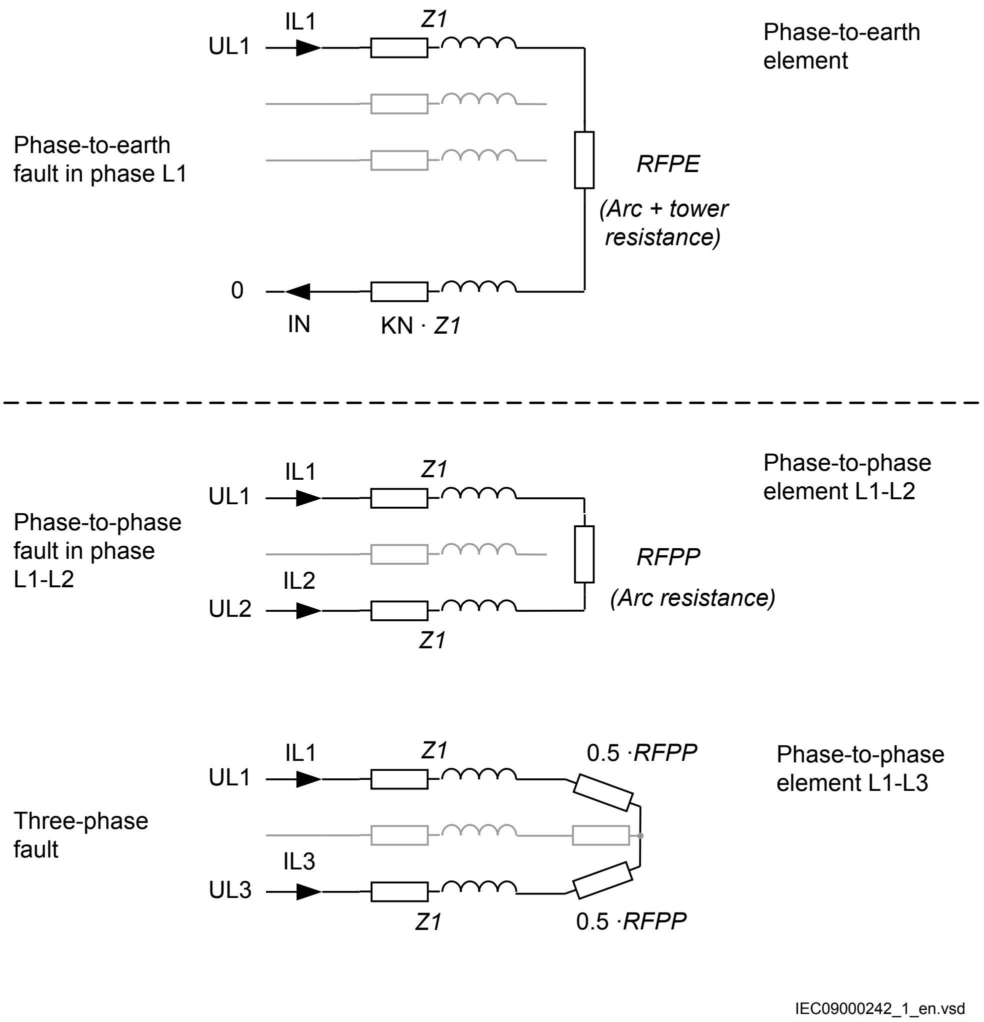

Figure 33: Fault loop model

The Z1 in figure 33 represents the positive sequence impedance from the measuring point to the fault location. The settings *RFPEx* and *RFPPx* (where *x* is 1-5 depending on selected zone) are the eventual fault resistances in the faulty place.

Regarding the illustration of three-phase fault in figure 33, there is of course fault current flowing also in the third phase during a three-phase fault. The illustration merely reflects the loop measurement, which is made phase-to-phase.

The zone can be set to operate in Non-directional, Forward or Reverse direction through the setting *DirModex* (where *x* is 1-5 depending on selected zone). The result from respective set value is illustrated in figure 34. The impedance reach is symmetric, in the sense that it conforms for forward and reverse direction. Therefore, all reach settings apply to both directions.

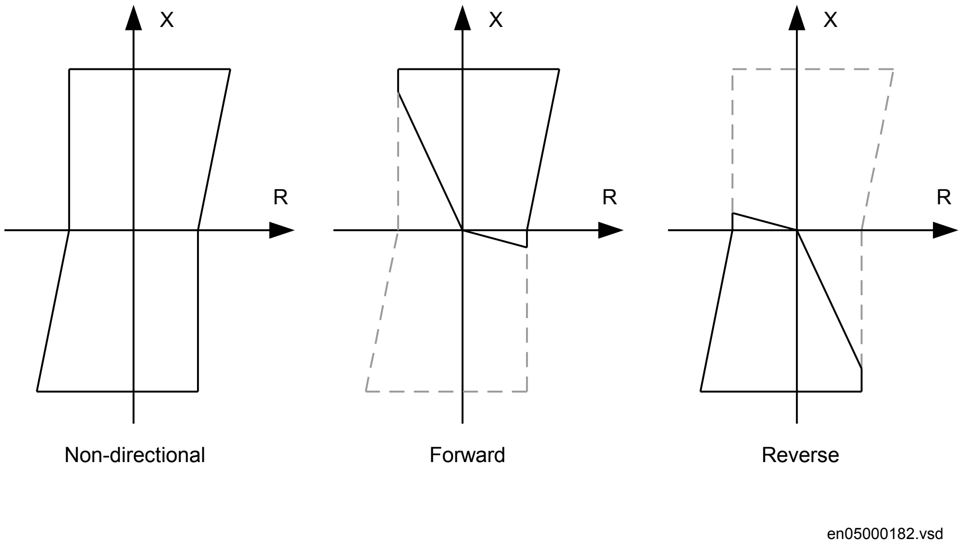

Figure 34: Directional operating modes of the distance measuring zones

4.1.6.3 Minimum operating current

The operation of Five zone distance protection, quadrilateral characteristic (ZQDPDIS) is blocked if the magnitude of input currents fall below certain threshold values.

The phase-to-earth loop Ln is blocked if ILn < *IMinOpPE*.

For zone 1 with load compensation feature the additional criterion applies, that all phase-to-earth loops will be blocked when IN < *IMinOpIN*, regardless of the phase currents.

ILn is the RMS value of the current in phase Ln. IN is the RMS value of the vector sum of the three-phase currents, that is residual current $3I_0$.

The phase-to-phase loop LmLn is blocked if ILmLn< *IMinOpPP*.

ILmLn is the RMS value of the vector difference between phase currents Lm and Ln.

All three current limits *IMinOpPE*, *IMinOpIN* and *IMinOpPP* are automatically reduced to 75% of regular set values if the zone is set to operate in reverse direction, that is *DirModex=Reverse* (where x is 1-5 depending on selected zone).

4.1.6.4 Measuring principles

Fault loop equations use the complex values of voltage, current, and changes in the current. Apparent impedances are calculated and compared with the set limits. The apparent impedances at phase-to-phase faults follows equation 1 (example for a phase L1 to phase L2 fault).

$$\overline{Z}_{app} = \frac{\overline{U_{L1}} - \overline{U_{L2}}}{\overline{I_{L1}} - \overline{I_{L2}}}$$

(Equation 1)

Here U and I represent the corresponding voltage and current phasors in the respective phase Ln (n = 1, 2, 3)

The earth return compensation applies in a conventional manner to phase-to-earth faults (example for a phase L1 to earth fault) according to equation 2.

$$\overline{Z}_{app} = \frac{\overline{U_{L1}}}{\overline{I_{L1}} + \overline{I}_{N} \cdot KN}$$

(Equation 2)

Where:

U_{L1}, I_{L1} and $_{IN}$ are the phase voltage, phase current and residual current present to the IED

KN is defined as:

$$KN = \frac{Z0 - Z1}{3 \cdot Z1}$$

$$Z0 = R0 + jX0$$

$$Z1 = R1 + jX1$$

Where

R0	is the resistive zero sequence reach
X0	is the reactive zero sequence reach
R1	is the resistive positive sequence reach
X1	is the reactive positive sequence reach

Here IN is a phasor of the residual current in IED point. This results in the same reach along the line for all types of faults.

The apparent impedance is considered as an impedance loop with resistance R and reactance X.

The formula given in equation 2 is only valid for radial feeder application without load. When load is considered in the case of single phase-to-earth fault, conventional distance protection might overreach at exporting end and underreach at importing end. The IED has an adaptive load compensation which increases the security in such applications.

The directional evaluations are performed simultaneously in both forward and reverse directions, and in all six fault loops. Positive sequence voltage and a phase locked positive sequence memory voltage are used as a reference. This ensures unlimited directional sensitivity for faults close to the IED point.

4.1.6.5 Simplified logic diagrams

Distance protection zones

The design of a distance protection zone is presented for all measuring loops: phase-to-earth as well as phase-to-phase.

Phase-to-earth related signals are designated by LnE, where n represents the corresponding phase number (L1E, L2E, and L3E). The phase-to-phase signals are designated by LnLm, where n and m represent the corresponding phase numbers (L1L2, L2L3, and L3L1).

Fulfillment of two different measuring conditions is necessary to obtain the one logical signal for each separate measuring loop:

- Zone measuring condition, which follows the operating equations described above.
- Group functional input signal (STCND), as presented in figure 35.

The STCND input signal represents a connection of six different integer values from Phase selection with load enchroachment, quadrilateral characteristic function (FDPSPDIS) within the IED, which are converted within the zone measuring function into corresponding boolean expressions for each condition separately. Input signal STCND is connected to FDPSPDIS function output STCNDZI.

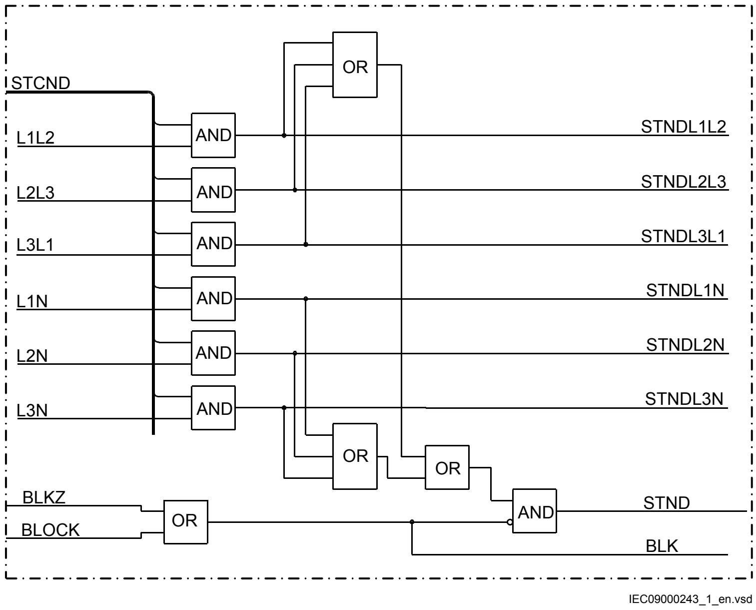

Figure 35: Conditioning by a group functional input signal STCND, external start condition

Results of the directional measurement enter the logic circuits, when the zone operates in directional (forward or reverse) mode, see figure 36.

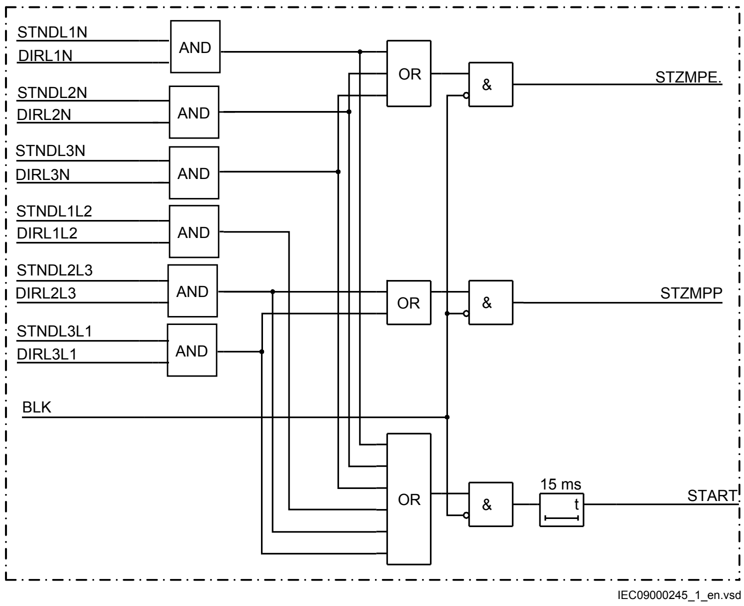

Figure 36: Composition of starting signals in directional operating mode

Tripping conditions for the distance protection zone one are symbolically presented in figure 37.

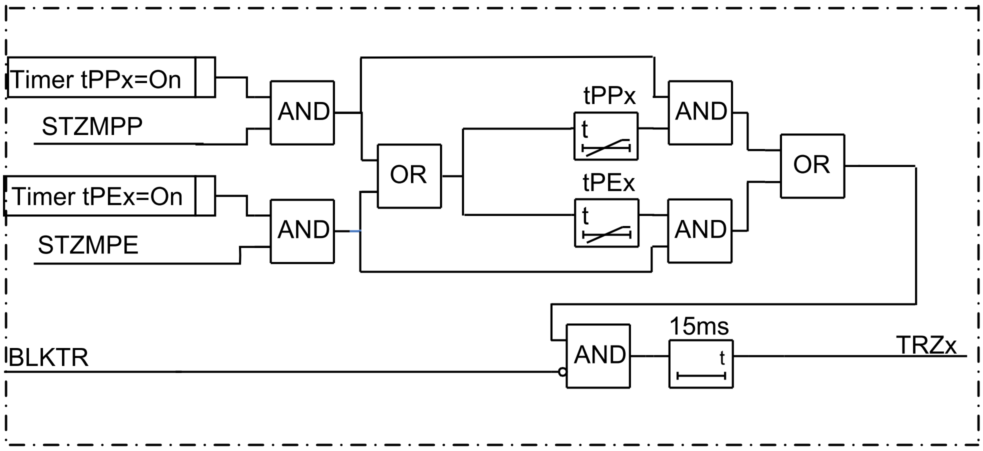

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Figure 37: Tripping logic for the distance protection zone (where x is 1-5 depending on selected zone)

4.1.7 Technical data

Table 17: ZQDPDIS Technical data

Function	Range or value	Accuracy
Number of zones	5 with selectable direction	-
Minimum operate residual current	(5-30)% of IBase	± 1,0 % of I_r
Minimum operate current, phase-to-phase and phase-to-earth	(10-30)% of IBase	± 1,0 % of I_r
Positive sequence impedance reach for zones	0.005 - 3000.000	± 2.0% static accuracy ± 2.0 degrees static angular accuracy Conditions: Voltage range: (0.1-1.1) x U_r Current range: (0.5-30) x I_r Angle: at 0 degrees and 85 degrees
Fault resistance, phase-to-earth	(1.00-9000.00) Ω/loop	
Fault resistance, phase-to-phase	(1.00-3000.00) Ω/loop	
Line angle for zones	(0 - 180) degrees	
Magnitude of earth return compensation factor KN for zones	0.00 - 3.00	-
Angle for earth return compensation factor KN for zones	(-180 - 180) degrees	-
Dynamic overreach	<5% at 85 degrees measured with CVT's and 0.5<SIR<30	-
Impedance zone timers	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time	1.5 cycles typically	-
Reset ratio	105% typically	-
Reset time	30 ms typically	-

4.2 Phase selection with load enchroachment, quadrilateral characteristic FDPSPDIS

4.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase selection with load encroachment, quadrilateral characteristic	FDPSPDIS	Z<phs	21

4.2.2 Functionality

The operation of transmission networks today is in many cases close to the stability limit. Due to environmental considerations, the rate of expansion and reinforcement of the power system is reduced e.g. difficulties to get permission to build new power lines. The phase selection function is designed to accurately select the proper fault loop in the distance function dependent on the fault type.

The heavy load transfer that is common in many transmission networks may make fault resistance coverage difficult to achieve. Therefore, the function has a built in algorithm for load encroachment, which gives the possibility to enlarge the resistive setting of both the phase selection and the measuring zones without interfering with the load.

The extensive output signals from the phase selection gives also important information about faulty phase(s) which can be used for fault analysis.

A current-based phase selection is also included. The measuring elements continuously measure three phase currents and the residual current and, compare them with the set values.

4.2.3 Function block

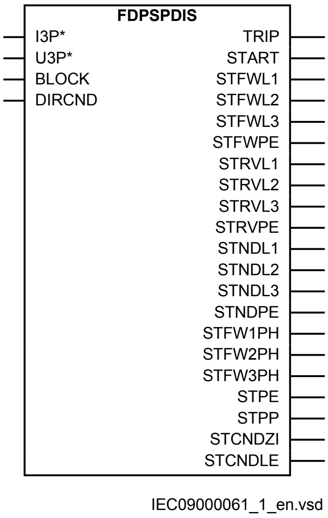

Figure 38: FDPSPDIS Function block

4.2.4 Signals

Table 18: FDPSPDIS Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
DIRCND	INTEGER	0	External directional condition

Table 19: FDPSPDIS Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip output
START	BOOLEAN	Start in any phase or loop
STFWL1	BOOLEAN	Fault detected in phase L1 - forward direction
STFWL2	BOOLEAN	Fault detected in phase L2 - forward direction
STFWL3	BOOLEAN	Fault detected in phase L3 - forward direction
STFWPE	BOOLEAN	Earth fault detected in forward direction
STRVL1	BOOLEAN	Fault detected in phase L1 - reverse direction
STRVL2	BOOLEAN	Fault detected in phase L2 - reverse direction
STRVL3	BOOLEAN	Fault detected in phase L3 - reverse direction
STRVPE	BOOLEAN	Earth fault detected in reverse direction

Table continues on next page

Name	Type	Description
STNDL1	BOOLEAN	Non directional start in L1
STNDL2	BOOLEAN	Non directional start in L2
STNDL3	BOOLEAN	Non directional start in L3
STNDPE	BOOLEAN	Non directional start, Phase-Earth
STFW1PH	BOOLEAN	Start in forward direction for single-phase fault
STFW2PH	BOOLEAN	Start in forward direction for two- phase fault
STFW3PH	BOOLEAN	Start in forward direction for three-phase fault
STPE	BOOLEAN	Current conditions release of Phase-Earth measuring elements
STPP	BOOLEAN	Current conditions release of Phase-Phase measuring elements
STCNDZI	INTEGER	Start condition (Z< with LE and/or I> and 3I0 E/F detection)
STCNDLE	INTEGER	Start condition (only LE and 3I0 E/F detection)

4.2.5 Settings

Table 20: FDPSPDIS Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
OperationZ<	Off On	-	-	On	Operation of impedance based measurement
OperationI>	Off On	-	-	Off	Operation of current based measurement
INBlockPP	10 - 100	%IPh	1	40	3I0 limit for blocking Phase-to-Phase measuring loops
INReleasePE	10 - 100	%IPh	1	20	3I0 limit for releasing Phase-to-Earth measuring loops
RLdFw	1.00 - 3000.00	ohm/p	0.01	80.00	Forward resistive reach within the load impedance area
RLdRv	1.00 - 3000.00	ohm/p	0.01	80.00	Reverse resistive reach within the load impedance area
ArgLd	5 - 70	Deg	1	30	Load angle determining the load impedance area
X0	0.50 - 3000.00	-	0.01	120.00	Zero sequence reactance reach
IPh>	10 - 2500	%IB	1	120	Start value for phase selection by over-current element
IN>	10 - 2500	%IB	1	20	Start value for trip from 3I0 over-current element
X1	0.50 - 3000.00	-	0.01	40.00	Positive sequence reactance reach
RFFwPP	0.50 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, forward
RFRvPP	0.50 - 3000.00	ohm/l	0.01	30.00	Fault resistance reach, Phase-Phase, reverse
RFFwPE	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, forward

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
RFRvPE	1.00 - 9000.00	ohm/l	0.01	100.00	Fault resistance reach, Phase-Earth, reverse
IMinOpPP	5 - 500	%IB	1	10	Minimum operate delta current for Phase-Phase loops
IMinOpPE	5 - 500	%IB	1	5	Minimum operate phase current for Phase-Earth loops

Table 21: FDPSPDIS Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
TimerPP	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase
tPP	0.000 - 60.000	s	0.001	3.000	Time delay to trip, Phase-Phase
TimerPE	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth
tPE	0.000 - 60.000	s	0.001	3.000	Time delay to trip, Phase-Earth

Table 22: FDPSPDIS Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.2.6 Operation principle

The basic impedance algorithm for the operation of the phase selection measuring elements is the same as for the distance zone measuring function. Phase selection with load encroachment function (FDPSPDIS) includes six impedance measuring loops; three intended for phase-to-earth faults, and three intended for phase-to-phase as well as for three-phase faults.

The difference, compared to the distance zone measuring function, is in the combination of the measuring quantities (currents and voltages) for different types of faults.

A current-based phase selection is also included. The measuring elements continuously measure three phase currents and the residual current, and compare them with the set values. The current signals are filtered by Fourier's recursive filter, and separate trip counter prevents too high overreaching of the measuring elements.

The characteristic is basically non-directional, but FDPSPDIS uses information from the directional function (ZDNRDIR) to discriminate whether the fault is in forward or reverse direction.

The start condition STCNDZI is essentially based on the following criteria:

1. Residual current criteria, that is, separation of faults with and without earth connection
2. Regular quadrilateral impedance characteristic
3. Load encroachment characteristics is always active but can be switched off by selecting a high setting.

The current start condition STCNDLE is based on the following criteria:

1. Residual current criteria
2. No quadrilateral impedance characteristic. The impedance reach outside the load area is theoretically infinite. The practical reach, however, will be determined by the minimum operating current limits.
3. Load encroachment characteristic is always active, but can be switched off by selecting a high setting.

The STCNDLE output is non-directional. The directionality is determined by the distance zones directional function (ZDNRDIR). There are output from FDPSPDIS that indicate whether a start is in forward or reverse direction or non-directional, for example STFWL1, STRVL1 and STNDL1.

These directional indications are based on the sector boundaries of the directional function and the impedance setting of FDPSPDIS function. Their operating characteristics are illustrated in figure 39.

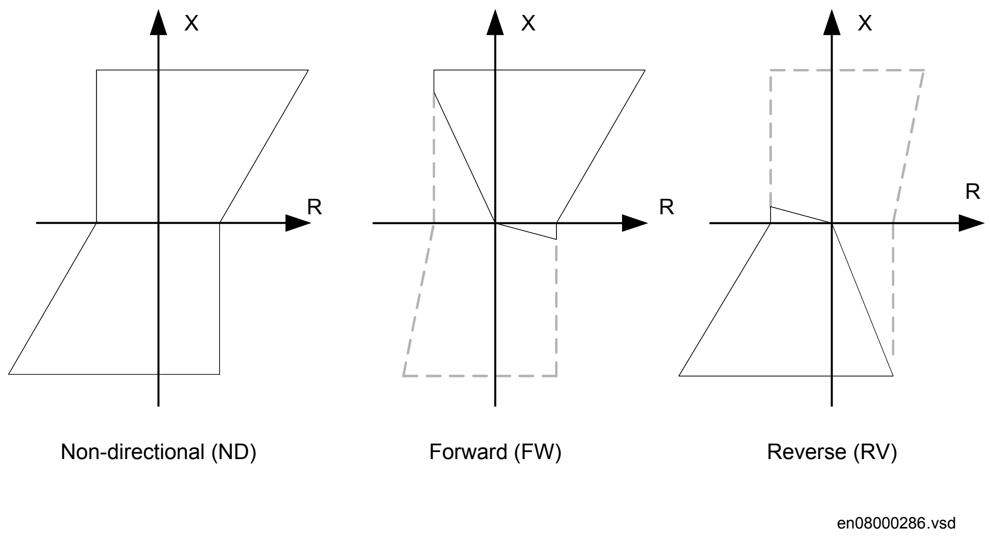

Figure 39: Characteristics for non-directional, forward and reverse operation of Phase selection with load encroachment function (FDPSPDIS)

The setting of the load encroachment function may influence the total operating characteristic, (for more information, refer to section "Load encroachment").

The input DIRCND contains binary coded information about the directional coming from the directional function (ZDNRDIR). It shall be connected to the

STDIR output on ZDNRDIR . This information is also transferred to the input DIRCND on the distance measuring zones, that is, the ZQDPDIS block.

The STCNDZI or STCNDLE output contains, in a similar way as DIRCND, binary coded information, in this case information about the condition for opening correct fault loop in the distance measuring element. It shall be connected to the STCND input on the ZQDPDIS blocks.

4.2.6.1 Phase-to-earth fault

For a phase-to-earth fault, the measured impedance by FDPSPDIS will be according to equation 3.

Index PHS in images and equations reference settings for Phase selection with load encroachment function (FDPSPDIS).

$$Z_{PHSn} = \frac{ULn}{ILn}$$

(Equation 3)

where:

n corresponds to the particular phase (n=1, 2 or 3)

The characteristic for FDPSPDIS function at phase-to-earth fault is according to figure 40. The characteristic has a fixed angle for the resistive boundary in the first quadrant of 60°.

The resistance RN and reactance XN are the impedance in the earth return path defined according to equation 4 and equation 5.

$$RN = \frac{R0 - R1}{3}$$

(Equation 4)

$$XN = \frac{X0 - X1}{3}$$

(Equation 5)

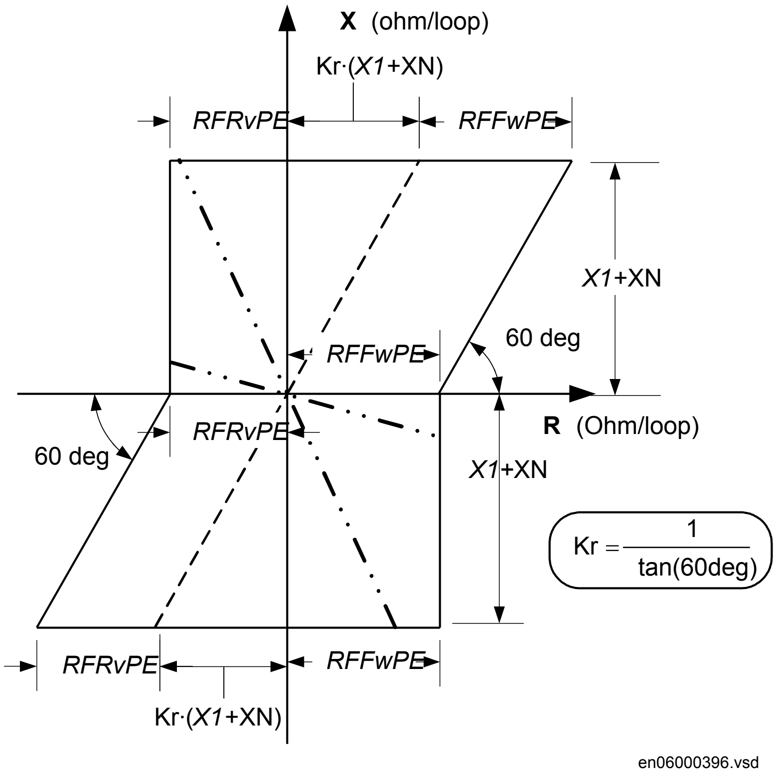

Figure 40: Characteristic of FDPSPDIS for phase-to-earth fault (setting parameters in italic), ohm/loop domain (directional lines are drawn as "line-dot-dot-line")

Besides this, the $3I_0$ residual current must fulfil the conditions according to equation 6 and equation 7.

$$3 \cdot I_0 \geq 0.5 \cdot IMinOpPE$$

(Equation 6)

$$|3 \cdot I_0| \geq \frac{INReleasePE}{100} \cdot I_{phmax}$$

(Equation 7)

where:

IMinOpPE	is the minimum operation current for forward zones
INReleasePE	is the setting for the minimum residual current needed to enable operation in the phase-to-earth fault loops (in %).
Iphmax	is the maximum phase current in any of three phases.

4.2.6.2 Phase-to-phase fault

For a phase-to-phase fault, the measured impedance by FDPSPDIS will be according to equation 8.

$$ZPHS = \frac{ULm - ULn}{-2 \cdot ILn}$$

(Equation 8)

ULm is the leading phase voltage, ULn the lagging phase voltage and ILn the phase current in the lagging phase n.

The operation characteristic is shown in figure 41.

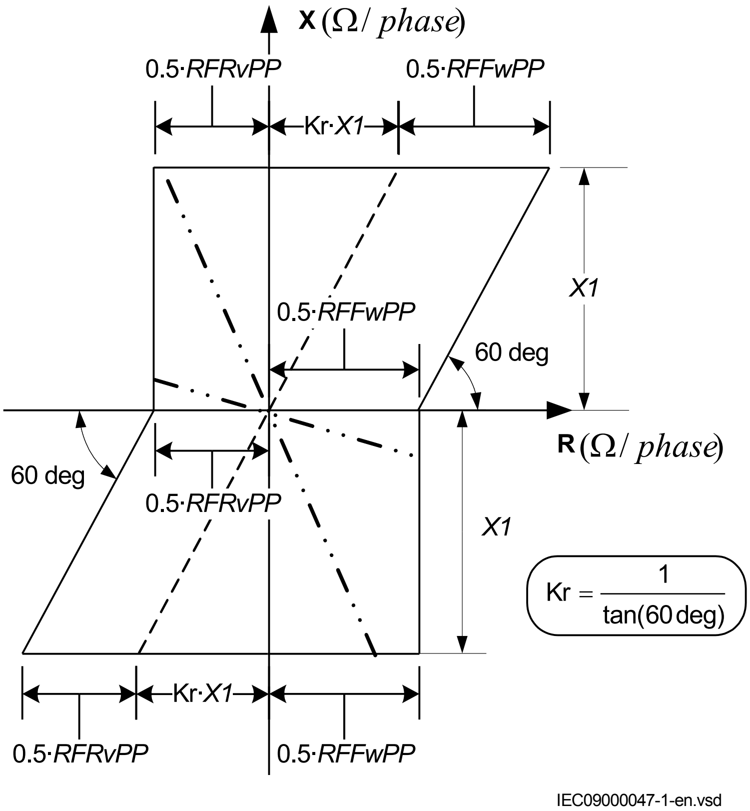

Figure 41: The operation characteristics for FDPSPDIS at phase-to-phase fault (setting parameters in italic, directional lines drawn as "line-dot-dot-line"), ohm/phase domain

In the same way as the condition for phase-to-earth fault, there are current conditions that have to be fulfilled in order to release the phase-to-phase loop. Those are according to equation 9 or equation 10.

$$\left|3I_0\right| < IMinOpPE$$

(Equation 9)

$$|3I_0| < \frac{INBlockPP}{100} \cdot Iph_{max}$$

(Equation 10)

where:

IMinOpPE	is the minimum operation current for forwardearth measuring loops,
INBlockPP	is $3I_0$ limit for blocking phase-to-phase measuring loop and
Iphmax	is maximal magnitude of the phase currents.

4.2.6.3 Three-phase faults

The operation conditions for three-phase faults are the same as for phase-to-phase fault, that is equation 8, equation 9 and equation 10 are used to release the operation of the function.

However, the reach is expanded by a factor 2/√3 (approximately 1.1547) in all directions. At the same time the characteristic is rotated 30 degrees, counter-clockwise. The characteristic is shown in figure 42.

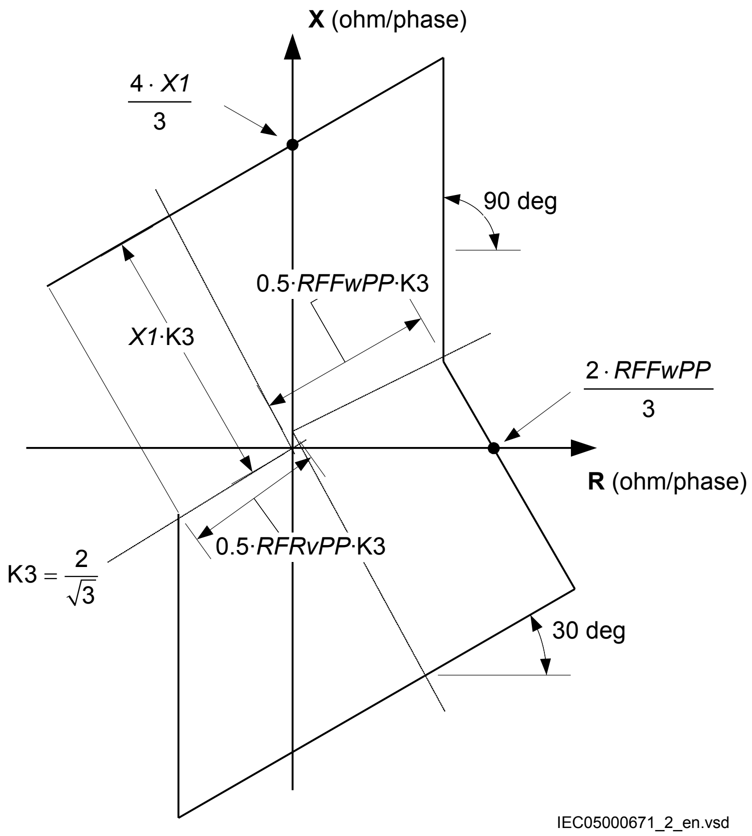

Figure 42: The characteristic of FDPSPDIS for three-phase fault (setting parameters in italic)

4.2.6.4 Load encroachment

Each of the six measuring loops has its own load encroachment characteristic based on the corresponding loop impedance. The load encroachment functionality is always active, but can be switched off by selecting a high setting.

The outline of the characteristic is presented in figure 43. As illustrated, the resistive blinders are set individually in forward and reverse direction while the angle of the sector is the same in all four quadrants.

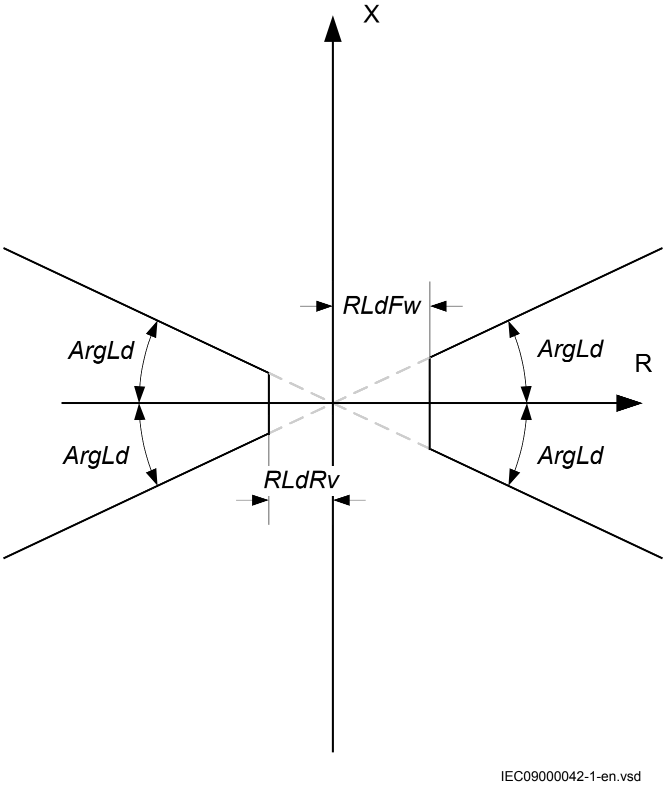

Figure 43: Characteristic of load encroachment function

The influence of load encroachment function on the operation characteristic is dependent on the chosen operation mode of FDPSPDIS function. When output signal STCNDZI is selected, the characteristic for FDPSPDIS (and also zone measurement depending on settings) will be reduced by the load encroachment characteristic (see figure 44, left illustration).

When output signal STCNDLE is selected, the operation characteristic will be as the right illustration in figure 44. The reach will in this case be limit by the minimum operation current and the distance measuring zones.

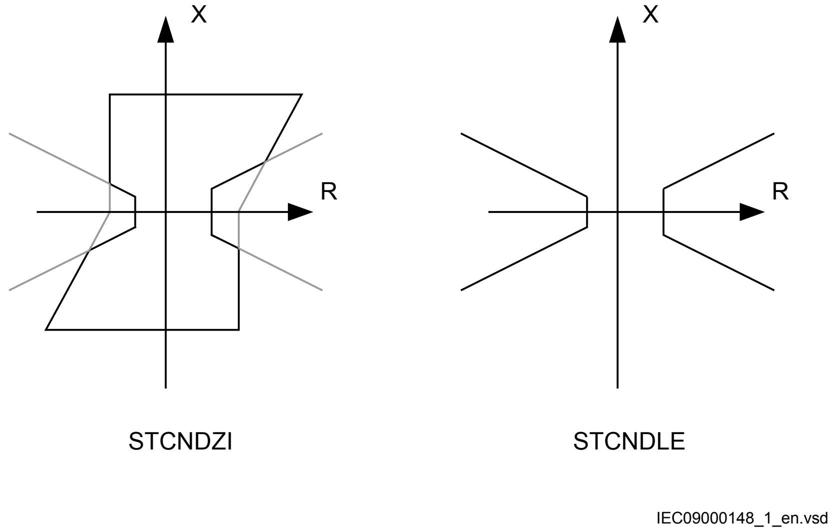

Figure 44: Difference in operating characteristic depending on operation mode when load encroachment is activated

When FDPSPDIS is set to operate together with a distance measuring zone the resultant operate characteristic could look like in figure 45. The figure shows a distance measuring zone operating in forward direction. Thus, the operating area is highlighted in black.

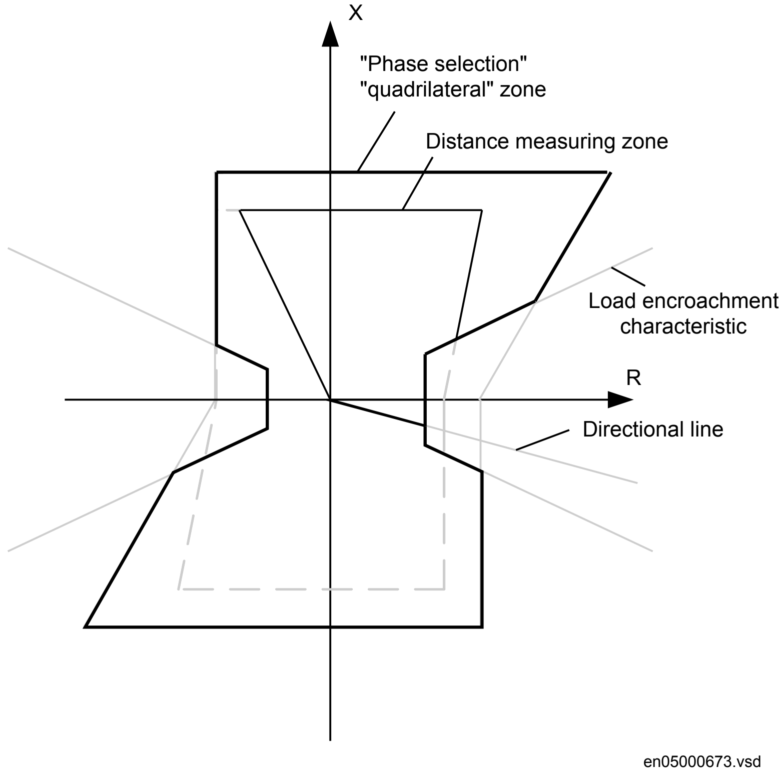

Figure 45: Operating characteristic in forward direction when load encroachment is activated

Figure 45 is valid for phase-to-earth. During a three-phase fault, or load, when the quadrilateral phase-to-phase characteristic is subject to enlargement and rotation the operate area is transformed according to figure 46. Due to the 30-degree rotation, the angle of the blinder in quadrant one is now 100 degrees instead of the original 70 degrees. The blinder that is nominally located to quadrant four will at the same time tilt outwards and increase the resistive reach around the R-axis. Consequently, it will be more or less necessary to use the load encroachment characteristic in order to secure a margin to the load impedance.

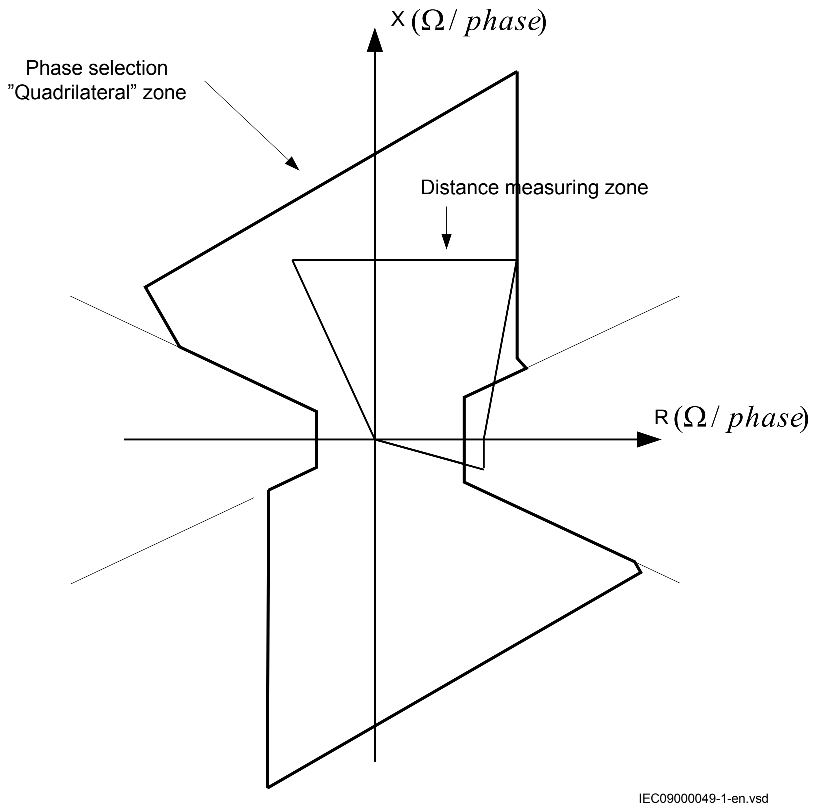

Figure 46: Operating characteristic for FDPSPDIS in forward direction for three-phase fault, ohm/phase domain

The result from rotation of the load characteristic at a fault between two phases is presented in fig 47. Since the load characteristic is based on the same measurement as the quadrilateral characteristic, it will rotate with the quadrilateral characteristic clockwise by 30 degrees when subject to a pure phase-to-phase fault. At the same time the characteristic will "shrink" by $2/\sqrt{3}$, from the full *RLdFw* and *RLdRv* reach which is valid at load or three-phase fault.

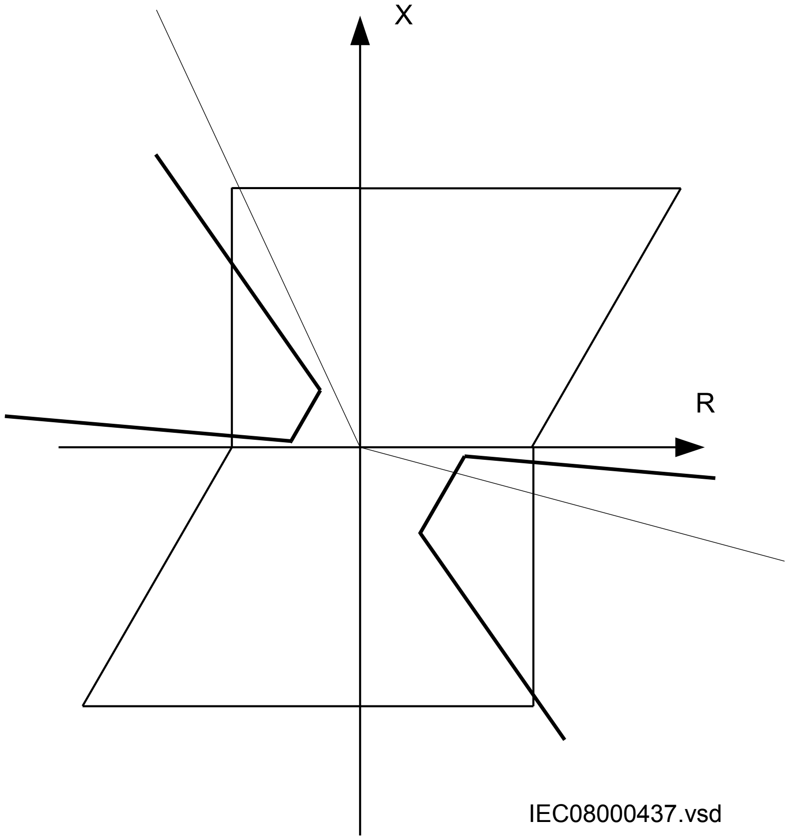

Figure 47: Rotation of load characteristic for a fault between two phases

There is a gain in selectivity by using the same measurement as for the quadrilateral characteristic since not all phase-to-phase loops will be fully affected by a fault between two phases. It should also provide better fault resistive coverage in quadrant one. The relative loss of fault resistive coverage in quadrant four should not be a problem even for applications on series compensated lines.

4.2.6.5 Minimum operate currents

The operation of the Phase selection with load encroachment function (FDPSPDIS) is blocked if the magnitude of input currents falls below certain threshold values.

The phase-to-earth loop Ln is blocked if ILn<*IMinOpPE*, where ILn is the RMS value of the current in phase Ln.

The phase-to-phase loop LmLn is blocked if (2·ILn<*IMinOpPP*).

4.2.6.6 Simplified logic diagrams

Figure 48 presents schematically the creation of the phase-to-phase and phase-to-earth operating conditions. Consider only the corresponding part of measuring and logic circuits, when only a phase-to-earth or phase-to-phase measurement is available within the IED.

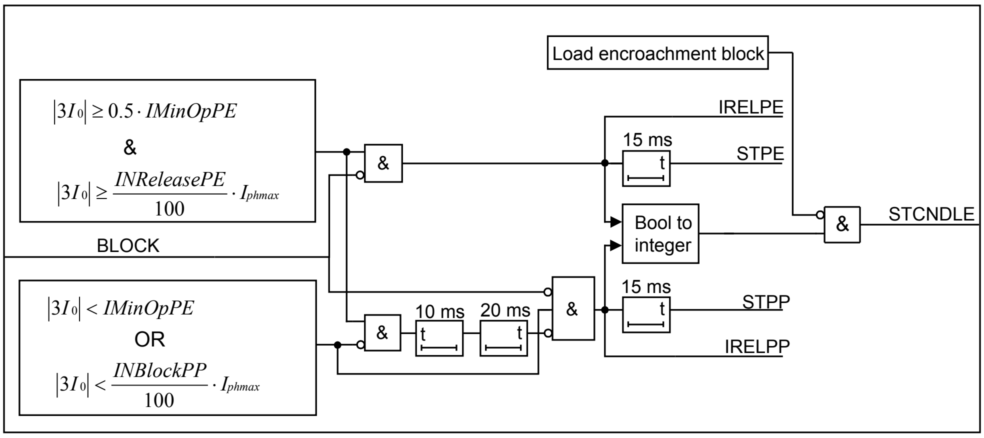

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Figure 48: Phase-to-phase and phase-to-earth operating conditions (residual current criteria)

A special attention is paid to correct phase selection at evolving faults. A STCNDLE output signal is created as a combination of the load encroachment characteristic and current criteria, refer to figure 48. This signal can be configured to STCND functional input signals of the distance protection zone and this way influence the operation of the phase-to-phase and phase-to-earth zone measuring elements and their phase related starting and tripping signals.

Figure 49 presents schematically the composition of non-directional phase selective signals STNDLn. Internal signals ZMLnN and ZMLmLn (m and n change between one and three according to the phase number) represent the fulfilled operating criteria for each separate loop measuring element, that is within the characteristic.

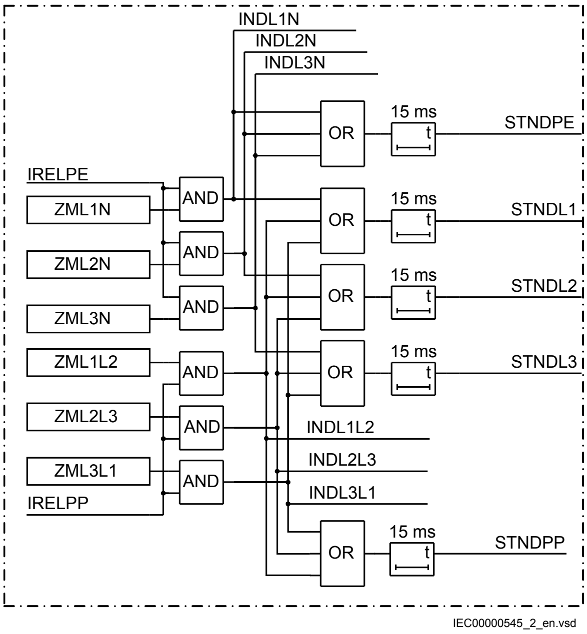

Figure 49: Composition on non-directional phase selection signals

Composition of the directional (forward and reverse) phase selective signals is presented schematically in figure 51 and figure 50. The directional criteria appears as a condition for the correct phase selection in order to secure a high phase selectivity for simultaneous and evolving faults on lines within the complex network configurations. Internal signals DFWLn and DFWLnLm present the corresponding directional signals for measuring loops with phases Ln and Lm. Designation FW (figure 51) represents the forward direction as well as the designation RV (figure 50) represents the reverse direction. All directional signals are derived within the corresponding digital signal processor.

Figure 50 presents additionally a composition of a STCNDZI output signal, which is created on the basis of impedance measuring conditions. This signal can be configured to STCND functional input signals of the distance protection zone and this way influence the operation of the phase-to-phase and phase-to-earth zone measuring elements and their phase related starting and tripping signals.

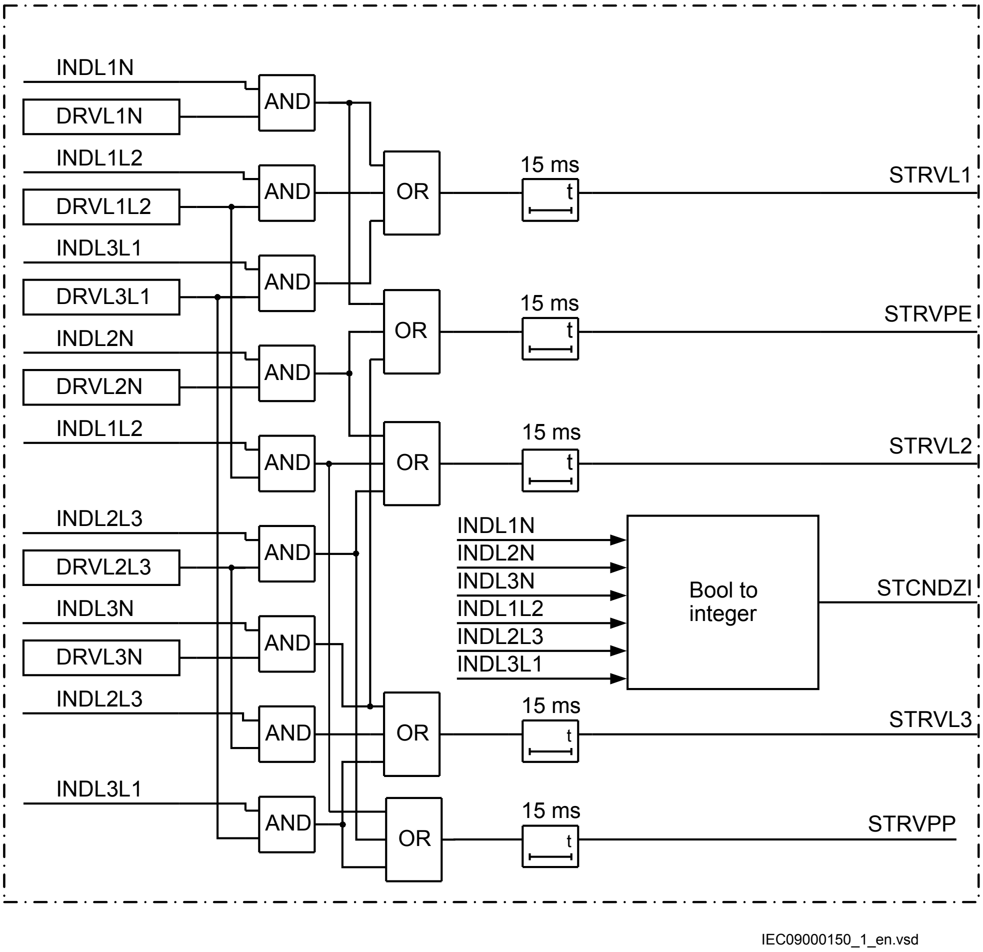

Figure 50: Composition of phase selection signals for reverse direction

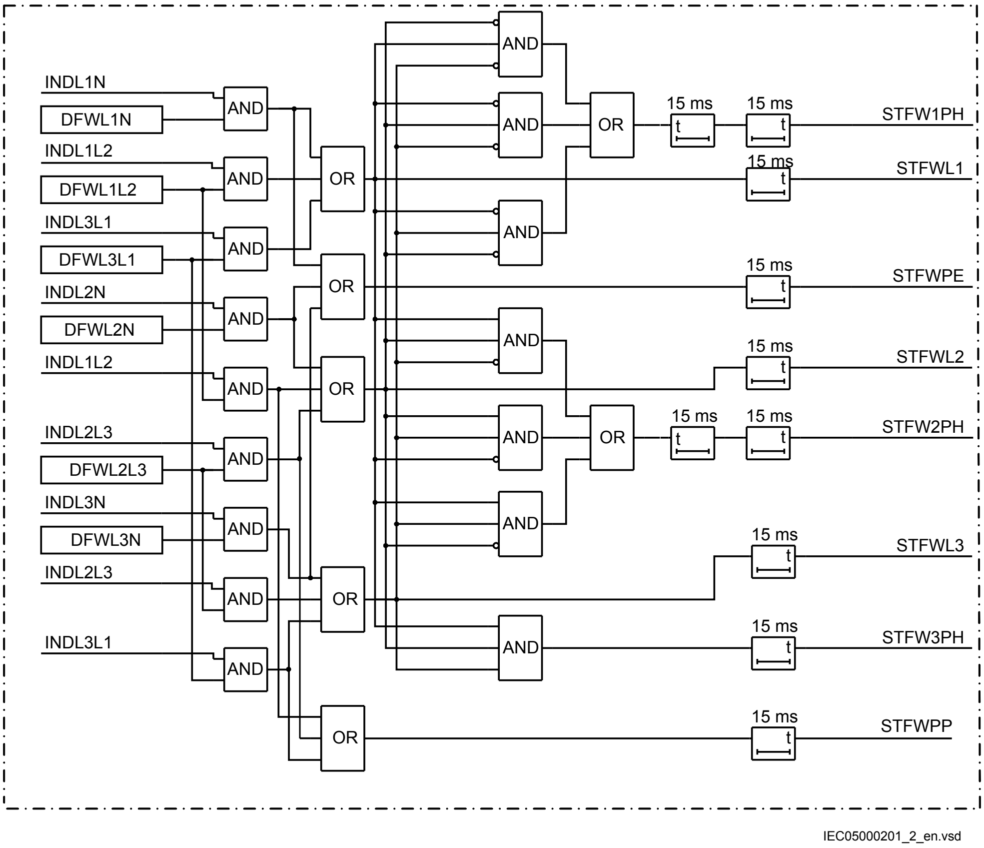

Figure 51: Composition of phase selection signals for forward direction

Figure 52 presents the composition of output signals TRIP and START, where internal signals STNDPP, STFWPP and STRVPP are the equivalent to internal signals STNDPE, STFWPE and STRVPE, but for the phase-to-phase loops.

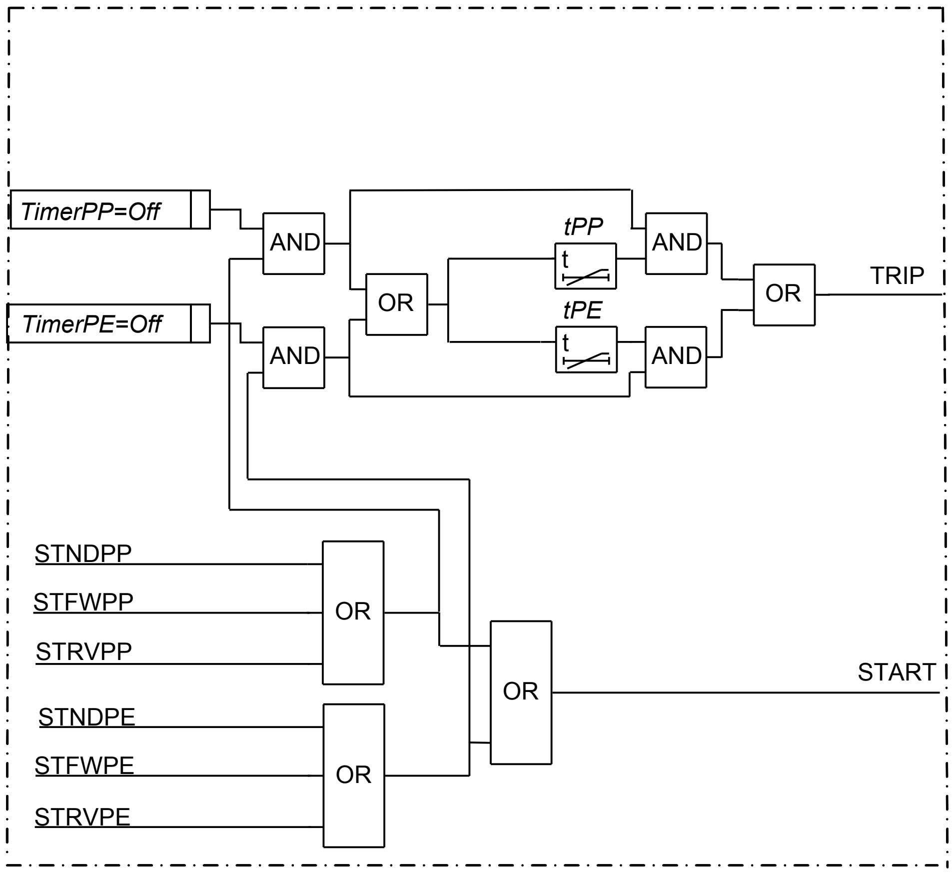

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Figure 52: TRIP and START signal logic

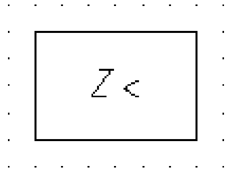
4.2.7 Technical data

Table 23: FDPSPDIS Technical data

Function	Range or value	Accuracy
Minimum operate current	(5-30)% of IBase	± 1.0% of I_r
Reactive reach, positive sequence	(0.50–3000.00)	± 2.0% static accuracy ± 2.0 degrees static angular accuracy Conditions: Voltage range: (0.1-1.1) x UBase Current range: (0.5-30) x IBase Angle: at 0 degrees and 85 degrees
Reactive reach, zero sequence, forward and reverse	(0.50 - 3000.00)	
Fault resistance, phase-to-earth faults, forward and reverse	(1.00–9000.00) Ω/loop	
Fault resistance, phase-to-phase faults, forward and reverse	(0.50–3000.00) Ω/loop	
Load encroachment criteria: Load resistance, forward and reverse Safety load impedance angle	(1.00–3000.00) Ω/phase (5-70) degrees	
Reset ratio	105% typically	-

4.3 Five zone distance measuring, mho characteristic ZMOPDIS

4.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Five zone distance protection, mho characteristic	ZMOPDIS		21

4.3.2 Functionality

The numerical mho line distance protection is a five zone full scheme protection for back-up detection of short circuit and earth-faults. The full scheme technique provides back-up protection of power lines with high sensitivity and low requirement on remote end communication. The five zones have fully independent measuring and settings which gives high flexibility for all types of lines.

The modern technical solution offers fast operating time down to ¾ cycles.

The IED can be used up to high voltage levels. It is suitable for the protection of heavily loaded lines and multi-terminal lines where the requirement for fast three-pole tripping is wanted.

Built-in adaptive load compensation algorithm prevents overreaching at phase-to-earth faults on heavily loaded power lines, see figure 53.

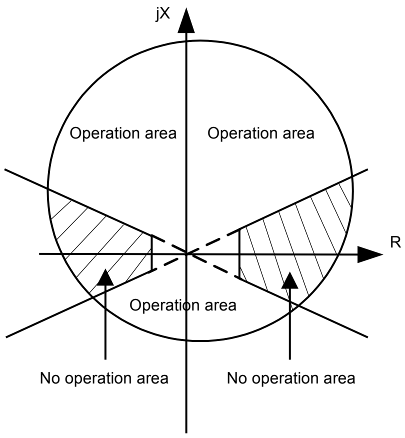


Figure 53: Load encroachment influence on the offset mho characteristic

The distance protection zones can operate, independent of each other, in directional (forward or reverse) or non-directional mode (offset). This makes them suitable, together with different communication schemes, for the protection of power lines and cables in complex network configurations, such as parallel lines, multi-terminal lines etc.

4.3.3 Function block

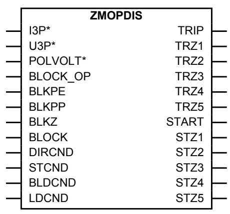


Figure 54: ZMOPDIS function block

4.3.4 Signals

Table 24: ZMOPDIS Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
POLVOLT	GROUP SIGNAL	-	Polarizing voltage for mho function
BLOCK_OP	BOOLEAN	0	Blocks all operate output signals
BLKPE	BOOLEAN	0	Blocks phase-to-earth operation
Table continues on next page			

Name	Type	Default	Description
BLKPP	BOOLEAN	0	Blocks phase-to-phase operation
BLKZ	BOOLEAN	0	Block due to fuse failure
BLOCK	BOOLEAN	0	Block of function
DIRCND	INTEGER	0	External directional condition
STCND	INTEGER	0	External start condition (loop enabler)
BLDCND	INTEGER	0	External blinder condition (loop enabler)
LDCND	INTEGER	0	External load condition (loop enabler)

Table 25: ZMOPDIS Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip general
TRZ1	BOOLEAN	Trip zone 1
TRZ2	BOOLEAN	Trip zone 2
TRZ3	BOOLEAN	Trip zone 3
TRZ4	BOOLEAN	Trip zone 4
TRZ5	BOOLEAN	Trip zone 5
START	BOOLEAN	Start general
STZ1	BOOLEAN	Start zone 1
STZ2	BOOLEAN	Start zone 2
STZ3	BOOLEAN	Start zone 3
STZ4	BOOLEAN	Start zone 4
STZ5	BOOLEAN	Start zone 5

4.3.5 Settings

Table 26: ZMOPDIS Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
KNMag1	0.00 - 3.00	-	0.01	0.80	Magnitude of earth return compensation factor KN for zone 1
KNAng1	-180 - 180	Deg	1	-15	Angle for earth return compensation factor KN for zone 1
LineAng	-180 - 180	Deg	1	80	Line Angle
KNMag2	0.00 - 3.00	-	0.01	0.80	Magnitude of earth return compensation factor KN for zones 2,3,4,5
KNAng2	-180 - 180	Deg	1	-15	Angle for earth return compensation factor KN for zones 2,3,4,5
IMinOpPE	10 - 30	%IB	1	20	Minimum operate phase current for Phase-Earth loops
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
IMinOpPP	10 - 30	%IB	1	20	Minimum operate delta current for Phase-Phase loops
OpModetPE1	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth for zone 1
tPE1	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Earth elements for zone 1
OpModetPP1	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase for zone 1
tPP1	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Phase elements for zone 1
OpModetPE2	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth for zone 2
tPE2	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Earth elements for zone 2
OpModetPP2	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase for zone 2
tPP2	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Phase elements for zone 2
OpModetPE3	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth for zone 3
tPE3	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Earth elements for zone 3
OpModetPP3	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase for zone 3
tPP3	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Phase elements for zone 3
OpModetPE4	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth for zone 4
tPE4	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Earth elements for zone 4
OpModetPP4	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase for zone 4
tPP4	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Phase elements for zone 4
OpModetPE5	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Earth for zone 5
tPE5	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Earth elements for zone 5
OpModetPP5	Off On	-	-	Off	Operation mode Off / On of zone timer, Phase-Phase for zone 5
tPP5	0.000 - 60.000	s	0.001	0.000	Time delay to trip of Phase-Phase elements for zone 5
OpMode1	Disable-Zone enable-PhG enable-PhPh enable PhG PhPh	-	-	enable PhG PhPh	Operation mode of zone 1
OpMode2	Disable-Zone enable-PhG enable-PhPh enable PhG PhPh	-	-	enable PhG PhPh	Operation mode of zone 2

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
Z1Rev	0.005 - 3000.000	ohm/p	0.001	30.000	Reverse positive sequence impedance setting for zone 1
Z1	0.005 - 3000.000	ohm/p	0.001	30.000	Positive sequence impedance setting for zone 1
Z2	0.005 - 3000.000	ohm/p	0.001	30.000	Positive sequence impedance setting for zone 2
Z2Rev	0.005 - 3000.000	ohm/p	0.001	30.000	Reverse positive sequence impedance setting for zone 2
Z3	0.005 - 3000.000	ohm/p	0.001	30.000	Positive sequence impedance setting for zone 3
Z3Rev	0.005 - 3000.000	ohm/p	0.001	30.000	Reverse positive sequence impedance setting for zone 3
Z4Rev	0.005 - 3000.000	ohm/p	0.001	30.000	Reverse positive sequence impedance setting for zone 4
Z4	0.005 - 3000.000	ohm/p	0.001	30.000	Positive sequence impedance setting zone 4
Z5	0.005 - 3000.000	ohm/p	0.001	30.000	Positive sequence impedance setting for zone 5
Z5Rev	0.005 - 3000.000	ohm/p	0.001	30.000	Reverse positive sequence impedance setting for zone 5
OpMode3	Disable-Zone enable-PhG enable-PhPh enable PhG PhPh	-	-	enable PhG PhPh	Operation mode of zone 3
OpMode4	Disable-Zone enable-PhG enable-PhPh enable PhG PhPh	-	-	enable PhG PhPh	Operation mode of zone 4
OpMode5	Disable-Zone enable-PhG enable-PhPh enable PhG PhPh	-	-	enable PhG PhPh	Operation mode of zone 5
DirMode1	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 1
DirMode2	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 2
DirMode3	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 3
DirMode4	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 4
DirMode5	Off Offset Forward Reverse	-	-	Forward	Direction mode zone 5

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
OffsetMhoDir1	Non-directional Forward Reverse	-	-	Non-directional	Direction mode for offset mho of zone 1
BlinderMode1	Off On	-	-	Off	Blinder mode Off/On of zone 1
LoadEnchMode1	Off On	-	-	Off	Load enchroachment mode Off/On of zone 1
OffsetMhoDir2	Non-directional Forward Reverse	-	-	Non-directional	Direction mode for offset mho of zone 2
BlinderMode2	Off On	-	-	Off	Blinder mode Off/On of zone 2
LoadEnchMode2	Off On	-	-	Off	Load enchroachment mode Off/On of zone 2
LoadEnchMode3	Off On	-	-	Off	Load enchroachment mode Off/On of zone 3
BlinderMode3	Off On	-	-	Off	Blinder mode Off/On of zone 3
LoadEnchMode4	Off On	-	-	Off	Load enchroachment mode Off/On of zone 4
BlinderMode4	Off On	-	-	Off	Blinder mode Off/On of zone 4
LoadEnchMode5	Off On	-	-	Off	Load enchroachment mode Off/On of zone 5
BlinderMode5	Off On	-	-	Off	Blinder mode Off/On of zone 5
OffsetMhoDir5	Non-directional Forward Reverse	-	-	Non-directional	Direction mode for offset mho of zone 5
OffsetMhoDir4	Non-directional Forward Reverse	-	-	Non-directional	Direction mode for offset mho of zone 4
OffsetMhoDir3	Non-directional Forward Reverse	-	-	Non-directional	Direction mode for offset mho of zone 3

Table 27: ZMOPDIS Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.3.6 Operation principle

4.3.6.1 Full scheme measurement

The execution of the different fault loops within the IED are of full scheme type, which means that each fault loop for phase-to-earth faults and phase-to-phase faults are executed in parallel.

The use of full scheme technique gives faster operation time compared to switched schemes which mostly uses a start element to select correct voltages and current depending on fault type. So each distance protection zone performs like one independent distance protection function with six measuring elements.

4.3.6.2 Impedance characteristic

The distance function consists of five zones. Each zone can be selected to be either forward or reverse with positive sequence polarized mho characteristic alternatively self polarized offset mho characteristics with reverse offset. The operating characteristic is in accordance to figure 55 where zone 5 is selected offset mho.

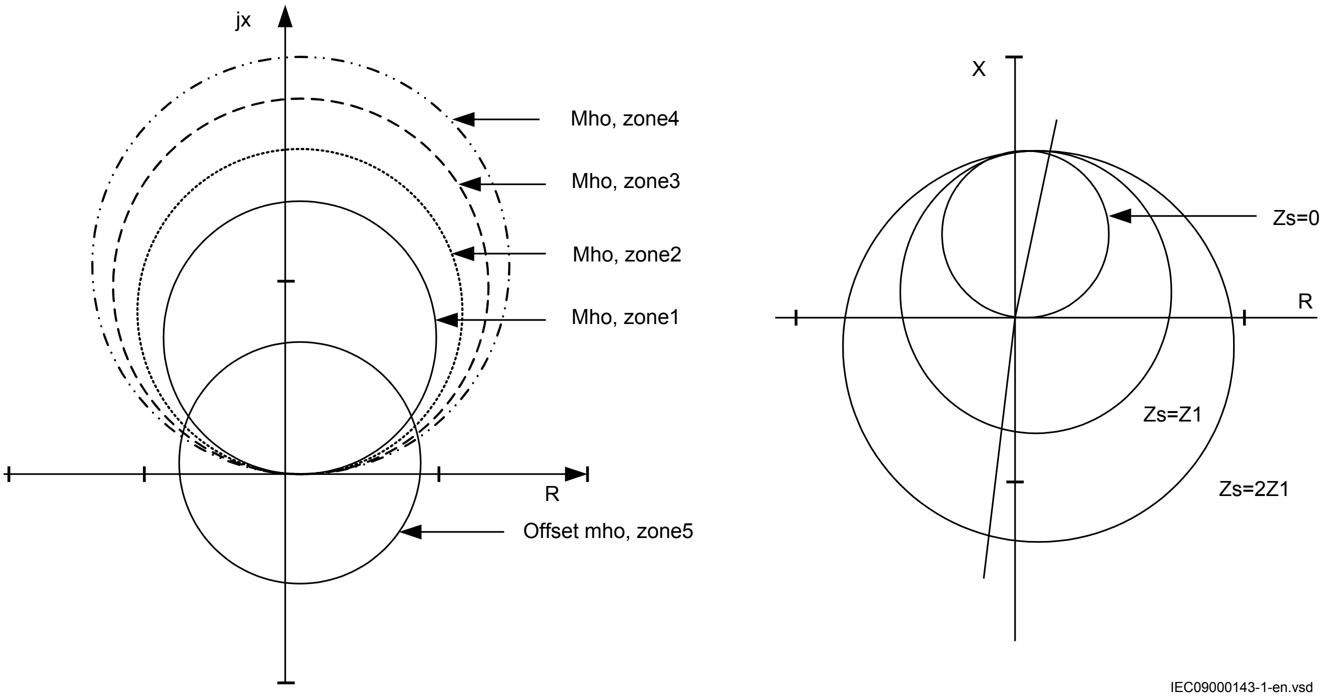


Figure 55: Mho, offset mho characteristic and the source impedance influence on the mho characteristic

The mho characteristic has a dynamic expansion due to the source impedance. Instead of crossing the origin as for the mho to the left of figure 55, which is only valid where the source impedance is zero, the crossing point is moved to the coordinates of the negative source impedance given an expansion of the circle shown to the right of figure 55. Z1 denotes the complex positive sequence impedance.

The polarisation quantities used for the mho circle is 100% memorized positive sequence voltages. This will give a somewhat less dynamic expansion of the mho circle during faults. However, if the source impedance is high, the dynamic expansion of the mho circle might lower the security of the function too much with high loading and mild power swing conditions.

The mho distance element has a load encroachment function which cut off a section of the characteristic when enabled. The function is enabled by setting the setting parameter *LoadEnchModex* (where *x* is 1-5 depending on selected zone) to *On*. Enabling of the load encroachment function increases the possibility to detect high resistive faults without interfering with the load impedance. The algorithm for the load encroachment is located in the Faulty phase identification with load encroachment for mho function (FMPSPDIS), where also the relevant settings can be found. Information about the load encroachment from FMPSPDIS to the zone measurement is given in binary format to the input signal LDCND.

4.3.6.3 Basic operation characteristics

Each zone can also be set to Offset, Forward or Reverse by setting the parameter *DirModex* (where *x* is 1-5 depending on selected zone).

Each impedance zone can be disabled, or set to operate for phase-to-earth or phase-to-phase fault by setting *OpModex* (where *x* is 1-5 depending on selected zone).

The offset mho characteristic can be set in Non-directional, Forward or Reverse by the setting parameter *OffsetMhoDirx* (where *x* is 1-5 depending on selected zone). When Forward or Reverse is selected a directional line is introduced. Information about the directional line is given from the directional element (ZDNRDIR) and given to the measuring element as binary coded signal to the input DIRCND.

The zone reach for phase-to-earth fault and phase-to-phase fault is set individually in polar coordinates.

The impedance is set by the parameter *Z* and the corresponding arguments by the parameter *LineAng*.

Compensation for earth return path for faults involving earth is done by setting the parameter *KNMagx* and *KNAngx*. *KNMagx* (where *x* is 1-5 depending on selected zone) and *KNAngx* (where *x* is 1-5 depending on selected zone) are defined according to equation 11 and equation 12.

$$KNMag = \left| \frac{Z0\text{-}Z1}{3 \cdot Z1} \right|$$

(Equation 11)

$$KNAng = \arg\left(\frac{Z0 - Z1}{3 \cdot Z1}\right)$$

(Equation 12)

where

Z0	is the complex zero sequence impedance of the line in Ω/phase
Z1	is the complex positive sequence impedance of the line in Ω/phase

The phase-to-earth and phase-to-phase measuring loops can be time delayed individually by setting the parameter *tPEx* (where *x* is 1-5 depending on selected zone) and *tPPx* (where *x* is 1-5 depending on selected zone) respectively. To release the time delay, the operation mode for the timers, *OpModetPEx* (where *x* is 1-5 depending on selected zone) and *OpModetPPx* (where *x* is 1-5 depending on selected zone), has to be set to *On*. This is also the case for instantaneous operation.

The function can be blocked in the following ways:

- activating of input BLOCK blocks the whole function
- activating of the input BLKZ (fuse failure) blocks all output signals
- activating of the input BLOCK_OP blocks all output signals
- activating the input BLKPE blocks the phase-to-earth fault loop outputs
- activating the input BLKPP blocks the phase-to-phase fault loop outputs

The activation of input signal BLKZ can be made by external fuse failure function.

4.3.6.4 Theory of operation

The mho algorithm is based on phase comparison of a operating phasor and a polarizing phasor. When the operating phasor leads the reference phasor by more than 90 degrees, the function will operate and give a trip output.

Phase-to-phase fault

Mho

The plain mho circle has the characteristic as in figur 56. The condition for deriving the angle β is according to equation 13.

$$\beta = \arg(\overline{U}_{L1L2} - \overline{I}_{L1L2} \cdot \overline{Z}) - \arg(U_{pol})$$

(Equation 13)

where

$\bar{U}_{L1L2}$	is the voltage vector difference between phases L1 and L2
$\bar{I}_{L1L2}$	is the current vector difference between phases L1 and L2
Z	is the positive sequence impedance setting for fault
U_{pol}	is the polarizing voltage

The polarized voltage consists of 100% memorized positive sequence voltage (UL1L2 for phase L1 to L2 fault). The memorized voltage will prevent collapse of the mho circle for close in faults.

Operation occurs if 90≤β≤270

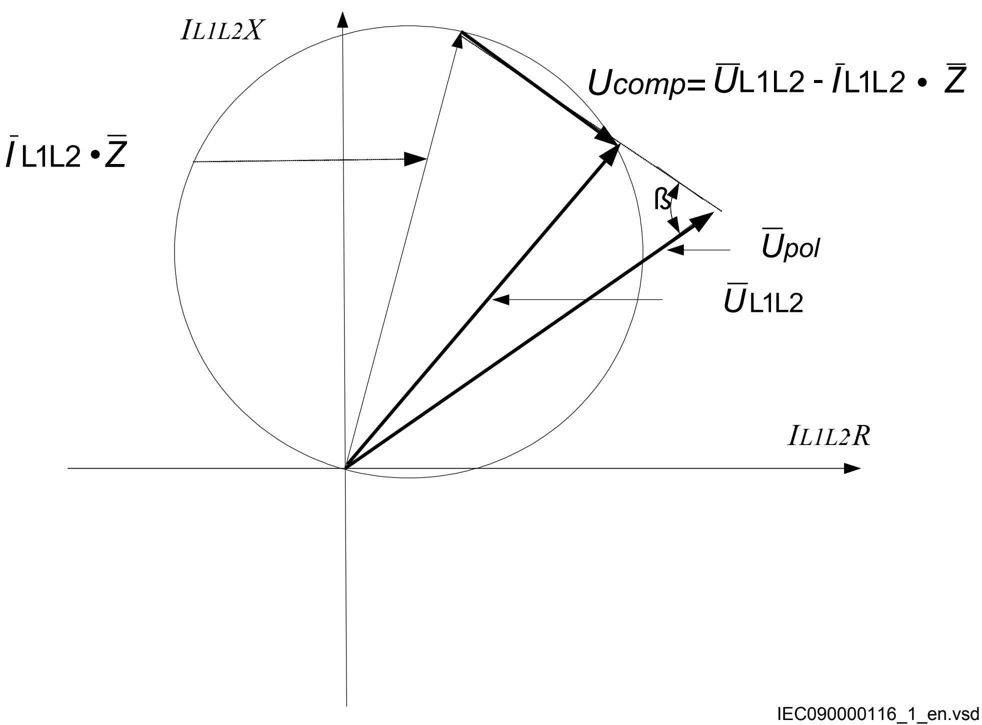


Figure 56: Simplified mho characteristic and vector diagram for phase L1-to-L2 fault.

Offset Mho

The characteristic for offset mho is a circle where two points on the circle are the setting parameters *Z* and *ZRev*. The vector Z in the impedance plane has the settable angle *LineAng* and the angle for *ZRev* is *LineAng+180°*.

The condition for operation at phase-to-phase fault is that the angle β between the two compensated voltages Ucomp1 and Ucomp2 is greater than or equal to 90° (figure 57). The angle will be 90° for fault location on the boundary of the circle.

The angle β for L1-to-L2 fault can be defined according to equation 14.

$$\beta = \mathrm{Arg}\left(\frac{\bar{U} - I_{L1L2} \cdot \bar{Z}}{\bar{U} - (-I_{L1L2} \cdot \bar{Z}Rev)}\right)$$

(Equation 14)

where

$\overline{U}$	is the U_{L1L2} voltage
ZRev	is the positive sequence impedance setting for phase-to-phase fault in reverse direction

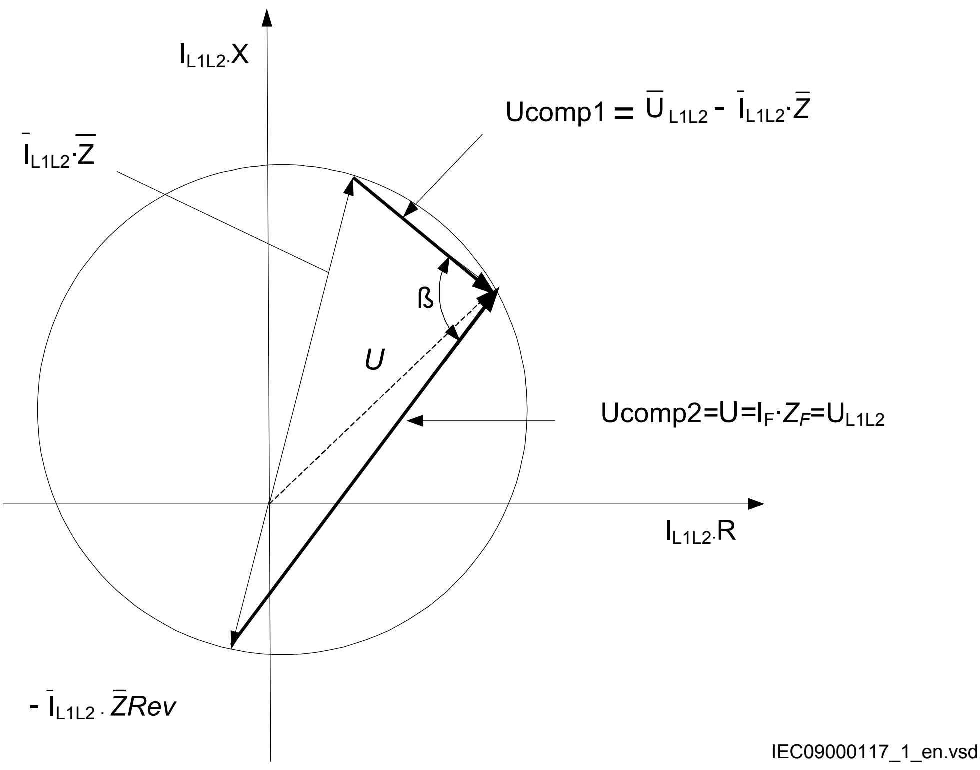


Figure 57: Simplified offset mho characteristic and voltage vectors for phase L1-to-L2 fault.

Operation occurs if 90≤β≤270.

Offset mho, forward direction

When forward direction has been selected for the offset mho, an extra criteria beside the one for offset mho (90<β<270) is introduced, that is the angle φ between the voltage and the current must lie between the blinders in second quadrant and fourth quadrant. See figure 58. Operation occurs if 90≤β≤270 and *ArgDir*≤φ≤*ArgNegRes*.

where

ArgDir	is the setting parameter for directional line in fourth quadrant in the directional element, ZDNRDIR
ArgNegRes	is the setting parameter for directional line in second quadrant in the directional element, ZDNRDIR
β	is calculated according to equation 14

The directional information is brought to the mho distance measurement from the mho directional element as binary coded information to the input DIRCND. See Directional impedance quadrilateral and mho (ZDNRDIR) for information about the mho directional element.

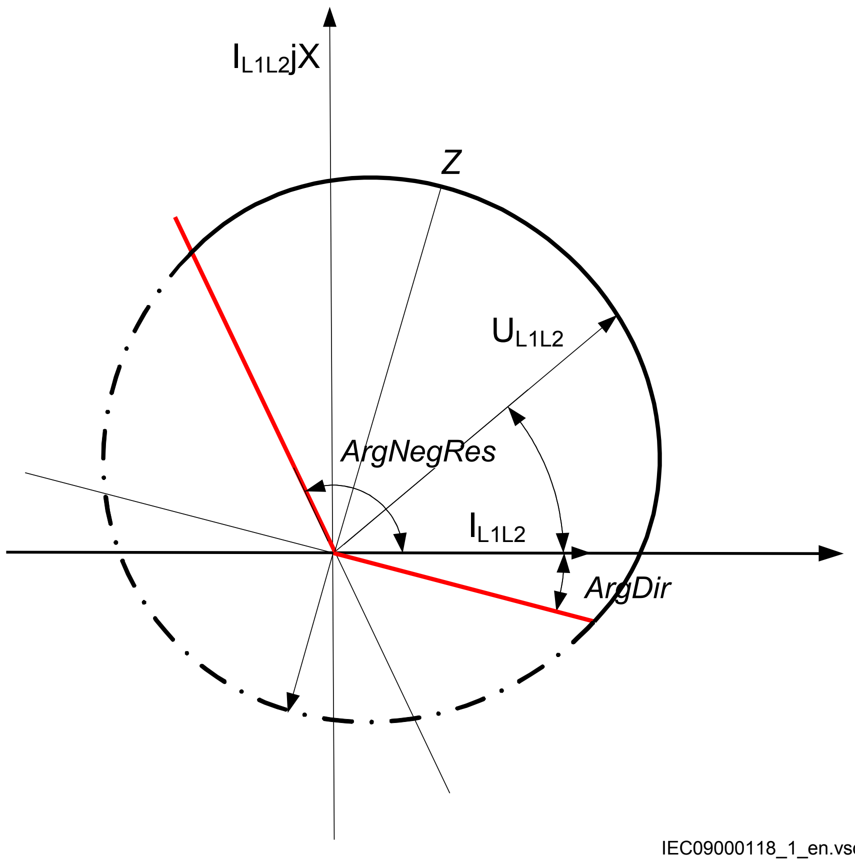


Figure 58: Simplified offset mho characteristic in forward direction for phase L1-to-L2 fault.

Offset mho, reverse direction

The operation area for offset mho in reverse direction is according to figure 59. The operation area in second quadrant is *ArgNegRes*+180°.

Operation occurs if 90≤β≤270 and 180° - *ArgDir* ≤*φ* ≤ *ArgNegRes* + 180°

The β is derived according to equation 14 for the mho circle and φ is the angle between the voltage and current.

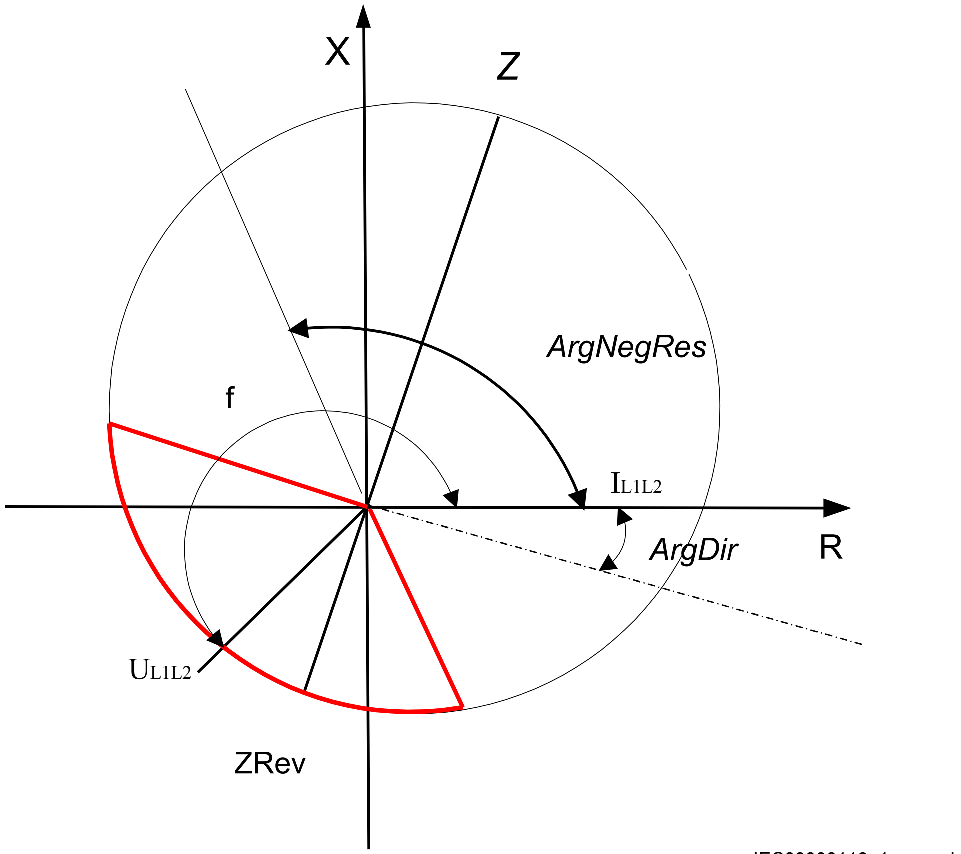


Figure 59: Operation characteristic for reverse phase L1-to-L2 fault.

Phase-to-earth fault

Mho

The measuring of earth-faults uses earth return compensation applied in a conventional way. The compensation voltage is derived by considering the influence from the earth return path.

For a earth-fault in phase L1, we can derive the compensation voltage Ucomp see figure 60 as

$$Ucomp = \overline{U}_{pol} - \overline{I}_{L1} \cdot \overline{Z}_{loop}$$

(Equation 15)

where

U_{pol}	is the polarizing voltage (memorized UL1 for Phase L1-to- earth fault)
Z_{loop}	is the loop impedance, which in general terms can be expressed as

$$\overline{Z}_1 + \overline{Z}N = \overline{Z}_1 \cdot \left(1 + \overline{KN}\right)$$

(Equation 16)

where

Z_1	is the positive sequence impedance of the line (Ohm/phase)
KN	is the zero sequence compensator factor

The angle β between the Ucomp and the polarize voltage Upol for a L1-to-earth fault is

$$\beta = \arg\left[\overline{U}_{L1} - (\overline{I}_{L1} + 3_{I0} \cdot \overline{K}N) \cdot \overline{ZPE}\right] - \arg(Upol)$$

(Equation 17)

where

U_{L1}	is the phase voltage in faulty phase L1	
I_{L1}	is the phase current in faulty phase L1	
$3I_0$	is the zero sequence current in faulty phase L1	
$\bar{K}N$	$\frac{Z0\text{-}Z1}{3 \cdot Z1}$	the setting parameter for the zero sequence compensation consisting of the magnitude *KNMag* and the angle *KNAng*.
U_{pol}	is the 100% of positive sequence memorized voltage U_{L1}	

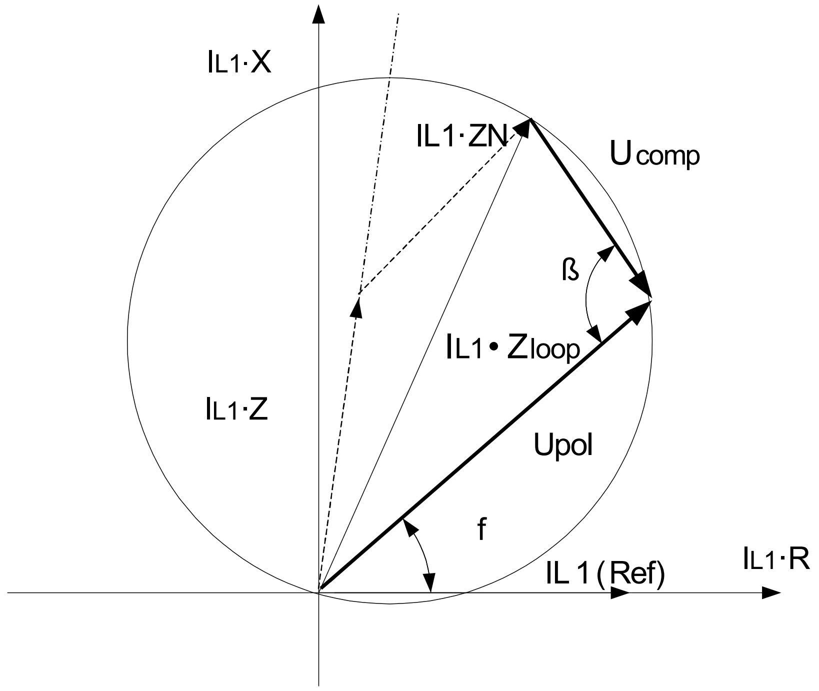


Figure 60: Simplified offset mho characteristic and vector diagram for phase L1-to-earth fault.

Operation occurs if 90≤β≤270.

Offset mho

The characteristic for offset mho at earth-fault is a circle containing the two vectors from the origin *Z* and *ZRev* where *Z* and *Zrev* are the settting reach for the positive sequence impedance in forward, reverse direction respectively. The vector *Z* in the impedance plane has the settable angle *LineAng* and the angle for *ZRev* is *LineAng* +180°

The condition for operation at phase-to-earth fault is that the angle β between the two compensated voltages Ucomp1 and Ucomp2 is greater or equal to 90° see figure 61. The angle will be 90° for fault location on the boundary of the circle.

The angle β for L1-to-earth fault can be defined as

$$\beta=\arg\left(\frac{\overline{U}_{L1}-\overline{I}_{L1}\cdot\overline{Z}}{\overline{U}_{L1}-(-\overline{I}_{L1}\cdot\overline{ZRev})}\right)$$

(Equation 20)

where

$\overline{U_{L1}}$	is the phase L1 voltage

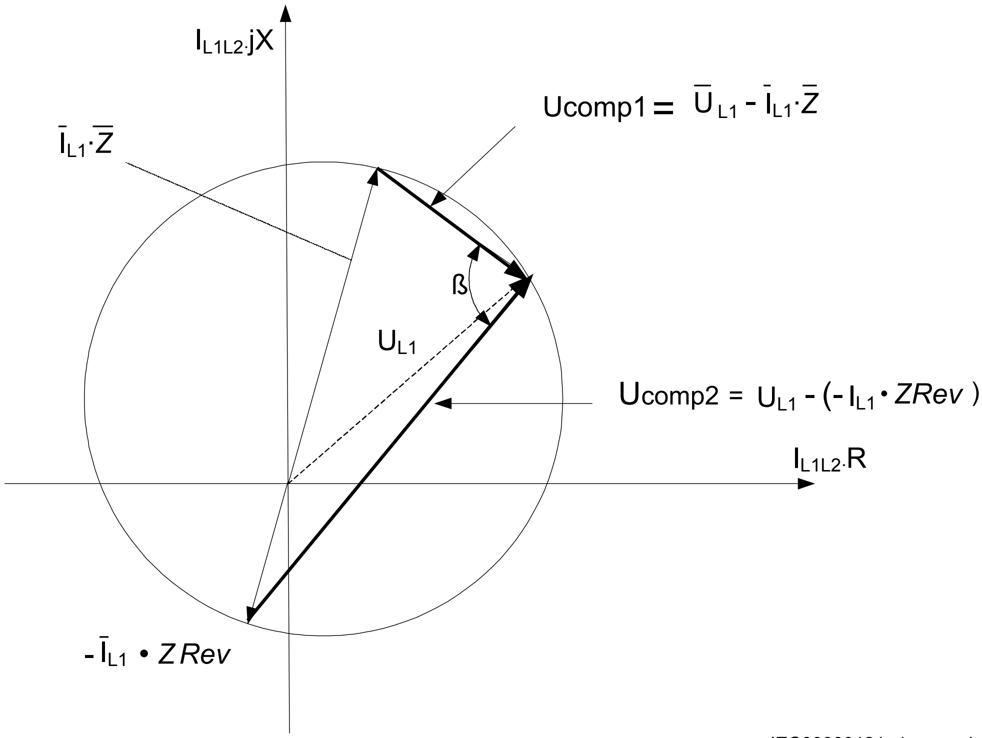


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Figure 61: Simplified offset mho characteristic and voltage vector for phase L1-to-L2 fault.

Operation occurs if 90≤β≤270.

Offset mho, forward direction

In the same way as for phase-to-phase fault, selection of forward direction of offset mho will introduce an extra criteria for operation. Beside the basic criteria for offset mho according to equation 20 and 90≤β≤270, also the criteria that the angle φ between the voltage and the current must lie between the blinders in second and fourth quadrant. See figure 62. Operation occurs if 90≤β≤270 and *ArgDir*≤φ≤*ArgNegRes*.

where

ArgDir	is the setting parameter for directional line in fourth quadrant in the directional element, ZDNRDIR.
ArgNegRes	is the setting parameter for directional line in second quadrant in the directional element, ZDNRDIR.
β	is calculated according to equation 20

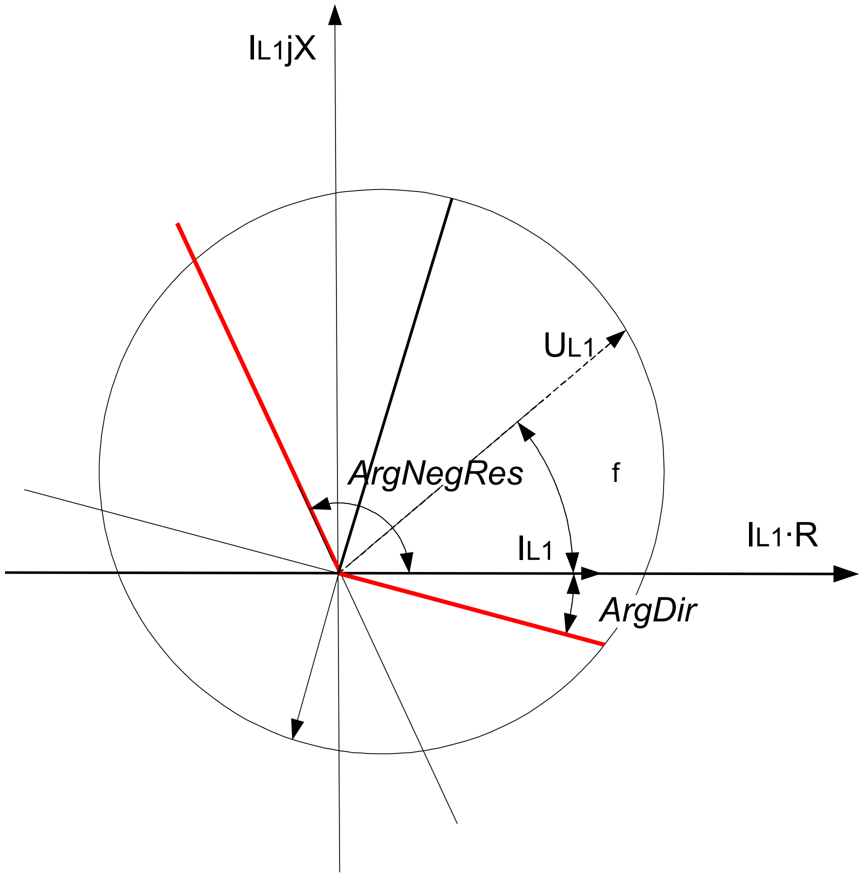


Figure 62: Simplified characteristic for offset mho in forward direction for L1-to-earth fault.

Offset mho, reverse direction

In the same way as for offset in forward direction, the selection of offset mho in reverse direction will introduce an extra criteria for operation compare to the normal offset mho. The extra is that the angle between the fault voltage and the fault current shall lie between the blinders in second and fourth quadrant. The operation area in second quadrant is limited by the blinder defined as 180° -*ArgDir* and in fourth quadrant *ArgNegRes*+180°, see figure 63

The conditions for operation of offset mho in reverse direction for L1-to- earth fault is 90≤β≤270 and 180°-*Argdir*≤φ≤*ArgNegRes*+180°.

The β is derived according to equation 20 for the offset mho circle and φ is the angle between the voltage and current.

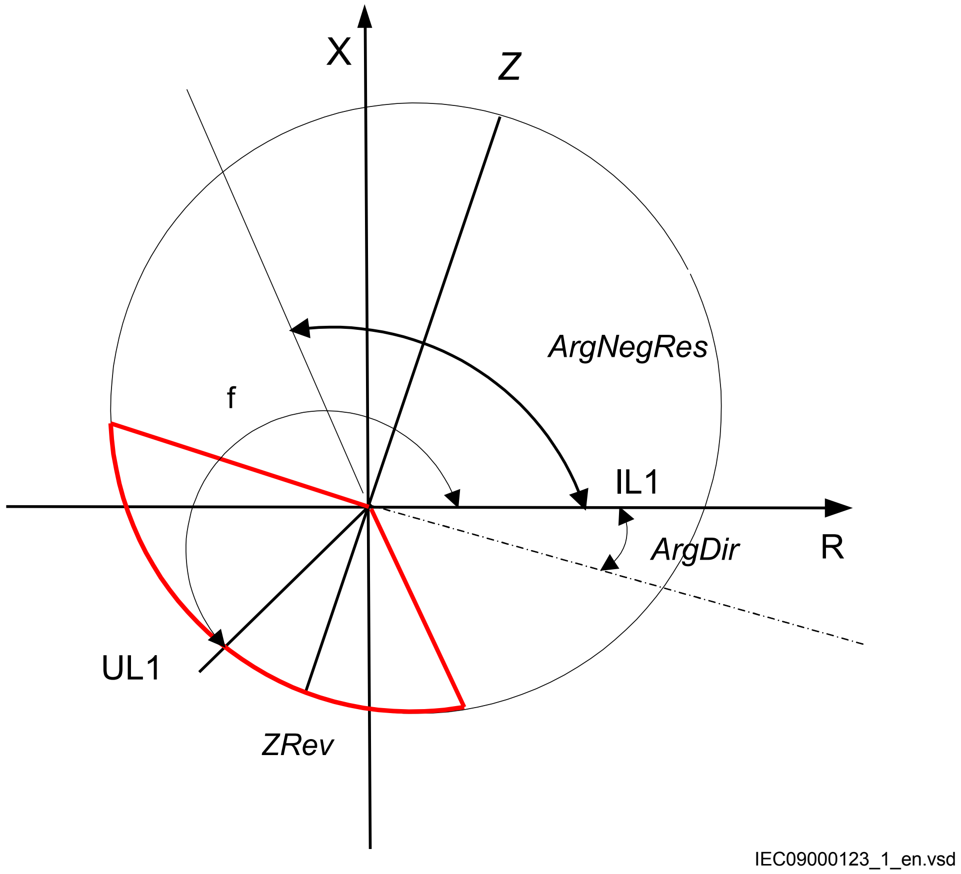


Figure 63: Simplified characteristic for offset mho in reverse direction for L1-to-earth fault.

4.3.7 Technical data

Table 28: ZMOPDIS Technical data

Function	Range or value	Accuracy
Number of zones with selectable directions	5 with selectable direction	-
Minimum operate current	(10–30)% of I_{Base}	± 2,0 % of I_r
Positive sequence impedance	(0.005–3000.000) Ω/phase	± 2.0% static accuracy Conditions: Voltage range: (0.1-1.1) x U_r Current range: (0.5-30) x I_r Angle: at 0 degrees and 85 degrees
Reverse positive sequence impedance	(0.005–3000.000) Ω/phase	
Impedance reach for phase-to-phase elements	(0.005–3000.000) Ω/phase	
Angle for positive sequence impedance, phase-to-phase elements	(10–90) degrees	
Reverse reach of phase-to-phase loop	(0.005–3000.000) Ω/phase	
Magnitude of earth return compensation factor KN	(0.00–3.00)	
Angle for earth compensation factor KN	(-180–180) degrees	
Dynamic overreach	<5% at 85 degrees measured with CVT's and 0.5<SIR<30	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time	1.5 cycles typically	-
Reset ratio	105% typically	-
Reset time	30ms typically	-

4.4 Faulty phase identification with load enchroachment for mho FMPSPDIS

4.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Faulty phase identification with load encroachment for mho	FMPSPDIS	Z<	21

4.4.2 Functionality

The phase selection function is design to accurate select the proper fault loop in the distance function dependent on the fault type.

The heavy load transfer that is common in many transmission networks may in some cases interfere with the distance protection zone reach and cause unwanted operation. Therefore the function has a built in algorithm for load encroachment, which gives the possibility to enlarge the resistive setting of the measuring zones without interfering with the load.

The output signals from the phase selection function produce important information about faulty phase(s) which can be used for fault analysis as well.

4.4.3 Function block

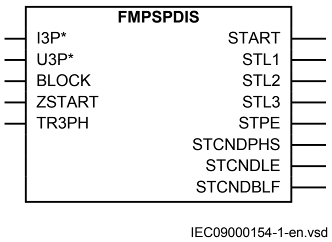


Figure 64: FMPSPDIS function block

4.4.4 Signals

Table 29: FMPSPDIS Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
ZSTART	BOOLEAN	0	Start from under impedance function
TR3PH	BOOLEAN	0	Three phase tripping initiated

Table 30: FMPSPDIS Output signals

Name	Type	Description
START	BOOLEAN	General start signal
STL1	BOOLEAN	Fault detected in phase L1
STL2	BOOLEAN	Fault detected in phase L2
STL3	BOOLEAN	Fault detected in phase L3
STPE	BOOLEAN	Earth fault detected
STCNDPHS	INTEGER	Binary coded starts from phase selection
STCNDLE	INTEGER	Binary coded starts from load encroachment only
STCNDBLF	INTEGER	Binary coded starts from fund. frequency based blinders

4.4.5 Settings

Table 31: FMPSPDIS Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
IMaxLoad	10 - 5000	%IB	1	200	Maximum load for identification of three phase fault in % of IBase
RLd	1.00 - 3000.00	ohm/p	0.01	80.00	Load resistive reach in ohm/phase
ArgLd	5 - 70	Deg	1	20	Load encroachment inclination of load angular sector
BlinderAng	5 - 90	Deg	1	80	Blinder angle

Table 32: FMPSPDIS Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
DeltaIMinOp	5 - 100	%IB	1	10	Delta current level in % of IBase
DeltaUMinOp	5 - 100	%UB	1	20	Delta voltage level in % of UBase
U1Level	5 - 100	%UB	1	80	Positive sequence voltage limit for identification of three phase fault
I1LowLevel	5 - 200	%IB	1	10	Positive sequence current level for identification of three phase fault in % of IBase
U1MinOp	5 - 100	%UB	1	20	Minimum operate positive sequence voltage for phase selection
U2MinOp	1 - 100	%UB	1	5	Minimum operate negative sequence voltage for phase selection
INRelPE	10 - 100	%IB	1	20	3I0 limit for release Phase-Earth measuring loops in % of maximum phase current
INBlockPP	10 - 100	%IB	1	40	3I0 limit for blocking Phase-to-Phase measuring loops in % of maximum phase current

Table 33: FMPSPDIS Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.4.6 Operation principle

4.4.6.1 The phase selection function

Faulty phase identification with load enchroachment for mho (FMPSPDIS) function can be decomposed into six different parts:

1. A high speed delta based current phase selector
2. A high speed delta based voltage phase selector
3. A symmetrical components based phase selector

4. Fault evaluation and selection logic
5. A load enchroachment logic
6. A blinder logic

The total function can be blocked by activating the input BLOCK.

Delta based current and voltages

The delta based fault detection function uses adaptive technique and is based on patent US4409636.

The aim of the delta based phase selector is to provide very fast and reliable phase selection for releasing of tripping from the high speed Mho measuring element.

The current and voltage samples for each phase passes through a notch filter that filters out the fundamental components. Under steady state load conditions or when no fault is present, the output of the filter is zero or close to zero. When a fault occurs, currents and voltages change resulting in sudden changes in the currents and voltages resulting in non-fundamental waveforms being introduced on the line. At this point the notch filter produces significant non-zero output. The filter output is processed by the delta function. The algorithm uses an adaptive relationship between phases to determine if a fault has occurred, and determines the faulty phases.

The current and voltage delta based phase selector gives a real output signal if the following criteria is fulfilled (only phase L1 shown):

Max(ΔUL1,ΔUL2,ΔUL3)>*DeltaUMinOp*

Max(ΔIL1,ΔIL2,ΔIL3)>*DeltaIMinOp*

where:

ΔUL1, ΔUL2 and ΔUL3	are the voltage change between sample t and sample t-1
DeltaUMinOp and *DeltaIMinOp*	are the minimum harmonic level settings for the voltage and current filters to decide that a fault has occurred. A slow evolving fault may not produce sufficient harmonics to detect the fault; however, in such a case speed is no longer the issue and the sequence components phase selector will operate.

The delta voltages ΔULn and delta current ΔILn (n prefix for phase order) are the voltage and current between sample t and sample t-1.

The delta phase selector employs adaptive techniques to determine the fault type. The logic determines the fault type by summing up all phase values and dividing by the largest value. Both voltages and currents are filtered out and evaluated. The condition for fault type classification for the voltages and currents can be expressed as:

$$\mathrm{FaulType} = \frac{\Sigma(\Delta UL1, \Delta UL2, \Delta UL3)}{\mathrm{Max}(\Delta IL1, \Delta IL2, \Delta UL3)}$$

(Equation 21)

$$FaultType = \frac{\Sigma(\Delta IL1, \Delta IL2, \Delta IL3)}{Max(\Delta IL1, \Delta IL2, \Delta IL3)}$$

(Equation 22)

The value of FaultType for different shunt faults are as follows:

Under ideal conditions: (Patent pending)	
Single phase-to-earth;	FaultType=1
Phase-to-phase fault	FaultType=2
Three-phase fault;	FaultType=3

The output signal is 1 for single-phase-to-earth fault, 2 for phase-to-phase fault and 3 for three-phase fault. At this point the filter does not know if earth was involved or not.

Typically there are induced harmonics in the non-faulted lines that will affect the result. This method allows for a significant tolerance in the evaluation of FaultType over its entire range.

When a single-phase-to-earth fault has been detected, the logic determines the largest quantity, and asserts that phase. If phase-phase fault is detected, the two largest phase quantities will be detected and asserted as outputs.

The faults detected by the delta based phase selector are coordinated in a separate block. Different phases of faults may be detected at slightly different times due to differences in the angles of incidence of fault on the wave shape. Therefore the output is forced to wait a certain time by means of a timer. If the timer expires, and a fault is detected in one phase only, the fault is deemed as phase-to-earth. This way a premature single phase-to-earth fault detection is not released for a phase-to-phase fault. If, however, earth current is detected before the timer expires, the phase-to-earth fault is released sooner.

If another phase picks up during the time delay, the wait time is reduced by a certain amount. Each detection of either earth-to-phase or additional phases further reduce the initial time delay and allow the delta phase selector output to be faster. There is no time delay , if for example, all three phases are faulty.

Symmetrical component based phase selector

The symmetrical component phase selector uses preprocessed calculated sequence voltages and currents as inputs. It also uses sampled values of the phase currents. All the symmetrical quantities mentioned further in this section are with reference to phase L1.

The function is made up of four main parts:

A	Detection of the presence of earth-fault
B	A phase-to-phase logic block based on U_1/U_2 angle relationship
C	A phase-to-earth component based on patent US5390067 where the angle relationships between U_2/I_0 and U_2/U_1 is evaluated to determine earth-fault or phase- to-phase to earth-fault
D	Logic for detection of three-phase fault

Presence of earth-fault detection

This detection of earth-fault is performed in two levels, first by evaluation of the magnitude of zero sequence current, and secondly by the evaluation of the zero and negative sequence voltage. It is a complement to the earth-fault signal built-in in the Symmetrical component based phase selector.

The phase-to-earth loops are released if both of the following criteria are fulfilled:

$|3I_0|>IBase \cdot 0.5$

$|3I_0|>\text{maxIph} \cdot INRelPE$

where:

maxIph	is the maximal current magnitude found in any of the three phases
INRelPE	is the setting of 3I0 limit for release of phase-to-earth measuring loop in % of *IBase*

In systems where the source impedance for zero sequence is high the change of zero sequence current may not be significant and the above detection may fail. In those cases the detection enters the second level, with evaluation of zero and negative sequence voltage. The release of the earth-fault loops can then be achieved if all of the following conditions are fulfilled:

$|3U_0|>|U_2| \cdot 0.5$

$|3U_0|>|U_1| \cdot 0.2$

$|U_1|> \text{UBase} \cdot 0.2/\sqrt{(3)}$

and

$3I_0> 0.1 \cdot \text{IBase}$

or

$3I_0<\text{maxIph} \cdot INRelPE$

where:

$\|3U_0\|$	is the magnitude of the zero sequence voltage
$\|U_1\|$	is the magnitude of the positive sequence voltage
$\|U_2\|$	is the magnitude of the negative sequence voltage
maxIph	is the maximal phase current

Phase-to-phase fault detection

The detection of phase-to-phase fault is performed by evaluation of the angle difference between the sequence voltages U_2 and U_1.

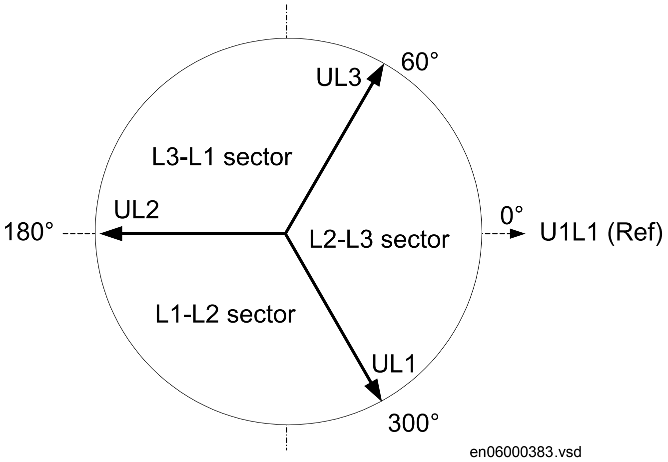


Figure 65: Definition of fault sectors for phase-to-phase fault

The phase-to-phase loop for the faulty phases will be determined if the angle between the sequence voltages U_2 and U_1 lies within the sector defined according to figure 65 and the following conditions are fulfilled:

$|U_1|>$*U1MinOP*

$|U_2|>$*U2MinOp*

where:

U1MinOP and *U2MinOp*	are the setting parameters for positive sequence and negative sequence minimum operate voltages

The positive sequence voltage U_1L1 in figure 65 above is reference.

If there is a three-phase fault, there will not be any release of the individual phase signals, even if the general conditions for U_2 and U_1 are fulfilled.

Phase-to-earth and phase-to-phase-to-earth-fault detection

The detection of phase-to-earth and phase-to-phase-to-earth-fault (US patent 5390067) is based on two conditions:

1. Angle relationship between U_2 and I_0

2. Angle relationship between U_2 and U_1

The condition 1 determines faulty phase at single phase-to-earth fault by determine the argument between U_2 and I_0.

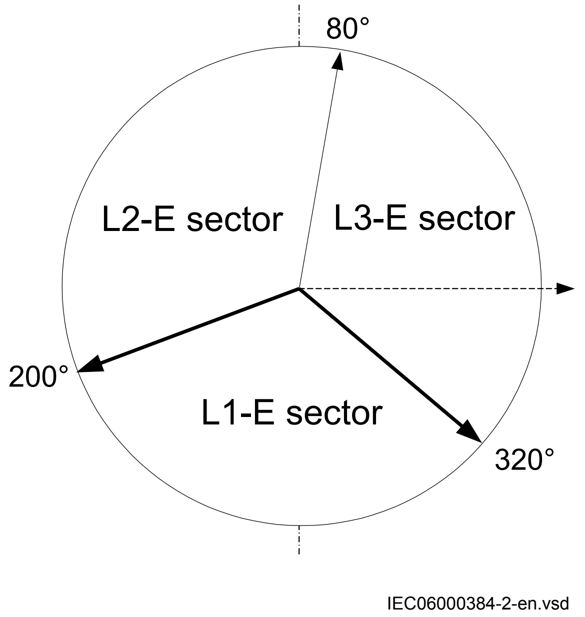


Figure 66: Condition 1: Definition of faulty phase sector as angle between U_2 and I_0

The angle is calculated in a directional function block and gives the angle in radians as input to the U_2 and I_0 function block. The input angle is released only if the fault is in forward direction. This is done by the directional element. The fault is classified as forward direction if the angle between U_0 and I_0 lies between 20 to 200 degrees see figure 67.

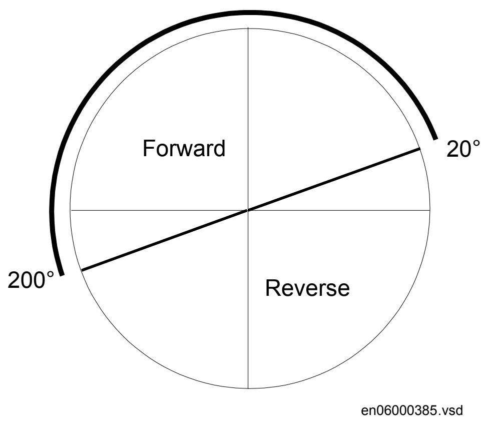


Figure 67: Directional element used to release the measured angle between U_o and I_0

The input radians are summarized with an offset angle and the result evaluated. If the angle is within the boundaries for a specific sector, the phase indication for that sector will be active see figure 66. Only one sector signal is allowed to be activated at the same time.

The sector function for condition 1 has an internal release signal which is active if the main sequence function has classified the angle between U_0 and I_0 as valid. The following conditions must be fulfilled for activating the release signals:

$|U_2|>U2MinOp$

$|3I_0|> 0.05 \cdot IBase$

$|3I_0|>\mathrm{maxIph} \cdot INRelPE$

where:

U_2 and $3I_0$	are the magnitude of the negative sequence voltage and zero sequence current ($3I_0$)
U2MinOp	is the setting parameter for minimum operating negative sequence voltage
maxIph	is the maximum phase current
INRelPE	is the setting parameter for $3I_0$ limit for releasing phase-to-earth loop

The angle difference is phase shifted by 180 degrees if the fault is in reverse direction.

The condition 2 looks at the angle relationship between the negative sequence voltage U_2 and the positive sequence voltage U_1. Since this is a phase-to-phase voltage relationship, there is no need for shifting phases if the fault is in reverse direction. A phase shift is introduced so that the fault sectors will have the same angle boarders as for condition 1. If the calculated angle between U_2 and U_1 lies within one sector, the corresponding phase for that sector will be activated. The condition 2 is released if both the following conditions are fulfilled:

$|U_2|>U2MinOp$

$|U_1|>U1MinOP$

where:

$\lvert U_1\rvert$ and $\lvert U_2\rvert$	are the magnitude of the positive and negative sequence voltages.
U1MinOP and *U2MinOp*	are the setting parameters for positive sequence and negative sequence minimum operating voltages.

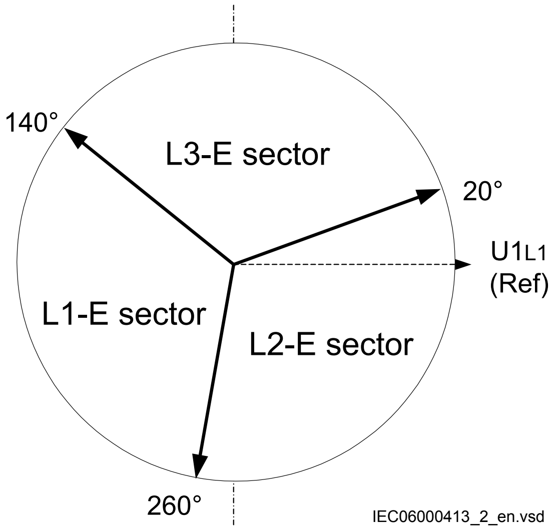


Figure 68: Condition 2: U_2 and U_1 angle relationship

If both conditions are true and there is sector match, the fault is deemed as single phase-to-earth. If the sectors, however, do not match the fault is determined to be the complement of the second condition, that is, a phase-to-phase-to- earth-fault.

Condition 1 and	Condition 2 ⇒	Fault type
L3-E	L3-E	L3-E
L2-E	L1-E	L2-L3-E

The sequence phase selector is blocked when earth is not involved or if a three-phase fault is detected.

Three-phase fault detection

Unless it has been categorized as a single or two-phase fault, the function classifies it as a three-phase fault if the following conditions are fulfilled:

$|U_1| < \mathit{U1Level}$

and

$|I_1| > \mathit{I1LowLevel}$

or

$|I_1| > \mathit{IMaxLoad}$

where:

$\vert U_1\vert$ and $\vert I_1\vert$	are the po
U1Level , *I1LowLevel*	are the se
IMaxLoad	is the setti

Fault evaluation and selection logic

The phase selection logic has an evaluation procedure that can be simplified according to figure 69. Only phase L1 is shown in the figure. If the internal signal 3 Phase fault is activated, all four outputs START, STL1, STL2 and STL3 will be activated.

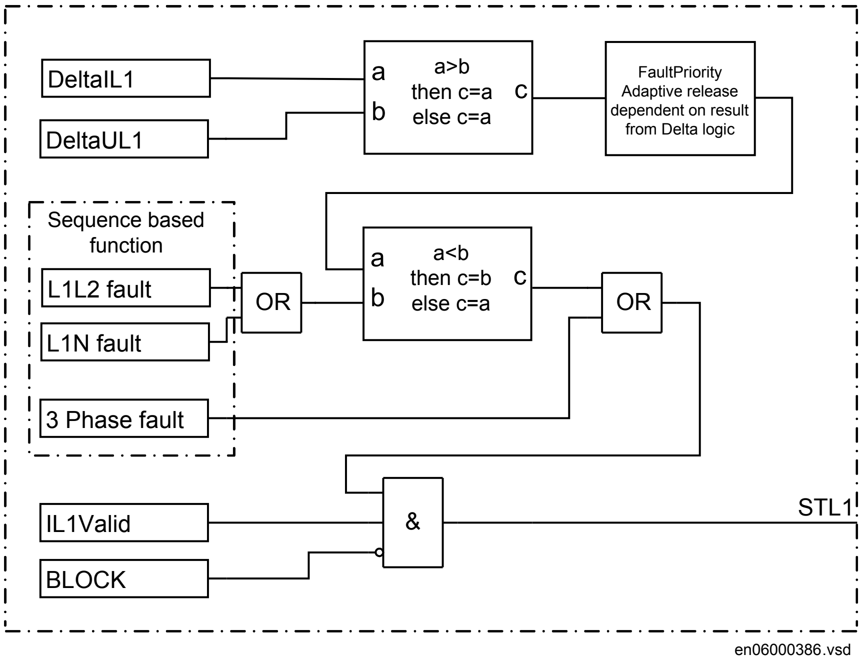


Figure 69: Simplified diagram for fault evaluation, phase L1

Load encroachment logic

Each of the six measuring loops has its own load (encroachment) characteristic based on the corresponding loop impedance. The load encroachment functionality is always activated in faulty phase identification with load enchroachment for mho (FMPSPDIS) function but the influence on the zone measurement can be switched on/off in the respective Five zone distance protection, mho characteristic (ZMOPDIS) function.

The outline of the characteristic is presented in figure 70. As illustrated, the resistive reach in forward and reverse direction and the angle of the sector is the same in all four quadrants. The reach for the phase selector will be reduced by the load encroachment function, see right figure 70.

Blinder

Blinder provides a mean to discriminate high load from a fault. The operating characteristic is illustrated in the figure below. There are six individual measuring loops with the blinder functionality. Three phase-to-earth loops which estimate the impedance according to

Zn = Uph / Iph

and three phase-to-phase loops according to

Zph-ph = Uph-ph / Iph-ph

The start operations from respective loop are binary coded into one word and provides an output signal STCNDBLF.

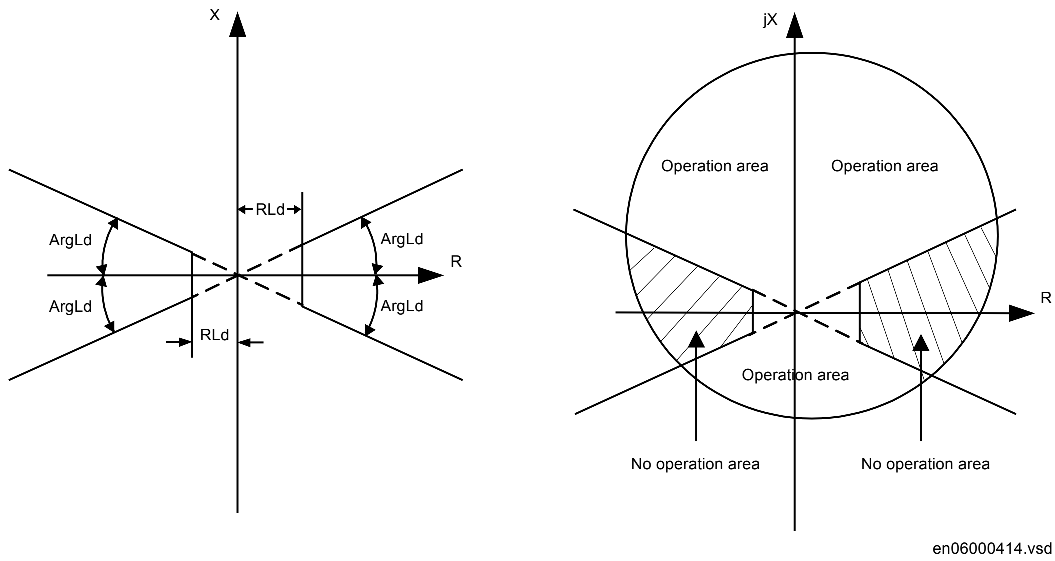


Figure 70: Influence on the characteristic by load encroachment logic

Outputs

The output of the sequence components based phase selector and the delta logic phase selector activates the output signals START, STL1, STL2 and STL3. If an earth fault is detected, then the signal STPE will be activated as well.

The phase selector also gives binary coded signals that are connected to the zone measuring element in ZMOPDIS for releasing the correct measuring loop(s).

The output STCNDPHS provides release information from the phase selection part only. STCNDLE provides release information from the load encroachmnet part only. In these signals, each fault type has an associated value, which represents the corresponding zone measuring loop to be released. The values are presented in the table below.

0=	no faulted phases
1=	L1E
2=	L2E
4=	L3E
8=	-L1L2E
16=	-L2L3E
32=	-L3L1E

Table continues on next page

56= -L1L2L3E

8= -L1L2

16= -L2L3

32= -L3L1

56= L1L2L3

The signal STCNDLE shall be connected to the input LDCND for selected mho impedance measuring zones ZMOPDIS.

In case several loops have to be released at the same time, the value will be the sum of the values for all loops, like the value for three-phase fault is the sum of the phase-to-phase loop values (8+16+32=56).

4.4.7 Technical data

Table 34: FMPSPDIS Technical data

Function	Range or value	Accuracy
Load encroachment criteria: Load resistance, forward and reverse	(1.00–3000) Ω/phase (5–70) degrees	± 2.0% static accuracy Conditions: Voltage range: (0.1–1.1) x U_n Current range: (0.5–30) x I_n

4.5 Directional impedance quadrilateral and mho ZDNRDIR

4.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional impedance quadrilateral and mho	ZDNRDIR	-	-

4.5.2 Functionality

The phase-to-earth impedance elements can be optionally supervised by a directional function based on symmetrical components.

4.5.3 Function block

Figure 71: ZDNRDIR function block

4.5.4 Signals

Table 35: ZDNRDIR Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs

Table 36: ZDNRDIR Output signals

Name	Type	Description
DIR_POL	GROUP SIGNAL	Polarizing voltage output for Mho
STDIRCND	INTEGER	Binary coded directional information per measuring loop

4.5.5 Settings

Table 37: ZDNRDIR Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
ArgNegRes	90 - 175	Deg	1	115	Angle of blinder in second quadrant for forward direction
ArgDir	5 - 45	Deg	1	15	Angle of blinder in fourth quadrant for forward direction
IMinOpPE	5 - 30	%IB	1	5	Minimum operate phase current for Phase-Earth loops
IMinOpPP	5 - 30	%IB	1	10	Minimum operate delta current for Phase-Phase loops

Table 38: ZDNRDIR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.5.6 Monitored data

Table 39: ZDNRDIR Monitored data

Name	Type	Values (Range)	Unit	Description
L1R	REAL	-	Ohm	Resistance in phase L1
L1X	REAL	-	Ohm	Reactance in phase L1
L2R	REAL	-	Ohm	Resistance in phase L2
L2X	REAL	-	Ohm	Reactance in phase L2
L3R	REAL	-	Ohm	Resistance in phase L3
L3X	REAL	-	Ohm	Reactance in phase L3
L1Dir	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction in phase L1
L2Dir	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction in phase L2
L3Dir	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction in phase L3

4.5.7 Operation principle

The evaluation of the directionality takes place in directional element ZDNRDIR for the quadrilateral and mho characteristic distance protections ZQDPDIS and ZMOPDIS. Equation 23 and equation 24 are used to classify that the fault is in the forward direction for phase-to-earth fault and phase-to-phase fault respectively.

$$-\mathrm{ArgDir} < \arg \frac{0.85 \cdot U1_{L1} + 0.15 \cdot U1_{L1M}}{I_{L1}} < \mathrm{ArgNegRes}$$

(Equation 23)

$$-\mathrm{ArgDir} < \arg \frac{0.85 \cdot U1_{L1L2} + 0.15 \cdot U1_{L1L2M}}{I_{L1L2}} < \mathrm{ArgNegRes}$$

(Equation 24)

Where:	
ArgDir	Setting for the lower boundary of the forward directional characteristic, by default set to 15 (= -15 degrees)
ArgNegRes	Setting for the upper boundary of the forward directional characteristic, by default set to 115 degrees, see figure 72 for mho characteristics and figure 73 for quadrilateral characteristics.
$U1_{L1}$	Positive sequence phase voltage in phase L1
$U1_{L1M}$	Positive sequence memorized phase voltage in phase L1
I_{L1}	Phase current in phase L1

Table continues on next page

$U1_{L1L2}$	Voltage difference between phase L1 and L2 (L2 lagging L1)
$U1_{L1L2M}$	Memorized voltage difference between phase L1 and L2 (L2 lagging L1)
I_{L1L2}	Current difference between phase L1 and L2 (L2 lagging L1)

The default settings for *ArgDir* and *ArgNegRes* are 15 (= -15) and 115 degrees respectively (see figure 72 and figure 73 Setting angles for discrimination of forward and reverse fault for mho and quadrilateral characteristic) and they should not be changed unless system studies show the necessity.

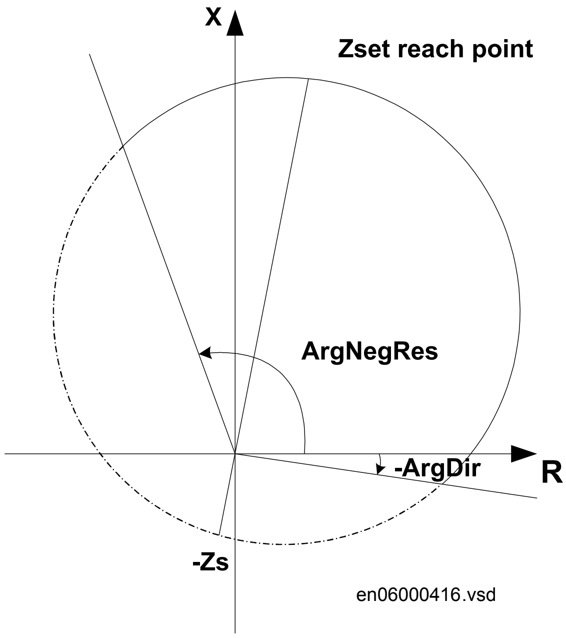


Figure 72: Setting angles for discrimination of forward and reverse fault for mho characteristic

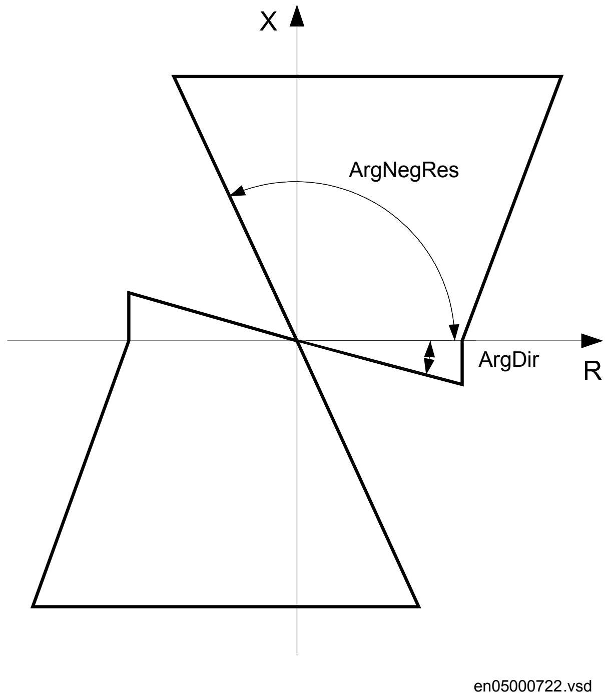


Figure 73: Setting angles for discrimination of forward and reverse fault for quadrilateral characteristic

The reverse directional characteristic is equal to the forward characteristic rotated by 180 degrees.

ZDNRDIR gives binary coded directional information per measuring loop on the output STDIRCND.

The polarizing voltage is available as long as the positive-sequence voltage exceeds 5% of the set base voltage *UBase*. So the directional element can use it for all unsymmetrical faults including close-in faults.

For close-in three-phase faults, the $U1_{L1M}$ memory voltage, based on the same positive sequence voltage, ensures correct directional discrimination.

The memory voltage is used for 100ms or until the positive sequence voltage is restored. After 100ms, the following occurs:

- If the current is still above the set value of the minimum operating current (between 10% and 30% of *IBase*) the condition seals in.
  - If the fault has caused tripping, the trip endures.
  - If the fault was detected in the reverse direction, the measuring element in the reverse direction remains in operation.
- If the current decreases below the minimum operating value, the memory resets and no directional indications will be given until the positive sequence voltage exceeds 10% of its rated value.

4.6 Phase preference logic PPLPHIZ

4.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase preference logic	PPLPHIZ	-	-

4.6.2 Functionality

Phase preference logic function (PPLPHIZ) is intended to be used in isolated or high impedance-earthed networks where there is a requirement to trip only one of the faulty lines at cross-country fault.

Phase preference logic inhibits tripping for single phase-to-earth faults in isolated and high impedance earthed networks, where such faults are not to be cleared by distance protection. For cross-country faults, the logic selects either the leading or the lagging phase-earth loop for measurement and initiates tripping of the preferred fault based on the selected phase preference. A number of different phase preference combinations are available for selection.

4.6.3 Function block

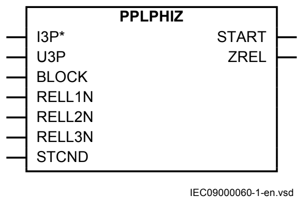


Figure 74: PPLPHIZ function block

4.6.4 Signals

Table 40: PPLPHIZ Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltageinputs
BLOCK	BOOLEAN	0	Block of function
RELL1N	BOOLEAN	0	Release condition for the L1 to earth loop
RELL2N	BOOLEAN	0	Release condition for the L2 to earth loop
RELL3N	BOOLEAN	0	Release condition for the L3 to earth loop
STCND	INTEGER	0	Integer coded external release signal

Table 41: PPLPHIZ Output signals

Name	Type	Description
START	BOOLEAN	Indicates start for earth fault(s), regardless of direction
ZREL	INTEGER	Integer coded output release signal

4.6.5 Settings

Table 42: PPLPHIZ Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
OperMode	No Filter NoPref 1231c 1321c 123a 132a 213a 231a 312a 321a	-	-	No Filter	Operating mode (c=cyclic,a=acyclic)
UPN<	10.0 - 100.0	%UB	1.0	70.0	Operate value of phase undervoltage in % of UBase
UPP<	10.0 - 100.0	%UB	1.0	50.0	Operate value of line to line undervoltage in % of UBase
3U0>	5.0 - 300.0	%UB	1.0	20.0	Operate value of residual voltage in % of UBase
IN>	10 - 200	%IB	1	20	Operate value of residual current in % of IBase
tUN	0.000 - 60.000	s	0.001	0.100	Pickup delay for residual voltage
tOffUN	0.000 - 60.000	s	0.001	0.100	Dropoff delay for residual voltage
tIN	0.000 - 60.000	s	0.001	0.150	Pickup delay for residual current

Table 43: PPLPHIZ Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

4.6.6 Operation principle

Phase preference logic (PPLPHIZ) has 10 operation modes which can be set by the parameter *OperMode*. The different modes and their explanation are shown in table 44 below. The difference between cyclic and acyclic operation can be explained by the following example. Assume a L1 fault on one line and a L3 fault on another line. For *OperMode = 2* the line with L3 fault will be tripped (L3 before L1) while for *OperMode = 4* the line with L1 fault will be tripped (L1 before L3).

Table 44: Operation modes for Phase preference logic

OperMode	Description
No filter	No filter, phase-to-phase measuring loops are not blocked during single phase-to-earth faults. Tripping is allowed without any particular phase preference at cross-country faults
No pref	No preference, trip is blocked during single phase-to-earth faults, trip is allowed without any particular phase preference at cross-country fault
1231 c	Cyclic 1231c; L1 before L2 before L3 before L1
1321 c	Cyclic 1321c; L1 before L3 before L2 before L1
123 a	Acyclic 123a; L1 before L2before L3
132 a	Acyclic 132a; L1 before L3 before L2
213 a	Acyclic 213a; L2 before L1 before L3
231 a	Acyclic 231a; L2 before L3 before L1
312 a	Acyclic 312a; L3 before L1 before L2
321 a	Acyclic 321a; L3 before L2 before L1

The function can be divided into two parts; one labeled voltage and current discrimination and the second one labeled phase preference evaluation, see figure 75.

The aim with the voltage and current discrimination part is to discriminate faulty phases and to determine if there is a cross-country fault. If cross-country fault is detected, an internal signal “Detected cross-country fault” is created and sent to the phase preference part to be used in the evaluation process for determining the condition for trip.

The voltage and current discrimination part gives phase segregated start signals if the respective measured phase voltage is below the setting parameter *UPN<* at the same time as the zero sequence voltage is above the setting parameter *3U0>*. If there is a start in any phase the START out put signal will be activated.

The internal signal for detection of cross-country fault, DetectCrossCountry, that come from the voltage and current discrimination part of the function can be achieved in three different ways:

1. The magnitude of $3I_0$ has been above the setting parameter *IN>* for a time longer than the setting of pick-up timer *tIN*.
2. The magnitude of $3I_0$ has been above the setting parameter *IN>* at the same time as the magnitude of $3U_0$ has been above the setting parameter *3U0>* during a time longer than the setting of pick-up timer *tUN*.
3. The magnitude of $3I_0$ has been above the setting parameter *IN>* at the same time as one of the following conditions are fulfilled:

- the measured phase-to-phase voltage in at least one of the phase combinations has been below the setting parameter *UPP<* for more than 20ms.
- At least two of the phase voltages are below the setting parameter *UPN<* for more than 20 ms.

The second part, phase preference evaluation, uses the internal signal DetectCrossCountry from the voltage and current evaluation together with the input signal STCND from the phase selection, FDPSPDIS, and the information from the setting parameter *OperMode* are used to determine the condition for trip. To release the Phase preference logic, at least two out of three phases must be faulty. The fault classification whether it is a single phase-to-earth, two-phase or cross-country fault and which phase to be tripped at cross-country fault is converted into a binary coded signal and sent to the distance protection measuring zone to release the correct measuring zone according to the setting of *OperMode*. This is done by activating the output ZREL and it shall be connected to the input STCND on the distance zone measuring element.

The input signals RELLx are additional fault release signals that can be connected to external protection functions through binary input.

The output start and trip signals can be blocked by activating the input BLOCK

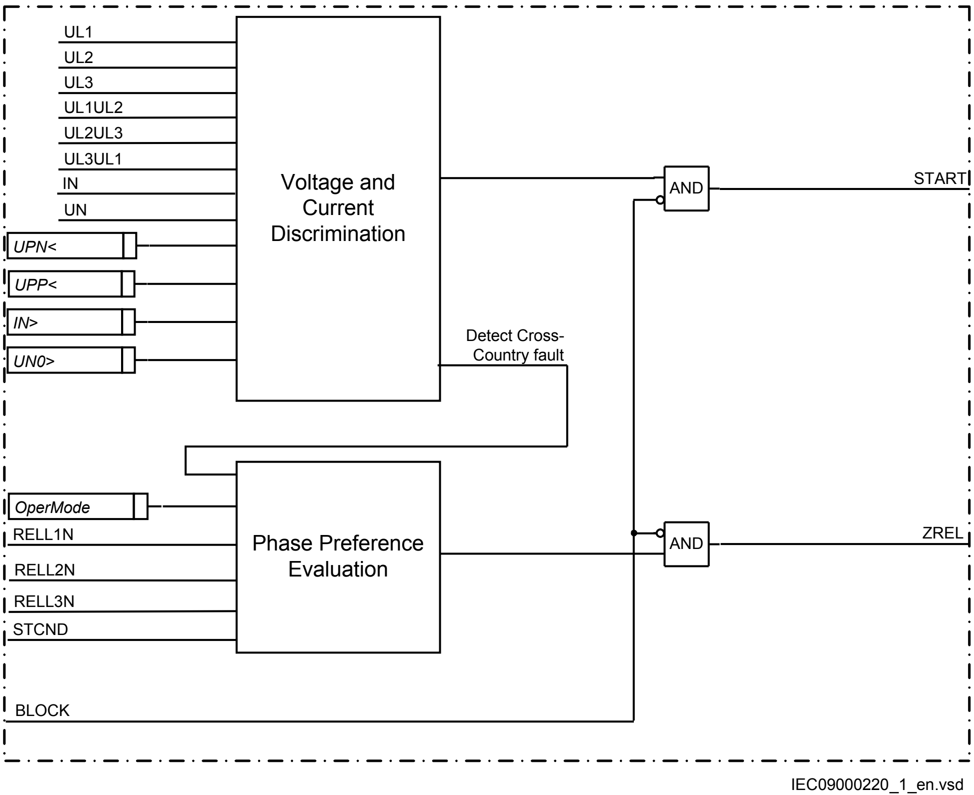


Figure 75: Simplified block diagram for Phase preference logic

4.6.7 Technical data

Table 45: PPLPHIZ Technical data

Function	Range or value	Accuracy
Operate value, phase-to-phase and phase-to-neutral undervoltage	(10.0 - 100.0)% of UBase	± 0,5% of U_r
Reset ratio, undervoltage	< 105%	-
Operate value, residual voltage	(5.0 - 300.0)% of UBase	± 0,5% of U_r
Reset ratio, residual voltage	> 95%	-
Operate value, residual current	(10 - 200)% of IBase	± 1,0% of I_r for I < Ir ± 1,0% of I for I > Ir
Reset ratio, residual current	> 95%	-
Timers	(0.000 - 60.000) s	± 0,5% ± 10ms
Operating mode	No Filter, NoPref Cyclic: 1231c, 1321c Acyclic: 123a, 132a, 213a, 231a, 312a, 321a	

4.7 Power swing detection ZMRPSB

4.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Power swing detection	ZMRPSB	Zpsb	68

4.7.2 Functionality

Power swings may occur after disconnection of heavy loads or trip of big generation plants.

Power swing detection function (ZMRPSB) is used to detect power swings and initiate block of selected distance protection zones. Occurrence of earth-fault currents during a power swing can block the Power swing detection function to allow fault clearance.

4.7.3 Function block

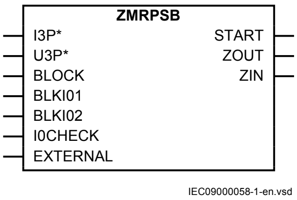


Figure 76: ZMRPSB function block

4.7.4 Signals

Table 46: ZMRPSB Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKI01	BOOLEAN	0	Block inhibit of start output for slow swing condition
BLKI02	BOOLEAN	0	Block inhibit of start output for subsequent residual current detect
I0CHECK	BOOLEAN	0	Residual current (3I0) detection to inhibit start output
EXTERNAL	BOOLEAN	0	Input for external detection of power swing

Table 47: ZMRPSB Output signals

Name	Type	Description
START	BOOLEAN	Power swing detected
ZOUT	BOOLEAN	Measured impedance within outer impedance boundary
ZIN	BOOLEAN	Measured impedance within inner impedance boundary

4.7.5 Settings

Table 48: ZMRPSB Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Mode On / Off
X1InFw	0.10 - 3000.00	ohm	0.01	30.00	Inner reactive boundary, forward
R1LIn	0.10 - 1000.00	ohm	0.01	30.00	Line resistance for inner characteristic angle
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
R1FInFw	0.10 - 1000.00	ohm	0.01	30.00	Fault resistance coverage to inner resistive line, forward
X1InRv	0.10 - 3000.00	ohm	0.01	30.00	Inner reactive boundary, reverse
R1FInRv	0.10 - 1000.00	ohm	0.01	30.00	Fault resistance line to inner resistive boundary, reverse
OperationLdCh	Off On	-	-	On	Operation of load discrimination characteristic
RLdOutFw	0.10 - 3000.00	ohm	0.01	30.00	Outer resistive load boundary, forward
ArgLd	5 - 70	Deg	1	25	Load angle determining load impedance area
RLdOutRv	0.10 - 3000.00	ohm	0.01	30.00	Outer resistive load boundary, reverse
kLdRFw	0.50 - 0.90	Mult	0.01	0.75	Multiplication factor for inner resistive load boundary, forward
kLdRRv	0.50 - 0.90	Mult	0.01	0.75	Multiplication factor for inner resistive load boundary, reverse
IMinOpPE	5 - 30	%IB	1	10	Minimum operate current in % of IBase

Table 49: ZMRPSB Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
tP1	0.000 - 60.000	s	0.001	0.045	Timer for detection of initial power swing
tP2	0.000 - 60.000	s	0.001	0.015	Timer for detection of subsequent power swings
tW	0.000 - 60.000	s	0.001	0.250	Waiting timer for activation of tP2 timer
tH	0.000 - 60.000	s	0.001	0.500	Timer for holding power swing START output
tR1	0.000 - 60.000	s	0.001	0.300	Timer giving delay to inhibit by the residual current
tR2	0.000 - 60.000	s	0.001	2.000	Timer giving delay to inhibit at very slow swing

Table 50: ZMRPSB Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

4.7.6 Operation principle

Power swing detection function (ZMRPSB) comprises an inner and an outer quadrilateral measurement characteristic with load encroachment, see figure 77.

Its principle of operation is based on the measurement of the time it takes for a power swing transient impedance to pass through the impedance area between the outer and the inner characteristics. Power swings are identified by transition times longer than a transition time set on corresponding timers. The impedance measuring principle is the same as that used for the distance protection zones. The impedance and the characteristic passing times are measured in all three phases separately.

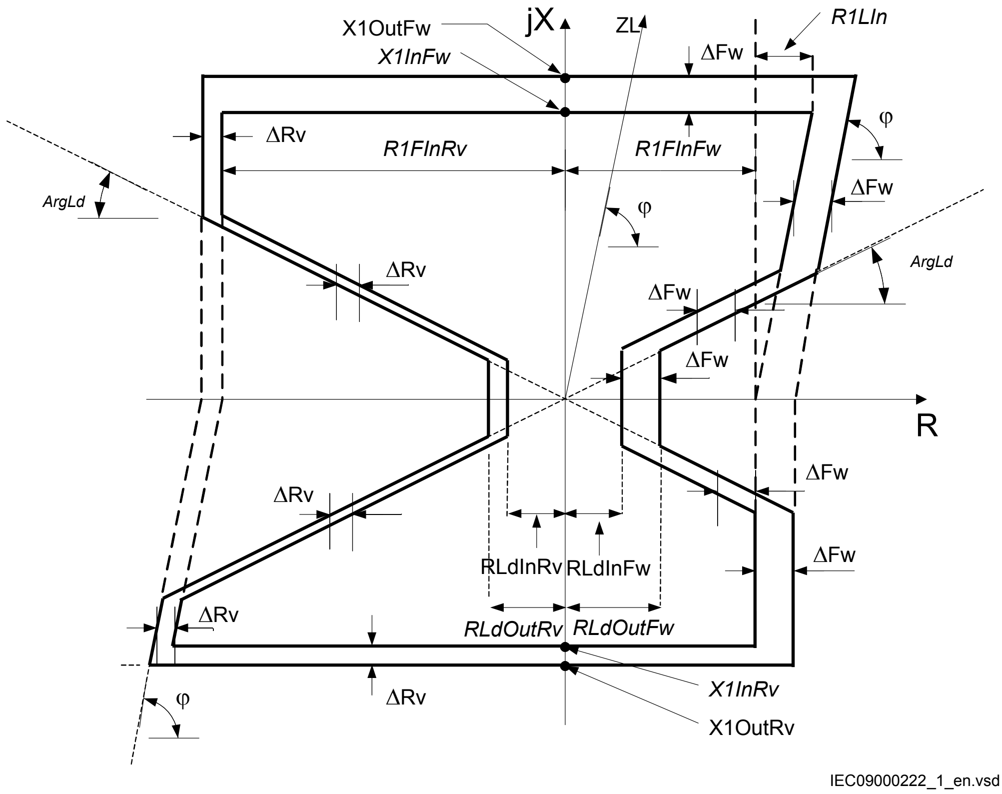


Figure 77: Operating characteristic for the ZMRPSB function (setting parameters in italic)

The impedance measurement within the ZMRPSB function is performed by solving equation 25 and equation 26 (n = 1, 2, 3 for each corresponding phase L1, L2 and L3).

$$\mathrm{Re}\left(\frac{\overline{U}_{Ln}}{\overline{I}_{Ln}}\right) \leq R_{set}$$

(Equation 25)

$$\mathrm{Im}\left(\frac{\overline{U}_{Ln}}{\overline{I}_{Ln}}\right) \leq X_{set}$$

(Equation 26)

The R_{set} and X_{set} are R and X boundaries.

4.7.6.1 Resistive reach in forward direction

To avoid load encroachment, the resistive reach is limited in forward direction by setting the parameter *RLdOutFw* which is the outer resistive load boundary value while the inner resistive boundary is calculated according to equation 27.

$$\mathrm{RLdInFw} = kLdRFw \cdot RLdOutFw$$

(Equation 27)

where:

kLdRFw is a settable multiplication factor less than 1

The slope of the load encroachment inner and outer boundary is defined by setting the parameter *ArgLd*.

The load encroachment in the fourth quadrant uses the same settings as in the first quadrant (same *ArgLd* and *RLdOutFw* and calculated value RLdInFw).

The quadrilateral characteristic in the first quadrant is tilted to get a better adaptation to the distance measuring zones. The angle is the same as the line angle and derived from the setting of the reactive reach inner boundary *X1InFw* and the line resistance for the inner boundary *R1LIn*. The fault resistance coverage for the inner boundary is set by the parameter *R1FInFw*.

From the setting parameter *RLdOutFw* and the calculated value RLdInFw a distance between the inner and outer boundary, ΔFw, is calculated. This value is valid for R direction in first and fourth quadrant and for X direction in first and second quadrant.

4.7.6.2 Resistive reach in reverse direction

To avoid load encroachment in reverse direction, the resistive reach is limited by setting the parameter *RLdOutRv* for the outer boundary of the load encroachment zone. The distance to the inner resistive load boundary RLdInRv is determined by using the setting parameter *kLdRRv* in equation 28.

$$\mathrm{RLdInRv} = kLdRRv \cdot RLdOutRv$$

(Equation 28)

where:

kLdRRv is a settable multiplication factor less than 1

From the setting parameter *RLdOutRv* and the calculated value RLdInRv, a distance between the inner and outer boundary, ΔRv, is calculated. This value is valid for R direction in second and third quadrant and for X direction in third and fourth quadrant.

The inner resistive characteristic in the second quadrant outside the load encroachment part corresponds to the setting parameter *R1FInRv* for the inner boundary. The outer boundary is internally calculated as the sum of ΔRv+*R1FInRv*.

The inner resistive characteristic in the third quadrant outside the load encroachment zone consist of the sum of the settings *R1FInRv* and the line resistance *R1LIn*. The argument of the tilted lines outside the load encroachment is the same as the tilted lines in the first quadrant. The distance between the inner and outer boundary is the same as for the load encroachment in reverse direction, that is ΔRv.

4.7.6.3 Reactive reach in forward and reverse direction

The inner characteristic for the reactive reach in forward direction correspond to the setting parameter *X1InFw* and the outer boundary is defined as *X1InFw* + ΔFw,

where:

ΔFw = *RLdOutFw* - *KLdRFw* · *RLdOutFw*

The inner characteristic for the reactive reach in reverse direction correspond to the setting parameter *X1InRv* for the inner boundary and the outer boundary is defined as *X1InRv* + ΔRv.

where:

ΔRv = *RLdOutRv* - KLdRRv · *RLdOutRv*

4.7.6.4 Basic detection logic

The operation of the Power swing detection (ZMRPSB) is only released if the magnitude of the current is above the setting of the min operating current, *IMinOpPE*.

- The "1-of-3" operating mode is based on detection of power swing in any of the three phases. Figure 78 presents a composition of an internal detection signal DET-L1 in this particular phase.

Signals ZOUTLn (outer boundary) and ZINLn (inner boundary) in figure 78 are related to the operation of the impedance measuring elements in each phase separately (Ln represents the corresponding phase L1, L2, and L3). They are internal signals, calculated by ZMRPSB function.

The *tP1* timer in figure 78 serve as detection of initial power swings, which are usually not as fast as the later swings are. The *tP2* timer become activated for the detection of the consecutive swings, if the measured impedance exit the operate area and returns within the time delay, set on the *tW* waiting timer. The upper part of figure 78 (internal input signal ZOUTL1, ZINL1, AND-gates and tP-timers etc.) are duplicated for phase L2 and L3. All *tP1* and *tP2* timers in the figure have the same settings.

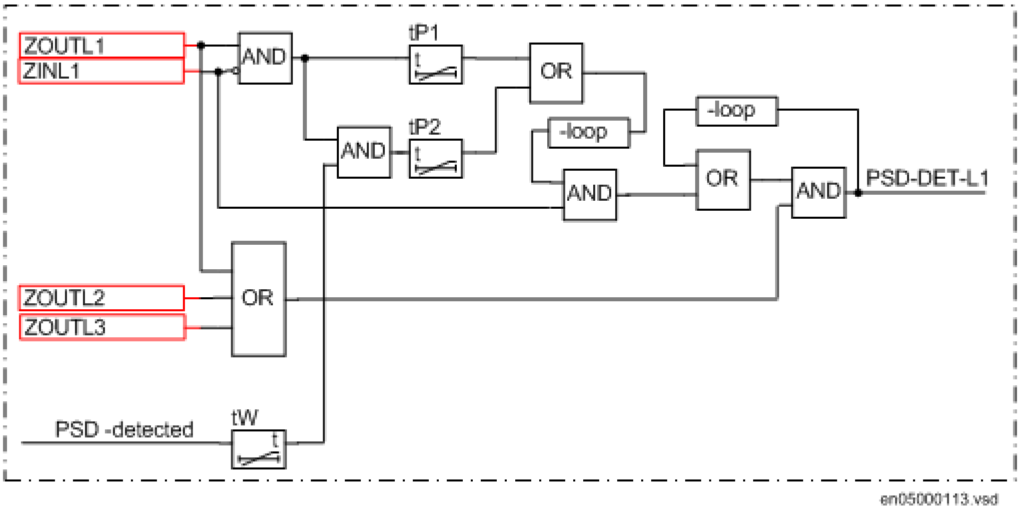


Figure 78: Detection of power swing in phase L1

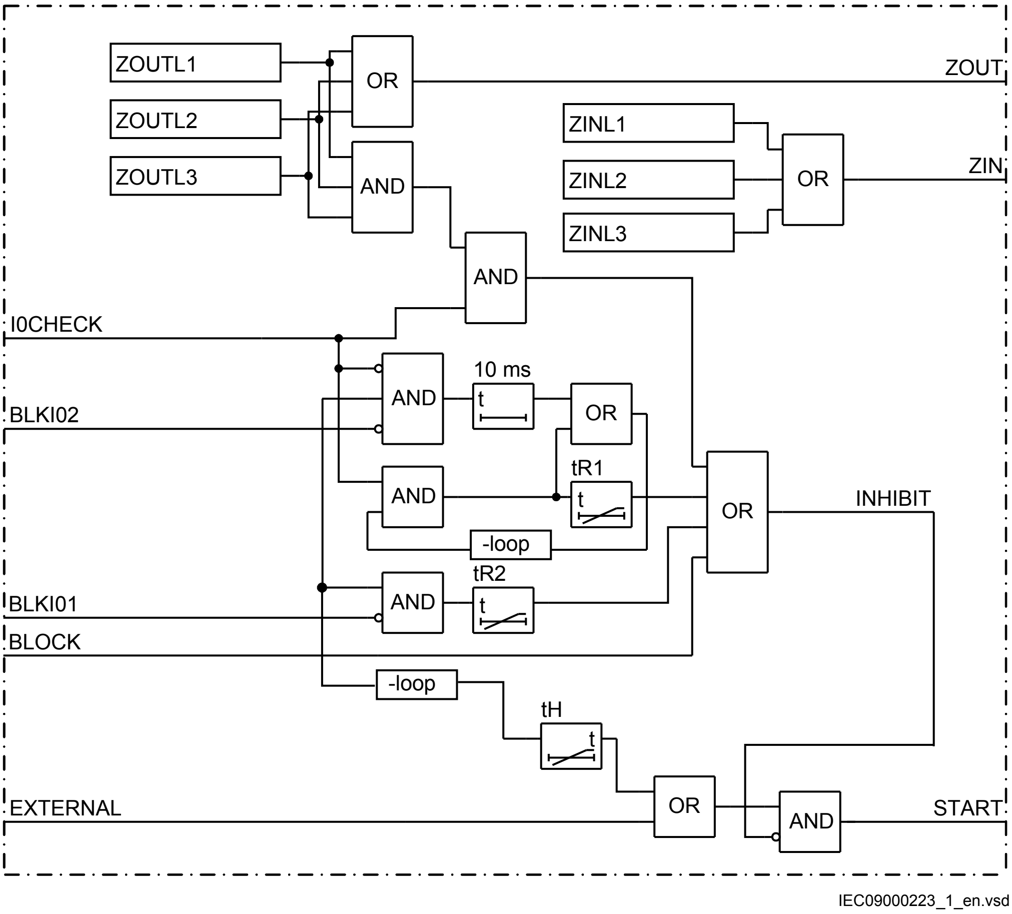


Figure 79: Simplified block diagram for ZMRPSB function

4.7.6.5 Operating and inhibit conditions

Figure 79 presents a simplified logic diagram for the Power swing detection function (ZMRPSB).

The load encroachment characteristic can be switched off by setting the parameter *OperationLdCh = Off*, but notice that the ΔFw and ΔRv will still be calculated from RLdOutFw and RLdOutRv. The characteristic will in this case be only quadrilateral.

There are three different ways to form the internal INHIBIT signal:

- Logical 1 on functional input BLOCK inhibits the output START signal instantaneously.
- The INHIBIT internal signal is activated, if the power swing has been detected and the measured impedance remains within its operate characteristic for the time, which is longer than the time delay set on *tR2* timer. It is possible to

disable this condition by connecting the logical 1 signal to the BLKI01 functional input.
- The INHIBIT internal signal is activated after the time delay, set on *tR1* timer, if an earth-fault appears during the power swing (input IOCHECK is high) and the power swing has been detected before the earth-fault (activation of the signal I0CHECK). It is possible to disable this condition by connecting the logical 1 signal to the BLKI02 functional input.

4.7.7 Technical data

Table 51: ZMRPSB Technical data

Function	Range or value	Accuracy
Reactive reach	(0.10-3000.00) Ω	± 2.0% static accuracy Conditions: Voltage range: (0.1-1.1) x U_r Current range: (0.5-30) x I_r Angle: at 0 degrees and 85 degrees
Resistive reach	(0.10–1000.00)Ω	
Timers	(0.000-60.000) s	± 0.5% ± 10 ms

4.8 Automatic switch onto fault logic, voltage and current based ZCVPSOF

4.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Automatic switch onto fault logic, voltage and current based	ZCVPSOF	-	-

4.8.2 Functionality

Automatic switch onto fault logic, voltage and current based (ZCVPSOF) is a function that gives an instantaneous trip at closing of breaker onto a fault. A dead line detection check is provided to activate the function when the line is dead.

Mho distance protections can not operate for switch onto fault condition when the phase voltages are close to zero. An additional logic based on UI Level is used for this purpose.

4.8.3 Function block

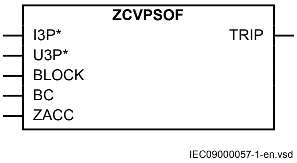


Figure 80: ZCVPSOF Function block

4.8.4 Signals

Table 52: ZCVPSOF Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BC	BOOLEAN	0	External enabling of SOTF
ZACC	BOOLEAN	0	Distance zone to be accelerated by SOTF

Table 53: ZCVPSOF Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip output

4.8.5 Settings

Table 54: ZCVPSOF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
Mode	Impedance UILevel UILvl&Imp	-	-	UILevel	Mode of operation of SOTF Function
AutoInit	Off On	-	-	Off	Automatic switch onto fault initialization
IPh<	1 - 100	%IB	1	20	Current level for detection of dead line in % of IBase
UPh<	1 - 100	%UB	1	70	Voltage level for detection of dead line in % of UBase
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
tDuration	0.000 - 60.000	s	0.001	0.020	Time delay for UI detection
tSOTF	0.000 - 60.000	s	0.001	1.000	Drop off delay time of switch onto fault function
tDLD	0.000 - 60.000	s	0.001	0.200	Delay time for activation of dead line detection

Table 55: ZCVPSOF Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

4.8.6 Operation principle

Automatic switch onto fault logic, voltage and current based function (ZCVPSOF) can be activated externally by Breaker Closed Input or internally (automatically) by using UI Level Based Logic see figure 81.

The activation from the Dead line detection function is released if the internal signal deadLine from the UILevel function is activated at the same time as the input ZACC is not activated during at least for a duration *tDLD* and the setting parameter *AutoInit* is set to *On*.

When the setting *AutoInit* is *Off*, the function is activated by an external binary input BC. To get a trip one of the following operation modes must also be selected by the parameter *Mode*:

Mode = *Impedance*; trip is released if the input ZACC is activated (normal connected to non directional distance protection zone).

Mode = *UILevel*; trip is released if UILevel detector is activated.

Mode = *UILvl&Imp*; trip is initiated based on impedance measured criteria or UILevel detection.

The internal signal deadLine from the UILevel detector is activated if all three phase currents and voltages are below the setting *IPh<* and *UPh<*.

UI Level based measurement detects the switch onto fault condition even though the voltage is very low. The logic is based on current change for activation, current level and voltage level. The internal signal SOTFU ILevel is activated if the phase voltage is below the setting *UPh<* and the corresponding phase current is above the setting *IPh<* in any phase.

ZCVPSOF can be activated externally from input BC and thus setting *AutoInit* is bypassed.

The function is released during a settable time *tSOTF*.

The function can be blocked by activating the input BLOCK.

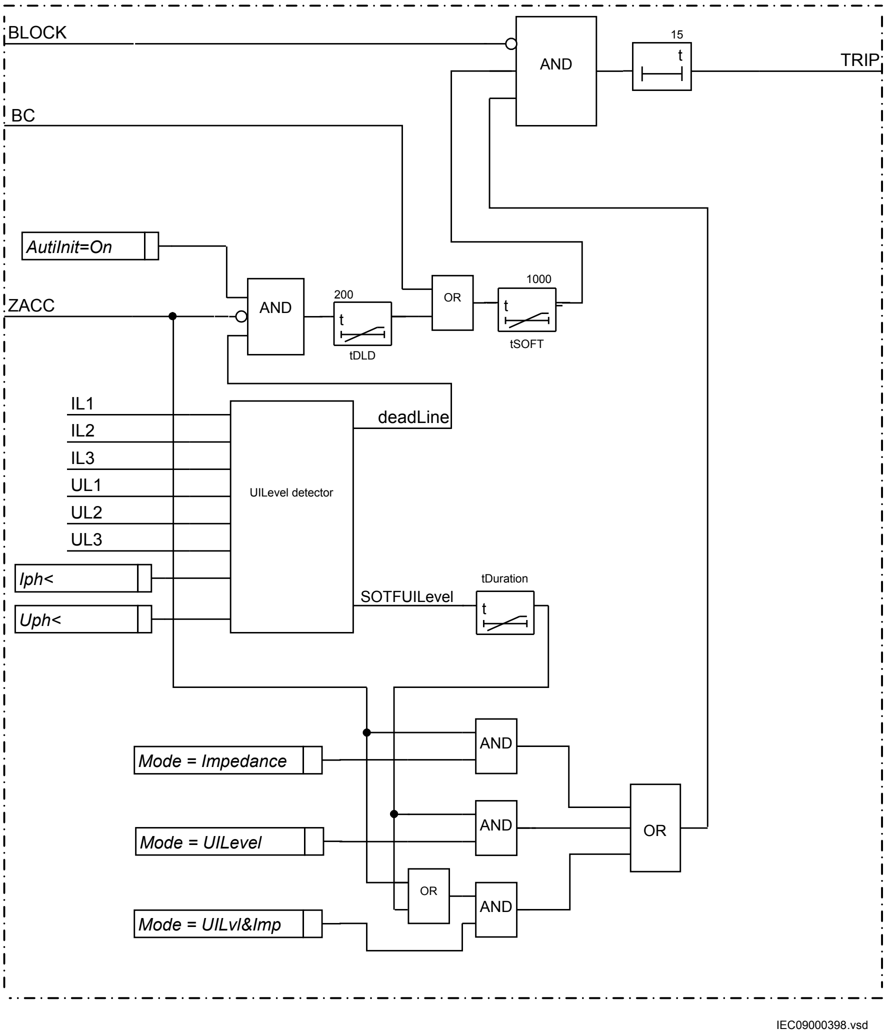


Figure 81: Simplified logic diagram for Automatic switch onto fault logic, voltage and current based.

4.8.7 Technical data

Table 56: ZCVPSOF Technical data

Parameter	Range or value	Accuracy
Operate voltage, detection of dead line	(1–100)% of UBase	± 0.5% of U_r
Operate current, detection of dead line	(1–100)% of IBase	± 1.0% of I_r
Delay following dead line detection input before Automatic switch onto fault logic function is automatically turned On	(0.000–60.000) s	± 0.5% ± 10 ms
Time period after circuit breaker closure in which Automatic switch onto fault logic function is active	(0.000–60.000) s	± 0.5% ± 10 ms

Section 5 Current protection

5.1 Instantaneous phase overcurrent protection PHPIOC

5.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Instantaneous phase overcurrent protection	PHPIOC	3I>>	50

5.1.2 Functionality

The instantaneous three phase overcurrent function has a low transient overreach and short tripping time to allow use as a high set short-circuit protection function.

5.1.3 Function block

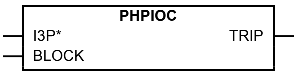


Figure 82: PHPIOC function block

5.1.4 Signals

Table 57: PHPIOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function

Table 58: PHPIOC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal

5.1.5 Settings

Table 59: PHPIOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
IP>>	5 - 2500	%IB	1	200	Operate phase current level in % of IBase

Table 60: PHPIOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.1.6 Monitored data

Table 61: PHPIOC Monitored data

Name	Type	Values (Range)	Unit	Description
IL1	REAL	-	A	Current in phase L1
IL2	REAL	-	A	Current in phase L2
IL3	REAL	-	A	Current in phase L3

5.1.7 Operation principle

The sampled analogue phase currents are pre-processed in a discrete Fourier filter (DFT) block. From the fundamental frequency components, as well as sampled values, of each phase current the RMS value of each phase current is derived. These phase current values are fed to the Instantaneous phase overcurrent protection (PHPIOC) function. In a comparator the RMS values are compared to the set operation current value of the function *(IP>>)*. If a phase current is larger than the set operation current a signal from the comparator for this phase is set to true. This signal will, without delay, activate the TRIP signal that is common for all three phases.

The function can be blocked from the binary input BLOCK.

5.1.8 Technical data

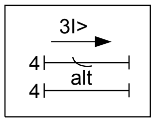
Table 62: PHPIOCTechnical data

Function	Range or value	Accuracy
Operate current	(5-2500)% of lBase	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$
Reset ratio	> 95%	-
Operate time	20 ms typically at 0 to 2 x I_{set}	-
Table continues on next page		

Function	Range or value	Accuracy
Reset time	25 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Operate time	10 ms typically at 0 to 10 x I_{set}	-
Reset time	35 ms typically at 10 to 0 x I_{set}	-
Critical impulse time	2 ms typically at 0 to 10 x I_{set}	-
Dynamic overreach	< 5% at τ = 100 ms	-

5.2 Four step phase overcurrent protection OC4PTOC

5.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Four step phase overcurrent protection	OC4PTOC		51/67

5.2.2 Functionality

The four step phase overcurrent function has an inverse or definite time delay independent for each step separately.

All IEC and ANSI time delayed characteristics are available.

The directional function is voltage polarized with memory. The function can be set to be directional or non-directional independently for each of the steps.

5.2.3 Function block

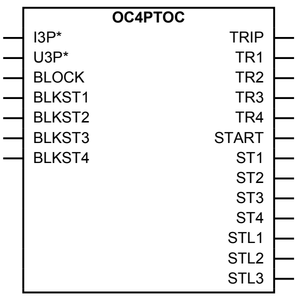


Figure 83: OC4PTOC function block

5.2.4 Signals

Table 63: OC4PTOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1
BLKST2	BOOLEAN	0	Block of step 2
BLKST3	BOOLEAN	0	Block of step 3
BLKST4	BOOLEAN	0	Block of step 4

Table 64: OC4PTOC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TR1	BOOLEAN	Trip signal from step 1
TR2	BOOLEAN	Trip signal from step 2
TR3	BOOLEAN	Trip signal from step 3
TR4	BOOLEAN	Trip signal from step 4
START	BOOLEAN	General start signal
ST1	BOOLEAN	Start signal from step 1
ST2	BOOLEAN	Start signal from step 2
ST3	BOOLEAN	Start signal from step 3
ST4	BOOLEAN	Start signal from step 4
STL1	BOOLEAN	Start signal from phase L1
STL2	BOOLEAN	Start signal from phase L2
STL3	BOOLEAN	Start signal from phase L3

5.2.5 Settings

Table 65: OC4PTOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
DirMode1	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 1 off / non-directional / forward / reverse
Characterist1	ANSI Ext. inv. ANSI Very inv. ANSI Norm. inv. ANSI Mod. inv. ANSI Def. Time L.T.E. inv. L.T.V. inv. L.T. inv. IEC Norm. inv. IEC Very inv. IEC inv. IEC Ext. inv. IEC S.T. inv. IEC L.T. inv. IEC Def. Time Reserved RI type RD type	-	-	ANSI Def. Time	Selection of time delay curve type for step 1
I1>	5 - 2500	%IB	1	1000	Phase current operate level for step1 in % of IBase
t1	0.000 - 60.000	s	0.001	0.000	Definite time delay of step 1
k1	0.05 - 999.00	-	0.01	0.05	Time multiplier for the inverse time delay for step 1
IMin1	1 - 10000	%IB	1	100	Minimum operate current for step1 in % of IBase
t1Min	0.000 - 60.000	s	0.001	0.000	Minimum operate time for inverse curves for step 1
DirMode2	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 2 off / non-directional / forward / reverse
I2>	5 - 2500	%IB	1	500	Phase current operate level for step 2 in % of IBase
t2	0.000 - 60.000	s	0.001	0.400	Definite time delay of step 2
DirMode3	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 3 off / non-directional / forward / reverse
I3>	5 - 2500	%IB	1	250	Phase current operate level for step3 in % of IBase
t3	0.000 - 60.000	s	0.001	0.800	Definite time delay of step 3
DirMode4	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 4 off / non-directional / forward / reverse

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
Characterist4	ANSI Ext. inv. ANSI Very inv. ANSI Norm. inv. ANSI Def. Time L.T.E. inv. L.T.V. inv. L.T. inv. IEC Norm. inv. IEC Very inv. IEC inv. IEC Ext. inv. IEC S.T. inv. IEC L.T. inv. IEC Def. Time Reserved RI type RD type	-	-	ANSI Def. Time	Selection of time delay curve type for step 4
I4>	5 - 2500	%IB	1	175	Phase current operate level for step 4 in % of IBase
t4	0.000 - 60.000	s	0.001	2.000	Definite time delay of step 4
k4	0.05 - 999.00	-	0.01	0.05	Time multiplier for the inverse time delay for step 4
IMin4	1 - 10000	%IB	1	17	Minimum operate current for step4 in % of IBase
t4Min	0.000 - 60.000	s	0.001	0.000	Minimum operate time for inverse curves for step 4

Table 66: OC4PTOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
MeasType	DFT RMS	-	-	DFT	Selection between DFT and RMS measurement

5.2.6 Monitored data

Table 67: OC4PTOC Monitored data

Name	Type	Values (Range)	Unit	Description
DIRL1	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction for phase L1
DIRL2	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction for phase L2
DIRL3	INTEGER	0=No direction 1=Forward 2=Reverse	-	Direction for phase L3
IL1	REAL	-	A	Current in phase L1
IL2	REAL	-	A	Current in phase L2
IL3	REAL	-	A	Current in phase L3

5.2.7 Operation principle

The function is divided into three different sub-functions, one for each step. For each step *x* , where x is step 1, 2, 3 and 4, an operation mode is set by *DirModex*: *Off/ Non-directional/Forward/Reverse.*

The protection design can be decomposed in three parts:

- The direction element
- The four step over current function
- The mode selection

If VT inputs are not available or not connected, setting parameter *DirModex* shall be left to default value, Non-directional.

The sampled analog phase currents are processed in a pre-processing function block. Using a parameter setting *MeasType* within the general settings for the Four step phase overcurrent protection (OC4PTOC) function; it is possible to select the type of the measurement used for all overcurrent stages. It is possible to select either discrete Fourier filter (DFT) or true RMS filter (RMS).

If DFT option is selected then only the RMS value of the fundamental frequency components of each phase current is derived. Influence of DC current component and higher harmonic current components are almost completely suppressed. If RMS option is selected then the true RMS values is used. The true RMS value in addition to the fundamental frequency component includes the contribution from the current DC component as well as from higher current harmonic. The selected current values are fed to the OC4PTOC function.

In a comparator, for each phase current, the DFT or RMS values are compared to the set operation current value of the function *(I1>, I2>, I3> or I4>)*. If a phase current is larger than the set operation current, outputs START, STx, STL1, STL2 and STL3 are, without delay, activated. Output signals STL1, STL2 and STL3 are common for all steps. This means that the lowest set step will initiate the activation. The START signal is common for all three phases and all steps. It shall be noted that the selection of measured value (DFT or RMS) do not influence the operation of directional part of OC4PTOC function.

Service value for individually measured phase currents are also available on the local HMI for OC4PTOC function, which simplifies testing, commissioning and in service operational checking of the function.

The function can be directional. The direction of the fault current is given as current angle in relation to the voltage angle. The fault current and fault voltage for the directional function is dependent of the fault type. To enable directional measurement at close in faults, causing low measured voltage, the polarization voltage is a combination of the apparent or phase voltage (85%) and a memory phase voltage (15%). The following combinations are used.

Phase-phase short circuit:

$$U_{refL1L2} = U_{L1} - U_{L2} \quad I_{dirL1L2} = I_{L1} - I_{L2}$$

(Equation 29)

$$U_{refL2L3} = U_{L2} - U_{L3} \quad I_{dirL2L3} = I_{L2} - I_{L3}$$

(Equation 30)

$$U_{refL3L1} = U_{L3} - U_{L1} \quad I_{dirL3L1} = I_{L3} - I_{L1}$$

(Equation 31)

Phase-earth short circuit:

$$U_{refL1} = U_{L1} \quad I_{dirL1} = I_{L1}$$

(Equation 32)

$$U_{refL2} = U_{L2} \quad I_{dirL2} = I_{L2}$$

(Equation 33)

$$U_{refL3} = U_{L3} \quad I_{dirL3} = I_{L3}$$

(Equation 34)

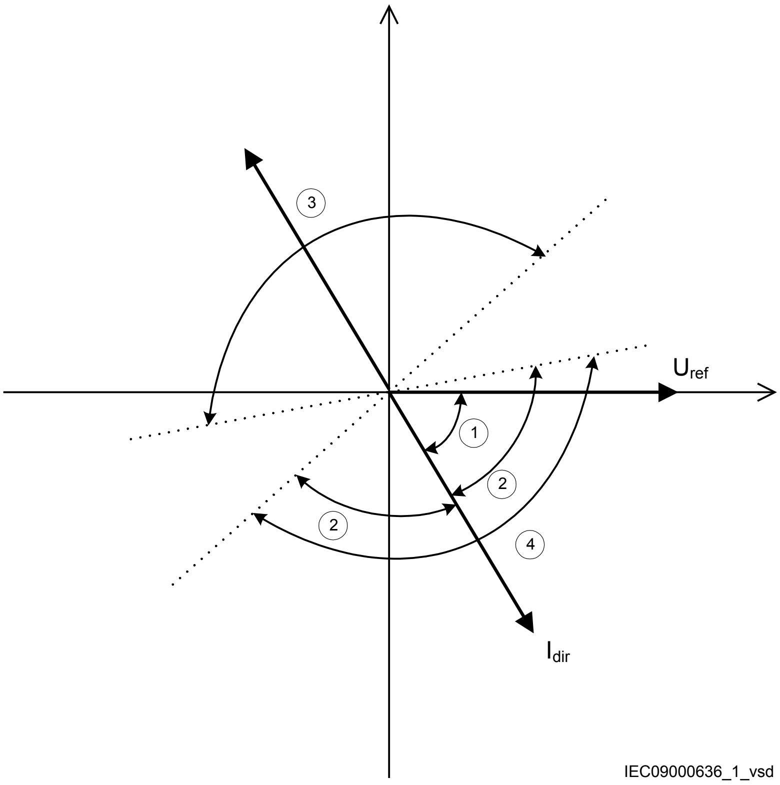


Figure 84: Directional characteristic of the phase overcurrent protection

1 RCA = Relay characteristic angle
2 ROA = Relay operating angle
3 Reverse
4 Forward

If no blockings are given the start signals will start the timers of the step. The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time characteristic. Step 2 and 3 are always definite time delayed. A wide range of standardized inverse time characteristics is available. The possibilities for inverse time characteristics are described in section 19.3 "Inverse time characteristics".

All four steps in OC4PTOC can be blocked from the binary input BLOCK. The binary input BLKSTx (x=1, 2, 3 or 4) blocks the operation of respective step.

5.2.8 Technical data

Table 68: OC4PTOCTechnical data

Function	Setting range	Accuracy
Operate current	(5-2500)% of IBase	± 1.0% of I_r at I ≤ I_r ± 1.0% of I at I > I_r
Reset ratio	> 95%	-
Min. operating current	(1-100)% of IBase	± 1.0% of I_r
Independent time delay	(0.000-60.000) s	± 0.5% ± 10 ms
Minimum operate time for inverse characteristics	(0.000-60.000) s	± 0.5% ± 10 ms
Inverse characteristics, see table 493, table 494 and table 495	17 curve types	See table 493, table 494 and table 495
Operate time, nondirectionalstart function	20 ms typically at 0 to 2 x I_{set}	-
Reset time, nondirectional start function	25 ms typically at 2 to 0 x I_{set}	-
Operate time, directional start function	30 ms typically at 0 to 2 x I_{set}	-
Reset time, directional start funciton	25 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Impulse margin time	15 ms typically	-

5.3 Instantaneous residual overcurrent protection EFPIOC

5.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Instantaneous residual overcurrent protection	EFPIOC	*IN>>*	50N

5.3.2 Functionality

The instantaneous residual overcurrent protection (EFPIOC) has a low transient overreach and short tripping times to allow the use for instantaneous earth fault protection, with the reach limited to less than typical eighty percent of the line at minimum source impedance. The function can be configured to measure the residual current from the three phase current inputs or the current from a separate current input. The function can be blocked by activating the input BLOCK.

5.3.3 Function block

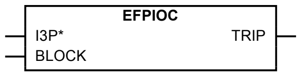


Figure 85: EFPIOC function block

5.3.4 Signals

Table 69: EFPIOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function

Table 70: EFPIOC Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip signal

5.3.5 Settings

Table 71: EFPIOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
IN>>	1 - 2500	%IB	1	200	Operate residual current level in % of IBase

Table 72: EFPIOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.3.6 Monitored data

Table 73: EFPIOC Monitored data

Name	Type	Values (Range)	Unit	Description
IN	REAL	-	A	Residual current

5.3.7 Operation principle

The sampled analogue residual currents are pre-processed in a discrete Fourier filter (DFT) block. From the fundamental frequency components of the residual current as well as, from the sample values the equivalent RMS value is derived. This current value is fed to the Instantaneous residual overcurrent protection (EFPIOC) function. In a comparator the RMS value is compared to the set operation current value of the function (*IN>>*). If the residual current is larger than the set operation current a signal from the comparator is set to true. This signal will, without delay, activate the output signal TRIP.

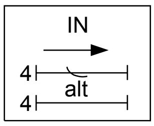
5.3.8 Technical data

Table 74: EFPIOC Technical data

Function	Range or value	Accuracy
Operate current	(1-2500)% of IBase	± 1.0% of I_r at $I \le I_r$ ± 1.0% of I at $I > I_r$
Reset ratio	> 95%	-
Operate time	20 ms typically at 0 to 2 x I_{set}	-
Reset time	30 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Operate time	10 ms typically at 0 to 10 x I_{set}	-
Reset time	40 ms typically at 10 to 0 x I_{set}	-
Critical impulse time	2 ms typically at 0 to 10 x I_{set}	-
Dynamic overreach	< 5% at τ = 100 ms	-

5.4 Four step residual overcurrent protection EF4PTOC

5.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Four step residual overcurrent protection	EF4PTOC		51N/67N

5.4.2 Functionality

The four step residual overcurrent protection (EF4PTOC) has an setable inverse or definite time delay independent for step 1 and 4 separately. Step 2 and 3 are always definite time delayed.

All IEC and ANSI time delayed characteristics are available.

The directional function is voltage polarized, current polarized or dual polarized.

The protection can be set directional or non-directional independently for each of the steps.

A second harmonic blocking can be enabled individually for each step.

The protection can be used as main protection for phase-to-earth faults.

The protection can also be used to provide a system back-up for example, in the case of the primary protection being out of service due to communication or voltage transformer circuit failure.

Directional operation can be combined together with corresponding communication logic in permissive or blocking teleprotection scheme. Current reversal and weak-end infeed functionality are available as well.

5.4.3 Function block

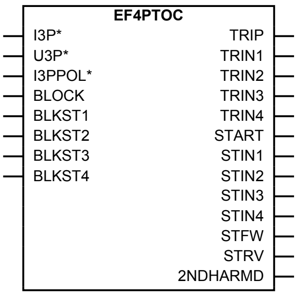


Figure 86: EF4PTOC function block

5.4.4 Signals

Table 75: EF4PTOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for polarizing voltage inputs
I3PPOL	GROUP SIGNAL	-	Three phase group signal for polarizing current inputs
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1 (start and trip)
BLKST2	BOOLEAN	0	Block of step 2 (start and trip)
BLKST3	BOOLEAN	0	Block of step 3 (start and trip)
BLKST4	BOOLEAN	0	Block of step 4 (start and trip)

Table 76: EF4PTOC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TRIN1	BOOLEAN	Trip signal from step 1
TRIN2	BOOLEAN	Trip signal from step 2
TRIN3	BOOLEAN	Trip signal from step 3
TRIN4	BOOLEAN	Trip signal from step 4
START	BOOLEAN	General start signal
STIN1	BOOLEAN	Start signal step 1
STIN2	BOOLEAN	Start signal step 2
STIN3	BOOLEAN	Start signal step 3
STIN4	BOOLEAN	Start signal step 4
STFW	BOOLEAN	Forward directional start signal
STRV	BOOLEAN	Reverse directional start signal
2NDHARMD	BOOLEAN	2nd harmonic block signal

5.4.5 Settings

Table 77: EF4PTOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
AngleRCA	-180 - 180	Deg	1	65	Relay characteristic angle (RCA)
polMethod	Voltage Current Dual	-	-	Voltage	Type of polarization
UPolMin	1 - 100	%UB	1	1	Minimum voltage level for polarization in % of UBase
IPolMin	2 - 100	%IB	1	5	Minimum current level for polarization in % of IBase
RNPol	0.50 - 1000.00	ohm	0.01	5.00	Real part of source Z to be used for current polarisation
XNPol	0.50 - 3000.00	ohm	0.01	40.00	Imaginary part of source Z to be used for current polarisation
IN>Dir	1 - 100	%IB	1	10	Residual current level for direction release in % of IBase
2ndHarmStab	5 - 100	%	1	20	Second harmonic restrain operation in % of IN amplitude
DirMode1	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 1 (off, non-directional, forward, reverse)

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
Characterist1	ANSI Ext. inv. ANSI Very inv. ANSI Norm. inv. ANSI Mod. inv. ANSI Def. Time L.T.E. inv. L.T.V. inv. L.T. inv. IEC Norm. inv. IEC Very inv. IEC inv. IEC Ext. inv. IEC S.T. inv. IEC L.T. inv. IEC Def. Time Reserved RI type RD type	-	-	ANSI Def. Time	Time delay curve type for step 1
IN1>	1 - 2500	%IB	1	100	Operate residual current level for step 1 in % of IBase
t1	0.000 - 60.000	s	0.001	0.000	Independent (definite) time delay of step 1
k1	0.05 - 999.00	-	0.01	0.05	Time multiplier for the dependent time delay for step 1
IMin1	1 - 10000	%IB	1	100	Minimum operate current for step1 in % of IBase
t1Min	0.000 - 60.000	s	0.001	0.000	Minimum operate time for inverse curves for step 1
HarmRestrain1	Off On	-	-	On	Enable block of step 1 from harmonic restrain
DirMode2	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 2 (off, non-directional, forward, reverse)
IN2>	1 - 2500	%IB	1	50	Operate residual current level for step 2 in % of IBase
t2	0.000 - 60.000	s	0.001	0.400	Independent (definite) time delay of step 2
IMin2	1 - 10000	%IB	1	50	Minimum operate current for step 2 in % of IBase
HarmRestrain2	Off On	-	-	On	Enable block of step 2 from harmonic restrain
DirMode3	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 3 (off, non-directional, forward, reverse)
IN3>	1 - 2500	%IB	1	33	Operate residual current level for step 3 in % of IBase
t3	0.000 - 60.000	s	0.001	0.800	Independent (definite) time delay of step 3
IMin3	1 - 10000	%IB	1	33	Minimum operate current for step 3 in % of IBase
HarmRestrain3	Off On	-	-	On	Enable block of step 3 from harmonic restrain

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
DirMode4	Off Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 4 (off, non-directional, forward, reverse)
Characterist4	ANSI Ext. inv. ANSI Very inv. ANSI Norm. inv. ANSI Mod. inv. ANSI Def. Time L.T.E. inv. L.T.V. inv. L.T. inv. IEC Norm. inv. IEC Very inv. IEC inv. IEC Ext. inv. IEC S.T. inv. IEC L.T. inv. IEC Def. Time Reserved RI type RD type	-	-	ANSI Def. Time	Time delay curve type for step 4
IN4>	1 - 2500	%IB	1	17	Operate residual current level for step 4 in % of IBase
t4	0.000 - 60.000	s	0.001	1.200	Independent (definite) time delay of step 4
k4	0.05 - 999.00	-	0.01	0.05	Time multiplier for the dependent time delay for step 4
IMin4	1 - 10000	%IB	1	17	Minimum operate current for step 4 in % of IBase
t4Min	0.000 - 60.000	s	0.001	0.000	Minimum operate time in inverse curves step 4
HarmRestrain4	Off On	-	-	On	Enable block of step 4 from harmonic restrain

Table 78: EF4PTOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.4.6 Monitored data

Table 79: EF4PTOC Monitored data

Name	Type	Values (Range)	Unit	Description
IOp	REAL	-	A	Operating current level
UPol	REAL	-	kV	Polarizing voltage level
IPol	REAL	-	A	Polarizing current level
UPOLIANG	REAL	-	deg	Angle between polarizing voltage and operating current
IPOLIANG	REAL	-	deg	Angle between polarizing current and operating current

5.4.7 Operation principle

This function has the following three “Analog Inputs” on its function block in the configuration tool:

1. I3P, input used for “Operating Quantity”.
2. U3P, input used for “Voltage Polarizing Quantity”.
3. I3PPOL, input used for “Current Polarizing Quantity”.

These inputs are connected from the corresponding pre-processing function blocks in the Configuration Tool within PCM600.

5.4.7.1 Operating quantity within the function

The function always uses Residual Current ($3I_0$) for its operating quantity. The residual current can be:

1. directly measured (when a dedicated CT input of the IED is connected in PCM600 tool to the fourth analog input of the pre-processing block connected to EF4PTOC (function input I3P). This dedicated IED CT input can be for example, connected to:
   - parallel connection of current instrument transformers in all three phases (Holm-Green connection).
   - one single core balance, current instrument transformer (cable CT).
   - one single current instrument transformer located between power system star point and earth(that is, current transformer located in the star point of a star connected transformer winding).
   - one single current instrument transformer located between two parts of a protected object (that is, current transformer located between two star points of double star shunt capacitor bank).
2. calculated from three-phase current input within the IED (when the fourth analog input into the pre-processing block connected to EF4PTOC function Analog Input I3P is not connected to a dedicated CT input of the IED in

PCM600 tool). In such case the pre-processing block will calculate $3I_0$ from the first three inputs into the pre-processing block by using the following formula:

$$Iop = 3I_0 = IL1 + IL2 + IL3$$

(Equation 35)

where:

IL1, IL2 and IL3	are fundamental frequency phasors of three individual phase currents.

The residual current is pre-processed by a discrete Fourier filter. Thus the phasor of the fundamental frequency component of the residual current is derived. The phasor magnitude is used within the EF4PTOC protection to compare it with the set operation current value of the four steps (*IN1>*, *IN2>*, *IN3>* or *IN4>*). If the residual current is larger than the set operation current and the step is used in non-directional mode a signal from the comparator for this step is set to true. This signal will, without delay, activate the output signal STINx (x=step 1-4) for this step and a common START signal.

5.4.7.2 Internal polarizing

A polarizing quantity is used within the protection in order to determine the direction to the earth-fault (Forward/Reverse).

The function can be set to use voltage polarizing, current polarizing or dual polarizing.

Voltage polarizing

When voltage polarizing is selected the protection will use the residual voltage $-3U_0$ as polarizing quantity U3P. This voltage can be:

1. directly measured (when a dedicated VT input of the IED is connected in PCM600 tool to the fourth analog input of the pre-processing block connected to EF4PTOC function input U3P). This dedicated IED VT input shall be then connected to open delta winding of a three phase main VT.
2. calculated from three phase voltage input within the IED (when the fourth analog input into the pre-processing block connected to EF4PTOC function analogue input U3P is NOT connected to a dedicated VT input of the IED in PCM600 tool). In such case the pre-processing block will calculate $-3U_0$ from the first three inputs into the pre-processing block by using the following formula:

$$UPol = -3U_0 = -(UL1 + UL2 + UL3)$$

(Equation 36)

where:

UL1, UL2 and UL3	are fundamental frequency phasors of three individual phase voltages.

Note! In order to use this all three phase-to-earth voltages must be connected to three IED VT inputs.

The residual voltage is pre-processed by a discrete fourier filter. Thus, the phasor of the fundamental frequency component of the residual voltage is derived. This phasor is used together with the phasor of the operating current, in order to determine the direction to the earth-fault (Forward/Reverse). In order to enable voltage polarizing the magnitude of polarizing voltage shall be bigger than a minimum level defined by setting parameter *UpolMin*.

It shall be noted that $-3U_0$ is used to determine the location of the earth-fault. This insures the required inversion of the polarizing voltage within the earth-fault function.

Current polarizing

When current polarizing is selected the function will use the residual current ($3I_0$) as polarizing quantity IPol. This current can be:

1. directly measured (when a dedicated CT input of the IED is connected in PCM600 tool to the fourth analog input of the pre-processing block connected to EF4PTOC function input I3PPOL). This dedicated IED CT input is then typically connected to one single current transformer located between power system star point and earth (current transformer located in the star point of a star connected transformer winding).
   - For some special line protection applications this dedicated IED CT input can be connected to parallel connection of current transformers in all three phases (Holm-Green connection)
2. calculated from three phase current input within the IED (when the fourth analog input into the pre-processing block connected to EF4PTOC function analog input I3PPOL is NOT connected to a dedicated CT input of the IED in PCM600 tool). In such case the pre-processing block will calculate $3I_0$ from the first three inputs into the pre-processing block by using the following formula:

$$IPol = 3I_0 = IL1 + IL2 + IL3$$

(Equation 37)

where:

IL1, IL2 and IL3 are fundamental frequency phasors of three individual phase currents.

The residual polarizing current is pre-processed by a discrete fourier filter. Thus the phasor of the fundamental frequency component of the residual current is derived. This phasor is then multiplied with pre-set equivalent zero sequence source Impedance in order to calculate equivalent polarizing voltage UIPol in accordance with the following formula:

$$UIPol = Z_{0s} \cdot IPol = (RNPol + j \cdot XNPol) \cdot IPol$$

(Equation 38)

which will be then used, together with the phasor of the operating current, in order to determine the direction to the earth-fault (Forward/Reverse). In order to enable current polarizing the magnitude of polarizing current shall be bigger than a minimum level defined by setting parameter *IPolMin*.

Dual polarizing

When dual polarizing is selected the function will use the vectorial sum of the voltage based and current based polarizing in accordance with the following formula:

$$UTotPol = UUPol + UIPol = -3U_0 + Z_{0s} \cdot IPol = -3U_0 + (RNPol + jXNPol) \cdot IPol$$

(Equation 39)

Then the phasor of the total polarizing voltage UTotPol will be used, together with the phasor of the operating current, to determine the direction to the earth-fault (Forward/Reverse).

5.4.7.3 External polarizing for earth-fault function

The individual steps within the protection can be set as non-directional. When this setting is selected it is then possible via function binary input BLKSTx (where x indicates the relevant step within the protection) to provide external directional control (that is, torque control) by for example using one of the following functions if available in the IED:

1. Distance protection directional function.
2. Negative sequence based overcurrent function.

5.4.7.4 Base quantities within the protection

The base quantities are entered as global settings for all functions in the IED. Base current (*IBase*) shall be entered as rated phase current of the protected object in primary amperes. Base voltage (*UBase*) shall be entered as rated phase-to-phase voltage of the protected object in primary kV.

5.4.7.5 Internal earth-fault protection structure

The protection is internally divided into the following parts:

1. Four residual overcurrent steps.
2. Directional supervision element for residual overcurrent steps with integrated directional comparison step for communication based earth-fault protection schemes (permissive or blocking).
3. Second harmonic blocking element with additional feature for sealed-in blocking during switching of parallel transformers.

Each part is described separately in the following sections.

5.4.7.6 Four residual overcurrent steps

Each overcurrent step uses operating quantity Iop (residual current) as measuring quantity. Each of the four residual overcurrent step has the following built-in facilities:

- Operating mode can be set *Off*/*Non-directional*/*Forward*/*Reverse*. By this parameter setting the operating mode of the step is selected. It shall be noted that the directional decision (Forward/Reverse) is not made within residual overcurrent step itself. The direction of the fault is determined in common "directional supervision element".
- Residual current pickup value.
- Type of operating characteristic. By this parameter setting it is possible to select inverse or definitive time delay for step 1 and 4 separately. Step 2 and 3 are always definite time delayed. Most of the standard IEC and ANSI inverse characteristics are available. For the complete list of available inverse curves please refer to section 19.3 "Inverse time characteristics".
- Time delay related settings. By these parameter settings the properties like definite time delay and minimum operating time for inverse curves delay are defined.
- Supervision by second harmonic blocking feature (On/Off). By this parameter setting it is possible to prevent operation of the step if the second harmonic content in the residual current exceeds the preset level.

Simplified logic diagram for one residual overcurrent step is shown in following figure 87:

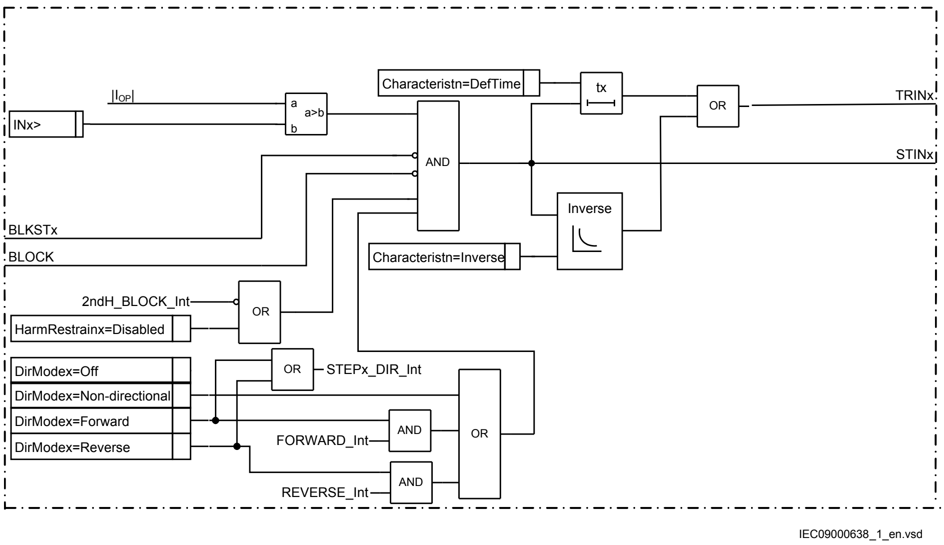


Figure 87: Simplified logic diagram for residual overcurrent, where x= step 1, 2, 3 or 4 n= step 1 and 4

The protection can be completely blocked from the binary input BLOCK. Output signals for respective step, STINx and TRINx, can be blocked from the binary input BLKSTx.

5.4.7.7 Directional supervision element with integrated directional comparison function

It shall be noted that at least one of the four residual overcurrent steps shall be set as directional in order to enable execution of the directional supervision element and the integrated directional comparison function.

The protection has integrated directional feature. As the operating quantity current Iop is always used. The polarizing method is determined by the parameter setting *polMethod*. The polarizing quantity will be selected by the function in one of the following three ways:

1. When *polMethod=Voltage*, UVPol will be used as polarizing quantity.
2. When *polMethod=Current*, UIpol will be used as polarizing quantity.
3. When *polMethod=Dual*, UTotPol will be used as polarizing quantity.

The operating and polarizing quantity are then used inside the directional element, as shown in figure 88, in order to determine the direction of the earth-fault.

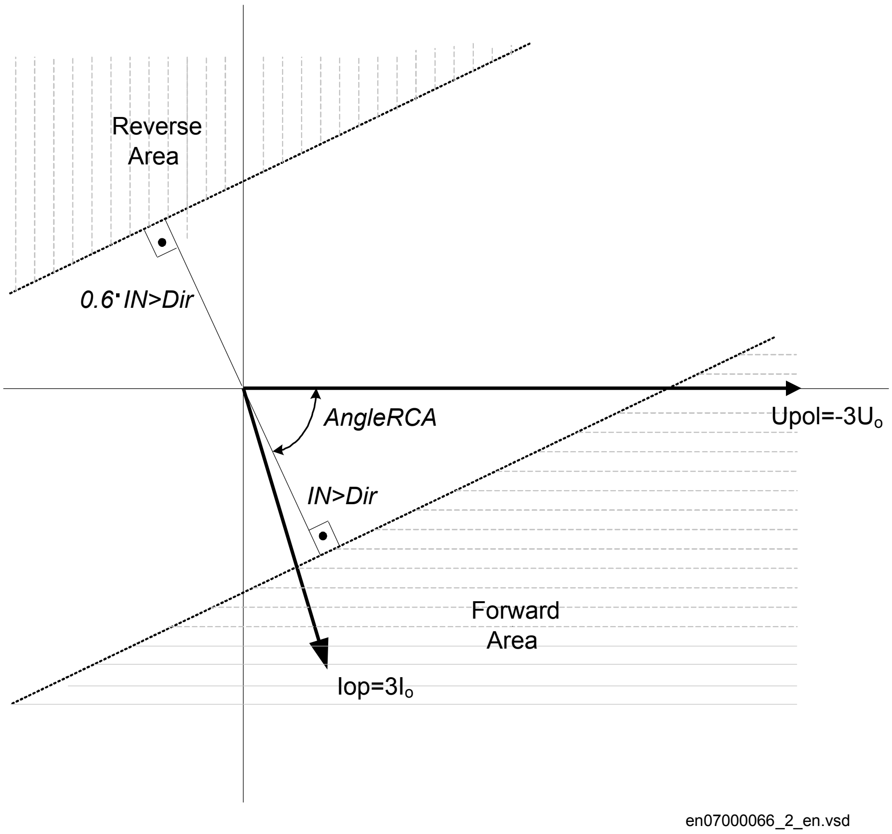


Figure 88: Operating characteristic for earth-fault directional element

Two relevant setting parameters for directional supervision element are:

- Operating current pickup *IN>Dir*. However it shall be noted that the directional element will be internally enabled to operate as soon as Iop cos(φ - *AngleRCA*) is bigger than 40% of *IN>Dir*.
- Relay characteristic angle *AngleRCA* which defines the position of forward and reverse areas in the operating characteristic.

Directional comparison step, built-in within directional supervision element, will set EF4PTOC function output binary signals:

1. STFW=1 when operating quantity magnitude is bigger than setting parameter *IN>Dir* and directional supervision element detects fault in forward direction.
2. STRV=1 when operating quantity magnitude is bigger than 60% of setting parameter *IN>Dir* and directional supervision element detects fault in reverse direction.

These signals shall be used for communication based earth-fault teleprotection communication schemes (permissive or blocking).

Simplified logic diagram for directional supervision element with integrated directional comparison step is shown in figure 89:

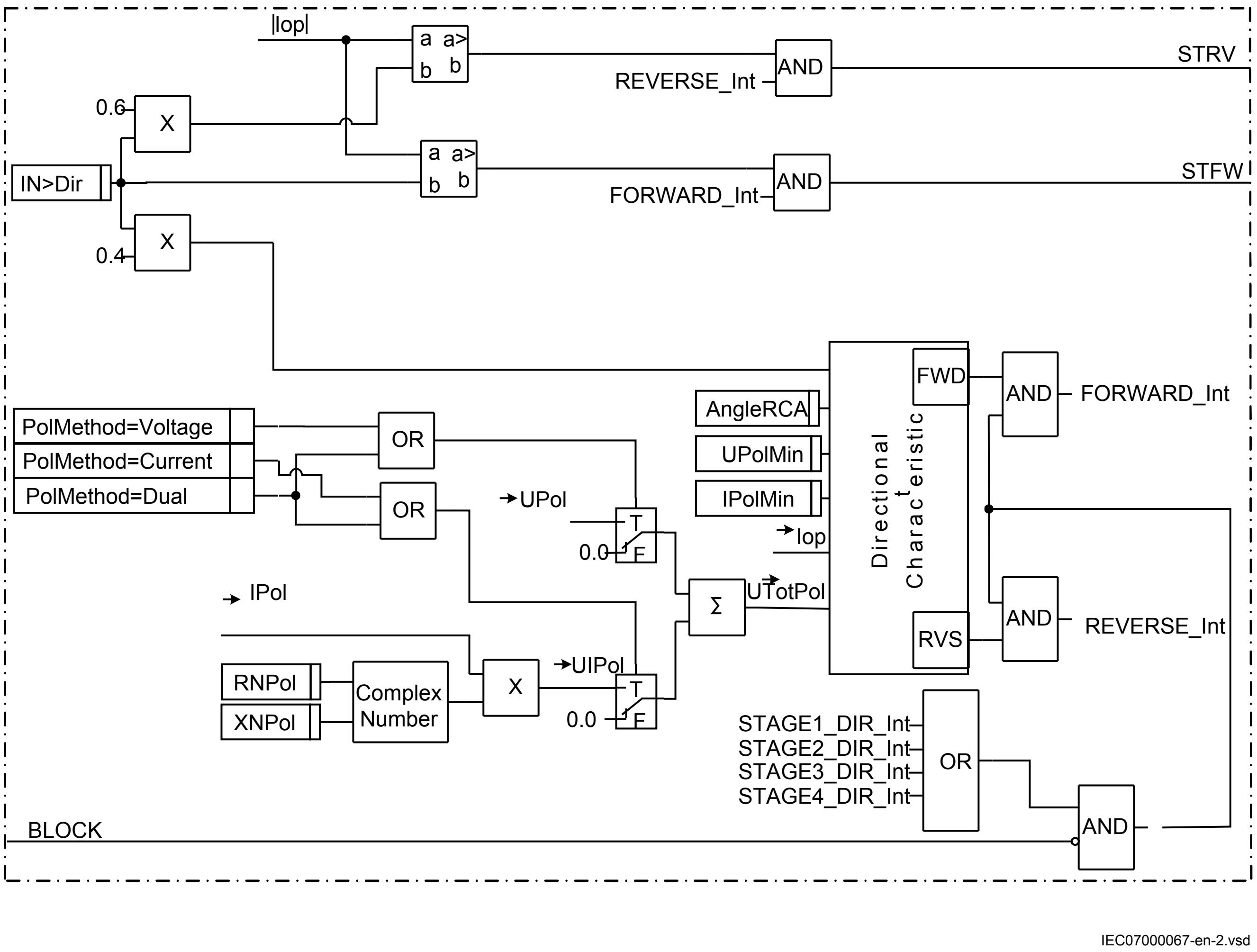


Figure 89: Simplified logic diagram for directional supervision element with integrated directional comparison step

5.4.8 Technical data

Table 80: EF4PTOC Technical data

Function	Range or value	Accuracy
Operate current	(1-2500)% of IBase	± 1.0% of I_r at I ≤ I_r ± 1.0% of I at I > I_r
Reset ratio	> 95%	-
Operate current for directional comparison	(1–100)% of IBase	± 1.0% of I_r
Timers	(0.000-60.000) s	± 0.5% ± 10 ms
Inverse characteristics, see table 493, table 494 and table 495	17 curve types	See table 493, table 494 and table 495
Table continues on next page		

Function	Range or value	Accuracy
Second harmonic restrain operation	(5–100)% of fundamental	± 2.0% of I_r
Relay characteristic angle	(-180 to 180) degrees	± 2.0 degrees
Minimum polarizing voltage	(1–100)% of UBase	± 0.5% of U_r
Minimum polarizing current	(2-100)% of IBase	±1.0% of I_r
Real part of source Z used for current polarization	(0.50-1000.00) Ω/phase	-
Imaginary part of source Z used for current polarization	(0.50–3000.00) Ω/phase	-
Operate time, start function	30 ms typically at 0.5 to 2 x Iset	-
Reset time, start function	30 ms typically at 2 to x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Impulse margin time	15 ms typically	-

5.5 Sensitive directional residual overcurrent and power protection SDEPSDE

5.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Sensitive directional residual over current and power protection	SDEPSDE	-	67N

5.5.2 Functionality

In isolated networks or in networks with high impedance earthing, the earth fault current is significantly smaller than the short circuit currents. In addition to this, the magnitude of the fault current is almost independent on the fault location in the network. The protection can be selected to use either the residual current or residual power component $3U_0 \cdot 3I_0 \cdot \cos \varphi$, for operating quantity. There is also available one non-directional $3I_0$ step and one non-directional $3U_0$ overvoltage tripping step.

5.5.3 Function block

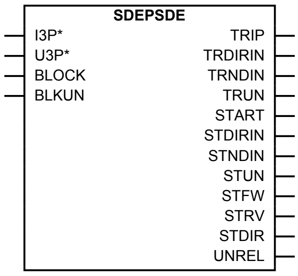


Figure 90: SDEPSDE function block

5.5.4 Signals

Table 81: SDEPSDE Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	‘Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKUN	BOOLEAN	0	Blocks the non-directional voltage residual outputs

Table 82: SDEPSDE Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TRDIRIN	BOOLEAN	Trip of the directional residual overcurrent
TRNDIN	BOOLEAN	Trip of non-directional residual overcurrent
TRUN	BOOLEAN	Trip of non-directional residual overvoltage
START	BOOLEAN	General start signal
STDIRIN	BOOLEAN	Start of the directional residual overcurrent function
STNDIN	BOOLEAN	Start of non directional residual overcurrent
STUN	BOOLEAN	Start of non directional residual overvoltage
STFW	BOOLEAN	Start of directional function for fault in forward direction
STRV	BOOLEAN	Start of directional function for fault in reverse direction
STDIR	INTEGER	Direction of fault
UNREL	BOOLEAN	Residual voltage release of operation of directional modes

5.5.5 Settings

Table 83: SDEPSDE Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
OpMode	3I0Cosfi 3I03U0Cosfi 3I0 and fi	-	-	3I0Cosfi	Selection of operation mode for protection
DirMode	Forward Reverse	-	-	Forward	Direction of operation forward or reverse
RCADir	-179 - 180	Deg	1	-90	Relay characteristic angle RCA
RCAComp	-10.0 - 10.0	Deg	0.1	0.0	Relay characteristic angle compensation
ROADir	0 - 90	Deg	1	90	Relay open angle ROA used as release in phase mode
INCosPhi>	0.25 - 200.00	%IB	0.01	1.00	Set level for 3I0cosPhi, directional residual overcurrent, in % of IBase
SN>	0.25 - 200.00	%SB	0.01	10.00	Set level for 3I0U0cosPhi, starting inverse time count, in % of SBase
INDir>	0.25 - 200.00	%IB	0.01	5.00	Set level for directional residual overcurrent protection, in % of IBase
tDef	0.000 - 60.000	s	0.001	0.100	Definite time delay directional residual overcurrent
SRef	0.03 - 200.00	%SB	0.01	10.00	Reference value of residual power for inverse time count, in % of SBase
kSN	0.00 - 2.00	-	0.01	0.10	Time multiplier setting for directional residual power mode
OpINNonDir>	Off On	-	-	Off	Operation of non-directional residual overcurrent protection
INNonDir>	1.00 - 400.00	%IB	0.01	10.00	Set level for non-directional residual overcurrent, in % of IBase
tINNonDir	0.000 - 60.000	s	0.001	1.000	Time delay for non-directional residual overcurrent
TimeChar	ANSI Ext. inv. ANSI Very inv. ANSI Norm. inv. ANSI Mod. inv. ANSI Def. Time L.T.E. inv. L.T.V. inv. L.T. inv. IEC Norm. inv. IEC Very inv. IEC inv. IEC Ext. inv. IEC S.T. inv. IEC L.T. inv. IEC Def. Time Reserved RI type RD type	-	-	IEC Norm. inv.	Operation curve selection for IDMT operation
tMin	0.000 - 60.000	s	0.001	0.040	Minimum operate time for IEC IDMT curves

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
kIN	0.00 - 2.00	-	0.01	1.00	IDMT time multiplier for non-directional residual overcurrent
OpUN>	Off On	-	-	Off	Operation of non-directional residual overvoltage
UN>	1.00 - 300.00	%UB	0.01	20.00	Set level for non-dir residual voltage, % of UBase
tUN	0.000 - 60.000	s	0.001	0.100	Time delay for non-directional residual overvoltage
INRel>	0.25 - 200.00	%IB	0.01	1.00	Residual release current for all directional modes, in % of IBase
UNRel>	1.00 - 300.00	%UB	0.01	3.00	Residual release volt for all dir modes, % of UBase

Table 84: SDEPSDE Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

5.5.6 Monitored data

Table 85: SDEPSDE Monitored data

Name	Type	Values (Range)	Unit	Description
INCOSPHI	REAL	-	A	Mag of residual current along polarizing qty 3I0cos(Fi-RCA)
IN	REAL	-	A	Measured magnitude of the residual current 3I0
UN	REAL	-	kV	Measured magnitude of the residual voltage 3U0
SN	REAL	-	MVA	Measured magnitude of residual power 3I03U0cos(Fi-RCA)
ANG FI-RCA	REAL	-	deg	Angle between 3U0 and 3I0 minus RCA (Fi-RCA)

5.5.7 Operation principle

5.5.7.1 Function inputs

The function is using phasors of the residual current and voltage. Group signals I3P and U3P containing phasors of residual current and voltage is taken from pre-processor blocks.

The sensitive directional earth fault protection has the following sub-functions included:

5.5.7.2 Directional residual current protection measuring $3I_0 \cdot \cos \varphi$

φ is defined as the angle between the residual current $3I_0$ and the reference voltage compensated with the set characteristic angle *RCADir* (φ=ang($3I_0$)-ang(U_{ref})). Uref = $-3U_0\ e^{jRCADIr}$. *RCADir* is normally set equal to 0 in a high impedance earthed network with a neutral point resistor as the active current component is appearing out on the faulted feeder only. *RCADir* is set equal to -90° in an isolated network as all currents are mainly capacitive. The function operates when $3I_0 \cdot \cos \varphi$ gets larger than the set value.

,

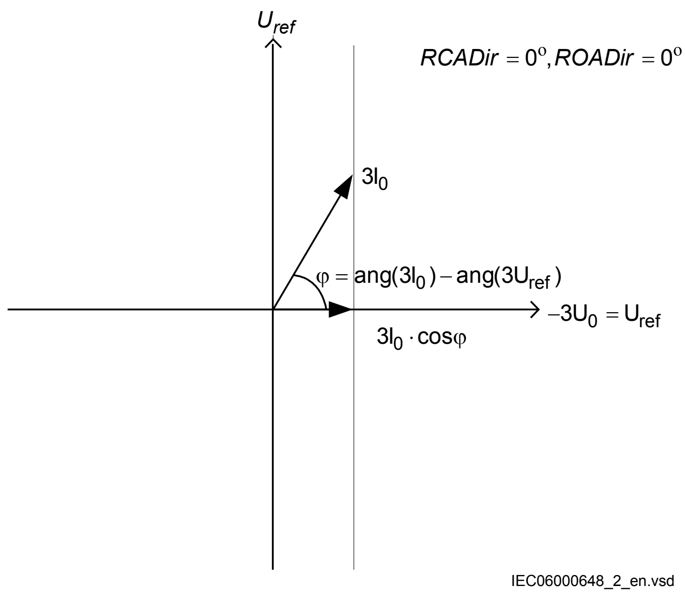


Figure 91: RCADIr set to 0°

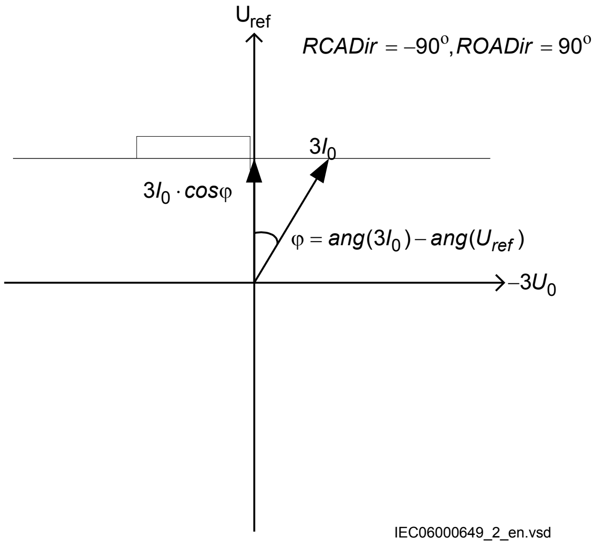


Figure 92: RCADIr set to -90°

For trip, both the residual current $3I_0 \cdot \cos \varphi$ and the release voltage $3U_0$, shall be larger than the set levels: *INCosPhi>* and *UNRel>*.

When the function is activated binary output signals START and STDIRIN are activated. If the activation is active after the set delay *tDef* the binary output signals TRIP and TRDIRIN are activated. The trip from this sub-function has definite time delay.

There is a possibility to increase the operate level for currents where the angle φ is larger than a set value as shown in the figure below. This is equivalent to blocking of the function if φ > *ROADir*. This option is used to handle angle error for the instrument transformers.

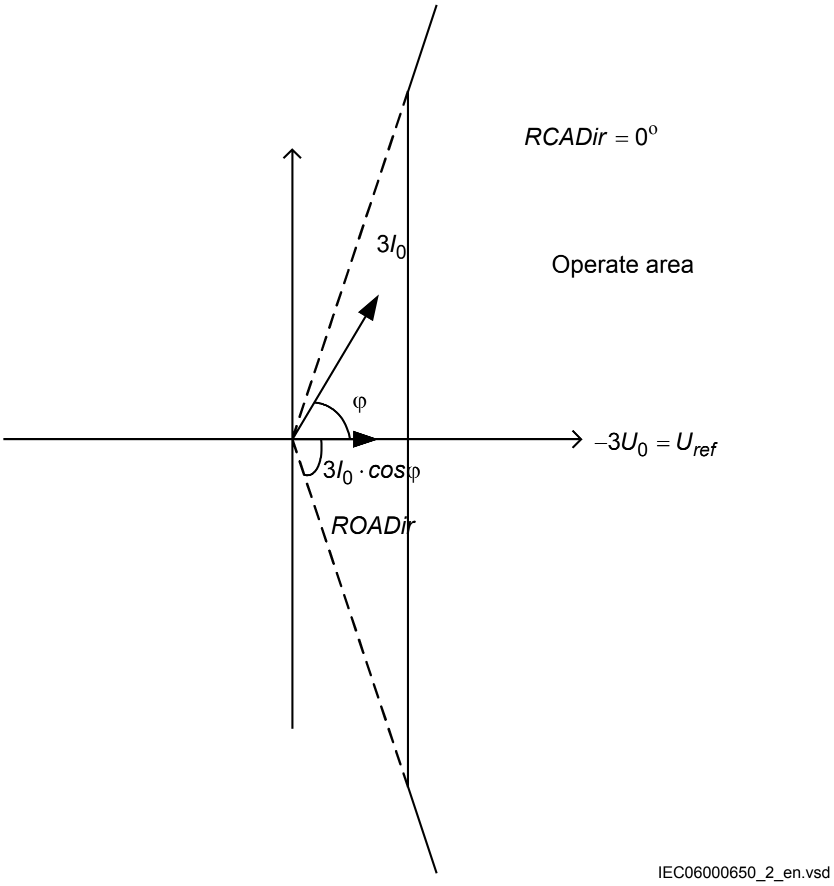


Figure 93: Characteristic with ROADir restriction

The function will indicate forward/reverse direction to the fault. Reverse direction is defined as $3I_0 \cdot \cos(\varphi + 180°) \geq$ the set value.

It shall also be possible to tilt the characteristic to compensate for current transformer angle error with a setting *RCAComp* as shown in the figure below:

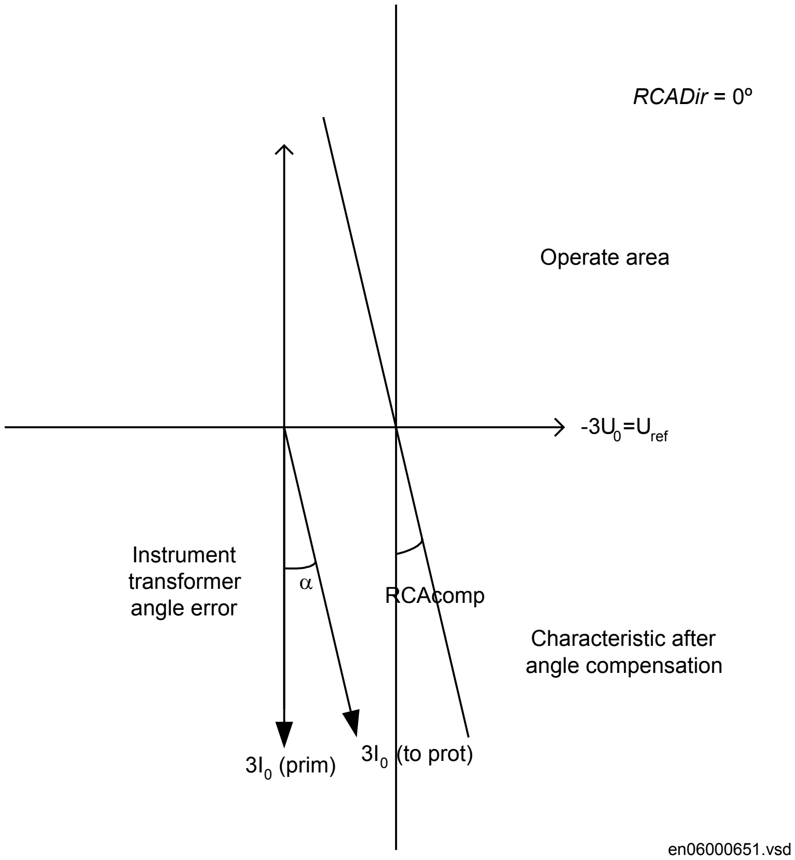


Figure 94: Explanation of RCAcomp.

5.5.7.3 Directional residual power protection measuring $3I_0 \cdot 3U_0 \cdot \cos \varphi$

φ is defined as the angle between the residual current $3I_0$ and the reference voltage compensated with the set characteristic angle *RCADir* (φ=ang($3I_0$)—ang(U_{ref})). $U_{ref} = -3U_0\ e^{jRCA}$. The function operates when $3I_0 \cdot 3U_0 \cdot \cos \varphi$ gets larger than the set value.

For trip, both the residual power $3I_0 \cdot 3U_0 \cdot \cos \varphi$, the residual current $3I_0$ and the release voltage $3U_0$, shall be larger than the set levels (*SN*>, *INRel*> and *UNRel*>).

When the function is activated binary output signals START and STDIRIN are activated. If the activation is active after the set delay *tDef* or after the inverse time delay (setting *kSN*) the binary output signals TRIP and TRDIRIN are activated.

The function shall indicate forward/reverse direction to the fault. Reverse direction is defined as $3I_0 \cdot 3U_0 \cdot \cos (\varphi + 180°) \geq$ the set value.

This variant has the possibility of choice between definite time delay and inverse time delay.

The inverse time delay is defined as:

$$t_{inv} = \frac{kSN \cdot (3I_0 \cdot 3U_0 \cdot \cos\varphi(\text{reference}))}{3I_0 \cdot 3U_0 \cdot \cos\varphi(\text{measured})}$$

(Equation 40)

5.5.7.4 Directional residual current protection measuring $3I_0$ and φ

The function will operate if the residual current is larger that the set value and the angle φ = ang($3I_0$)-ang(U_{ref}) is within the sector *RCADir* ± *ROADir*

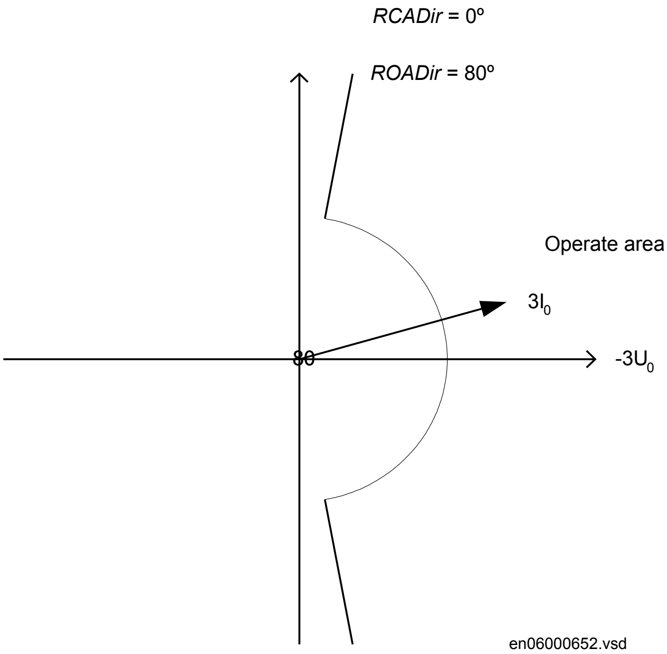


Figure 95: Example of characteristic

For trip, both the residual current $3I_0$ and the release voltage $3U_0$, shall be larger than the set levels *INDir>* and *UNREL>* and the angle φ shall be in the set sector *ROADir* and *RCADir*.

When the function is activated binary output signals START and STDIRIN are activated. If the activation is active after the set delay *tDef* the binary output signals TRIP and TRDIRIN are activated.

The function indicate forward/reverse direction to the fault. Reverse direction is defined as φ is within the angle sector: *RCADir* + 180° ± *ROADir*

This variant shall have definite time delay.

5.5.7.5 Directional functions

For all the directional functions there are directional start signals STFW: fault in the forward direction, and STRV: start in the reverse direction. Even if the directional function is set to operate for faults in the forward direction a fault in the reverse direction will give the start signal STRV. Also if the directional function is set to operate for faults in the reverse direction a fault in the forward direction will give the start signal STFW.

5.5.7.6 Non-directional earth fault current protection

This function will measure the residual current without checking the phase angle. The function will be used to detect cross-country faults. This function can serve as alternative or back-up to distance protection with phase preference logic.

If available the non-directional function is using the calculated residual current, derived as sum of the phase currents. This will give a better ability to detect cross-country faults with high residual current, also when dedicated core balance CT for the sensitive earth fault protection will saturate.

This variant shall have the possibility of choice between definite time delay and inverse time delay. The inverse time delay shall be according to IEC 60255-3.

For trip, the residual current $3I_0$ shall be larger than the set levels (*INNonDir>*).

When the function is activated binary output signal STNDIN is activated. If the activation is active after the set delay *tINNonDir* or after the inverse time delay the binary output signals TRIP and TRNDIN are activated.

5.5.7.7 Residual overvoltage release and protection

The directional function shall be released when the residual voltage gets higher than a set level.

There shall also be a separate trip, with its own definite time delay, from this set voltage level.

For trip, the residual voltage $3U_0$ shall be larger than the set levels (*UN>*).

Trip from this function can be blocked from the binary input BLKUN.

When the function is activated binary output signal STUN is activated. If the activation is active after the set delay *tUNNonDir* TRIP and TRUN are activated. A simplified logical diagram of the total function is shown in figure 96.

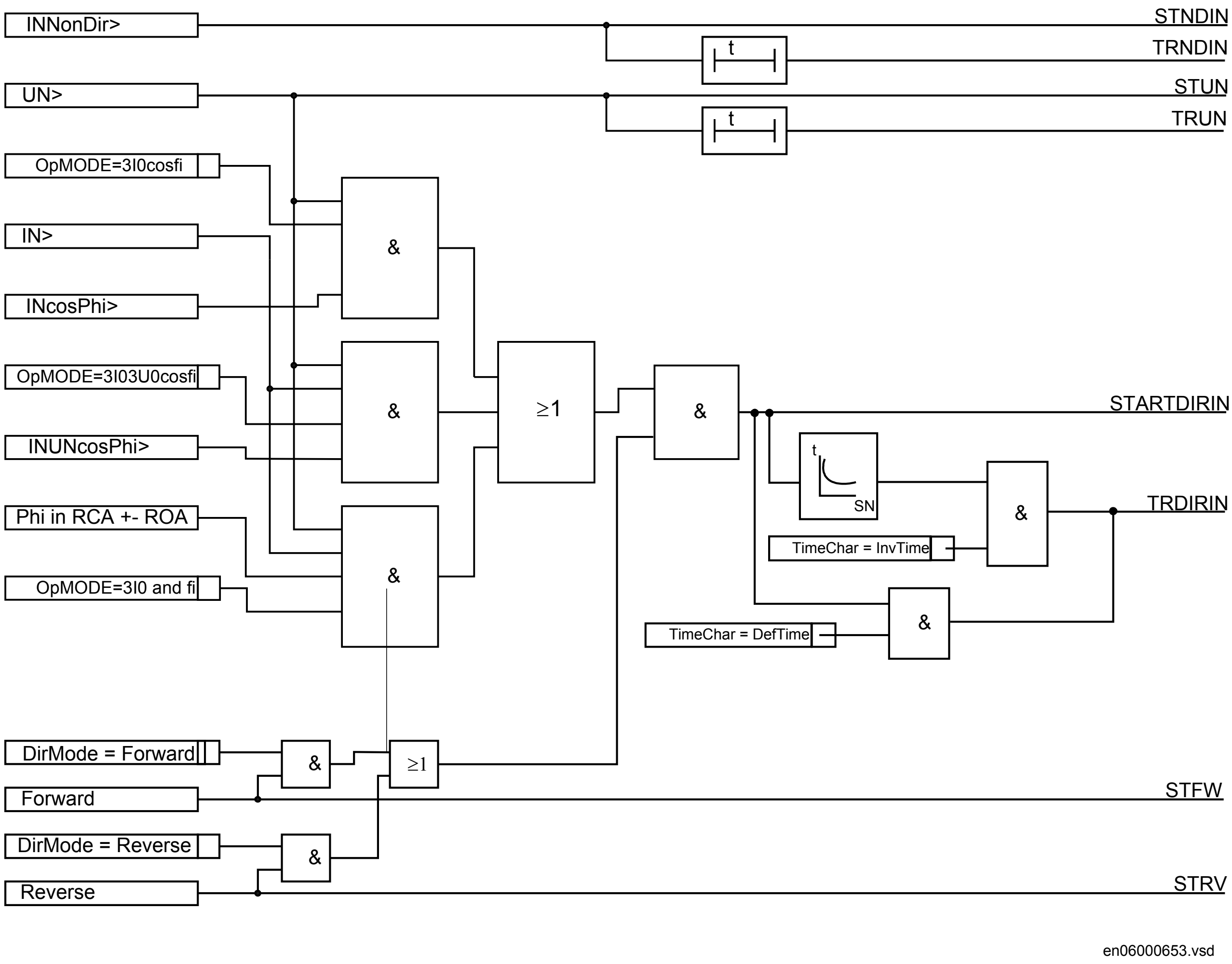


Figure 96: Simplified logical diagram of the sensitive earth-fault current protection

5.5.8 Technical data

Table 86: SDEPSDE Technical data

Function	Range or value	Accuracy
Operate level for $3I_0 \cdot \cos\varphi$ directional residual overcurrent	(0.25-200.00)% of IBase At low setting: (2.5-10) mA (10-50) mA	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$ ±0.5 mA ±1.0 mA
Operate level for $3I_0 \cdot 3U_0 \cdot \cos\varphi$ directional residual power	(0.25-200.00)% of SBase At low setting: (0.25-5.00)% of SBase	± 1.0% of S_r at $S \leq S_r$ ± 1.0% of S at $S > S_r$ ± 10% of set value
Operate level for $3I_0$ and φ residual overcurrent	(0.25-200.00)% of IBase At low setting: (2.5-10) mA (10-50) mA	± 1.0% of I_r at $\leq I_r$ ± 1.0% of I at $I > I_r$ ±0.5 mA ±1.0 mA
Operate level for non directional overcurrent	(1.00-400.00)% of IBase At low setting: (10-50) mA	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$ ± 1.0 mA
Operate level for non directional residual overvoltage	(1.00-200.00)% of UBase	± 0.5% of U_r at $U \leq U_r$ ± 0.5% of U at $U > U_r$
Residual release current for all directional modes	(0.25-200.00)% of IBase At low setting: (2.5-10) mA (10-50) mA	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$ ±0.5 mA ± 1.0 mA
Residual release voltage for all directional modes	(1.00 - 300.00)% of UBase	± 0.5% of U_r at $U \leq U_r$ ± 0.5% of U at $> U_r$
Reset ratio	> 95%	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms
Inverse characteristics, see table 493, table 494 and table 495	17 curve types	See table 493, table 494 and table 495
Relay characteristic angle RCA	(-179 to 180) degrees	± 2.0 degrees
Relay open angle ROA	(0-90) degrees	± 2.0 degrees
Operate time, non directional residual over current	35 ms typically at 0.5 to 2 $\cdot I_{set}$	-
Reset time, non directinal residual over current	40 ms typically at 1.2 to 0 $\cdot I_{set}$	-
Operate time, nondirectional residual overvoltage	150 ms typically at 0.8 to 1.5 $\cdot U_{set}$	-
Reset time, nondirectional residual overvoltage	60 ms typically at 1.2 to 0.8 $\cdot U_{set}$	-

5.6 Time delayed 2-step undercurrent protection UC2PTUC

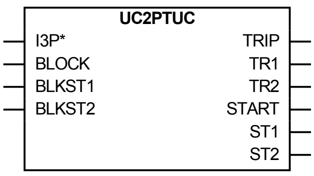
5.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time delayed 2-step undercurrent protection	UC2PTUC	2I<	37

5.6.2 Functionality

Time delayed 2-step undercurrent protection (UC2PTUC) function is used to supervise the line for low current, for example, to detect a loss-of-load condition, which results in a current lower than the normal load current.

5.6.3 Function block



IEC09000124-1-en.vsd

Figure 97: UC2PTUC function block

5.6.4 Signals

Table 87: UC2PTUC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current input
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1
BLKST2	BOOLEAN	0	Block of step 2

Table 88: UC2PTUC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TR1	BOOLEAN	Operate signal for step 1
TR2	BOOLEAN	Operate signal for step 2
START	BOOLEAN	General start signal
ST1	BOOLEAN	Start of step 1
ST2	BOOLEAN	Start of step 2

5.6.5 Settings

Table 89: UC2PTUC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
I1Mode	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate for step 1
I1<	5.0 - 100.0	%IB	1.0	10.0	Current setting for step 1 in % of IBase
t1	0.000 - 60.000	s	0.001	5.000	Time delay for step 1
tReset1	0.000 - 60.000	s	0.001	0.000	Reset time delay for step 1
I2Mode	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate for step 2
I2<	5.0 - 100.0	%IB	1.0	30.0	Current setting for step 2 in % of IBase
t2	0.000 - 60.000	s	0.001	2.000	Time delay for step 2
tReset2	0.000 - 60.000	s	0.001	0.000	Reset time delay for step 2
tPulse	0.01 - 2.00	s	0.01	0.10	Operate pulse duration
IBlk	5.0 - 100.0	%IB	1.0	5.0	Current setting for blocking in % of IBase

Table 90: UC2PTUC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSelector	1 - 6	-	1	1	Selection of one of the Global Base Value groups

5.6.6 Operation principle

Time delayed 2-step undercurrent protection (UC2PTUC) function generates output signals START and TRIP. The 2-steps in the function are identical, hence, only step1 is explained below.

UC2PTUC function compares the magnitude of the measured current with a set current level, *I1<*. The undercurrent function operates and generates output signals, START and ST1, when the magnitude of the measured current is smaller than the set current level *I1<*.

The low current condition also starts a definite time delay, *t1*. The current measuring condition is based on a selected number of phases involved for operation according to setting parameter, *I1Mode*. When the low current condition continues for longer time than the set time *t1*, the UC2PTUC function generates trip signals, TRIP and TR1. The lengths of these signals are controlled by a pulse timer, *tPulse*. The START and TRIP output signals can be reset instantaneous or time delay with the time setting, *tReset1*.

An included blocking step is used to block UC2PTUC when the power is shut off. The blocking step operates when all three phase currents are below the set value of *IBlk*.

Step 2 is exactly designed as step 1. All corresponding output signals and settings of step 2 are suffixed with ‘2’.

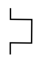
5.6.7 Technical data

Table 91: UC2PTUC Technical data

Function	Setting range	Accuracy
Low-set step of undercurrent limit, ILLow<	5.0-100.0% of Ibase in steps of 0.1%	± 2.5 % of I_r
High-set step of undercurrent limit, ILHigh<	5.0-100.0% of Ibase in steps of 0.1%	± 2.5 % of I_r
Time delayed operation of low-set step, tLow	0.000-60.000 s in steps of 1 ms	± 0.5 % ± 10 ms
Time delayed operation of high-set step, tHigh	0.000-60.000 s in steps of 1 ms	± 0.5 % ± 10 ms
Reset ratio	> 106% typically	

5.7 Thermal overload protection, one time constant LPTTR

5.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Thermal overload protection, one time constant	LPTTR		26

5.7.2 Functionality

The increasing utilizing of the power system closer to the thermal limits have generated a need of a thermal overload protection also for power lines.

A thermal overload will often not be detected by other protection functions and the introduction of the thermal overload protection can allow the protected circuit to operate closer to the thermal limits.

The three-phase current measuring protection has an I^2t characteristic with settable time constant and a thermal memory.

An alarm level gives early warning to allow operators to take action well before the line is tripped.

5.7.3 Function block

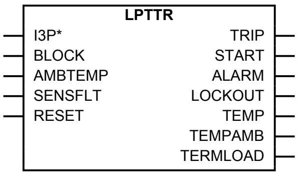


Figure 98: LPTTR function block

5.7.4 Signals

LPTTR has no input for external temperature sensor in first release of 650 series.

Table 92: LPTTR Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
AMBTEMP	REAL	0	Ambient temperature from external temperature sensor
SENSFLT	BOOLEAN	0	Validity status of ambient temperature sensor
RESET	BOOLEAN	0	Reset of internal thermal load counter

Table 93: LPTTR Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
START	BOOLEAN	General start signal
ALARM	BOOLEAN	Alarm signal
LOCKOUT	BOOLEAN	Lockout signal
TEMP	REAL	Calculated temperature of the device
TEMPAMB	REAL	Ambient temperature used in the calculations
TERMLOAD	REAL	Temperature relative to operate temperature

5.7.5 Settings

Table 94: LPTTR Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
TRef	0 - 600	Deg	1	90	End temperature rise above ambient of the line when loaded with IRef
IRef	0 - 400	%IB	1	100	Load current in % of IBase leading to TRef temperature
Tau	0 - 1000	Min	1	45	Time constant of the line
AlarmTemp	0 - 200	Deg	1	80	Temperature level for start (alarm)
TripTemp	0 - 600	Deg	1	90	Temperature level for trip
ReclTemp	0 - 600	Deg	1	75	Temperature for reset of lockout after trip
AmbiSens	Off On	-	-	Off	External temperature sensor available
DefaultAmbTemp	-50 - 250	Deg	1	20	Ambient temperature used when AmbiSens is set to Off
DefaultTemp	-50 - 600	Deg	1	50	Temperature raise above ambient temperature at startup

Table 95: LPTTR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.7.6 Monitored data

Table 96: LPTTR Monitored data

Name	Type	Values (Range)	Unit	Description
TTRIP	REAL	-	-	Estimated time to trip (in min)
TENRECL	REAL	-	-	Estimated time to reset of lockout (in min)
TEMP	REAL	-	-	Calculated temperature of the device
TEMPAMB	REAL	-	-	Ambient temperature used in the calculations

5.7.7 Operation principle

The sampled analog phase currents are pre-processed and for each phase current the RMS value is derived. These phase current values are fed to the Thermal overload protection, one time constant function (LPTTR).

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

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

(Equation 41)

where:

I	is the largest phase current,
I_{ref}	is a given reference current and
T_{ref}	is steady state temperature corresponding to I_{ref}

If this temperature is larger than the set operate temperature level, *TripTemp*, a START output signal is activated.

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 42)

where:

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

The calculated component temperature is available as a real figure signal, TEMP.

When the component temperature reaches the set alarm level *AlarmTemp* the output signal ALARM is set. When the component temperature reaches the set trip level *TripTemp* the output signal TRIP is set.

There is also a calculation of the present time to operate 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 43)

The calculated time to trip is available as a real figure signal, TTRIP.

After a trip, caused by the thermal overload protection, there can be a lockout to reconnect the tripped circuit. The output lockout signal LOCKOUT is activated when the device temperature is above the set lockout release temperature setting *ReclTemp*.

The time to lockout release is calculated that is, a calculation of the cooling time to a set value. The thermal content of the function can be reset with input RESET.

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

(Equation 44)

The calculated time to reset of lockout is available as a real figure signal, TENRECL.

The protection has a reset input: RESET. By activating this input the calculated temperature is reset to its default initial value. This is useful during testing when secondary injected current has given a calculated “false” temperature level.

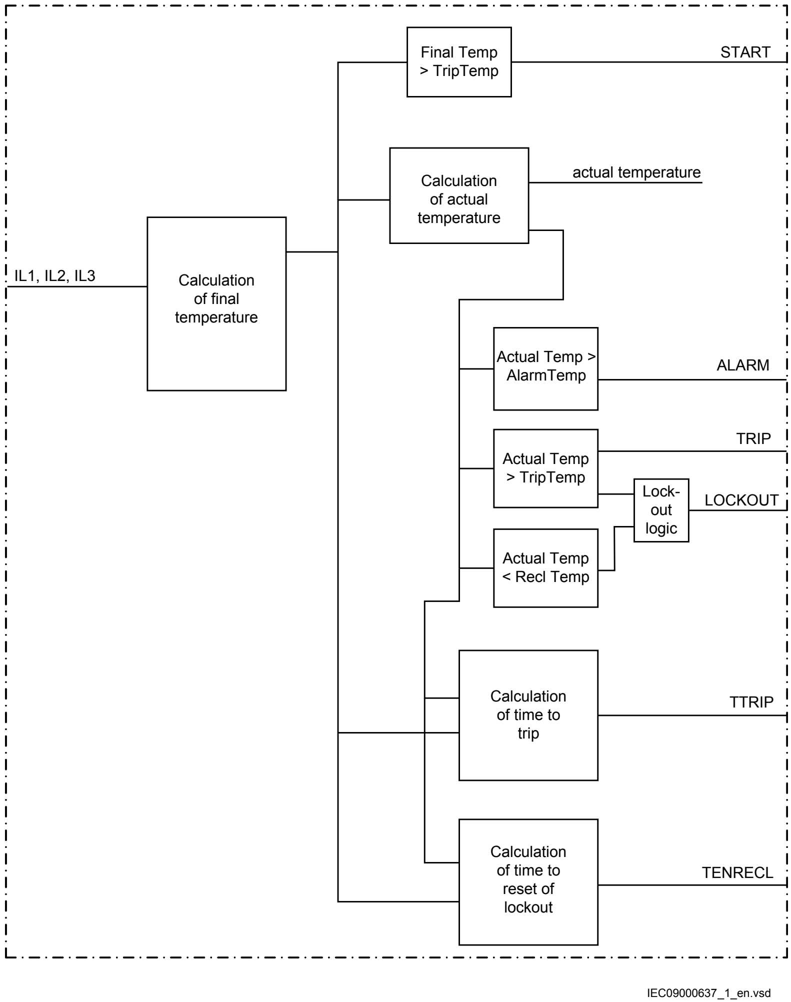


Figure 99: Functional overview of LPTTR

5.7.8 Technical data

Table 97: LPTTR Technical data

Function	Range or value	Accuracy
Reference current	(0-400)% of IBase	± 1.0% of I_r
Start temperature reference	(0-400)°C	± 1.0°C
Operate time: $$t = \tau \cdot \ln\left(\frac{I^2 - I_p{}^2}{I^2 - I_b{}^2}\right)$$ (Equation 45) I = actual measured current I_p = load current before overload occurs I_b = base current, IBase	Time constant τ = (0–1000) minutes	IEC 60255-8, class 5 + 200 ms
Alarm temperature	(0-200)°C	± 2.0% of heat content trip
Trip temperature	(0-600)°C	± 2.0% of heat content trip
Reset level temperature	(0-600)°C	± 2.0% of heat content trip

5.8 Breaker failure protection CCRBRF

5.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Breaker failure protection	CCRBRF	3I>BF	50BF

5.8.2 Functionality

Breaker failure protection (CCRBRF) function ensures fast back-up tripping of surrounding breakers in case of own breaker failure to open. CCRBRF can be current based, contact based, or adaptive combination between these two principles.

A current check with extremely short reset time is used as a check criteria to achieve a high security against unnecessary operation.

A contact check criteria can be used where the fault current through the breaker is small.

Breaker failure protection (CCRBRF) function current criteria can be fulfilled by one or two phase currents, or one phase current plus residual current. When those currents exceed the user defined settings, the function is activated. These conditions increase the security of the back-up trip command.

CCRBRF function can be programmed to give a three-phase re-trip of the own breaker to avoid unnecessary tripping of surrounding breakers at an incorrect initiation due to mistakes during testing.

5.8.3 Function block

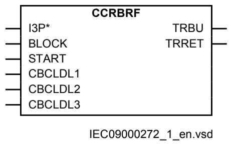


Figure 100: CCRBRF function block

5.8.4 Signals

Table 98: CCRBRF Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
START	BOOLEAN	0	Three phase start of breaker failure protection function
CBCLDL1	BOOLEAN	1	Circuit breaker closed in phase L1
CBCLDL2	BOOLEAN	1	Circuit breaker closed in phase L2
CBCLDL3	BOOLEAN	1	Circuit breaker closed in phase L3

Table 99: CCRBRF Output signals

Name	Type	Description
TRBU	BOOLEAN	Back-up trip by breaker failure protection function
TRRET	BOOLEAN	Retrip by breaker failure protection function

5.8.5 Settings

Table 100: CCRBRF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
FunctionMode	Current Contact Current&Contact	-	-	Current	Detection principle for back-up trip
BuTripMode	2 out of 4 1 out of 3 1 out of 4	-	-	1 out of 3	Back-up trip mode
RetripMode	Retrip Off CB Pos Check No CBPos Check	-	-	Retrip Off	Operation mode of re-trip logic
IP>	5 - 200	%IB	1	10	Operate phase current level in % of IBase
IN>	2 - 200	%IB	1	10	Operate residual current level in % of IBase
t1	0.000 - 60.000	s	0.001	0.000	Time delay of re-trip
t2	0.000 - 60.000	s	0.001	0.150	Time delay of back-up trip

Table 101: CCRBRF Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
I>BlkCont	5 - 200	%IB	1	20	Current for blocking of CB contact operation in % of IBase

Table 102: CCRBRF Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

5.8.6 Monitored data

Table 103: CCRBRF Monitored data

Name	Type	Values (Range)	Unit	Description
IL1	REAL	-	A	Measured current in phase L1
IL2	REAL	-	A	Measured current in phase L2
IL3	REAL	-	A	Measured current in phase L3
IN	REAL	-	A	Measured residual current

5.8.7 Operation principle

Breaker failure protection (CCRBRF) is initiated from protection trip command, either from protection functions within the IED or from external protection devices.

The start signal is general for all three phases. A re-trip attempt can be made after a set time delay. The re-trip function can be done with or without current or contact check. With the current check the re-trip is only performed if the current through the circuit breaker is larger than the operate current level. With contact check the re-trip is only performed if breaker is indicated as closed.

The start signal can be an internal or external protection trip signal. This signal will start the back-up trip timer. If the opening of the breaker is successful this is detected by the function, both by detection of low RMS current and by a special adapted algorithm. The special algorithm enables a very fast detection of successful breaker opening, that is, fast resetting of the current measurement. If the current detection has not detected breaker opening before the back-up timer has run its time a back-up trip is initiated.

Further the following possibilities are available:

- In the current detection it is possible to use three different options: *1 out of 3* where it is sufficient to detect failure to open (high current) in one pole, *1 out of 4* where it is sufficient to detect failure to open (high current) in one pole or high residual current and *2 out of 4* where at least two current (phase current and/or residual current) shall be high for breaker failure detection.
- The current detection level for the residual current can be set different from the setting of phase current detection.
- Back-up trip is always made with current or contact check.It is possible to have this option activated for small load currents only.

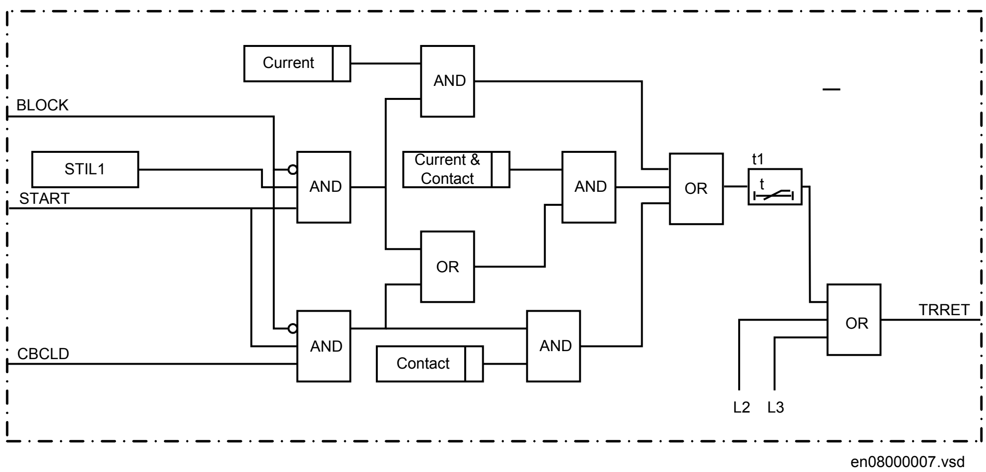


Figure 101: Simplified logic scheme of the retrip function

Internal logical signals STIL1, STIL2, STIL3 have logical value 1 when current in respective phase has magnitude larger than setting parameter *IP>*.

Internal logical signal STN has logical value 1 when neutral current has magnitude larger than setting parameter *IN>*.

5.8.8 Technical data

Table 104: CCRBRF Technical data

Function	Range or value	Accuracy
Operate phase current	(5-200)% of IBase	$\pm$ 1.0% of I_r at $I \leq I_r$ $\pm$ 1.0% of I at $I > I_r$
Reset ratio, phase current	> 95%	-
Operate residual current	(2-200)% of IBase	$\pm$ 1.0% of I_r at $I \leq I_r$ $\pm$ 1.0% of I at $I > I_r$
Reset ratio, residual current	> 95%	-
Phase current level for blocking of contact function	(5-200)% of IBase	$\pm$ 1.0% of I_r at $I \leq I_r$ $\pm$ 1.0% of I at $I > I_r$
Reset ratio	> 95%	-
Timers	(0.000-60.000) s	$\pm$ 0.5% $\pm$ 10 ms
Operate time for current detection	10 ms typically	-
Reset time for current detection	15 ms maximum	-

5.9 Stub protection STBPTOC

5.9.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Stub protection	STBPTOC	3I>STUB	50STB

5.9.2 Functionality

When a power line is taken out of service for maintenance and the line disconnector is opened the voltage transformers will mostly be outside on the disconnected part. The primary line distance protection will thus not be able to operate and must be blocked.

The stub protection covers the zone between the current transformers and the open disconnector. The three-phase instantaneous overcurrent function is released from a normally open, NO (b) auxiliary contact on the line disconnector.

5.9.3 Function block

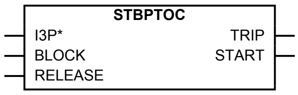


Figure 102: STBPTOC function block

5.9.4 Signals

Table 105: STBPTOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
RELEASE	BOOLEAN	0	Release of stub protection

Table 106: STBPTOC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
START	BOOLEAN	General start signal

5.9.5 Settings

Table 107: STBPTOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
I>	1 - 2500	%IB	1	200	Operate current level in % of IBase

Table 108: STBPTOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.9.6 Monitored data

Table 109: STBPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
IL1	REAL	-	A	Current in phase L1
IL2	REAL	-	A	Current in phase L2
IL3	REAL	-	A	Current in phase L3

5.9.7 Operation principle

The sampled analog phase currents are pre-processed in a discrete Fourier filter (DFT) block. From the fundamental frequency components of each phase current the RMS value of each phase current is derived. These phase current values are fed to a comparator in Stub protection (STBPTOC) function. In a comparator the RMS values are compared to the set operating current value of the function *I*>. If a phase current is larger than the set operating current the signal from the comparator for this phase is set to true and a TRIP signal is activated. The function can be blocked by activation of the BLOCK input.

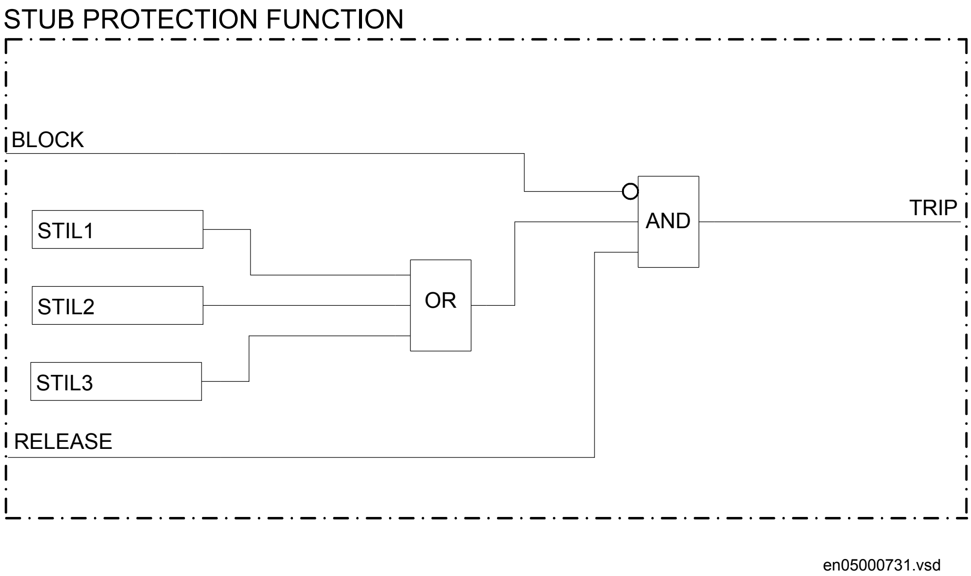


Figure 103: Simplified logic diagram for the stub protection

5.9.8 Technical data

Table 110: STBPTOC Technical data

Function	Range or value	Accuracy
Operating current	(1-2500)% of IBase	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$
Reset ratio	> 95%	-
Operating time	20 ms typically at 0 to 2 x I_{set}	-
Resetting time	25 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set}	-
Impulse margin time	15 ms typically	-

5.10 Pole discordance protection CCRPLD

5.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pole discordance protection	CCRPLD	PD	52PD

5.10.2 Functionality

Circuit breakers or disconnectors can due to electrical or mechanical failures end up with the different poles in different positions (close-open). This can cause negative and zero sequence currents which gives thermal stress on rotating machines and can cause unwanted operation of zero sequence or negative sequence current functions.

Normally the own breaker is tripped to correct such a situation. If the situation persists the surrounding breaker should be tripped to clear the unsymmetrical load situation.

The pole discordance function operates based on information from the circuit breaker logic with additional criteria from unsymmetrical phase current when required.

5.10.3 Function block

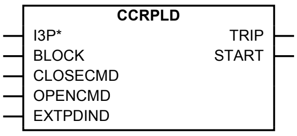


Figure 104: CCRPLD function block

5.10.4 Signals

Table 111: CCRPLD Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
CLOSECMD	BOOLEAN	0	Close order to CB
OPENCMD	BOOLEAN	0	Open order to CB
EXTPDIND	BOOLEAN	0	Pole discordance signal from CB logic

Table 112: CCRPLD Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip signal to CB
START	BOOLEAN	Trip condition TRUE, waiting for time delay

5.10.5 Settings

Table 113: CCRPLD Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
tTrip	0.000 - 60.000	s	0.001	0.300	Time delay between trip condition and trip signal
ContSel	Off PD signal from CB	-	-	Off	Contact function selection
CurrSel	Off CB oper monitor Continuous monitor	-	-	Off	Current function selection
CurrUnsymLevel	0 - 100	%	1	80	Unsym magn of lowest phase current compared to the highest.
CurrRelLevel	0 - 100	%IB	1	10	Current magnitude for release of the function in % of IBase

Table 114: CCRPLD Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.10.6 Monitored data

Table 115: CCRPLD Monitored data

Name	Type	Values (Range)	Unit	Description
IMin	REAL	-	A	Lowest phase current
IMax	REAL	-	A	Highest phase current

5.10.7 Operation principle

The detection of pole discordance can be made in two different ways. If the contact based function is used an external logic can be made by connecting the auxiliary contacts of the circuit breaker so that a pole discordance is indicated. This is shown in figure 105

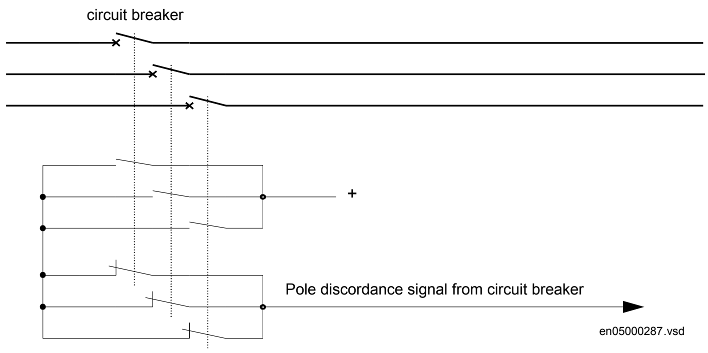


Figure 105: Pole discordance external detection logic

This binary signal is connected to a binary input of the IED. The appearance of this signal will start a timer that will give a trip signal after the set time delay.

Pole discordance can also be detected by means of phase selective current measurement. The sampled analogue phase currents are pre-processed in a discrete Fourier filter (DFT) block. From the fundamental frequency components of each phase current the RMS value of each phase current is derived. The difference between the smallest and the largest phase current is derived. If this difference is larger than the setting *CurrUnsymLevel* the setable trip timer (*tTrip*) is started. The *tTrip* timer gives a trip signal after the set delay. The TRIP signal is a pulse 150 ms long. The current based pole discordance function can be set to be active either continuously or only directly in connection to breaker open or close command.

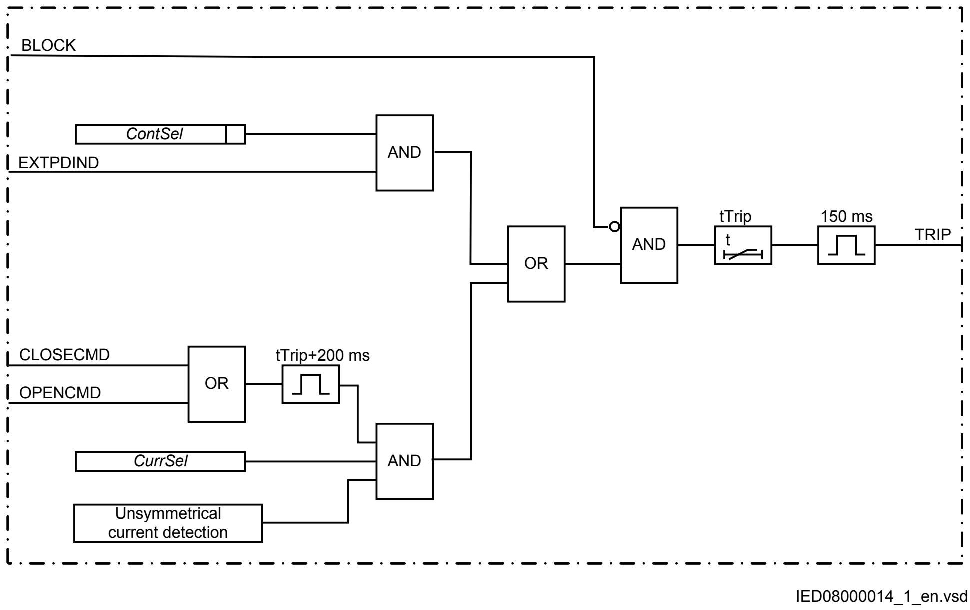


Figure 106: Simplified block diagram of pole discordance function - contact and current based

The pole discordance protection is blocked if the input signal BLOCK is high.

The BLOCK signal is a general purpose blocking signal of the pole discordance protection. It can be connected to a binary input of the IED in order to receive a block command from external devices or can be software connected to other internal functions of the IED itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

If the pole discordance protection is enabled, then two different criteria can generate a trip signal TRIP:

- Pole discordance signalling from the circuit breaker.
- Unsymmetrical current detection.

5.10.7.1 Pole discordance signalling from circuit breaker

If one or two poles of the circuit breaker have failed to open or to close (pole discordance status), then the function input EXTPDIND is activated from the pole discordance signal in figure 105.After a settable time *tTrip*, a 150 ms trip pulse command TRIP is generated by the pole discordance function.

5.10.7.2 Unsymmetrical current detection

Unsymmetrical current detection is based on:

- any phase current is lower than *CurrUnsymLevel* · the highest phase current.
- the highest phase current is greater than *CurrRelLevel* of the rated current.

If these conditions are true, an unsymmetrical condition is detected. This detection is enabled to generate a trip after a set time delay *tTrip* if the detection occurs in the next 200 ms after the circuit breaker has received a command to open trip or close and if the unbalance persists. The 200 ms limitation is for avoiding unwanted operation during unsymmetrical load conditions.

The pole discordance protection is informed that a trip or close command has been given to the circuit breaker through the inputs CLOSECMD (for closing command information) and OPENCMD (for opening command information). These inputs can be connected to terminal binary inputs if the information are generated from the field (that is from auxiliary contacts of the close and open push buttons) or may be software connected to the outputs of other integrated functions (that is close command from a control function or a general trip from integrated protections).

5.10.8 Technical data

Table 116: CCRPLD Technical data

Function	Range or value	Accuracy
Operate value, current unsymmetry level	(0-100) %	± 1.0% of I_r
Reset ratio	>95%	-
Operate current, current release level	(0–100)% of IBase	± 1.0% of I_r
Time delay	(0.000-60.000) s	± 0.5% ± 10 ms

5.11 Broken conductor check BRCPTOC

5.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Broken conductor check	BRCPTOC	-	46

5.11.2 Functionality

Conventional protection functions can not detect the broken conductor condition. Broken conductor check (BRCPTOC) function, consisting of continuous current unsymmetry check on the line where the IED is connected will give alarm or trip at detecting broken conductors.

5.11.3 Function block

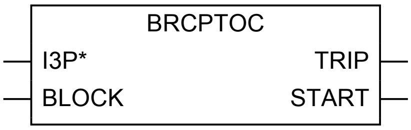


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Figure 107: BRCPTOC function block

5.11.4 Signals

Table 117: BRCPTOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function

Table 118: BRCPTOC Output signals

Name	Type	Description
TRIP	BOOLEAN	Operate signal of the protection logic
START	BOOLEAN	Start signal of the protection logic

5.11.5 Settings

Table 119: BRCPTOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
Iub>	50 - 90	%IM	1	50	Unbalance current operation value in percent of max current
IP>	5 - 100	%IB	1	20	Minimum phase current for operation of Iub> in % of Ibase
tOper	0.000 - 60.000	s	0.001	5.000	Operate time delay

Table 120: BRCPTOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

5.11.6 Monitored data

Table 121: BRCPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
IUNBAL	REAL	-	-	Measured unbalance of phase currents

5.11.7 Operation principle

Broken conductor check (BRCPTOC) detects a broken conductor condition by detecting the unsymmetry between currents in the three phases. The current-measuring elements continuously measure the three-phase currents.

The current unsymmetry signal output START is set on if :

- The difference in currents between the phase with the lowest current and the phase with the highest current is greater than set percentage *Iub>* of the highest phase current
- The highest phase current is greater than the minimum setting value *IP>*.
- The lowest phase current is below 50% of the minimum setting value *IP>*

The third condition is included to avoid problems in systems involving parallel lines. If a conductor breaks in one phase on one line, the parallel line will experience an increase in current in the same phase. This might result in the first two conditions being satisfied. If the unsymmetrical detection lasts for a period longer than the set time *tOper* the TRIP output is activated.

The simplified logic diagram of the broken conductor check function is shown in figure 108

BRCPTOC is disabled (blocked) if:

- The IED is in test mode and BRCPTOC has been blocked from the HMI test menu (*Blocked*=*Yes*).
- The input signal BLOCK is high.

The BLOCK input can be connected to a binary input of the IED in order to receive a block command from external devices, or can be software connected to other internal functions of the IED itself to receive a block command from internal functions.

The output trip signal TRIP is a three-phase trip. It can be used to command a trip to the circuit breaker or for alarm purpose only.

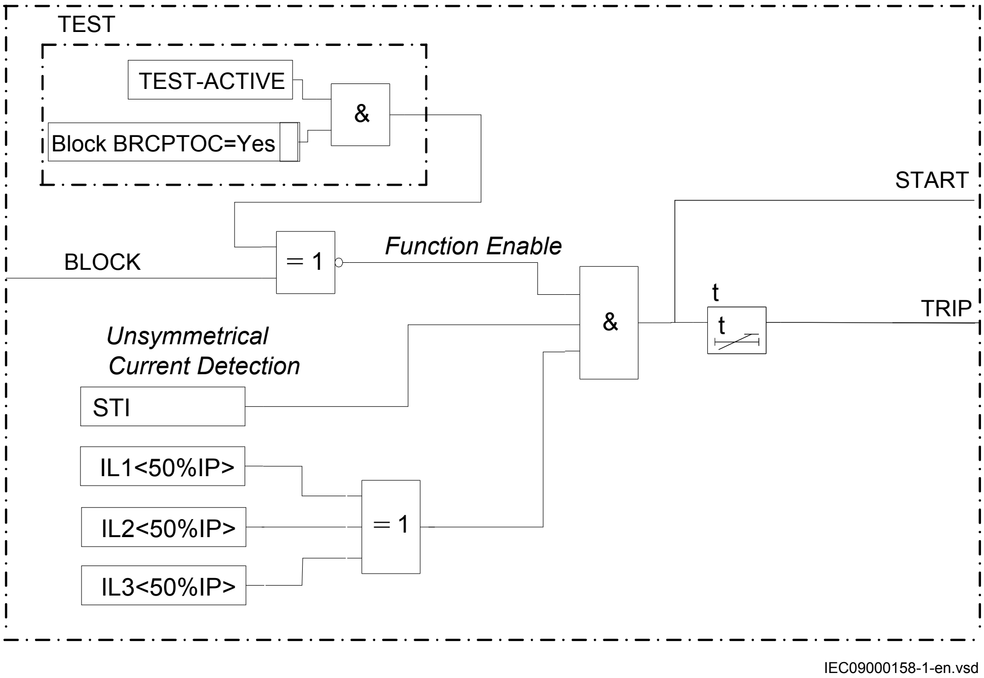

Figure 108: Simplified logic diagram for Broken conductor check (BRCPTOC)

5.11.8 Technical data

Table 122: BRCPTOC Technical data

Function	Range or value	Accuracy
Minimum phase current for operation	(5–100)% of IBase	± 1.0% of I_r
Unbalance current operation	(50-90)% of maximum current	± 1.0% of I_r
Timer	(0.00-6000.00) s	± 0.5% ± 10 ms
Operate time for start function	25 ms typically	-
Reset time for start function	15 ms typically	-
Critical impulse time	15 ms typically	-
Impulse margin time	10 ms typically	-

5.12 Directional over-/under-power protection GOPPDOP/GUPPDUP

5.12.1 Functionality

The directional over-/under-power protection (GOPPDOP/GUPPDUP) can be used wherever a high/low active, reactive or apparent power protection or alarming is required. The functions can alternatively be used to check the direction of active or reactive power flow in the power system. There are number of applications where such functionality is needed. Some of them are:

- detection of reversed active power flow
- detection of high reactive power flow

Each function has two steps with definite time delay. Reset times for every step can be set as well.

5.12.2 Directional over-power protection GOPPDOP

5.12.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional over-power protection	GOPPDOP	P > →	32

5.12.2.2 Function block

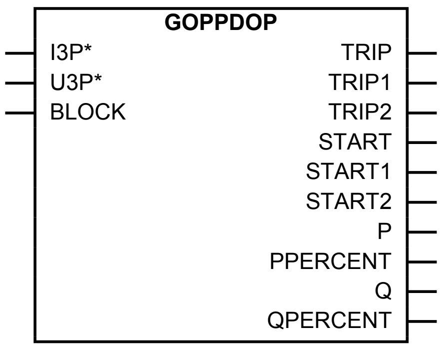

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Figure 109: GOPPDOP function block

5.12.2.3 Signals

Table 123: GOPPDOP Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function

Table 124: GOPPDOP Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TRIP1	BOOLEAN	Trip signal from stage 1
TRIP2	BOOLEAN	Trip signal from stage 2
START	BOOLEAN	General start signal
START1	BOOLEAN	Start signal from stage 1
START2	BOOLEAN	Start signal from stage 2
P	REAL	Active Power in MW
PPERCENT	REAL	Active power in % of SBase
Q	REAL	Reactive power in MVar
QPERCENT	REAL	Reactive power in % of Sbase

5.12.2.4 Settings

Table 125: GOPPDOP Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
OpMode1	Off OverPower	-	-	OverPower	Operation mode 1
Power1	0.0 - 500.0	%	0.1	1.0	Power setting for stage 1 in % of calculated power base value
Angle1	-180.0 - 180.0	Deg	0.1	0.0	Characteristic angle for stage 1
TripDelay1	0.010 - 6000.000	s	0.001	1.000	Trip delay for stage 1
OpMode2	Off OverPower	-	-	OverPower	Operation mode 2
Power2	0.0 - 500.0	%	0.1	1.0	Power setting for stage 2 in % of calculated power base value
Angle2	-180.0 - 180.0	Deg	0.1	0.0	Characteristic angle for stage 2
TripDelay2	0.010 - 6000.000	s	0.001	1.000	Trip delay for stage 2

Table 126: GOPPDOP Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
k	0.00 - 0.99	-	0.01	0.00	Low pass filter coefficient for power measurement, U and I

Table 127: GOPPDOP Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
Mode	L1, L2, L3 Arone Pos Seq L1L2 L2L3 L3L1 L1 L2 L3	-	-	Pos Seq	Mode of measurement for current and voltage

5.12.2.5 Monitored data

Table 128: GOPPDOP Monitored data

Name	Type	Values (Range)	Unit	Description
P	REAL	-	MW	Active Power
PPERCENT	REAL	-	%	Active power in % of calculated power base value
Q	REAL	-	MVAr	Reactive power
QPERCENT	REAL	-	%	Reactive power in % of calculated power base value

5.12.3 Directional under-power protection GUPPDUP

5.12.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Directional under-power protection	GUPPDUP	P < →	37

5.12.3.2 Function block

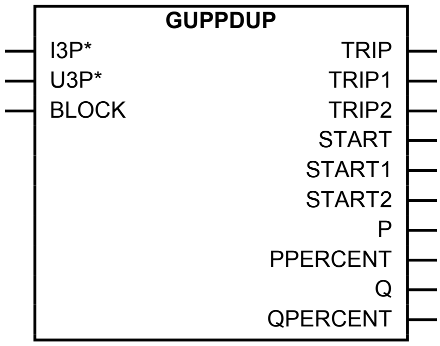

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Figure 110: GUPPDUP function block

5.12.3.3 Signals

Table 129: GUPPDUP Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function

Table 130: GUPPDUP Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TRIP1	BOOLEAN	Trip signal from stage 1
TRIP2	BOOLEAN	Trip signal from stage 2
START	BOOLEAN	General start signal
START1	BOOLEAN	Start signal from stage 1
START2	BOOLEAN	Start signal from stage 2
P	REAL	Active Power in MW
PPERCENT	REAL	Active power in % of SBase
Q	REAL	Reactive power in MVar
QPERCENT	REAL	Reactive power in % of SBase

5.12.3.4 Settings

Table 131: GUPPDUP Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
OpMode1	Off UnderPower	-	-	UnderPower	Operation mode 1
Power1	0.0 - 500.0	%	0.1	1.0	Power setting for stage 1 in % of calculated power base value
Angle1	-180.0 - 180.0	Deg	0.1	0.0	Characteristic angle for stage 1
TripDelay1	0.010 - 6000.000	s	0.001	1.000	Trip delay for stage 1
OpMode2	Off UnderPower	-	-	UnderPower	Operation mode 2
Power2	0.0 - 500.0	%	0.1	1.0	Power setting for stage 2 in % of calculated power base value
Angle2	-180.0 - 180.0	Deg	0.1	0.0	Characteristic angle for stage 2
TripDelay2	0.010 - 6000.000	s	0.001	1.000	Trip delay for stage 2

Table 132: GUPPDUP Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
k	0.00 - 0.99	-	0.01	0.00	Low pass filter coefficient for power measurement, U and I

Table 133: GUPPDUP Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
Mode	L1, L2, L3 Arone Pos Seq L1L2 L2L3 L3L1 L1 L2 L3	-	-	Pos Seq	Mode of measurement for current and voltage

5.12.3.5 Monitored data

Table 134: GUPPDUP Monitored data

Name	Type	Values (Range)	Unit	Description
P	REAL	-	MW	Active Power
PPERCENT	REAL	-	%	Active power in % of calculated power base value
Q	REAL	-	MVAr	Reactive power
QPERCENT	REAL	-	%	Reactive power in % of calculated power base value

5.12.4 Operation principle

A simplified scheme showing the principle of the power protection function is shown in figure 111. The function has two stages with individual settings.

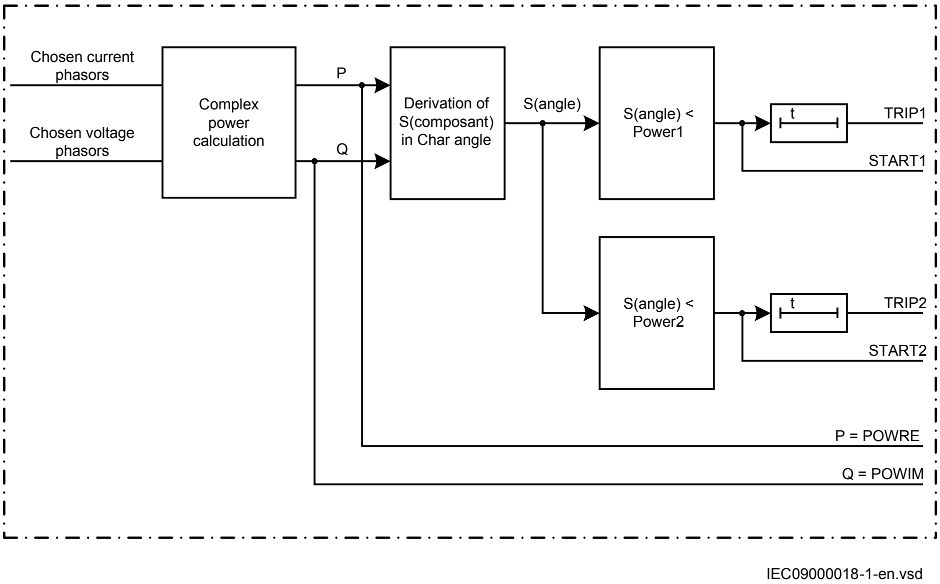

Figure 111: Simplified logic diagram of the power protection function

The function will use voltage and current phasors calculated in the pre-processing blocks. The apparent complex power is calculated according to chosen formula as shown in table 135.

Table 135: Complex power calculation

Set value: *Mode*	Formula used for complex power calculation
L1, L2, L3	$\bar{S} = \bar{U}_{L1} \cdot \bar{I}_{L1}^{*} + \bar{U}_{L2} \cdot \bar{I}_{L2}^{*} + \bar{U}_{L3} \cdot \bar{I}_{L3}^{*}$ (Equation 46)
Arone	$\bar{S} = \bar{U}_{L1L2} \cdot \bar{I}_{L1}^{*} - \bar{U}_{L2L3} \cdot \bar{I}_{L3}^{*}$ (Equation 47)
PosSeq	$\bar{S} = 3 \cdot \bar{U}_{PosSeq} \cdot \bar{I}_{PosSeq}^{*}$ (Equation 48)
L1L2	$\bar{S} = \bar{U}_{L1L2} \cdot (\bar{I}_{L1}^{*} - \bar{I}_{L2}^{*})$ (Equation 49)
L2L3	$\bar{S} = \bar{U}_{L2L3} \cdot (\bar{I}_{L2}^{*} - \bar{I}_{L3}^{*})$ (Equation 50)
L3L1	$\bar{S} = \bar{U}_{L3L1} \cdot (\bar{I}_{L3}^{*} - \bar{I}_{L1}^{*})$ (Equation 51)
L1	$\bar{S} = 3 \cdot \bar{U}_{L1} \cdot \bar{I}_{L1}^{*}$ (Equation 52)
L2	$\bar{S} = 3 \cdot \bar{U}_{L2} \cdot \bar{I}_{L2}^{*}$ (Equation 53)
L3	$\bar{S} = 3 \cdot \bar{U}_{L3} \cdot \bar{I}_{L3}^{*}$ (Equation 54)

The active and reactive power is available from the function and can be used for monitoring and fault recording.

The component of the complex power S = P + jQ in the direction *Angle1(2)* is calculated. If this angle is 0° the active power component P is calculated. If this angle is 90° the reactive power component Q is calculated.

The calculated power component is compared to the power pick up setting *Power1(2)*. For directional under-power protection, a start signal START1(2) is activated if the calculated power component is smaller than the pick up value. For directional over-power protection, a start signal START1(2) is activated if the calculated power component is larger than the pick up value. After a set time delay *TripDelay1(2)* a trip TRIP1(2) signal is activated if the start signal is still active. At activation of any of the two stages a common signal START will be activated. At trip from any of the two stages also a common signal TRIP will be activated.

To avoid instability there is a hysteresis in the power function. The absolute hysteresis for stage 1(2) is 0.5 pu for Power1(2) ≥ 1.0 pu, else the hysteresis is 0.5 Power1(2).

If the measured power drops under the (Power1(2) - hysteresis) value, the over-power function will reset after 0.06 seconds. If the measured power comes over the (Power1(2) + hysteresis) value, the under-power function will reset after 0.06 seconds. The reset means that the start signal will drop out and that the timer of the stage will reset.

5.12.4.1 Low pass filtering

In order to minimize the influence of the noise signal on the measurement it is possible to introduce the recursive, low pass filtering of the measured values for S (P, Q). This will make slower measurement response to the step changes in the measured quantity. Filtering is performed in accordance with the following recursive formula:

$$S = k \cdot S_{Old} + (1 - k) \cdot S_{Calculated}$$

(Equation 55)

Where	
S	is a new measured value to be used for the protection function
S_{old}	is the measured value given from the function in previous execution cycle
SCalculated	is the new calculated value in the present execution cycle
k	is settable parameter by the end user which influence the filter properties

Default value for parameter *k* is *0.00*. With this value the new calculated value is immediately given out without any filtering (that is without any additional delay). When *k* is set to value bigger than 0, the filtering is enabled. A typical value for *k=0.92* in case of slow operating functions.

5.12.5 Technical data

Table 136: GOPPDOP/GUPPDUP Technical data

Function	Range or value	Accuracy
Power level	(0.0–500.0)% of Sbase At low setting: (0.5-2.0)% of Sbase (2.0-10)% of Sbase	± 1.0% of S_r at S < S_r ± 1.0% of S at S > S_r < ±50% of set value < ± 20% of set value
Characteristic angle	(-180.0–180.0) degrees	2 degrees
Timers	(0.010 - 6000.000) s	± 0.5% ± 10 ms

5.13 Negative sequence based overcurrent function DNSPTOC

5.13.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Negative sequence based overcurrent function	DNSPTOC	I2>	46

5.13.2 Functionality

Negative sequence based overcurrent function (DNSPTOC) is typically used as sensitive earth-fault protection of power lines, where incorrect zero sequence polarization may result from mutual induction between two or more parallel lines.

Additionally, it is used in applications on underground cables, where zero sequence impedance depends on the fault current return paths, but the cable negative sequence impedance is practically constant.

DNSPTOC protects against all unbalance faults including phase-to-phase faults. Always remember to set the minimum pickup current of the function above natural system unbalance level.

5.13.3 Function block

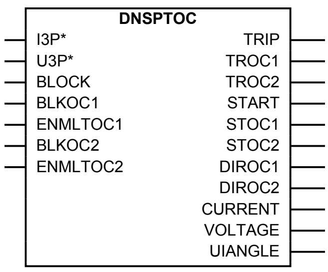

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Figure 112: DNSPTOC function block

5.13.4 Signals

Table 137: DNSPTOC Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKOC1	BOOLEAN	0	Block of over current function OC1
ENMLTOC1	BOOLEAN	0	Enable signal for current multiplier - step1 (OC1)
BLKOC2	BOOLEAN	0	Block of over current function OC2
ENMLTOC2	BOOLEAN	0	Enable signal for current multiplier - step 2 (OC2)

Table 138: DNSPTOC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TROC1	BOOLEAN	Trip signal from step 1 (OC1)
TROC2	BOOLEAN	Trip signal from step 2 (OC2)
START	BOOLEAN	General start signal
STOC1	BOOLEAN	Start signal from step 1 (OC1)
STOC2	BOOLEAN	Start signal from step 2 (OC2)
DIROC1	INTEGER	Directional mode of step 1 (non-directional, forward, reverse)
DIROC2	INTEGER	Directional mode of step 2 (non-directional, forward, reverse)
CURRENT	REAL	Measured current value
VOLTAGE	REAL	Measured voltage value
UIANGLE	REAL	Angle between voltage and current

5.13.5 Settings

Table 139: DNSPTOC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
RCADir	-180 - 180	Deg	1	-75	Relay characteristic angle
ROADir	1 - 90	Deg	1	75	Relay operate angle
LowVolt_VM	0.0 - 5.0	%UB	0.1	0.5	Voltage level in % of Ubase below which ActLowVolt control takes over
Operation_OC1	Off On	-	-	Off	Operation Off/On for step 1 (OC1)
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
StartCurr_OC1	2.0 - 5000.0	%IB	1.0	120.0	Operate current level in % of IBase for step 1 (OC1)
CurrMult_OC1	1.0 - 10.0	-	0.1	2.0	Multiplier for current operate level for step 1 (OC1)
tDef_OC1	0.00 - 6000.00	s	0.01	0.50	Independent (definite) time delay for step 1 (OC1)
DirMode_OC1	Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 1 (non-directional, forward, reverse)
DirPrinc_OC1	I&U IcosPhi&U	-	-	I&U	Measuring on I & U or IcosPhi & U for step 1 (OC1)
ActLowVolt1_VM	Non-directional Block Memory	-	-	Non-directional	Low votlage level action for step 1 (Non-directional, Block, Memory)
Operation_OC2	Off On	-	-	Off	Operation Off/On for step 2 (OC2)
StartCurr_OC2	2.0 - 5000.0	%IB	1.0	120.0	Operate current level in % of Ibase for step 2 (OC2)
CurrMult_OC2	1.0 - 10.0	-	0.1	2.0	Multiplier for current operate level for step 2 (OC2)
tDef_OC2	0.00 - 6000.00	s	0.01	0.50	Independent (definite) time delay for step 2 (OC2)
DirMode_OC2	Non-directional Forward Reverse	-	-	Non-directional	Directional mode of step 2 (non-directional, forward, reverse)
DirPrinc_OC2	I&U IcosPhi&U	-	-	I&U	Measuring on I & U or IcosPhi & U for step 2 (OC2)
ActLowVolt2_VM	Non-directional Block Memory	-	-	Non-directional	Low votlage level action for step 2 (Non-directional, Block, Memory)

Table 140: DNSPTOC Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

5.13.6 Monitored data

Table 141: DNSPTOC Monitored data

Name	Type	Values (Range)	Unit	Description
CURRENT	REAL	-	A	Measured current value
VOLTAGE	REAL	-	kV	Measured voltage value
UIANGLE	REAL	-	deg	Angle between voltage and current

5.13.7 Operation principle

Negative sequence based overcurrent function (DNSPTOC) has two settable current levels, setting parameters *StartCurr_OC1* and *StartCurr_OC2*. Both features have definite time characteristics with settings *tDef_OC1* and *tDef_OC2* respectively. It is possible to change the direction of these steps to *forward*, *reverse* or *non-directional* by setting parameters *DirMode_OC1* and *DirMode_OC2*. At too low polarizing voltage the overcurrent feature can be either blocked, non-directional or use the voltage memory. This is controlled by settings *ActLowVolt1_VM* and *ActLowVolt2_VM*.

5.13.8 Technical data

Table 142: DNSPTOC Technical data

Function	Range or value	Accuracy
Operate current	(2.0 - 5000.0) % of IBase	± 1.0% of I_r at I <I_r ± 1.0% of I at I > I_r
Reset ratio	> 95 %	-
Low voltage level for memory	(0.0 - 5.0) % of UBase	< ± 0,5% of U_r
Relay characteristic angle	(-180 - 180) degrees	± 2,0 degrees
Relay operate angle	(1 - 90) degrees	± 2,0 degrees
Timers	(0.00 - 6000.00) s	± 0.5% ± 10 ms
Operate time, nondirectional	25 ms typically at 0 to 2 x I_{set} 15 ms typically at 0 to 10 x I_{set}	-
Reset time, nondirectional	30 ms typically at 2 to 0 x I_{set}	-
Operate time, directional	25 ms typically at 0.5 to 2 x I_{set} 15 ms typically at 0 to 10 x I_{set}	-
Reset time, directional	30 ms typically at 2 to 0 x I_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x I_{set} 2 ms typically at 0 to 10 x I_{set}	-
Impulse margin time	15 ms typically	-
Dynamic overreach	< 10% at t = 300 ms	-

Section 6 Voltage protection

6.1 Two step undervoltage protection UV2PTUV

6.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step undervoltage protection	UV2PTUV	3*U*<	27

6.1.2 Functionality

Undervoltages can occur in the power system during faults or abnormal conditions. Two step undervoltage protection (UV2PTUV) function can be used to open circuit breakers to prepare for system restoration at power outages or as long-time delayed back-up to primary protection.

UV2PTUV has two voltage steps, each with inverse or definite time delay.

6.1.3 Function block

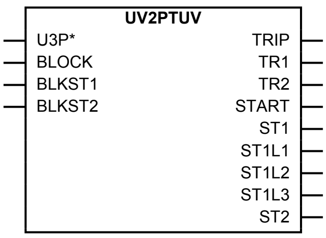

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Figure 113: UV2PTUV function block

6.1.4 Signals

Table 143: UV2PTUV Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1
BLKST2	BOOLEAN	0	Block of step 2

Table 144: UV2PTUV Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TR1	BOOLEAN	Trip signal from step 1
TR2	BOOLEAN	Trip signal from step 2
START	BOOLEAN	General start signal
ST1	BOOLEAN	Start signal from step 1
ST1L1	BOOLEAN	Start signal from step 1 phase L1
ST1L2	BOOLEAN	Start signal from step 1 phase L2
ST1L3	BOOLEAN	Start signal from step 1 phase L3
ST2	BOOLEAN	Start signal from step 2

6.1.5 Settings

Table 145: UV2PTUV Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
Characterist1	Definite time Inverse curve A Inverse curve B Prog. inv. curve	-	-	Definite time	Selection of time delay curve type for step 1
OpMode1	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate (1 of 3, 2 of 3, 3 of 3) from step 1
U1<	1 - 100	%UB	1	70	Voltage start value (DT & IDMT) in % of UBase for step 1
t1	0.00 - 6000.00	s	0.01	5.00	Definite time delay of step 1
t1Min	0.000 - 60.000	s	0.001	5.000	Minimum operate time for inverse curves for step 1
k1	0.05 - 1.10	-	0.01	0.05	Time multiplier for the inverse time delay for step 1

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
OpMode2	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate (1 of 3, 2 of 3, 3 of 3) from step 2
U2<	1 - 100	%UB	1	50	Voltage start value (DT & IDMT) in % of UBase for step 2
t2	0.000 - 60.000	s	0.001	5.000	Definie time delay of step 2

Table 146: UV2PTUV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
ConnType	PhN DFT PhN RMS PhPh DFT PhPh RMS	-	-	PhN DFT	Group selector for connection type

6.1.6 Monitored data

Table 147: UV2PTUV Monitored data

Name	Type	Values (Range)	Unit	Description
UL1	REAL	-	kV	Voltage in phase L1
UL2	REAL	-	kV	Voltage in phase L2
UL3	REAL	-	kV	Voltage in phase L3

6.1.7 Operation principle

Two-step undervoltage protection (UV2PTUV) is used to detect low power system voltage. UV2PTUV has two voltage measuring steps with separate time delays. If one, two or three phase voltages decrease below the set value, a corresponding START signal is generated. UV2PTUV can be set to START/TRIP based on *1 out of 3*, *2 out of 3* or *3 out of 3* of the measured voltages, being below the set point. If the voltage remains below the set value for a time period corresponding to the chosen time delay, the corresponding trip signal is issued. To avoid an unwanted trip due to disconnection of the related high voltage equipment, a voltage controlled blocking of the function is available, that is, if the voltage is lower than the set blocking level the function is blocked and no START or TRIP signal is generated. The time delay characteristic is individually chosen for each step and can be either definite time delay or inverse time delay.

UV2PTUV can be set to measure phase-to-earth fundamental value, phase-to-phase fundamental value, phase-to-earth true RMS value or phase-to-phase true RMS value. The choice of the measuring is done by the parameter *ConnType*. The voltage related settings are made in percent of base voltage which is set in kV phase-to-phase voltage. This means operation for phase-to-earth voltage under:

$$U<(\%)\cdot UBase(kV)/\sqrt{3}$$

(Equation 56)

and operation for phase-to-phase voltage under:

$$\mathrm{U}<(\%)\cdot \mathrm{UBase(kV)}$$

(Equation 57)

6.1.7.1 Measurement principle

Depending on the set *ConnType* value, UV2PTUV measures phase-to-earth or phase-to-phase voltages and compare against set values, *U1<* and *U2<*. The parameters *OpMode1* and *OpMode2* influence the requirements to activate the START outputs. Either 1 out of 3, 2 out of 3, or 3 out of 3 measured voltages have to be lower than the corresponding set point to issue the corresponding START signal.

To avoid oscillations of the output START signal, a hysteresis has been included.

6.1.7.2 Time delay

The time delay for step 1 can be either definite time delay (DT) or inverse time delay (IDMT). Step 2 is always definite time delay (DT). For the inverse time delay two different modes are available; inverse curve A and inverse curve B.

The type A curve is described as:

$$t=\frac{k}{\left(\frac{U<-U}{U<}\right)}$$

(Equation 58)

The type B curve is described as:

$$t=\frac{k\cdot 480}{\left(32\cdot\frac{U<-U}{U<}-0.5\right)^{2.0}}+0.055$$

(Equation 59)

When the denominator in the expression is equal to zero the time delay will be infinity. There will be an undesired discontinuity. Therefore a tuning parameter is set to compensate for this phenomenon.

The lowest voltage is always used for the inverse time delay integration. The details of the different inverse time characteristics are shown in section 19.3 "Inverse time characteristics".

Trip signal issuing requires that the undervoltage condition continues for at least the user set time delay. This time delay is set by the parameter *t1* and *t2* for definite time mode (DT) and by some special voltage level dependent time curves for the inverse time mode (IDMT). If the start condition, with respect to the measured voltage ceases during the delay time, and is not fulfilled again within a defined reset time, the corresponding start output is reset. Here it should be noted that after leaving the hysteresis area, the start condition must be fulfilled again and it is not sufficient for the signal to return back into the hysteresis area. Note that for the undervoltage function the IDMT reset time is constant and does not depend on the voltage fluctuations during the drop-off period. However, there are three ways to reset the timer, either the timer is reset instantaneously, or the timer value is frozen during the reset time, or the timer value is linearly decreased during the reset time. See figure 114 and figure 115.

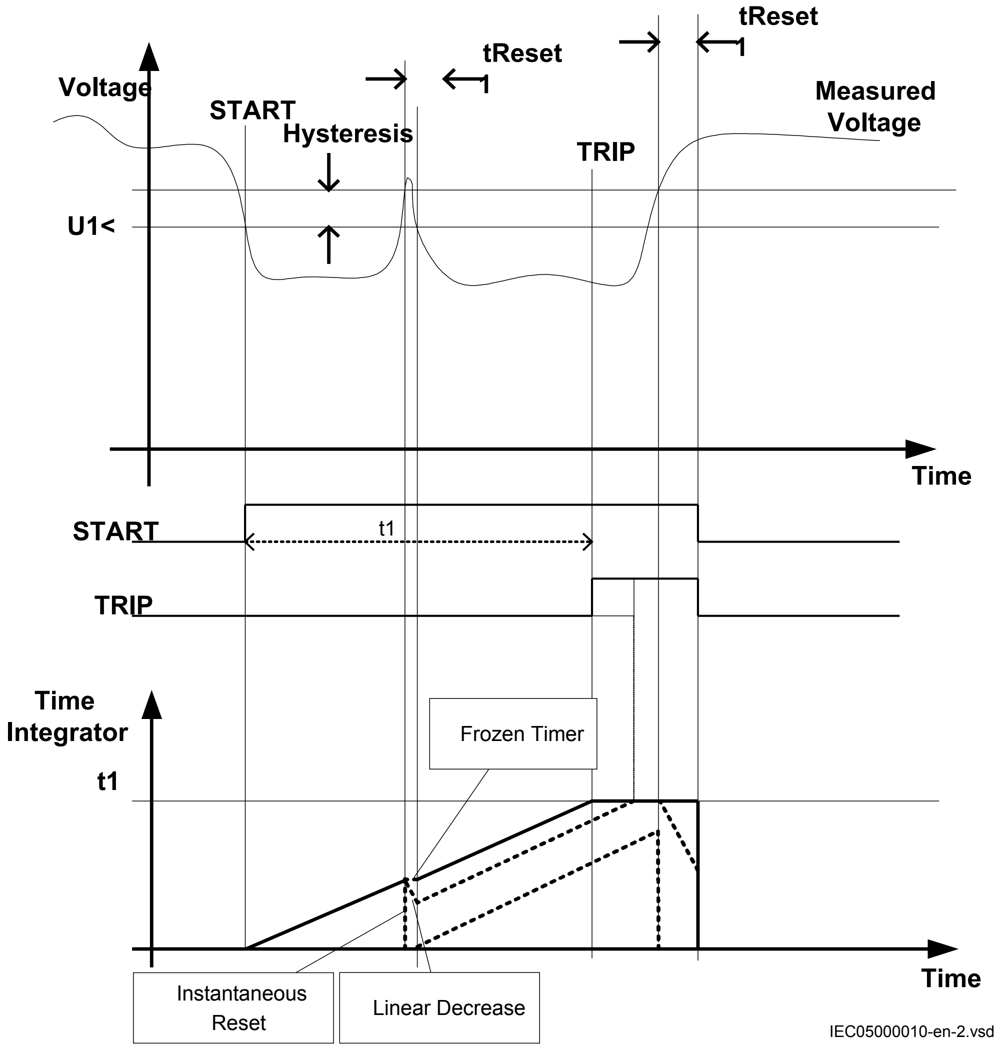

Figure 114: Voltage profile not causing a reset of the start signal for step 1, and definite time delay

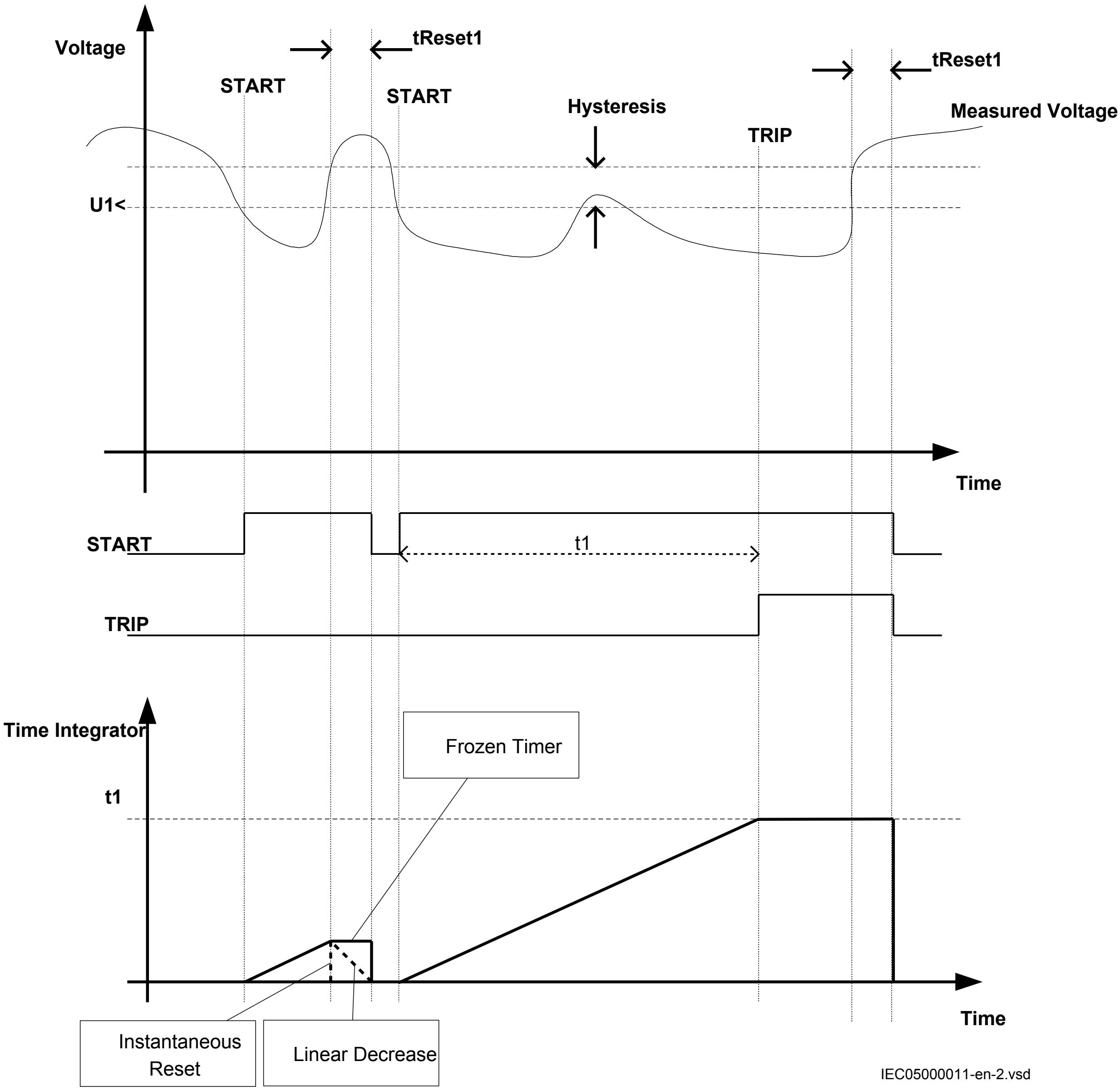

Figure 115: Voltage profile causing a reset of the start signal for step 1, and definite time delay

6.1.7.3 Blocking

It is possible to block Two step undervoltage protection (UV2PTUV) partially or completely, by binary input signals or by parameter settings, where:

BLOCK:	blocks all outputs
BLKST1:	blocks all start and trip outputs related to step 1
BLKST2:	blocks all start and trip outputs related to step 2

6.1.7.4 Design

The voltage measuring elements continuously measure the three phase-to-neutral voltages or the three phase-to-phase voltages. Recursive fourier filters, true RMS filters or input voltage signals are used. The voltages are individually compared to the set value, and the lowest voltage is used for the inverse time characteristic integration. A special logic is included to achieve the 1 out of 3, 2 out of 3 and 3 out of 3 criteria to fulfill the START condition. The design of Two step undervoltage protection (UV2PTUV) is schematically shown in figure 116.

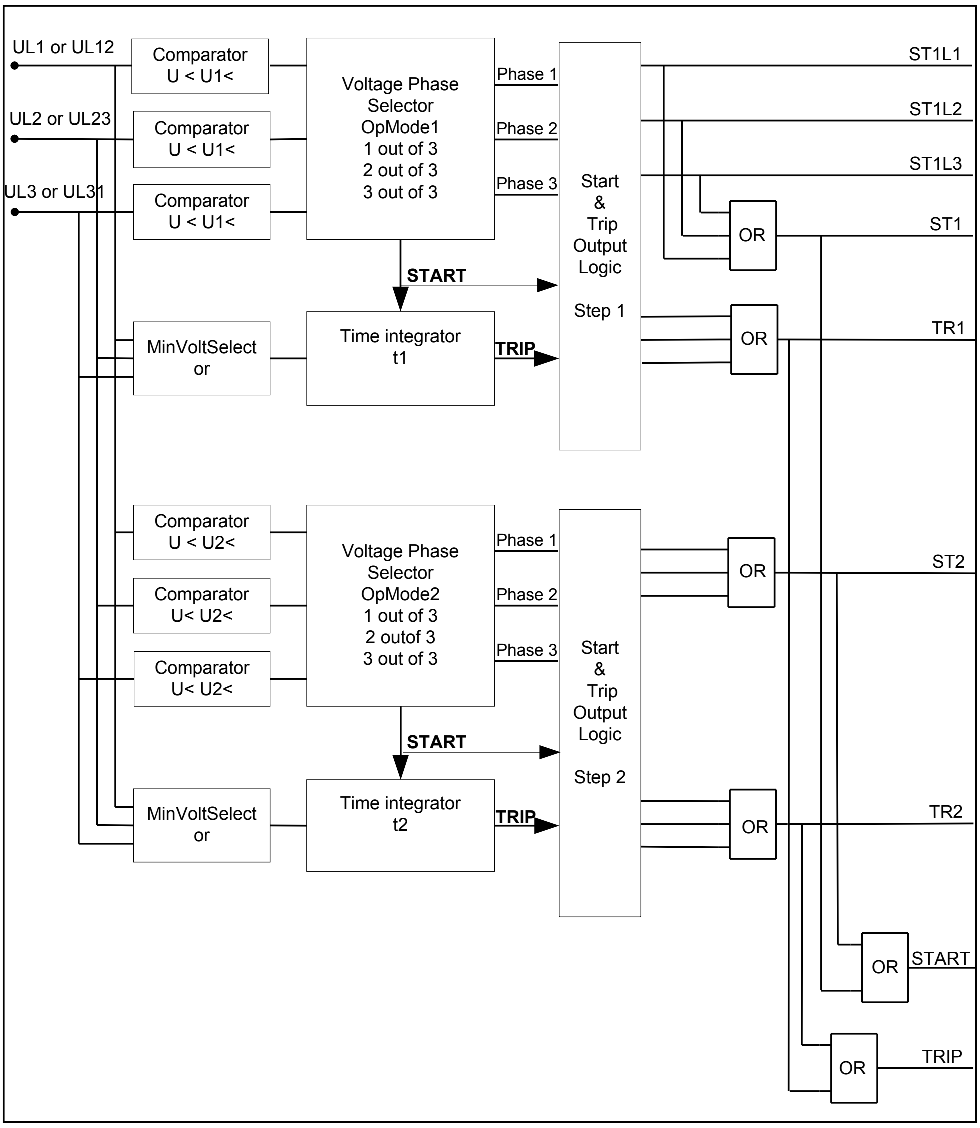

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Figure 116: Schematic design of Two step undervoltage protection (UV2PTUV)

6.1.8 Technical data

Table 148: UV2PTUV Technical data

Function	Range or value	Accuracy
Operate voltage, low and high step	(1–100)% of UBase	± 0.5% of U_r
Reset ratio	<105%	-
Inverse time characteristics for low and high step, see table 496	-	See table 496
Definite time delay, step 1	(0.00 - 6000.00) s	± 0.5% ± 10 ms
Definite time delays, step 2	(0.000-60.000) s	± 0.5% ±10 ms
Minimum operate time, inverse characteristics	(0.000–60.000) s	± 0.5% ± 10 ms
Operate time, start function	20 ms typically at 2 to 0.5 x U_{set}	-
Reset time, start function	25 ms typically at 0.5 to 2 x U_{set}	-
Critical impulse time	10 ms typically at 2 to 0 x U_{set}	-
Impulse margin time	15 ms typically	-

6.2 Two step overvoltage protection OV2PTOV

6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step overvoltage protection	OV2PTOV	3U>	59

6.2.2 Functionality

Overvoltages may occur in the power system during abnormal conditions, such as, sudden power loss, tap changer regulating failures, open line ends on long lines.

Two step overvoltage protection (OV2PTOV) can be used as open line end detector, normally then combined with directional reactive over-power function or as system voltage supervision, normally then giving alarm only or switching in reactors or switch out capacitor banks to control the voltage.

OV2PTOV has two voltage steps, where step 1 is setable as inverse or definite time delayed. Step 2 is always definite time delayed.

OV2PTOV has an extremely high reset ratio to allow setting close to system service voltage.

6.2.3 Function block

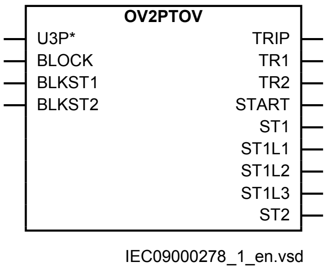


Figure 117: OV2PTOV function block

6.2.4 Signals

Table 149: OV2PTOV Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1
BLKST2	BOOLEAN	0	Block of step 2

Table 150: OV2PTOV Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TR1	BOOLEAN	Trip signal from step 1
TR2	BOOLEAN	Trip signal from step 2
START	BOOLEAN	General start signal
ST1	BOOLEAN	Start signal from step 1
ST1L1	BOOLEAN	Start signal from step 1 phase L1
ST1L2	BOOLEAN	Start signal from step 1 phase L2
ST1L3	BOOLEAN	Start signal from step 1 phase L3
ST2	BOOLEAN	Start signal from step 2

6.2.5 Settings

Table 151: OV2PTOV Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
Characterist1	Definite time Inverse curve A Inverse curve B Inverse curve C	-	-	Definite time	Selection of time delay curve type for step 1
OpMode1	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate (1 of 3, 2 of 3, 3 of 3) from step 1
U1>	1 - 200	%UB	1	120	Voltage start value (DT & IDMT) in % of UBase for step 1
t1	0.00 - 6000.00	s	0.01	5.00	Definite time delay of step 1
t1Min	0.000 - 60.000	s	0.001	5.000	Minimum operate time for inverse curves for step 1
k1	0.05 - 1.10	-	0.01	0.05	Time multiplier for the inverse time delay for step 1
OpMode2	1 out of 3 2 out of 3 3 out of 3	-	-	1 out of 3	Number of phases required to operate (1 of 3, 2 of 3, 3 of 3) from step 2
U2>	1 - 200	%UB	1	150	Voltage start value (DT & IDMT) in % of UBase for step 2
t2	0.000 - 60.000	s	0.001	5.000	Definite time delay of step 2

Table 152: OV2PTOV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
ConnType	PhN DFT PhN RMS PhPh DFT PhPh RMS	-	-	PhN DFT	Group selector for connection type

6.2.6 Monitored data

Table 153: OV2PTOV Monitored data

Name	Type	Values (Range)	Unit	Description
UL1	REAL	-	kV	Voltage in phase L1
UL2	REAL	-	kV	Voltage in phase L2
UL3	REAL	-	kV	Voltage in phase L3

6.2.7 Operation principle

Two-step overvoltage protection (OV2PTOV) is used to detect high power system voltage. OV2PTOV has two steps with separate time delays. If one, two or three phase voltages increase above the set value, a corresponding START signal is issued. OV2PTOV can be set to START/TRIP, based on *1 out of 3, 2 out of 3* or *3 out of 3* of the measured voltages, being above the set point. If the voltage remains above the set value for a time period corresponding to the chosen time delay, the corresponding trip signal is issued.

The time delay characteristic is setable for step 1 and can be either definite or inverse time delayed. Step 2 is always definite time delayed.

The voltage related settings are made in percent of the global set base voltage, which is set in kV, phase-to-phase.

OV2PTOV can be set to measure phase-to-earth fundamental value, phase-to-phase fundamental value, phase-to-earth RMS value or phase-to-phase RMS value. The choice of measuring is done by the parameter *ConnType* in PST or local HMI.

The setting of the analog inputs are given as primary phase-to-earth or phase-to-phase voltage. OV2PTOV will operate if the voltage gets higher than the set percentage of the set global base voltage *UBase*. This means operation for phase to earth voltage over:

$$U > (\%) \cdot UBase(kV) \big/ \sqrt{3}$$

(Equation 60)

and operation for phase for phase voltage over:

$$\mathrm{U} > (\%) \cdot \mathrm{UBase(kV)}$$

(Equation 61)

6.2.7.1 Measurement principle

All the three voltages are measured continuously, and compared with the set values, *U1>* and *U2>*. The parameters *OpMode1* and *OpMode2* influence the requirements to activate the START outputs. Either *1 out of 3, 2 out of 3* or *3 out of 3* measured voltages have to be higher than the corresponding set point to issue the corresponding START signal.

To avoid oscillations of the output START signal, a hysteresis has been included.

6.2.7.2 Time delay

The time delay for step 1 can be either definite time delay (DT) or inverse time delay (IDMT). Step 2 is always definite time delayed (DT). For the inverse time delay three different modes are available; inverse curve A, inverse curve B and inverse curve C.

The type A curve is described as:

$$t = \frac{k}{\left(\frac{U - U>}{U>} \right)}$$

(Equation 62)

The type B curve is described as:

$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5 \right)^{2.0}} + 0.035$$

(Equation 63)

The type C curve is described as:

$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5 \right)^{3.0}} + 0.035$$

(Equation 64)

When the denominator in the expression is equal to zero the time delay will be infinity. There will be an undesired discontinuity. Therefore, a tuning parameter is set to compensate for this phenomenon.

The highest phase (or phase-to-phase) voltage is always used for the inverse time delay integration, see figure 118. The details of the different inverse time characteristics are shown in section 19.3 "Inverse time characteristics"

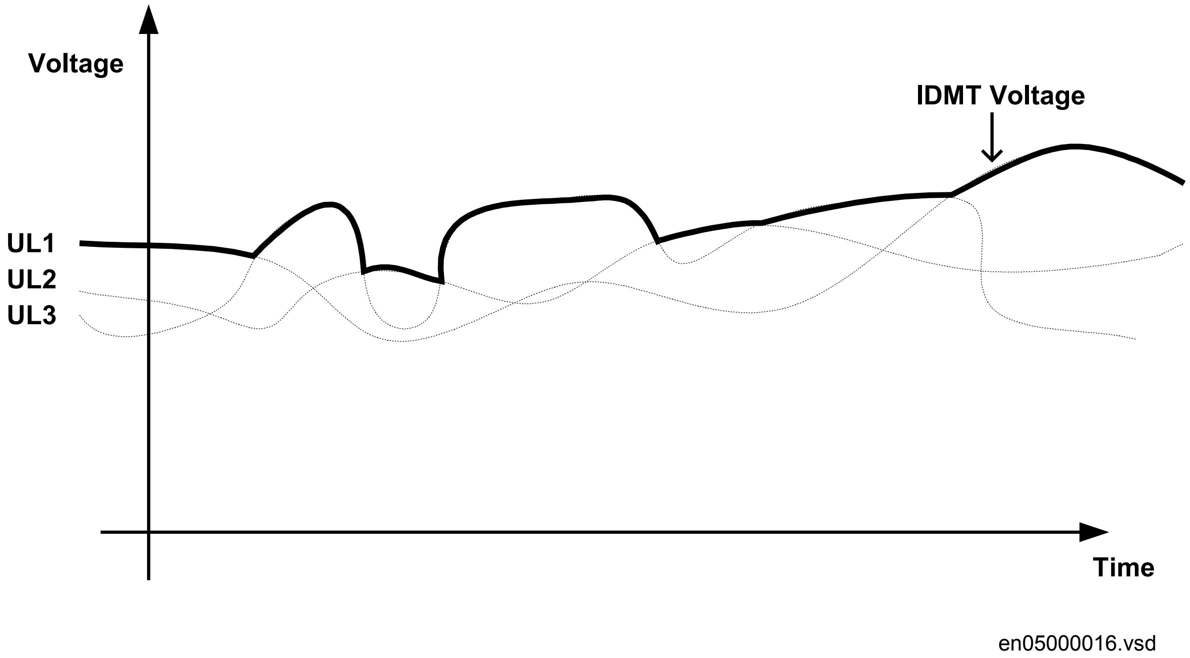


Figure 118: Voltage used for the inverse time characteristic integration

Trip signal issuing requires that the overvoltage condition continues for at least the user set time delay. This time delay is set by the parameter *t1* and *t2* for definite time mode (DT) and by selected voltage level dependent time curves for the inverse time mode (IDMT). If the START condition, with respect to the measured voltage ceases during the delay time, and is not fulfilled again within a defined reset time the corresponding START output is reset. Here it should be noted that after leaving the hysteresis area, the START condition must be fulfilled again and it is not sufficient for the signal to only return back to the hysteresis area. It is also remarkable that for Two step overvoltage protection (OV2PTOV) the IDMT reset time is constant and does not depend on the voltage fluctuations during the drop-off period. However, there are three ways to reset the timer, either the timer is reset instantaneously, or the timer value is frozen during the reset time, or the timer value is linearly decreased during the reset time.

6.2.7.3 Blocking

It is possible to block two step overvoltage protection (OV2PTOV) partially or completely, by binary input signals where:

BLOCK:	blocks all outputs
BLKST1:	blocks all start and trip outputs related to step 1
BLKST2:	blocks all start and trip outputs related to step 2

6.2.7.4 Design

The voltage measuring elements continuously measure the three phase-to-earth voltages or the three phase-to-phase voltages. Recursive Fourier filters filter the input voltage signals. The phase voltages are individually compared to the set value, and the highest voltage is used for the inverse time characteristic integration. A special logic is included to achieve the *1 out of 3, 2 out of 3* or *3 out of 3* criteria to fulfill the START condition. The design of Two step overvoltage protection (OV2PTOV) is schematically described in figure 119.

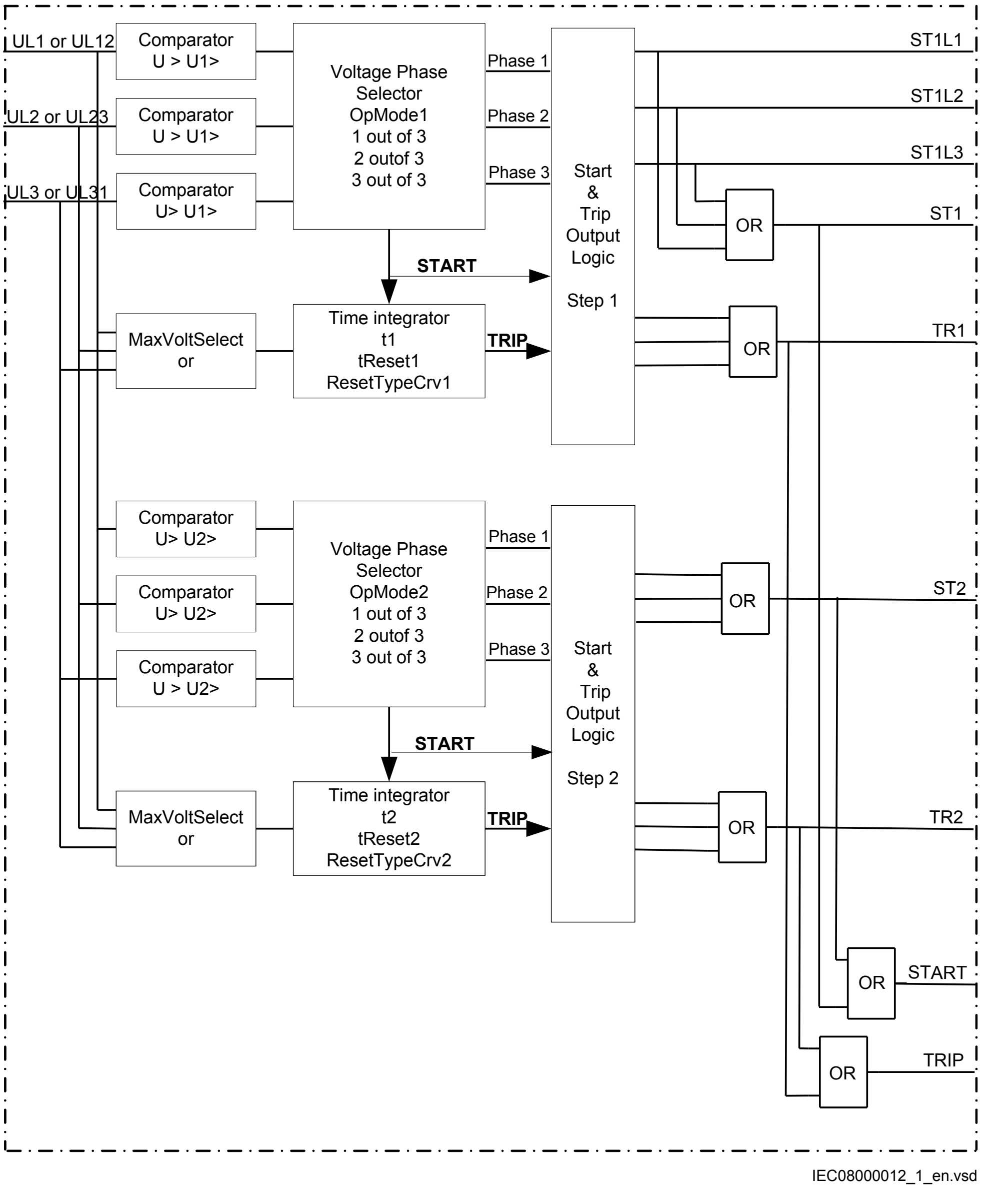


Figure 119: Schematic design of Two step overvoltage protection (OV2PTOV)

6.2.8 Technical data

Table 154: OV2PTOV Technical data

Function	Range or value	Accuracy
Operate voltage, low and high step	(1-200)% of Ubase	± 0.5% of U_r at $U < U_r$ ± 0.5% of U at $U > U_r$
Reset ratio	>95%	-
Inverse time characteristics for low and high step, see table 497	-	See table 497
Definite time delay, step 1	(0.00 - 6000.00) s	± 0.5% ± 10 ms
Definite time delays, step 2	(0.000-60.000) s	± 0.5% ± 10 ms
Minimum operate time, Inverse characteristics	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time, start function	20 ms typically at 0 to 2 x U_{set}	-
Reset time, start function	25 ms typically at 2 to 0 x U_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x U_{set}	-
Impulse margin time	15 ms typically	-

6.3 Two step residual overvoltage protection ROV2PTOV

6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Two step residual overvoltage protection	ROV2PTOV	$\boxed{3U0}$	59N

6.3.2 Functionality

Residual voltages may occur in the power system during earth-faults.

Two step residual overvoltage protection (ROV2PTOV) calculates the residual voltage from the three-phase voltage input transformers or from a single-phase voltage input transformer fed from an open delta or neutral point voltage transformer.

ROV2PTOV has two voltage steps, where step 1 is setable as inverse or definite time delayed. Step 2 is always definite time delayed.

6.3.3 Function block

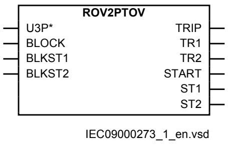


Figure 120: ROV2PTOV function block

6.3.4 Signals

Table 155: ROV2PTOV Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
BLKST1	BOOLEAN	0	Block of step 1
BLKST2	BOOLEAN	0	Block of step 2

Table 156: ROV2PTOV Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
TR1	BOOLEAN	Trip signal from step 1
TR2	BOOLEAN	Trip signal from step 2
START	BOOLEAN	General start signal
ST1	BOOLEAN	Start signal from step 1
ST2	BOOLEAN	Start signal from step 2

6.3.5 Settings

Table 157: ROV2PTOV Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
Characterist1	Definite time Inverse curve A Inverse curve B Inverse curve C Prog. inv. curve	-	-	Definite time	Selection of time delay curve type for step 1
U1>	1 - 200	%UB	1	30	Voltage start value (DT & IDMT) in % of UBase for step 1
t1	0.00 - 6000.00	s	0.01	5.00	Definite time delay of step 1
t1Min	0.000 - 60.000	s	0.001	5.000	Minimum operate time for inverse curves for step 1
k1	0.05 - 1.10	-	0.01	0.05	Time multiplier for the inverse time delay for step 1
U2>	1 - 100	%UB	1	45	Voltage start value (DT & IDMT) in % of UBase for step 2
t2	0.000 - 60.000	s	0.001	5.000	Definite time delay of step 2

Table 158: ROV2PTOV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

6.3.6 Monitored data

Table 159: ROV2PTOV Monitored data

Name	Type	Values (Range)	Unit	Description
ULevel	REAL	-	kV	Magnitude of measured voltage

6.3.7 Operation principle

Two-step residual overvoltage protection (ROV2PTOV) is used to detect high single-phase voltage, such as high residual voltage, also called 3U0. The residual voltage can be measured directly from a voltage transformer in the neutral of a power transformer or from a three-phase voltage transformer, where the secondary windings are connected in an open delta. Another possibility is to measure the three-phase voltages and internally in the IED calculate the corresponding residual voltage and connect this calculated residual voltage to ROV2PTOV function. ROV2PTOV has two steps with separate time delays. If the single-phase (residual) voltage remains above the set value for a time period corresponding to the chosen time delay, the corresponding TRIP signal is issued.

The time delay characteristic is setable for step 1 and can be either definite or inverse time delayed. Step 2 is always definite time delayed.

The voltage related settings are made in percent of the global phase-to-phase base voltage divided by √3.

6.3.7.1 Measurement principle

The residual voltage is measured continuously, and compared with the set values, *U1>* and *U2>*.

To avoid oscillations of the output START signal, a hysteresis has been included.

6.3.7.2 Time delay

The time delay for step 1 can be either definite time delay (DT) or inverse time delay (IDMT). Step 2 is always definite time delay (DT). For the inverse time delay three different modes are available; inverse curve A, inverse curve B and inverse curve C.

The type A curve is described as:

$$t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$$

The type B curve is described as:

$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0}} + 0.035$$

(Equation 65)

The type C curve is described as:

$$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0}} + 0.035$$

(Equation 66)

When the denominator in the expression is equal to zero the time delay will be infinity. There will be an undesired discontinuity. Therefore a tuning parameter is set to compensate for this phenomenon.

The details of the different inverse time characteristics are shown in section 19.3 "Inverse time characteristics".

TRIP signal issuing requires that the residual overvoltage condition continues for at least the user set time delay. This time delay is set by the parameter *t1* and *t2* for definite time mode (DT) and by some special voltage level dependent time curves for the inverse time mode (IDMT). If the START condition, with respect to the measured voltage ceases during the delay time, and is not fulfilled again within a defined reset time, the corresponding START output is reset. Here it should be noted that after leaving the hysteresis area, the START condition must be fulfilled again and it is not sufficient for the signal to only return back to the hysteresis area. Also notice that for the overvoltage function IDMT reset time is constant and does not depend on the voltage fluctuations during the drop-off period. However, there are three ways to reset the timer, either the timer is reset instantaneously, or the timer value is frozen during the reset time, or the timer value is linearly decreased during the reset time. See figure 121 and figure 122.

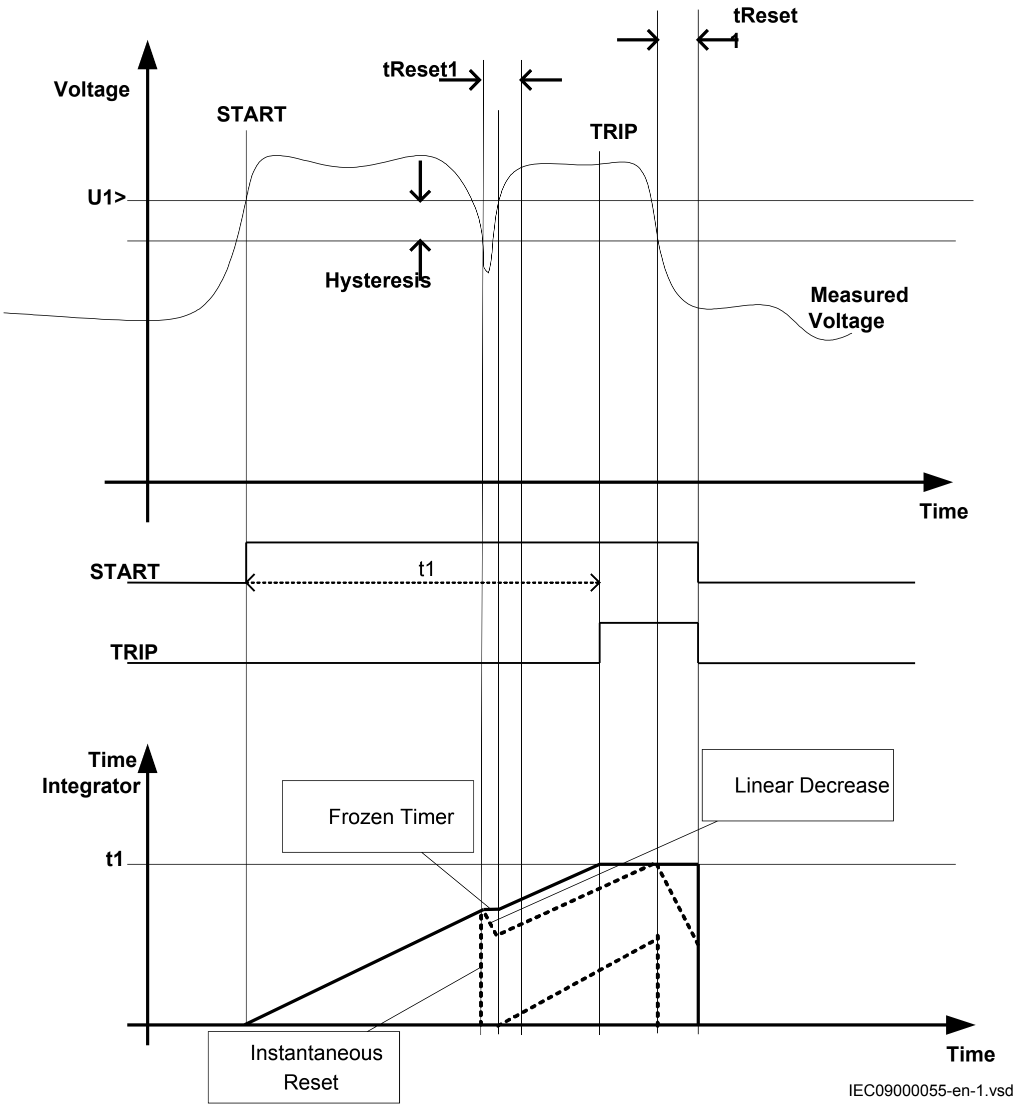


Figure 121: Voltage profile not causing a reset of the START signal for step 1, and definite time delay

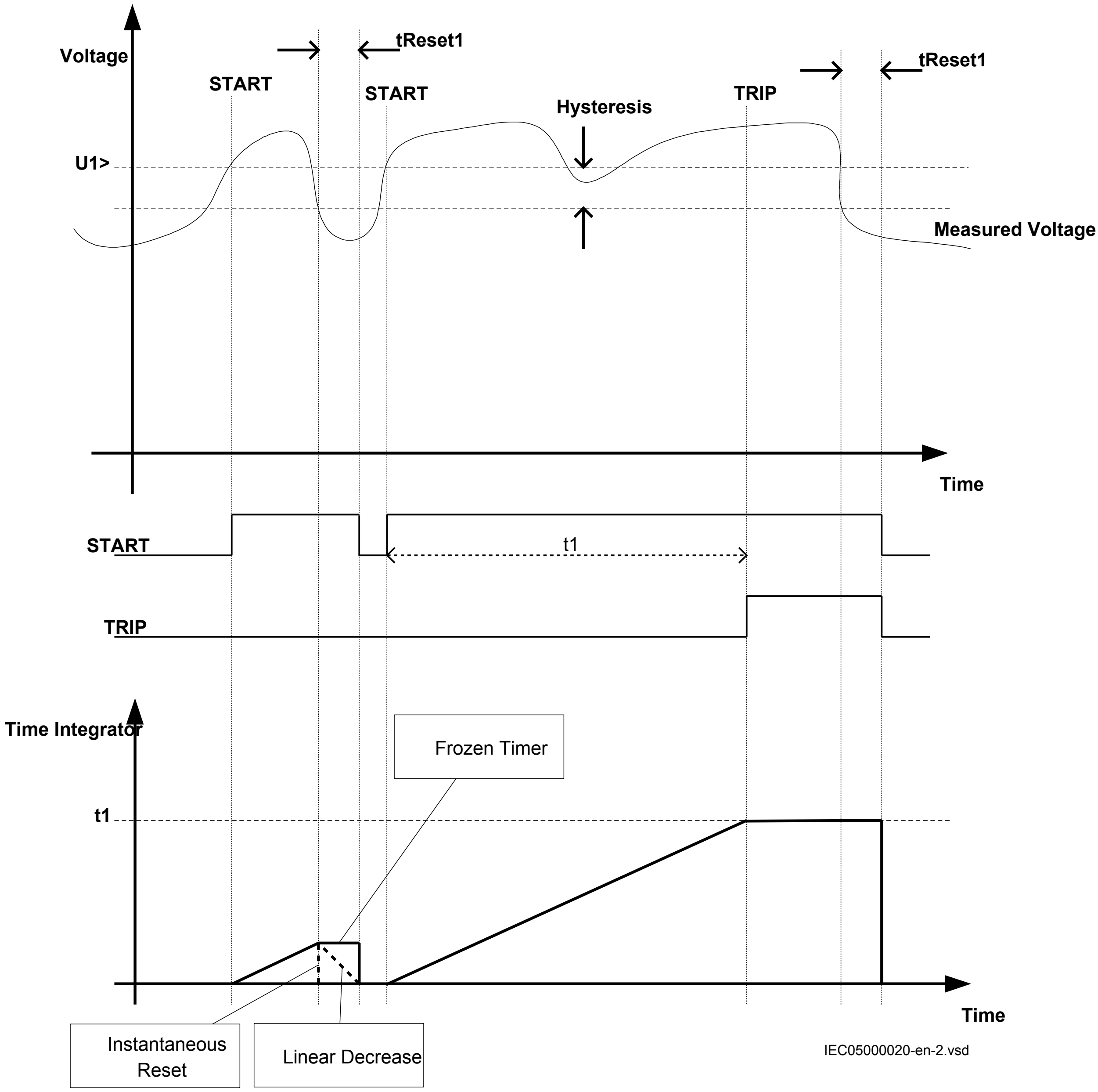


Figure 122: Voltage profile causing a reset of the START signal for step 1, and definite time delay

6.3.7.3 Blocking

It is possible to block Two step residual overvoltage protection (ROV2PTOV) partially or completely, by binary input signals where:

BLOCK:	blocks all outputs
BLKST1:	blocks all startand trip outputs related to step 1
BLKST2:	blocks all start and trip inputs related to step 2

6.3.7.4 Design

The voltage measuring elements continuously measure the residual voltage. Recursive Fourier filters filter the input voltage signal. The single input voltage is compared to the set value, and is also used for the inverse time characteristic integration. The design of Two step residual overvoltage protection (ROV2PTOV) is schematically described in figure 123.

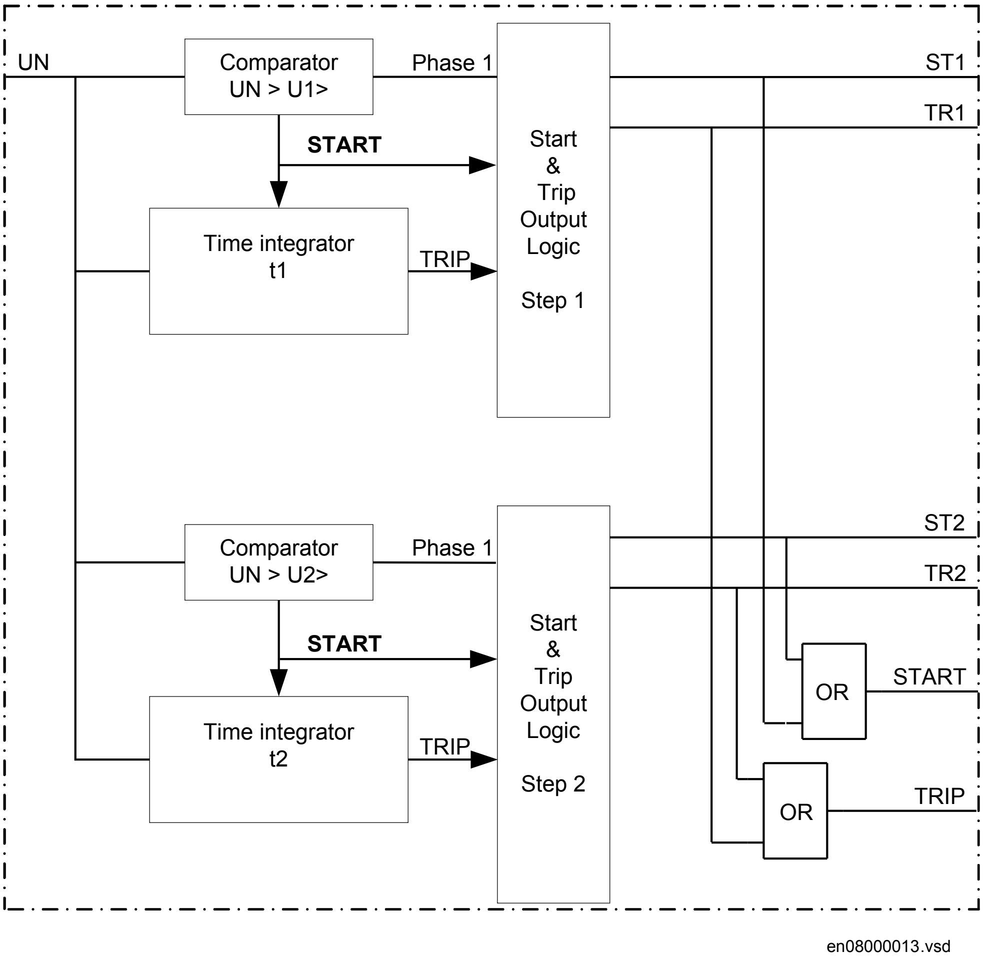


Figure 123: Schematic design of Two step residual overvoltage protection (ROV2PTOV)

6.3.8 Technical data

Table 160: ROV2PTOV Technical data

Function	Range or value	Accuracy
Operate voltage, step 1	(1-200)% of Ubase	± 0.5% of U_r at U < U_r ± 0.5% of U at U > U_r
Operate voltage, step 2	(1–100)% of Ubase	± 0.5% of U_r at U < U_r ± % of U at U > U_r
Reset ratio	>95%	-
Inverse time characteristics for low and high step, see table 498	-	See table 498
Definite time setting, step 1	(0.00–6000.00) s	± 0.5% ± 10 ms
Definite time setting, step 2	(0.000–60.000) s	± 0.5% ± 10 ms
Minimum operate time for step 1 inverse characteristic	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time, start function	20 ms typically at 0 to 2 x U_{set}	-
Reset time, start function	25 ms typically at 2 to 0 x U_{set}	-
Critical impulse time	10 ms typically at 0 to 2 x U_{set}	-
Impulse margin time	15 ms typically	-

6.4 Loss of voltage check LOVPTUV

6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Loss of voltage check	LOVPTUV	-	27

6.4.2 Functionality

Loss of voltage check (LOVPTUV) is suitable for use in networks with an automatic system restoration function. LOVPTUV issues a three-pole trip command to the circuit breaker, if all three phase voltages fall below the set value for a time longer than the set time and the circuit breaker remains closed.

6.4.3 Function block

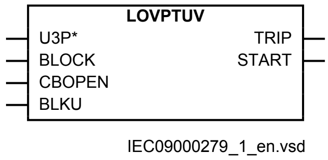


Figure 124: LOVPTUV function block

6.4.4 Signals

Table 161: LOVPTUV Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
CBOPEN	BOOLEAN	0	Circuit breaker open
BLKU	BOOLEAN	0	Block from voltage circuit supervision

Table 162: LOVPTUV Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip signal
START	BOOLEAN	Start signal

6.4.5 Settings

Table 163: LOVPTUV Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
UPE	1 - 100	%UB	1	70	Operate voltage in% of base voltage Ubase
tTrip	0.000 - 60.000	s	0.001	7.000	Operate time delay

Table 164: LOVPTUV Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
tPulse	0.050 - 60.000	s	0.001	0.150	Duration of TRIP pulse
tBlock	0.000 - 60.000	s	0.001	5.000	Time delay to block when all 3ph voltages are not low
tRestore	0.000 - 60.000	s	0.001	3.000	Time delay for enable the function after restoration

Table 165: LOVPTUV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

6.4.6 Operation principle

The operation of Loss of voltage check (LOVPTUV) is based on line voltage measurement. LOVPTUV is provided with a logic, which automatically recognises if the line was restored for at least *tRestore* before starting the *tTrip* timer. All three phases are required to be low before the output TRIP is activated. START is available on output START.

Additionally, LOVPTUV is automatically blocked if only one or two phase voltages have been detected low for more than *tBlock*.

LOVPTUV operates again only if the line has been restored to full voltage for at least *tRestore*. Operation of the function is also inhibited by fuse failure and open circuit breaker information signals, by their connection to dedicated inputs of the function block.

Due to undervoltage conditions being continuous the trip pulse is limited to a length set by setting *tPulse*.

The operation of LOVPTUV is supervised by the fuse-failure function (VTSU input) and the information about the open position (CBOPEN) of the associated circuit breaker.

The BLOCK input can be connected to a binary input of the IED in order to receive a block command from external devices or can be software connected to other internal functions of the IED itself in order to receive a block command from internal functions. LOVPTUV is also blocked when the IED is in test mode and LOVPTUV has been blocked from the HMI test menu (*Blocked*=*Yes*).

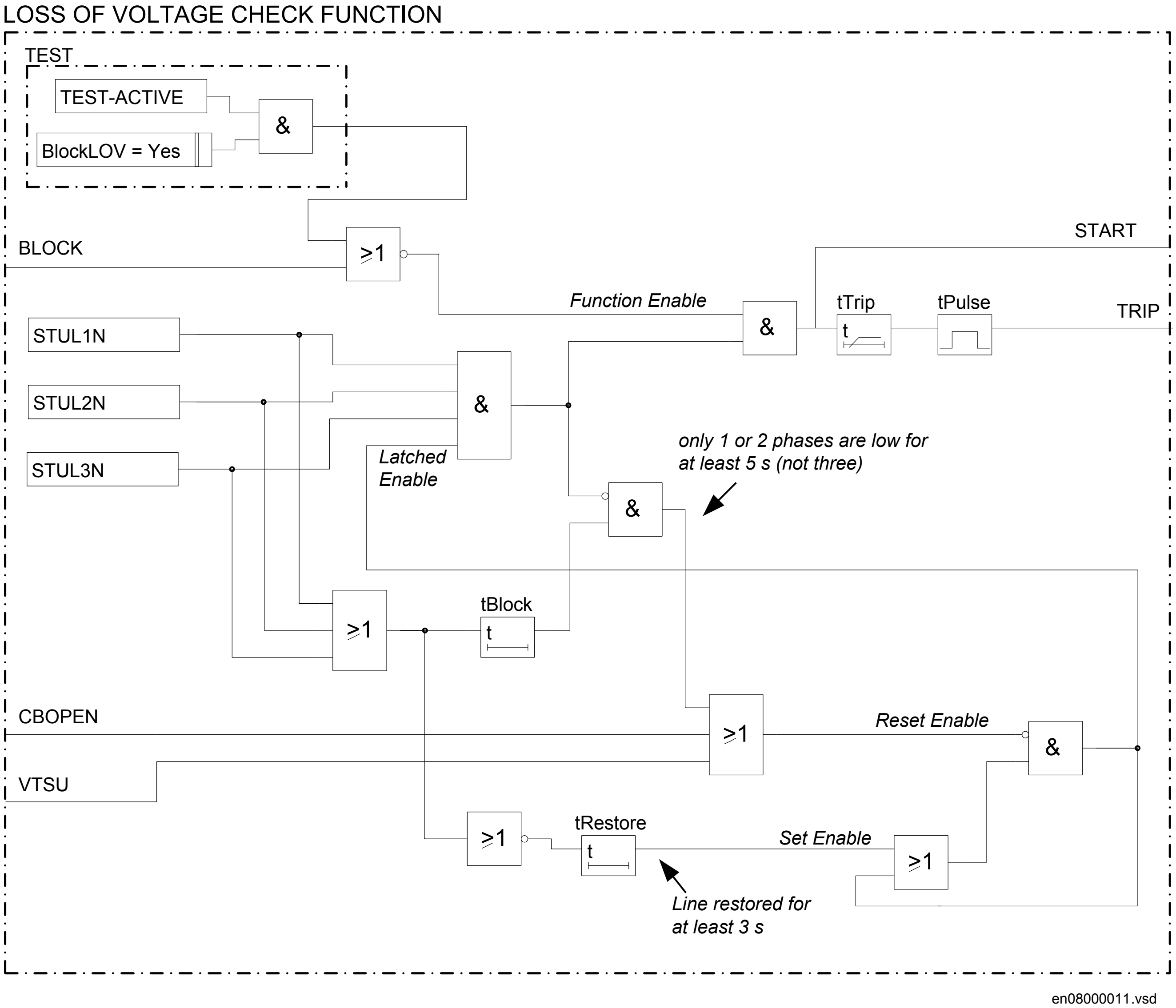


Figure 125: Simplified diagram of Loss of voltage check (LOVPTUV)

6.4.7 Technical data

Table 166: LOVPTUV Technical data

Function	Range or value	Accuracy
Operate voltage	(0–100)% of Ubase	± 0.5% of U_r
Reset ratio	<105%	-
Pulse timer	(0.050–60.000) s	± 0.5% ± 10 ms
Timers	(0.000–60.000) s	± 0.5% ± 10 ms

Section 7 Frequency protection

7.1 Under frequency protection SAPTUF

7.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Under frequency protection	SAPTUF	f <	81

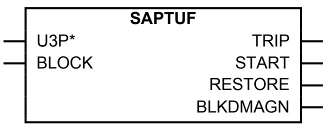
7.1.2 Functionality

Under frequency occurs as a result of lack of generation in the network.

Under frequency protection (SAPTUF) is used for load shedding systems, remedial action schemes, gas turbine start-up and so on.

SAPTUF is provided with an under voltage blocking.

7.1.3 Function block



IEC09000282_1_en.vsd

Figure 126: SAPTUF function block

7.1.4 Signals

Table 167: SAPTUF Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function

Table 168: SAPTUF Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
START	BOOLEAN	General start signal
RESTORE	BOOLEAN	Restore signal for load restoring purposes
BLKDMAGN	BOOLEAN	Measurement blocked due to low voltage amplitude

7.1.5 Settings

Table 169: SAPTUF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
StartFrequency	35.00 - 75.00	Hz	0.01	48.80	Frequency set value
tDelay	0.000 - 60.000	s	0.001	0.200	Operate time delay
tRestore	0.000 - 60.000	s	0.001	0.000	Restore time delay
RestoreFreq	45.00 - 65.00	Hz	0.01	49.90	Restore frequency if frequency is above frequency value

7.1.6 Monitored data

Table 170: SAPTUF Monitored data

Name	Type	Values (Range)	Unit	Description
FREQ	REAL	-	Hz	Measured frequency

7.1.7 Operation principle

Under frequency protection (SAPTUF) function is used to detect low power system frequency. If the frequency remains below the set value for a time period corresponding to the chosen time delay, the corresponding trip signal is issued. To avoid an unwanted trip due to uncertain frequency measurement at low voltage magnitude, a voltage controlled blocking of the function is available from the preprocessing function, that is, if the voltage is lower than the set blocking voltage in the preprocessing function, the function is blocked and no START or TRIP signal is issued.

7.1.7.1 Measurement principle

The fundamental frequency of the measured input voltage is measured continuously, and compared with the set value, *StartFrequency*. The frequency function is dependent on the voltage magnitude. If the voltage magnitude decreases the setting *MinValFreqMeas* in the SMAI preprocessing function, which is set as a percentage of a global base voltage parameter, SAPTUF gets blocked, and the output BLKDMAGN is issued. All voltage settings are made in percent of the setting of the global parameter *UBase*.

To avoid oscillations of the output START signal, a hysteresis has been included.

7.1.7.2 Time delay

The time delay for SAPTUF is a settable definite time delay, specified by the setting *tDelay*.

Trip signal issuing requires that the under frequency condition continues for at least the user set time delay. If the START condition, with respect to the measured frequency ceases during the delay time, and is not fulfilled again within a defined reset time, the START output is reset.

On the RESTORE output of SAPTUF a 100 ms pulse is issued, after a time delay corresponding to the setting of *tRestore*, when the measured frequency returns to the level corresponding to the setting *RestoreFreq*.

7.1.7.3 Blocking

It is possible to block Under frequency protection (SAPTUF) completely, by binary input signal:

BLOCK:	blocks all outputs

If the measured voltage level decreases below the setting of *MinValFreqMeas* in the preprocessing function, both the START and the TRIP outputs, are blocked.

7.1.7.4 Design

The frequency measuring element continuously measures the frequency of the positive sequence voltage and compares it to the setting *StartFrequency*. The frequency signal is filtered to avoid transients due to switchings and faults in the power systems. When the frequency has returned back to the setting of *RestoreFreq*, the RESTORE output is issued after the time delay *tRestore*. The design of Under frequency protection (SAPTUF) is schematically described in figure 127.

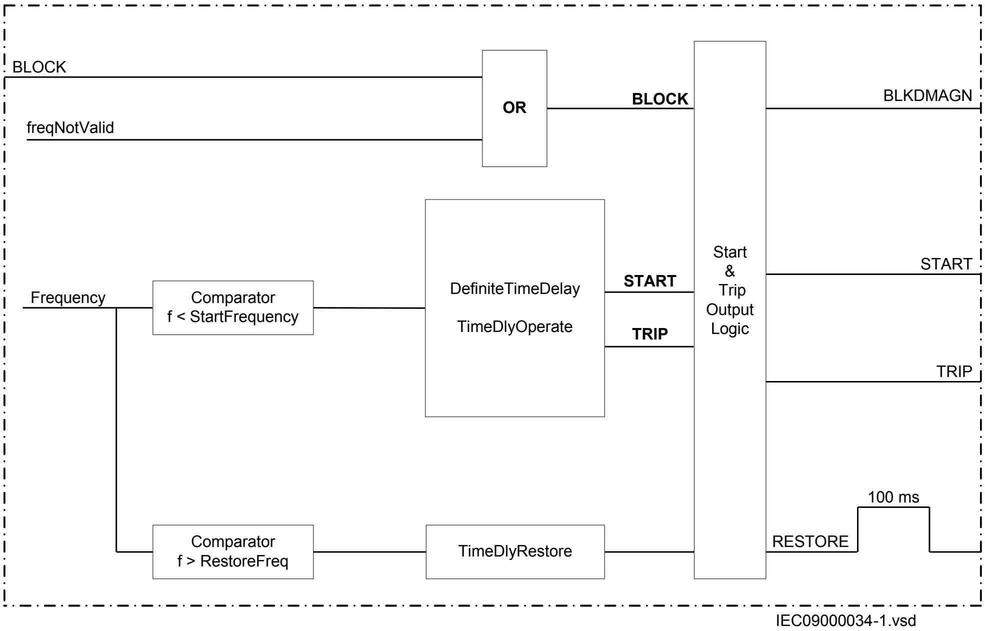


Figure 127: Schematic design of Under frequency function SAPTUF

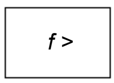
7.1.8 Technical data

Table 171: SAPTUF Technical data

Function	Range or value	Accuracy
Operate value, start function	(35.00-75.00) Hz	± 2.0 mHz
Operate value, restore frequency	(45 - 65) Hz	± 2.0 mHz
Operate time, start function	200 ms typically at f_r to 0.99 x f_{set}	-
Reset time, start function	50 ms typically at 1.01 x f_{set} to f_r	-
Timers	(0.000-60.000)s	± 0.5% + 10 ms

7.2 Over frequency protection SAPTOF

7.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Over frequency protection	SAPTOF		81

7.2.2 Functionality

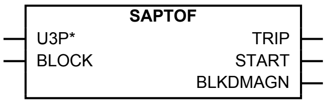
Over frequency protection (SAPTOF) function is applicable in all situations, where reliable detection of high fundamental power system frequency is needed.

Over frequency occurs at sudden load drops or shunt faults in the power network. Close to the generating plant, generator governor problems can also cause over frequency.

SAPTOF is used mainly for generation shedding and remedial action schemes. It is also used as a frequency stage initiating load restoring.

SAPTOF is provided with an under voltage blocking.

7.2.3 Function block



IEC09000280_1_en.vsd

Figure 128: SAPTOF function block

7.2.4 Signals

Table 172: SAPTOF Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function

Table 173: SAPTOF Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
START	BOOLEAN	General start signal
BLKDMAGN	BOOLEAN	Measurement blocked due to low amplitude

7.2.5 Settings

Table 174: SAPTOF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
StartFrequency	35.00 - 75.00	Hz	0.01	51.20	Frequency set value
tDelay	0.000 - 60.000	s	0.001	0.200	Operate time delay

7.2.6 Monitored data

Table 175: SAPTOF Monitored data

Name	Type	Values (Range)	Unit	Description
FREQ	REAL	-	Hz	Measured frequency

7.2.7 Operation principle

Over frequency protection (SAPTOF) is used to detect high power system frequency. SAPTOF has a settable definite time delay. If the frequency remains above the set value for a time period corresponding to the chosen time delay, the corresponding TRIP signal is issued. To avoid an unwanted TRIP due to uncertain frequency measurement at low voltage magnitude, a voltage controlled blocking of the function is available from the preprocessing function, that is, if the voltage is lower than the set blocking voltage in the preprocessing function, the function is blocked and no START or TRIP signal is issued.

7.2.7.1 Measurement principle

The fundamental frequency of the positive sequence voltage is measured continuously, and compared with the set value, *StartFrequency*. Over frequency protection (SAPTOF) is dependent on the voltage magnitude. If the voltage magnitude decreases below the setting *MinValFreqMeas* in the SMAI preprocessing function, which is set as a percentage of a global base voltage parameter *UBase*, SAPTOF is blocked, and the output BLKDMAGN is issued. All voltage settings are made in percent of the global parameter *UBase*. To avoid oscillations of the output START signal, a hysteresis has been included.

7.2.7.2 Time delay

The time delay for SAPTOF is a settable definite time delay, specified by the setting *tDelay*.

TRIP signal issuing requires that the over frequency condition continues for at least the user set time delay. If the START condition, with respect to the measured frequency ceases during the delay time, and is not fulfilled again within a defined reset time, the START output is reset.

7.2.7.3 Blocking

It is possible to block Over frequency protection (SAPTOF) completely, by binary input signals or by parameter settings, where:

BLOCK:	blocks all outputs

If the measured voltage level decreases below the setting of *MinValFreqMeas* in the preprocessing function SMAI, both the START and the TRIP outputs, are blocked.

7.2.7.4 Design

The frequency measuring element continuously measures the frequency of the positive sequence voltage and compares it to the setting *StartFrequency*. The frequency signal is filtered to avoid transients due to switchings and faults in the power system. The design of Over frequency protection (SAPTOF) is schematically described in figure 129.

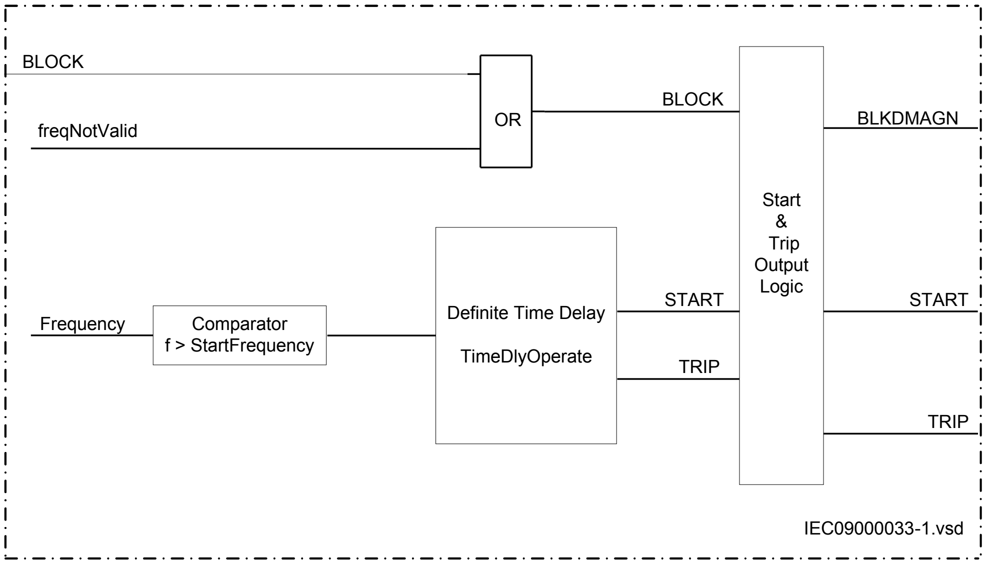


Figure 129: Schematic design of Over frequency protection (SAPTOF)

7.2.8 Technical data

Table 176: SAPTOF Technical data

Function	Range or value	Accuracy
Operate value, start function	(35.00-75.00) Hz	± 2.0 mHz at symmetrical three-phase voltage
Operate time, start function	200 ms typically at f_r to 1.01 x f_{set}	-
Reset time, start function	50 ms typically at 1.01 x f_{set} to f_r	-
Timer	(0.000-60.000)s	± 0.5% + 10 ms

7.3 Rate-of-change frequency protection SAPFRC

7.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Rate-of-change frequency protection	SAPFRC	df/dt ≷	81

7.3.2 Functionality

Rate-of-change frequency protection (SAPFRC) function gives an early indication of a main disturbance in the system. It can be used for generation shedding, load shedding, remedial action schemes etc. SAPFRC can discriminate between positive or negative change of frequency.

7.3.3 Function block

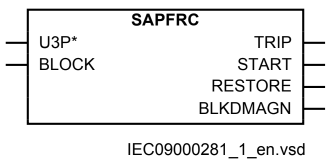


Figure 130: SAPFRC function block

7.3.4 Signals

Table 177: SAPFRC Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function

Table 178: SAPFRC Output signals

Name	Type	Description
TRIP	BOOLEAN	Operate/trip signal for frequency gradient
START	BOOLEAN	Start/pick-up signal for frequency gradient
RESTORE	BOOLEAN	Restore signal for load restoring purposes
BLKDMAGN	BOOLEAN	Blocking indication due to low amplitude

7.3.5 Settings

Table 179: SAPFRC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
StartFreqGrad	-10.00 - 10.00	Hz/s	0.01	0.50	Frequency gradient start value, the sign defines direction
tTrip	0.000 - 60.000	s	0.001	0.200	Operate time delay in positive / negative frequency gradient mode
RestoreFreq	45.00 - 65.00	Hz	0.01	49.90	Restore is enabled if frequency is above set frequency value
tRestore	0.000 - 60.000	s	0.001	0.000	Restore time delay

7.3.6 Operation principle

Rate-of-change frequency protection (SAPFRC) is used to detect fast power system frequency changes, increase as well as, decrease at an early stage. SAPFRC has a settable definite time delay. If the rate-of-change of frequency remains below the set value, for negative rate-of-change, for a time period equal to the chosen time delay, the TRIP signal is issued. If the rate-of-change of frequency remains above the set value, for positive rate-of-change, for a time period equal to the chosen time delay, the TRIP signal is issued. To avoid an unwanted trip due to uncertain frequency measurement at low voltage magnitude, a voltage controlled blocking of the function is available from the preprocessing function that is, if the voltage is lower than the set blocking voltage in the preprocessing function, the function is blocked and no START or TRIP signal is issued. If the frequency recovers, after a frequency decrease, a restore signal is issued.

7.3.6.1 Measurement principle

The rate-of-change of the fundamental frequency of the selected voltage is measured continuously, and compared with the set value, *StartFreqGrad*. Rate-of-change frequency protection (SAPFRC) is also dependent on the voltage magnitude. If the voltage magnitude decreases below the setting *MinValFreqMeas* in the preprocessing function,which is set as a percentage of a global base voltage parameter, SAPFRC is blocked, and the output BLKDMAGN is issued. The sign of the setting *StartFreqGrad*, controls if SAPFRC function reacts on a positive or on a negative change in frequency. If SAPFRC is used for decreasing frequency that is, the setting *StartFreqGrad* has been given a negative value, and a trip signal has been issued, then a 100 ms pulse is issued on the RESTORE output, when the frequency recovers to a value higher than the setting *RestoreFreq*. A positive setting of *StartFreqGrad*, sets SAPFRC function to START and TRIP for frequency increases.

To avoid oscillations of the output START signal, a hysteresis has been included.

7.3.6.2 Time delay

SAPFRC has a settable definite time delay, *tTrip*.

Trip signal issuing requires that SAPFRC condition continues for at least the user set time delay, *tTrip*. If the START condition, with respect to the measured frequency ceases during the delay time, and is not fulfilled again within a defined reset time, the START output is reset after the reset time has elapsed.

The RESTORE output of SAPFRC function is set, after a time delay equal to the setting of *tRestore*, when the measured frequency has returned to the level corresponding to *RestoreFreq*, after an issue of the TRIP output signal. If *tRestore* is set to 0.000 s the restore functionality is disabled, and no output will be given. The restore functionality is only active for lowering frequency conditions and the restore sequence is disabled if a new negative frequency gradient is detected during the restore period, defined by the settings *RestoreFreq* and *tRestore*.

7.3.6.3 Design

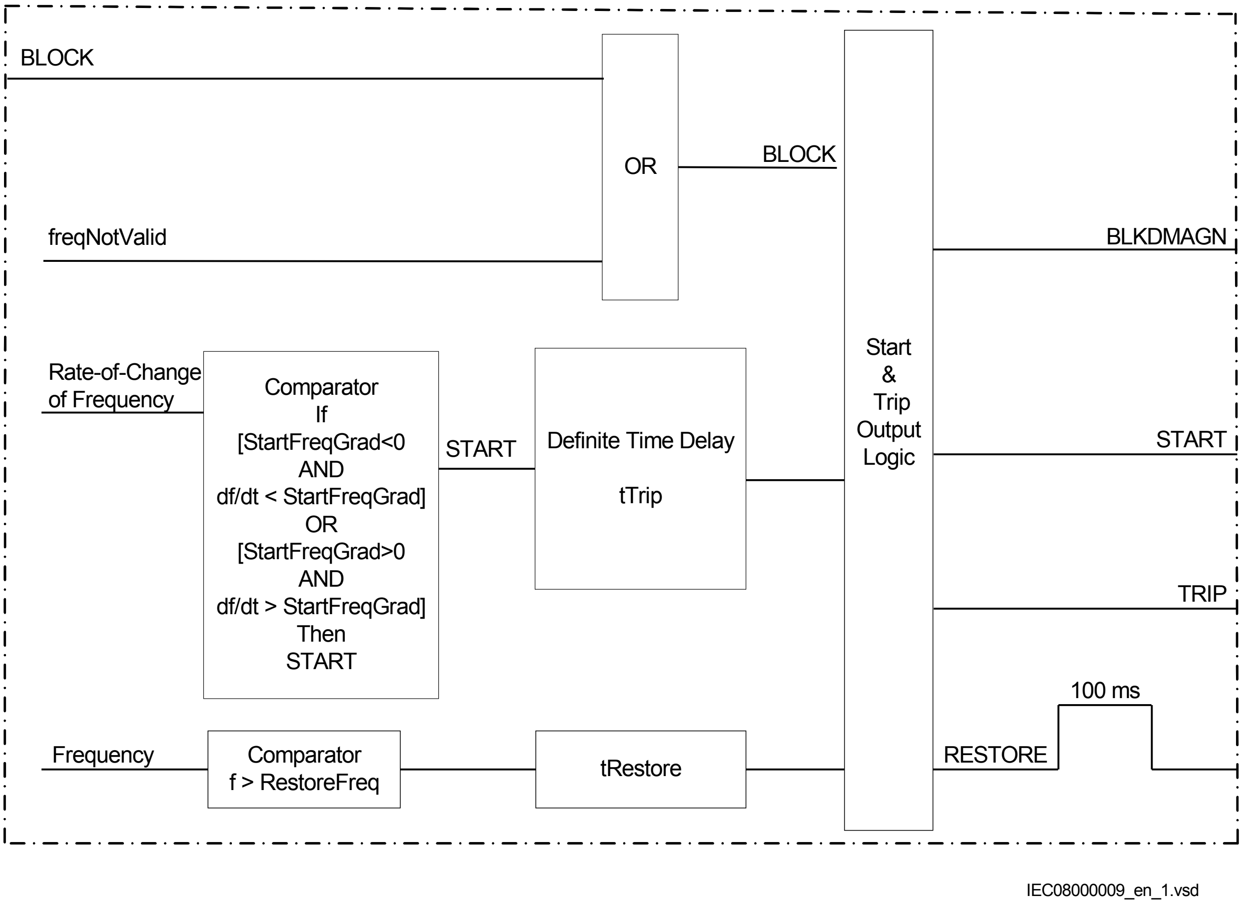


Figure 131: Schematic design of Rate-of-change frequency protection (SAPFRC)

7.3.7 Technical data

Table 180: SAPFRC Technical data

Function	Range or value	Accuracy
Operate value, start function	(-10.00-10.00) Hz/s	± 10.0 mHz/s
Operate value, restore enable frequency	(45.00 - 65.00) Hz	
Timers	(0.000 - 60.000) s	± 0.5% + 10 ms
Operate time, start function	100 ms typically	-

Section 8 Secondary system supervision

8.1 Current circuit supervison CCSRDIF

8.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current circuit supervision	CCSRDIF	-	-

8.1.2 Functionality

Open or short circuited current transformer cores can cause unwanted operation of many protection functions such as differential, earth fault current and negative sequence current functions.

It must be remembered that a blocking of protection functions at an occurrence of open CT circuit will mean that the situation will remain and extremely high voltages will stress the secondary circuit.

Current circuit supervision (CCSRDIF) compares the residual current from a three phase set of current transformer cores with the neutral point current on a separate input taken from another set of cores on the current transformer.

A detection of a difference indicates a fault in the circuit and is used as alarm or to block protection functions expected to give unwanted tripping.

8.1.3 Function block

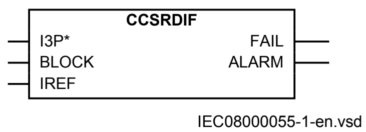


Figure 132: CCSRDIF function block

8.1.4 Signals

Table 181: CCSRDIF Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
IREF	GROUP SIGNAL	-	Group signal for current reference
BLOCK	BOOLEAN	0	Block of function

Table 182: CCSRDIF Output signals

Name	Type	Description
FAIL	BOOLEAN	Detection of current circuit failure
ALARM	BOOLEAN	Alarm for current circuit failure

8.1.5 Settings

Table 183: CCSRDIF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
IMinOp	5 - 200	%IB	1	20	Minimum operate current differential level in % of IBase

Table 184: CCSRDIF Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
Ip>Block	5 - 500	%IB	1	150	Block of the function at high phase current, in % of IBase

Table 185: CCSRDIF Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups

8.1.6 Operation principle

Current circuit supervison (CCSRDIF) compares the absolute value of the vectorial sum of the three phase currents |ΣIphase| and the numerical value of the residual current |Iref| from another current transformer set, see figure 133.

The FAIL output will be set to a logical one when the following criteria are fulfilled:

- The numerical value of the difference |ΣIphase| – |Iref| is higher than 80% of the numerical value of the sum |ΣIphase| + |Iref|.
- The numerical value of the current |ΣIphase| – |Iref| is equal to or higher than the set operate value *IMinOp*.
- No phase current has exceeded *Ip>Block* during the last 10 ms.
- CCSRDIF is enabled by setting *Operation = On*.

The FAIL output remains activated 100 ms after the AND-gate resets when being activated for more than 20 ms. If the FAIL lasts for more than 150 ms a ALARM will be issued. In this case the FAIL and ALARM will remain activated 1 s after the AND-gate resets. This prevents unwanted resetting of the blocking function when phase current supervision element(s) operate, for example, during a fault.

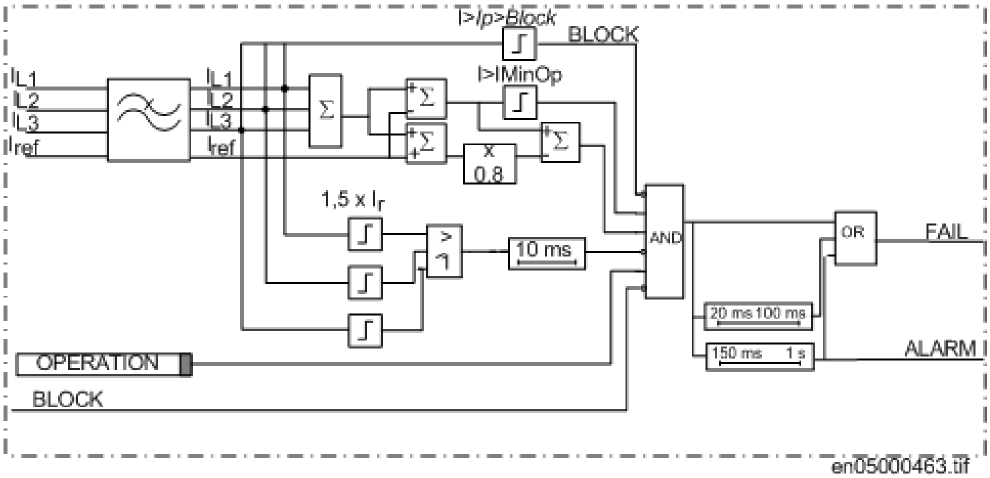


Figure 133: Simplified logic diagram for Current circuit supervision (CCSRDIF)

The operate characteristic is percentage restrained, see figure 134.

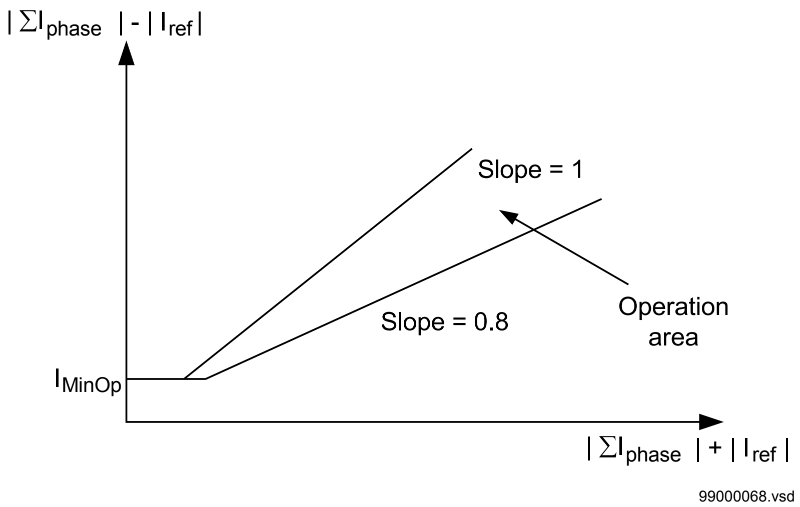


Figure 134: Operate characteristics

Due to the formulas for the axis compared, |ΣIphase | - |I ref | and |Σ I phase | + | I ref | respectively, the slope can not be above 2.

8.1.7 Technical data

Table 186: CCSRDIF Technical data

Function	Range or value	Accuracy
Operate current	(5-200)% of I_r	± 10.0% of I_r at $I \le I_r$ ± 10.0% of I at $I > I_r$
Block current	(5-500)% of I_r	± 5.0% of I_r at $I \le I_r$ ± 5.0% of I at $I > I_r$

8.2 Fuse failure supervision SDDRFUF

8.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fuse failure supervision	SDDRFUF	-	-

8.2.2 Functionality

The aim of the fuse failure supervision function (SDDRFUF) is to block voltage measuring functions at failures in the secondary circuits between the voltage transformer and the IED in order to avoid unwanted operations that otherwise might occur.

The fuse failure supervision function basically has two different algorithms, negative sequence and zero sequence based algorithm and an additional delta voltage and delta current algorithm.

The negative sequence detection algorithm is recommended for IEDs used in isolated or high-impedance earthed networks. It is based on the negative-sequence measuring quantities, a high value of voltage $3U_2$ without the presence of the negative-sequence current $3I_2$.

The zero sequence detection algorithm is recommended for IEDs used in directly or low impedance earthed networks. It is based on the zero sequence measuring quantities, a high value of voltage $3U_0$ without the presence of the residual current $3I_0$.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.

For better adaptation to system requirements, an operation mode setting has been introduced which makes it possible to select the operating conditions for negative sequence and zero sequence based function. The selection of different operation modes makes it possible to choose different interaction possibilities between the negative sequence and zero sequence based algorithm.

8.2.3 Function block

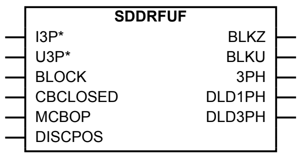


Figure 135: SDDRFUF function block

8.2.4 Signals

Table 187: SDDRFUF Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
Table continues on next page			

Name	Type	Default	Description
CBCLOSED	BOOLEAN	0	Active when circuit breaker is closed
MCBOP	BOOLEAN	0	Active when external MCB opens protected voltage circuit
DISCPOS	BOOLEAN	0	Active when line disconnector is open

Table 188: SDDRFUF Output signals

Name	Type	Description
BLKZ	BOOLEAN	Start of current and voltage controlled function
BLKU	BOOLEAN	General start of function
3PH	BOOLEAN	Three-phase start of function
DLD1PH	BOOLEAN	Dead line condition in at least one phase
DLD3PH	BOOLEAN	Dead line condition in all three phases

8.2.5 Settings

Table 189: SDDRFUF Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
OpMode	Off UNsINs UZsIZs UZsIZs OR UNsINs UZsIZs AND UNsINs OptimZsNs	-	-	UZsIZs	Operating mode selection
3U0>	1 - 100	%UB	1	30	Operate level of residual overvoltage element in % of UBase
3I0<	1 - 100	%IB	1	10	Operate level of residual undercurrent element in % of IBase
3U2>	1 - 100	%UB	1	30	Operate level of neg seq overvoltage element in % of UBase
3I2<	1 - 100	%IB	1	10	Operate level of neg seq undercurrent element in % of IBase
OpDUDI	Off On	-	-	Off	Operation of change based function Off/On
DU>	1 - 100	%UB	1	60	Operate level of change in phase voltage in % of UBase
DI<	1 - 100	%IB	1	15	Operate level of change in phase current in % of IBase
UPh>	1 - 100	%UB	1	70	Operate level of phase voltage in % of UBase
IPh>	1 - 100	%IB	1	10	Operate level of phase current in % of IBase
SealIn	Off On	-	-	On	Seal in functionality Off/On

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
USealIn<	1 - 100	%UB	1	70	Operate level of seal-in phase voltage in % of UBase
IDLD<	1 - 100	%IB	1	5	Operate level for open phase current detection in % of IBase
UDLD<	1 - 100	%UB	1	60	Operate level for open phase voltage detection in % of UBase

Table 190: SDDRFUF Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

8.2.6 Monitored data

Table 191: SDDRFUF Monitored data

Name	Type	Values (Range)	Unit	Description
3I0	REAL	-	A	Magnitude of zero sequence current
3I2	REAL	-	A	Magnitude of negative sequence current
3U0	REAL	-	kV	Magnitude of zero sequence voltage
3U2	REAL	-	kV	Magnitude of negative sequence voltage

8.2.7 Operation principle

8.2.7.1 Zero sequence

The fuse failure supervision (SDDRFUF) function can be set in five different modes by setting the parameter *OpMode*. The zero sequence function continuously measure the internal currents and voltages in all three phases and calculate:

- the zero-sequence voltage $3U_0$
- the zero-sequence current $3I_0$.

The measured signals are compared with their respective set values *3U0<* and *3I0>*.

The function enable the internal signal fuseFailDetected if the measured zero sequence voltage is higher than the set value *3U0>*, the measured zero sequence current is below the set value *3I0<* and the operation mode selector *(OpMode* is set to 2 (zero sequence mode). This will activate the output signal BLKU, intended to block voltage related protection functions in the IED. The output signal BLKZ will be activated as well if not the internal dead line detection is activated at the same time.

If the fuseFailDetected signal is present for more than 5 seconds at the same time as all phase voltages are below the set value *UPh>* and the setting parameter *SealIn* is set to On, the function will activate the output signals 3PH, BLKU and BLKZ. The same signals will also be activated if all phase voltages are below the value *UPh>*, SealIn=On and any of the phase voltages below the setting value for more than 5 seconds.

It is recommended to always set *SealIn* to *On* since this will secure that no unwanted operation of fuse failure will occur at closing command of breaker when the line is already energized from the other end. The system voltages shall be normal before fuse failure is allowed to be activated and initiate block of different protection functions.

The output signal BLKU can also be activated if no phase voltages is below the setting *UPh>* for more than 60 seconds at the same time as the zero sequence voltage is above the set value *3U0>* for more than 5 seconds, all phase currents are below the setting *IDLD<* (operate level for dead line detection) and the circuit breaker is closed (input CBCLOSED is activated). This condition covers for fuse failure at open breaker position.

Fuse failure condition is unlatched when the normal voltage conditions are restored.

Fuse failure condition is stored in the non volatile memory in the IED. In the new start-up procedure the IED checks the stored value in its non volatile memory and establishes the corresponding starting conditions.

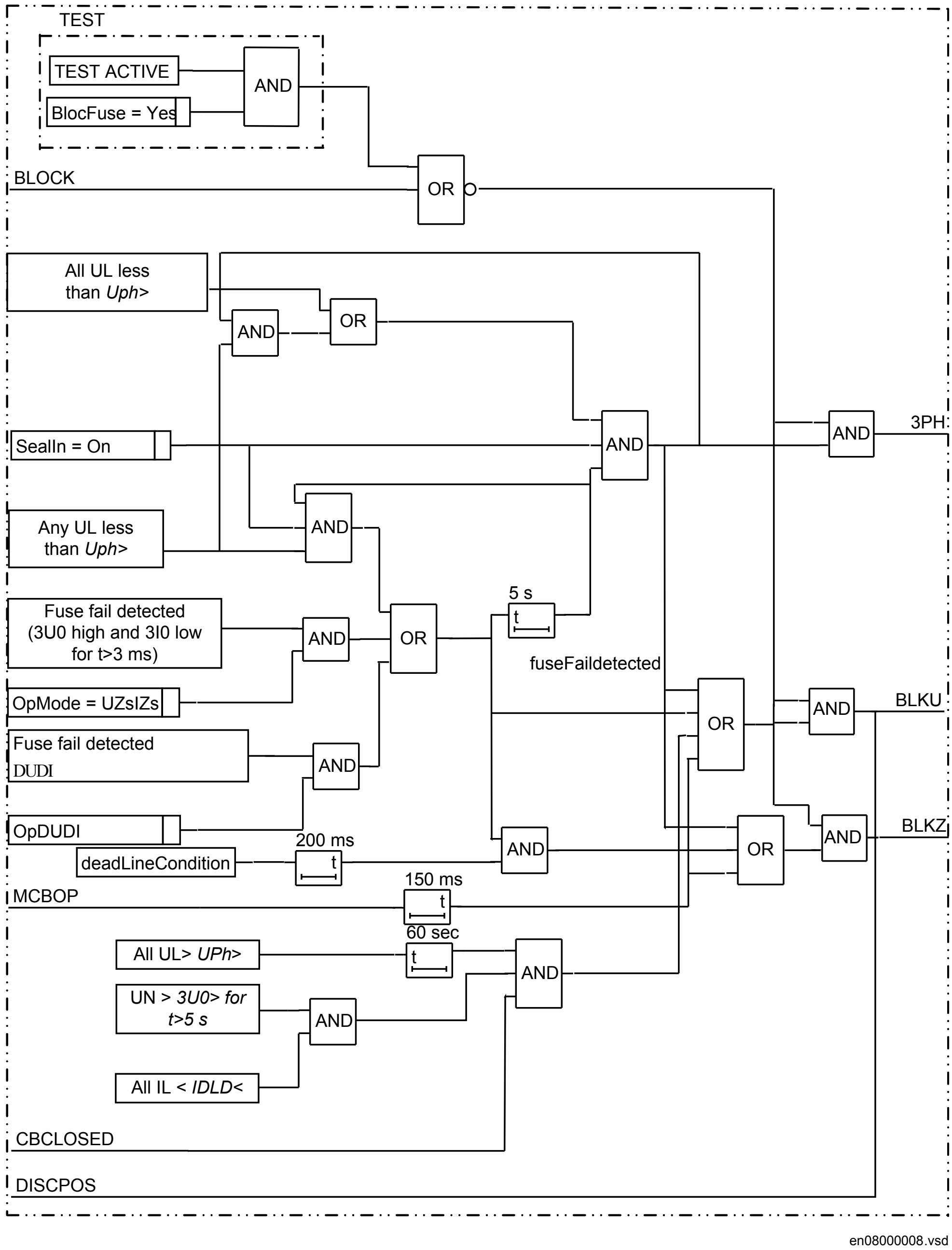


Figure 136: Simplified logic diagram for fuse failure supervision function, zero sequence based

Input and output signals

The output signals 3PH, BLKU and BLKZ can be blocked in the following conditions:

- The input BLOCK is activated
- The operation mode selector *OpMode* is set to *Off*.
- The IED is in TEST status (TEST-ACTIVE is high) and the function has been blocked from the HMI (*BlockFUSE=Yes*)

The input BLOCK signal is a general purpose blocking signal of the fuse failure supervision function. It can be connected to a binary input of the IED in order to receive a block command from external devices or can be software connected to other internal functions of the IED itself in order to receive a block command from internal functions. Through OR gate it can be connected to both binary inputs and internal function outputs.

The input BLKSP is intended to be connected to the trip output at any of the protection functions included in the IED. When activated for more than 20 ms, the operation of the fuse failure is blocked during a fixed time of 100 ms. The aim is to increase the security against unwanted operations during the opening of the breaker, which might cause unbalance conditions for which the fuse failure might operate.

The output signal BLKZ will also be blocked if the internal dead line detection is activated. The block signal has a 200 ms drop-out time delay.

The input signal MCBOP is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the miniature circuit breaker protecting the VT secondary circuit. The MCBOP signal sets the output signals BLKU and BLKZ in order to block all the voltage related functions when the MCB is open independent of the setting of *OpMode* selector. The additional drop-out timer of 150 ms prolongs the presence of MCBOP signal to prevent the unwanted operation of voltage dependent function due to non simultaneous closing of the main contacts of the miniature circuit breaker.

The input signal DISCPOS is supposed to be connected via a terminal binary input to the N.C. auxiliary contact of the line disconnector. The DISCPOS signal sets the output signal BLKU in order to block the voltage related functions when the line disconnector is open. The impedance protection function is not affected by the position of the line disconnector since there will be no line currents that can cause malfunction of the distance protection. If DISCPOS=0 it signifies that the line is connected to the system and when the DISCPOS=1 it signifies that the line is disconnected from the system and the block signal BLKU is generated.

The output BLKU can be used for blocking the voltage related measuring functions (undervoltage protection, synchro-check and so on) except for the impedance protection.

The function output BLKZ shall be used for blocking the impedance protection function.

8.2.7.2 Negative sequence

The negative sequence operates in the same way as the zero sequence, but it calculates the negative sequence component of current and voltage.

- the negative sequence current $3I_2$
- the negative sequence voltage $3U_2$

The function enable the internal signal fuseFailDetected if the measured negative sequence voltage is higher than the set value *3U2>*, the measured negative sequence current is below the value *3I2<* and the operation mode selector (*OpMode*) is set to 1 (negative sequence mode).

8.2.7.3 du/dt and di/dt

The delta function can be activated by setting the parameter *OperationDUDI* to *On*. When it is selected *On* it operates in parallel with the sequence based algorithm.

The current and voltage is continuously measured in all three phases and the following quantities are calculated:

- The change of voltage $\Delta U/\Delta t$
- The change of current $\Delta I/\Delta t$

The calculated delta quantities are compared with their respective set values *DI<* and *DU>*.

The delta current and delta voltage algorithm, detects a fuse failure if a sufficient negative change in voltage amplitude without a sufficient change in current amplitude is detected in each phase separately. This check is performed if the circuit breaker is closed. Information about the circuit breaker position is brought to the function input CBCLOSED through a binary input of the IED.

There are two conditions for activating the internal STDU signal and set the latch:

- The magnitude of ΔU is higher than the corresponding setting *DU>* and ΔI is below the setting *DI>* in any phase at the same time as the circuit breaker is closed (CBCLOSED = 1)
- The magnitude ΔU is higher than the setting *DU>* and the magnitude of ΔI is below the setting *DI>* in any phase at the same time as the magnitude of the phase current in the same phase is higher than the setting *IPh>*.

The first criterion requires that the delta condition shall be fulfilled in any phase at the same time as circuit breaker is closed. Opening circuit breaker at one end and energizing the line from other end onto a fault could lead to wrong start of the fuse failure function at the end with the open breaker. If this is considering to be an important disadvantage, connect the CBCLOSED input to FALSE. In this way only the second criterion can activate the delta function.

The second criterion means that detection of failure in one phase together with high current for the same phase will set the latch. The measured phase current is used to reduce the risk of false fuse failure detection. If the current on the protected line is low, a voltage drop in the system (not caused by fuse failure) is not by certain followed by current change and a false fuse failure might occur. To prevent that the phase current criterion is introduced.

If a fuse fail is detected (see figure 136), the output BLKU will be activated. If not the internal dead line detection is activated, BLKZ will be activated as well.

If all measured voltages are low (lower than the setting *UPh>*) for more than 5 seconds at the same time as a fuse fail is detected, the output 3PH will be activated. To release this indication all voltages must be over the setting *UPh>* and no fuse fail detected.

8.2.7.4 Operation modes

The fuse failure supervision function can be switched on or off by the setting parameter *Operation* to *On* or *Off*.

Negative and zero sequence algorithm

For increased flexibility and adaptation to system requirements, an operation mode selector, *OperationMode* has been introduced to make it possible to select different operating modes for the negative and zero sequence based algorithm. The different operation modes are:

- *OpMode* = 0, the negative and zero sequence function is switched off
- *OpMode* = 1; Negative sequence is selected
- *OpMode* = 2; Zero sequence is selected
- *OMode* = 3; Both negative and zero sequence is activated and working in parallel in an OR-condition
- *OpMode* = 4; Both negative and zero sequence is activated and working in series (AND-condition for operation)
- *OpMode* = 5; Optimum of negative and zero sequence (the function that has the highest magnitude of measured negative and zero sequence current will be activated).

du/dt and di/dt algorithm

The ΔU and ΔI function can be switched on or off by the setting parameter *OpDUDI* to *On* or *Off*.

Negative and zero sequence algorithm

For increased flexibility and adaptation to system requirements, an operation mode selector, *OperationMode* has been introduced to make it possible to select different operating modes for the negative and zero sequence based algorithm. The different operation modes are:

- *OpMode* = 0, the negative and zero sequence function is switched off
- *OpMode* = 1; Negative sequence is selected
- *OpMode* = 2; Zero sequence is selected

- *OMode* = 3; Both negative and zero sequence is activated and working in parallel in an OR-condition
- *OpMode* = 4; Both negative and zero sequence is activated and working in series (AND-condition for operation)
- *OpMode* = 5; Optimum of negative and zero sequence (the function that has the highest magnitude of measured negative and zero sequence current will be activated).

du/dt and di/dt algorithm

The ΔU and ΔI function can be switched on or off by the setting parameter *OpDUDI* to *On* or *Off*.

8.2.7.5 Dead line detection

The function input signal deadLineCondition (see figure 136) is related to the internal dead line detection function. This signal is activated from the dead line condition function when the voltage and the current in at least one phase is below their respective setting values *UDLD<* and *IDLD<*. It prevents the blocking of the impedance protection by a fuse failure detection during dead line condition (that occurs also during single pole auto-reclosing). The 200 ms drop-off timer prolongs the dead line condition after the line-energization in order to prevent the blocking of the impedance protection for unequal pole closing.

8.2.8 Technical data

Table 192: SDDRFUF Technical data

Function	Range or value	Accuracy
Operate voltage, zero sequence	(1-100)% of UBase	± 0.5% of U_r
Operate current, zero sequence	(1–100)% of IBase	± 1.0% of I_r
Operate voltage, negative sequence	(1–100)% of UBase	± 0.5% of U_r
Operate current, negative sequence	(1–100)% of IBase	± 1.0% of I_r
Operate voltage change level	(1–100)% of UBase	± 5.0% of U_r
Operate current change level	(1–100)% of IBase	± 5.0% of I_r

8.3 Breaker close/trip circuit monitoring TCSSCBR

8.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip circuit supervision	TCSSCBR	-	-

8.3.2 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 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.

8.3.3 Function block

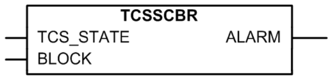


Figure 137: Function block

8.3.4 Signals

Table 193: TCSSCBR Input signals

Name	Type	Default	Description
TCS_STATE	BOOLEAN	0	Trip circuit fail indication from I/O-card
BLOCK	BOOLEAN	0	Block of function

Table 194: TCSSCBR Output signals

Name	Type	Description
ALARM	BOOLEAN	Trip circuit fault indication

8.3.5 Settings

Table 195: TCSSCBR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off/On
tDelay	0.020 - 300.000	s	0.001	3.000	Operate time delay

8.3.6 Monitored data

Table 196: TCSSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
ALARM	BOOLEAN	0=FALSE 1=TRUE	-	Trip circuit fault indication

8.3.7 Operation principle

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

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

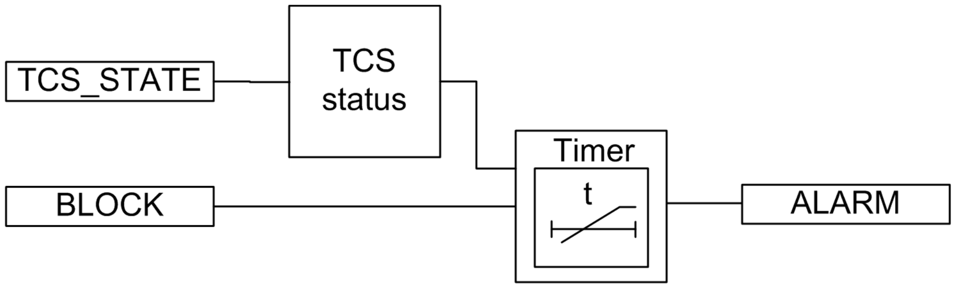


Figure 138: Functional module diagram

Trip circuit supervision generates a current of approximately 1.0 mA through the supervised circuit. It must be ensured that this current will not cause a latch up of the controlled object.

To protect the trip circuit supervision circuits in the IED, the output contacts are provided with parallel transient voltage suppressors. The breakdown voltage of these suppressors is 400 +/– 20 V DC.

Timer

Once activated, the timer runs until the set value *tDelay* is elapsed. The time characteristic is according to DT. When the operation timer has reached the maximum time value, the ALARM output is activated. If a drop-off situation occurs during the operate time up counting, the reset timer is activated.

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates the ALARM output and resets the internal timer.

8.3.8 Technical data

Table 197: TCSSCBR Technical data

Function	Range or value	Accuracy
Operate time delay	(0.020 - 300.000)s	± 0,5% ± 10ms

Section 9 Control

9.1 Synchrocheck, energizing check, and synchronizing SESRSYN

9.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Synchrocheck, energizing check, and synchronizing	SESRSYN	sc/vc	25

9.1.2 Functionality

The Synchronizing function allows closing of asynchronous networks at the correct moment including the breaker closing time. The systems can thus be reconnected after an auto-reclose or manual closing which improves the network stability.

The Synchrocheck, energizing check function (SESRSYN) checks that the voltages on both sides of the circuit breaker are in synchronism, or with at least one side dead to ensure that closing can be done safely.

The function includes a built-in voltage selection scheme for double bus and 1½ or ring busbar arrangements.

Manual closing as well as automatic reclosing can be checked by the function and can have different settings.

For systems which are running asynchronous a synchronizing function is provided. The main purpose of the synchronizing function is to provide controlled closing of circuit breakers when two asynchronous systems are going to be connected. It is used for slip frequencies that are larger than those for synchrocheck and lower than a set maximum level for the synchronizing function.

Do not configure inputs LNQOPEN and LNQCLD, since they are not supported in the IED.

9.1.3 Function block

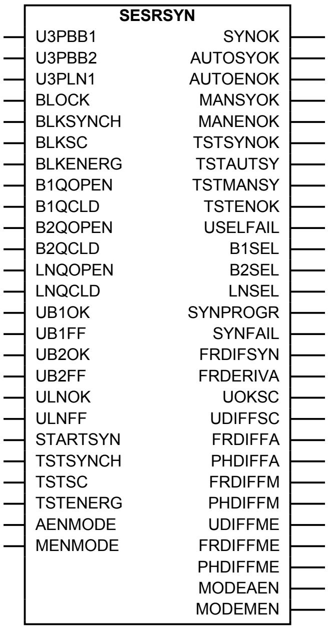


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Figure 139: SESRSYN function block

9.1.4 Signals

Table 198: SESRSYN Input signals

Name	Type	Default	Description
U3PBB1	GROUP SIGNAL	-	Group Signal for Voltage input Bus Bar 1
U3PBB2	GROUP SIGNAL	-	Group Signal for Voltage input Bus Bar 2
U3PLN1	GROUP SIGNAL	-	Group Signal for Voltage input Line 1
BLOCK	BOOLEAN	0	General block
BLKSYNCH	BOOLEAN	0	Block synchronizing
BLKSC	BOOLEAN	0	Block synchro check
BLKENERG	BOOLEAN	0	Block energizing check
B1QOPEN	BOOLEAN	0	Open status for CB or disconnector connected to bus1
B1QCLD	BOOLEAN	0	Close status for CB or disconnector connected to bus1
B2QOPEN	BOOLEAN	0	Open status for CB or disconnector connected to bus2
B2QCLD	BOOLEAN	0	Close status for CB or disconnector connected to bus2

Table continues on next page

Name	Type	Default	Description
LNQOPEN	BOOLEAN	0	Open status for CB or disconnector connected to line
LNQCLD	BOOLEAN	0	Close status for CB or disconnector connected to line
UB1OK	BOOLEAN	0	Bus1 voltage transformer OK
UB1FF	BOOLEAN	0	Bus1 voltage transformer fuse failure
UB2OK	BOOLEAN	0	Bus2 voltage transformer OK
UB2FF	BOOLEAN	0	Bus2 voltage transformer fuse failure
ULNOK	BOOLEAN	0	Line voltage transformer OK
ULNFF	BOOLEAN	0	Line voltage transformer fuse failure
STARTSYN	BOOLEAN	0	Start synchronizing
TSTSYNCH	BOOLEAN	0	Set synchronizing in test mode
TSTSC	BOOLEAN	0	Set synchro check in test mode
TSTENERG	BOOLEAN	0	Set energizing check in test mode
AENMODE	INTEGER	0	Input for setting of automatic energizing mode
MENMODE	INTEGER	0	Input for setting of manual energizing mode

Table 199: SESRSYN Output signals

Name	Type	Description
SYNOK	BOOLEAN	Synchronizing OK output
AUTOSYOK	BOOLEAN	Auto synchro check OK
AUTOENOK	BOOLEAN	Automatic energizing check OK
MANSYOK	BOOLEAN	Manual synchro check OK
MANENOK	BOOLEAN	Manual energizing check OK
TSTSYNOK	BOOLEAN	Synchronizing OK test output
TSTAUTSY	BOOLEAN	Auto synchro check OK test output
TSTMANSY	BOOLEAN	Manual synchro check OK test output
TSTENOK	BOOLEAN	Energizing check OK test output
USELFAIL	BOOLEAN	Selected voltage transformer fuse failed
B1SEL	BOOLEAN	Bus1 selected
B2SEL	BOOLEAN	Bus2 selected
LNSEL	BOOLEAN	Line selected
SYNPROGR	BOOLEAN	Synchronizing in progress
SYNFAIL	BOOLEAN	Synchronizing failed
FRDIFSYN	BOOLEAN	Frequency difference out of limit for synchronizing
FRDERIVA	BOOLEAN	Frequency derivative out of limit for synchronizing
UOKSC	BOOLEAN	Voltage amplitudes above set limits
UDIFFSC	BOOLEAN	Voltage difference out of limit
FRDIFFA	BOOLEAN	Frequency difference out of limit for Auto operation

Table continues on next page

Name	Type	Description
PHDIFFA	BOOLEAN	Phase angle difference out of limit for Auto operation
FRDIFFM	BOOLEAN	Frequency difference out of limit for Manual operation
PHDIFFM	BOOLEAN	Phase angle difference out of limit for Manual Operation
UDIFFME	REAL	Calculated difference in voltage
FRDIFFME	REAL	Calculated difference in frequency
PHDIFFME	REAL	Calculated difference of phase angle
MODEAEN	INTEGER	Selected mode for automatic energizing
MODEMEN	INTEGER	Selected mode for manual energizing

9.1.5 Settings

Table 200: SESRSYN Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
SelPhaseBus1	phase1 phase2 phase3 phase1-phase2 phase2-phase3 phase3-phase1	-	-	phase2	Select phase for bus1
SelPhaseBus2	phase1 phase2 phase3 phase1-phase2 phase2-phase3 phase3-phase1	-	-	phase2	Select phase for bus2
SelPhaseLine	phase1 phase2 phase3 phase1-phase2 phase2-phase3 phase3-phase1	-	-	phase2	Select phase for line
PhaseShift	-180 - 180	Deg	5	0	Phase shift
URatio	0.20 - 5.00	-	0.01	1.00	Voltage ratio
OperationSynch	Off On	-	-	Off	Operation for synchronizing function Off/ On
FreqDiffMin	0.003 - 0.250	Hz	0.001	0.010	Minimum frequency difference limit for synchronizing
FreqDiffMax	0.050 - 0.500	Hz	0.001	0.200	Maximum frequency difference limit for synchronizing
FreqRateChange	0.000 - 5.000	Hz/s	0.001	0.300	Maximum allowed frequency rate of change
tBreaker	0.000 - 60.000	s	0.001	0.080	Closing time of the breaker
tClosePulse	0.050 - 60.000	s	0.001	0.200	Breaker closing pulse duration
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
tMaxSynch	0.00 - 6000.00	s	0.01	600.00	Resets synchronization if no close has been made before set time
tMinSynch	0.000 - 60.000	s	0.001	2.000	Minimum time to accept synchronizing conditions
OperationSC	Off On	-	-	On	Operation for synchronism check function Off/On
UDiffSC	2.0 - 50.0	%UB	1.0	15.0	Voltage difference limit in % of UBase
FreqDiffA	0.003 - 1.000	Hz	0.001	0.010	Frequency difference limit between bus and line Auto
FreqDiffM	0.003 - 1.000	Hz	0.001	0.010	Frequency difference limit between bus and line Manual
PhaseDiffA	5.0 - 90.0	Deg	1.0	25.0	Phase angle difference limit between bus and line Auto
PhaseDiffM	5.0 - 90.0	Deg	1.0	25.0	Phase angle difference limit between bus and line Manual
tSCA	0.000 - 60.000	s	0.001	0.100	Time delay for synchrocheck Auto
tSCM	0.000 - 60.000	s	0.001	0.100	Time delay for synchrocheck Manual
AutoEnerg	Off DLLB DBLL Both	-	-	DBLL	Automatic energizing check mode
ManEnerg	Off DLLB DBLL Both	-	-	Both	Manual energizing check mode
ManEnergDBDL	Off On	-	-	Off	Manual dead bus, dead line energizing
tAutoEnerg	0.000 - 60.000	s	0.001	0.100	Time delay for automatic energizing check
tManEnerg	0.000 - 60.000	s	0.001	0.100	Time delay for manual energizing check

Table 201: SESRSYN Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

9.1.6 Monitored data

Table 202: SESRSYN Monitored data

Name	Type	Values (Range)	Unit	Description
UDIFFME	REAL	-	kV	Calculated difference in voltage
FRDIFFME	REAL	-	Hz	Calculated difference in frequency
PHDIFFME	REAL	-	deg	Calculated difference of phase angle

9.1.7 Operation principle

9.1.7.1 Basic functionality

The synchrocheck function measures the conditions across the circuit breaker and compares them to set limits. The output is only given when all measured quantities are simultaneously within their set limits.

The energizing check function measures the bus and line voltages and compares them to both high and low threshold detectors. The output is given only when the actual measured quantities match the set conditions.

The synchronizing function measures the conditions across the circuit breaker, and also determines the angle change occurring during the closing delay of the circuit breaker, from the measured slip frequency. The output is given only when all measured conditions are simultaneously within their set limits. The issue of the output is timed to give closure at the optimal time including the time for the circuit breaker and the closing circuit.

For single circuit breaker arrangements, the SESRSYN function blocks have the capability to make the necessary voltage selection. The selection of correct voltage is made using auxiliary contacts of the bus disconnectors.

The internal logic for each function block as well as, the Input and Outputs, and the settings with default setting and setting ranges is described in this document. For application related information, please refer to the Application manual.

9.1.7.2 Synchrocheck

The voltage difference, frequency difference and phase angle difference values are measured in the IED centrally and are available for the Synchrocheck function for evaluation. If the bus voltage is connected as phase-phase and the line voltage as phase-neutral (or the opposite), this need to be compensated. This is done with a setting, which scales up the line voltage to a level equal to the bus voltage.

When the function is set to *OperationSC* = *On*, the measuring will start.

The function compares bus and line values with the set values for acceptable frequency, phase angle and voltage difference: FreqDiffA/M, PhaseDiffA/M and UDiffSC. If a compensation factor is set due to the use of different voltages on the bus and line, the factor is deducted from the line voltage before the comparison of the phase angle values.

The frequency on both sides of the circuit breaker is also measured. The frequencies must not deviate from the rated frequency more than +/-5Hz. The frequency difference between the bus frequency and the line frequency is measured and may not exceed the set value.

Two sets of settings for frequency difference and phase angle difference are available and used for the manual closing and Autoreclose functions respectively, as required.

The inputs BLOCK and BLKSC are available for total block of the complete Synchrocheck function and block of the Synchrocheck function respectively. Input TSTSC will allow testing of the function where the fulfilled conditions are connected to a separate test output.

The outputs MANSYOK and AUTOSYOK are activated when the actual measured conditions match the set conditions for the respective output. The output signal can be delayed independently for MANSYOK and AUTOSYOK conditions.

A number of outputs are available as information about fulfilled checking conditions. UOKSC shows that the voltages are high, UDIFFSC, FRDIFFM/A, PHDIFFM/A shows when the voltage difference, frequency difference and phase angle difference conditions are met.

9.1.7.3 Synchronizing

When the function is set to *OperationSynch=On* the measuring will be performed.

The function compares the values for the bus and line voltage which is a supervision that the voltages are both live. If both sides are live, the measured values are compared with the set values for acceptable frequency, rate of change of frequency and phase angle and *FreqDiffMin*.

Measured frequencies between the settings for the maximum and minimum frequency will initiate the measuring and the evaluation of the angle change to allow operation to be sent in the right moment including the set *tBreaker* time. There is a phase angle release internally to block any incorrect closing pulses. At operation the SYNOK output will be activated with a pulse *tClosePulse* and the function reset. The function will also reset if the syncronizing conditions are not fulfilled within the set *tMaxSynch* time. This prevents that the functions are, by mistake, maintained in operation for a long time, waiting for conditions to be fulfilled.

The inputs BLOCK and BLKSYNCH are available for total block of the complete function and of the synchronizing part.TSTSYNCH will allow testing of the function where the fulfilled conditions are connected to a separate output.

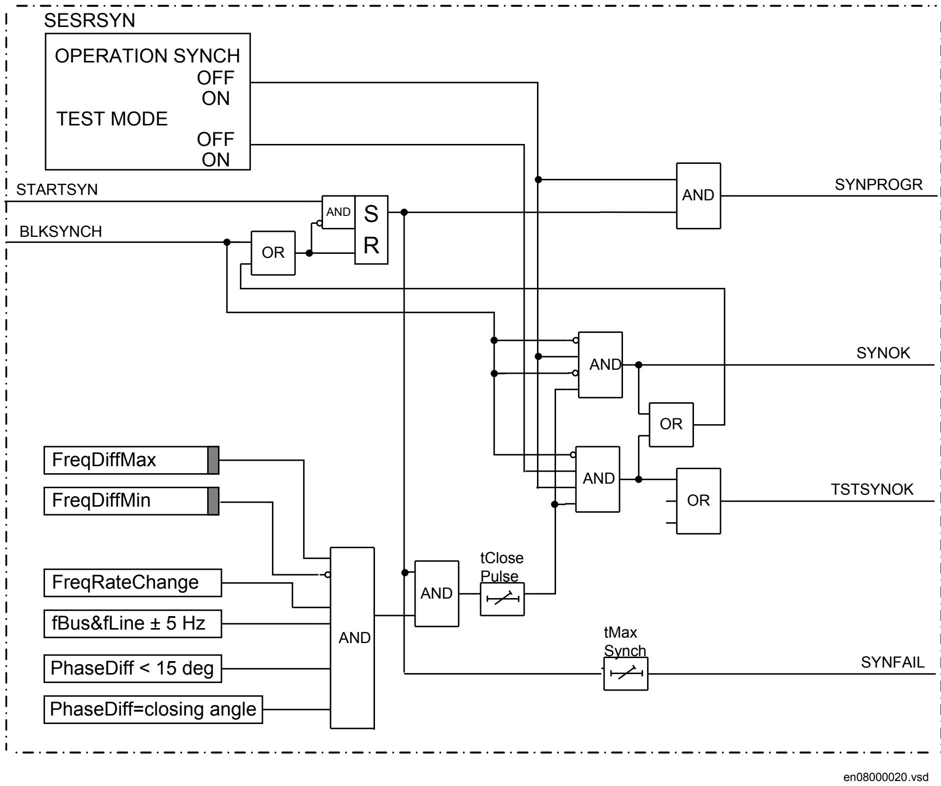

Figure 140: Simplified logic diagram for the synchronizing function

9.1.7.4 Energizing check

Voltage values are measured in the IED centrally and are available for evaluation by the Energizing check function.

The frequency on both sides of the circuit breaker is also measured. The frequencies must not deviate from the rated frequency more than +/-5Hz.

The Energizing direction can be selected individually for the Manual and the Automatic functions respectively. When the conditions are met the outputs AUTOENOK and MANENOK respectively will be activated if the fuse supervision conditions are fulfilled. The output signal can be delayed independently for MANENOK and AUTOENOK conditions. The Energizing direction can also be selected by an integer input AENMODE and MENMODE, which for example, can be connected to a Binary to Integer function block (B16I). Integers supplied shall be 1=off, 2=DLLB, 3=DBLL and 4= Both. Not connected input with connection of INTZERO output from Fixed Signals function block will mean that the setting is done from PST tool. The active position can be read on outputs MODEAEN resp MODEMEN. The modes are 0=OFF, 1=DLLB, 2=DBLL and 3=Both.

The inputs BLOCK and BLKENERG are available for total block of the complete Synchronizing function and block of the Energizing check function. TSTENERG will allow testing of the function where the fulfilled conditions are connected to a separate test output.

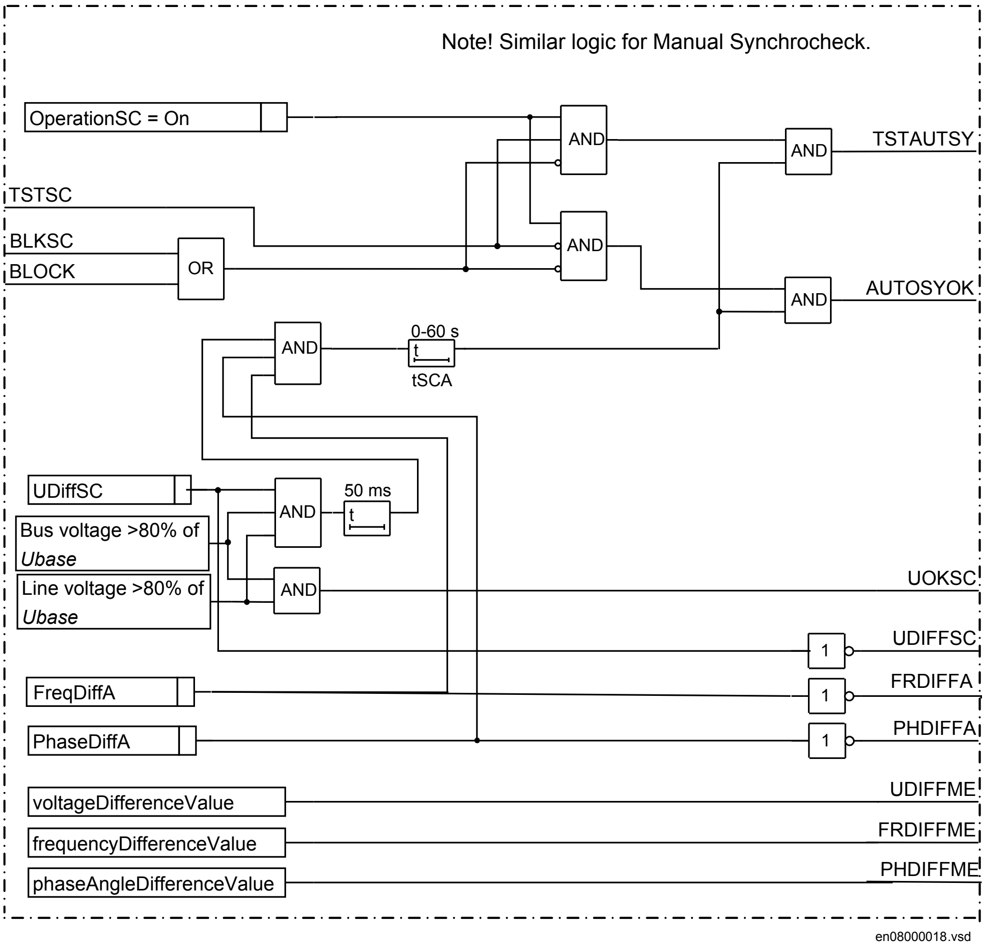

Figure 141: Simplified logic diagram for the Synchrocheck function

9.1.7.5 Voltage selection

The voltage selection module including supervision of included voltage transformer fuses for the different arrangements is a basic part of the Synchronizing function and determines the parameters fed to the Synchronizing, Synchrocheck and Energizing check functions. This includes the selection of the appropriate Line and Bus voltages and fuse supervision.

The default voltages used will be ULine1 and UBus1. This is also the case when external voltage selection is provided. Fuse failure supervision for the used inputs must also be connected.

The voltage selection function, selected voltages, and fuse conditions are the Synchronizing, Synchrocheck and Energizing check inputs.

For the disconnector positions it is advisable to use (NO) a and (NC) b type contacts to supply Disconnector Open and Closed positions but, it is also possible to use an inverter for one of the positions.

9.1.7.6 Fuse failure supervision

External fuse-failure signals or signals from a tripped fuse switch/MCB are connected to binary inputs that are configured to the inputs of the Synchronizing functions in the IED. Alternatively, the internal signals from fuse failure supervision can be used when available. There are two alternative connection possibilities. Inputs labelled OK must be connected if the available contact indicates that the voltage circuit is healthy. Inputs labelled FF must be connected if the available contact indicates that the voltage circuit is faulty.

The UB1OK/UB2OK and UB1FF/UB2FF inputs are related to the busbar voltage and theULNOK and ULNFF inputs are related to the line voltage. Configure them to the binary inputs or function outputs that indicate the status of the external fuse failure of the busbar and line voltages. In the event of a fuse failure, the energizing check functions are blocked. The Synchronizing and the Synchrocheck function requires full voltage on both sides and will be blocked automatically in the event of fuse failures.

9.1.7.7 Voltage selection for a single circuit breaker with double busbars

This function uses the binary input from the disconnectors auxiliary contacts B1QOPEN-B1QCLD for Bus 1, and B2QOPEN-B2QCLD for Bus 2 to select between bus 1 and bus 2 voltages. If the disconnector connected to bus 2 is closed and the disconnector connected to bus 1 is opened the bus 2 voltage is used. All other combinations use the bus 1 voltage. The Outputs B1SEL and B2SEL respectively indicate the selected Bus voltage.

The function checks the fuse-failure signals for bus 1, bus 2 and line voltage transformers. Inputs UB1OK-UB1FF supervise the fuse for Bus 1. UB2OK-UB2FF supervises the fuse for Bus 2 and ULNOK-ULNFF supervises the fuse for the Line voltage transformer. The inputs fail (FF) or healthy (OK) can alternatively be used dependent on the available signal. If a fuse-failure is detected in the selected voltage source an output signal USELFAIL is set. This output signal is true if the selected bus or line voltages have a fuse failure. This output as well as the function can be blocked with the input signal BLOCK. The function logic diagram is shown in figure 142.

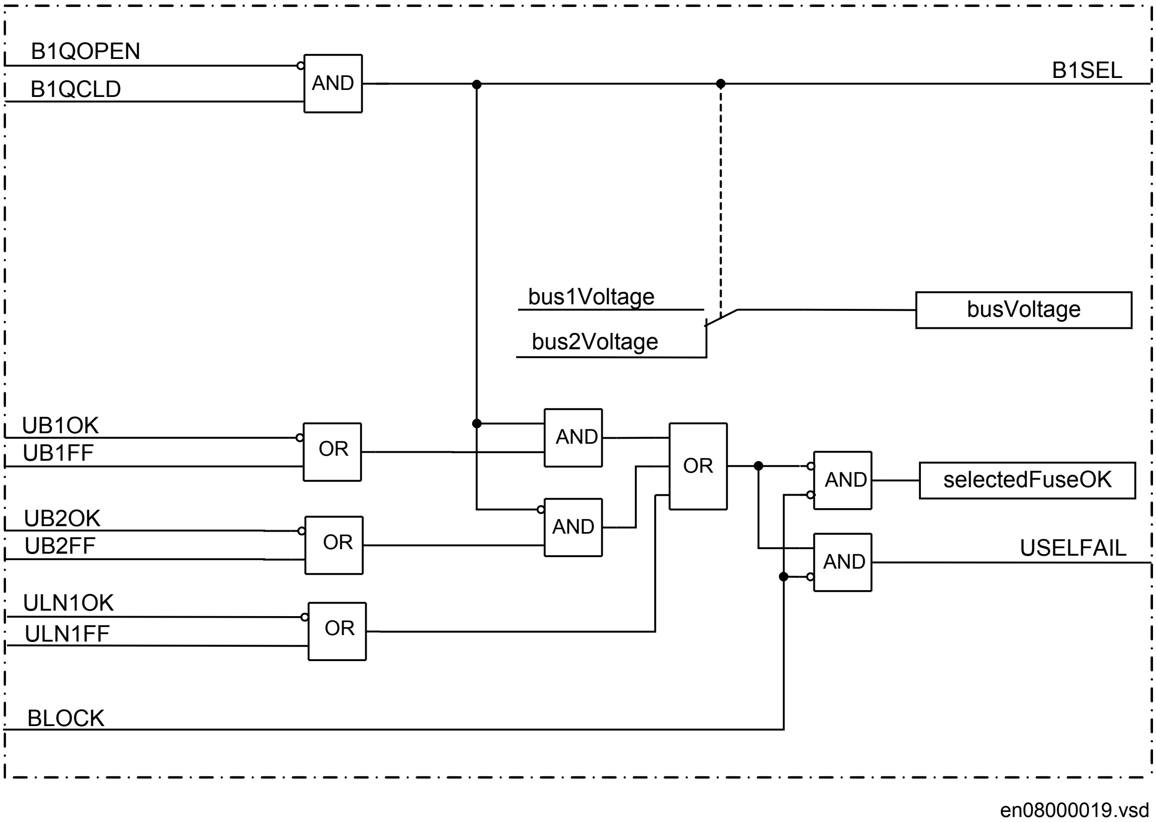

Figure 142: Logic diagram for the voltage selection function of a single circuit breaker with double busbars

9.1.8 Technical data

Table 203: SESRSYN Technical data

Function	Range or value	Accuracy
Phase shift, φ_{line} - φ_{bus}	(-180 to 180) degrees	-
Voltage ratio, U_{bus}/U_{line}	0.20-5.00	-
Frequency difference limit between bus and line	(0.003-1.000) Hz	± 2.0 mHz
Phase angle difference limit between bus and line	(5.0-90.0) degrees	± 2.0 degrees
Voltage difference limit between bus and line	(2.0-50.0)% of Ubase	± 0.5% of U_r
Time delay output for synchrocheck	(0.000-60.000) s	± 0.5% ± 10 ms
Time delay for energizing check	(0.000-60.000) s	± 0.5% ± 10 ms
Operate time for synchrocheck function	160 ms typically	-
Operate time for energizing function	80 ms typically	-

9.2 Autorecloser SMBRREC

9.2.1 Identification

Function Description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Autorecloser	SMBRREC	O->I	79

9.2.2 Functionality

The autoreclosing function provides high-speed and/or delayed auto-reclosing for single breaker applications.

Up to five reclosing attempts can be programmed.

The autoreclosing function can be configured to co-operate with a synchrocheck function.

9.2.3 Function block

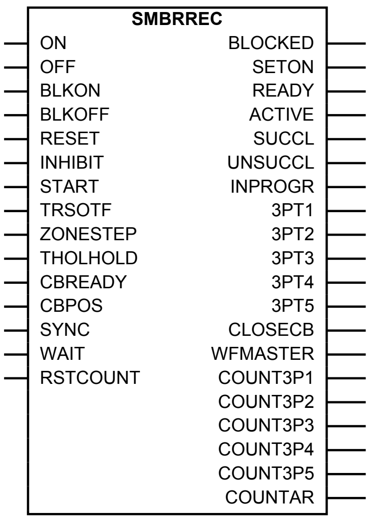

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Figure 143: SMBRREC function block

9.2.4 Signals

Table 204: SMBRREC Input signals

Name	Type	Default	Description
ON	BOOLEAN	0	Switches AR On when Operation = ExternalCtrl
OFF	BOOLEAN	0	Switches AR Off when Operation = ExternalCtrl
BLKON	BOOLEAN	0	Sets AR in blocked state
BLKOFF	BOOLEAN	0	Releases AR from blocked state
RESET	BOOLEAN	0	Resets AR to initial conditions
INHIBIT	BOOLEAN	0	Interrupts and inhibits reclosing sequence
START	BOOLEAN	0	Reclosing sequence starts by a protection trip signal
TRSOTF	BOOLEAN	0	Makes AR to continue to shots 2-5 at a trip from SOTF
ZONESTEP	BOOLEAN	0	Coordination between local AR and down stream devices
THOLHOLD	BOOLEAN	0	Holds AR in wait state
CBREADY	BOOLEAN	0	CB must be ready for CO/OCO operation to allow start / close
CBPOS	BOOLEAN	0	Status of the circuit breaker Closed/Open
SYNC	BOOLEAN	0	Synchronizing check fulfilled for 3Ph closing attempts
WAIT	BOOLEAN	0	Wait for master in Multi-breaker arrangements
RSTCOUNT	BOOLEAN	0	Resets all counters

Table 205: SMBRREC Output signals

Name	Type	Description
BLOCKED	BOOLEAN	AR is in blocked state
SETON	BOOLEAN	AR operation is switched on
READY	BOOLEAN	Indicates that AR is ready for a new sequence
ACTIVE	BOOLEAN	Reclosing sequence in progress
SUCCL	BOOLEAN	Activated if CB closes during the time tUnsucCl
UNSUCCL	BOOLEAN	Reclosing unsuccessful, signal resets after the reclaim time
INPROGR	BOOLEAN	Reclosing shot in progress, activated during open time
3PT1	BOOLEAN	Three-phase reclosing in progress, shot 1
3PT2	BOOLEAN	Three-phase reclosing in progress, shot 2
3PT3	BOOLEAN	Three-phase reclosing in progress, shot 3
3PT4	BOOLEAN	Three-phase reclosing in progress, shot 4
3PT5	BOOLEAN	Three-phase reclosing in progress, shot 5
CLOSECB	BOOLEAN	Closing command for CB

Table continues on next page

Name	Type	Description
WFMASTER	BOOLEAN	Signal to Slave issued by Master for sequential reclosing
COUNT3P1	INTEGER	Counting the number of three-phase reclosing shot 1
COUNT3P2	INTEGER	Counting the number of three-phase reclosing shot 2
COUNT3P3	INTEGER	Counting the number of three-phase reclosing shot 3
COUNT3P4	INTEGER	Counting the number of three-phase reclosing shot 4
COUNT3P5	INTEGER	Counting the number of three-phase reclosing shot 5
COUNTAR	INTEGER	Counting total number of reclosing shots

9.2.5 Settings

Table 206: SMBRREC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off External ctrl On	-	-	External ctrl	Off / ExternalCtrl / On
t1 3Ph	0.000 - 60.000	s	0.001	6.000	Open time for shot 1, delayed reclosing 3ph
tReclaim	0.00 - 6000.00	s	0.01	60.00	Duration of the reclaim time
tSync	0.00 - 6000.00	s	0.01	30.00	Maximum wait time for synchrocheck OK
tTrip	0.000 - 60.000	s	0.001	0.200	Maximum trip pulse duration
tCBClosedMin	0.00 - 6000.00	s	0.01	5.00	Minimum time that CB must be closed before new sequence allows
tUnsucCl	0.00 - 6000.00	s	0.01	30.00	Wait time for CB before indicating Unsuccessful/Successful
Priority	None Low High	-	-	None	Priority selection between adjacent terminals None/Low/High
tWaitForMaster	0.00 - 6000.00	s	0.01	60.00	Maximum wait time for release from Master

Table 207: SMBRREC Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
NoOfShots	1 2 3 4 5	-	-	1	Maximum number of reclosing shots 1-5
StartByCBOpen	Off On	-	-	Off	To be set ON if AR is to be started by CB open position
CBAuxContType	NormClosed NormOpen	-	-	NormOpen	Select CB auxilary contact type NC/NO for CBPOS input
CBReadyType	CO OCO	-	-	CO	Select type of circuit breaker ready signal CO/OCO
t2 3Ph	0.00 - 6000.00	s	0.01	30.00	Open time for shot 2, three-phase
t3 3Ph	0.00 - 6000.00	s	0.01	30.00	Open time for shot 3, three-phase
t4 3Ph	0.00 - 6000.00	s	0.01	30.00	Open time for shot 4, three-phase
t5 3Ph	0.00 - 6000.00	s	0.01	30.00	Open time for shot 5, three-phase
tInhibit	0.000 - 60.000	s	0.001	5.000	Inhibit reclosing reset time
Follow CB	Off On	-	-	Off	Advance to next shot if CB has been closed during dead time
AutoCont	Off On	-	-	Off	Continue with next reclosing-shot if breaker did not close
tAutoContWait	0.000 - 60.000	s	0.001	2.000	Wait time after close command before proceeding to next shot
UnsucClByCBChk	NoCBCheck CB check	-	-	NoCBCheck	Unsuccessful closing signal obtained by checking CB position
BlockByUnsucCl	Off On	-	-	Off	Block AR at unsuccessful reclosing
ZoneSeqCoord	Off On	-	-	Off	Coordination of down stream devices to local protection unit’s AR

9.2.6 Operation principle

9.2.6.1 Auto-reclosing operation Off and On

Operation of the automatic reclosing can be set to Off or On via the setting parameters and through external control. With the setting *Operation=ON*, the function is activated while with the setting *Operation=OFF* the function is deactivated. With the setting *Operation=External ctrl*, the activation/deactivation is made by input signal pulses, for example, from a control system.

When the function is set On and is operative the output SETON is activated (high). Other input conditions such as CBPOS and CBREADY must also be fulfilled. At this point the automatic recloser is prepared to start the reclosing cycle and the output signal READY on the SMBRREC function block is activated (high).

9.2.6.2 Start auto-reclosing and conditions for start of a reclosing cycle

The usual way in which to start a reclosing cycle, or sequence, is to start it when a line protection tripping has occurred, by applying a signal to the START input.

For a new auto-reclosing cycle to be started, a number of conditions need to be met. They are linked to dedicated inputs. The inputs are:

- CBREADY: CB ready for a reclosing cycle, for example, charged operating gear
- CBPOS: to ensure that the CB was closed when the line fault occurred and start was applied
- No blocking or inhibit signal shall be present.

After the start has been accepted, it is latched in and an internal signal “Started” is set. It can be interrupted by certain events, like an inhibit signal.

To start auto-reclosing by CB position Open instead of from protection trip signals, one has to configure the CB Open position signal to inputs CBPOS and START and set a parameter *StartByCBOpen = ON* and *CBAuxContType = NormClosed* (normally closed). One also has to configure and connect signals from manual trip commands to input INHIBIT.

The logic for switching the auto-recloser ON/OFF and the starting of the reclosing is shown in figure 144. The following should be considered:

- Setting *Operation* can be set to *Off, External ctrl or On*. *External ctrl* offers the possibility of switching by external switches to inputs ON and OFF, communication commands to the same inputs etc.
- SMBRREC is normally started by tripping. It is either a Zone 1 and Communication aided trip, or a general trip. If the general trip is used the function must be blocked from all back-up tripping connected to INHIBIT. In both alternatives the breaker failure function must be connected to inhibit the function. START makes a first attempt with synchrocheck. TRSOTF starts shots 2-5.
- Circuit breaker checks that the breaker was closed for a certain length of time before the starting occurred and that the CB has sufficient stored energy to perform an auto-reclosing sequence and is connected to inputs CBPOS and CBREADY.

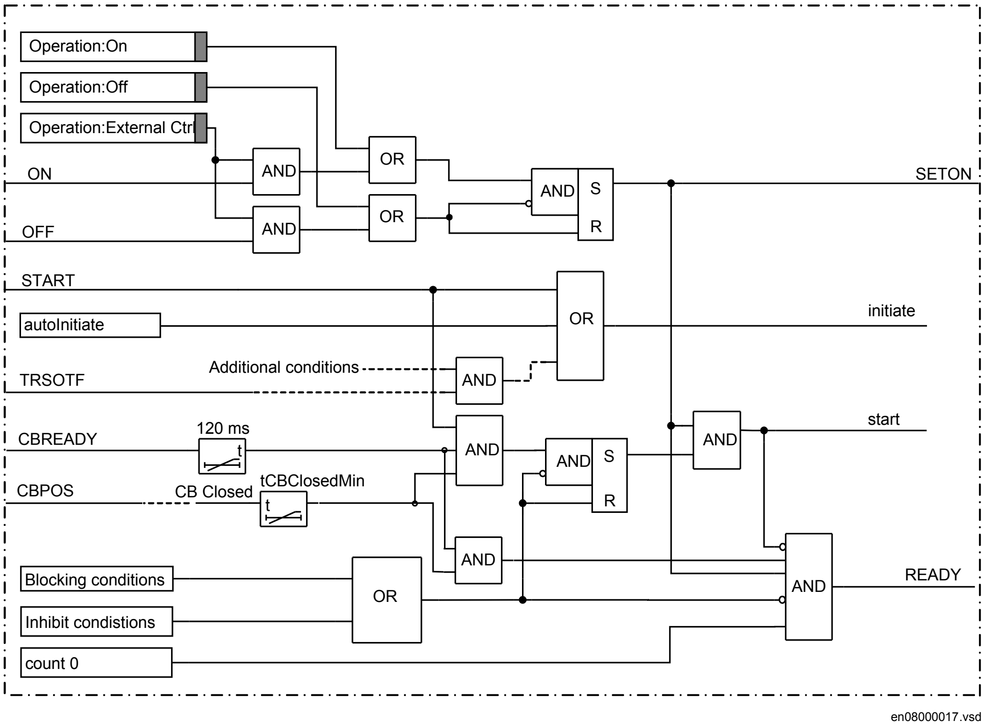


Figure 144: Auto-reclosing Off/On and start

9.2.6.3 Control of the auto-reclosing open time

There are settings for three-phase auto-reclosing open time, *t1 3Ph to t5 3Ph*.

9.2.6.4 Long trip signal

In normal circumstances the trip command resets quickly due to fault clearing. The user can set a maximum trip pulse duration *tTrip*. A long trip signal interrupts the reclosing sequence in the same way as a signal to input INHIBIT.

Reclosing checks and the reclaim timer

When dead time has elapsed during the auto-reclosing procedure certain conditions must be fulfilled before the CB closing command is issued. To achieve this, signals are exchanged between program modules to check that these conditions are met. In three-phase reclosing a synchronizing and/or energizing check can be used. It is possible to use a synchro-check function in the same physical device or an external one. The release signal is configured by connecting to the auto-reclosing function input SYNC. If reclosing without checking is preferred the SYNC input can be set to TRUE (set high). Another possibility is to set the output of the synchro-check function to a permanently activated state. At confirmation from the synchro-check, the signal passes on.

By choosing *CBReadyType = CO* (CB ready for a Close-Open sequence) the readiness of the circuit breaker is also checked before issuing the CB closing command. If the CB has a readiness contact of type *CBReadyType = OCO* (CB ready for an Open-Close-Open sequence) this condition may not be complied with after the tripping and at the moment of reclosure. The Open-Close-Open condition was however checked at the start of the reclosing cycle and it is then likely that the CB is prepared for a Close-Open sequence.

The synchro-check or energizing check must be fulfilled within a set time interval, *tSync*. If it is not, or if other conditions are not met, the reclosing is interrupted and blocked.

The reclaim timer defines a time from the issue of the reclosing command, after which the reclosing function resets. Should a new trip occur during this time, it is treated as a continuation of the first fault. The reclaim timer is started when the CB closing command is given.

A number of outputs for Autoreclosing state control keeps track of the actual state in the reclosing sequence.

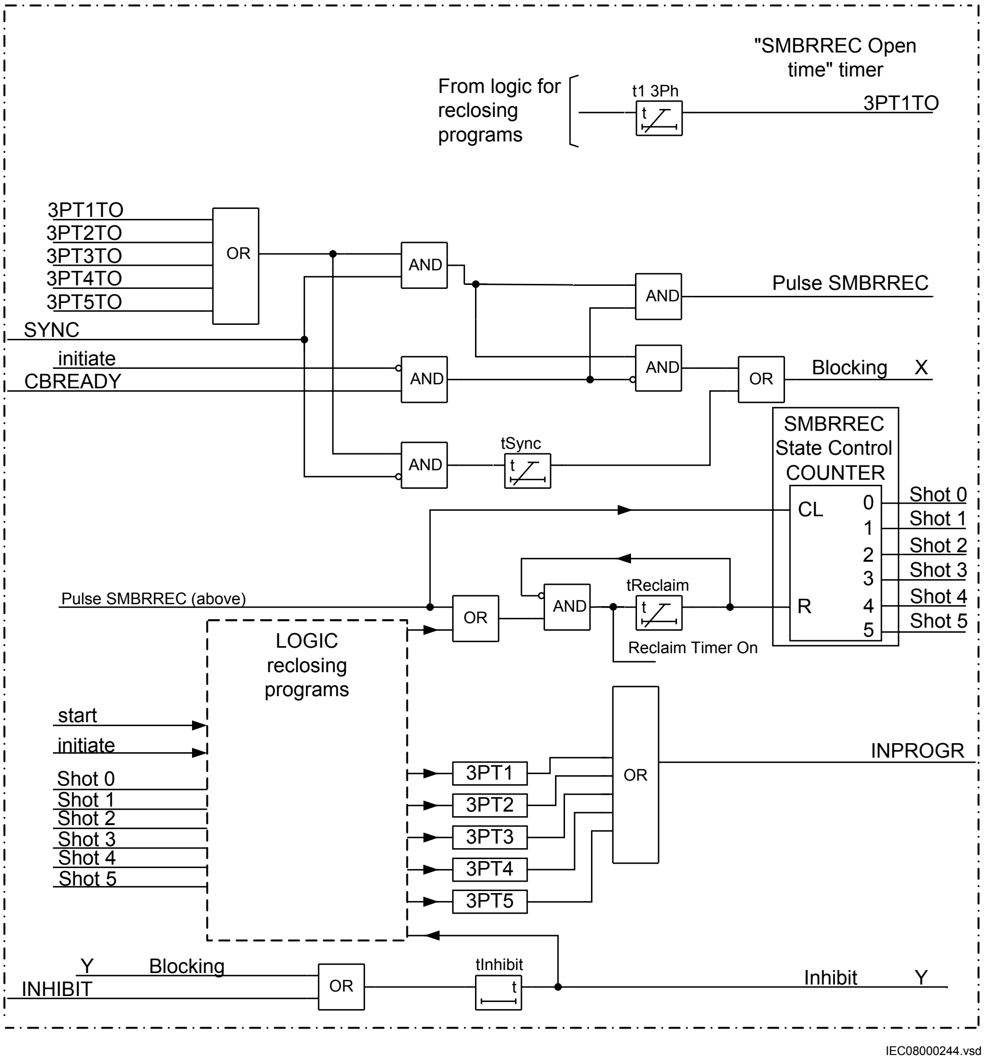


Figure 145: Reclosing Reclaim and Inhibit timers

Pulsing of the CB closing command

The duration of the pulse is fixed 200 ms. See figure 146

When a reclosing command is issued, the appropriate reclosing operation counter is incremented. There is a counter for each reclosing shot and one for the total number of reclosing commands issued.

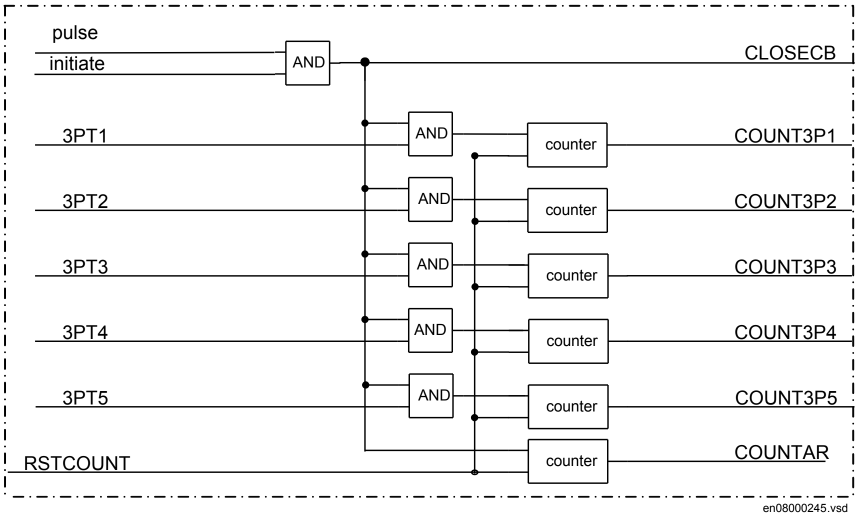


Figure 146: Pulsing of closing command and driving the operation counters

Transient fault

After the reclosing command the reclaim timer *tReclaim* starts running for the set time. If no tripping occurs within this time, the auto-reclosing will reset.

Permanent fault and reclosing unsuccessful signal

If a new trip occurs after the CB closing command, and a new input signal START or TRSOTF appears, the output UNSUCCL (unsuccessful closing) is set high. The timers for the first shot can no longer be started. Depending on the setting for the number of reclosing shots, further shots may be made or the reclosing sequence will be ended. After the reclaim time has elapsed, the auto-reclosing function resets but the CB remains open. The CB closed data at the CBPOS input will be missing. Because of this, the reclosing function will not be ready for a new reclosing cycle.

Normally the signal UNSUCCL appears when a new trip and start is received after the last reclosing shot has been made and the auto-reclosing function is blocked. The signal resets once the reclaim time has elapsed. The “unsuccessful“ signal can also be made to depend on CB position input. The parameter *UnsucClByCBChk* should then be set to *CBCheck*, and a timer *tUnsucCl* should also be set. If the CB does not respond to the closing command and does not close, but remains open, the output UNSUCCL is set high after time *tUnsucCl*.

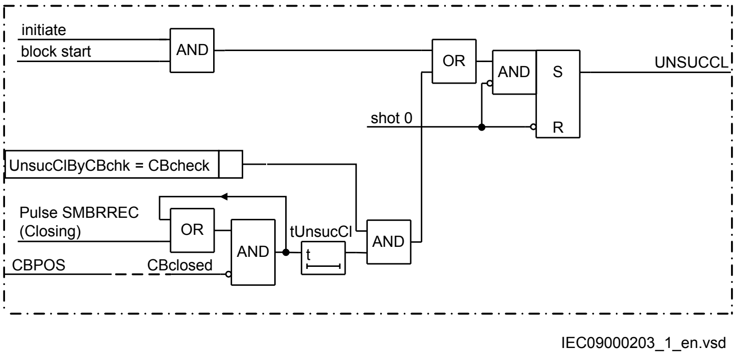


Figure 147: Issue of signal UNSUCCL, unsuccessful reclosing

Automatic continuation of the reclosing sequence

The auto-reclosing function can be programmed to proceed to the following reclosing shots (if selected) even if the start signals are not received from the protection functions, but the breaker is still not closed. This is done by setting parameter *AutoCont = On* and *tAutoContWait* to the required delay for the function to proceed without a new start.

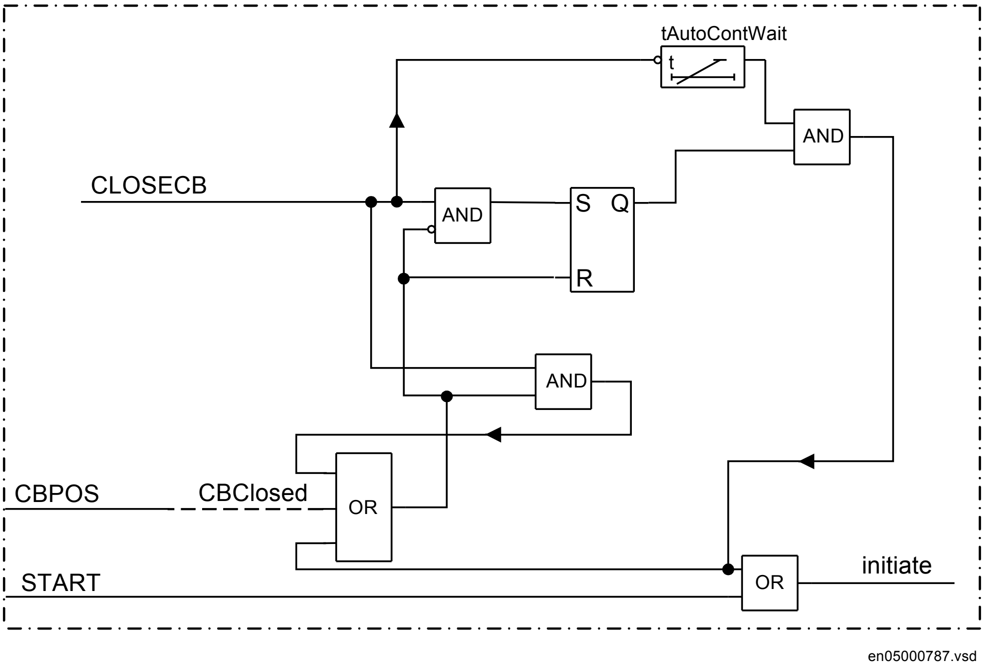


Figure 148: Automatic proceeding of shot 2 to 5

Start of reclosing from CB open information

If a user wants to apply starting of auto-reclosing from CB open position instead of from protection trip signals, the function offers such a possibility. This starting mode is selected by a setting parameter *StartByCBOpen = On*. One needs then to block reclosing at all manual trip operations. Typically, one also set

CBAuxContType = NormClosed and connect a CB auxiliary contact of type NC (normally closed) to inputs CBPOS and START. When the signal changes from CB closed to CB open an auto-reclosing start pulse of limited length is generated and latched in the function, subject to the usual checks. Then the reclosing sequence continues as usual. One needs to connect signals from manual tripping and other functions, which shall prevent reclosing, to the input INHIBIT.

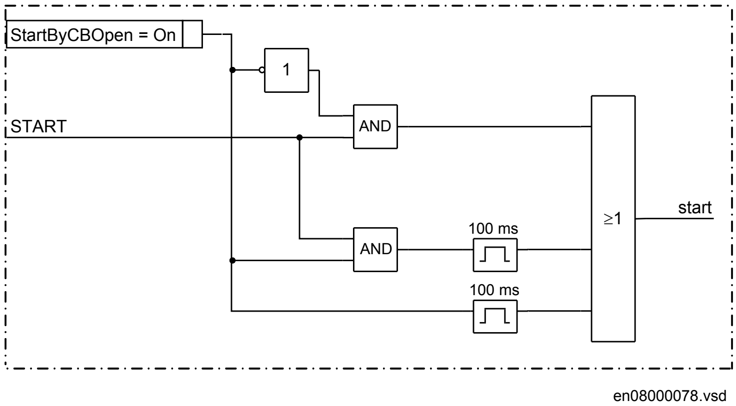


Figure 149: Pulsing of the start inputs

9.2.7 Technical data

Table 208: SMBRREC Technical data

Function	Range or value	Accuracy
Number of autoreclosing shots	1 - 5	-
Autoreclosing open time: shot 1 - t1 3Ph	(0.000-60.000) s	± 0.5% ± 10 ms
shot 2 - t2 3Ph shot 3 - t3 3Ph shot 4 - t4 3Ph shot 5 - t5 3Ph	(0.00-6000.00) s	
Autorecloser maximum wait time for sync	(0.00-6000.00) s	
Maximum trip pulse duration	(0.000-60.000) s	
Inhibit reset time	(0.000-60.000) s	
Reclaim time	(0.00-6000.00) s	
Minimum time CB must be closed before AR becomes ready for autoreclosing cycle	(0.00-6000.00) s	
CB check time before unsuccessful	(0.00-6000.00) s	
Wait for master release	(0.00-6000.00) s	
Wait time after close command before proceeding to next shot	(0.000-60.000) s	

9.3 Apparatus control APC

9.3.1 Functionality

The apparatus control is a function for control and supervision of circuit breakers, disconnectors and earthing switches within a bay. Permission to operate is given after evaluation of conditions from other functions such as interlocking, synchrocheck, operator place selection and external or internal blockings.

9.3.2 Bay control QCBAY

9.3.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Bay control	QCBAY	-	-

9.3.2.2 Functionality

The bay control (QCBAY) function is used to handle the selection of the operator place per bay. QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay.

9.3.2.3 Function block

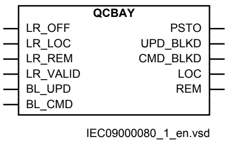


Figure 150: QCBAY function block

9.3.2.4 Signals

Table 209: QCBAY Input signals

Name	Type	Default	Description
LR_OFF	BOOLEAN	0	External Local/Remote switch is in Off position
LR_LOC	BOOLEAN	0	External Local/Remote switch is in Local position
LR_REM	BOOLEAN	0	External Local/Remote switch is in Remote position
LR_VALID	BOOLEAN	0	Data representing the L/R switch position is valid
BL_UPD	BOOLEAN	0	Steady signal to block the position updates
BL_CMD	BOOLEAN	0	Steady signal to block the command

Table 210: QCBAY Output signals

Name	Type	Description
PSTO	INTEGER	Value for the operator place allocation
UPD_BLKD	BOOLEAN	Update of position is blocked
CMD_BLKD	BOOLEAN	Function is blocked for commands
LOC	BOOLEAN	Local operation allowed
REM	BOOLEAN	Remote operation allowed

9.3.2.5 Settings

Table 211: QCBAY Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
AllPSTOValid	Priority No priority	-	-	Priority	Priority of originators

9.3.3 Local remote LOCREM

9.3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Local remote	LOCREM	-	-

9.3.3.2 Functionality

The signals from the local HMI or from an external local/remote switch are applied via function blocks LOCREM and LOCREMCTRL to the Bay control (QCBAY) function block. A parameter in function block LOCREM is set to choose if the switch signals are coming from the local HMI or from an external hardware switch connected via binary inputs.

9.3.3.3 Function block

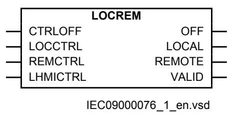


Figure 151: LOCREM function block

9.3.3.4 Signals

Table 212: LOCREM Input signals

Name	Type	Default	Description
CTRLOFF	BOOLEAN	0	Disable control
LOCCTRL	BOOLEAN	0	Local in control
REMCTRL	BOOLEAN	0	Remote in control
LHMICTRL	INTEGER	0	LHMI control

Table 213: LOCREM Output signals

Name	Type	Description
OFF	BOOLEAN	Control is disabled
LOCAL	BOOLEAN	Local control is activated
REMOTE	BOOLEAN	Remote control is activated
VALID	BOOLEAN	Outputs are valid

9.3.3.5 Settings

Table 214: LOCREM Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
ControlMode	Internal LR-switch External LR-switch	-	-	Internal LR-switch	Control mode for internal/external LR-switch

9.3.4 Local remote control LOCREMCTRL

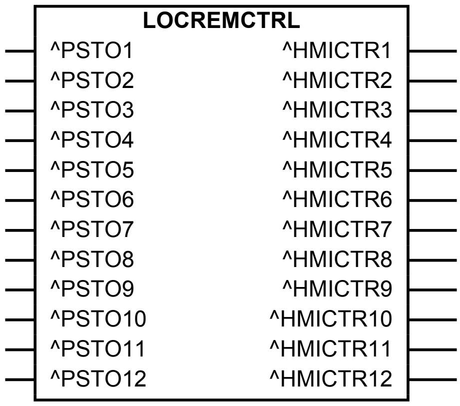
9.3.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Local remote control	LOCREMCTRL	-	-

9.3.4.2 Functionality

The signals from the local HMI or from an external local/remote switch are applied via function blocks LOCREM and LOCREMCTRL to the Bay control (QCBAY) function block. A parameter in function block LOCREM is set to choose if the switch signals are coming from the local HMI or from an external hardware switch connected via binary inputs.

9.3.4.3 Function block



IEC09000074_1_en.vsd

Figure 152: LOCREMCTRL function block

9.3.4.4 Signals

Table 215: LOCREMCTRL Input signals

Name	Type	Default	Description
PSTO1	INTEGER	0	PSTO input channel 1
PSTO2	INTEGER	0	PSTO input channel 2
PSTO3	INTEGER	0	PSTO input channel 3
PSTO4	INTEGER	0	PSTO input channel 4
PSTO5	INTEGER	0	PSTO input channel 5
PSTO6	INTEGER	0	PSTO input channel 6
PSTO7	INTEGER	0	PSTO input channel 7
PSTO8	INTEGER	0	PSTO input channel 8
PSTO9	INTEGER	0	PSTO input channel 9
PSTO10	INTEGER	0	PSTO input channel 10
PSTO11	INTEGER	0	PSTO input channel 11
PSTO12	INTEGER	0	PSTO input channel 12

Table 216: LOCREMCTRL Output signals

Name	Type	Description
HMICTR1	INTEGER	Bitmask output 1 to local remote LHMI input
HMICTR2	INTEGER	Bitmask output 2 to local remote LHMI input
HMICTR3	INTEGER	Bitmask output 3 to local remote LHMI input
HMICTR4	INTEGER	Bitmask output 4 to local remote LHMI input
HMICTR5	INTEGER	Bitmask output 5 to local remote LHMI input
Table continues on next page		

Name	Type	Description
HMICTR6	INTEGER	Bitmask output 6 to local remote LHMI input
HMICTR7	INTEGER	Bitmask output 7 to local remote LHMI input
HMICTR8	INTEGER	Bitmask output 8 to local remote LHMI input
HMICTR9	INTEGER	Bitmask output 9 to local remote LHMI input
HMICTR10	INTEGER	Bitmask output 10 to local remote LHMI input
HMICTR11	INTEGER	Bitmask output 11 to local remote LHMI input
HMICTR12	INTEGER	Bitmask output 12 to local remote LHMI input

9.3.4.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

9.3.5 Operation principle

9.3.5.1 Bay control QCBAY

The functionality of the Bay control (QCBAY) function is not defined in the IEC 61850–8–1 standard, which means that the function is a vendor specific logical node.

The function sends information about the Permitted Source To Operate (PSTO) and blocking conditions to other functions within the bay for example, switch control functions, voltage control functions and measurement functions.

Local panel switch

The local panel switch is a switch that defines the operator place selection. The switch connected to this function can have three positions remote/local/off. The positions are here defined so that remote means that operation is allowed from station/ remote level and local from the IED level. The local/remote switch is normally situated on the control/protection IED itself, which means that the position of the switch and its validity information are connected internally, and not via I/O boards. When the switch is mounted separately on the IED the signals are connected to the function via I/O boards.

When the local panel switch is in Off position all commands from remote and local level will be ignored. If the position for the local/remote switch is not valid the PSTO output will always be set to faulty state (3), which means no possibility to operate.

To adapt the signals from the local HMI or from an external local/remote switch, the function blocks LOCREM and LOCREMCTRL are needed and connected to QCBAY.

Permitted Source To Operate (PSTO)

The actual state of the operator place is presented by the value of the Permitted Source To Operate, PSTO signal. The PSTO value is evaluated from the local/remote switch position according to table 217. In addition, there is one configuration parameter that affects the value of the PSTO signal. If the parameter *AllPSTOValid* is set and LR-switch position is in Local or Remote state, the PSTO value is set to 5 (all), that is, it is permitted to operate from both local and remote level without any priority. When the external panel switch is in Off position the PSTO value shows the actual state of switch that is, 0. In this case it is not possible to control anything.

Table 217: PSTO values for different Local panel switch positions

Local panel switch positions	PSTO value	AllPSTOValid (configuration parameter)	Possible locations that shall be able to operate
0 = Off	0	--	Not possible to operate
1 = Local	1	FALSE	Local Panel
1 = Local	5	TRUE	Local or Remote level without any priority
2 = Remote	2	FALSE	Remote level
2 = Remote	5	TRUE	Local or Remote level without any priority
3 = Faulty	3	--	Not possible to operate

Blockings

The blocking states for position indications and commands are intended to provide the possibility for the user to make common blockings for the functions configured within a complete bay.

The blocking facilities provided by the bay control function are the following:

- Blocking of position indications, BL_UPD. This input will block all inputs related to apparatus positions for all configured functions within the bay.
- Blocking of commands, BL_CMD. This input will block all commands for all configured functions within the bay.
- Blocking of function, BLOCK, signal from DO (Data Object) Behavior (IEC 61850–8–1). If DO Behavior is set to "blocked" it means that the function is active, but no outputs are generated, no reporting, control commands are rejected and functional and configuration data is visible.

The switching of the Local/Remote switch requires at least system operator level. The password will be requested at an attempt to operate if authority levels have been defined in the IED. Otherwise the default authority level, SuperUser, can handle the control without LogOn. The users and passwords are defined in PCM600.

9.3.5.2 Local remote/Local remote control LOCREM/LOCREMCTRL

The function block Local remote (LOCREM) handles the signals coming from the local/remote switch. The connections are seen in figure 153, where the inputs on function block LOCREM are connected to binary inputs if an external switch is used. When a local HMI is used, the inputs are not used and are set to FALSE in the configuration. The outputs from the LOCREM function block control the output PSTO (Permitted Source To Operate) on Bay control (QCBAY).

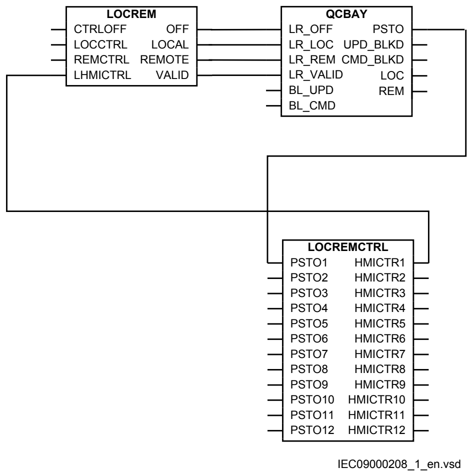


Figure 153: Configuration for the local/remote handling for a local HMI with two bays and two screen pages

The switching of the local/remote switch requires at least system operator level. The password will be requested at an attempt to operate if authority levels have been defined in the IED. Otherwise the default authority level, SuperUser, can handle the control without LogOn. The users and passwords are defined in PCM600.

9.4 Logic rotating switch for function selection and LHMI presentation SLGGIO

9.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Logic rotating switch for function selection and LHMI presentation	SLGGIO	-	-

9.4.2 Functionality

The Logic rotating switch for function selection and LHMI presentation (SLGGIO) function block (or the selector switch function block) is used within the ACT tool in order to get a selector switch functionality similar with the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and extended purchase portfolio. The virtual selector switches eliminate all these problems.

9.4.3 Function block

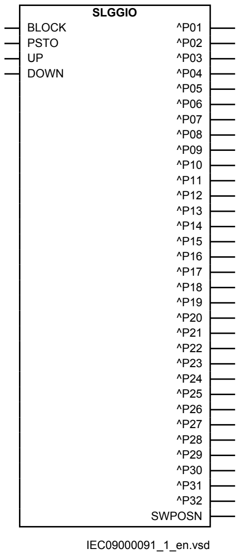


Figure 154: SLGGIO function block

9.4.4 Signals

Table 218: SLGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
PSTO	INTEGER	0	Operator place selection
UP	BOOLEAN	0	Binary "UP" command
DOWN	BOOLEAN	0	Binary "DOWN" command

Table 219: SLGGIO Output signals

Name	Type	Description
P01	BOOLEAN	Selector switch position 1
P02	BOOLEAN	Selector switch position 2
P03	BOOLEAN	Selector switch position 3
P04	BOOLEAN	Selector switch position 4
Table continues on next page		

Name	Type	Description
P05	BOOLEAN	Selector switch position 5
P06	BOOLEAN	Selector switch position 6
P07	BOOLEAN	Selector switch position 7
P08	BOOLEAN	Selector switch position 8
P09	BOOLEAN	Selector switch position 9
P10	BOOLEAN	Selector switch position 10
P11	BOOLEAN	Selector switch position 11
P12	BOOLEAN	Selector switch position 12
P13	BOOLEAN	Selector switch position 13
P14	BOOLEAN	Selector switch position 14
P15	BOOLEAN	Selector switch position 15
P16	BOOLEAN	Selector switch position 16
P17	BOOLEAN	Selector switch position 17
P18	BOOLEAN	Selector switch position 18
P19	BOOLEAN	Selector switch position 19
P20	BOOLEAN	Selector switch position 20
P21	BOOLEAN	Selector switch position 21
P22	BOOLEAN	Selector switch position 22
P23	BOOLEAN	Selector switch position 23
P24	BOOLEAN	Selector switch position 24
P25	BOOLEAN	Selector switch position 25
P26	BOOLEAN	Selector switch position 26
P27	BOOLEAN	Selector switch position 27
P28	BOOLEAN	Selector switch position 28
P29	BOOLEAN	Selector switch position 29
P30	BOOLEAN	Selector switch position 30
P31	BOOLEAN	Selector switch position 31
P32	BOOLEAN	Selector switch position 32
SWPOSN	INTEGER	Switch position as integer value

9.4.5 Settings

Table 220: SLGGIO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
NrPos	2 - 32	-	1	32	Number of positions in the switch
OutType	Pulsed Steady	-	-	Steady	Output type, steady or pulse

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
tPulse	0.000 - 60.000	s	0.001	0.200	Operate pulse duration
tDelay	0.000 - 60000.000	s	0.010	0.000	Output time delay
StopAtExtremes	Disabled Enabled	-	-	Disabled	Stop when min or max position is reached

9.4.6 Monitored data

Table 221: SLGGIO Monitored data

Name	Type	Values (Range)	Unit	Description
SWPOSN	INTEGER	-	-	Switch position as integer value

9.4.7 Operation principle

The Logic rotating switch for function selection and LHMI presentation (SLGGIO) has two operating inputs – UP and DOWN. When a signal is received on the UP input, the block will activate the output next to the present activated output, in ascending order (if the present activated output is 3 – for example and one operates the UP input, then the output 4 will be activated). When a signal is received on the DOWN input, the block will activate the output next to the present activated output, in descending order (if the present activated output is 3 – for example and one operates the DOWN input, then the output 2 will be activated). Depending on the output settings the output signals can be steady or pulsed. In case of steady signals, in case of UP or DOWN operation, the previously active output will be deactivated. Also, depending on the settings one can have a time delay between the UP or DOWN activation signal positive front and the output activation.

Besides the inputs visible in ACT tool, there are other possibilities that will allow an user to set the desired position directly (without activating the intermediate positions), either locally or remotely, using a “select before execute” dialog. One can block the function operation, by activating the BLOCK input. In this case, the present position will be kept and further operation will be blocked. The operator place (local or remote) is specified through the PSTO input. If any operation is allowed the signal INTONE from the Fixed signal function block can be connected. The SLGGIO function block has also an integer value output, that generates the actual position number. The positions and the block names are fully settable by the user. These names will appear in the menu, so the user can see the position names instead of a number.

9.5 Selector mini switch VSGGIO

9.5.1 Identification

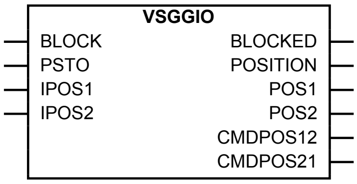
Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Selector mini switch	VSGGIO	-	-

9.5.2 Functionality

Selector mini switch (VSGGIO) function block is a multipurpose function used in the configuration tool in PCM600 for a variety of applications, as a general purpose switch.

VSGGIO can be controlled from the menu or from a symbol on the single line diagram (SLD) on the local HMI.

9.5.3 Function block



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9.5.4 Signals

Table 222: VSGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
PSTO	INTEGER	0	Operator place selection
IPOS1	BOOLEAN	0	Position 1 indicating input
IPOS2	BOOLEAN	0	Position 2 indicating input

Table 223: VSGGIO Output signals

Name	Type	Description
BLOCKED	BOOLEAN	The function is active but the functionality is blocked
POSITION	INTEGER	Position indication, integer
POS1	BOOLEAN	Position 1 indication, logical signal

Table continues on next page

Name	Type	Description
POS2	BOOLEAN	Position 2 indication, logical signal
CMDPOS12	BOOLEAN	Execute command from position 1 to position 2
CMDPOS21	BOOLEAN	Execute command from position 2 to position 1

9.5.5 Settings

Table 224: VSGGIO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
CtlModel	Dir Norm SBO Enh	-	-	Dir Norm	Specifies the type for control model according to IEC 61850
Mode	Steady Pulsed	-	-	Pulsed	Operation mode
tSelect	0.000 - 60.000	s	0.001	30.000	Max time between select and execute signals
tPulse	0.000 - 60.000	s	0.001	0.200	Command pulse lenght

9.5.6 Operation principle

Selector mini switch (VSGGIO) function can be used for double purpose, in the same way as switch controller (SCSWI) functions are used:

- for indication on the single line diagram (SLD). Position is received through the IPOS1 and IPOS2 inputs and distributed in the configuration through the POS1 and POS2 outputs, or to IEC 61850 through reporting, or GOOSE.
- for commands that are received via the local HMI or IEC 61850 and distributed in the configuration through outputs CMDPOS12 and CMDPOS21. The output CMDPOS12 is set when the function receives a CLOSE command from the local HMI when the SLD is displayed and the object is chosen. The output CMDPOS21 is set when the function receives an OPEN command from the local HMI when the SLD is displayed and the object is chosen.

It is important for indication in the SLD that the a symbol is associated with a controllable object, otherwise the symbol won't be displayed on the screen. A symbol is created and configured in GDE tool in PCM600.

The PSTO input is connected to the Local remote switch to have a selection of operators place , operation from local HMI (Local) or through IEC 61850 (Remote). An INTONE connection from Fixed signal function block (FXDSIGN) will allow operation from local HMI.

As it can be seen, both indications and commands are done in double-bit representation, where a combination of signals on both inputs/outputs generate the desired result.

The following table shows the relationship between IPOS1/IPOS2 inputs and the name of the string that is shown on the SLD. The value of the strings are set in PST.

IPOS1	IPOS2	Name of displayed string	Default string value
0	0	PosUndefined	P00
1	0	Position1	P01
0	1	Position2	P10
1	1	PosBadState	P11

9.6 IEC 61850 generic communication I/O functions DPGGIO

9.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions	DPGGIO	-	-

9.6.2 Functionality

The IEC 61850 generic communication I/O functions (DPGGIO) function block is used to send three logical signals to other systems or equipment in the substation. It is especially used in the interlocking and reservation station-wide logics.

9.6.3 Function block

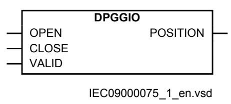

Figure 155: DPGGIO function block

9.6.4 Signals

Table 225: DPGGIO Input signals

Name	Type	Default	Description
OPEN	BOOLEAN	0	Open indication
CLOSE	BOOLEAN	0	Close indication
VALID	BOOLEAN	0	Valid indication

Table 226: DPGGIO Output signals

Name	Type	Description
POSITION	INTEGER	Double point indication

9.6.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

9.6.6 Operation principle

Upon receiving the input signals, the IEC 61850 generic communication I/O functions (DPGGIO) function block will send the signals over IEC 61850-8-1 to the equipment or system that requests these signals. To be able to get the signals, PCM600 must be used to define which function block in which equipment or system should receive this information.

9.7 Single point generic control 8 signals SPC8GGIO

9.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Single point generic control 8 signals	SPC8GGIO	-	-

9.7.2 Functionality

The Single point generic control 8 signals (SPC8GGIO) function block is a collection of 8 single point commands, designed to bring in commands from REMOTE (SCADA) to those parts of the logic configuration that do not need complicated function blocks that have the capability to receive commands (for example, SCSWI). In this way, simple commands can be sent directly to the IED outputs, without confirmation. Confirmation (status) of the result of the commands is supposed to be achieved by other means, such as binary inputs and SPGGIO function blocks.

9.7.3 Function block

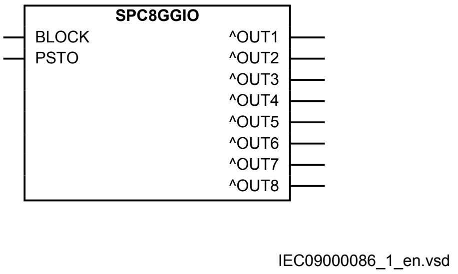

Figure 156: SPC8GGIO function block

9.7.4 Signals

Table 227: SPC8GGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
PSTO	INTEGER	2	Operator place selection

Table 228: SPC8GGIO Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1
OUT2	BOOLEAN	Output2
OUT3	BOOLEAN	Output3
OUT4	BOOLEAN	Output4
OUT5	BOOLEAN	Output5
OUT6	BOOLEAN	Output6
OUT7	BOOLEAN	Output7
OUT8	BOOLEAN	Output8

9.7.5 Settings

Table 229: SPC8GGIO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
Latched1	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 1
tPulse1	0.01 - 6000.00	s	0.01	0.10	Output1 Pulse Time
Latched2	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 2
tPulse2	0.01 - 6000.00	s	0.01	0.10	Output2 Pulse Time
Latched3	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 3
tPulse3	0.01 - 6000.00	s	0.01	0.10	Output3 Pulse Time
Latched4	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 4
tPulse4	0.01 - 6000.00	s	0.01	0.10	Output4 Pulse Time
Latched5	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 5
tPulse5	0.01 - 6000.00	s	0.01	0.10	Output5 Pulse Time
Latched6	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 6
tPulse6	0.01 - 6000.00	s	0.01	0.10	Output6 Pulse Time
Latched7	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 7
tPulse7	0.01 - 6000.00	s	0.01	0.10	Output7 Pulse Time
Latched8	Pulsed Latched	-	-	Pulsed	Setting for pulsed/latched mode for output 8
tPulse8	0.01 - 6000.00	s	0.01	0.10	Output8 pulse time

9.7.6 Operation principle

The PSTO input will determine which the allowed position for the operator (LOCAL, REMOTE, ALL) is. Upon sending a command from an allowed operator position, one of the 8 outputs will be activated. The settings *Latchedx* and *tPulsex* (where x is the respective output) will determine if the signal will be pulsed (and how long the pulse is) or latched (steady). BLOCK will block the operation of the function – in case a command is sent, no output will be activated.

PSTO is the universal operator place selector for all control functions. Even if PSTO can be configured to allow LOCAL or ALL operator positions, the only functional position usable with the SP8GGIO function block is REMOTE.

9.8 Automation bits AUTOBITS

9.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Automation bits	AUTOBITS	-	-

9.8.2 Functionality

Automation bits function (AUTOBITS) is used within PCM600 in order to get into the configuration of the commands coming through the DNP3 protocol.

9.8.3 Function block

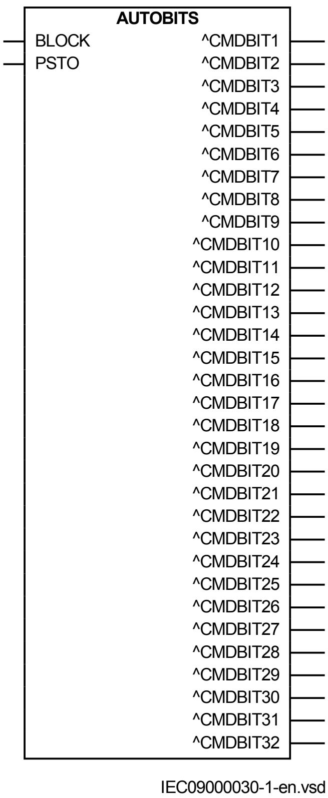

Figure 157: AUTOBITS function block

9.8.4 Signals

Table 230: AUTOBITS Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
PSTO	INTEGER	0	Operator place selection

Table 231: AUTOBITS Output signals

Name	Type	Description
CMDBIT1	BOOLEAN	Command out bit 1
CMDBIT2	BOOLEAN	Command out bit 2
CMDBIT3	BOOLEAN	Command out bit 3
CMDBIT4	BOOLEAN	Command out bit 4
CMDBIT5	BOOLEAN	Command out bit 5
CMDBIT6	BOOLEAN	Command out bit 6
CMDBIT7	BOOLEAN	Command out bit 7
CMDBIT8	BOOLEAN	Command out bit 8
CMDBIT9	BOOLEAN	Command out bit 9
CMDBIT10	BOOLEAN	Command out bit 10
CMDBIT11	BOOLEAN	Command out bit 11
CMDBIT12	BOOLEAN	Command out bit 12
CMDBIT13	BOOLEAN	Command out bit 13
CMDBIT14	BOOLEAN	Command out bit 14
CMDBIT15	BOOLEAN	Command out bit 15
CMDBIT16	BOOLEAN	Command out bit 16
CMDBIT17	BOOLEAN	Command out bit 17
CMDBIT18	BOOLEAN	Command out bit 18
CMDBIT19	BOOLEAN	Command out bit 19
CMDBIT20	BOOLEAN	Command out bit 20
CMDBIT21	BOOLEAN	Command out bit 21
CMDBIT22	BOOLEAN	Command out bit 22
CMDBIT23	BOOLEAN	Command out bit 23
CMDBIT24	BOOLEAN	Command out bit 24
CMDBIT25	BOOLEAN	Command out bit 25
CMDBIT26	BOOLEAN	Command out bit 26
CMDBIT27	BOOLEAN	Command out bit 27
CMDBIT28	BOOLEAN	Command out bit 28
CMDBIT29	BOOLEAN	Command out bit 29
CMDBIT30	BOOLEAN	Command out bit 30
CMDBIT31	BOOLEAN	Command out bit 31
CMDBIT32	BOOLEAN	Command out bit 32

9.8.5 Settings

Table 232: AUTOBITS Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On

9.8.6 Operation principle

Automation bits function (AUTOBITS) has 32 individual outputs which each can be mapped as a Binary Output point in DNP. The output is operated by a "Object 12" in DNP3. This object contains parameters for control-code, count, on-time and off-time. To operate an AUTOBITS output point, send a control-code of latch-On, latch-Off, pulse-On, pulse-Off, Trip or Close. The remaining parameters will be regarded were appropriate. ex: pulse-On, on-time=100, off-time=300, count=5 would give 5 positive 100 ms pulses, 300 ms apart.

There is a BLOCK input signal, which will disable the operation of the function, in the same way the setting *Operation*: *On/Off* does. That means that, upon activation of the BLOCK input, all 32 CMDBITxx outputs will be set to 0. The BLOCK acts like an overriding, the function still receives data from the DNP3 master. Upon deactivation of BLOCK, all the 32 CMDBITxx outputs will be set by the DNP3 master again, momentarily. For the AUTOBITS, the PSTO input determines the operator place. The command can be written to the block while in “Remote”. If PSTO is in “Local” then no change is applied to the outputs.

See DNP3 communication protocol manual for description of the DNP3 protocol implementation.

Section 10 Scheme communication

10.1 Scheme communication logic for distance or overcurrent protection ZCPSCH

10.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Scheme communication logic for distance or overcurrent protection	ZCPSCH	-	85

10.1.2 Functionality

To achieve instantaneous fault clearance for all line faults, a scheme communication logic is provided. All types of communication schemes e.g. permissive underreaching, permissive overreaching, blocking, unblocking, intertrip etc. are available.

10.1.3 Function block

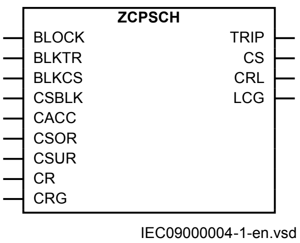

Figure 158: ZCPSCH function block

10.1.4 Signals

Table 233: ZCPSCH Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
BLKTR	BOOLEAN	0	Signal for block of trip output from communication logic
BLKCS	BOOLEAN	0	Block of carrier send in permissive OR and blocking schemes
Table continues on next page			

Name	Type	Default	Description
CSBLK	BOOLEAN	0	Reverse directed distance protection zone signal
CACC	BOOLEAN	0	Permissive distance protection zone signal
CSOR	BOOLEAN	0	Overreaching distance protection zone signal
CSUR	BOOLEAN	0	Underreaching distance protection zone signal
CR	BOOLEAN	0	Carrier Signal Received
CRG	BOOLEAN	0	Carrier guard signal received

Table 234: ZCPSCH Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip output
CS	BOOLEAN	Carrier Send signal
CRL	BOOLEAN	Carrier signal received or missing carrier guard signal
LCG	BOOLEAN	Loss of carrier guard signal

10.1.5 Settings

Table 235: ZCPSCH Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
SchemeType	Off Intertrip Permissive UR Permissive OR Blocking	-	-	Permissive UR	Scheme type
tCoord	0.000 - 60.000	s	0.001	0.035	Co-ordination time for blocking communication scheme
tSendMin	0.000 - 60.000	s	0.001	0.100	Minimum duration of a carrier send signal

Table 236: ZCPSCH Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
Unblock	Off NoRestart Restart	-	-	Off	Operation mode of unblocking logic
tSecurity	0.000 - 60.000	s	0.001	0.035	Security timer for loss of carrier guard detection

10.1.6 Operation principle

Depending on whether a reverse or forward directed impedance zone is used to issue the send signal, the communication schemes are divided into Blocking and Permissive schemes, respectively.

A permissive scheme is inherently faster and has better security against false tripping than a blocking scheme. On the other hand, a permissive scheme depends on a received signal for a fast trip, so its dependability is lower than that of a blocking scheme.

10.1.6.1 Blocking scheme

The principle of operation for a blocking scheme is that an overreaching zone is allowed to trip instantaneously after the settable co-ordination time *tCoord* has elapsed, when no signal is received from the remote terminal.

The received signal, which shall be connected to CR, is used to not release the zone to be accelerated to clear the fault instantaneously (after time *tCoord*). The overreaching zone to be accelerated is connected to the input CACC, see figure 159.

In case of external faults, the blocking signal (CR) must be received before the settable timer *tCoord* elapses, to prevent a false trip, see figure 159.

The function can be totally blocked by activating the input BLOCK, block of trip by activating the input BLKTR, Block of signal send by activating the input BLKCS.

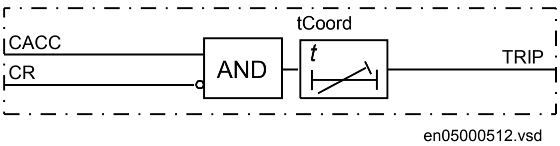

Figure 159: Basic logic for trip signal in blocking scheme

Channels for communication in each direction must be available.

10.1.6.2 Permissive underreaching scheme

In a permissive underreaching scheme, a forward directed underreach measuring element (normally zone1) sends a permissive signal CS to the remote end if a fault is detected in forward direction. The received signal CR is used to allow an overreaching zone to trip after the *tCoord* timer has elapsed. The *tCoord* in permissive underreaching schemes is normally set to zero.

The logic for trip signal in permissive scheme is shown in figure 160.

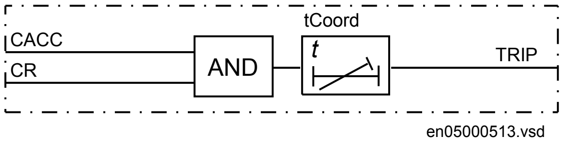

Figure 160: Logic for trip signal in permissive scheme

The permissive underreaching scheme has the same blocking possibilities as mentioned for blocking scheme.

10.1.6.3 Permissive overreaching scheme

In a permissive overreaching scheme, a forward directed overreach measuring element (normally zone2) sends a permissive signal CS to the remote end if a fault is detected in forward direction. The received signal CR is used to allow an overreaching zone to trip after the settable *tCoord* timer has elapsed. The *tCoord* in permissive overreaching schemes is normally set to zero.

The logic for trip signal is the same as for permissive underreaching, as in figure 160.

The permissive overreaching scheme has the same blocking possibilities as mentioned for blocking scheme.

10.1.6.4 Unblocking scheme

In unblocking scheme, the lower dependability in permissive scheme is overcome by using the loss of guard signal from the communication equipment to locally create a receive signal. It is common or suitable to use the function when older, less reliable, power-line carrier (PLC) communication is used.

The unblocking function uses a guard signal CRG, which must always be present, even when no CR signal is received. The absence of the CRG signal for a time longer than the setting *tSecurity* time is used as a CR signal, see figure 161. This also enables a permissive scheme to operate when the line fault blocks the signal transmission.

The received signal created by the unblocking function is reset 150 ms after the security timer has elapsed. When that occurs an output signal LCG is activated for signalling purpose. The unblocking function is reset 200 ms after that the guard signal is present again.

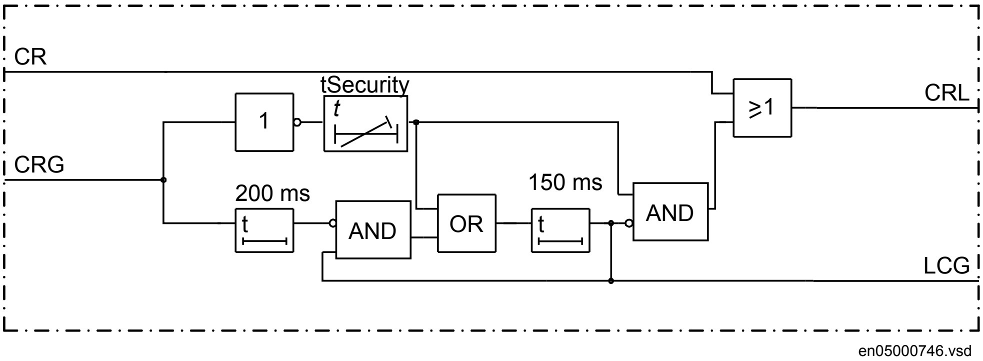

Figure 161: Guard signal logic with unblocking scheme

The unblocking function can be set in three operation modes (setting *Unblock*):

Off:	The unblocking function is out of operation
No restart:	Communication failure shorter than *tSecurity* will be ignored
	If CRG disappears a CRL signal will be transferred to the trip logic
	There will not be any information in case of communication failure (LCG)
Restart	Communication failure shorter than *tSecurity* will be ignored
	It sends a defined (150 ms) CRL after the disappearance of the CRG signal
	The function will activate LCG output in case of communication failure
	If the communication failure comes and goes (<200 ms) there will not be recurrent signalling

10.1.6.5 Intertrip scheme

In the direct intertrip scheme, the send signal CS is sent from an underreaching zone that is tripping the line.

The received signal CR is directly transferred to a TRIP for tripping without local criteria. The signal is further processed in the tripping logic.

10.1.6.6 Simplified logic diagram

The simplified logic diagram for the complete logic is shown in figure 162.

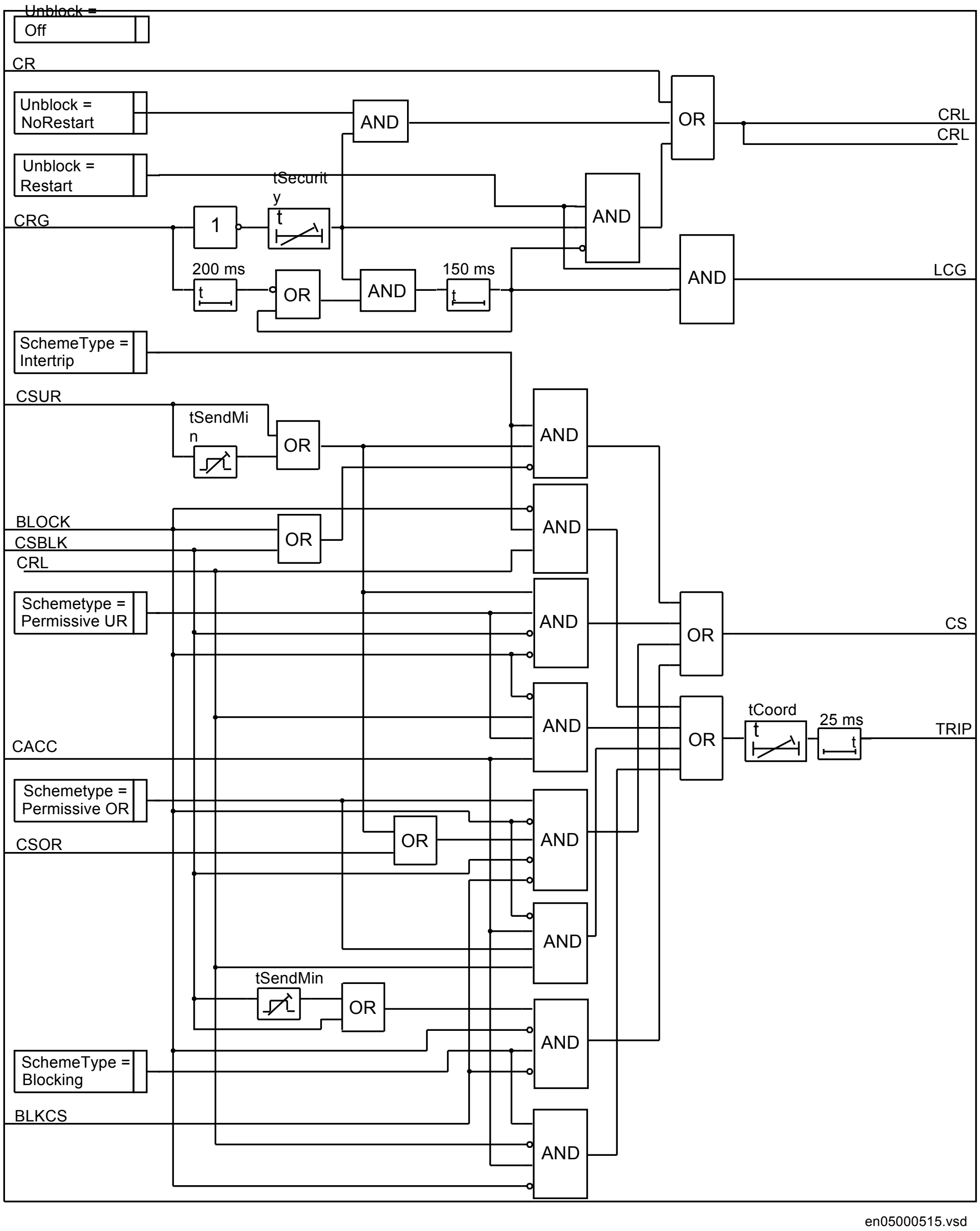

Figure 162: Scheme communication logic for distance or overcurrent protection, simplified logic diagram

10.1.7 Technical data

Table 237: ZCPSCH Technical data

Function	Range or value	Accuracy
Scheme type	Off Intertrip Permissive UR Permissive OR Blocking	-
Co-ordination time for blocking communication scheme	(0.000-60.000) s	± 0.5% ± 10 ms
Minimum duration of a carrier send signal	(0.000-60.000) s	± 0.5% ± 10 ms
Security timer for loss of guard signal detection	(0.000-60.000) s	± 0.5% ± 10 ms
Operation mode of unblocking logic	Off NoRestart Restart	-

10.2 Current reversal and weak-end infeed logic for distance protection ZCRWPSCH

10.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current reversal and weak-end infeed logic for distance protection	ZCRWPSCH	-	85

10.2.2 Functionality

The current reversal function is used to prevent unwanted operations due to current reversal when using permissive overreach protection schemes in application with parallel lines when the overreach from the two ends overlap on the parallel line.

The weak-end infeed logic is used in cases where the apparent power behind the protection can be too low to activate the distance protection function. When activated, received carrier signal together with local under voltage criteria and no reverse zone operation gives an instantaneous trip. The received signal is also echoed back to accelerate the sending end.

10.2.3 Function block

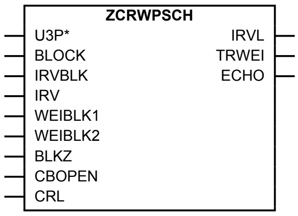

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Figure 163: ZCRWPSCH function block

10.2.4 Signals

Table 238: ZCRWPSCH Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
IRVBLK	BOOLEAN	0	Block of current reversal function
IRV	BOOLEAN	0	Activation of current reversal logic
WEIBLK1	BOOLEAN	0	Block of WEI logic
WEIBLK2	BOOLEAN	0	Block of WEI logic due to operation of other protections
BLKZ	BOOLEAN	0	Block of trip from WEI logic through fuse-failure function
CBOPEN	BOOLEAN	0	Block of trip from WEI logic by an open breaker
CRL	BOOLEAN	0	POR Carrier receive for WEI logic

Table 239: ZCRWPSCH Output signals

Name	Type	Description
IRVL	BOOLEAN	Operation of current reversal logic
TRWEI	BOOLEAN	Trip of WEI logic
ECHO	BOOLEAN	Carrier send by WEI logic

10.2.5 Settings

Table 240: ZCRWPSCH Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
CurrRev	Off On	-	-	Off	Operating mode of Current Reversal Logic
tPickUpRev	0.000 - 60.000	s	0.001	0.020	Pickup time for current reversal logic
tDelayRev	0.000 - 60.000	s	0.001	0.060	Time Delay to prevent Carrier send and local trip
WEI	Off Echo Echo & Trip	-	-	Off	Operating mode of WEI logic
tPickUpWEI	0.000 - 60.000	s	0.001	0.010	Coordination time for the WEI logic
UPP<	10 - 90	%UB	1	70	Phase to Phase voltage for detection of fault condition
UPN<	10 - 90	%UB	1	70	Phase to Neutral voltage for detection of fault condition

Table 241: ZCRWPSCH Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

10.2.6 Operation principle

10.2.6.1 Current reversal logic

The current reversal logic uses a reverse zone connected to the input IRV to recognize the fault on the parallel line in any of the phases. When the reverse zone has been activated for a certain settable time *tPickUpRev* it prevents sending of a communication signal and activation of trip signal for a predefined time *tDelayRev*. This makes it possible for the receive signal to reset before the trip signal is activated due to the current reversal by the forward directed zone, see figure 164.

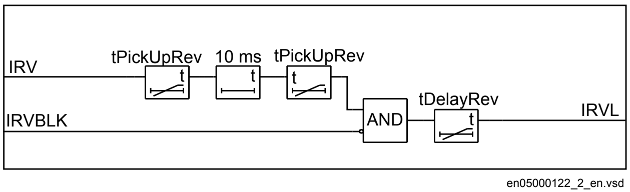


Figure 164: Current reversal logic

The preventing of sending the send signal CS and activating of the TRIP in the scheme communication block ZCPSCH is carried out by connecting the IRVL signal to input BLOCK in the ZCPSCH function.

The function has an internal 10 ms drop-off timer which secure that the current reversal logic will be activated for short input signals even if the pick-up timer is set to zero.

10.2.6.2 Weak-end infeed logic

The weak-end infeed logic (WEI) function sends back (echoes) the received signal under the condition that no fault has been detected on the weak-end by different fault detection elements (distance protection in forward and reverse direction).

The WEI function returns the received signal, see figure 165, when:

- No active signal present on the input BLOCK.
- The functional input CRL is active. This input is usually connected to the CRL output on the scheme communication logic ZCPSCH.
- The WEI function is not blocked by the active signal connected to the WEIBLK1 functional input or to the BLKZ functional input. The later is usually configured to the BLOCK functional output of the fuse-failure function.
- No active signal has been present for at least 200 ms on the WEIBLK2 functional input. An OR combination of all fault detection functions (not undervoltage) as present within the IED is usually used for this purpose.

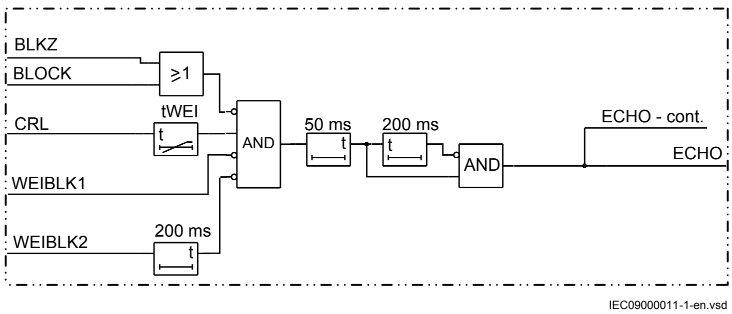


Figure 165: Echo of a received signal by the WEI function

When an echo function is used in both IEDs (should generally be avoided), a spurious signal can be looped round by the echo logics. To avoid a continuous lock-up of the system, the duration of the echoed signal is limited to 200 ms.

An undervoltage criteria is used as an additional tripping criteria, when the tripping of the local breaker is selected, setting *WEI = Echo&Trip,* together with the WEI function and ECHO signal has been issued by the echo logic, see figure 166.

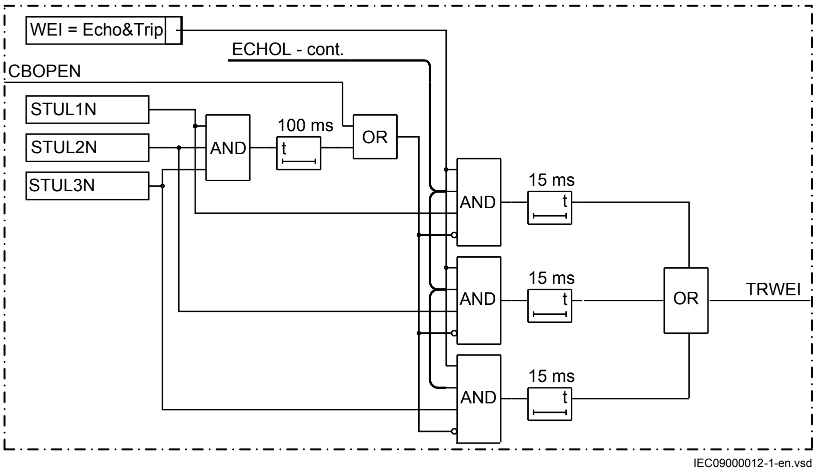


Figure 166: Tripping part of the WEI logic, simplified diagram

10.2.7 Technical data

Table 242: ZCRWPSCH Technical data

Function	Range or value	Accuracy
Operating mode of WEI logic	Off Echo Echo & Trip	-
Detection level phase-to-neutral and phase-to-phase voltage	(10-90)% of UBase	± 0.5% of U_r
Reset ratio	<105%	-
Operate time for current reversal logic	(0.000-60.000) s	± 0.5% ± 10 ms
Delay time for current reversal	(0.000-60.000) s	± 0.5% ± 10 ms
Coordination time for weak-end infeed logic	(0.000-60.000) s	± 0.5% ± 10 ms

10.3 Local acceleration logic ZCLCPLAL

10.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Local acceleration logic	ZCLCPLAL	-	-

10.3.2 Functionality

To achieve fast clearing of faults on the whole line, when no communication channel is available, local acceleration logic (ZCLCPLAL) can be used. This logic enables fast fault clearing during certain conditions, but naturally, it can not fully replace a communication channel.

The logic can be controlled either by the autorecloser (zone extension) or by the loss-of-load current (loss-of-load acceleration).

10.3.3 Function block

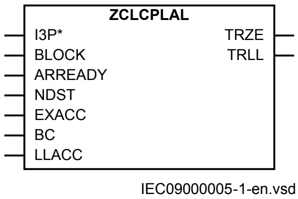


Figure 167: ZCLCPLAL function block

10.3.4 Signals

Table 243: ZCLCPLAL Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
ARREADY	BOOLEAN	0	Autoreclosure ready, releases function used for fast trip
NDST	BOOLEAN	0	Non directional criteria used to prevent instantaneous trip
EXACC	BOOLEAN	0	Connected to function used for tripping at zone extension
BC	BOOLEAN	0	Breaker Close
LLACC	BOOLEAN	0	Connected to function used for tripping at loss of load

Table 244: ZCLCPLAL Output signals

Name	Type	Description
TRZE	BOOLEAN	Trip by zone extension
TRLL	BOOLEAN	Trip by loss of load

10.3.5 Settings

Table 245: ZCLCPLAL Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
LoadCurr	1 - 100	%IB	1	10	Load current before disturbance in % of IBase
LossOfLoad	Off On	-	-	Off	Enable/Disable operation of Loss of load
ZoneExtension	Off On	-	-	Off	Enable/Disable operation of Zone extension
MinCurr	1 - 100	%IB	1	5	Level taken as current loss due to remote CB trip in % of IBase
tLowCurr	0.000 - 60.000	s	0.001	0.200	Time delay on pick-up for MINCURR value
tLoadOn	0.000 - 60.000	s	0.001	0.000	Time delay on pick-up for load current release
tLoadOff	0.000 - 60.000	s	0.001	0.300	Time delay on drop off for load current release

Table 246: ZCLCPLAL Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector

10.3.6 Operation principle

10.3.6.1 Zone extension

The overreaching zone is connected to the input EXACC. For this reason, configure the ARREADY functional input to a READY functional output of a used autoreclosing function or via the selected binary input to an external autoreclosing device, see figure 168.

This will allow the overreaching zone to trip instantaneously.

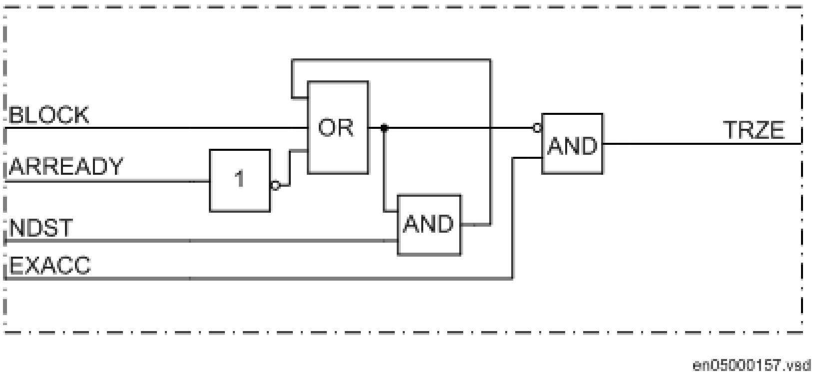


Figure 168: Simplified logic diagram for local acceleration logic

After the autorecloser initiates the close command and remains in the reclaim state, there will be no ARREADY signal, and the protection will trip normally with step distance time functions.

In case of a fault on the adjacent line within the overreaching zone range, an unwanted autoreclosing cycle will occur. The step distance function at the reclosing attempt will prevent an unwanted retrip when the breaker is reclosed.

On the other hand, at a persistent line fault on line section not covered by instantaneous zone (normally zone 1) only the first trip will be "instantaneous".

The function will be blocked if the input BLOCK is activated (common with loss-of-load acceleration).

10.3.6.2 Loss-of-Load acceleration

When the "acceleration" is controlled by a loss-of-load, the overreaching zone used for "acceleration" connected to input LLACC is not allowed to trip "instantaneously" during normal non-fault system conditions. When all three-phase currents have been above the set value *MinCurr* for more than setting *tLowCurr*, an overreaching zone will be allowed to trip "instantaneously" during a fault condition when one or two of the phase currents will become low due to a three-phase trip at the opposite IED, see figure 169. The current measurement is performed internally and the internal STILL signal becomes logical one under the described conditions. The load current in a healthy phase is in this way used to indicate the tripping at the opposite IED. Note that this function will not operate in case of three-phase faults, because none of the phase currents will be low when the opposite terminal is tripped.

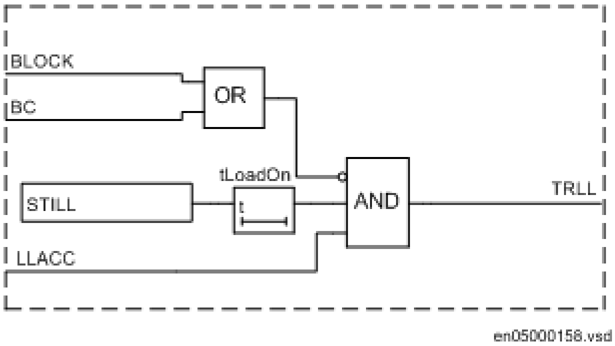


Figure 169: Loss-of-load acceleration - simplified logic diagram

Breaker closing signals can if decided be connected to block the function during normal closing.

10.4 Scheme communication logic for residual overcurrent protection ECPSCH

10.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Scheme communication logic for residual overcurrent protection	ECPSCH	-	85

10.4.2 Functionality

To achieve fast fault clearance of earth-faults on the part of the line not covered by the instantaneous step of the residual overcurrent protection, the directional residual overcurrent protection can be supported with a logic that uses communication channels.

In the directional scheme, information of the fault current direction must be transmitted to the other line end. With directional comparison, a short operate time of the protection including a channel transmission time, can be achieved. This short operate time enables rapid autoreclosing function after the fault clearance.

The communication logic module for directional residual current protection enables blocking as well as permissive under/overreaching schemes.

10.4.3 Function block

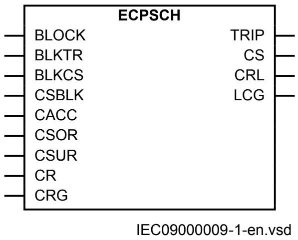


Figure 170: ECPSCH function block

10.4.4 Signals

Table 247: ECPSCH Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
BLKTR	BOOLEAN	0	Signal for blocking trip due to communication logic
BLKCS	BOOLEAN	0	Signal for blocking CS in Overreach and Blocking schemes
CSBLK	BOOLEAN	0	Reverse residual overcurrent signal for Carrier Send
CACC	BOOLEAN	0	Signal to be used for tripping by Communication Scheme
CSOR	BOOLEAN	0	Overreaching residual overcurrent signal for Carrier Send
CSUR	BOOLEAN	0	Underreaching residual overcurrent signal for Carrier Send
CR	BOOLEAN	0	Carrier Receive for Communication Scheme Logic
CRG	BOOLEAN	0	Carrier guard signal received

Table 248: ECPSCH Output signals

Name	Type	Description
TRIP	BOOLEAN	Trip by Communication Scheme Logic
CS	BOOLEAN	Carrier Send by Communication Scheme Logic
CRL	BOOLEAN	Carrier Receive from Communication Scheme Logic
LCG	BOOLEAN	loss of carrier guard signal

10.4.5 Settings

Table 249: ECPSCH Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
SchemeType	Off Intertrip Permissive UR Permissive OR Blocking	-	-	Permissive UR	Scheme type, Mode of Operation
tCoord	0.000 - 60.000	s	0.001	0.035	Communication scheme coordination time
tSendMin	0.000 - 60.000	s	0.001	0.100	Minimum duration of a carrier send signal

Table 250: ECPSCH Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
Unblock	Off NoRestart Restart	-	-	Off	Operation mode of unblocking logic
tSecurity	0.000 - 60.000	s	0.001	0.035	Security timer for loss of carrier guard detection

10.4.6 Operation principle

The four step directional residual overcurrent protection (EF4PTOC) is configured to give input information, that is directional fault detection signals, to the ECPSCH logic:

- Input signal CACC is used for tripping of the communication scheme, normally the start signal of a forward overreaching step of STFW.
- Input signal CSBLK is used for sending block signal in the blocking communication scheme, normally the start signal of a reverse overreaching step of STRV.
- Input signal CSUR is used for sending permissive signal in the underreaching permissive communication scheme, normally the start signal of a forward underreaching step of STINn, where n corresponds to the underreaching step.
- Input signal CSOR is used for sending permissive signal in the overreaching permissive communication scheme, normally the start signal of a forward overreaching step of STINn, where n corresponds to the overreaching step.

10.4.6.1 Blocking scheme

In the blocking scheme a signal is sent to the other line end if the directional element detects an earth-fault in the reverse direction. When the forward directional element operates, it trips after a short time delay if no blocking signal is received from the opposite line end. The time delay, normally 30 – 40 ms, depends on the communication transmission time and a chosen safety margin.

One advantage of the blocking scheme is that only one channel (carrier frequency) is needed if the ratio of source impedances at both end is approximately equal for zero and positive sequence source impedances, the channel can be shared with the impedance measuring system, if that system also works in the blocking mode. The communication signal is transmitted on a healthy line and no signal attenuation will occur due to the fault.

Blocking schemes are particular favorable for three-terminal applications if there is no zero sequence outfeed from the tapping. The blocking scheme is immune to current reversals because the received signal is maintained long enough to avoid unwanted operation due to current reversal. There is never any need for weak-end infeed logic, because the strong end trips for an internal fault when no blocking signal is received from the weak end. The fault clearing time is however generally longer for a blocking scheme than for a permissive scheme.

If the fault is on the line, the forward direction measuring element operates. If no blocking signal comes from the other line end via the CR binary input (received signal) the TRIP output is activated after the *tCoord* set time delay.

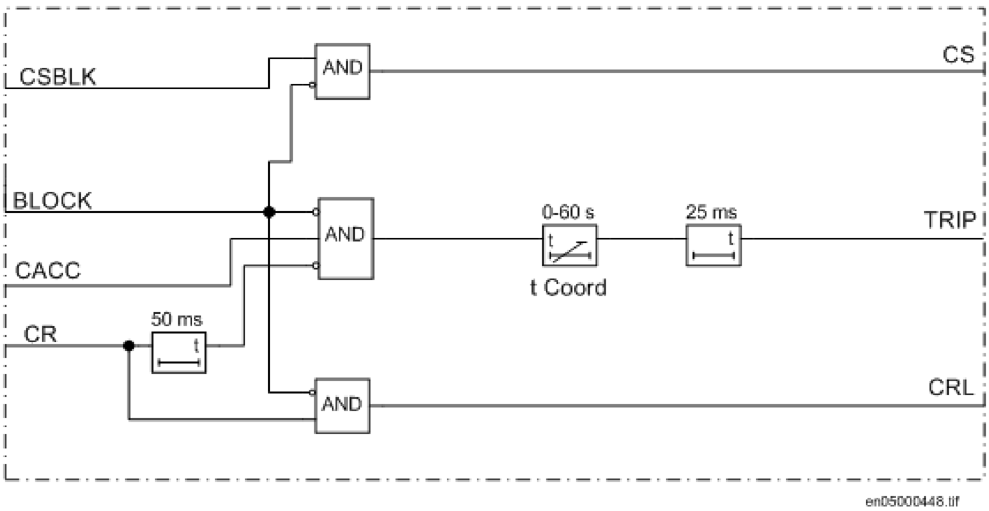


Figure 171: Simplified logic diagram for blocking scheme.

10.4.6.2 Permissive under/overreaching scheme

In the permissive scheme the forward directed earth-fault measuring element sends a permissive signal to the other end, if an earth-fault is detected in the forward direction. The directional element at the other line end must wait for a permissive signal before activating a trip signal. Independent channels must be available for the communication in each direction.

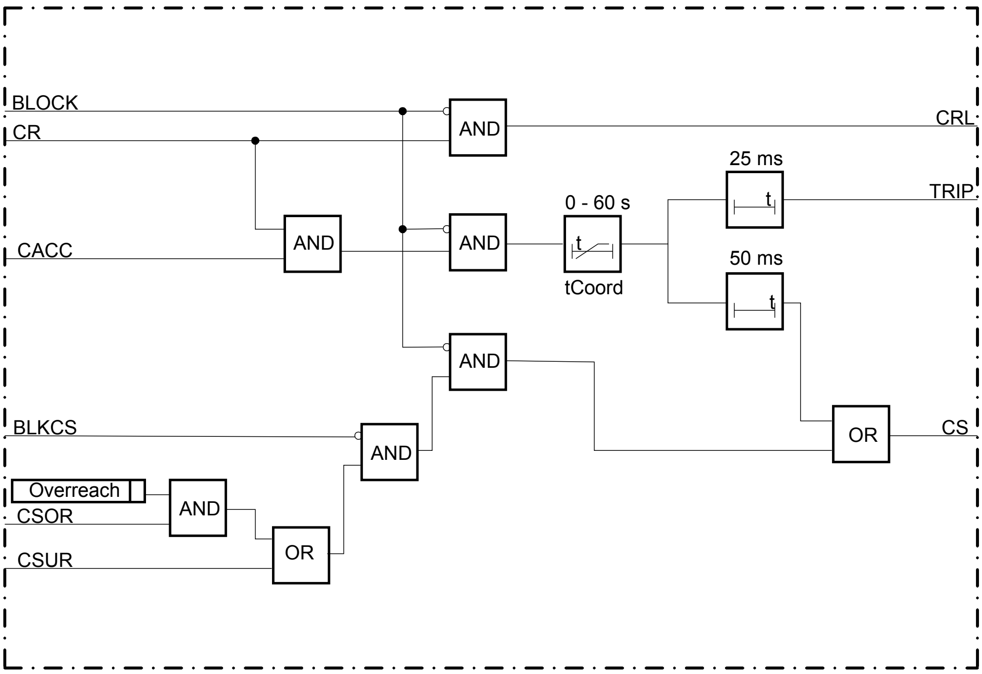
An impedance measuring IED which works in the same type of permissive mode, with one channel in each direction, can share the channels with the communication scheme for residual overcurrent protection. If the impedance measuring IED works in the permissive overreaching mode, common channels can be used in single line applications. In case of double lines connected to a common bus at both ends, use common channels only if the ratio Z_{1S}/Z_{0S} (positive through zero-sequence source impedance) is about equal at both ends. If the ratio is different, the impedance measuring and the directional earth-fault current system of the healthy line may detect a fault in different directions, which could result in unwanted tripping.

Common channels cannot be used when the weak-end infeed function is used in the distance or earth-fault protection.

In case of an internal earth-fault, the forward directed measuring element operates and sends a permissive signal to the remote end via the CS output (sent signal). Local tripping is permitted when the forward direction measuring element operates and a permissive signal is received via the CR binary input (received signal).

The permissive scheme can be of either underreaching or overreaching type. In the underreaching alternative, an underreaching directional residual overcurrent measurement element will be used as sending criterion of the permissive input signal CSUR.

In the overreaching alternative, an overreaching directional residual overcurrent measurement element will be used as sending criterion of the permissive input signal CSOR. Also the underreaching input signal CSUR can initiate sending.



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10.4.6.3 Unblocking scheme

In unblocking scheme, the lower dependability in permissive scheme is overcome by using the loss of guard signal from the communication equipment to locally create a receive signal. It is common or suitable to use the function when older, less reliable, power line carrier (PLC) communication is used.

The unblocking function uses a guard signal CRG, which must always be present, even when no CR signal is received. The absence of the CRG signal for a time longer than the setting *tSecurity* time is used as a CR signal, see figure 172. This also enables a permissive scheme to operate when the line fault blocks the signal transmission.

The received signal created by the unblocking function is reset 150 ms after the security timer has elapsed. When that occurs an output signal LCG is activated for signalling purpose. The unblocking function is reset 200 ms after that the guard signal is present again.

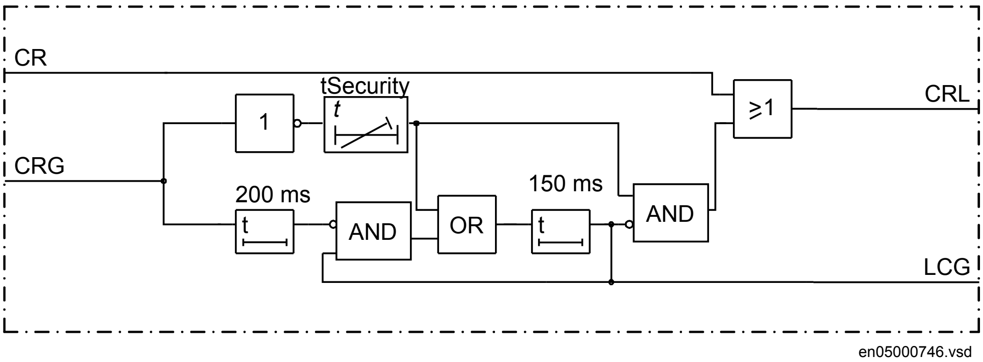

Figure 172: Guard signal logic with unblocking scheme

The unblocking function can be set in three operation modes (setting *Unblock*):

Off:	The unblocking function is out of operation
No restart:	Communication failure shorter than *tSecurity* will be ignored
	If CRG disappears, a CRL signal will be transferred to the trip logic
	There will not be any information in case of communication failure (LCG)
Restart	Communication failure shorter than *tSecurity* will be ignored
	It sends a defined (150 ms) CRL after the disappearance of the CRG signal
	The function will activate LCG output in case of communication failure
	If the communication failure comes and goes (<200 ms) there will not be recurrent signalling

10.4.7 Technical data

Table 251: ECPSCH Technical data

Function	Range or value	Accuracy
Scheme type	Off Intertrip Permissive UR Permissive OR Blocking	-
Communication scheme coordination time	(0.000-60.000) s	± 0.5% ± 10 ms
Minimum duration of a send signal	(0.000-60.000) s	± 0.5% ± 10 ms
Security timer for loss of carrier guard detection	(0.000-60.000) s	± 0.5% ± 10 ms

10.5 Current reversal and weak-end infeed logic for residual overcurrent protection ECRWPSCH

10.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current reversal and weak-end infeed logic for residual overcurrent protection	ECRWPSCH	-	85

10.5.2 Functionality

The Current reversal and weak-end infeed logic for residual overcurrent protection (ECRWPSCH) is a supplement to Scheme communication logic for residual overcurrent protection (ECPSCH).

To achieve fast fault clearing for all earth-faults on the line, the directional earth-fault protection function can be supported with logic, that uses communication channels.

The 650 series IEDs have for this reason available additions to scheme communication logic.

If parallel lines are connected to common busbars at both terminals, overreaching permissive communication schemes can trip unselectively due to fault current reversal. This unwanted tripping affects the healthy line when a fault is cleared on the other line. This lack of security can result in a total loss of interconnection between the two buses. To avoid this type of disturbance, a fault current reversal logic (transient blocking logic) can be used.

Permissive communication schemes for residual overcurrent protection, can basically operate only when the protection in the remote terminal can detect the fault. The detection requires a sufficient minimum residual fault current, out from this terminal. The fault current can be too low due to an opened breaker or high positive and/or zero sequence source impedance behind this terminal. To overcome these conditions, weak end infeed (WEI) echo logic is used.

10.5.3 Function block

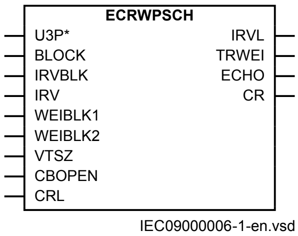

Figure 173: ECRWPSCH function block

10.5.4 Signals

Table 252: ECRWPSCH Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs
BLOCK	BOOLEAN	0	Block of function
IRVBLK	BOOLEAN	0	Block of current reversal function
IRV	BOOLEAN	0	Activation of current reversal logic
WEIBLK1	BOOLEAN	0	Block of WEI Logic
WEIBLK2	BOOLEAN	0	Block of WEI logic due to operation of other protections
VTSZ	BOOLEAN	0	Block of trip from WEI logic through fuse-failure function
CBOPEN	BOOLEAN	0	Block of trip from WEI logic by an open breaker
CRL	BOOLEAN	0	POR Carrier receive for WEI logic

Table 253: ECRWPSCH Output signals

Name	Type	Description
IRVL	BOOLEAN	Operation of current reversal logic
TRWEI	BOOLEAN	Trip of WEI logic
ECHO	BOOLEAN	Carrier send by WEI logic
CR	BOOLEAN	POR Carrier signal received from remote end

10.5.5 Settings

Table 254: ECRWPSCH Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
CurrRev	Off On	-	-	Off	Operating mode of Current Reversal Logic
tPickUpRev	0.000 - 60.000	s	0.001	0.020	Pickup time for current reversal logic
tDelayRev	0.000 - 60.000	s	0.001	0.060	Time Delay to prevent Carrier send and local trip
WEI	Off Echo Echo & Trip	-	-	Off	Operating mode of WEI logic
tPickUpWEI	0.000 - 60.000	s	0.001	0.000	Coordination time for the WEI logic
3U0>	5 - 70	%UB	1	25	Neutral voltage setting for fault conditions measurement

Table 255: ECRWPSCH Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Global base selector

10.5.6 Operation principle

10.5.6.1 Directional comparison logic function

The directional comparison function contains logic for blocking overreaching and permissive overreaching schemes.

The circuits for the permissive overreaching scheme contain logic for current reversal and weak-end infeed functions. These functions are not required for the blocking overreaching scheme.

Use the independent or inverse time functions in the directional earth-fault protection module to get back-up tripping in case the communication equipment malfunctions and prevents operation of the directional comparison logic.

Figure 174 and figure 175 show the logic circuits.

10.5.6.2 Fault current reversal logic

The fault current reversal logic uses a reverse directed element, connected to input signal IRV, which recognizes that the fault is in reverse direction. When the reverse direction element is activated during the *tPickUpRev* time, the output signal IRVL is activated, see figure 174. The logic is now ready to handle a current reversal without tripping. Output signal IRVL will be connected to the block input on the permissive overreaching scheme.

When the fault current is reversed on the non faulty line, IRV is deactivated and IRVBLK is activated. The reset of IRVL is delayed by the *tDelayRev* time, see figure 174. This ensures the reset of the received CR signal.

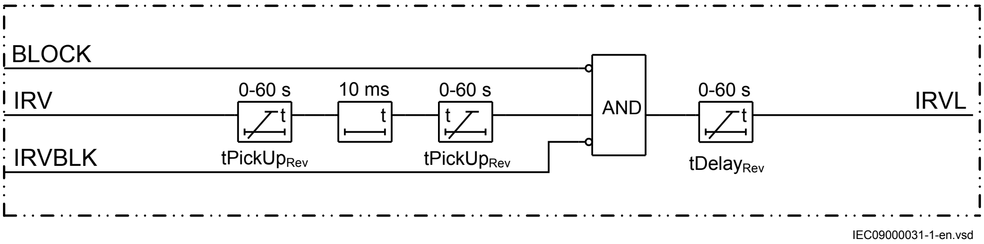

Figure 174: Simplified logic diagram, current reversal

10.5.6.3 Weak-end infeed logic

The weak-end infeed function can be set to send only an echo signal (*WEI=Echo*) or an echo signal and a trip signal (*WEI=Echo & Trip*). See figure 175 and figure 176.

The weak-end infeed logic uses normally a reverse and a forward direction element, connected to WEIBLK1 via an OR-gate. See figure 175. If neither the forward nor the reverse directional measuring element is activated during the last 200 ms. The weak-end infeed logic echoes back the received permissive signal. See figure 175.

If the forward or the reverse directional measuring element is activated during the last 200 ms, the fault current is sufficient for the IED to detect the fault with the earth-fault function that is in operation.

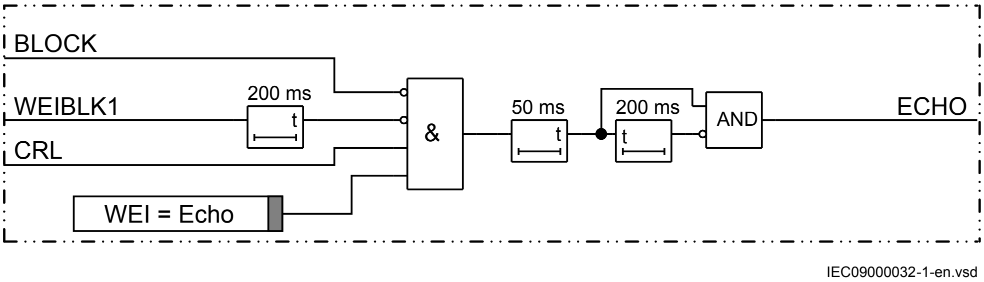

Figure 175: Simplified logic diagram, weak-end infeed - Echo.

With the *Echo & Trip* setting, the logic sends an echo according to above. Further, it activates the TRWEI signal to trip the breaker if the echo conditions are fulfilled and the neutral point voltage is above the set operate value for $3U_0$>.

The voltage signal that is used to calculate the zero sequence voltage is set in the earth-fault function that is in operation.

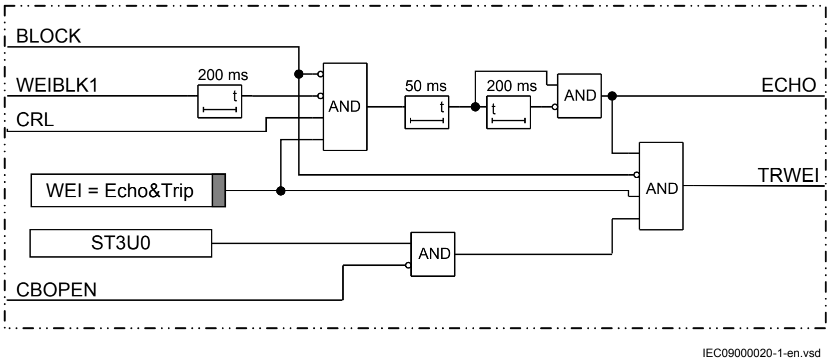

Figure 176: Simplified logic diagram, weak-end infeed - Echo & Trip.

The weak-end infeed echo sent to the strong line end has a maximum duration of 200 ms. When this time period has elapsed, the conditions that enable the echo signal to be sent are set to zero for a time period of 50 ms. This avoids ringing action if the weak-end echo is selected for both line ends.

10.5.7 Technical data

Table 256: ECRWPSCH Technical data

Function	Range or value	Accuracy
Operating mode of WEI logic	Off Echo Echo & Trip	-
Operate voltage $3U_o$ for WEI trip	(5-70)% of UBase	± 1.0% of U_r
Reset ratio	>95%	-
Operate time for current reversal logic	(0.000-60.000) s	± 0.5% ± 10 ms
Delay time for current reversal	(0.000-60.000) s	± 0.5% ± 10 ms
Coordination time for weak-end infeed logic	(0.000–60.000) s	± 0.5% ± 10 ms

Section 11 Logic

11.1 Tripping logic SMPPTRC

11.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Tripping logic	SMPPRTC	*I->O*	94

11.1.2 Functionality

A function block for protection tripping is provided for each circuit breaker involved in the tripping of the fault. It provides the pulse prolongation to ensure a trip pulse of sufficient length, as well as all functionality necessary for correct co-operation with autoreclosing functions.

The trip function block includes functionality for breaker lock-out.

11.1.3 Function block

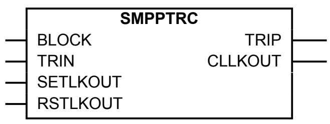

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Figure 177: SMPPTRC function block

11.1.4 Signals

Table 257: SMPPTRC Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
TRIN	BOOLEAN	0	Trip all phases
SETLKOUT	BOOLEAN	0	Input for setting the circuit breaker lockout function
RSTLKOUT	BOOLEAN	0	Input for resetting the circuit breaker lockout function

Table 258: SMPPTRC Output signals

Name	Type	Description
TRIP	BOOLEAN	General trip signal
CLLKOUT	BOOLEAN	Circuit breaker lockout output (set until reset)

11.1.5 Settings

Table 259: SMPPTRC Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
tTripMin	0.000 - 60.000	s	0.001	0.150	Minimum duration of trip output signal

Table 260: SMPPTRC Group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
TripLockout	Off On	-	-	Off	On: Activate output (CLLKOUT) and trip latch, Off: Only output
AutoLock	Off On	-	-	Off	On: Lockout from input (SETLKOUT) and trip, Off: Only input

11.1.6 Operation principle

The duration of a trip output signal from tripping logic (SMPPTRC) function is settable (*tTripMin*). The pulse length should be long enough to secure the breaker opening.

For three-phase tripping, SMPPTRC function has a single input (TRIN) through which all trip output signals from the protection functions within the IED, or from external protection functions via one or more of the IEDs binary inputs, are routed. It has a single trip output (TRIP) for connection to one or more of the IEDs binary outputs, as well as to other functions within the IED requiring this signal.

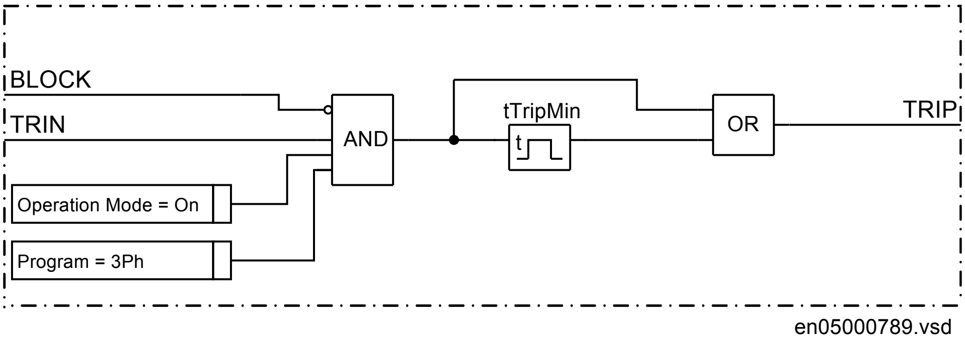


Figure 178: Simplified logic diagram for three phase trip

In multi-breaker arrangements, one SMPPTRC function block is used for each breaker.

The breaker close lockout function can be activated from an external trip signal from another protection function via input (SETLKOUT) or internally at a three-phase trip, if desired.

It is possible to lockout seal in the tripping output signals or use blocking of closing only the choice is by setting *TripLockout.*

11.1.7 Technical data

Table 261: SMPPTRC Technical data

Function	Range or value	Accuracy
Trip action	3-ph	-
Minimum trip pulse length	(0.000-60.000) s	± 0.5% ± 10 ms

11.2 Trip matrix logic TMAGGIO

11.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Trip matrix logic	TMAGGIO	-	-

11.2.2 Functionality

Trip matrix logic (TMAGGIO) function is used to route trip signals and/or other logical output signals to different output contacts on the IED.

TMAGGIO output signals and the physical outputs are available in PCM600 and this allows the user to adapt the signals to the physical tripping outputs according to the specific application needs.

11.2.3 Function block

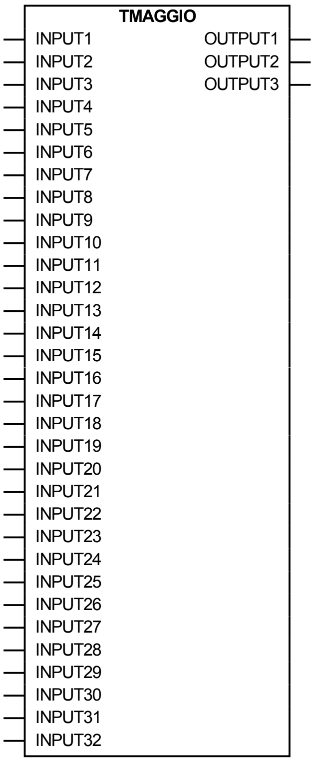


Figure 179: TMAGGIO function block

11.2.4 Signals

Table 262: TMAGGIO Input signals

Name	Type	Default	Description
INPUT1	BOOLEAN	0	Binary input 1
INPUT2	BOOLEAN	0	Binary input 2
INPUT3	BOOLEAN	0	Binary input 3
INPUT4	BOOLEAN	0	Binary input 4
INPUT5	BOOLEAN	0	Binary input 5
INPUT6	BOOLEAN	0	Binary input 6
INPUT7	BOOLEAN	0	Binary input 7
INPUT8	BOOLEAN	0	Binary input 8
INPUT9	BOOLEAN	0	Binary input 9
INPUT10	BOOLEAN	0	Binary input 10

Table continues on next page

Name	Type	Default	Description
INPUT11	BOOLEAN	0	Binary input 11
INPUT12	BOOLEAN	0	Binary input 12
INPUT13	BOOLEAN	0	Binary input 13
INPUT14	BOOLEAN	0	Binary input 14
INPUT15	BOOLEAN	0	Binary input 15
INPUT16	BOOLEAN	0	Binary input 16
INPUT17	BOOLEAN	0	Binary input 17
INPUT18	BOOLEAN	0	Binary input 18
INPUT19	BOOLEAN	0	Binary input 19
INPUT20	BOOLEAN	0	Binary input 20
INPUT21	BOOLEAN	0	Binary input 21
INPUT22	BOOLEAN	0	Binary input 22
INPUT23	BOOLEAN	0	Binary input 23
INPUT24	BOOLEAN	0	Binary input 24
INPUT25	BOOLEAN	0	Binary input 25
INPUT26	BOOLEAN	0	Binary input 26
INPUT27	BOOLEAN	0	Binary input 27
INPUT28	BOOLEAN	0	Binary input 28
INPUT29	BOOLEAN	0	Binary input 29
INPUT30	BOOLEAN	0	Binary input 30
INPUT31	BOOLEAN	0	Binary input 31
INPUT32	BOOLEAN	0	Binary input 32

Table 263: TMAGGIO Output signals

Name	Type	Description
OUTPUT1	BOOLEAN	OR function betweeen inputs 1 to 16
OUTPUT2	BOOLEAN	OR function between inputs 17 to 32
OUTPUT3	BOOLEAN	OR function between inputs 1 to 32

11.2.5 Settings

Table 264: TMAGGIO Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
PulseTime	0.050 - 60.000	s	0.001	0.150	Output pulse time
OnDelay	0.000 - 60.000	s	0.001	0.000	Output on delay time
OffDelay	0.000 - 60.000	s	0.001	0.000	Output off delay time

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
ModeOutput1	Steady Pulsed	-	-	Steady	Mode for output 1, steady or pulsed
ModeOutput2	Steady Pulsed	-	-	Steady	Mode for output 2, steady or pulsed
ModeOutput3	Steady Pulsed	-	-	Steady	Mode for output 3, steady or pulsed

11.2.6 Operation principle

Trip matrix logic (TMAGGIO) block is provided with 32 input signals and 3 output signals. The function block incorporates internal logic OR gates in order to provide the necessary grouping of connected input signals (e.g. for tripping and alarming purposes) to the three output signals from the function block.

Internal built-in OR logic is made in accordance with the following three rules:

1. when any one of first 16 inputs signals (INPUT1 to INPUT16) has logical value 1 (TRUE) the first output signal (OUTPUT1) will get logical value 1 (TRUE).
2. when any one of second 16 inputs signals (INPUT17 to INPUT32) has logical value 1 (TRUE) the second output signal (OUTPUT2) will get logical value 1 (TRUE).
3. when any one of all 32 input signals (INPUT1 to INPUT32) has logical value 1 (TRUE) the third output signal (OUTPUT3) will get logical value 1 (TRUE).

By use of the settings *ModeOutput1, ModeOutput2, ModeOutput3, PulseTime, OnDelay* and *OffDelay* the behaviour of each output can be customized. The *OnDelay* is always active and will delay the input to output transition by the set time. The *ModeOutput* for respective output decides wether the output shall be steady with an drop-off delay as set by *OffDelay* or if it shall give a pulse with duration set by *PulseTime*. Note that for pulsed operation since the inputs are connected in an OR-function a new pulse will only be given on the output if all related inputs are reset and then one is activated again. And for steady operation the of delay will start when all related inputs have reset. Detailed logical diagram is shown in figure 180

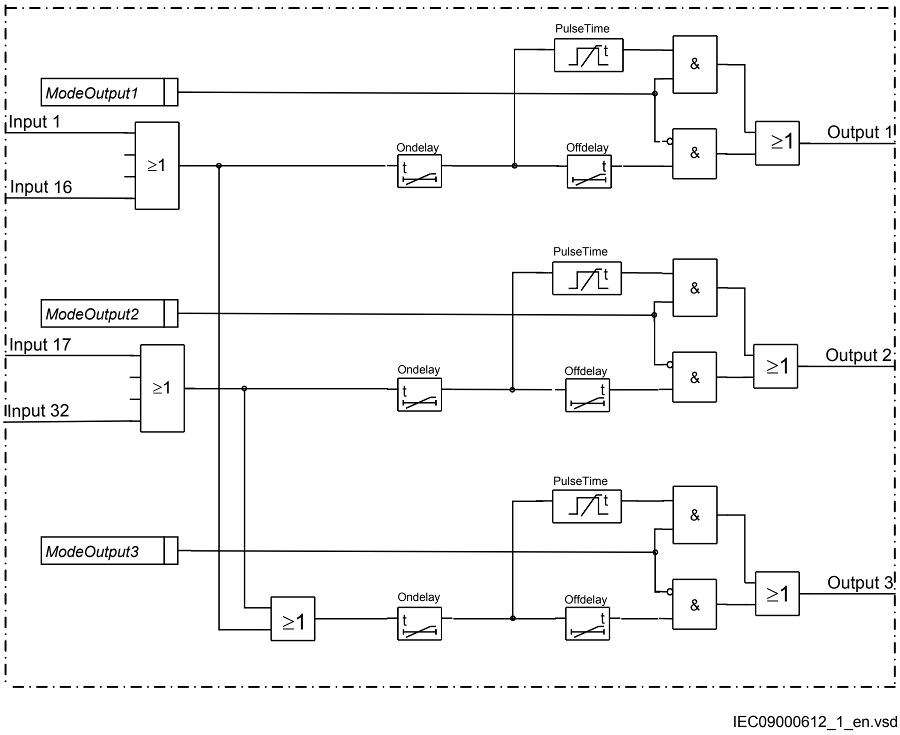


Figure 180: Trip matrix internal logic

Output signals from TMAGGIO are typically connected to other logic blocks or directly to output contacts in the IED. When used for direct tripping of the circuit breaker(s) the pulse time delay shall be set to approximately 0.150 seconds in order to obtain satisfactory minimum duration of the trip pulse to the circuit breaker trip coils.

11.3 Configurable logic blocks

11.3.1 Standard configurable logic blocks

11.3.1.1 Functionality

A number of logic blocks and timers are available for user to adapt the configuration to the specific application needs.

- **OR** function block.
- **INVERTER** function blocks that inverts the input signal.
- **PULSETIMER** function block can be used, for example, for pulse extensions or limiting of operation of outputs.

- **GATE** function block is used for controlling if a signal should be able to pass from the input to the output or not depending on a setting.
- **XOR** function block.
- **LOOPDELAY** function block used to delay the output signal one execution cycle.
- **TIMERSET** function has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay.
- **AND** function block.
- **SRMEMORY** function block is a flip-flop that can set or reset an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block after a power interruption should return to the state before the interruption, or be reset. Set input has priority.
- **RSMEMORY** function block is a flip-flop that can reset or set an output from two inputs respectively. Each block has two outputs where one is inverted. The memory setting controls if the block after a power interruption should return to the state before the interruption, or be reset. Reset input has priority.

11.3.1.2 OR function block

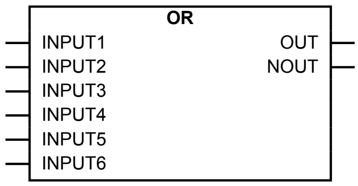
Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
OR Function block	OR	-	-

Functionality

The OR function is used to form general combinatory expressions with boolean variables. The OR function block has six inputs and two outputs. One of the outputs is inverted.

Function block



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Signals

Table 265: OR Input signals

Name	Type	Default	Description
INPUT1	BOOLEAN	0	Input signal 1
INPUT2	BOOLEAN	0	Input signal 2
INPUT3	BOOLEAN	0	Input signal 3
INPUT4	BOOLEAN	0	Input signal 4
INPUT5	BOOLEAN	0	Input signal 5
INPUT6	BOOLEAN	0	Input signal 6

Table 266: OR Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
NOUT	BOOLEAN	Inverted output signal

Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.3.1.3 Inverter function block INVERTER

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Inverter function block	INVERTER	-	-

Function block

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Signals

Table 267: INVERTER Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Input signal

Table 268: INVERTER Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.3.1.4 PULSETIMER function block

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
PULSETIMER function block	PULSETIMER	-	-

Functionality

The pulse function can be used, for example for pulse extensions or limiting of operation of outputs. The PULSETIMER has a settable length.

Function block

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Signals

Table 269: PULSETIMER Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Input signal

Table 270: PULSETIMER Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

Settings

Table 271: PULSETIMER Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
t	0.000 - 90000.000	s	0.001	0.010	Pulse time length

11.3.1.5 Controllable gate function block GATE

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Controllable gate function block	GATE	-	-

Functionality

The GATE function block is used for controlling if a signal should pass from the input to the output or not, depending on setting.

Function block

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Signals

Table 272: GATE Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Input signal

Table 273: GATE Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal

Settings

Table 274: GATE Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On

11.3.1.6 Exclusive OR function block XOR

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Exclusive OR function block	XOR	-	-

Functionality

The exclusive OR function XOR is used to generate combinatory expressions with boolean variables. The function block XOR has two inputs and two outputs. One of the outputs is inverted. The output signal is 1 if the input signals are different and 0 if they are equal.

Function block

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Signals

Table 275: XOR Input signals

Name	Type	Default	Description
INPUT1	BOOLEAN	0	Input signal 1
INPUT2	BOOLEAN	0	Input signal 2

Table 276: XOR Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
NOUT	BOOLEAN	Inverted output signal

Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.3.1.7 Loop delay function block LOOPDELAY

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Logic loop delay function block	LOOPDELAY	-	-

The LOOPDELAY function is used to delay the output signal one execution cycle.

Function block

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Signals

Table 277: LOOPDELAY Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Input signal

Table 278: LOOPDELAY Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal, signal is delayed one execution cycle

Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.3.1.8 Timer function block TIMERSET

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Timer function block	TIMERSET	-	-

Functionality

The function block TIMERSET has pick-up and drop-out delayed outputs related to the input signal. The timer has a settable time delay (*t*).

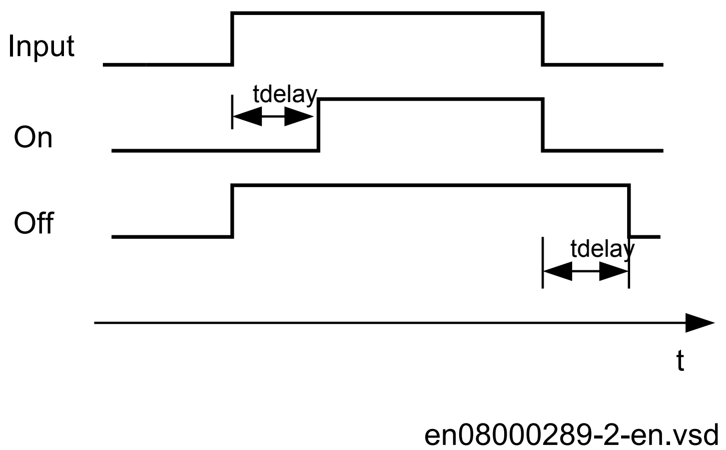

Figure 181: TIMERSET Status diagram

Function block

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Signals

Table 279: TIMERSET Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Input signal

Table 280: TIMERSET Output signals

Name	Type	Description
ON	BOOLEAN	Output signal, pick-up delayed
OFF	BOOLEAN	Output signal, drop-out delayed

Settings

Table 281: TIMERSET Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
t	0.000 - 90000.000	s	0.001	0.000	Delay for settable timer n

11.3.1.9 AND function block

Identification

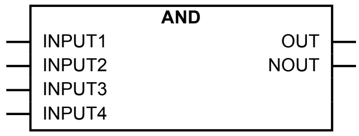
Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
AND function block	AND	-	-

Functionality

The AND function is used to form general combinatory expressions with boolean variables. The AND function block has four inputs and two outputs.

Default value on all four inputs are logical 1 which makes it possible for the user to just use the required number of inputs and leave the rest un-connected. The output OUT has a default value 0 initially, which suppresses one cycle pulse if the function has been put in the wrong execution order.

Function block



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Signals

Table 282: AND Input signals

Name	Type	Default	Description
INPUT1	BOOLEAN	1	Input signal 1
INPUT2	BOOLEAN	1	Input signal 2
INPUT3	BOOLEAN	1	Input signal 3
INPUT4	BOOLEAN	1	Input signal 4

Table 283: AND Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
NOUT	BOOLEAN	Inverted output signal

Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.3.1.10 Set-reset memory function block SRMEMORY

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Set-reset memory function block	SRMEMORY	-	-

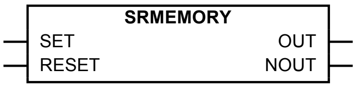
Functionality

The Set-Reset function SRMEMORY is a flip-flop with memory that can set or reset an output from two inputs respectively. Each SRMEMORY function block has two outputs, where one is inverted. The memory setting controls if the flip-flop after a power interruption will return the state it had before or if it will be reset. For a Set-Reset flip-flop, SET input has higher priority over RESET input.

Table 284: Truth table for the Set-Reset (SRMEMORY) function block

SET	RESET	OUT	NOUT
1	0	1	0
0	1	0	1
1	1	1	0
0	0	0	1

Function block



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Signals

Table 285: SRMEMORY Input signals

Name	Type	Default	Description
SET	BOOLEAN	0	Input signal to set
RESET	BOOLEAN	0	Input signal to reset

Table 286: SRMEMORY Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
NOUT	BOOLEAN	Inverted output signal

Settings

Table 287: SRMEMORY Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Memory	Off On	-	-	On	Operating mode of the memory function

11.3.1.11 Reset-set with memory function block RSMEMORY

Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Reset-set with memory function block	RSMEMORY	-	-

Functionality

The Reset-Set function RSMEMORY is a flip-flop with memory that can reset or set an output from two inputs respectively. Each RSMEMORY function block has two outputs, where one is inverted. The memory setting controls if the flip-flop after a power interruption will return the state it had before or if it will be reset. For a Reset-Set flip-flop, RESET input has higher priority over SET input.

Table 288: Truth table for the Reset-Set (RSMEMORY) function block

SET	RESET	OUT	NOUT
1	0	1	0
0	1	0	1
1	1	0	1
0	0	0	1

Function block

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Signals

Table 289: RSMEMORY Input signals

Name	Type	Default	Description
SET	BOOLEAN	0	Input signal to set
RESET	BOOLEAN	0	Input signal to reset

Table 290: RSMEMORY Output signals

Name	Type	Description
OUT	BOOLEAN	Output signal
NOUT	BOOLEAN	Inverted output signal

Settings

Table 291: RSMEMORY Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Memory	Off On	-	-	On	Operating mode of the memory function

11.3.2 Technical data

Table 292: Configurable logic blocks

Logic block	Quantity with cycle time			Range or value	Accuracy
	5 ms	20 ms	100 ms		
LogicAND	60	60	160	-	-
LogicOR	60	60	160	-	-
LogicXOR	10	10	20	-	-
LogicInverter	30	30	80	-	-
LogicSRMemory	10	10	20	-	-
LogicGate	10	10	20	-	-
LogicPulseTimer	10	10	20	(0.000–90000.000) s	± 0.5% ± 10 ms
LogicTimerSet	10	10	20	(0.000–90000.000) s	± 0.5% ± 10 ms
LogicLoopDelay	10	10	20		

11.4 Fixed signals FXDSIGN

11.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fixed signals	FXDSIGN	-	-

11.4.2 Functionality

The Fixed signals function (FXDSIGN) generates a number of pre-set (fixed) signals that can be used in the configuration of an IED, either for forcing the unused inputs in other function blocks to a certain level/value, or for creating a certain logic.

11.4.3 Function block

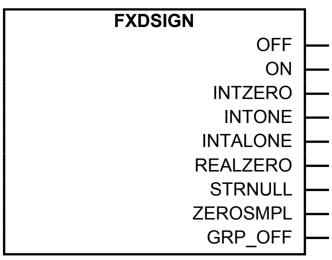

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Figure 182: FXDSIGN function block

11.4.4 Signals

Table 293: FXDSIGN Output signals

Name	Type	Description
OFF	BOOLEAN	Boolean signal fixed off
ON	BOOLEAN	Boolean signal fixed on
INTZERO	INTEGER	Integer signal fixed zero
INTONE	INTEGER	Integer signal fixed one
INTALONE	INTEGER	Integer signal fixed all ones
REALZERO	REAL	Real signal fixed zero
STRNULL	STRING	String signal with no characters
ZEROSMPL	GROUP SIGNAL	Channel id for zero sample
GRP_OFF	GROUP SIGNAL	Group signal fixed off

11.4.5 Settings

The function does not have any settings available in Local HMI or Protection and Control IED Manager (PCM600).

11.4.6 Operation principle

There are nine outputs from the FXDSIGN function block:

- OFF is a boolean signal, fixed to OFF (boolean 0) value
- ON is a boolean signal, fixed to ON (boolean 1) value
- INTZERO is an integer number, fixed to integer value 0
- INTONE is an integer number, fixed to integer value 1
- INTALONE is an integer value FFFF
- REALZERO is a floating point real number, fixed to 0.0 value
- STRNULL is a string, fixed to an empty string (null) value
- ZEROSMPL is a channel index, fixed to 0 value
- GRP_OFF is a group signal, fixed to 0 value

11.5 Boolean 16 to integer conversion B16I

11.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Boolean 16 to integer conversion	B16I	-	-

11.5.2 Functionality

Boolean 16 to integer conversion function (B16I) is used to transform a set of 16 binary (logical) signals into an integer.

11.5.3 Function block

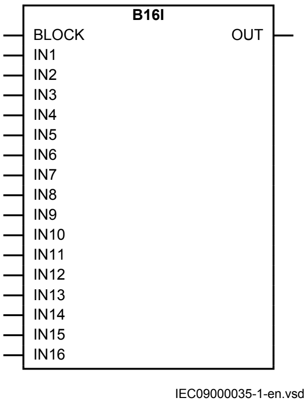

Figure 183: B16I function block

11.5.4 Signals

Table 294: B16I Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
IN1	BOOLEAN	0	Input 1
IN2	BOOLEAN	0	Input 2
IN3	BOOLEAN	0	Input 3
IN4	BOOLEAN	0	Input 4
IN5	BOOLEAN	0	Input 5
IN6	BOOLEAN	0	Input 6
IN7	BOOLEAN	0	Input 7
IN8	BOOLEAN	0	Input 8
IN9	BOOLEAN	0	Input 9
IN10	BOOLEAN	0	Input 10
IN11	BOOLEAN	0	Input 11
IN12	BOOLEAN	0	Input 12
IN13	BOOLEAN	0	Input 13
IN14	BOOLEAN	0	Input 14
IN15	BOOLEAN	0	Input 15
IN16	BOOLEAN	0	Input 16

Table 295: B16I Output signals

Name	Type	Description
OUT	INTEGER	Output value

11.5.5 Settings

The function does not have any parameters available in local HMI or Protection and Control IED Manager (PCM600)

11.5.6 Monitored data

Table 296: B16I Monitored data

Name	Type	Values (Range)	Unit	Description
OUT	INTEGER	-	-	Output value

11.5.7 Operation principle

Boolean 16 to integer conversion function (B16I) is used to transform a set of 16 binary (logical) signals into an integer. The BLOCK input will freeze the output at the last value.

11.6 Boolean 16 to integer conversion with logic node representation B16IFCVI

11.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Boolean 16 to integer conversion with logic node representation	B16IFCVI	-	-

11.6.2 Functionality

Boolean 16 to integer conversion with logic node representation function (B16IFCVI) is used to transform a set of 16 binary (logical) signals into an integer.

11.6.3 Function block

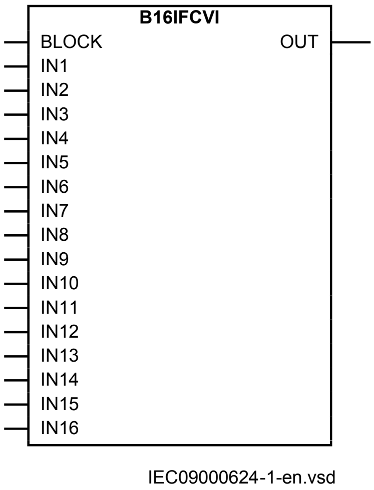

Figure 184: B16IFCVI function block

11.6.4 Signals

Table 297: B16IFCVI Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
IN1	BOOLEAN	0	Input 1
IN2	BOOLEAN	0	Input 2
IN3	BOOLEAN	0	Input 3
IN4	BOOLEAN	0	Input 4
IN5	BOOLEAN	0	Input 5
IN6	BOOLEAN	0	Input 6
IN7	BOOLEAN	0	Input 7
IN8	BOOLEAN	0	Input 8
IN9	BOOLEAN	0	Input 9
IN10	BOOLEAN	0	Input 10
IN11	BOOLEAN	0	Input 11
IN12	BOOLEAN	0	Input 12
IN13	BOOLEAN	0	Input 13
IN14	BOOLEAN	0	Input 14
IN15	BOOLEAN	0	Input 15
IN16	BOOLEAN	0	Input 16

Table 298: B16IFCVI Output signals

Name	Type	Description
OUT	INTEGER	Output value

11.6.5 Settings

The function does not have any parameters available in local HMI or Protection and Control IED Manager (PCM600)

11.6.6 Monitored data

Table 299: B16IFCVI Monitored data

Name	Type	Values (Range)	Unit	Description
OUT	INTEGER	-	-	Output value

11.6.7 Operation principle

Boolean 16 to integer conversion with logic node representation function (B16IFCVI) is used to transform a set of 16 binary (logical) signals into an integer. The BLOCK input will freeze the output at the last value.

11.7 Integer to boolean 16 conversion IB16A

11.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Integer to boolean 16 conversion	IB16A	-	-

11.7.2 Functionality

Integer to boolean 16 conversion function (IB16A) is used to transform an integer into a set of 16 binary (logical) signals.

11.7.3 Function block

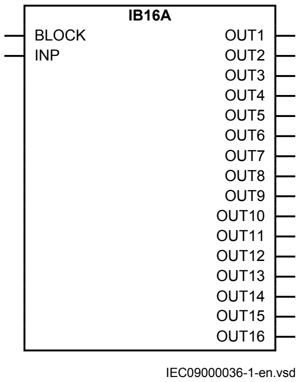

Figure 185: IB16A function block

11.7.4 Signals

Table 300: IB16A Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
INP	INTEGER	0	Integer Input

Table 301: IB16A Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1
OUT2	BOOLEAN	Output 2
OUT3	BOOLEAN	Output 3
OUT4	BOOLEAN	Output 4
OUT5	BOOLEAN	Output 5
OUT6	BOOLEAN	Output 6
OUT7	BOOLEAN	Output 7
OUT8	BOOLEAN	Output 8
OUT9	BOOLEAN	Output 9
OUT10	BOOLEAN	Output 10
OUT11	BOOLEAN	Output 11
OUT12	BOOLEAN	Output 12
OUT13	BOOLEAN	Output 13
OUT14	BOOLEAN	Output 14
OUT15	BOOLEAN	Output 15
OUT16	BOOLEAN	Output 16

11.7.5 Settings

The function does not have any parameters available in local HMI or Protection and Control IED Manager (PCM600)

11.7.6 Operation principle

Integer to boolean 16 conversion function (IB16A) is used to transform an integer into a set of 16 binary (logical) signals. IB16A function is designed for receiving the integer input locally. The BLOCK input will freeze the logical outputs at the last value.

11.8 Integer to boolean 16 conversion with logic node representation IB16FCVB

11.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Integer to boolean 16 conversion with logic node representation	IB16FCVB	-	-

11.8.2 Functionality

Integer to boolean conversion with logic node representation function (IB16FCVB) is used to transform an integer to 16 binary (logic) signals.

IB16FCVB function can receive remote values over IEC 61850 depending on the operator position input (PSTO).

11.8.3 Function block

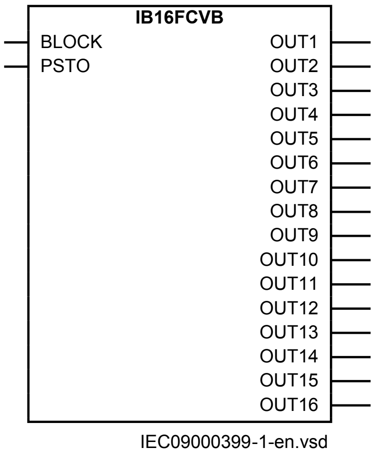

Figure 186: IB16FCVB function block

11.8.4 Signals

Table 302: IB16FCVB Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
PSTO	INTEGER	1	Operator place selection

Table 303: IB16FCVB Output signals

Name	Type	Description
OUT1	BOOLEAN	Output 1
OUT2	BOOLEAN	Output 2
OUT3	BOOLEAN	Output 3
OUT4	BOOLEAN	Output 4
OUT5	BOOLEAN	Output 5
OUT6	BOOLEAN	Output 6
OUT7	BOOLEAN	Output 7
OUT8	BOOLEAN	Output 8
OUT9	BOOLEAN	Output 9
OUT10	BOOLEAN	Output 10
OUT11	BOOLEAN	Output 11
OUT12	BOOLEAN	Output 12
OUT13	BOOLEAN	Output 13
OUT14	BOOLEAN	Output 14
OUT15	BOOLEAN	Output 15
OUT16	BOOLEAN	Output 16

11.8.5 Settings

The function does not have any parameters available in local HMI or Protection and Control IED Manager (PCM600)

11.8.6 Operation principle

Integer to boolean conversion with logic node representation function (IB16FCVB) is used to transform an integer into a set of 16 binary (logical) signals. IB16FCVB function can receive an integer from a station computer – for example, over IEC 61850. The BLOCK input will freeze the logical outputs at the last value.

The operator position input (PSTO) determines the operator place. The integer number can be written to the block while in “Remote”. If PSTO is in ”Off” or ”Local”, then no change is applied to the outputs.

Section 12 Monitoring

12.1 IEC 61850 generic communication I/O functions SPGGIO

12.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions	SPGGIO	-	-

12.1.2 Functionality

IEC 61850 generic communication I/O functions (SPGGIO) is used to send one single logical signal to other systems or equipment in the substation.

12.1.3 Function block

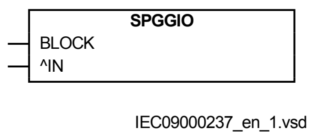

Figure 187: SPGGIO function block

12.1.4 Signals

Table 304: SPGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
IN	BOOLEAN	0	Input status

12.1.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

12.1.6 Operation principle

Upon receiving a signal at its input, IEC 61850 generic communication I/O functions (SPGGIO) function sends the signal over IEC 61850-8-1 to the equipment or system that requests this signal. To be able to get the signal, one must use other tools, described in the Engineering manual and define which function block in which equipment or system should receive this information.

12.2 IEC 61850 generic communication I/O functions 16 inputs SP16GGIO

12.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions 16 inputs	SP16GGIO	-	-

12.2.2 Functionality

IEC 61850 generic communication I/O functions 16 inputs (SP16GGIO) function is used to send up to 16 logical signals to other systems or equipment in the substation.

12.2.3 Function block

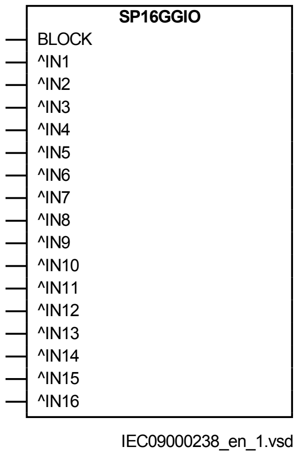

Figure 188: SP16GGIO function block

12.2.4 Signals

Table 305: SP16GGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
IN1	BOOLEAN	0	Input 1 status
IN2	BOOLEAN	0	Input 2 status
IN3	BOOLEAN	0	Input 3 status
IN4	BOOLEAN	0	Input 4 status
IN5	BOOLEAN	0	Input 5 status
IN6	BOOLEAN	0	Input 6 status
IN7	BOOLEAN	0	Input 7 status
IN8	BOOLEAN	0	Input 8 status
IN9	BOOLEAN	0	Input 9 status
IN10	BOOLEAN	0	Input 10 status
IN11	BOOLEAN	0	Input 11 status
IN12	BOOLEAN	0	Input 12 status
IN13	BOOLEAN	0	Input 13 status
IN14	BOOLEAN	0	Input 14 status
IN15	BOOLEAN	0	Input 15 status
IN16	BOOLEAN	0	Input 16 status

12.2.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

12.2.6 Operation principle

Upon receiving signals at its inputs, IEC 61850 generic communication I/O functions 16 inputs (SP16GGIO) function will send the signals over IEC 61850-8-1 to the equipment or system that requests this signals. To be able to get the signal, one must use other tools, described in the Engineering manual and define which function block in which equipment or system should receive this information.

There are also 16 output signals that show the input status for each input as well as an OR type output combined for all 16 input signals. These output signals are handled in PST.

12.3 IEC 61850 generic communication I/O functions MVGGIO

12.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850 generic communication I/O functions	MVGGIO	-	-

12.3.2 Functionality

IEC 61850 generic communication I/O functions (MVGGIO) function is used to send the instantaneous value of an analog output to other systems or equipment in the substation. It can also be used inside the same IED, to attach a RANGE aspect to an analog value and to permit measurement supervision on that value.

12.3.3 Function block

IEC09000239_en.vsd

12.3.4 Signals

Table 306: MVGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
IN	REAL	0	Analog input value

Table 307: MVGGIO Output signals

Name	Type	Description
VALUE	REAL	Magnitude of deadband value
RANGE	INTEGER	Range

12.3.5 Settings

Table 308: MVGGIO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
BaseValue	0.001 - 99.000	-	0.001	1.000	Base value multiplied by prefix value is used as base for all level settings
Prefix	micro milli unit kilo Mega Giga Tera	-	-	unit	Prefix (multiplication factor) for base value setting
MV db	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
MV zeroDb	0 - 100000	m%	1	500	Zero point clamping in 0,001% of range
MV hhLim	-5000.00 - 5000.00	%Base	0.01	500.00	High High limit
MV hLim	-5000.00 - 5000.00	%Base	0.01	200.00	High limit
MV lLim	-5000.00 - 5000.00	%Base	0.01	-200.00	Low limit
MV llLim	-5000.00 - 5000.00	%Base	0.01	-500.00	Low Low limit
MV min	-5000.00 - 5000.00	%Base	0.01	-1000.00	Minimum value
MV max	-5000.00 - 5000.00	%Base	0.01	1000.00	Maximum value
MV dbType	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
MV limHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)

12.3.6 Monitored data

Table 309: MVGGIO Monitored data

Name	Type	Values (Range)	Unit	Description
VALUE	REAL	-	-	Magnitude of deadband value
RANGE	INTEGER	0=Normal 1=High 2=Low 3=High-High 4=Low-Low	-	Range

12.3.7 Operation principle

Upon receiving an analog signal at its input, IEC 61850 generic communication I/O functions (MVGGIO) will give the instantaneous value of the signal and the range, as output values. In the same time, it will send over IEC 61850-8-1 the value, to other IEC 61850 clients in the substation.

12.4 Measurements

12.4.1 Functionality

Measurement functions is used for power system measurement, supervision and reporting to the local HMI, monitoring tool within PCM600 or to station level for example, via IEC 61850. The possibility to continuously monitor measured values of active power, reactive power, currents, voltages, frequency, power factor etc. is vital for efficient production, transmission and distribution of electrical energy. It provides to the system operator fast and easy overview of the present status of the power system. Additionally, it can be used during testing and commissioning of protection and control IEDs in order to verify proper operation and connection of instrument transformers (CTs & VTs). During normal service by periodic comparison of the measured value from the IED with other independent meters the proper operation of the IED analogue measurement chain can be verified. Finally, it can be used to verify proper direction orientation for distance or directional overcurrent protection function.

The available measured values of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

All measured values can be supervised with four settable limits that is, low-low limit, low limit, high limit and high-high limit. A zero clamping reduction is also supported, that is, the measured value below a settable limit is forced to zero which reduces the impact of noise in the inputs. There are no interconnections regarding any settings or parameters, neither between functions nor between signals within each function.

Zero clampings are handled by *ZeroDb* for each signal separately for each of the functions. For example, the zero clamping of U12 is handled by *UL12ZeroDb* in VMMXU, zero clamping of I1 is handled by *ILZeroDb* in CMMXU.

Dead-band supervision can be used to report measured signal value to station level when change in measured value is above set threshold limit or time integral of all changes since the last time value updating exceeds the threshold limit. Measure value can also be based on periodic reporting.

The measurement function, CVMMXN, provides the following power system quantities:

- P, Q and S: three phase active, reactive and apparent power
- PF: power factor
- U: phase-to-phase voltage amplitude
- I: phase current amplitude
- F: power system frequency

The output values are displayed in the local HMI under **Main menu/Tests/ Function status/Monitoring/CVMMXN/Outputs**

The measuring functions CMMXU, VNMMXU and VMMXU provides physical quantities:

- I: phase currents (amplitude and angle) (CMMXU)
- U: voltages (phase-to-earth and phase-to-phase voltage, amplitude and angle) (VMMXU, VNMMXU)

It is possible to calibrate the measuring function above to get better then class 0.5 presentation. This is accomplished by angle and amplitude compensation at 5, 30 and 100% of rated current and at 100% of rated voltage.

The power system quantities provided, depends on the actual hardware, (TRM) and the logic configuration made in PCM600.

The measuring functions CMSQI and VMSQI provides sequential quantities:

- I: sequence currents (positive, zero, negative sequence, amplitude and angle)
- U: sequence voltages (positive, zero and negative sequence, amplitude and angle).

The CVMMXN function calculates three-phase power quantities by using fundamental frequency phasors (DFT values) of the measured current respectively voltage signals. The measured power quantities are available either, as instantaneously calculated quantities or, averaged values over a period of time (low pass filtered) depending on the selected settings.

12.4.2 Measurements CVMMXN

12.4.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Measurements	CVMMXN	P, Q, S, I, U, f	-

12.4.2.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

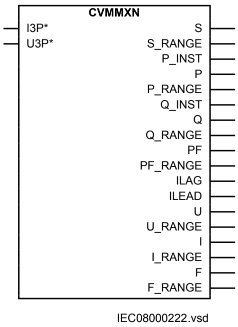

Figure 189: CVMMXN function block

12.4.2.3 Signals

Table 310: CVMMXN Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs

Table 311: CVMMXN Output signals

Name	Type	Description
S	REAL	Apparent power magnitude of deadband value
S_RANGE	INTEGER	Apparent power range
P_INST	REAL	Active power
P	REAL	Active power magnitude of deadband value
P_RANGE	INTEGER	Active power range
Q_INST	REAL	Reactive power
Q	REAL	Reactive power magnitude of deadband value
Q_RANGE	INTEGER	Reactive power range
PF	REAL	Power factor magnitude of deadband value
PF_RANGE	INTEGER	Power factor range
ILAG	BOOLEAN	Current is lagging voltage
ILEAD	BOOLEAN	Current is leading voltage
U	REAL	Calculated voltage magnitude of deadband value
U_RANGE	INTEGER	Calcuated voltage range
I	REAL	Calculated current magnitude of deadband value
I_RANGE	INTEGER	Calculated current range
F	REAL	System frequency magnitude of deadband value
F_RANGE	INTEGER	System frequency range

12.4.2.4 Settings

Table 312: CVMMXN Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
Mode	L1, L2, L3 Arone Pos Seq L1L2 L2L3 L3L1 L1 L2 L3	-	-	L1, L2, L3	Selection of measured current and voltage
PowAmpFact	0.000 - 6.000	-	0.001	1.000	Amplitude factor to scale power calculations
PowAngComp	-180.0 - 180.0	Deg	0.1	0.0	Angle compensation for phase shift between measured I & U
k	0.00 - 1.00	-	0.01	0.00	Low pass filter coefficient for power measurement
SLowLim	0.0 - 2000.0	%SB	0.1	80.0	Low limit in % of SBase
SLowLowLim	0.0 - 2000.0	%SB	0.1	60.0	Low Low limit in % of SBase
SMin	0.0 - 2000.0	%SB	0.1	50.0	Minimum value in % of SBase
SMax	0.0 - 2000.0	%SB	0.1	200.0	Maximum value in % of SBase
SRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type
PMin	-2000.0 - 2000.0	%SB	0.1	-200.0	Minimum value in % of SBase
PMax	-2000.0 - 2000.0	%SB	0.1	200.0	Maximum value in % of SBase
PRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type
QMin	-2000.0 - 2000.0	%SB	0.1	-200.0	Minimum value in % of SBase
QMax	-2000.0 - 2000.0	%SB	0.1	200.0	Maximum value in % of SBase
QRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type
PFMin	-1.000 - 1.000	-	0.001	-1.000	Minimum value
PFMax	-1.000 - 1.000	-	0.001	1.000	Maximum value
PFRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type
UMin	0.0 - 200.0	%UB	0.1	50.0	Minimum value in % of UBase
UMax	0.0 - 200.0	%UB	0.1	200.0	Maximum value in % of UBase
URepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
IMin	0.0 - 500.0	%IB	0.1	50.0	Minimum value in % of IBase
IMax	0.0 - 500.0	%IB	0.1	200.0	Maximum value in % of IBase
IRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type
FrMin	0.000 - 100.000	Hz	0.001	0.000	Minimum value
FrMax	0.000 - 100.000	Hz	0.001	70.000	Maximum value
FrRepTyp	Cyclic Dead band Int deadband	-	-	Cyclic	Reporting type

Table 313: CVMMXN Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
SDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
SZeroDb	0 - 100000	m%	1	500	Zero point clamping in 0,001% of range
SHiHiLim	0.0 - 2000.0	%SB	0.1	150.0	High High limit in % of SBase
SHiLim	0.0 - 2000.0	%SB	0.1	120.0	High limit in % of SBase
PHiHiLim	-2000.0 - 2000.0	%SB	0.1	150.0	High High limit in % of SBase
SLimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
PDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
PZeroDb	0 - 100000	m%	1	500	Zero point clamping
PHiLim	-2000.0 - 2000.0	%SB	0.1	120.0	High limit in % of SBase
PLowLim	-2000.0 - 2000.0	%SB	0.1	-120.0	Low limit in % of SBase
PLowLowLim	-2000.0 - 2000.0	%SB	0.1	-150.0	Low Low limit in % of SBase
PLimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
QDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
QZeroDb	0 - 100000	m%	1	500	Zero point clamping
QHiHiLim	-2000.0 - 2000.0	%SB	0.1	150.0	High High limit in % of SBase
QHiLim	-2000.0 - 2000.0	%SB	0.1	120.0	High limit in % of SBase
QLowLim	-2000.0 - 2000.0	%SB	0.1	-120.0	Low limit in % of SBase
QLowLowLim	-2000.0 - 2000.0	%SB	0.1	-150.0	Low Low limit in % of SBase
QLimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
PFDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
PFZeroDb	0 - 100000	m%	1	500	Zero point clamping
PFHiHiLim	-1.000 - 1.000	-	0.001	1.000	High High limit (physical value)
PFHiLim	-1.000 - 1.000	-	0.001	0.800	High limit (physical value)

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
PFLowLim	-1.000 - 1.000	-	0.001	-0.800	Low limit (physical value)
PFLowLowLim	-1.000 - 1.000	-	0.001	-1.000	Low Low limit (physical value)
PFLimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
UDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
UZeroDb	0 - 100000	m%	1	500	Zero point clamping
UHiHiLim	0.0 - 200.0	%UB	0.1	150.0	High High limit in % of UBase
UHiLim	0.0 - 200.0	%UB	0.1	120.0	High limit in % of UBase
ULowLim	0.0 - 200.0	%UB	0.1	80.0	Low limit in % of UBase
ULowLowLim	0.0 - 200.0	%UB	0.1	60.0	Low Low limit in % of UBase
ULimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
IDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
IZeroDb	0 - 100000	m%	1	500	Zero point clamping
IHiHiLim	0.0 - 500.0	%IB	0.1	150.0	High High limit in % of IBase
IHiLim	0.0 - 500.0	%IB	0.1	120.0	High limit in % of IBase
ILowLim	0.0 - 500.0	%IB	0.1	80.0	Low limit in % of IBase
ILowLowLim	0.0 - 500.0	%IB	0.1	60.0	Low Low limit in % of IBase
ILimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
FrDbRepInt	1 - 300	Type	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
FrZeroDb	0 - 100000	m%	1	500	Zero point clamping
FrHiHiLim	0.000 - 100.000	Hz	0.001	65.000	High High limit (physical value)
FrHiLim	0.000 - 100.000	Hz	0.001	63.000	High limit (physical value)
FrLowLim	0.000 - 100.000	Hz	0.001	47.000	Low limit (physical value)
FrLowLowLim	0.000 - 100.000	Hz	0.001	45.000	Low Low limit (physical value)
FrLimHyst	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range (common for all limits)
UAmpComp5	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate voltage at 5% of Ur
UAmpComp30	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate voltage at 30% of Ur
UAmpComp100	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate voltage at 100% of Ur
IAmpComp5	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 5% of Ir
IAmpComp30	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 30% of Ir
IAmpComp100	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 100% of Ir

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
IAngComp5	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 5% of Ir
IAngComp30	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 30% of Ir
IAngComp100	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 100% of Ir

12.4.2.5 Monitored data

Table 314: CVMMXN Monitored data

Name	Type	Values (Range)	Unit	Description
S	REAL	-	MVA	Apparent power magnitude of deadband value
P	REAL	-	MW	Active power magnitude of deadband value
Q	REAL	-	MVAr	Reactive power magnitude of deadband value
PF	REAL	-	-	Power factor magnitude of deadband value
U	REAL	-	kV	Calculated voltage magnitude of deadband value
I	REAL	-	A	Calculated current magnitude of deadband value
F	REAL	-	Hz	System frequency magnitude of deadband value

12.4.3 Phase current measurement CMMXU

12.4.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase current measurement	CMMXU	$\boxed{I}$	-

12.4.3.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

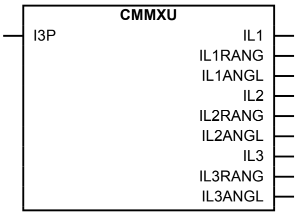

Figure 190: CMMXU function block

12.4.3.3 Signals

Table 315: CMMXU Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs

Table 316: CMMXU Output signals

Name	Type	Description
IL1	REAL	IL1 Amplitude
IL1RANG	INTEGER	IL1 Amplitude range
IL1ANGL	REAL	IL1 Angle
IL2	REAL	IL2 Amplitude
IL2RANG	INTEGER	IL2 Amplitude range
IL2ANGL	REAL	IL2 Angle
IL3	REAL	IL3 Amplitude
IL3RANG	INTEGER	IL3 Amplitude range
IL3ANGL	REAL	IL3 Angle

12.4.3.4 Settings

Table 317: CMMXU Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
ILDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
ILMax	0 - 500000	A	1	1300	Maximum value
ILRepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
ILAngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s

Table 318: *CMMXU Non group settings (advanced)*

Name	Values (Range)	Unit	Step	Default	Description
ILZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
ILHiHiLim	0 - 500000	A	1	1200	High High limit (physical value)
ILHiLim	0 - 500000	A	1	1100	High limit (physical value)
ILLowLim	0 - 500000	A	1	0	Low limit (physical value)
ILLowLowLim	0 - 500000	A	1	00	Low Low limit (physical value)
ILMin	0 - 500000	A	1	0	Minimum value
ILLimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
IAmpComp5	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 5% of Ir
IAmpComp30	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 30% of Ir
IAmpComp100	-10.000 - 10.000	%	0.001	0.000	Amplitude factor to calibrate current at 100% of Ir
IAngComp5	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 5% of Ir
IAngComp30	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 30% of Ir
IAngComp100	-10.000 - 10.000	Deg	0.001	0.000	Angle calibration for current at 100% of Ir

12.4.3.5 Monitored data

Table 319: *CMMXU Monitored data*

Name	Type	Values (Range)	Unit	Description
IL1	REAL	-	A	IL1 Amplitude
IL1ANGL	REAL	-	deg	IL1 Angle
IL2	REAL	-	A	IL2 Amplitude
IL2ANGL	REAL	-	deg	IL2 Angle
IL3	REAL	-	A	IL3 Amplitude
IL3ANGL	REAL	-	deg	IL3 Angle

12.4.4 Phase-phase voltage measurement VMMXU

12.4.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase-phase voltage measurement	VMMXU	U	-

12.4.4.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

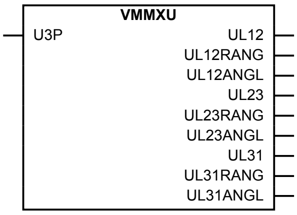

Figure 191: VMMXU function block

12.4.4.3 Signals

Table 320: VMMXU Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs

Table 321: VMMXU Output signals

Name	Type	Description
UL12	REAL	UL12 Amplitude
UL12RANG	INTEGER	UL12 Amplitude range
UL12ANGL	REAL	UL12 Angle
UL23	REAL	UL23 Amplitude
UL23RANG	INTEGER	UL23 Amplitude range
UL23ANGL	REAL	UL23 Angle
UL31	REAL	UL31 Amplitude
UL31RANG	INTEGER	UL31Amplitude range
UL31ANGL	REAL	UL31 Angle

12.4.4.4 Settings

Table 322: VMMXU Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
ULDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
ULMax	0 - 4000000	V	1	170000	Maximum value
ULRepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
ULAngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s

Table 323: VMMXU Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
ULZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
ULHiHiLim	0 - 4000000	V	1	160000	High High limit (physical value)
ULHiLim	0 - 4000000	V	1	150000	High limit (physical value)
ULLowLim	0 - 4000000	V	1	125000	Low limit (physical value)
ULLowLowLim	0 - 4000000	V	1	115000	Low Low limit (physical value)
ULMin	0 - 4000000	V	1	0	Minimum value
ULLimHys	0.000 - 100.000	V	0.001	5.0000	Hysteresis value in % of range and is common for all limits

12.4.4.5 Monitored data

Table 324: VMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
UL12	REAL	-	kV	UL12 Amplitude
UL12ANGL	REAL	-	deg	UL12 Angle
UL23	REAL	-	kV	UL23 Amplitude
UL23ANGL	REAL	-	deg	UL23 Angle
UL31	REAL	-	kV	UL31 Amplitude
UL31ANGL	REAL	-	deg	UL31 Angle

12.4.5 Current sequence component measurement CMSQI

12.4.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Current sequence component measurement	CMSQI	$\boxed{I1, I2, I0}$	-

12.4.5.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

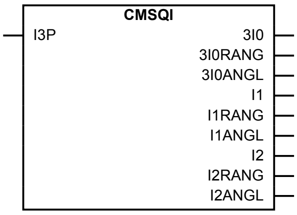

Figure 192: CMSQI function block

12.4.5.3 Signals

Table 325: CMSQI Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs

Table 326: CMSQI Output signals

Name	Type	Description
3I0	REAL	3I0 Amplitude
3I0RANG	INTEGER	3I0 Amplitude range
3I0ANGL	REAL	3I0 Angle
I1	REAL	I1 Amplitude
I1RANG	INTEGER	I1Amplitude range
I1ANGL	REAL	I1 Angle
I2	REAL	I2 Amplitude
I2RANG	INTEGER	I2 Amplitude range
I2ANGL	REAL	I2Angle

12.4.5.4 Settings

Table 327: CMSQI Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
3I0DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
3I0Min	0 - 500000	A	1	0	Minimum value
3I0Max	0 - 500000	A	1	3300	Maximum value
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
3I0RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
3I0LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
3I0AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
I1DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
I1Min	0 - 500000	A	1	0	Minimum value
I1Max	0 - 500000	A	1	1300	Maximum value
I1RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
I1AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
I2DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
I2Min	0 - 500000	A	1	0	Minimum value
I2Max	0 - 500000	A	1	1300	Maximum value
I2RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
I2LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
I2AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s

Table 328: CMSQI Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
3I0ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
3I0HiHiLim	0 - 500000	A	1	3600	High High limit (physical value)
3I0HiLim	0 - 500000	A	1	3300	High limit (physical value)
3I0LowLim	0 - 500000	A	1	0	Low limit (physical value)
3I0LowLowLim	0 - 500000	A	1	0	Low Low limit (physical value)
I1ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
I1HiHiLim	0 - 500000	A	1	1200	High High limit (physical value)
I1HiLim	0 - 500000	A	1	1100	High limit (physical value)
I1LowLim	0 - 500000	A	1	0	Low limit (physical value)
I1LowLowLim	0 - 500000	A	1	0	Low Low limit (physical value)
I1LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
I2ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
I2HiHiLim	0 - 500000	A	1	1200	High High limit (physical value)

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
I2HiLim	0 - 500000	A	1	1100	High limit (physical value)
I2LowLim	0 - 500000	A	1	0	Low limit (physical value)
I2LowLowLim	0 - 500000	A	1	0	Low Low limit (physical value)

12.4.5.5 Monitored data

Table 329: CMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
3I0	REAL	-	A	3I0 Amplitude
3I0ANGL	REAL	-	deg	3I0 Angle
I1	REAL	-	A	I1 Amplitude
I1ANGL	REAL	-	deg	I1 Angle
I2	REAL	-	A	I2 Amplitude
I2ANGL	REAL	-	deg	I2Angle

12.4.6 Voltage sequence measurement VMSQI

12.4.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Voltage sequence measurement	VMSQI	U1, U2, U0	-

12.4.6.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

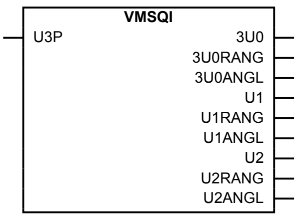

Figure 193: VMSQI function block

12.4.6.3 Signals

Table 330: VMSQI Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs

Table 331: VMSQI Output signals

Name	Type	Description
3U0	REAL	3U0 Amplitude
3U0RANG	INTEGER	3U0 Amplitude range
3U0ANGL	REAL	3U0 Angle
U1	REAL	U1 Amplitude
U1RANG	INTEGER	U1 Amplitude range
U1ANGL	REAL	U1 Angle
U2	REAL	U2 Amplitude
U2RANG	INTEGER	U2 Amplitude range
U2ANGL	REAL	U2 Angle

12.4.6.4 Settings

Table 332: VMSQI Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
3U0DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
3U0Min	0 - 2000000	V	1	0	Minimum value
3U0Max	0 - 2000000	V	1	318000	Maximum value
3U0RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
3U0LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
3U0AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
U1DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
U1Min	0 - 2000000	V	1	0	Minimum value
U1Max	0 - 2000000	V	1	106000	Maximum value
U1RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
U1AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
U2DbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
U2Min	0 - 2000000	V	1	0	Minimum value
U2Max	0 - 2000000	V	1	106000	Maximum value
U2RepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
U2LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
U2AngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s

Table 333: VMSQI Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
3U0ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
3U0HiHiLim	0 - 2000000	V	1	288000	High High limit (physical value)
3U0HiLim	0 - 2000000	V	1	258000	High limit (physical value)
3U0LowLim	0 - 2000000	V	1	213000	Low limit (physical value)
3U0LowLowLim	0 - 2000000	V	1	198000	Low Low limit (physical value)
U1ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
U1HiHiLim	0 - 2000000	V	1	96000	High High limit (physical value)
U1HiLim	0 - 2000000	V	1	86000	High limit (physical value)
U1LowLim	0 - 2000000	V	1	71000	Low limit (physical value)
U1LowLowLim	0 - 2000000	V	1	66000	Low Low limit (physical value)
U1LimHys	0.000 - 100.000	%	0.001	5.000	Hysteresis value in % of range and is common for all limits
U2ZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping
U2HiHiLim	0 - 2000000	V	1	96000	High High limit (physical value)
U2HiLim	0 - 2000000	V	1	86000	High limit (physical value)
U2LowLim	0 - 2000000	V	1	71000	Low limit (physical value)
U2LowLowLim	0 - 2000000	V	1	66000	Low Low limit (physical value)

12.4.6.5 Monitored data

Table 334: VMSQI Monitored data

Name	Type	Values (Range)	Unit	Description
3U0	REAL	-	kV	3U0 Amplitude
3U0ANGL	REAL	-	deg	3U0 Angle
U1	REAL	-	kV	U1 Amplitude

Table continues on next page

Name	Type	Values (Range)	Unit	Description
U1ANGL	REAL	-	deg	U1 Angle
U2	REAL	-	kV	U2 Amplitude
U2ANGL	REAL	-	deg	U2 Angle

12.4.7 Phase-neutral voltage measurement VNMMXU

12.4.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Phase-neutral voltage measurement	VNMMXU	U	-

12.4.7.2 Function block

The available function blocks of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

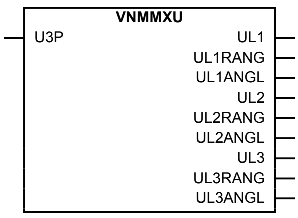

Figure 194: VNMMXU function block

12.4.7.3 Signals

Table 335: VNMMXU Input signals

Name	Type	Default	Description
U3P	GROUP SIGNAL	-	Three phase group signal for voltage inputs

Table 336: VNMMXU Output signals

Name	Type	Description
UL1	REAL	UL1 Amplitude, magnitude of reported value
UL1RANG	INTEGER	UL1 Amplitude range
UL1ANGL	REAL	UL1 Angle, magnitude of reported value
Table continues on next page		

Name	Type	Description
UL2	REAL	UL2 Amplitude, magnitude of reported value
UL2RANG	INTEGER	UL2 Amplitude range
UL2ANGL	REAL	UL2 Angle, magnitude of reported value
UL3	REAL	UL3 Amplitude, magnitude of reported value
UL3RANG	INTEGER	UL3 Amplitude range
UL3ANGL	REAL	UL3 Angle, magnitude of reported value

12.4.7.4 Settings

Table 337: VNMMXU Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Mode On / Off
GlobalBaseSel	1 - 6	-	1	1	Global Base Selector
UDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s
UMax	0 - 2000000	V	1	106000	Maximum value
URepTyp	Cyclic Dead band Int deadband	-	-	Dead band	Reporting type
ULimHys	0.000 - 100.000	V	0.001	5.0000	Hysteresis value in % of range and is common for all limits
UAngDbRepInt	1 - 300	s,%,%s	1	10	Cycl: Report interval (s), Db: In % of range, Int Db: In %s

Table 338: VNMMXU Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
UZeroDb	0 - 100000	1/1000%	1	500	Zero point clamping in 0,001% of range
UHiHiLim	0 - 2000000	V	1	96000	High High limit (physical value)
UHiLim	0 - 2000000	V	1	86000	High limit (physical value)
ULowLim	0 - 2000000	V	1	71000	Low limit (physical value)
ULowLowLim	0 - 2000000	V	1	66000	Low Low limit (physical value)
UMin	0 - 2000000	V	1	0	Minimum value

12.4.7.5 Monitored data

Table 339: VNMMXU Monitored data

Name	Type	Values (Range)	Unit	Description
UL1	REAL	-	kV	UL1 Amplitude, magnitude of reported value
UL1ANGL	REAL	-	deg	UL1 Angle, magnitude of reported value
UL2	REAL	-	kV	UL2 Amplitude, magnitude of reported value
UL2ANGL	REAL	-	deg	UL2 Angle, magnitude of reported value
UL3	REAL	-	kV	UL3 Amplitude, magnitude of reported value
UL3ANGL	REAL	-	deg	UL3 Angle, magnitude of reported value

12.4.8 Operation principle

12.4.8.1 Measurement supervision

The protection, control, and monitoring IEDs have functionality to measure and further process information for currents and voltages obtained from the pre-processing blocks. The number of processed alternate measuring quantities depends on the type of IED and built-in options.

The information on measured quantities is available for the user at different locations:

- Locally by means of the local HMI
- Remotely using the monitoring tool within PCM600 or over the station bus
- Internally by connecting the analogue output signals to the Disturbance Report function

Phase angle reference

All phase angles are presented in relation to a defined reference channel. The General setting parameter *PhaseAngleRef* defines the reference. The *PhaseAngleRef* is set in local HMI under: **Configuration/Analog modules/ Reference** channel service values.

Zero point clamping

Measured value below zero point clamping limit is forced to zero. This allows the noise in the input signal to be ignored. The zero point clamping limit is a general setting (*XZeroDb* where X equals S, P, Q, PF, U, I, F, IL1-3, UL1-3, UL12-31, I1, I2, 3I0, U1, U2 or 3U0). Observe that this measurement supervision zero point clamping might be overridden by the zero point clamping used for the measurement values within CVMMXN.

Continuous monitoring of the measured quantity

Users can continuously monitor the measured quantity available in each function block by means of four defined operating thresholds, see figure 195. The monitoring has two different modes of operating:

- Overfunction, when the measured current exceeds the High limit (*XHiLim*) or High-high limit (*XHiHiLim*) pre-set values
- Underfunction, when the measured current decreases under the Low limit (*XLowLim*) or Low-low limit (*XLowLowLim*) pre-set values.

X_RANGE is illustrated in figure 195.

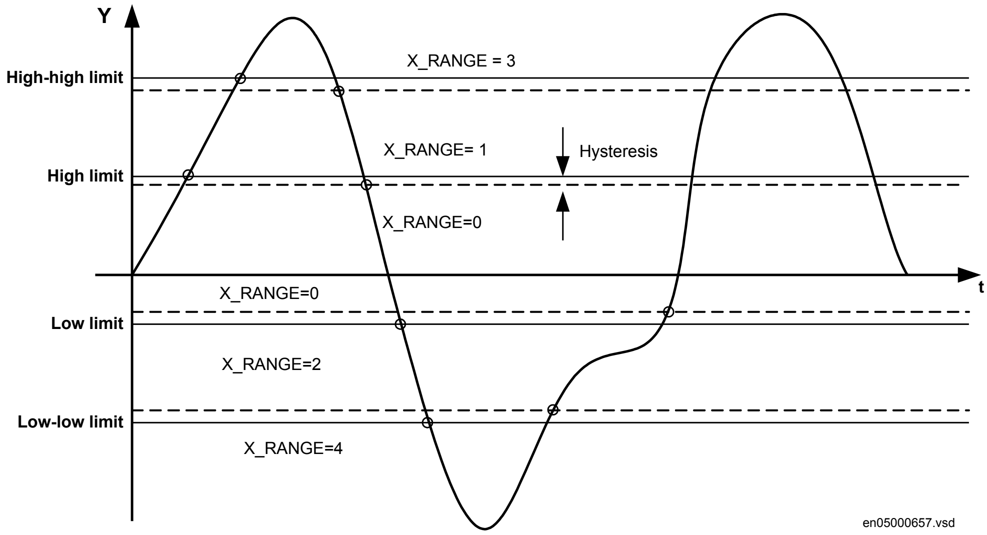

Figure 195: Presentation of operating limits

Each analogue output has one corresponding supervision level output (X_RANGE). The output signal is an integer in the interval 0-4 (0: Normal, 1: High limit exceeded, 3: High-high limit exceeded, 2: below Low limit and 4: below Low-low limit). The output may be connected to a measurement expander block (XP (RANGE_XP)) to get measurement supervision as binary signals.

The logical value of the functional output signals changes according to figure 195.

The user can set the hysteresis (*XLimHyst*), which determines the difference between the operating and reset value at each operating point, in wide range for each measuring channel separately. The hysteresis is common for all operating values within one channel.

Actual value of the measured quantity

The actual value of the measured quantity is available locally and remotely. The measurement is continuous for each measured quantity separately, but the reporting of the value to the higher levels depends on the selected reporting mode. The following basic reporting modes are available:

- Cyclic reporting (*Cyclic*)
- Amplitude dead-band supervision (*Dead band*)
- Integral dead-band supervision (*Int deadband*)

Cyclic reporting

The cyclic reporting of measured value is performed according to chosen setting (*XRepTyp*). The measuring channel reports the value independent of amplitude or integral dead-band reporting.

In addition to the normal cyclic reporting the IED also report spontaneously when measured value passes any of the defined threshold limits.

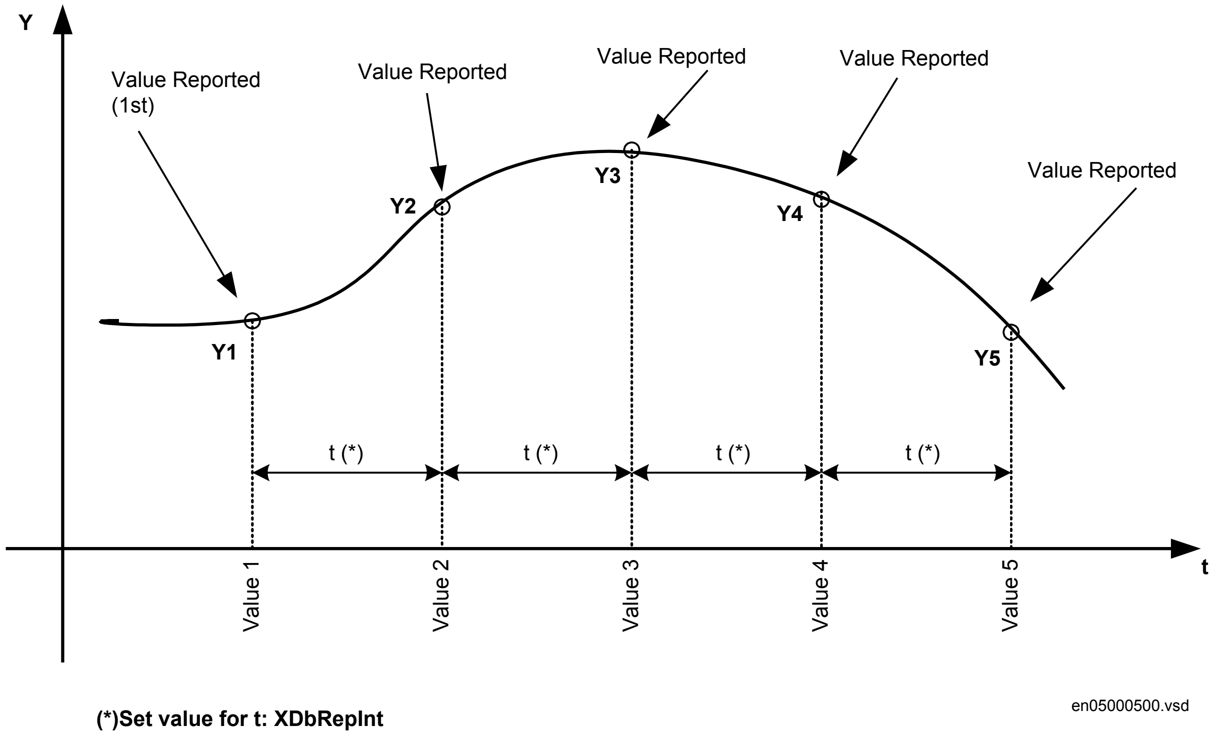

Figure 196: Periodic reporting

Amplitude dead-band supervision

If a measuring value is changed, compared to the last reported value, and the change is larger than the ±ΔY pre-defined limits that are set by user (*XZeroDb*), then the measuring channel reports the new value to a higher level, if this is detected by a new measured value. This limits the information flow to a minimum necessary. Figure 197 shows an example with the amplitude dead-band supervision. The picture is simplified: the process is not continuous but the values are evaluated with a time interval of one execution cycle from each other.

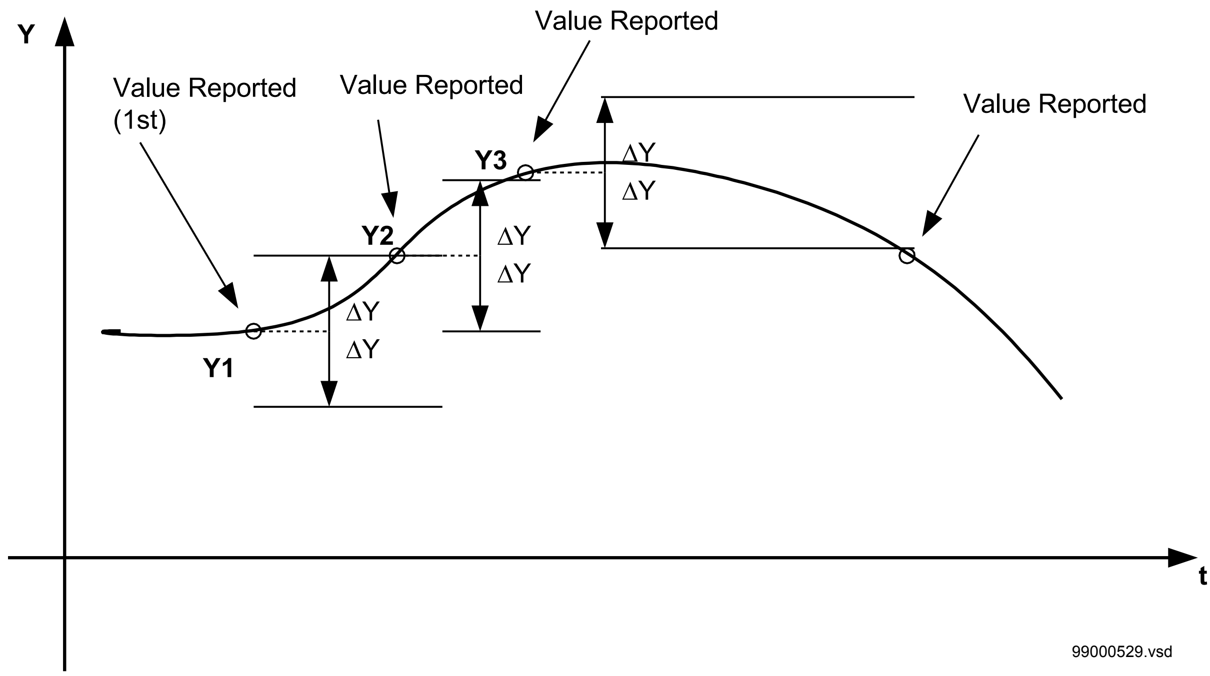

Figure 197: Amplitude dead-band supervision reporting

After the new value is reported, the ±ΔY limits for dead-band are automatically set around it. The new value is reported only if the measured quantity changes more than defined by the ±ΔY set limits. Even if amplitude dead-band reporting is selected, there will be a 30 s "back-ground" cyclic reporting as well.

Integral dead-band reporting

The measured value is reported if the time integral of all changes exceeds the pre-set limit (*XZeroDb*), figure 198, where an example of reporting with integral dead-band supervision is shown. The picture is simplified: the process is not continuous but the values are evaluated with a time interval of one execution cycle from each other.

The last value reported, Y1 in figure 198 serves as a basic value for further measurement. A difference is calculated between the last reported and the newly measured value and is multiplied by the time increment (discrete integral). The absolute values of these integral values are added until the pre-set value is exceeded. This occurs with the value Y2 that is reported and set as a new base for the following measurements (as well as for the values Y3, Y4 and Y5).

The integral dead-band supervision is particularly suitable for monitoring signals with small variations that can last for relatively long periods. Even if integral dead-band reporting is selected, there will be a 30 s "back-ground" cyclic reporting as well.

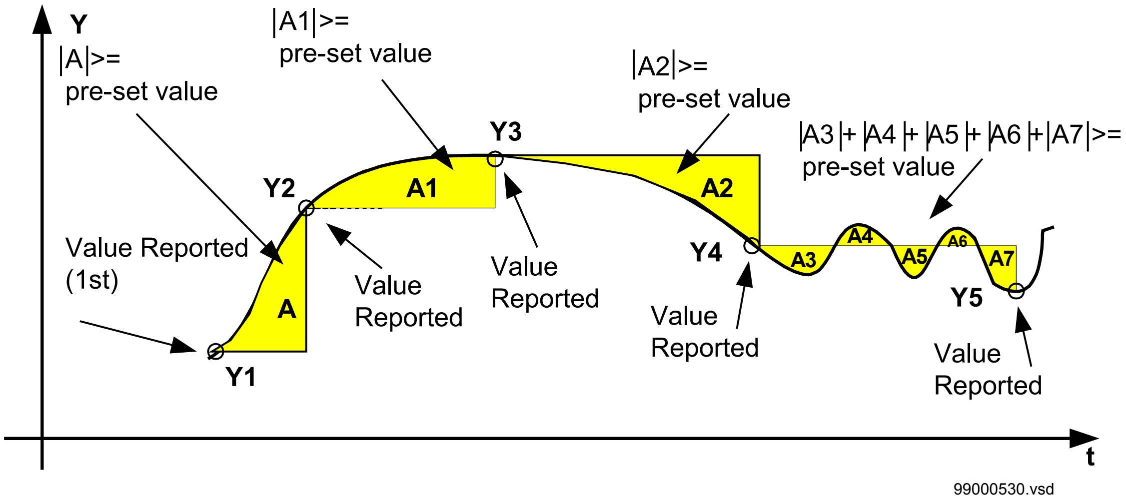

Figure 198: Reporting with integral dead-band supervision

12.4.8.2 Measurements CVMMXN

Mode of operation

The measurement function must be connected to three-phase current and three-phase voltage input in the configuration tool (group signals), but it is capable to measure and calculate above mentioned quantities in nine different ways depending on the available VT inputs connected to the IED. The end user can freely select by a parameter setting, which one of the nine available measuring modes shall be used within the function. Available options are summarized in the following table:

	Set value for parameter "Mode"	Formula used for complex, three-phase power calculation	Formula used for voltage and current magnitude calculation	Comment
1	L1, L2, L3	$\bar{S} = \overline{U_{L1}} \cdot \overline{I_{L1}^{*}} + \overline{U_{L2}} \cdot \overline{I_{L2}^{*}} + \overline{U_{L3}} \cdot \overline{I_{L3}^{*}}$	$U = (\lvert\overline{U_{L1}}\rvert + \lvert\overline{U_{L2}}\rvert + \lvert\overline{U_{L3}}\rvert)/\sqrt{3}$ $I = (\lvert\overline{I_{L1}}\rvert + \lvert\overline{I_{L2}}\rvert + \lvert\overline{I_{L3}}\rvert)/3$	Used when three phase-to-earth voltages are available
2	Arone	$\bar{S} = \overline{U_{L1L2}} \cdot \overline{I_{L1}^{*}} - \overline{U_{L2L3}} \cdot \overline{I_{L3}^{*}}$ (Equation 67)	$U = (\lvert\overline{U_{L1L2}}\rvert + \lvert\overline{U_{L2L3}}\rvert)/2$ $I = (\lvert\overline{I_{L1}}\rvert + \lvert\overline{I_{L3}}\rvert)/2$ (Equation 68)	Used when three two phase-to-phase voltages are available
3	PosSeq	$\bar{S} = 3 \cdot \overline{U_{PosSeq}} \cdot \overline{I_{PosSeq}^{*}}$ (Equation 69)	$U = \sqrt{3} \cdot \lvert\overline{U_{PosSeq}}\rvert$ $I = \lvert\overline{I_{PosSeq}}\rvert$ (Equation 70)	Used when only symmetrical three phase power shall be measured

Table continues on next page

	Set value for parameter “Mode”	Formula used for complex, three-phase power calculation	Formula used for voltage and current magnitude calculation	Comment
4	L1L2	$\overline{S} = \overline{U_{L1L2}} \cdot (\overline{I^*_{L1}} - \overline{I^*_{L2}})$ (Equation 71)	$U = \lvert\overline{U_{L1L2}}\rvert$ $I = (\lvert\overline{I_{L1}}\rvert + \lvert\overline{I_{L2}}\rvert)/2$ (Equation 72)	Used when only U_{L1L2} phase-to-phase voltage is available
5	L2L3	$\overline{S} = \overline{U_{L2L3}} \cdot (\overline{I^*_{L2}} - \overline{I^*_{L3}})$ (Equation 73)	$U = \lvert\overline{U_{L2L3}}\rvert$ $I = (\lvert\overline{I_{L2}}\rvert + \lvert\overline{I_{L3}}\rvert)/2$ (Equation 74)	Used when only U_{L2L3} phase-to-phase voltage is available
6	L3L1	$\overline{S} = \overline{U_{L3L1}} \cdot (\overline{I^*_{L3}} - \overline{I^*_{L1}})$ (Equation 75)	$U = \lvert\overline{U_{L3L1}}\rvert$ $I = (\lvert\overline{I_{L3}}\rvert + \lvert\overline{I_{L1}}\rvert)/2$ (Equation 76)	Used when only U_{L3L1} phase-to-phase voltage is available
7	L1	$\overline{S} = 3 \cdot \overline{U_{L1}} \cdot \overline{I^*_{L1}}$ (Equation 77)	$U = \sqrt{3} \cdot \lvert\overline{U_{L1}}\rvert$ $I = \lvert\overline{I_{L1}}\rvert$ (Equation 78)	Used when only U_{L1} phase-to-earth voltage is available
8	L2	$\overline{S} = 3 \cdot \overline{U_{L2}} \cdot \overline{I^*_{L2}}$ (Equation 79)	$U = \sqrt{3} \cdot \lvert\overline{U_{L2}}\rvert$ $I = \lvert\overline{I_{L2}}\rvert$ (Equation 80)	Used when only U_{L2} phase-to-earth voltage is available
9	L3	$\overline{S} = 3 \cdot \overline{U_{L3}} \cdot \overline{I^*_{L3}}$ (Equation 81)	$U = \sqrt{3} \cdot \lvert\overline{U_{L3}}\rvert$ $I = \lvert\overline{I_{L3}}\rvert$ (Equation 82)	Used when only U_{L3} phase-to-earth voltage is available
* means complex conjugated value				

It shall be noted that only in the first two operating modes that is, 1 & 2 the measurement function calculates exact three-phase power. In other operating modes that is, from 3 to 9 it calculates the three-phase power under assumption that the power system is fully symmetrical. Once the complex apparent power is calculated then the P, Q, S, & PF are calculated in accordance with the following formulas:

$$P = \mathrm{Re}(\overline{S})$$

(Equation 83)

$$Q = \mathrm{Im}(\overline{S})$$

(Equation 84)

$$S = \left|\overline{S}\right| = \sqrt{P^2 + Q^2}$$

(Equation 85)

$$PF = \cos\varphi = \frac{P}{S}$$

(Equation 86)

Additionally to the power factor value the two binary output signals from the function are provided which indicates the angular relationship between current and voltage phasors. Binary output signal ILAG is set to one when current phasor is lagging behind voltage phasor. Binary output signal ILEAD is set to one when current phasor is leading the voltage phasor.

Each analogue output has a corresponding supervision level output (X_RANGE). The output signal is an integer in the interval 0-4, see section "Measurement supervision".

Calibration of analogue inputs

Measured currents and voltages used in the CVMMXN function can be calibrated to get class 0.5 measuring accuracy. This is achieved by amplitude and angle compensation at 5, 30 and 100% of rated current and voltage. The compensation below 5% and above 100% is constant and linear in between, see example in figure 199.

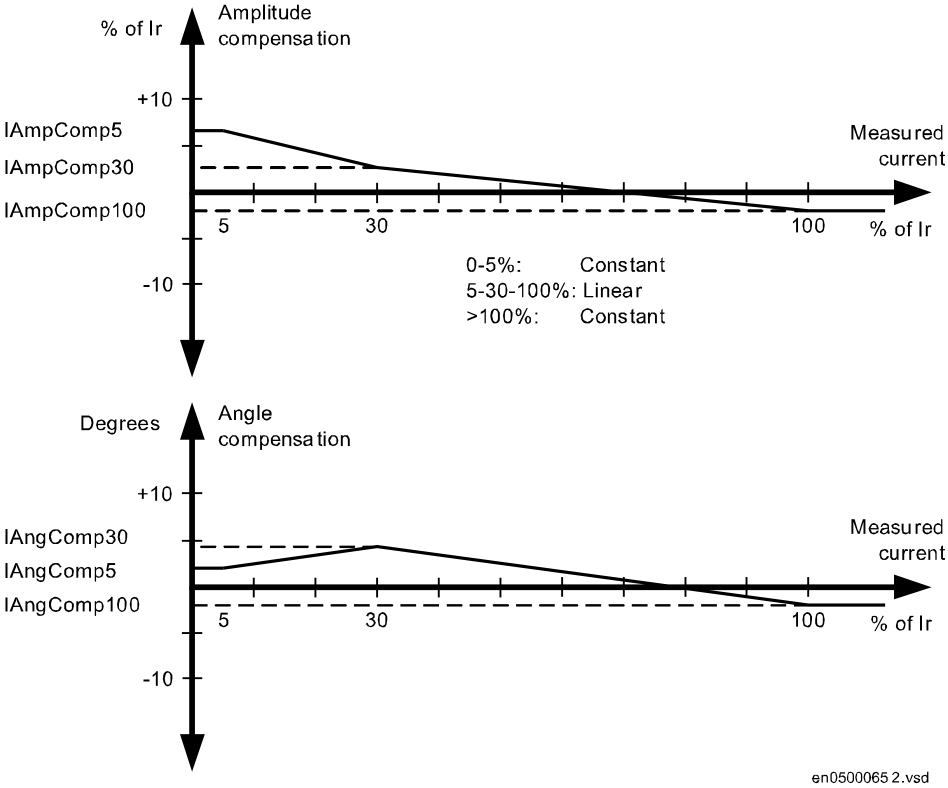

Figure 199: Calibration curves

The first current and voltage phase in the group signals will be used as reference and the amplitude and angle compensation will be used for related input signals.

Low pass filtering

In order to minimize the influence of the noise signal on the measurement it is possible to introduce the recursive, low pass filtering of the measured values for P, Q, S, U, I and power factor. This will make slower measurement response to the step changes in the measured quantity. Filtering is performed in accordance with the following recursive formula:

$$X = k \cdot X_{Old} + (1 - k) \cdot X_{Calculated}$$

(Equation 87)

where:

X	is a new measured value (that is P, Q, S, U, I or PF) to be given out from the function
X_{Old}	is the measured value given from the measurement function in previous execution cycle
$X_{Calculated}$	is the new calculated value in the present execution cycle
k	is settable parameter by the end user which influence the filter properties

Default value for parameter *k* is 0.00. With this value the new calculated value is immediately given out without any filtering (that is, without any additional delay). When *k* is set to value bigger than 0, the filtering is enabled. Appropriate value of *k* shall be determined separately for every application. Some typical value for *k* =0.14.

Zero point clamping

In order to avoid erroneous measurements when either current or voltage signal is not present, the amplitude level for current and voltage measurement is forced to zero. When either current or voltage measurement is forced to zero automatically the measured values for power (P, Q & S) and power factor are forced to zero as well. Since the measurement supervision functionality, included in the CVMMXN function, is using these values the zero clamping will influence the subsequent supervision (observe the possibility to do zero point clamping within measurement supervision, see section "Measurement supervision").

Compensation facility

In order to compensate for small amplitude and angular errors in the complete measurement chain (CT error, VT error, IED input transformer errors etc.) it is possible to perform on site calibration of the power measurement. This is achieved by setting the complex constant which is then internally used within the function to multiply the calculated complex apparent power S. This constant is set as amplitude (setting parameter *PowAmpFact*, default value 1.000) and angle (setting parameter *PowAngComp*, default value 0.0 degrees). Default values for these two parameters are done in such way that they do not influence internally calculated value (complex constant has default value 1). In this way calibration, for specific operating range (for example, around rated power) can be done at site. However, to perform this calibration it is necessary to have an external power meter with high accuracy class available.

Directionality

CTStartPoint defines if the CTs earthing point is located towards or from the protected object under observation. If everything is properly set power is always measured towards protection object.

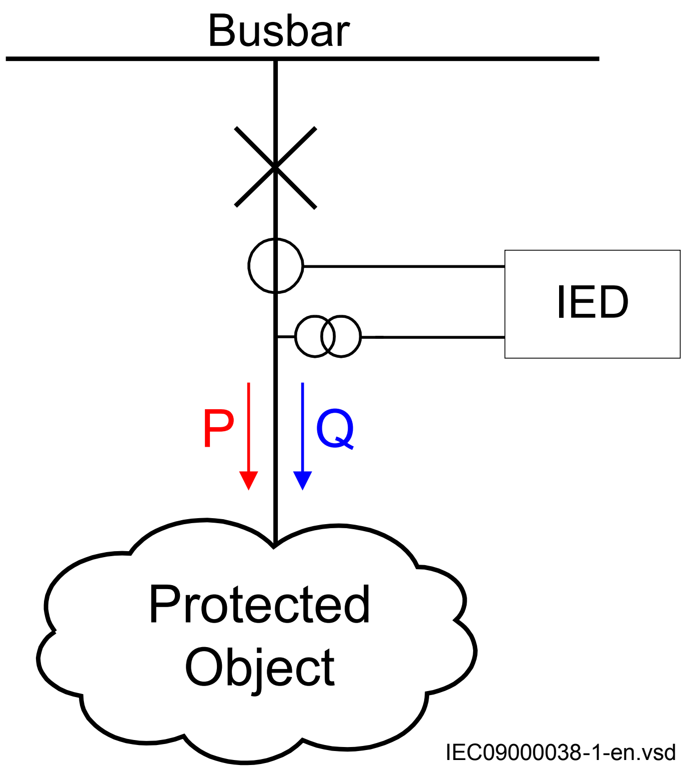

Figure 200: Internal IED directionality convention for P & Q measurements

Practically, it means that active and reactive power will have positive values when they flow from the busbar towards the protected object and they will have negative values when they flow from the protected object towards the busbar.

In some application, for example, when power is measured on the secondary side of the power transformer it might be desirable, from the end client point of view, to have actually opposite directional convention for active and reactive power measurements. This can be easily achieved by setting parameter *PowAngComp* to value of 180.0 degrees. With such setting the active and reactive power will have positive values when they flow from the protected object towards the busbar.

Frequency

Frequency is actually not calculated within measurement block. It is simply obtained from the pre-processing block and then just given out from the measurement block as an output.

12.4.8.3 Phase current measurement CMMXU

The CMMXU function must be connected to three-phase current input in the configuration tool to be operable. Currents handled in the function can be calibrated to get better then class 0.5 measuring accuracy for internal use, on the outputs and IEC 61850. This is achieved by amplitude and angle compensation at

5, 30 and 100% of rated current. The compensation below 5% and above 100% is constant and linear in between, see figure 199 above.

Phase currents (amplitude and angle) are available on the outputs and each amplitude output has a corresponding supervision level output (ILx_RANG). The supervision output signal is an integer in the interval 0-4, see section "Measurement supervision".

12.4.8.4 Phase-phase and phase-neutral voltage measurements VMMXU/ VNMMXU

The voltage function must be connected to three-phase voltage input in the configuration tool to be operable. Voltages are handled in the same way as currents when it comes to class 0.5 calibrations, see above.

The voltages (phase or phase-phase voltage, amplitude and angle) are available on the outputs and each amplitude output has a corresponding supervision level output (ULxy_RANG). The supervision output signal is an integer in the interval 0-4, see section "Measurement supervision".

12.4.8.5 Voltage and current sequence measurements VMSQI/CMSQI

The measurement functions must be connected to three-phase current (CMSQI) or voltage (VMSQI) input in the configuration tool to be operable. No outputs, but XRANG, are calculated within the measuring block and it is not possible to calibrate the signals. Input signals are obtained from the pre-processing block and transferred to corresponding output.

Positive, negative and three times zero sequence quantities are available on the outputs (voltage and current, amplitude and angle). Each amplitude output has a corresponding supervision level output (X_RANGE). The output signal is an integer in the interval 0-4, see section "Measurement supervision".

12.4.9 Technical data

Table 340: CVMMXN Tehcnical data

Function	Range or value	Accuracy
Frequency	(0.95-1.05) × f_r	± 2.0 mHz
Connected current	(0.2-4.0) × I_r	± 0.5% of I_r at $I \leq I_r$ ± 0.5% of I at $I > I_r$

12.5 Event Counter CNTGGIO

12.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Event counter	CNTGGIO		-

12.5.2 Functionality

Event counter (CNTGGIO) has six counters which are used for storing the number of times each counter input has been activated.

12.5.3 Function block

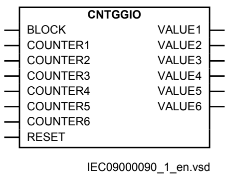

Figure 201: CNTGGIO function block

12.5.4 Signals

Table 341: CNTGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
COUNTER1	BOOLEAN	0	Input for counter 1
COUNTER2	BOOLEAN	0	Input for counter 2
COUNTER3	BOOLEAN	0	Input for counter 3
COUNTER4	BOOLEAN	0	Input for counter 4
COUNTER5	BOOLEAN	0	Input for counter 5
COUNTER6	BOOLEAN	0	Input for counter 6
RESET	BOOLEAN	0	Reset of function

Table 342: CNTGGIO Output signals

Name	Type	Description
VALUE1	INTEGER	Output of counter 1
VALUE2	INTEGER	Output of counter 2
VALUE3	INTEGER	Output of counter 3
VALUE4	INTEGER	Output of counter 4
VALUE5	INTEGER	Output of counter 5
VALUE6	INTEGER	Output of counter 6

12.5.5 Settings

Table 343: CNTGGIO Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On

12.5.6 Monitored data

Table 344: CNTGGIO Monitored data

Name	Type	Values (Range)	Unit	Description
VALUE1	INTEGER	-	-	Output of counter 1
VALUE2	INTEGER	-	-	Output of counter 2
VALUE3	INTEGER	-	-	Output of counter 3
VALUE4	INTEGER	-	-	Output of counter 4
VALUE5	INTEGER	-	-	Output of counter 5
VALUE6	INTEGER	-	-	Output of counter 6

12.5.7 Operation principle

Event counter (CNTGGIO) has six counter inputs. CNTGGIO stores how many times each of the inputs has been activated. The counter memory for each of the six inputs is updated, giving the total number of times the input has been activated, as soon as an input is activated. The maximum count up speed is 10 pulses per second. The maximum counter value is 10 000. For counts above 10 000 the counter will stop at 10 000 and no restart will take place.

To not risk that the flash memory is worn out due to too many writings, a mechanism for limiting the number of writings per time period is included in the product. This however gives as a result that it can take long time, up to several minutes, before a new value is stored in the flash memory. And if a new CNTGGIO value is not stored before auxiliary power interruption, it will be lost.

The CNTGGIO stored values in flash memory will however not be lost at an auxiliary power interruption.

The function block also has an input BLOCK. At activation of this input all six counters are blocked. The input can for example, be used for blocking the counters at testing.The function block has an input RESET. At activation of this input all six counters are set to 0.

All inputs are configured via PCM 600.

12.5.7.1 Reporting

The content of the counters can be read in the local HMI.

Reset of counters can be performed in the local HMI and a binary input.

Reading of content can also be performed remotely, for example from a IEC 61850 client. The value can also be presented as a measuring value on the local HMI graphical display.

12.5.8 Technical data

Table 345: CNTGGIO Technical data

Function	Range or value	Accuracy
Counter value	0-10000	-
Max. count up speed	10 pulses/s	-

12.6 Disturbance report

12.6.1 Functionality

Complete and reliable information about disturbances in the primary and/or in the secondary system together with continuous event-logging is accomplished by the disturbance report functionality.

Disturbance report, always included in the IED, acquires sampled data of all selected analog input and binary signals connected to the function block that is, maximum 40 analog and 96 binary signals.

Disturbance report functionality is a common name for several functions:

- Event List
- Indications
- Event recorder
- Trip Value recorder
- Disturbance recorder
- Fault Locator (FL)

Disturbance report function is characterized by great flexibility regarding configuration, starting conditions, recording times and large storage capacity.

A disturbance is defined as an activation of an input in the AxRADR or BxRBDR function blocks which is set to trigger the disturbance recorder. All signals from start of pre-fault time to the end of post-fault time, will be included in the recording.

Every disturbance report recording is saved in the IED in the standard Comtrade format. The same applies to all events, which are continuously saved in a ring-buffer. The local HMI is used to get information about the recordings, but the disturbance report files may be uploaded to PCM600 (Protection and Control IED Manager) and further analysis using the disturbance handling tool.

12.6.2 Disturbance report DRPRDRE

12.6.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Disturbance report	DRPRDRE	-	-

12.6.2.2 Function block

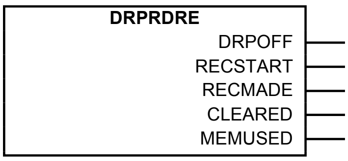

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Figure 202: DRPRDRE function block

12.6.2.3 Signals

Table 346: DRPRDRE Output signals

Name	Type	Description
DRPOFF	BOOLEAN	Disturbance report function turned off
RECSTART	BOOLEAN	Disturbance recording started
RECMADE	BOOLEAN	Disturbance recording made
CLEARED	BOOLEAN	All disturbances in the disturbance report cleared
MEMUSED	BOOLEAN	More than 80% of memory used

12.6.2.4 Settings

Table 347: DRPRDRE Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
PreFaultRecT	0.05 - 1.00	s	0.01	0.10	Pre-fault recording time
PostFaultRecT	0.1 - 10.0	s	0.1	0.5	Post-fault recording time
TimeLimit	0.5 - 10.0	s	0.1	1.0	Fault recording time limit
PostRetrig	Off On	-	-	Off	Post-fault retrig enabled (On) or not (Off)
MaxNoStoreRec	10 - 100	-	1	100	Maximum number of stored disturbances
ZeroAngleRef	1 - 30	Ch	1	1	Trip value recorder, phasor reference channel
OpModeTest	Off On	-	-	Off	Operation mode during test mode

12.6.2.5 Monitored data

Table 348: DRPRDRE Monitored data

Name	Type	Values (Range)	Unit	Description
MemoryUsed	INTEGER	-	%	Memory usage (0-100%)
UnTrigStatCh1	BOOLEAN	-	-	Under level trig for analog channel 1 activated
OvTrigStatCh1	BOOLEAN	-	-	Over level trig for analog channel 1 activated
UnTrigStatCh2	BOOLEAN	-	-	Under level trig for analog channel 2 activated
OvTrigStatCh2	BOOLEAN	-	-	Over level trig for analog channel 2 activated
UnTrigStatCh3	BOOLEAN	-	-	Under level trig for analog channel 3 activated
OvTrigStatCh3	BOOLEAN	-	-	Over level trig for analog channel 3 activated
UnTrigStatCh4	BOOLEAN	-	-	Under level trig for analog channel 4 activated
OvTrigStatCh4	BOOLEAN	-	-	Over level trig for analog channel 4 activated
UnTrigStatCh5	BOOLEAN	-	-	Under level trig for analog channel 5 activated
OvTrigStatCh5	BOOLEAN	-	-	Over level trig for analog channel 5 activated

Table continues on next page

Name	Type	Values (Range)	Unit	Description
UnTrigStatCh6	BOOLEAN	-	-	Under level trig for analog channel 6 activated
OvTrigStatCh6	BOOLEAN	-	-	Over level trig for analog channel 6 activated
UnTrigStatCh7	BOOLEAN	-	-	Under level trig for analog channel 7 activated
OvTrigStatCh7	BOOLEAN	-	-	Over level trig for analog channel 7 activated
UnTrigStatCh8	BOOLEAN	-	-	Under level trig for analog channel 8 activated
OvTrigStatCh8	BOOLEAN	-	-	Over level trig for analog channel 8 activated
UnTrigStatCh9	BOOLEAN	-	-	Under level trig for analog channel 9 activated
OvTrigStatCh9	BOOLEAN	-	-	Over level trig for analog channel 9 activated
UnTrigStatCh10	BOOLEAN	-	-	Under level trig for analog channel 10 activated
OvTrigStatCh10	BOOLEAN	-	-	Over level trig for analog channel 10 activated
UnTrigStatCh11	BOOLEAN	-	-	Under level trig for analog channel 11 activated
OvTrigStatCh11	BOOLEAN	-	-	Over level trig for analog channel 11 activated
UnTrigStatCh12	BOOLEAN	-	-	Under level trig for analog channel 12 activated
OvTrigStatCh12	BOOLEAN	-	-	Over level trig for analog channel 12 activated
UnTrigStatCh13	BOOLEAN	-	-	Under level trig for analog channel 13 activated
OvTrigStatCh13	BOOLEAN	-	-	Over level trig for analog channel 13 activated
UnTrigStatCh14	BOOLEAN	-	-	Under level trig for analog channel 14 activated
OvTrigStatCh14	BOOLEAN	-	-	Over level trig for analog channel 14 activated
UnTrigStatCh15	BOOLEAN	-	-	Under level trig for analog channel 15 activated
OvTrigStatCh15	BOOLEAN	-	-	Over level trig for analog channel 15 activated

Table continues on next page

Name	Type	Values (Range)	Unit	Description
UnTrigStatCh16	BOOLEAN	-	-	Under level trig for analog channel 16 activated
OvTrigStatCh16	BOOLEAN	-	-	Over level trig for analog channel 16 activated
UnTrigStatCh17	BOOLEAN	-	-	Under level trig for analog channel 17 activated
OvTrigStatCh17	BOOLEAN	-	-	Over level trig for analog channel 17 activated
UnTrigStatCh18	BOOLEAN	-	-	Under level trig for analog channel 18 activated
OvTrigStatCh18	BOOLEAN	-	-	Over level trig for analog channel 18 activated
UnTrigStatCh19	BOOLEAN	-	-	Under level trig for analog channel 19 activated
OvTrigStatCh19	BOOLEAN	-	-	Over level trig for analog channel 19 activated
UnTrigStatCh20	BOOLEAN	-	-	Under level trig for analog channel 20 activated
OvTrigStatCh20	BOOLEAN	-	-	Over level trig for analog channel 20 activated
UnTrigStatCh21	BOOLEAN	-	-	Under level trig for analog channel 21 activated
OvTrigStatCh21	BOOLEAN	-	-	Over level trig for analog channel 21 activated
UnTrigStatCh22	BOOLEAN	-	-	Under level trig for analog channel 22 activated
OvTrigStatCh22	BOOLEAN	-	-	Over level trig for analog channel 22 activated
UnTrigStatCh23	BOOLEAN	-	-	Under level trig for analog channel 23 activated
OvTrigStatCh23	BOOLEAN	-	-	Over level trig for analog channel 23 activated
UnTrigStatCh24	BOOLEAN	-	-	Under level trig for analog channel 24 activated
OvTrigStatCh24	BOOLEAN	-	-	Over level trig for analog channel 24 activated
UnTrigStatCh25	BOOLEAN	-	-	Under level trig for analog channel 25 activated
OvTrigStatCh25	BOOLEAN	-	-	Over level trig for analog channel 25 activated

Table continues on next page

Name	Type	Values (Range)	Unit	Description
UnTrigStatCh26	BOOLEAN	-	-	Under level trig for analog channel 26 activated
OvTrigStatCh26	BOOLEAN	-	-	Over level trig for analog channel 26 activated
UnTrigStatCh27	BOOLEAN	-	-	Under level trig for analog channel 27 activated
OvTrigStatCh27	BOOLEAN	-	-	Over level trig for analog channel 27 activated
UnTrigStatCh28	BOOLEAN	-	-	Under level trig for analog channel 28 activated
OvTrigStatCh28	BOOLEAN	-	-	Over level trig for analog channel 28 activated
UnTrigStatCh29	BOOLEAN	-	-	Under level trig for analog channel 29 activated
OvTrigStatCh29	BOOLEAN	-	-	Over level trig for analog channel 29 activated
UnTrigStatCh30	BOOLEAN	-	-	Under level trig for analog channel 30 activated
OvTrigStatCh30	BOOLEAN	-	-	Over level trig for analog channel 30 activated
UnTrigStatCh31	BOOLEAN	-	-	Under level trig for analog channel 31 activated
OvTrigStatCh31	BOOLEAN	-	-	Over level trig for analog channel 31 activated
UnTrigStatCh32	BOOLEAN	-	-	Under level trig for analog channel 32 activated
OvTrigStatCh32	BOOLEAN	-	-	Over level trig for analog channel 32 activated
UnTrigStatCh33	BOOLEAN	-	-	Under level trig for analog channel 33 activated
OvTrigStatCh33	BOOLEAN	-	-	Over level trig for analog channel 33 activated
UnTrigStatCh34	BOOLEAN	-	-	Under level trig for analog channel 34 activated
OvTrigStatCh34	BOOLEAN	-	-	Over level trig for analog channel 34 activated
UnTrigStatCh35	BOOLEAN	-	-	Under level trig for analog channel 35 activated
OvTrigStatCh35	BOOLEAN	-	-	Over level trig for analog channel 35 activated

Table continues on next page

Name	Type	Values (Range)	Unit	Description
UnTrigStatCh36	BOOLEAN	-	-	Under level trig for analog channel 36 activated
OvTrigStatCh36	BOOLEAN	-	-	Over level trig for analog channel 36 activated
UnTrigStatCh37	BOOLEAN	-	-	Under level trig for analog channel 37 activated
OvTrigStatCh37	BOOLEAN	-	-	Over level trig for analog channel 37 activated
UnTrigStatCh38	BOOLEAN	-	-	Under level trig for analog channel 38 activated
OvTrigStatCh38	BOOLEAN	-	-	Over level trig for analog channel 38 activated
UnTrigStatCh39	BOOLEAN	-	-	Under level trig for analog channel 39 activated
OvTrigStatCh39	BOOLEAN	-	-	Over level trig for analog channel 39 activated
UnTrigStatCh40	BOOLEAN	-	-	Under level trig for analog channel 40 activated
OvTrigStatCh40	BOOLEAN	-	-	Over level trig for analog channel 40 activated
FaultNumber	INTEGER	-	-	Disturbance fault number

12.6.2.6 Measured values

Table 349: DRPRDRE Measured values

Name	Type	Default	Description
ManTrig	BOOLEAN	0	Manual trig of disturbance report
ClearDist	BOOLEAN	0	Clear all disturbances
ClearProcessEv	BOOLEAN	0	Clear all process events

12.6.3 Analog input signals AxRADR

12.6.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Analog input signals	A1RADR	-	-
Analog input signals	A2RADR	-	-
Analog input signals	A3RADR	-	-

12.6.3.2 Function block

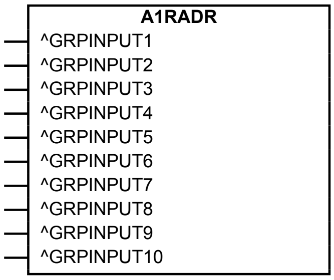

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Figure 203: A1RADR function block, analog inputs, example for A1RADR, A2RADR and A3RADR

12.6.3.3 Signals

A1RADR - A3RADR Input signals

Tables for input signals for A1RADR, A2RADR and A3RADR are similar except for GRPINPUT number.

- A1RADR, GRPINPUT1 - GRPINPUT10
- A2RADR, GRPINPUT11 - GRPINPUT20
- A3RADR, GRPINPUT21 - GRPINPUT30

Table 350: A1RADR Input signals

Name	Type	Default	Description
GRPINPUT1	GROUP SIGNAL	-	Group signal for input 1
GRPINPUT2	GROUP SIGNAL	-	Group signal for input 2
GRPINPUT3	GROUP SIGNAL	-	Group signal for input 3
GRPINPUT4	GROUP SIGNAL	-	Group signal for input 4
GRPINPUT5	GROUP SIGNAL	-	Group signal for input 5
GRPINPUT6	GROUP SIGNAL	-	Group signal for input 6
GRPINPUT7	GROUP SIGNAL	-	Group signal for input 7
GRPINPUT8	GROUP SIGNAL	-	Group signal for input 8
GRPINPUT9	GROUP SIGNAL	-	Group signal for input 9
GRPINPUT10	GROUP SIGNAL	-	Group signal for input 10

12.6.3.4 Settings

A1RADR - A3RADR Settings

Setting tables for A1RADR, A2RADR and A3RADR are similar except for channel numbers.

- A1RADR, channel01 - channel10
- A2RADR, channel11 - channel20
- A3RADR, channel21 - channel30

Table 351: A1RADR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation01	Off On	-	-	Off	Operation On/Off
Operation02	Off On	-	-	Off	Operation On/Off
Operation03	Off On	-	-	Off	Operation On/Off
Operation04	Off On	-	-	Off	Operation On/Off
Operation05	Off On	-	-	Off	Operation On/Off
Operation06	Off On	-	-	Off	Operation On/Off
Operation07	Off On	-	-	Off	Operation On/Off
Operation08	Off On	-	-	Off	Operation On/Off
Operation09	Off On	-	-	Off	Operation On/Off
Operation10	Off On	-	-	Off	Operation On/Off

Table 352: A1RADR Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
NomValue01	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 1
UnderTrigOp01	Off On	-	-	Off	Use under level trigger for analog channel 1 (on) or not (off)
UnderTrigLe01	0 - 200	%	1	50	Under trigger level for analog channel 1 in % of signal
OverTrigOp01	Off On	-	-	Off	Use over level trigger for analog channel 1 (on) or not (off)
OverTrigLe01	0 - 5000	%	1	200	Over trigger level for analog channel 1 in % of signal
NomValue02	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 2
UnderTrigOp02	Off On	-	-	Off	Use under level trigger for analog channel 2 (on) or not (off)

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
UnderTrigLe02	0 - 200	%	1	50	Under trigger level for analog channel 2 in % of signal
OverTrigOp02	Off On	-	-	Off	Use over level trigger for analog channel 2 (on) or not (off)
OverTrigLe02	0 - 5000	%	1	200	Over trigger level for analog channel 2 in % of signal
NomValue03	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 3
UnderTrigOp03	Off On	-	-	Off	Use under level trigger for analog channel 3 (on) or not (off)
UnderTrigLe03	0 - 200	%	1	50	Under trigger level for analog channel 3 in % of signal
OverTrigOp03	Off On	-	-	Off	Use over level trigger for analog channel 3 (on) or not (off)
OverTrigLe03	0 - 5000	%	1	200	Overtrigger level for analog channel 3 in % of signal
NomValue04	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 4
UnderTrigOp04	Off On	-	-	Off	Use under level trigger for analog channel 4 (on) or not (off)
UnderTrigLe04	0 - 200	%	1	50	Under trigger level for analog channel 4 in % of signal
OverTrigOp04	Off On	-	-	Off	Use over level trigger for analog channel 4 (on) or not (off)
OverTrigLe04	0 - 5000	%	1	200	Over trigger level for analog channel 4 in % of signal
NomValue05	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 5
UnderTrigOp05	Off On	-	-	Off	Use under level trigger for analog channel 5 (on) or not (off)
UnderTrigLe05	0 - 200	%	1	50	Under trigger level for analog channel 5 in % of signal
OverTrigOp05	Off On	-	-	Off	Use over level trigger for analog channel 5 (on) or not (off)
OverTrigLe05	0 - 5000	%	1	200	Over trigger level for analog channel 5 in % of signal
NomValue06	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 6
UnderTrigOp06	Off On	-	-	Off	Use under level trigger for analog channel 6 (on) or not (off)
UnderTrigLe06	0 - 200	%	1	50	Under trigger level for analog channel 6 in % of signal
OverTrigOp06	Off On	-	-	Off	Use over level trigger for analog channel 6 (on) or not (off)
OverTrigLe06	0 - 5000	%	1	200	Over trigger level for analog channel 6 in % of signal
NomValue07	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 7
UnderTrigOp07	Off On	-	-	Off	Use under level trigger for analog channel 7 (on) or not (off)
UnderTrigLe07	0 - 200	%	1	50	Under trigger level for analog channel 7 in % of signal
Table continues on next page					

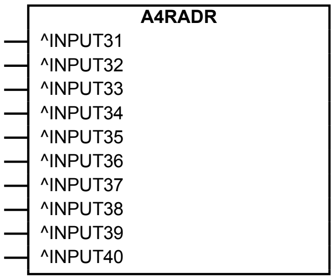
Name	Values (Range)	Unit	Step	Default	Description
OverTrigOp07	Off On	-	-	Off	Use over level trigger for analog channel 7 (on) or not (off)
OverTrigLe07	0 - 5000	%	1	200	Over trigger level for analog channel 7 in % of signal
NomValue08	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 8
UnderTrigOp08	Off On	-	-	Off	Use under level trigger for analog channel 8 (on) or not (off)
UnderTrigLe08	0 - 200	%	1	50	Under trigger level for analog channel 8 in % of signal
OverTrigOp08	Off On	-	-	Off	Use over level trigger for analog channel 8 (on) or not (off)
OverTrigLe08	0 - 5000	%	1	200	Over trigger level for analog channel 8 in % of signal
NomValue09	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 9
UnderTrigOp09	Off On	-	-	Off	Use under level trigger for analog channel 9 (on) or not (off)
UnderTrigLe09	0 - 200	%	1	50	Under trigger level for analog channel 9 in % of signal
OverTrigOp09	Off On	-	-	Off	Use over level trigger for analog channel 9 (on) or not (off)
OverTrigLe09	0 - 5000	%	1	200	Over trigger level for analog channel 9 in % of signal
NomValue10	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 10
UnderTrigOp10	Off On	-	-	Off	Use under level trigger for analog channel 10 (on) or not (off)
UnderTrigLe10	0 - 200	%	1	50	Under trigger level for analog channel 10 in % of signal
OverTrigOp10	Off On	-	-	Off	Use over level trigger for analog channel 10 (on) or not (off)
OverTrigLe10	0 - 5000	%	1	200	Over trigger level for analog channel 10 in % of signal

12.6.4 Analog input signals A4RADR

12.6.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Analog input signals	A41RADR	-	-

12.6.4.2 Function block



IEC09000350-1-en.vsd

Figure 204: A4RADR function block, derived analog inputs

12.6.4.3 Signals

Table 353: A4RADR Input signals

Name	Type	Default	Description
INPUT31	REAL	0	Analog channel 31
INPUT32	REAL	0	Analog channel 32
INPUT33	REAL	0	Analog channel 33
INPUT34	REAL	0	Analog channel 34
INPUT35	REAL	0	Analog channel 35
INPUT36	REAL	0	Analog channel 36
INPUT37	REAL	0	Analog channel 37
INPUT38	REAL	0	Analog channel 38
INPUT39	REAL	0	Analog channel 39
INPUT40	REAL	0	Analog channel 40

12.6.4.4 Settings

Table 354: A4RADR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation31	Off On	-	-	Off	Operation On/off
Operation32	Off On	-	-	Off	Operation On/off
Operation33	Off On	-	-	Off	Operation On/off
Operation34	Off On	-	-	Off	Operation On/off
Operation35	Off On	-	-	Off	Operation On/off
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
Operation36	Off On	-	-	Off	Operation On/off
Operation37	Off On	-	-	Off	Operation On/off
Operation38	Off On	-	-	Off	Operation On/off
Operation39	Off On	-	-	Off	Operation On/off
Operation40	Off On	-	-	Off	Operation On/off

Table 355: A4RADR Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
NomValue31	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 31
UnderTrigOp31	Off On	-	-	Off	Use under level trigger for analog channel 31 (on) or not (off)
UnderTrigLe31	0 - 200	%	1	50	Under trigger level for analog channel 31 in % of signal
OverTrigOp31	Off On	-	-	Off	Use over level trigger for analog channel 31 (on) or not (off)
OverTrigLe31	0 - 5000	%	1	200	Over trigger level for analog channel 31 in % of signal
NomValue32	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 32
UnderTrigOp32	Off On	-	-	Off	Use under level trigger for analog channel 32 (on) or not (off)
UnderTrigLe32	0 - 200	%	1	50	Under trigger level for analog channel 32 in % of signal
OverTrigOp32	Off On	-	-	Off	Use over level trigger for analog channel 32 (on) or not (off)
OverTrigLe32	0 - 5000	%	1	200	Over trigger level for analog channel 32 in % of signal
NomValue33	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 33
UnderTrigOp33	Off On	-	-	Off	Use under level trigger for analog channel 33 (on) or not (off)
UnderTrigLe33	0 - 200	%	1	50	Under trigger level for analog channel 33 in % of signal
OverTrigOp33	Off On	-	-	Off	Use over level trigger for analog channel 33 (on) or not (off)
OverTrigLe33	0 - 5000	%	1	200	Overtrigger level for analog channel 33 in % of signal
NomValue34	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 34
UnderTrigOp34	Off On	-	-	Off	Use under level trigger for analog channel 34 (on) or not (off)
UnderTrigLe34	0 - 200	%	1	50	Under trigger level for analog channel 34 in % of signal
OverTrigOp34	Off On	-	-	Off	Use over level trigger for analog channel 34 (on) or not (off)

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
OverTrigLe34	0 - 5000	%	1	200	Over trigger level for analog channel 34 in % of signal
NomValue35	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 35
UnderTrigOp35	Off On	-	-	Off	Use under level trigger for analog channel 35 (on) or not (off)
UnderTrigLe35	0 - 200	%	1	50	Under trigger level for analog channel 35 in % of signal
OverTrigOp35	Off On	-	-	Off	Use over level trigger for analog channel 35 (on) or not (off)
OverTrigLe35	0 - 5000	%	1	200	Over trigger level for analog channel 35 in % of signal
NomValue36	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 36
UnderTrigOp36	Off On	-	-	Off	Use under level trigger for analog channel 36 (on) or not (off)
UnderTrigLe36	0 - 200	%	1	50	Under trigger level for analog channel 36 in % of signal
OverTrigOp36	Off On	-	-	Off	Use over level trigger for analog channel 36 (on) or not (off)
OverTrigLe36	0 - 5000	%	1	200	Over trigger level for analog channel 36 in % of signal
NomValue37	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 37
UnderTrigOp37	Off On	-	-	Off	Use under level trigger for analog channel 37 (on) or not (off)
UnderTrigLe37	0 - 200	%	1	50	Under trigger level for analog channel 37 in % of signal
OverTrigOp37	Off On	-	-	Off	Use over level trigger for analog channel 37 (on) or not (off)
OverTrigLe37	0 - 5000	%	1	200	Over trigger level for analog channel 37 in % of signal
NomValue38	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 38
UnderTrigOp38	Off On	-	-	Off	Use under level trigger for analog channel 38 (on) or not (off)
UnderTrigLe38	0 - 200	%	1	50	Under trigger level for analog channel 38 in % of signal
OverTrigOp38	Off On	-	-	Off	Use over level trigger for analog channel 38 (on) or not (off)
OverTrigLe38	0 - 5000	%	1	200	Over trigger level for analog channel 38 in % of signal
NomValue39	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 39
UnderTrigOp39	Off On	-	-	Off	Use under level trigger for analog channel 39 (on) or not (off)
UnderTrigLe39	0 - 200	%	1	50	Under trigger level for analog channel 39 in % of signal
OverTrigOp39	Off On	-	-	Off	Use over level trigger for analog channel 39 (on) or not (off)
OverTrigLe39	0 - 5000	%	1	200	Over trigger level for analog channel 39 in % of signal
NomValue40	0.0 - 999999.9	-	0.1	0.0	Nominal value for analog channel 40

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
UnderTrigOp40	Off On	-	-	Off	Use under level trigger for analog channel 40 (on) or not (off)
UnderTrigLe40	0 - 200	%	1	50	Under trigger level for analog channel 40 in % of signal
OverTrigOp40	Off On	-	-	Off	Use over level trigger for analog channel 40 (on) or not (off)
OverTrigLe40	0 - 5000	%	1	200	Over trigger level for analog channel 40 in % of signal

12.6.5 Binary input signals BxRBDR

12.6.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Binary input signals	B1RBDR	-	-
Binary input signals	B2RBDR	-	-
Binary input signals	B3RBDR	-	-
Binary input signals	B4RBDR	-	-
Binary input signals	B5RBDR	-	-
Binary input signals	B6RBDR	-	-

12.6.5.2 Function block

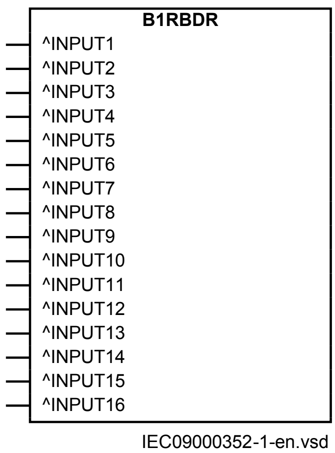


Figure 205: B1RBDR function block, binary inputs, example for B1RBDR - B6RBDR

12.6.5.3 Signals

B1RBDR - B6RBDR Input signals

Tables for input signals for B1RBDR - B6RBDR are all similar except for INPUT and description number.

- B1RBDR, INPUT1 - INPUT16
- B2RBDR, INPUT17 - INPUT32
- B3RBDR, INPUT33 - INPUT48
- B4RBDR, INPUT49 - INPUT64
- B5RBDR, INPUT65 - INPUT80
- B6RBDR, INPUT81 - INPUT96

Table 356: B1RBDR Input signals

Name	Type	Default	Description
INPUT1	BOOLEAN	0	Binary channel 1
INPUT2	BOOLEAN	0	Binary channel 2
INPUT3	BOOLEAN	0	Binary channel 3
INPUT4	BOOLEAN	0	Binary channel 4
INPUT5	BOOLEAN	0	Binary channel 5
INPUT6	BOOLEAN	0	Binary channel 6
INPUT7	BOOLEAN	0	Binary channel 7
INPUT8	BOOLEAN	0	Binary channel 8
INPUT9	BOOLEAN	0	Binary channel 9
INPUT10	BOOLEAN	0	Binary channel 10
INPUT11	BOOLEAN	0	Binary channel 11
INPUT12	BOOLEAN	0	Binary channel 12
INPUT13	BOOLEAN	0	Binary channel 13
INPUT14	BOOLEAN	0	Binary channel 14
INPUT15	BOOLEAN	0	Binary channel 15
INPUT16	BOOLEAN	0	Binary channel 16

12.6.5.4 Settings

B1RBDR - B6RBDR Settings

Setting tables for B1RBDR - B6RBDR are all similar except for binary channel and description numbers.

- B1RBDR, channel1 - channel16
- B2RBDR, channel17 - channel32
- B3RBDR, channel33 - channel48
- B4RBDR, channel49 - channel64
- B5RBDR, channel65 - channel80
- B6RBDR, channel81 - channel96

Table 357: B1RBDR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
TrigDR01	Off On	-	-	Off	Trigger operation On/Off
SetLED01	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 1
TrigDR02	Off On	-	-	Off	Trigger operation On/Off
SetLED02	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 2
TrigDR03	Off On	-	-	Off	Trigger operation On/Off
SetLED03	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 3
TrigDR04	Off On	-	-	Off	Trigger operation On/Off
SetLED04	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 4
TrigDR05	Off On	-	-	Off	Trigger operation On/Off
SetLED05	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 5
TrigDR06	Off On	-	-	Off	Trigger operation On/Off
SetLED06	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 6
TrigDR07	Off On	-	-	Off	Trigger operation On/Off
SetLED07	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 7
TrigDR08	Off On	-	-	Off	Trigger operation On/Off
SetLED08	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 8
TrigDR09	Off On	-	-	Off	Trigger operation On/Off

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
SetLED09	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 9
TrigDR10	Off On	-	-	Off	Trigger operation On/Off
SetLED10	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 10
TrigDR11	Off On	-	-	Off	Trigger operation On/Off
SetLED11	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 11
TrigDR12	Off On	-	-	Off	Trigger operation On/Off
SetLED12	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary input 12
TrigDR13	Off On	-	-	Off	Trigger operation On/Off
SetLED13	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 13
TrigDR14	Off On	-	-	Off	Trigger operation On/Off
SetLED14	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 14
TrigDR15	Off On	-	-	Off	Trigger operation On/Off
SetLED15	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 15
TrigDR16	Off On	-	-	Off	Trigger operation On/Off
SetLED16	Off Start Trip Start and Trip	-	-	Off	Set LED on HMI for binary channel 16

Table 358: B1RBDR Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
TrigLevel01	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 1
IndicationMa01	Hide Show	-	-	Hide	Indication mask for binary channel 1
TrigLevel02	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 2
IndicationMa02	Hide Show	-	-	Hide	Indication mask for binary channel 2
TrigLevel03	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 3
IndicationMa03	Hide Show	-	-	Hide	Indication mask for binary channel 3
TrigLevel04	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 4
IndicationMa04	Hide Show	-	-	Hide	Indication mask for binary channel 4
TrigLevel05	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 5
IndicationMa05	Hide Show	-	-	Hide	Indication mask for binary channel 5
TrigLevel06	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 6
IndicationMa06	Hide Show	-	-	Hide	Indication mask for binary channel 6
TrigLevel07	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 7
IndicationMa07	Hide Show	-	-	Hide	Indication mask for binary channel 7
TrigLevel08	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 8
IndicationMa08	Hide Show	-	-	Hide	Indication mask for binary channel 8
TrigLevel09	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 9
IndicationMa09	Hide Show	-	-	Hide	Indication mask for binary channel 9
TrigLevel10	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 10
IndicationMa10	Hide Show	-	-	Hide	Indication mask for binary channel 10
TrigLevel11	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 11
IndicationMa11	Hide Show	-	-	Hide	Indication mask for binary channel 11
TrigLevel12	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 12
IndicationMa12	Hide Show	-	-	Hide	Indication mask for binary channel 12

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
TrigLevel13	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 13
IndicationMa13	Hide Show	-	-	Hide	Indication mask for binary channel 13
TrigLevel14	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 14
IndicationMa14	Hide Show	-	-	Hide	Indication mask for binary channel 14
TrigLevel15	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 15
IndicationMa15	Hide Show	-	-	Hide	Indication mask for binary channel 15
TrigLevel16	Trig on 0 Trig on 1	-	-	Trig on 1	Trigger on positive (1) or negative (0) slope for binary input 16
IndicationMa16	Hide Show	-	-	Hide	Indication mask for binary channel 16

12.6.6 Operation principle

Disturbance report is a common name for several functions to supply the operator, analysis engineer, etc. with sufficient information about events in the system.

The functions included in the disturbance report are:

- General disturbance information
- Indications
- Event recorder
- Event list
- Trip value recorder
- Disturbance recorder
- Fault locator (FL)

Figure 206 shows the relations between Disturbance Report, included functions and function blocks. Event list, Event recorder and Indications uses information from the binary input function blocks (BxRBDR). Trip value recorder uses analog information from the analog input function blocks (AxRADR) which is used by FL after estimation by TVR. Disturbance recorder function acquires information from both AxRADR and BxRBDR.

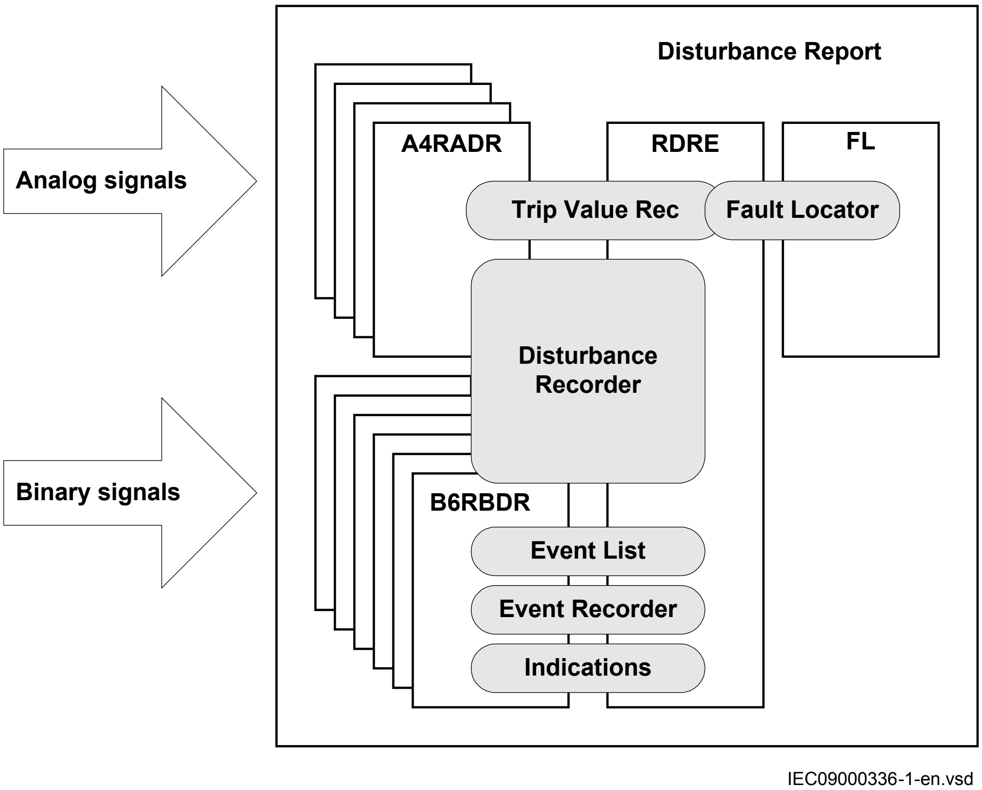


Figure 206: Disturbance report functions and related function blocks

The whole disturbance report can contain information for a number of recordings, each with the data coming from all the parts mentioned above. The event list function is working continuously, independent of disturbance triggering, recording time etc. All information in the disturbance report is stored in non-volatile flash memories. This implies that no information is lost in case of loss of auxiliary power. Each report will get an identification number in the interval from 0-999.

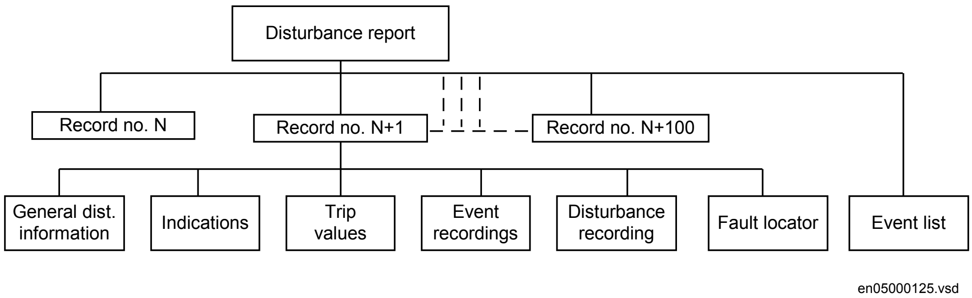


Figure 207: Disturbance report structure

Up to 100 disturbance reports can be stored. If a new disturbance is to be recorded when the memory is full, the oldest disturbance report is over-written by the new one. The total recording capacity for the disturbance recorder is depending of sampling frequency, number of analog and binary channels and recording time. In a 50 Hz system it's possible to record 100 where the maximum recording time is

3.4 seconds. The memory limit does not affect the rest of the disturbance report (Event list, Event recorder, Indications and Trip value recorder).

12.6.6.1 Disturbance information

Date and time of the disturbance, the indications, events, fault location and the trip values are available on the local human-machine interface (LHMI). To acquire a complete disturbance report the use of a PC and PCM600 is required. The PC may be connected to the IED-front, rear or remotely via the station bus (Ethernet ports).

12.6.6.2 Indications

Indications is a list of signals that were activated during the total recording time of the disturbance (not time-tagged). See Indication section for detailed information.

12.6.6.3 Event recorder

The event recorder may contain a list of up to 150 time-tagged events, which have occurred during the disturbance. The information is available via the local HMI or PCM600. See Event recorder section for detailed information.

12.6.6.4 Event list

The event list may contain a list of totally 1000 time-tagged events. The list information is continuously updated when selected binary signals change state. The oldest data is overwritten. The logged signals may be presented via local HMI or PCM600. See Event list section for detailed information.

12.6.6.5 Trip value recorder

The recorded trip values include phasors of selected analog signals before the fault and during the fault. See Trip value recorder section for detailed information.

12.6.6.6 Disturbance recorder

Disturbance recorder records analog and binary signal data before, during and after the fault. See Disturbance recorder section for detailed information.

12.6.6.7 Fault locator

The fault location function calculates the distance to fault. See Fault locator section for detailed information.

12.6.6.8 Time tagging

The IED has a built-in real-time calendar and clock. This function is used for all time tagging within the disturbance report

12.6.6.9 Recording times

Disturbance report records information about a disturbance during a settable time frame. The recording times are valid for the whole disturbance report. Disturbance recorder , event recorder and indication function register disturbance data and events during tRecording, the total recording time.

The total recording time, tRecording, of a recorded disturbance is:

tRecording =	*PreFaultrecT* + tFault + *PostFaultrecT* or *PreFaultrecT* + *TimeLimit*, depending on which criterion stops the current disturbance recording

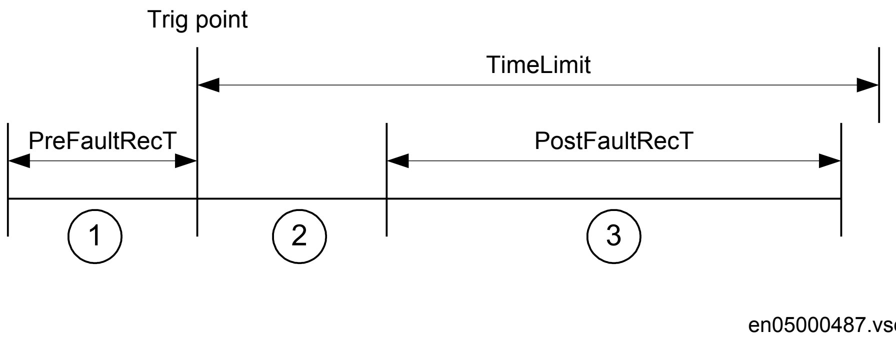


Figure 208: The recording times definition

PreFaultRecT, 1	Pre-fault or pre-trigger recording time. The time before the fault including the operate time of the trigger. Use the setting *PreFaultRecT* to set this time.
tFault, 2	Fault time of the recording. The fault time cannot be set. It continues as long as any valid trigger condition, binary or analog, persists (unless limited by *TimeLimit* the limit time).
PostFaultRecT, 3	Post fault recording time. The time the disturbance recording continues after all activated triggers are reset. Use the setting *PostFaultRecT* to set this time.
TimeLimit	Limit time. The maximum allowed recording time after the disturbance recording was triggered. The limit time is used to eliminate the consequences of a trigger that does not reset within a reasonable time interval. It limits the maximum recording time of a recording and prevents subsequent overwriting of already stored disturbances. Use the setting *TimeLimit* to set this time.

12.6.6.10 Analog signals

Up to 40 analog signals can be selected for recording by the Disturbance recorder and triggering of the Disturbance report function. Out of these 40, 30 are reserved for external analog signals from analog input modules via preprocessing function blocks (SMAI) and summation block (3PHSUM). The last 10 channels may be connected to internally calculated analog signals available as function block output signals (phase differential currents, bias currents etc.).

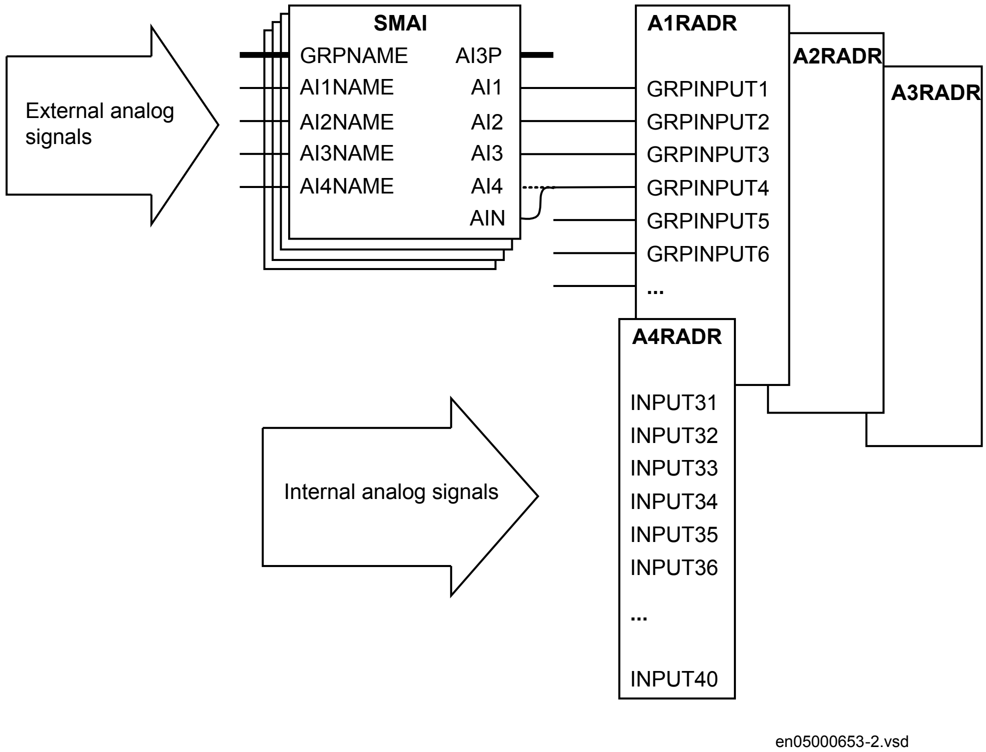


Figure 209: Analog input function blocks

The external input signals will be acquired, filtered and skewed and (after configuration) available as an input signal on the AxRADR function block via the SMAI function block. The information is saved at the Disturbance report base sampling rate (1000 or 1200 Hz). Internally calculated signals are updated according to the cycle time of the specific function. If a function is running at lower speed than the base sampling rate, Disturbance recorder will use the latest updated sample until a new updated sample is available.

Application configuration tool (ACT) is used for analog configuration of the Disturbance report.

The preprocessor function block (SMAI) calculates the residual quantities in cases where only the three phases are connected (AI4-input not used).SMAI makes the information available as a group signal output, phase outputs and calculated residual output (AIN-output). In situations where AI4-input is used as a input signal the corresponding information is available on the non-calculated output (AI4) on the SMAI-block. Connect the signals to the AxRADR accordingly.

For each of the analog signals, *Operation= On* means that it is recorded by the disturbance recorder. The trigger is independent of the setting of *Operation*, and triggers even if operation is set to *Off*. Both undervoltage and overvoltage can be used as trigger conditions. The same applies for the current signals.

If *Operation=Off* , no waveform (samples) will be recorded and reported in graph. However, Trip value, pre-fault and fault value will be recorded and reported. The input channel can still be used to trig the disturbance recorder.

If *Operation=On* l, waveform (samples) will also be recorded and reported in graph.

The analog signals are presented only in the disturbance recording, but they affect the entire disturbance report when being used as triggers.

12.6.6.11 Binary signals

Up to 96 binary signals can be selected to be handled by disturbance report. The signals can be selected from internal logical and binary input signals. A binary signal is selected to be recorded when:

- the corresponding function block is included in the configuration
- the signal is connected to the input of the function block

Each of the 96 signals can be selected as a trigger of the disturbance report (*Operation=ON/OFF*). A binary signal can be selected to activate the yellow (START) and red (TRIP) LED on the local HMI (*SetLED=Off/Start/Trip/Start and Trip*).

The selected signals are presented in the event recorder, event list and the disturbance recording. But they affect the whole disturbance report when they are used as triggers. The indications are also selected from these 96 signals with local HMI *IndicationMask=Show/Hide*.

12.6.6.12 Trigger signals

The trigger conditions affect the entire disturbance report, except the event list, which runs continuously. As soon as at least one trigger condition is fulfilled, a complete disturbance report is recorded. On the other hand, if no trigger condition is fulfilled, there is no disturbance report, no indications, and so on. This implies the importance of choosing the right signals as trigger conditions.

A trigger can be of type:

- Manual trigger
- Binary-signal trigger
- Analog-signal trigger (over/under function)

Manual trigger

A disturbance report can be manually triggered from the local HMI, PCM600 or via station bus (IEC 61850). When the trigger is activated, the manual trigger signal is generated. This feature is especially useful for testing.

Binary-signal trigger

Any binary signal state (logic one or a logic zero) can be selected to generate a trigger (*Triglevel* = Trig on 0/Trig on 1). When a binary signal is selected to generate a trigger from a logic zero, the selected signal will not be listed in the indications list of the disturbance report.

Analog-signal trigger

All analog signals are available for trigger purposes, no matter if they are recorded in the disturbance recorder or not. The settings are *OverTrigOp*, *UnderTrigOp*, *OverTrigLe* and *UnderTrigLe*.

The check of the trigger condition is based on peak-to-peak values. When this is found, the absolute average value of these two peak values is calculated. If the average value is above the threshold level for an overvoltage or overcurrent trigger, this trigger is indicated with a greater than (>) sign with the user-defined name.

If the average value is below the set threshold level for an undervoltage or undercurrent trigger, this trigger is indicated with a less than (<) sign with its name. The procedure is separately performed for each channel.

This method of checking the analog start conditions gives a function which is insensitive to DC offset in the signal. The operate time for this start is typically in the range of one cycle, 20 ms for a 50 Hz network.

All under/over trig signal information is available on local HMI and PCM600 .

12.6.6.13 Post Retrigger

Disturbance report function does not respond to any new trig condition, during a recording. Under certain circumstances the fault condition may reoccur during the post-fault recording, for instance by automatic reclosing to a still faulty power line.

In order to capture the new disturbance it is possible to allow retriggering (*PostRetrigPost-retrig = On)*during the post-fault time. In this case a new, complete recording will start and, during a period, run in parallel with the initial recording.

When the retrig parameter is disabled (*PostRetrig = Off*), a new recording will not start until the post-fault (*PostFaultrecT* or *TimeLimit*) period is terminated. If a new trig occurs during the post-fault period and lasts longer than the proceeding recording a new complete recording will be fetched.

Disturbance report function can handle maximum 3 simultaneous disturbance recordings.

12.6.7 Technical data

Table 359: DRPRDRE Technical data

Function	Range or value	Accuracy
Current recording	-	± 1,0% of I_r at $I \leq I_r$ ± 1,0% of I at I > Ir
Voltage recording	-	± 1,0% of U_r at $U \leq U_r$ ± 1,0% of U at $U > U_r$
Pre-fault time	(0.05–3.00) s	-
Post-fault time	(0.1–10.0) s	-
Limit time	(0.5–8.0) s	-
Maximum number of recordings	100	-
Time tagging resolution	1 ms	See time synchronization technical data
Maximum number of analog inputs	30 + 10 (external + internally derived)	-
Maximum number of binary inputs	96	-
Maximum number of phasors in the Trip Value recorder per recording	30	-
Maximum number of indications in a disturbance report	96	-
Maximum number of events in the Event recording per recording	150	-
Maximum number of events in the Event list	1000, first in - first out	-
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)	340 seconds (100 recordings) at 50 Hz, 280 seconds (80 recordings) at 60 Hz	-
Sampling rate	1 kHz at 50 Hz 1.2 kHz at 60 Hz	-
Recording bandwidth	(5-300) Hz	-

12.7 Indications

12.7.1 Functionality

To get fast, condensed and reliable information about disturbances in the primary and/or in the secondary system it is important to know, for example binary signals that have changed status during a disturbance. This information is used in the short perspective to get information via the local HMI in a straightforward way.

There are three LEDs on the local HMI (green, yellow and red), which will display status information about the IED and the Disturbance report function (trigged).

The Indication list function shows all selected binary input signals connected to the Disturbance report function that have changed status during a disturbance.

The indication information is available for each of the recorded disturbances in the IED and the user may use the local HMI to get the information.

12.7.2 Function block

The Indications function has no function block of it’s own. .

12.7.3 Signals

12.7.3.1 Input signals

The Indications function may log the same binary input signals as the Disturbance report function.

12.7.4 Operation principle

The LED indications display this information:

Green LED:

Steady light	In Service
Flashing light	Internal fail
Dark	No power supply

Yellow LED:

Function controlled by *SetLEDn* setting in Disturbance report function.

Red LED:

Function controlled by *SetLEDn* setting in Disturbance report function.

Indication list:

The possible indicated signals are the same as the ones chosen for the disturbance report function and disturbance recorder.

The indication function tracks 0 to 1 changes of binary signals during the recording period of the collection window. This means that constant logic zero, constant logic one or state changes from logic one to logic zero will not be visible in the list of indications. Signals are not time tagged. In order to be recorded in the list of indications the:

- the signal must be connected to binary input BxRBDR function block
- the DRPRDRE parameter *Operation* must be set *On*
- the DRPRDRE must be trigged (binary or analog)
- the input signal must change state from logical 0 to 1 during the recording time.

Indications are selected with the indication mask (*IndicationMask*) when configuring the binary inputs.

The name of the binary input signal that appears in the Indication function is the user-defined name assigned at configuration of the IED. The same name is used in disturbance recorder function , indications and event recorder function .

12.7.5 Technical data

Table 360: DRPRDRE Technical data

Function		Value
Buffer capacity	Maximum number of indications presented for single disturbance	96
	Maximum number of recorded disturbances	100

12.8 Event recorder

12.8.1 Functionality

Quick, complete and reliable information about disturbances in the primary and/or in the secondary system is vital, for example, time tagged events logged during disturbances. This information is used for different purposes in the short term (for example corrective actions) and in the long term (for example Functional Analysis).

The event recorder logs all selected binary input signals connected to the Disturbance report function. Each recording can contain up to 150 time-tagged events.

The event recorder information is available for the disturbances locally in the IED.

The information may be uploaded to the PCM600 and further analyzed using the Disturbance handling tool.

The event recording information is an integrated part of the disturbance record (Comtrade file).

12.8.2 Function block

The Event recorder has no function block of it’s own.

12.8.3 Signals

12.8.3.1 Input signals

The Event recorder function logs the same binary input signals as the Disturbance report function.

12.8.4 Operation principle

When one of the trig conditions for the disturbance report is activated, the event recorder logs every status change in the 96 selected binary signals. The events can be generated by both internal logical signals and binary input channels. The internal signals are time-tagged in the main processor module, while the binary input channels are time-tagged directly in each I/O module. The events are collected during the total recording time (pre-, post-fault and limit time), and are stored in the disturbance report flash memory at the end of each recording.

In case of overlapping recordings, due to *PostRetrig* = *On* and a new trig signal appears during post-fault time, events will be saved in both recording files.

The name of the binary input signal that appears in the event recording is the user-defined name assigned when configuring the IED. The same name is used in the disturbance recorder function , indications and event recorder function .

The event record is stored as a part of the disturbance report information and managed via the local HMI or PCM600.

12.8.5 Technical data

Table 361: DRPRDRE Technical data

Function		Value
Buffer capacity	Maximum number of events in disturbance report	150
	Maximum number of disturbance reports	100
Resolution		1 ms
Accuracy		Depending on time synchronizing

12.9 Event list

12.9.1 Functionality

Continuous event-logging is useful for monitoring of the system from an overview perspective and is a complement to specific disturbance recorder functions.

The event list logs all binary input signals connected to the Disturbance report function. The list may contain of up to 1000 time-tagged events stored in a ring-buffer.

The event list information is available in the IED and is reported to higher control systems via the station bus together with other logged events in the IED. The local HMI can be used to view the event list.

To view events that occurs during the time while the event list is displayed in the local HMI, the list has to be closed and reopened.

12.9.2 Function block

The Event list has no function block of it’s own.

12.9.3 Signals

12.9.3.1 Input signals

The Event list logs the same binary input signals as configured for the Disturbance report function.

12.9.4 Operation principle

When a binary signal, connected to the disturbance report function, changes status, the event list function stores input name, status and time in the event list in chronological order. The list can contain up to 1000 events from both internal logic signals and binary input channels. If the list is full, the oldest event is overwritten when a new event arrives.

The list can be configured to show oldest or newest events first with a setting on the local HMI.

The event list function runs continuously, in contrast to the event recorder function, which is only active during a disturbance.

The name of the binary input signal that appears in the event recording is the user-defined name assigned when the IED is configured. The same name is used in the disturbance recorder function , indications and the event recorder function .

The event list is stored and managed separate from the disturbance report information .

12.9.5 Technical data

Table 362: DRPRDRE Technical data

Function		Value
Buffer capacity	Maximum number of events in the list	1000
Resolution		1 ms
Accuracy		Depending on time synchronizing

12.10 Trip value recorder

12.10.1 Functionality

Information about the pre-fault and fault values for currents and voltages are vital for the disturbance evaluation.

The Trip value recorder calculates the values of all selected analog input signals connected to the Disturbance report function. The result is magnitude and phase angle before and during the fault for each analog input signal.

The trip value recorder information is available for the disturbances locally in the IED.

The information may be uploaded to the PCM600 and further analyzed using the Disturbance Handling tool.

The trip value recorder information is an integrated part of the disturbance record (Comtrade file).

12.10.2 Function block

The Trip value recorder has no function block of it’s own.

12.10.3 Signals

12.10.3.1 Input signals

The trip value recorder function uses analog input signals connected to (not).

12.10.4 Operation principle

Trip value recorder calculates and presents both fault and pre-fault amplitudes as well as the phase angles of all the selected analog input signals. The parameter *ZeroAngleRef* points out which input signal is used as the angle reference. The calculated data is input information to the fault locator .

When the disturbance report function is triggered the sample for the fault interception is searched for, by checking the non-periodic changes in the analog input signals. The channel search order is consecutive, starting with the analog input with the lowest number.

When a starting point is found, the Fourier estimation of the pre-fault values of the complex values of the analog signals starts 1.5 cycle before the fault sample. The estimation uses samples during one period. The post-fault values are calculated using the Recursive Least Squares (RLS) method. The calculation starts a few samples after the fault sample and uses samples during 1/2 - 2 cycles depending on the shape of the signals.

If no starting point is found in the recording, the disturbance report trig sample is used as the start sample for the Fourier estimation. The estimation uses samples during one cycle before the trig sample. In this case the calculated values are used both as pre-fault and fault values.

The name of the analog input signal that appears in the Trip value recorder function is the user-defined name assigned when the IED is configured. The same name is used in the Disturbance recorder function .

The trip value record is stored as a part of the disturbance report information (LMBRFLO) and managed in via the local HMI or PCM600.

12.10.5 Technical data

Table 363: DRPRDRE Technical data

Function		Value
Buffer capacity	Maximum number of analog inputs	30
	Maximum number of disturbance reports	100

12.11 Disturbance recorder

12.11.1 Functionality

The Disturbance recorder function supplies fast, complete and reliable information about disturbances in the power system. It facilitates understanding system behavior and related primary and secondary equipment during and after a disturbance. Recorded information is used for different purposes in the short perspective (for example corrective actions) and long perspective (for example Functional Analysis).

The Disturbance recorder acquires sampled data from all selected analog input and binary signals connected to the Disturbance report function (maximum 40 analog and 96 binary signals). The binary signals are the same signals as available under the event recorder function.

The function is characterized by great flexibility and is not dependent on the operation of protection functions. It can record disturbances not detected by protection functions.

The disturbance recorder information for the last 100 disturbances are saved in the IED and the local HMI is used to view the list of recordings.

The disturbance recording information can be uploaded to the PCM600 and further analyzed using the Disturbance handling tool.

12.11.2 Function block

The Disturbance recorder has no function block of it's own.

12.11.3 Signals

12.11.3.1 Input and output signals

See Disturbance report for input and output signals.

12.11.4 Setting parameters

See Disturbance report for settings.

12.11.5 Operation principle

Disturbance recording is based on the acquisition of binary and analog signals. The binary signals can be either true binary input signals or internal logical signals generated by the functions in the IED. The analog signals to be recorded are input channels from the Transformer Input Module (TRM) through the Signal Matrix Analog Input (SMAI) and possible summation (Sum3Ph) function blocks and some internally derived analog signals. .

Disturbance recorder collects analog values and binary signals continuously, in a cyclic buffer. The pre-fault buffer operates according to the FIFO principle; old data will continuously be overwritten as new data arrives when the buffer is full. The size of this buffer is determined by the set pre-fault recording time.

Upon detection of a fault condition (triggering), the disturbance is time tagged and the data storage continues in a post-fault buffer. The storage process continues as long as the fault condition prevails - plus a certain additional time. This is called the post-fault time and it can be set in the disturbance report.

The above mentioned two parts form a disturbance recording. The whole memory, intended for disturbance recordings, acts as a cyclic buffer and when it is full, the oldest recording is overwritten. The last 100 recordings are stored in the IED.

The time tagging refers to the activation of the trigger that starts the disturbance recording. A recording can be trigged by, manual start, binary input and/or from analog inputs (over-/underlevel trig).

A user-defined name for each of the signals can be set. These names are common for all functions within the disturbance report functionality.

12.11.5.1 Memory and storage

When a recording is completed, a post recording processing occurs.

This post-recording processing comprises:

- Saving the data for analog channels with corresponding data for binary signals
- Add relevant data to be used by the Disturbance handling tool (part of PCM 600)
- Compression of the data, which is performed without losing any data accuracy
- Storing the compressed data in a non-volatile memory (flash memory)

The recorded disturbance is now ready for retrieval and evaluation.

The recording files comply with the Comtrade standard IEC 60255-24 and are divided into three files; a header file (HDR), a configuration file (CFG) and a data file (DAT).

The header file (optional in the standard) contains basic information about the disturbance, that is, information from the Disturbance report sub-functions . The Disturbance handling tool use this information and present the recording in a user-friendly way.

General:

- Station name, object name and unit name
- Date and time for the trig of the disturbance
- Record number
- Sampling rate
- Time synchronization source
- Recording times
- Activated trig signal
- Active setting group

Analog:

- Signal names for selected analog channels
- Information e.g. trig on analog inputs
- Primary and secondary instrument transformer rating
- Over- or Undertrig: level and operation
- Over- or Undertrig status at time of trig
- CT direction

Binary:

- Signal names
- Status of binary input signals

The configuration file is a mandatory file containing information needed to interpret the data file. For example sampling rate, number of channels, system frequency, channel info etc.

The data file, which also is mandatory, containing values for each input channel for each sample in the record (scaled value). The data file also contains a sequence number and time stamp for each set of samples.

12.11.6 Technical data

Table 364: DRPRDRE Technical data

Function		Value
Buffer capacity	Maximum number of analog inputs	40
	Maximum number of binary inputs	96
	Maximum number of disturbance reports	100
Maximum total recording time (3.4 s recording time and maximum number of channels, typical value)		340 seconds (100 recordings) at 50 Hz 280 seconds (80 recordings) at 60 Hz

12.12 Measured value expander block MVEXP

12.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Measured value expander block	MVEXP	-	-

12.12.2 Functionality

The current and voltage measurements functions (CVMMXN, CMMXU, VMMXU and VNMMXU), current and voltage sequence measurement functions (CMSQI and VMSQI) and IEC 61850 generic communication I/O functions (MVGGIO) are provided with measurement supervision functionality. All measured values can be supervised with four settable limits, that is low-low limit, low limit, high limit and high-high limit. The measure value expander block has been introduced to be able to translate the integer output signal from the measuring functions to 5 binary signals, that is below low-low limit, below low limit, normal, above high-high limit or above high limit. The output signals can be used as conditions in the configurable logic.

12.12.3 Function block

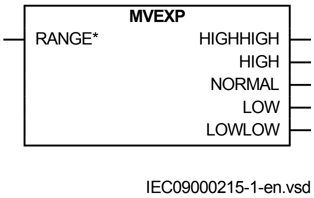


Figure 210: MVEXP function block

12.12.4 Signals

Table 365: MVEXP Input signals

Name	Type	Default	Description
RANGE	INTEGER	0	Measured value range

Table 366: MVEXP Output signals

Name	Type	Description
HIGHHIGH	BOOLEAN	Measured value is above high-high limit
HIGH	BOOLEAN	Measured value is between high and high-high limit
NORMAL	BOOLEAN	Measured value is between high and low limit
LOW	BOOLEAN	Measured value is between low and low-low limit
LOWLOW	BOOLEAN	Measured value is below low-low limit

12.12.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

Common base IED values for primary current (setting *IBase*), primary voltage (setting *UBase*) and primary power (setting *SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

12.12.6 Operation principle

The input signal must be connected to a range output of a measuring function block (CVMMXN, CMMXU, VMMXU, VNMMXU, CMSQI, VMSQ or MVGGIO). The function block converts the input integer value to five binary output signals according to table 367.

Table 367: Input integer value converted to binary output signals

Measured supervised value is: / Output:	below low-low limit	between low-low and low limit	between low and high limit	between high-high and high limit	above high-high limit
LOWLOW	High				
LOW		High			
NORMAL			High		
HIGH				High	
HIGHHIGH					High

12.13 Fault locator LMBRFLO

12.13.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Fault locator	LMBRFLO	-	-

12.13.2 Functionality

The accurate fault locator is an essential component to minimize the outages after a persistent fault and/or to pin-point a weak spot on the line.

The fault locator is an impedance measuring function giving the distance to the fault in percent, km or miles. The main advantage is the high accuracy achieved by compensating for load current.

The compensation includes setting of the remote and local sources and calculation of the distribution of fault currents from each side. This distribution of fault current, together with recorded load (pre-fault) currents, is used to exactly calculate the fault position. The fault can be recalculated with new source data at the actual fault to further increase the accuracy.

Specially on heavily loaded long lines (where the fault locator is most important) where the source voltage angles can be up to 35-40 degrees apart the accuracy can be still maintained with the advanced compensation included in fault locator.

12.13.3 Function block

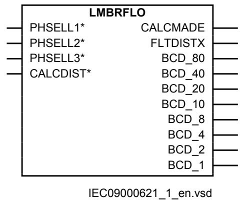


Figure 211: LMBRFLO function block

12.13.4 Signals

Table 368: LMBRFLO Input signals

Name	Type	Default	Description
PHSELL1	BOOLEAN	0	Phase selecton L1
PHSELL2	BOOLEAN	0	Phase selecton L2
PHSELL3	BOOLEAN	0	Phase selecton L3
CALCDIST	BOOLEAN	0	Do calculate fault distance (release)

Table 369: LMBRFLO Output signals

Name	Type	Description
CALCMADE	BOOLEAN	Fault calculation made
FLTDISTX	REAL	Reactive distance to fault
BCD_80	BOOLEAN	Distance in binary coded data, bit represents 80%
BCD_40	BOOLEAN	Distance in binary coded data, bit represents 40%
BCD_20	BOOLEAN	Distance in binary coded data, bit represents 20%
BCD_10	BOOLEAN	Distance in binary coded data, bit represents 10%
BCD_8	BOOLEAN	Distance in binary coded data, bit represents 8%
BCD_4	BOOLEAN	Distance in binary coded data, bit represents 4%
BCD_2	BOOLEAN	Distance in binary coded data, bit represents 2%
BCD_1	BOOLEAN	Distance in binary coded data, bit represents 1%

12.13.5 Settings

Table 370: LMBRFLO Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
R1A	0.001 - 1500.000	ohm/p	0.001	2.000	Source resistance A (near end)
X1A	0.001 - 1500.000	ohm/p	0.001	12.000	Source reactance A (near end)
R1B	0.001 - 1500.000	ohm/p	0.001	2.000	Source resistance B (far end)
X1B	0.001 - 1500.000	ohm/p	0.001	12.000	Source reactance B (far end)
Table continues on next page					

Name	Values (Range)	Unit	Step	Default	Description
R1L	0.001 - 1500.000	ohm/p	0.001	2.000	Positive sequence line resistance
X1L	0.001 - 1500.000	ohm/p	0.001	12.500	Positive sequence line reactance
R0L	0.001 - 1500.000	ohm/p	0.001	8.750	Zero sequence line resistance
X0L	0.001 - 1500.000	ohm/p	0.001	50.000	Zero sequence line reactance
R0M	0.000 - 1500.000	ohm/p	0.001	0.000	Zero sequence mutual resistance
X0M	0.000 - 1500.000	ohm/p	0.001	0.000	Zero sequence mutual reactance
LineLength	0.0 - 10000.0	-	0.1	40.0	Length of line

Table 371: LMBRFLO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
DrepChNoIL1	1 - 30	Ch	1	1	Recorder input number recording phase current, IL1
DrepChNoIL2	1 - 30	Ch	1	2	Recorder input number recording phase current, IL2
DrepChNoIL3	1 - 30	Ch	1	3	Recorder input number recording phase current, IL3
DrepChNoIN	0 - 30	Ch	1	4	Recorder input number recording residual current, IN
DrepChNoIP	0 - 30	Ch	1	0	Recorder input number recording 3I0 on parallel line
DrepChNoUL1	1 - 30	Ch	1	5	Recorder input number recording phase voltage, UL1
DrepChNoUL2	1 - 30	Ch	1	6	Recorder input number recording phase voltage, UL2
DrepChNoUL3	1 - 30	Ch	1	7	Recorder input number recording phase voltage, UL3

12.13.6 Monitored data

Table 372: LMBRFLO Monitored data

Name	Type	Values (Range)	Unit	Description
FaultDistRelat	REAL	-	-	Distance to fault, relative
FltDistLngUnit	REAL	-	-	Distance to fault in line length unit
FLTDISTX	REAL	-	Ohm	Reactive distance to fault
ResistiveDist	REAL	-	Ohm	Resistive distance to fault
FaultLoop	INTEGER	-	-	Fault loop

12.13.7 Operation principle

The Fault locator (LMBRFLO) in the IED is an essential complement to other monitoring functions, since it measures and indicates the distance to the fault with great accuracy.

When calculating distance to fault, pre-fault and fault phasors of currents and voltages are selected from the Trip value recorder data, thus the analogue signals used by the fault locator must be among those connected to the disturbance report function. The analogue configuration (channel selection) is performed using the parameter setting tool within PCM600.

The calculation algorithm considers the effect of load currents, double-end infeed and additional fault resistance.

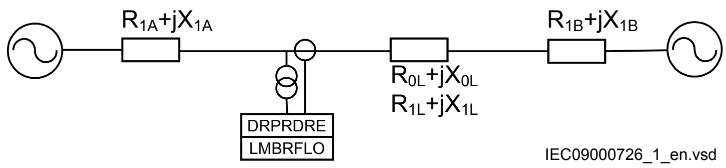


Figure 212: Simplified network configuration with network data, required for settings of the fault location-measuring function.

If source impedance in the near and far end of the protected line have changed in a significant manner relative to the set values at fault location calculation time (due to exceptional switching state in the immediate network, power generation out of order etc.), new values can be entered via the local HMI and a recalculation of the distance to the fault can be ordered using the algorithm described below. It’s also possible to change fault loop. In this way, a more accurate location of the fault can be achieved.

The function indicates the distance to the fault as a percentage of the line length. The fault location is stored as a part of the disturbance report information and managed via the LHMI or PCM600.

12.13.7.1 Measuring Principle

For transmission lines with voltage sources at both line ends, the effect of double-end infeed and additional fault resistance must be considered when calculating the distance to the fault from the currents and voltages at one line end. If this is not done, the accuracy of the calculated figure will vary with the load flow and the amount of additional fault resistance.

The calculation algorithm used in the fault locator in compensates for the effect of double-end infeed, additional fault resistance and load current.

12.13.7.2 Accurate algorithm for measurement of distance to fault

Figure 213 shows a single-line diagram of a single transmission line, that is fed from both ends with source impedances Z_A and Z_B. Assume, that the fault occurs at a distance F from IED A on a line with the length L and impedance Z_L. The fault resistance is defined as R_F. A single-line model is used for better clarification of the algorithm.

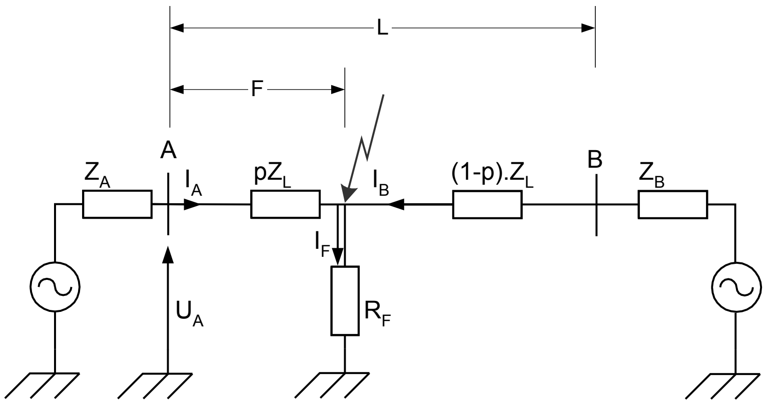


Figure 213: Fault on transmission line fed from both ends.

From figure 213 it is evident that:

$$U_A = I_A \cdot p \cdot Z_L + I_F \cdot R_F$$

(Equation 88)

Where:

I_A is the line current after the fault, that is, pre-fault current plus current change due to the fault,

I_F is the fault current and

p is a relative distance to the fault

The fault current is expressed in measurable quantities by:

$$I_F = \frac{I_{FA}}{D_A}$$

(Equation 89)

Where:

I_{FA} is the change in current at the point of measurement, IED A and

D_A is a fault current-distribution factor, that is, the ratio between the fault current at line end A and the total fault current.

For a single line, the value is equal to:

$$D_A = \frac{(1-p)\cdot Z_L + Z_B}{Z_A + Z_L + Z_B}$$

(Equation 90)

Thus, the general fault location equation for a single line is:

$$U_A = I_A \cdot p \cdot Z_L + \frac{I_{FA}}{D_A} \cdot R_F$$

(Equation 91)

Table 373: Expressions for U_A, I_A and I_{FA} for different types of faults

Fault type:	U_A	I_A	I_{FA}
L1-N	U_{L1A}	I_{L1A} + K_N x I_{NA}	$\frac{3}{2} \times \Delta(I_{L1A} - I_{0A})$ (Equation 92)
L2-N	U_{L2A}	I_{L2A} + K_N x I_{NA}	$\frac{3}{2} \times \Delta(I_{L2A} - I_{0A})$ (Equation 93)
L3-N	U_{L3A}	I_{L3A} + K_N x I_{NA}	$\frac{3}{2} \times \Delta(I_{L3A} - I_{0A})$ (Equation 94)
L1-L2-L3, L1-L2,L1-L2-N	U_{L1A}-U_{L2A}	I_{L1A} - I_{L2A}	ΔI_{L1L2A} (Equation 95)
L2-L3, L2-L3-N	U_{L2A}-U_{L3A}	I_{L2A} - I_{L3A}	ΔI_{L2L3A} (Equation 96)
L3-L1, L3-L1-N	U_{L3A}-U_{L1A}	I_{L3A} - I_{L1A}	ΔI_{L3L1A} (Equation 97)

The K_N complex quantity for zero-sequence compensation for the single line is equal to:

$$K_N = \frac{Z_{0L} - Z_{1L}}{3 \cdot Z_{1L}}$$

(Equation 98)

ΔI is the change in current, that is the current after the fault minus the current before the fault.

In the following, the positive sequence impedance for Z_A, Z_B and Z_L is inserted into the equations, because this is the value used in the algorithm.

For double lines, the fault equation is:

$$U_A = I_A \cdot p \cdot Z_{1L} + \frac{I_{FA}}{D_A} \cdot R_F + I_{0P} \cdot Z_{0M}$$

(Equation 99)

Where:

I_{0P} is a zero sequence current of the parallel line,

Z_{0M} is a mutual zero sequence impedance and

D_A is the distribution factor of the parallel line, which is:

$$D_A = \frac{(1-p) \cdot (Z_A + Z_{AL} + Z_B) + Z_B}{2 \cdot Z_A + Z_L + 2 \cdot Z_B}$$

The K_N compensation factor for the double line becomes:

$$K_N = \frac{Z_{0L} - Z_{1L}}{3 \cdot Z_{1L}} + \frac{Z_{0M}}{3 \cdot Z_{1L}} \cdot \frac{I_{0P}}{I_{0A}}$$

(Equation 101)

From these equations it can be seen, that, if $Z_{0m} = 0$, then the general fault location equation for a single line is obtained. Only the distribution factor differs in these two cases.

Because the D_A distribution factor according to equation 91 or 100 is a function of p, the general equation 100 can be written in the form:

$$p^2 - p \cdot K_1 + K_2 - K_3 \cdot R_F = 0$$

(Equation 102)

Where:

$$K_1 = \frac{U_A}{I_A \cdot Z_L} + \frac{Z_B}{Z_L + Z_{ADD}} + 1$$

(Equation 103)

$$K_2 = \frac{U_A}{I_A \cdot Z_L} \cdot \left(\frac{Z_B}{Z_L + Z_{ADD}} + 1\right)$$

(Equation 104)

$$K_3 = \frac{I_{FA}}{I_A \cdot Z_L} \cdot \left(\frac{Z_A + Z_B}{Z_1 + Z_{ADD}} + 1\right)$$

(Equation 105)

and:

- $Z_{ADD} = Z_A + Z_B$ for parallel lines.
- I_A, I_{FA} and U_A are given in the above table.
- K_N is calculated automatically according to equation 101.
- Z_A, Z_B, Z_L, Z_{0L} and Z_{0M} are setting parameters.

For a single line, $Z_{0M} = 0$ and $Z_{ADD} = 0$. Thus, equation 102 applies to both single and parallel lines.

Equation 102 can be divided into real and imaginary parts:

$$p^2 - p \cdot Re(K_1) + Re(K_2) - R_F \cdot Re(K_3) = 0$$

(Equation 106)

$$-p \cdot Im \cdot (K_1) + Im \cdot (K_2) - R_F \cdot Im \cdot (K_3) = 0$$

(Equation 107)

If the imaginary part of K_3 is not zero, R_F can be solved according to equation 107, and then inserted to equation 106. According to equation 106, the relative distance to the fault is solved as the root of a quadratic equation.

Equation 106 gives two different values for the relative distance to the fault as a solution. A simplified load compensated algorithm, that gives an unequivocal figure for the relative distance to the fault, is used to establish the value that should be selected.

If the load compensated algorithms according to the above do not give a reliable solution, a less accurate, non-compensated impedance model is used to calculate the relative distance to the fault.

12.13.7.3 The non-compensated impedance model

In the non-compensated impedance model, I_A line current is used instead of I_{FA} fault current:

$$U_A = p \cdot Z_{1L} \cdot I_A + R_F \cdot I_A$$

(Equation 108)

Where:

I_A is according to table 373.

The accuracy of the distance-to-fault calculation, using the non-compensated impedance model, is influenced by the pre-fault load current. So, this method is only used if the load compensated models do not function.

12.13.8 Technical data

Table 374: LMBRFLO Technical data

Function	Value or range	Accuracy
Reactive and resistive reach	(0.001-1500.000) Ω/phase	± 2.0% static accuracy ± 2.0% degrees static angular accuracy Conditions: Voltage range: (0.1-1.1) x U_r Current range: (0.5-30) x I_r
Phase selection	According to input signals	-
Maximum number of fault locations	100	-

12.14 Station battery supervision SPVNZBAT

12.14.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Station battery supervision function	SPVNZBAT	U<>	-

12.14.2 Functionality

The station battery supervision function SPVNZBAT is used for monitoring battery terminal voltage.

SPVNZBAT activates the start and alarm outputs when the battery terminal voltage exceeds the set upper limit or drops below the set lower limit. A time delay for the overvoltage and undervoltage alarms can be set according to definite time characteristics.

In the definite time (DT) mode, SPVNZBAT operates after a predefined operate time and resets when the battery undervoltage or overvoltage condition disappears.

12.14.3 Function block

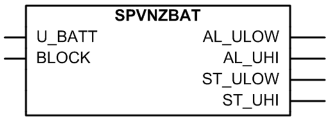


Figure 214: Function block

12.14.4 Signals

Table 375: SPVNZBAT Input signals

Name	Type	Default	Description
U_BATT	REAL	0.00	Battery terminal voltage that has to be supervised
BLOCK	BOOLEAN	0	Blocks all the output signals of the function

Table 376: SPVNZBAT Output signals

Name	Type	Description
AL_ULOW	BOOLEAN	Alarm when voltage has been below low limit for a set time
AL_UHI	BOOLEAN	Alarm when voltage has exceeded high limit for a set time
ST_ULOW	BOOLEAN	Start signal when battery voltage drops below lower limit
ST_UHI	BOOLEAN	Start signal when battery voltage exceeds upper limit

12.14.5 Settings

Table 377: SPVNZBAT Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation mode Off / On
RtdBattVolt	20.00 - 250.00	V	1.00	110.00	Battery rated voltage
BattVoltLowLim	60 - 140	%Ubat	1	70	Lower limit for the battery terminal voltage
BattVoltHiLim	60 - 140	%Ubat	1	120	Upper limit for the battery terminal voltage
tDelay	0.000 - 60.000	s	0.001	0.200	Delay time for alarm
tReset	0.000 - 60.000	s	0.001	0.000	Time delay for reset of alarm

12.14.6 Monitored data

Table 378: SPVNZBAT Monitored data

Name	Type	Values (Range)	Unit	Description
BATTVOLT	REAL	-	kV	Service value of the battery terminal voltage

12.14.7 Operation principle

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

The function execution requires that at least one of the function outputs is connected in configuration.

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

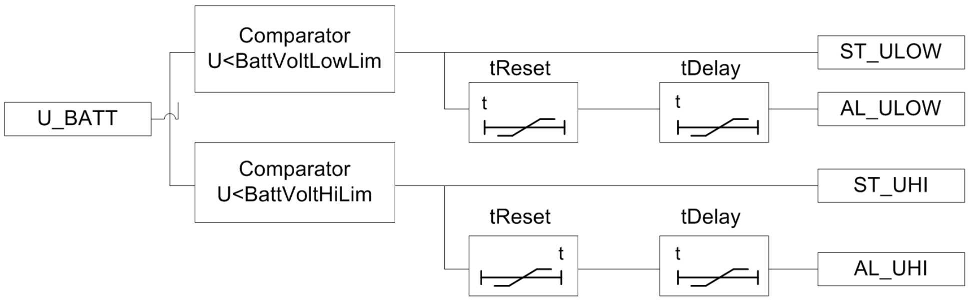


Figure 215: Functional module diagram

The battery rated voltage is set with the *RtdBattVolt* setting. The value of the *BattVoltLowLim* and *BattVoltHiLim* settings are given in relative per unit to the *RtdBattVolt* setting.

It is possible to block the function outputs by the BLOCK input.

Low level detector

The level detector compares the battery voltage U_BATT with the set value of the *BattVoltLowLim* setting. If the value of the U_BATT input drops below the set value of the *BattVoltLowLim* setting, the start signal ST_ULOW is activated.

The measured voltage between the battery terminals U_BATT is available through the Monitored data view.

High level detector

The level detector compares the battery voltage U_BATT with the set value of the *BattVoltHiLim* setting. If the value of the U_BATT input exceeds the set value of the *BattVoltHiLim* setting, the start signal ST_UHI is activated.

Time delay

When the operate timer has reached the value set by the *tDelay* setting, the AL_ULOW and AL_UHI outputs are activated. If the voltage returns to the normal value before the module operates, the reset timer is activated. If the reset timer reaches the value set by *tReset*, the operate timer resets and the ST_ULOW and ST_UHI outputs are deactivated.

Table 379: SPVNZBAT Technical data

Function	Range or value	Accuracy
Lower limit for the battery terminal voltage	(60-140) % of Ubat	± 0,5% of set battery voltage
Reset ratio, lower limit	<105 %	-
Upper limit for the battery terminal voltage	(60-140) % of Ubat	± 0,5% of set battery voltage
Reset ratio, upper limit	>95 %	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms

12.15 Insulation gas monitoring function SSIMG

12.15.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Insulation gas monitoring function	SSIMG	-	63

12.15.2 Functionality

Insulation gas monitoring function (SSIMG) is used for monitoring the circuit breaker condition. Binary information based on the gas pressure in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

12.15.3 Function block

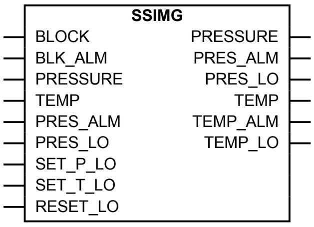


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Figure 216: SSIMG function block

12.15.4 Signals

Inputs PRESSURE and TEMP together with settings *PressAlmLimit*, *PressLOLimit*, *TempAlarmLimit* and *TempLOLimit* are not supported in first release of 650 series.

Table 380: SSIMG Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
BLK_ALM	BOOLEAN	0	Block all the alarms
PRESSURE	REAL	0.0	Pressure input from CB
TEMP	REAL	0.0	Temperature of the insulation medium from CB
PRES_ALM	BOOLEAN	0	Pressure alarm signal
PRES_LO	BOOLEAN	0	Pressure lockout signal
SET_P_LO	BOOLEAN	0	Set pressure lockout
SET_T_LO	BOOLEAN	0	Set temperature lockout
RESET_LO	BOOLEAN	0	Reset pressure and temperature lockout

Table 381: SSIMG Output signals

Name	Type	Description
PRESSURE	REAL	Pressure service value
PRES_ALM	BOOLEAN	Pressure below alarm level
PRES_LO	BOOLEAN	Pressure below lockout level
TEMP	REAL	Temperature of the insulation medium
TEMP_ALM	BOOLEAN	Temperature above alarm level
TEMP_LO	BOOLEAN	Temperature above lockout level

12.15.5 Settings

Table 382: SSIMG Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
PressAlmLimit	0.00 - 25.00	-	0.01	5.00	Alarm setting for pressure
PressLOLimit	0.00 - 25.00	-	0.01	3.00	Pressure lockout setting
TempAlarmLimit	-40.00 - 200.00	-	0.01	30.00	Temperature alarm level setting of the medium
TempLOLimit	-40.00 - 200.00	-	0.01	30.00	Temperature lockout level of the medium
tPressureAlarm	0.000 - 60.000	s	0.001	0.000	Time delay for pressure alarm
tPressureLO	0.000 - 60.000	s	0.001	0.000	Time delay for pressure lockout indication
tTempAlarm	0.000 - 60.000	s	0.001	0.000	Time delay for temperature alarm
tTempLockOut	0.000 - 60.000	s	0.001	0.000	Time delay for temperture lockout
tResetPressAlm	0.000 - 60.000	s	0.001	0.000	Reset time delay for pressure alarm
tResetPressLO	0.000 - 60.000	s	0.001	0.000	Reset time delay for pressure lockout
tResetTempAlm	0.000 - 60.000	s	0.001	0.000	Reset time delay for temperture alarm
tResetTempLO	0.000 - 60.000	s	0.001	0.000	Reset time delay for temperture lockout

12.15.6 Operation principle

Insulation gas monitoring function (SSIMG) is used to monitor gas pressure in the circuit breaker. Two binary output signals are used from the circuit breaker to initiate alarm signals, pressure below alarm level and pressure below lockout level. If the input signal PRES_ALM is high, which indicate that the gas pressure in the circuit breaker is below alarm level, the function initiates output signal PRES_ALM, pressure below alarm level, after a set time delay and indicate that maintenance of the circuit breaker is required. Similarly, if the input signal PRES_LO is high, which indicate gas pressure in the circuit breaker is below lockout level, the function initiates output signal PRES_LO, after a time delay. The two time delay settings, *tPressureAlarm* and *tPressureLO*, are included in order not to initiate any alarm for short sudden changes in the gas pressure. If the gas pressure in the circuit breaker goes below the levels for more than the set time delays the corresponding signals, PRES_ALM, pressure below alarm level and PRES_LO, pressure below lockout level alarm will be obtained.

The input signal BLK_ALM is used to block the two alarms and the input signal BLOCK to block both alarms and the function.

12.15.7 Technical data

Table 383: SSIMG Technical data

Function	Range or value	Accuracy
Pressure alarm	0.00-25.00	-
Pressure lockout	0.00-25.00	-
Temperature alarm	-40.00-200.00	-
Temperature lockout	-40.00-200.00	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms

12.16 Insulation liquid monitoring function SSIML

12.16.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Insulation liquid monitoring function	SSIML	-	71

12.16.2 Functionality

Insulation liquid monitoring function (SSIML) is used for monitoring the circuit breaker condition. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

12.16.3 Function block

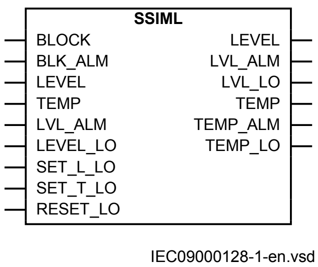


Figure 217: SSIML function block

12.16.4 Signals

Inputs LEVEL and TEMP together with settings *LevelAlmLimit*, *LevelLOLimit*, *TempAlarmLimit* and *TempLOLimit* are not supported in first release of 650 series.

Table 384: SSIML Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
BLK_ALM	BOOLEAN	0	Block all the alarms
LEVEL	REAL	0.0	Level input from CB
TEMP	REAL	0.0	Temperature of the insulation medium from CB
LVL_ALM	BOOLEAN	0	Level alarm signal
LEVEL_LO	BOOLEAN	0	Level lockout signal
SET_L_LO	BOOLEAN	0	Set level lockout
SET_T_LO	BOOLEAN	0	Set temperature lockout
RESET_LO	BOOLEAN	0	Reset level and temperature lockout

Table 385: SSIML Output signals

Name	Type	Description
LEVEL	REAL	Level service value
LVL_ALM	BOOLEAN	Level below alarm level
LVL_LO	BOOLEAN	Level below lockout level
TEMP	REAL	Temperature of the insulation medium
TEMP_ALM	BOOLEAN	Temperature above alarm level
TEMP_LO	BOOLEAN	Temperature above lockout level

12.16.5 Settings

Table 386: SSIML Group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off / On
LevelAlmLimit	0.00 - 25.00	-	0.01	5.00	Alarm setting for level
LevelLOLimit	0.00 - 25.00	-	0.01	3.00	Level lockout setting
TempAlarmLimit	-40.00 - 200.00	-	0.01	30.00	Temperature alarm level setting of the medium
TempLOLimit	-40.00 - 200.00	-	0.01	30.00	Temperature lockout level of the medium
tLevelAlarm	0.000 - 60.000	s	0.001	0.000	Time delay for level alarm
tLevelLockOut	0.000 - 60.000	s	0.001	0.000	Time delay for level lockout indication

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
tTempAlarm	0.000 - 60.000	s	0.001	0.000	Time delay for temperature alarm
tTempLockOut	0.000 - 60.000	s	0.001	0.000	Time delay for temperture lockout
tResetLevelAlm	0.000 - 60.000	s	0.001	0.000	Reset time delay for level alarm
tResetLevelLO	0.000 - 60.000	s	0.001	0.000	Reset time delay for level lockout
tResetTempLO	0.000 - 60.000	s	0.001	0.000	Reset time delay for temperture lockout
tResetTempAlm	0.000 - 60.000	s	0.001	0.000	Reset time delay for temperture alarm

12.16.6 Operation principle

Insulation liquid monitoring function (SSIML) is used to monitor oil level in the circuit breaker. Two binary output signals are used from the circuit breaker to initiate alarm signals, level below alarm level and level below lockout level. If the input signal LVL_ALM is high, which indicate that the oil level in the circuit breaker is below alarm level, the output signal LVL_ALM, level below alarm level, will be initiated after a set time delay and indicate that maintenance of the circuit breaker is required. Similarly, if the input signal LVL_LO is high, which indicate oil level in the circuit breaker is below lockout level, the output signal LVL_LO, will be initiated after a time delay. The two time delay settings, *tLevelAlarm* and *tLevelLockOut*, are included in order not to initiate any alarm for short sudden changes in the oil level. If the oil level in the circuit breaker goes below the levels for more than the set time delays the corresponding signals, LVL_ALM, level below alarm level and LVL_LO, level below lockout level alarm will be obtained.

The input signal BLK_ALM is used to block the two alarms and the input signal BLOCK to block both alarms and the function.

12.16.7 Technical data

Table 387: SSIML Technical data

Function	Range or value	Accuracy
Alarm, oil level	0.00-25.00	-
Oil level lockout	0.00-25.00	-
Temperature alarm	-40.00-200.00	-
Temperature lockout	-40.00-200.00	-
Timers	(0.000-60.000) s	± 0.5% ± 10 ms

12.17 Circuit breaker condition monitoring SSCBR

12.17.1 Identification

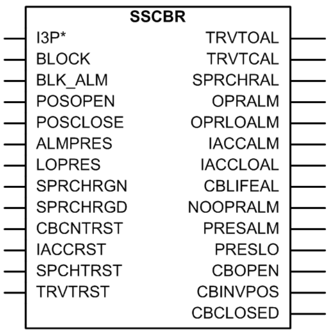
Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Circuit breaker condition monitoring	SSCBR	-	-

12.17.2 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. It is possible to block the function outputs, if desired.

12.17.3 Function block



12.17.4 Signals

Table 388: SSCBR Input signals

Name	Type	Default	Description
I3P	GROUP SIGNAL	-	Three phase group signal for current inputs
BLOCK	BOOLEAN	0	Block of function
BLK_ALM	BOOLEAN	0	Block all the alarms
POSOPEN	BOOLEAN	0	Signal for open position of apparatus from I/O
POSCLOSE	BOOLEAN	0	Signal for close position of apparatus from I/O
ALMPRES	BOOLEAN	0	Binary pressure alarm input
LOPRES	BOOLEAN	0	Binary pressure input for lockout indication
SPRCHRGN	BOOLEAN	0	CB spring charging started input
SPRCHRGD	BOOLEAN	0	CB spring charged input
CBCNTRST	BOOLEAN	0	Reset input for CB remaining life and operation counter

Table continues on next page

Name	Type	Default	Description
IACCRST	BOOLEAN	0	Reset accumulated currents power
SPCHTRST	BOOLEAN	0	Reset spring charge time
TRVTRST	BOOLEAN	0	Reset travel time

Table 389: SSCBR Output signals

Name	Type	Description
TRVTOAL	BOOLEAN	CB open travel time exceeded set value
TRVTCAL	BOOLEAN	CB close travel time exceeded set value
SPRCHRAL	BOOLEAN	Spring charging time has crossed the set value
OPRALM	BOOLEAN	Number of CB operations exceeds alarm limit
OPRLOALM	BOOLEAN	Number of CB operations exceeds lockout limit
IACCALM	BOOLEAN	Accumulated currents power (Iyt),exceeded alarm limit
IACCLOAL	BOOLEAN	Accumulated currents power (Iyt),exceeded lockout limit
CBLIFEAL	BOOLEAN	Remaining life of CB exceeded alarm limit
NOOPRALM	BOOLEAN	CB 'not operated for long time' alarm
PRESALM	BOOLEAN	Pressure below alarm level
PRESLO	BOOLEAN	Pressure below lockout level
CBOPEN	BOOLEAN	CB is in open position
CBINVPOS	BOOLEAN	CB is in intermediate position
CBCLOSED	BOOLEAN	CB is in closed position

12.17.5 Settings

Table 390: SSCBR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	On	Operation Off / On
AccDisLevel	5.00 - 500.00	A	0.01	10.00	RMS current setting below which energy accumulation stops
CurrExp	0.00 - 2.00	-	0.01	2.00	Current exponent setting for energy calculation
RatedFaultCurr	500.00 - 75000.00	A	0.01	5000.00	Rated fault current of the breaker
RatedOpCurr	100.00 - 5000.00	A	0.01	1000.00	Rated operating current of the breaker
AccCurrAlmLvl	0.00 - 20000.00	-	0.01	2500.00	Setting of alarm level for accumulated currents power
AccCurrLO	0.00 - 20000.00	-	0.01	2500.00	Lockout limit setting for accumulated currents power
DirCoef	-3.00 - -0.50	-	0.01	-1.50	Directional coefficient for CB life calculation
LifeAlmLevel	0 - 99999	-	1	5000	Alarm level for CB remaining life

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
OpNumRatCurr	1 - 99999	-	1	10000	Number of operations possible at rated current
OpNumFaultCurr	1 - 10000	-	1	1000	Number of operations possible at rated fault current
OpNumAlm	0 - 9999	-	1	200	Alarm limit for number of operations
OpNumLO	0 - 9999	-	1	300	Lockout limit for number of operations
tOpenAlm	0 - 200	ms	1	40	Alarm level setting for open travel time
tCloseAlm	0 - 200	ms	1	40	Alarm level setting for close travel time
OpenTimeCorr	0 - 100	ms	1	10	Correction factor for open travel time
CloseTimeCorr	0 - 100	ms	1	10	Correction factor for CB close travel time
DifTimeCorr	-10 - 10	ms	1	5	Correction factor for time difference in auxiliary and main contacts open time
tSprngChrgAlm	0.00 - 60.00	s	0.01	1.00	Setting of alarm for spring charging time
tPressAlm	0.00 - 60.00	s	0.01	0.10	Time delay for gas pressure alarm
TPressLO	0.00 - 60.00	s	0.01	0.10	Time delay for gas pressure lockout
AccEnerInitVal	0.00 - 9999.99	-	0.01	0.00	Accumulation energy initial value
CountInitVal	0 - 9999	-	1	0	Operation numbers counter initialization value
CBRemLife	0 - 9999	-	1	5000	Initial value for the CB remaining life estimates
InactDayAlm	0 - 9999	Day	1	2000	Alarm limit value of the inactive days counter
InactDayInit	0 - 9999	Day	1	0	Initial value of the inactive days counter
InactHourAlm	0 - 23	Hour	1	0	Alarm time of the inactive days counter in hours

12.17.6 Monitored data

Table 391: SSCBR Monitored data

Name	Type	Values (Range)	Unit	Description
CBOTRVT	REAL	-	ms	Travel time of the CB during opening operation
CBCLTRVT	REAL	-	ms	Travel time of the CB during closing operation
SPRCHRT	REAL	-	s	The charging time of the CB spring
NO_OPR	INTEGER	-	-	Number of CB operation cycle
NOOPRDAY	INTEGER	-	-	The number of days CB has been inactive
CBLIFEL1	INTEGER	-	-	CB Remaining life phase L1
CBLIFEL2	INTEGER	-	-	CB Remaining life phase L2

Table continues on next page

Name	Type	Values (Range)	Unit	Description
CBLIFEL3	INTEGER	-	-	CB Remaining life phase L3
IACCL1	REAL	-	-	Accumulated currents power (Iyt), phase L1
IACCL2	REAL	-	-	Accumulated currents power (Iyt), phase L2
IACCL3	REAL	-	-	Accumulated currents power (Iyt), phase L3

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

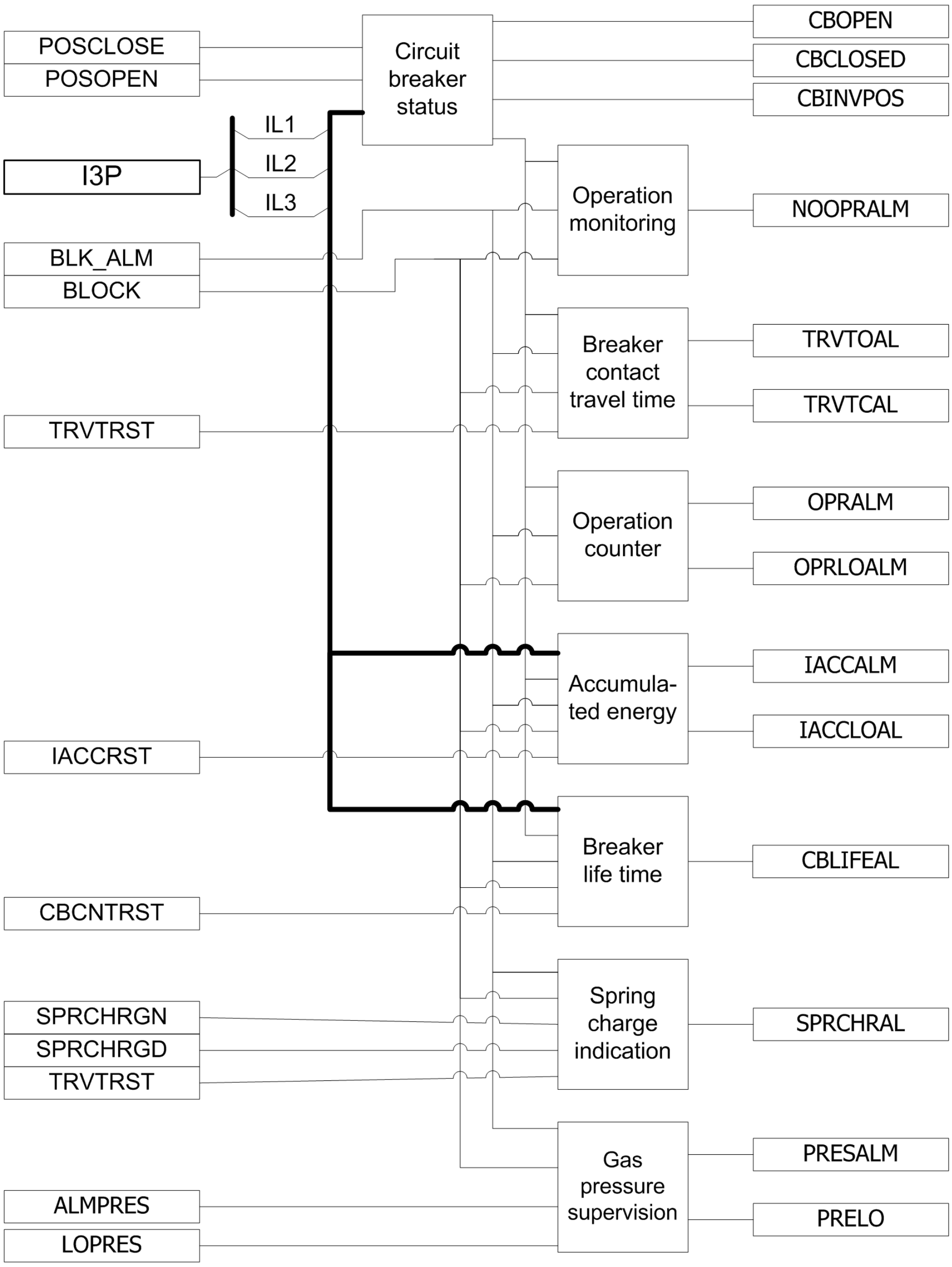


Figure 218: Functional module diagram

12.17.7.1 Circuit breaker status

The circuit breaker status subfunction monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position. The operation of the breaker status monitoring can be described by using a module diagram. All the modules in the diagram are explained in the next sections.

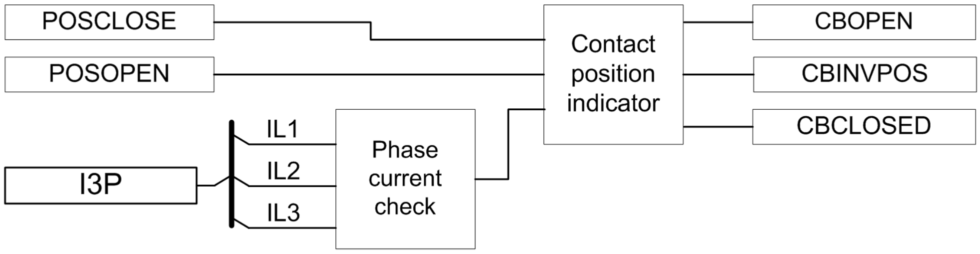


Figure 219: Functional module diagram for monitoring circuit breaker status

Phase current check

This module compares the three phase currents with the setting *AccDisLevel*. If the current in a phase exceeds the set level, information about phase is reported to the contact position indicator module.

Contact position indicator

The circuit breaker status is open if the auxiliary input contact `POSCLOSE` is low, the `POSOPEN` input is high and the current is zero. The circuit breaker is closed when the `POSOPEN` input is low and the `POSCLOSE` input is high. The breaker is in the intermediate position if both the auxiliary contacts have the same value, that is, both are in the logical level "0", or if the auxiliary input contact `POSCLOSE` is low and the `POSOPEN` input is high, but the current is not zero.

The status of the breaker is indicated with the binary outputs `CBOPEN`, `CBINVPOS`, and `CBCLOSED` for open, intermediate, and closed position respectively.

12.17.7.2 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 by using a module diagram. All the modules in the diagram are explained in the next sections.

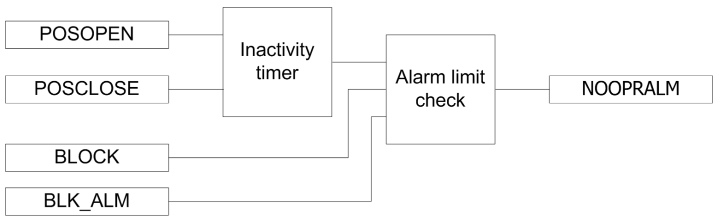


Figure 220: Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

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 NOOPRDAY is available through the Monitored data view. It is also possible to set the initial inactive days by using the *InactDayInit* parameter.

Alarm limit check

When the inactive days exceed the limit value defined with the *InactDayAlm* setting, the NOOPRALM alarm is initiated. The time in hours at which this alarm is activated can be set with the *InactHourAlm* parameter as coordinates of UTC. The alarm signal NOOPRALM can be blocked by activating the binary input BLOCK.

12.17.7.3 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 by using a module diagram. All the modules in the diagram are explained in the next sections.

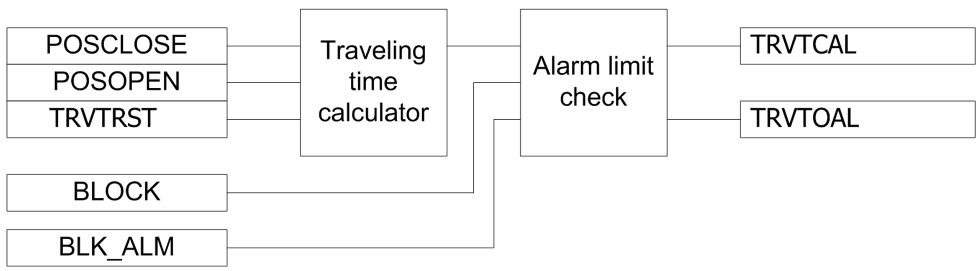
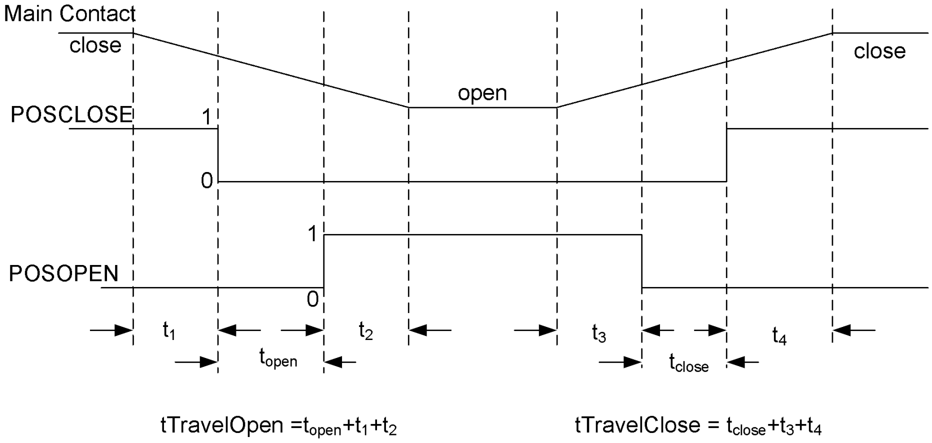


Figure 221: Functional module diagram for breaker contact travel time

Traveling time calculator

The contact travel time of the breaker is calculated from the time between auxiliary contacts' state change. The open travel time is measured between the opening of the POSCLOSE auxiliary contact and the closing of the POSOPEN auxiliary contact. Travel time is also measured between the opening of the POSOPEN auxiliary contact and the closing of the POSCLOSE auxiliary contact.



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. Therefore, in order to incorporate the time t_1+t_2, a correction factor needs to be added with 10 to get the actual opening time. This factor is added with the *OpenTimeCorr* (=t_1+t_2). The closing time is calculated by adding the value set with the *CloseTimeCorr* (t_3+t_4) setting to the measured closing time.

The last measured opening travel time tTravelOpen and the closing travel time tTravelClose are available through the Monitored data view on the LHMI or through tools via communications.

Alarm limit check

When the measured open travel time is longer than the value set with the *tOpenAlm* setting, the TRVTOAL output is activated. Respectively, when the measured close travel time is longer than the value set with the *tCloseAlm* setting, the , the TRVTCAL output is activated.

It is also possible to block the TRVTCAL and TRVTOAL alarm signals by activating the BLOCK input.

12.17.7.4 Operation counter

The operation counter subfunction calculates the number of breaker operation cycles. Both open and close operations are included in one operation cycle. The operation counter value is updated after each open operation.

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

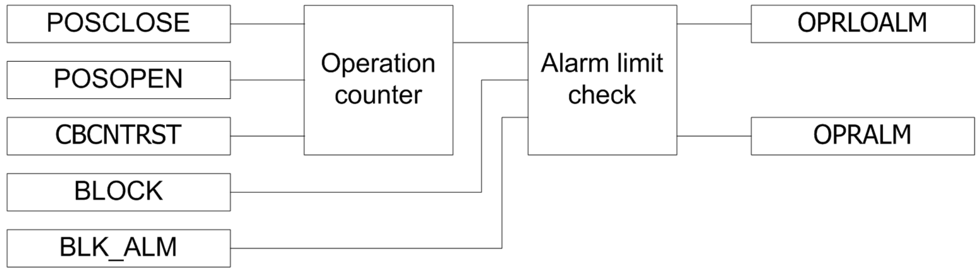


Figure 222: Functional module diagram for counting circuit breaker operations

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 through 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 *CountInitVal* parameter and can be reset by *Clear CB wear* in the clear menu from LHMI.

Alarm limit check

The `OPRALM` operation alarm is generated when the number of operations exceeds the value set with the *OpNumAlm* threshold setting. However, if the number of operations increases further and exceeds the limit value set with the *OpNumLO* setting, the `OPRLOALM` output is activated.

The binary outputs `OPRLOALM` and `OPRALM` are deactivated when the `BLOCK` input is activated.

12.17.7.5 Accumulation of $I^y t$

Accumulation of the $I^y t$ module calculates the accumulated energy.

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

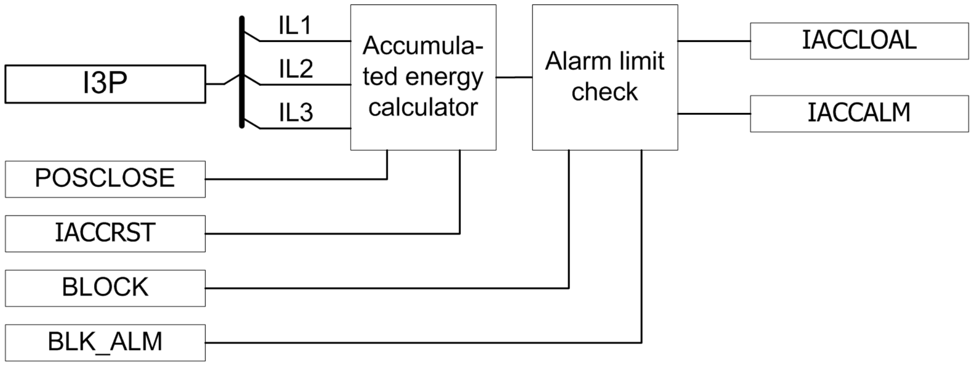


Figure 223: Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

This module calculates the accumulated energy $I^y t$. The factor y is set with the *CurrExp* setting.

The calculation is initiated with the `POSCLOSE` input open events. It ends when the RMS current becomes lower than the *AccDisLevel* setting value.

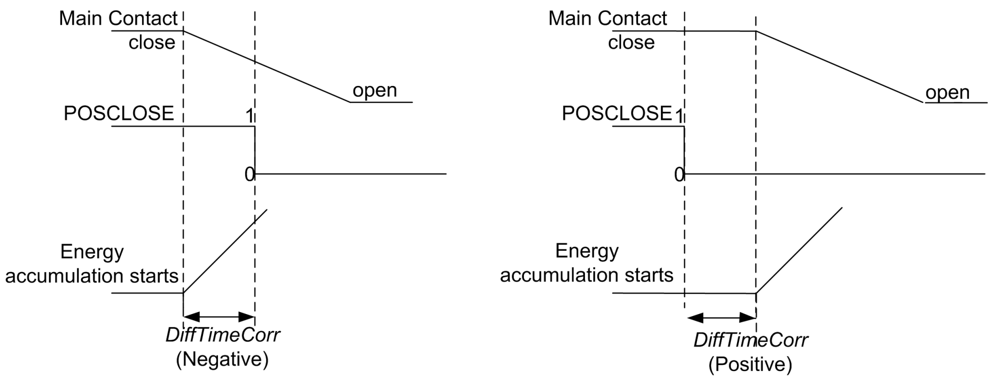


Figure 224: Significance of theDiffTimeCorr setting

The *DiffTimeCorr* 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 *DiffTimeCorr* setting. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

The accumulated energy outputs `IACCL1 (L2, L3)` are available through the Monitored data view on the LHMI or through tools via communications. The values can be reset by setting the *Clear accum. breaking curr* setting to true in the clear menu from LHMI.

Alarm limit check

The IACCALM alarm is activated when the accumulated energy exceeds the value set with the *AccCurrAlmLvl* threshold setting. However, when the energy exceeds the limit value set with the *AccCurrLO* threshold setting, the IACCLOAL output is activated.

The IACCALM and IACCLOAL outputs can be blocked by activating the binary input BLOCK.

12.17.7.6 Remaining life of the 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 by using a module diagram. All the modules in the diagram are explained in the next sections.

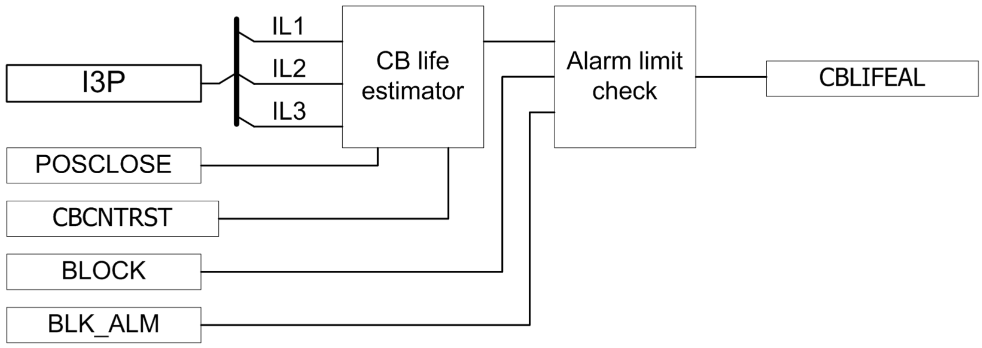


Figure 225: Functional module diagram for estimating the life of the circuit breaker

Circuit breaker life estimator

The circuit breaker life estimator module calculates the remaining life of the circuit breaker. If the tripping current is less than the rated operating current set with the *RatedOpCurr* setting, the remaining operation of the breaker reduces by one operation. If the tripping current is more than the rated fault current set with the *RatedFaultCurr* setting, the possible operations are zero. The remaining life of the tripping current in between these two values is calculated based on the trip curve given by the manufacturer. The *OpNumRatCurr* and *OPNumFaultCurr* parameters set the number of operations the breaker can perform at the rated current and at the rated fault current, respectively.

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 *CB wear values* in the clear menu from LHMI.

Clearing *CB wear values* also resets the operation counter.

The remaining life is calculated separately for all three phases and it is available as a monitored data value CBLIFEL1 (L2, L3).

Alarm limit check

When the remaining life of any phase drops below the *LifeAlmLevel* threshold setting, the corresponding circuit breaker life alarm CBLIFEAL 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 under the **Clear CB wear values** menu.

It is possible to deactivate the CBLIFEAL alarm signal by activating the binary input BLOCK.

12.17.7.7 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 by using a module diagram. All the modules in the diagram are explained in the next sections.

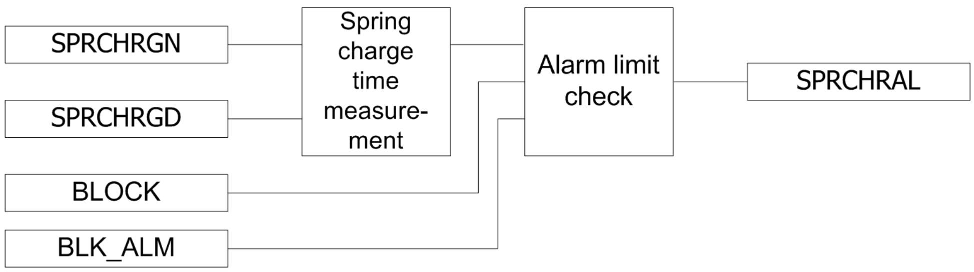


Figure 226: Functional module diagram for circuit breaker spring charged indication and alarm

Spring charge time measurement

Two binary inputs, SPRCHRGN and SPRCHRGD, 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 SPRCHRT is available through the Monitored data view .

Alarm limit check

If the time taken by the spring to charge is more than the value set with the *tSprngChrgAlm* setting, the subfunction generates the SPRCHRAL alarm.

It is possible to block the SPRCHRAL alarm signal by activating the BLOCK binary input.

12.17.7.8 Gas pressure supervision

The gas pressure supervision subfunction monitors the gas pressure inside the arc chamber.

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

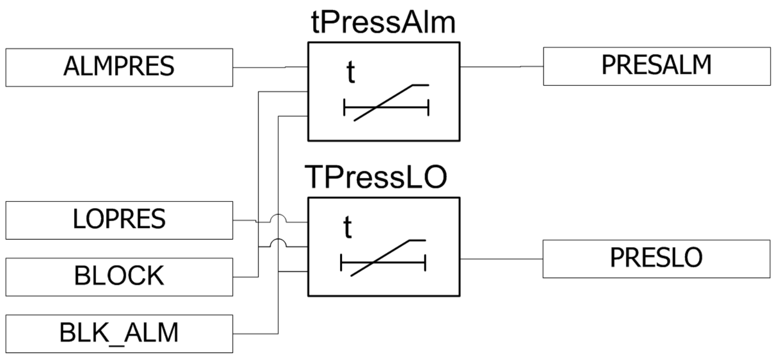


Figure 227: Functional module diagram for circuit breaker gas pressure alarm

The gas pressure is monitored through the binary input signals LOPRES and ALMPRES.

Pressure alarm time delay

When the ALMPRES binary input is activated, the PRESALM alarm is activated after a time delay set with the *tPressAlm* setting. The PRESALM alarm can be blocked by activating the BLOCK input.

If the pressure drops further to a very low level, the LOPRES binary input becomes high, activating the lockout alarm PRESLO after a time delay set with the *TPressLO* setting. The PRESLO alarm can be blocked by activating the BLOCK input.

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates all outputs and resets internal timers. The alarm signals from the function can be blocked by activating the binary input BLK_ALM.

12.17.8 Technical data

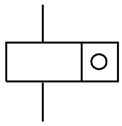
Table 392: SSCBR Technical data

Function	Range or value	Accuracy
RMS current setting below which energy accumulation stops	(5.00-500.00) A	± 1.0% of I_r at $I \leq I_r$ ± 1.0% of I at $I > I_r$
Alarm level for accumulated energy	0.00-20000.00	< ± 5.0% of set value
Lockout limit for accumulated energy	0.00-20000.00	< ± 5.0% of set value
Alarm levels for open and close travel time	(0-200) ms	± 0.5% ± 10ms
Setting of alarm for spring charging time	(0.00-60.00) s	± 0.5% ± 10ms
Time delay for gas pressure alarm	(0.00-60.00) s	± 0.5% ± 10ms
Time delay for gas pressure lockout	(0.00-60.00) s	± 0.5% ± 10ms

Section 13 Metering

13.1 Pulse counter PCGGIO

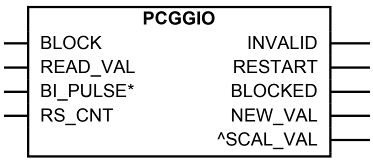
13.1.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Pulse counter	PCGGIO		-

13.1.2 Functionality

Pulse counter (PCGGIO) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the BIO (binary input/output) module and then read by the PCGGIO function. A scaled service value is available over the station bus.

13.1.3 Function block



IEC09000335-1-en.vsd

Figure 228: PCGGIO function block

13.1.4 Signals

Table 393: PCGGIO Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of function
READ_VAL	BOOLEAN	0	Initiates an additional pulse counter reading
BI_PULSE	BOOLEAN	0	Connect binary input channel for metering
RS_CNT	BOOLEAN	0	Resets pulse counter value

Table 394: PCGGIO Output signals

Name	Type	Description
INVALID	BOOLEAN	The pulse counter value is invalid
RESTART	BOOLEAN	The reported value does not comprise a complete integration cycle
BLOCKED	BOOLEAN	The pulse counter function is blocked
NEW_VAL	BOOLEAN	A new pulse counter value is generated
SCAL_VAL	REAL	Scaled value with time and status information

13.1.5 Settings

Table 395: PCGGIO Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
EventMask	NoEvents ReportEvents	-	-	NoEvents	Report mask for analog events from pulse counter
CountCriteria	Off RisingEdge Falling edge OnChange	-	-	RisingEdge	Pulse counter criteria
Scale	1.000 - 90000.000	-	0.001	1.000	Scaling value for SCAL_VAL output to unit per counted value
Quantity	Count ActivePower ApparentPower ReactivePower ActiveEnergy ApparentEnergy ReactiveEnergy	-	-	Count	Measured quantity for SCAL_VAL output
tReporting	1 - 3600	s	1	60	Cycle time for reporting of counter value

13.1.6 Monitored data

Table 396: PCGGIO Monitored data

Name	Type	Values (Range)	Unit	Description
CNT_VAL	INTEGER	-	-	Actual pulse counter value
SCAL_VAL	REAL	-	-	Scaled value with time and status information

13.1.7 Operation principle

The registration of pulses is done according to setting of *CountCriteria* parameter on one of the 9 binary input channels located on the BIO module. Pulse counter values are sent to the station HMI with predefined cyclicity without reset.

The reporting time period can be set in the range from 1 second to 60 minutes and is synchronized with absolute system time. Interrogation of additional pulse counter values can be done with a command (intermediate reading) for a single counter. All active counters can also be read by IEC 61850.

Pulse counter (PCGGIO) function in the IED supports unidirectional incremental counters. That means only positive values are possible. The counter uses a 32 bit format, that is, the reported value is a 32-bit, signed integer with a range 0...+2147483647. The counter value is stored in semiretain memory.

The reported value to station HMI over the station bus contains Identity, Scaled Value (pulse count x scale), Time, and Pulse Counter Quality. The Pulse Counter Quality consists of:

- Invalid (board hardware error or configuration error)
- Wrapped around
- Blocked
- Adjusted

The transmission of the counter value can be done as a service value, that is, the value frozen in the last integration cycle is read by the station HMI from the database. PCGGIO updates the value in the database when an integration cycle is finished and activates the NEW_VAL signal in the function block. This signal can be time tagged, and transmitted to the station HMI. This time corresponds to the time when the value was frozen by the function.

The BLOCK and READ_VAL inputs can be connected to blocks, which are intended to be controlled either from the station HMI or/and the local HMI. As long as the BLOCK signal is set, the pulse counter is blocked. The signal connected to READ_VAL performs readings according to the setting of parameter *CountCriteria*. The signal must be a pulse with a length >1 second.

The BI_PULSE input is connected to the used input of the function block for the binary input output module (BIO).

The RS_CNT input is used for resetting the counter.

Each PCGGIO function block has four binary output signals that can be used for for event recording: INVALID, RESTART, BLOCKED and NEW_VAL. These signals and the SCAL_VAL signal are accessable over IEC 61850.

The INVALID signal is a steady signal and is set if the binary input module, where the pulse counter input is located, fails or has wrong configuration.

The RESTART signal is a steady signal and is set when the reported value does not comprise a complete integration cycle. That is, in the first message after IED start-up, in the first message after deblocking, and after the counter has wrapped around during last integration cycle.

The BLOCKED signal is a steady signal and is set when the counter is blocked. There are two reasons why the counter is blocked:

- The BLOCK input is set, or
- The binary input module, where the counter input is situated, is inoperative.

The NEW_VAL signal is a pulse signal. The signal is set if the counter value was updated since last report.

The SCAL_VAL signal consists of scaled value (according to parameter *Scale*), time and status information.

13.1.8 Technical data

Table 397: PCGGIO Technical data

Function	Setting range	Accuracy
Cycle time for report of counter value	(1–3600) s	-

13.2 Energy calculation and demand handling ETPMMTR

13.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Energy calculation and demand handling	ETPMMTR	-	-

13.2.2 Functionality

Outputs from Measurements (CVMMXN) function can be used to calculate energy. Active as well as reactive values are calculated in import and export direction. Values can be read or generated as pulses. Maximum demand power values are also calculated by the function.

13.2.3 Function block

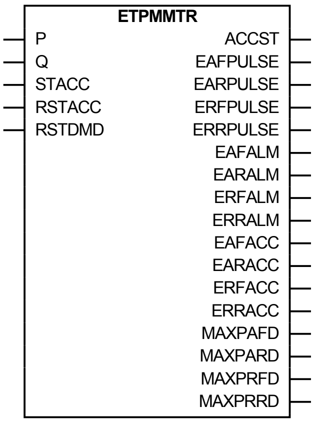


Figure 229: ETPMMTR function block

13.2.4 Signals

Table 398: ETPMMTR Input signals

Name	Type	Default	Description
P	REAL	0	Measured active power
Q	REAL	0	Measured reactive power
STACC	BOOLEAN	0	Start to accumulate energy values
RSTACC	BOOLEAN	0	Reset of accumulated enery reading
RSTDMD	BOOLEAN	0	Reset of maximum demand reading

Table 399: ETPMMTR Output signals

Name	Type	Description
ACCST	BOOLEAN	Start of accumulating energy values
EAFPULSE	BOOLEAN	Accumulated forward active energy pulse
EARPULSE	BOOLEAN	Accumulated reverse active energy pulse
ERFPULSE	BOOLEAN	Accumulated forward reactive energy pulse
ERRPULSE	BOOLEAN	Accumulated reverse reactive energy pulse
EAFALM	BOOLEAN	Alarm for active forward energy exceed limit in set interval
EARALM	BOOLEAN	Alarm for active reverse energy exceed limit in set interval
ERFALM	BOOLEAN	Alarm for reactive forward energy exceed limit in set interval
ERRALM	BOOLEAN	Alarm for reactive reverse energy exceed limit in set interval
EAFACC	REAL	Accumulated forward active energy value
Table continues on next page		

Name	Type	Description
EARACC	REAL	Accumulated reverse active energy value
ERFACC	REAL	Accumulated forward reactive energy value
ERRACC	REAL	Accumulated reverse reactive energy value
MAXPAFD	REAL	Maximum forward active power demand value for set interval
MAXPARD	REAL	Maximum reverse active power demand value for set interval
MAXPRFD	REAL	Maximum forward reactive power demand value for set interval
MAXPRRD	REAL	Maximum reactive power demand value in reverse direction

13.2.5 Settings

Table 400: ETPMMTR Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
StartAcc	Off On	-	-	Off	Activate the accumulation of energy values
tEnergy	1 Minute 5 Minutes 10 Minutes 15 Minutes 30 Minutes 60 Minutes 180 Minutes	-	-	1 Minute	Time interval for energy calculation
tEnergyOnPls	0.000 - 60.000	s	0.001	1.000	Energy accumulated pulse ON time
tEnergyOffPls	0.000 - 60.000	s	0.001	0.500	Energy accumulated pulse OFF time
EAFAccPlsQty	0.001 - 10000.000	MWh	0.001	100.000	Pulse quantity for active forward accumulated energy value
EARAccPlsQty	0.001 - 10000.000	MWh	0.001	100.000	Pulse quantity for active reverse accumulated energy value
ERFAccPlsQty	0.001 - 10000.000	MVArh	0.001	100.000	Pulse quantity for reactive forward accumulated energy value
ERRAccPlsQty	0.001 - 10000.000	MVArh	0.001	100.000	Pulse quantity for reactive reverse accumulated energy value

Table 401: ETPMMTR Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
EALim	0.001 - 10000000000.000	MWh	0.001	1000000.000	Active energy limit
ERLim	0.001 - 10000000000.000	MVArh	0.001	1000.000	Reactive energy limit
EnZeroClamp	Off On	-	-	On	Enable of zero point clamping detection function

Table continues on next page

Name	Values (Range)	Unit	Step	Default	Description
LevZeroClampP	0.001 - 10000.000	MW	0.001	10.000	Zero point clamping level at active Power
LevZeroClampQ	0.001 - 10000.000	MVAr	0.001	10.000	Zero point clamping level at reactive Power
DirEnergyAct	Forward Reverse	-	-	Forward	Direction of active energy flow Forward/ Reverse
DirEnergyReac	Forward Reverse	-	-	Forward	Direction of reactive energy flow Forward/ Reverse
EAFPrestVal	0.000 - 10000.000	MWh	0.001	0.000	Preset Initial value for forward active energy
EARPrestVal	0.000 - 10000.000	MWh	0.001	0.000	Preset Initial value for reverse active energy
ERFPresetVal	0.000 - 10000.000	MVArh	0.001	0.000	Preset Initial value for forward reactive energy
ERRPresetVal	0.000 - 10000.000	MVArh	0.001	0.000	Preset Initial value for reverse reactive energy

13.2.6 Monitored data

Table 402: ETPMMTR Monitored data

Name	Type	Values (Range)	Unit	Description
EAFACC	REAL	-	MWh	Accumulated forward active energy value
EARACC	REAL	-	MWh	Accumulated reverse active energy value
ERFACC	REAL	-	MVArh	Accumulated forward reactive energy value
ERRACC	REAL	-	MVArh	Accumulated reverse reactive energy value
MAXPAFD	REAL	-	MW	Maximum forward active power demand value for set interval
MAXPARD	REAL	-	MW	Maximum reverse active power demand value for set interval
MAXPRFD	REAL	-	MVAr	Maximum forward reactive power demand value for set interval
MAXPRRD	REAL	-	MVAr	Maximum reactive power demand value in reverse direction

13.2.7 Operation principle

The instantaneous output values of active and reactive power from the Measurements (CVMMXN) function block are used and integrated over a selected time *tEnergy* to measure the integrated energy. The energy values (in MWh and MVarh) are available as output signals and also as pulsed output which can be connected to a pulse counter. Outputs are available for forward as well as reverse direction. The accumulated energy values can be reset from the local HMI reset menu or with input signal RSTACC.

The maximum demand values for active and reactive power are calculated for the set time *tEnergy* and the maximum value is stored in a register available over communication and from outputs MAXPAFD, MAXPARD, MAXPRFD, MAXPRRD for the active and reactive power forward and reverse direction until reset with input signal RSTDMD or from the local HMI reset menu.

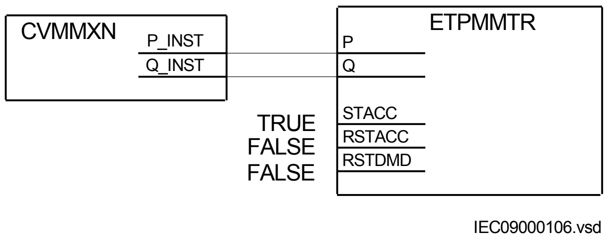


Figure 230: Connection of Energy calculation and demand handling function (ETPMMTR) to the Measurements function (CVMMXN)

13.2.8 Technical data

Table 403: ETPMMTRTechnical data

Function	Range or value	Accuracy
Energy metering	kWh Export/Import, kvarh Export/ Import	Input from MMXU. No extra error at steady load

Section 14 Station communication

14.1 DNP3 protocol

DNP3 (Distributed Network Protocol) is a set of communications protocols used to communicate data between components in process automation systems. For a detailed description of the DNP3 protocol, see the DNP3 Communication protocol manual.

14.2 IEC 61850-8-1 communication protocol

14.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IEC 61850-8-1 communication protocol	IEC 61850-8-1	-	-

14.2.2 Functionality

The IED supports communication protocols IEC 61850-8-1 and DNP3 over TCP/IP. All operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication (GOOSE) between the IEDs, is only enabled by the IEC 61850-8-1 communication protocol.

The IED is equipped an optical Ethernet rear port for substation communication standard IEC 61850-8-1. IEC 61850-8-1 communication is also possible from the optical Ethernet front port. IEC 61850-8-1 protocol allows intelligent devices (IEDs) from different vendors to exchange information and simplifies system engineering. Peer-to-peer communication according to GOOSE is part of the standard. Disturbance files uploading is provided.

Disturbance files are accessed using the IEC 61850-8-1 protocol. Disturbance files are available to any Ethernet based application in the standard COMTRADE format. Further, the IED sends and receives binary signals from other IEDs using the IEC 61850-8-1 GOOSE profile. The IED meets the GOOSE performance requirements for tripping applications in substations, as defined by the IEC 61850 standard. The IED interoperates with other IEC 61850 compliant IEDs, tools and systems and simultaneously reports events to five different clients on the IEC 61850 station bus.

All communication connectors, except for the front port connector, are placed on integrated communication modules. The IED is connected to Ethernet-based communication systems via the fibre-optic multimode LC connector (100BASE-FX).

The IED supports SNTP and IRIG-B time synchronization methods with a time-stamping resolution of 1 ms.

- Ethernet based: SNTP and DNP3
- With time synchronization wiring: IRIG-B

Table 404: Supported communication interface and protocol alternatives

Interfaces/Protocols	Ethernet 100BASE-FX LC
IEC 61850-8-1	●
DNP3	●
● = Supported	

14.2.3 Settings

Table 405: IEC 61850-8-1 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On
GOOSE	Front LAN1	-	-	LAN1	Port for GOOSE communication

14.2.4 Technical data

Table 406: IEC 61850-8-1 communication protocol

Function	Value
Protocol	IEC 61850-8-1
Communication speed for the IEDs	100BASE-FX

14.3 Horizontal communication via GOOSE for interlocking

14.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Horizontal communication via GOOSE for interlocking	GOOSEINTLKRCV	-	-

14.3.2 Function block

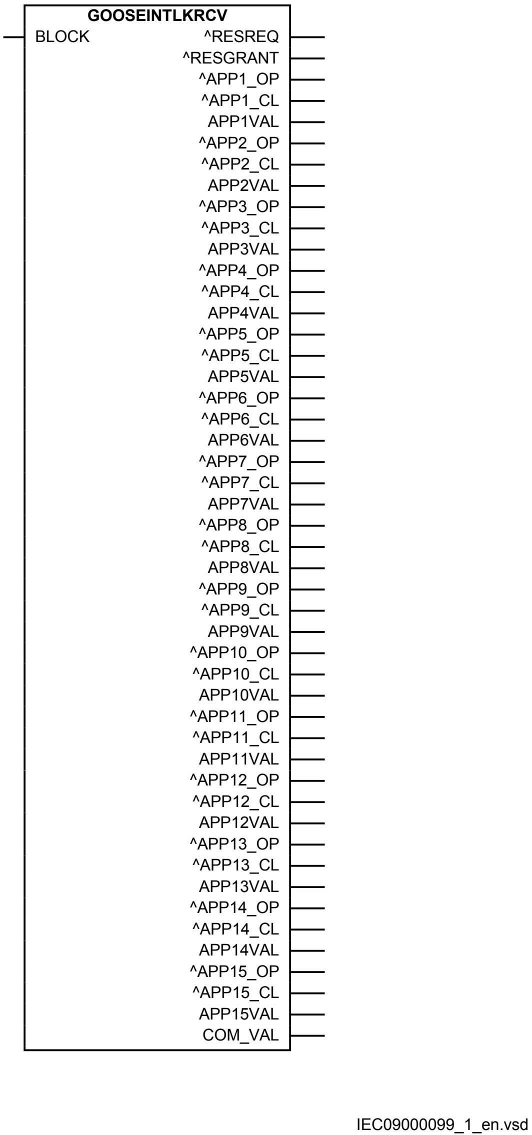


Figure 231: GOOSEINTLKRCV function block

14.3.3 Signals

Table 407: GOOSEINTLKRCV Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of output signals

Table 408: GOOSEINTLKRCV Output signals

Name	Type	Description
RESREQ	BOOLEAN	Reservation request
RESGRANT	BOOLEAN	Reservation granted
APP1_OP	BOOLEAN	Apparatus 1 position is open
APP1_CL	BOOLEAN	Apparatus 1 position is closed
APP1VAL	BOOLEAN	Apparatus 1 position is valid
APP2_OP	BOOLEAN	Apparatus 2 position is open
APP2_CL	BOOLEAN	Apparatus 2 position is closed
APP2VAL	BOOLEAN	Apparatus 2 position is valid
APP3_OP	BOOLEAN	Apparatus 3 position is open
APP3_CL	BOOLEAN	Apparatus 3 position is closed
APP3VAL	BOOLEAN	Apparatus 3 position is valid
APP4_OP	BOOLEAN	Apparatus 4 position is open
APP4_CL	BOOLEAN	Apparatus 4 position is closed
APP4VAL	BOOLEAN	Apparatus 4 position is valid
APP5_OP	BOOLEAN	Apparatus 5 position is open
APP5_CL	BOOLEAN	Apparatus 5 position is closed
APP5VAL	BOOLEAN	Apparatus 5 position is valid
APP6_OP	BOOLEAN	Apparatus 6 position is open
APP6_CL	BOOLEAN	Apparatus 6 position is closed
APP6VAL	BOOLEAN	Apparatus 6 position is valid
APP7_OP	BOOLEAN	Apparatus 7 position is open
APP7_CL	BOOLEAN	Apparatus 7 position is closed
APP7VAL	BOOLEAN	Apparatus 7 position is valid
APP8_OP	BOOLEAN	Apparatus 8 position is open
APP8_CL	BOOLEAN	Apparatus 8 position is closed
APP8VAL	BOOLEAN	Apparatus 8 position is valid
APP9_OP	BOOLEAN	Apparatus 9 position is open
APP9_CL	BOOLEAN	Apparatus 9 position is closed
APP9VAL	BOOLEAN	Apparatus 9 position is valid
APP10_OP	BOOLEAN	Apparatus 10 position is open
APP10_CL	BOOLEAN	Apparatus 10 position is closed
APP10VAL	BOOLEAN	Apparatus 10 position is valid
APP11_OP	BOOLEAN	Apparatus 11 position is open
APP11_CL	BOOLEAN	Apparatus 11 position is closed
APP11VAL	BOOLEAN	Apparatus 11 position is valid
APP12_OP	BOOLEAN	Apparatus 12 position is open
APP12_CL	BOOLEAN	Apparatus 12 position is closed
APP12VAL	BOOLEAN	Apparatus 12 position is valid

Table continues on next page

Name	Type	Description
APP13_OP	BOOLEAN	Apparatus 13 position is open
APP13_CL	BOOLEAN	Apparatus 13 position is closed
APP13VAL	BOOLEAN	Apparatus 13 position is valid
APP14_OP	BOOLEAN	Apparatus 14 position is open
APP14_CL	BOOLEAN	Apparatus 14 position is closed
APP14VAL	BOOLEAN	Apparatus 14 position is valid
APP15_OP	BOOLEAN	Apparatus 15 position is open
APP15_CL	BOOLEAN	Apparatus 15 position is closed
APP15VAL	BOOLEAN	Apparatus 15 position is valid
COM_VAL	BOOLEAN	Receive communication status is valid

14.3.4 Settings

Table 409: GOOSEINTLKRCV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On

14.4 Goose binary receive GOOSEBINRCV

14.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Goose binary receive	GOOSEBINRCV	-	-

14.4.2 Function block

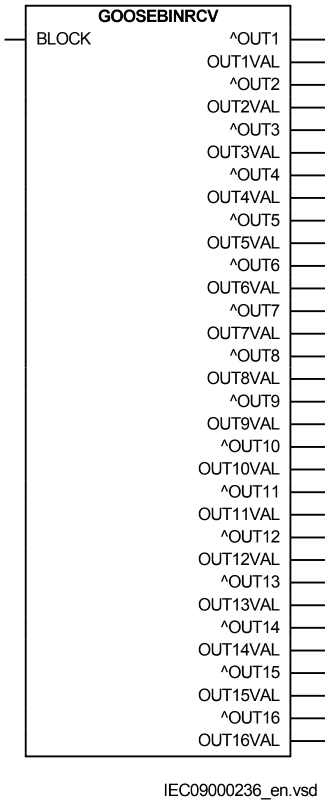


Figure 232: GOOSEBINRCV function block

14.4.3 Signals

Table 410: GOOSEBINRCV Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block of output signals

Table 411: GOOSEBINRCV Output signals

Name	Type	Description
OUT1	BOOLEAN	Binary output 1
OUT1VAL	BOOLEAN	Valid data on binary output 1
OUT2	BOOLEAN	Binary output 2
OUT2VAL	BOOLEAN	Valid data on binary output 2
OUT3	BOOLEAN	Binary output 3
OUT3VAL	BOOLEAN	Valid data on binary output 3
OUT4	BOOLEAN	Binary output 4
OUT4VAL	BOOLEAN	Valid data on binary output 4
Table continues on next page		

Name	Type	Description
OUT5	BOOLEAN	Binary output 5
OUT5VAL	BOOLEAN	Valid data on binary output 5
OUT6	BOOLEAN	Binary output 6
OUT6VAL	BOOLEAN	Valid data on binary output 6
OUT7	BOOLEAN	Binary output 7
OUT7VAL	BOOLEAN	Valid data on binary output 7
OUT8	BOOLEAN	Binary output 8
OUT8VAL	BOOLEAN	Valid data on binary output 8
OUT9	BOOLEAN	Binary output 9
OUT9VAL	BOOLEAN	Valid data on binary output 9
OUT10	BOOLEAN	Binary output 10
OUT10VAL	BOOLEAN	Valid data on binary output 10
OUT11	BOOLEAN	Binary output 11
OUT11VAL	BOOLEAN	Valid data on binary output 11
OUT12	BOOLEAN	Binary output 12
OUT12VAL	BOOLEAN	Valid data on binary output 12
OUT13	BOOLEAN	Binary output 13
OUT13VAL	BOOLEAN	Valid data on binary output 13
OUT14	BOOLEAN	Binary output 14
OUT14VAL	BOOLEAN	Valid data on binary output 14
OUT15	BOOLEAN	Binary output 15
OUT15VAL	BOOLEAN	Valid data on binary output 15
OUT16	BOOLEAN	Binary output 16
OUT16VAL	BOOLEAN	Valid data on binary output 16

14.4.4 Settings

Table 412: GOOSEBINRCV Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Operation	Off On	-	-	Off	Operation Off/On

Section 15 Basic IED functions

15.1 Self supervision with internal event list

15.1.1 Functionality

Self supervision with internal event list (INTERRSIG and SELFSUPEVLST) function listens and reacts to internal system events, generated by the different built-in self-supervision elements. The internal events are saved in an internal event list.

15.1.2 Internal error signals INTERRSIG

15.1.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Internal error signal	INTERRSIG	-	-

15.1.2.2 Function block

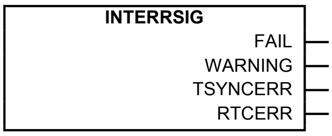


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Figure 233: INTERRSIG function block

15.1.2.3 Signals

Table 413: INTERRSIG Output signals

Name	Type	Description
FAIL	BOOLEAN	Internal fail
WARNING	BOOLEAN	Internal warning
TSYNCERR	BOOLEAN	Time synchronization error
RTCERR	BOOLEAN	Real time clock error

15.1.2.4 Settings

The function does not have any settings available in Local HMI or Protection and Control IED Manager (PCM600).

15.1.3 Internal event list SELFSUPEVLST

15.1.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Internal event list	SELFSUPEVLST	-	-

15.1.3.2 Settings

The function does not have any settings available in Local HMI or Protection and Control IED Manager (PCM600).

15.1.4 Operation principle

The self-supervision operates continuously and includes:

- Normal micro-processor watchdog function.
- Checking of digitized measuring signals.
- Other alarms, for example hardware and time synchronization.

The SELFSUPEVLST function status can be monitored from the local HMI, PCM Event viewer, or a SMS/SCS system.

Under the Diagnostics menu in the local HMI the present information from the self-supervision function can be reviewed. The information can be found under **Diagnostics/Internal events** or **Diagnostics/IED status/General**. The information from self supervision function is also available in Event viewer in PCM600.

A self-supervision summary can be obtained by means of the potential free alarm contact (INTERNAL FAIL) located on the power supply module. This output relay is activated (no fault) and deactivated (fault) by the Internal Fail signal, see figure 234. Also the software watchdog timeout and the undervoltage detection of the PSM will deactivate the relay.

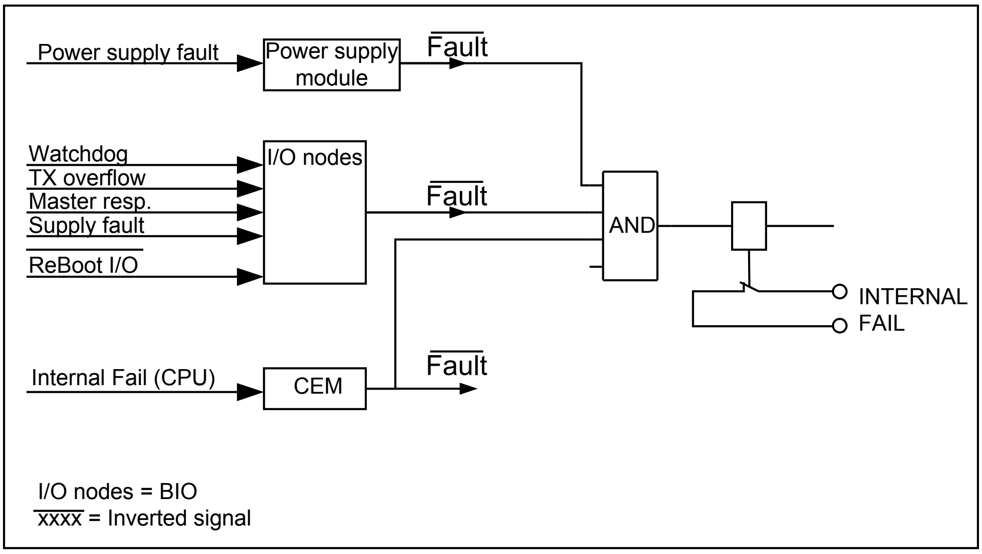

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Figure 234: Hardware self-supervision, potential-free contact

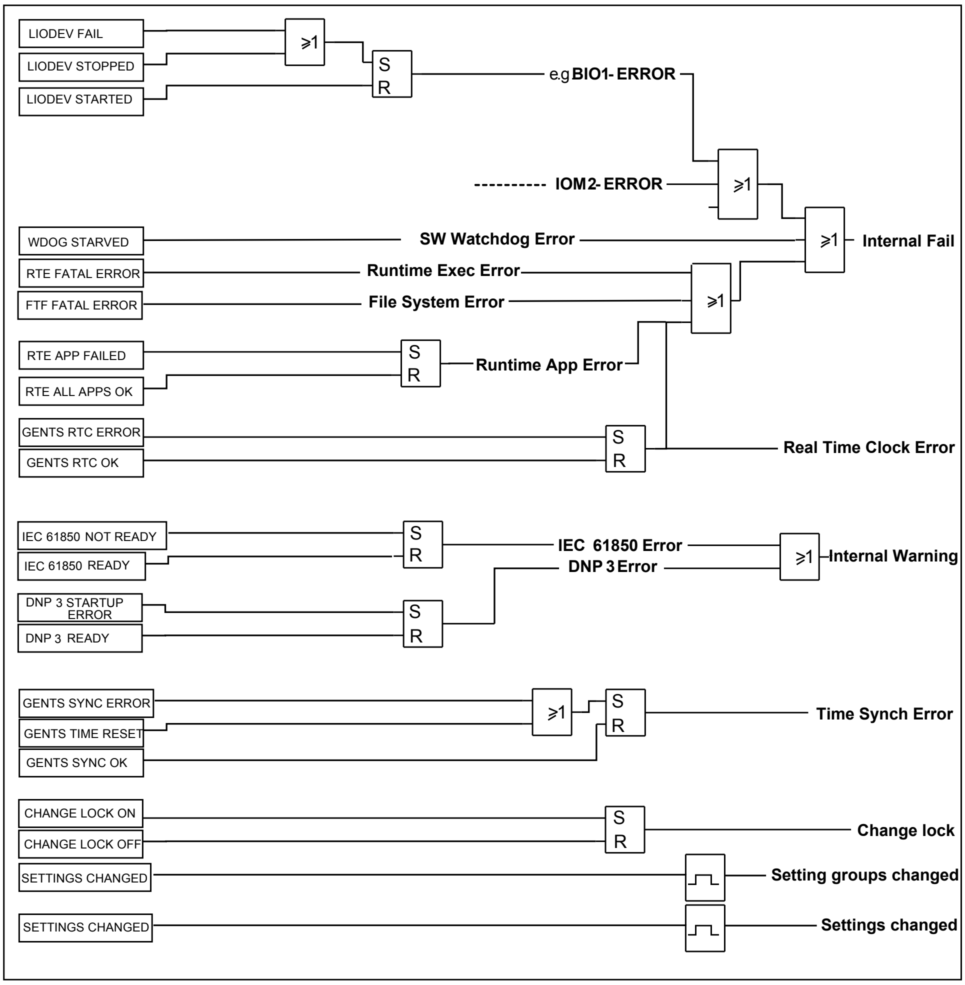

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Figure 235: Self supervision, function block internal signals

Some signals are available from the INTERRSIG function block. The signals from INTERRSIG function block are sent as events to the station level of the control system. The signals from the INTERRSIG function block can also be connected to binary outputs for signalization via output relays or they can be used as conditions for other functions if required/desired.

Individual error signals from I/O modules can be obtained from respective module in the Signal Matrix Tool. Error signals from time synchronization can be obtained from the time synchronization block INTERSIG.

15.1.4.1 Internal signals

SELFSUPEVLST function provides several status signals, that tells about the condition of the IED. As they provide information about the internal status of the IED, they are also called internal signals. The internal signals can be divided into two groups. One group handles signals that are always present in the IED; standard signals. Another group handles signals that are collected depending on the hardware configuration. The standard signals are listed in table 414. The hardware dependent internal signals are listed in table 415. Explanations of internal signals are listed in table 416.

Table 414: SELFSUPEVLST standard internal signals

Name of signal	Description
Internal Fail	Internal Fail status
Internal Warning	Internal Warning status
Real Time Clock Error	Real Time Clock status
Time Synch Error	Time Synchronization status
Runtime App Error	Runtime Application Error status
Runtime Exec Error	Runtime Execution Error status
IEC61850 Error	IEC 61850 Error status
SW Watchdog Error	SW Watchdog Error status
Settings Changed	Settings Changed
Setting Group Changed	Setting Groups Changed
Change Lock	Change Lock status
File System Error	Fault tolerant filesystem status
DNP3 Error	DNP3 error status

Table 415: Self-supervision's HW dependent internal signals

Card	Name of signal	Description
PSM	PSM-Error	Power Supply Module Error status
TRM	TRM-Error	Transformator Module Error status
COM	COM-Error	Communication Module Error status
BIO	BIO-Error	Binary Input / Output Module Error status
AIM	AIM-Error	Analog Input Module Error status

Table 416: Explanations of internal signals

Name of signal	Reasons for activation
Internal Fail	This signal will be active if one or more of the following internal signals are active; Real Time Clock Error, Runtime App Error, Runtime Exec Error, SW Watchdog Error, File System Error
Internal Warning	This signal will be active if one or more of the following internal signals are active; IEC 61850 Error, DNP3 Error
Real Time Clock Error	This signal will be active if there is a hardware error with the real time clock.
Time Synch Error	This signal will be active when the source of the time synchronization is lost, or when the time system has to make a time reset.
Table continues on next page	

Name of signal	Reasons for activation
Runtime Exec Error	This signal will be active if the Runtime Engine failed to do some actions with the application threads. The actions can be loading of settings or parameters for components, changing of setting groups, loading or unloading of application threads.
IEC61850 Error	This signal will be active if the IEC61850 stack did not succeed in some actions like reading IEC61850 configuration, startup etc.
SW Watchdog Error	This signal will be activated when the IED has been under too heavy load for at least 5 minutes. The operating systems background task is used for the measurements.
Runtime App Error	This signal will be active if one or more of the application threads are not in the state that Runtime Engine expects. The states can be CREATED, INITIALIZED, RUNNING, etc.
Settings Changed	This signal will generate an internal event to the internal event list if any settings are changed.
Setting Groups Changed	This signal will generate an internal event to the Internal Event List if any setting groups are changed.
Change Lock	This signal will generate an internal Event to the Internal Event List if the Change Lock status is changed
File System Error	This signal will be active if both the working file and the backup file are corrupted and cannot be recovered.
DNP3 Error	This signal will be active when DNP3 detects any configuration error during startup.

15.1.4.2 Run-time model

The analog signals to the A/D converter is internally distributed into two different converters, one with low amplification and one with high amplification, see figure 236.

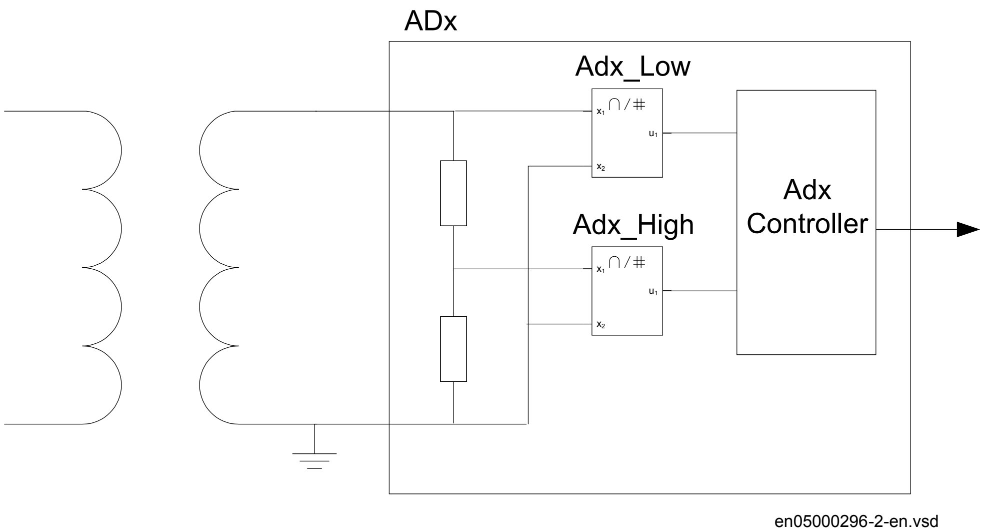


Figure 236: Simplified drawing of A/D converter for the IED.

The technique to split the analog input signal into two A/D converters with different amplification makes it possible to supervise the incoming signals under normal conditions where the signals from the two converters should be identical. An alarm is given if the signals are out of the boundaries. Another benefit is that it improves the dynamic performance of the A/D conversion.

The self-supervision of the A/D conversion is controlled by the ADx_Controller function. One of the tasks for the controller is to perform a validation of the input signals. This is done in a validation filter which has mainly two objects: First is the validation part that checks that the A/D conversion seems to work as expected. Secondly, the filter chooses which of the two signals that shall be sent to the CPU, that is the signal that has the most suitable level, the *ADx_LO* or the 16 times higher*ADx_HI*.

When the signal is within measurable limits on both channels, a direct comparison of the two channels can be performed. If the validation fails, the CPU will be informed and an alarm will be given.

The ADx_Controller also supervise other parts of the A/D converter.

15.1.5 Technical data

Table 417: Self supervision with internal event list

Data	Value
Recording manner	Continuous, event controlled
List size	40 events, first in - first out

15.2 Time synchronization

15.2.1 Functionality

Use the time synchronization source selector to select a common source of absolute time for the IED when it is a part of a protection system. This makes comparison of events and disturbance data between all IEDs in a station automation system possible.

Micro SCADA OPC server should not be used as a time synchronization source.

15.2.2 Time synchronization TIMESYNCHGEN

15.2.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization	TIMESYNCHGEN	-	-

15.2.2.2 Settings

Table 418: TIMESYNCHGEN Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
CoarseSyncSrc	Off SNTP DNP	-	-	Off	Coarse time synchronization source
FineSyncSource	Off SNTP IRIG-B	-	-	Off	Fine time synchronization source
SyncMaster	Off SNTP-Server	-	-	Off	Activate IED as synchronization master

15.2.3 Time synchronization via SNTP

15.2.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization via SNTP	SNTP	-	-

15.2.3.2 Settings

Table 419: SNTP Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
ServerIP-Add	0 - 255	IP Address	1	0.0.0.0	Server IP-address
RedServIP-Add	0 - 255	IP Address	1	0.0.0.0	Redundant server IP-address

15.2.4 Time system, summer time begin DTSBEGIN

15.2.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time system, summer time begins	DTSBEGIN	-	-

15.2.4.2 Settings

Table 420: DTSBEGIN Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
MonthInYear	January February March April May June July August September October November December	-	-	March	Month in year when daylight time starts
DayInWeek	Sunday Monday Tuesday Wednesday Thursday Friday Saturday	-	-	Sunday	Day in week when daylight time starts
WeekInMonth	Last First Second Third Fourth	-	-	Last	Week in month when daylight time starts
UTCTimeOfDay	0 - 86400	s	1	3600	UTC Time of day in seconds when daylight time starts

15.2.5 Time system, summer time ends DTSEND

15.2.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time system, summer time ends	DTSEND	-	-

15.2.5.2 Settings

Table 421: DTSEND Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
MonthInYear	January February March April May June July August September October November December	-	-	October	Month in year when daylight time ends
DayInWeek	Sunday Monday Tuesday Wednesday Thursday Friday Saturday	-	-	Sunday	Day in week when daylight time ends
WeekInMonth	Last First Second Third Fourth	-	-	Last	Week in month when daylight time ends
UTCTimeOfDay	0 - 86400	s	1	3600	UTC Time of day in seconds when daylight time ends

15.2.6 Time zone from UTC TIMEZONE

15.2.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time zone from UTC	TIMEZONE	-	-

15.2.6.2 Settings

Table 422: TIMEZONE Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
NoHalfHourUTC	-24 - 24	-	1	0	Number of half-hours from UTC

15.2.7 Time synchronization via IRIG-B

15.2.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Time synchronization via IRIG-B	IRIG-B	-	-

15.2.7.2 Settings

Table 423: IRIG-B Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
TimeDomain	LocalTime UTC	-	-	LocalTime	Time domain
Encoding	IRIG-B 1344 1344TZ	-	-	IRIG-B	Type of encoding
TimeZoneAs1344	MinusTZ PlusTZ	-	-	PlusTZ	Time zone as in 1344 standard

15.2.8 Operation principle

15.2.8.1 General concepts

Time definitions

The error of a clock is the difference between the actual time of the clock, and the time the clock is intended to have. The rate accuracy of a clock is normally called the clock accuracy and means how much the error increases, that is how much the clock gains or loses time. A disciplined (trained) clock knows its own faults and tries to compensate for them.

Design of the time system (clock synchronization)

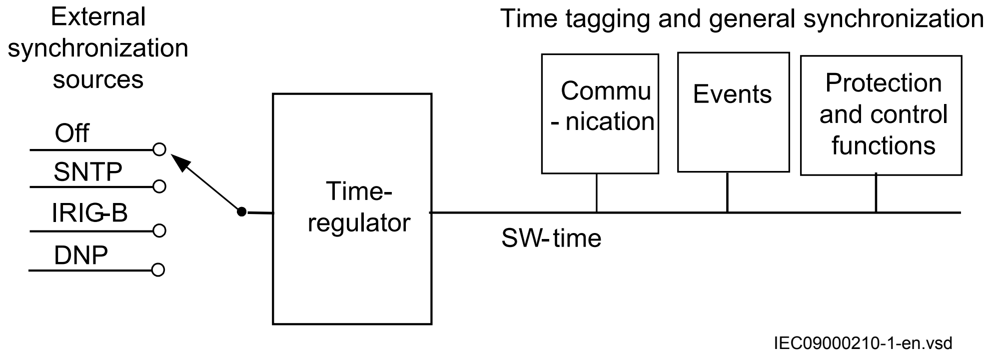


Figure 237: Design of time system (clock synchronization)

Synchronization principle

From a general point of view synchronization can be seen as a hierarchical structure. A function is synchronized from a higher level and provides synchronization to lower levels.

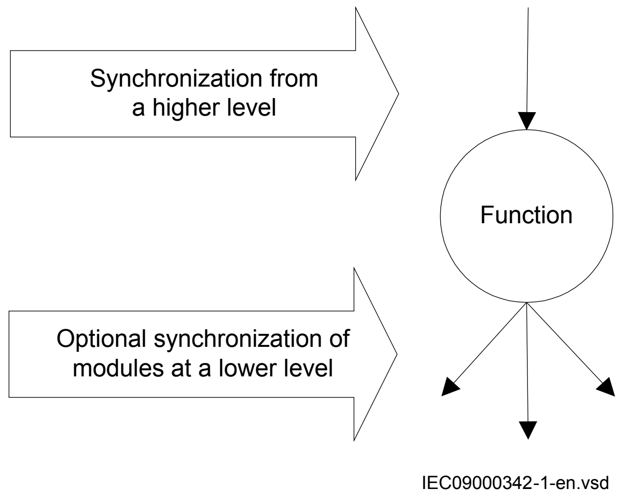


Figure 238: Synchronization principle

A function is said to be synchronized when it periodically receives synchronization messages from a higher level. As the level decreases, the accuracy of the synchronization decreases as well. A function can have several potential sources of synchronization, with different maximum errors, which give the function the possibility to choose the source with the best quality, and to adjust its internal clock after this source. The maximum error of a clock can be defined as:

- The maximum error of the last used synchronization message
- The time since the last used synchronization message
- The rate accuracy of the internal clock in the function.

15.2.8.2 Real-time clock (RTC) operation

The IED has a built-in real-time clock (RTC) with a resolution of one second. The clock has a built-in calendar that handles leap years through 2038.

Real-time clock at power off

During power off, the system time in the IED is kept by a capacitor-backed real-time clock that will provide 35 ppm accuracy for 5 days. This means that if the power is off, the time in the IED may drift with 3 seconds per day, during 5 days, and after this time the time will be lost completely.

Real-time clock at startup

Time synchronization startup procedure

The first message that contains the full time (as for instance SNTP and IRIG-B) gives an accurate time to the IED. The IED is brought into a safe state and the time is set to the correct value. After the initial setting of the clock, one of three things happens with each of the coming synchronization messages, configured as “fine”:

- If the synchronization message, which is similar to the other messages, from its origin has an offset compared to the internal time in the IED, the message is used directly for synchronization, that is, for adjusting the internal clock to obtain zero offset at the next coming time message.
- If the synchronization message has an offset that is large compared to the other messages, a spike-filter in the IED removes this time-message.
- If the synchronization message has an offset that is large, and the following message also has a large offset, the spike filter does not act and the offset in the synchronization message is compared to a threshold that defaults to 500 milliseconds. If the offset is more than the threshold, the IED is brought into a safe state and the clock is set to the correct time. If the offset is lower than the threshold, the clock is adjusted with 10 000 ppm until the offset is removed. With an adjustment of 10 000 ppm, it takes 50 seconds to remove an offset of 500 milliseconds.

Synchronization messages configured as coarse are only used for initial setting of the time. After this has been done, the messages are checked against the internal time and only an offset of more than 10 seconds resets the time.

Rate accuracy

In the IED, the rate accuracy at cold start is 100 ppm but if the IED is synchronized for a while, the rate accuracy is approximately 1 ppm if the surrounding temperature is constant. Normally, it takes 20 minutes to reach full accuracy.

Time-out on synchronization sources

All synchronization interfaces has a time-out and a configured interface must receive time-messages regularly in order not to give an error signal (TSYNCERR). Normally, the time-out is set so that one message can be lost without getting a TSYNCERR, but if more than one message is lost, a TSYNCERR is given.

15.2.8.3 Synchronization alternatives

Two main alternatives of external time synchronization are available. The synchronization message is applied either via any of the communication ports of the IED as a telegram message including date and time or via IRIG-B.

Synchronization via SNTP

SNTP provides a ping-pong method of synchronization. A message is sent from an IED to an SNTP server, and the SNTP server returns the message after filling in a reception time and a transmission time. SNTP operates via the normal Ethernet network that connects IEDs together in an IEC 61850 network. For SNTP to operate properly, there must be an SNTP-server present, preferably in the same station. The SNTP synchronization provides an accuracy that gives 1 ms accuracy for binary inputs. The IED itself can be set as an SNTP-time server.

The SNTP server to be used is connected to the local network, that is not more than 4-5 switches or routers away from the IED. The SNTP server is dedicated for its task, or at least equipped with a real-time operating system, that is not a PC with SNTP server software. The SNTP server should be stable, that is, either synchronized from a stable source like GPS, or local without synchronization. Using a local SNTP server without synchronization as primary or secondary server in a redundant configuration is not recommended.

Synchronization via IRIG-B

The DNP 3.0 communication can be the source for the course time synchronization, while the fine time synchronization needs a source with higher accuracy. See Communication manual for a detailed description of the DNP 3.0 protocol.

IRIG-B is a protocol used only for time synchronization. A clock can provide local time of the year in this format. The “B” in IRIG-B states that 100 bits per second are transmitted, and the message is sent every second. After IRIG-B there numbers stating if and how the signal is modulated and the information transmitted.

To receive IRIG-B there are one dedicated connector for the IRIG-B port. IRIG-B 00x messages can be supplied via the galvanic interface, where x (in 00x) means a number in the range of 1-7.

If the x in 00x is 4, 5, 6 or 7, the time message from IRIG-B contains information of the year. If x is 0, 1, 2 or 3, the information contains only the time within the year, and year information has to come from the tool or local HMI.

The IRIG-B input also takes care of IEEE1344 messages that are sent by IRIG-B clocks, as IRIG-B previously did not have any year information. IEEE1344 is compatible with IRIG-B and contains year information and information of the time-zone.

It is recommended to use IEEE 1344 for supplying time information to the IRIG module. In this case, send also the local time in the messages.

15.2.9 Technical data

Table 424: Time synchronization, time tagging

Function	Value
Time tagging resolution, events and sampled measurement values	1 ms
Time tagging error with synchronization once/min (minute pulse synchronization), events and sampled measurement values	± 1.0 ms typically
Time tagging error with SNTP synchronization, sampled measurement values	± 1.0 ms typically

15.3 Parameter setting group handling

15.3.1 Functionality

Use the four sets of settings to optimize IED operation for different system conditions. By creating and switching between fine tuned setting sets, either from the local HMI or configurable binary inputs, results in a highly adaptable IED that can cope with a variety of system scenarios.

15.3.2 Setting group handling SETGRPS

15.3.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Setting group handling	SETGRPS	-	-

15.3.2.2 Settings

Table 425: SETGRPS Non group settings (basic)

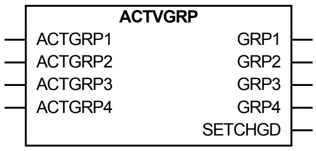
Name	Values (Range)	Unit	Step	Default	Description
ActiveSetGrp	SettingGroup1 SettingGroup2 SettingGroup3 SettingGroup4	-	-	SettingGroup1	ActiveSettingGroup
MaxNoSetGrp	1 - 4	-	1	1	Max number of setting groups 1-4

15.3.3 Parameter setting groups ACTVGRP

15.3.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Parameter setting groups	ACTVGRP	-	-

15.3.3.2 Function block



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15.3.3.3 Signals

Table 426: ACTVGRP Input signals

Name	Type	Default	Description
ACTGRP1	BOOLEAN	0	Selects setting group 1 as active
ACTGRP2	BOOLEAN	0	Selects setting group 2 as active
ACTGRP3	BOOLEAN	0	Selects setting group 3 as active
ACTGRP4	BOOLEAN	0	Selects setting group 4 as active

Table 427: ACTVGRP Output signals

Name	Type	Description
GRP1	BOOLEAN	Setting group 1 is active
GRP2	BOOLEAN	Setting group 2 is active
GRP3	BOOLEAN	Setting group 3 is active
GRP4	BOOLEAN	Setting group 4 is active
SETCHGD	BOOLEAN	Pulse when setting changed

15.3.3.4 Settings

The function does not have any settings available in Local HMI or Protection and Control IED Manager (PCM600).

15.3.4 Operation principle

Parameter setting groups (ACTVGRP) function has four functional inputs, each corresponding to one of the setting groups stored in the IED. Activation of any of these inputs changes the active setting group. Five functional output signals are available for configuration purposes.

A setting group is selected by using the local HMI, from a front connected personal computer, remotely from the station control or station monitoring system or by activating the corresponding input to the ACTVGRP function block.

Each input of the function block can be configured to connect to any of the binary inputs in the IED. To do this the PCM600 configuration tool must be used.

The external control signals are used for activating a suitable setting group when adaptive functionality is necessary. Input signals that should activate setting groups must be either permanent or a pulse exceeding 400 ms.

More than one input may be activated at the same time. In such cases the lower order setting group has priority. This means that if for example both group four and group two are set to activate, group two will be the one activated.

Every time the active group is changed, the output signal SETCHGD is sending a pulse.

The parameter *MaxNoSetGrp* defines the maximum number of setting groups in use to switch between.

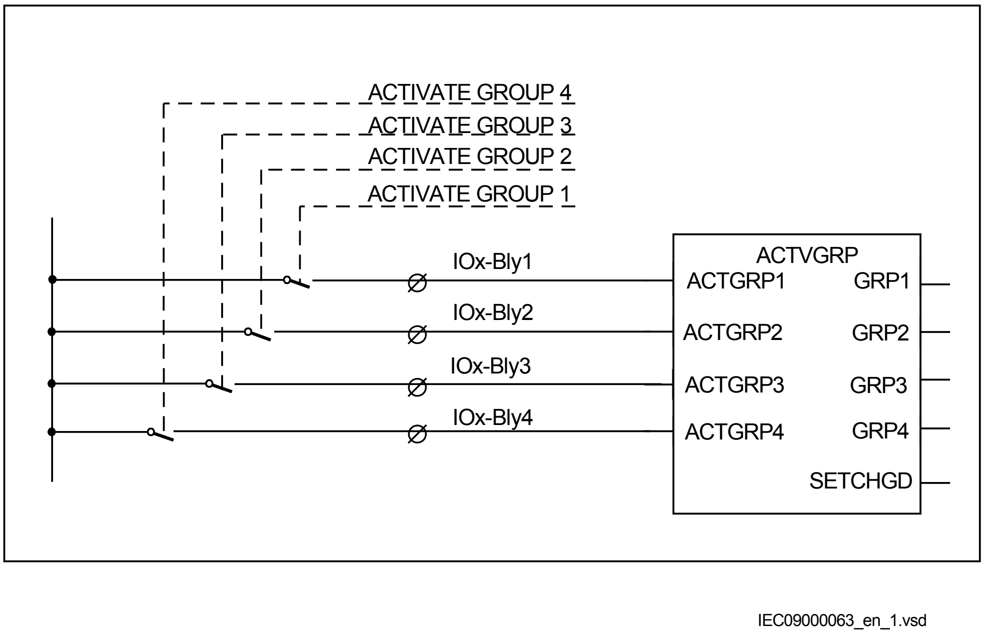

Figure 239: Connection of the function to external circuits

The above example also includes five output signals, for confirmation of which group that is active.

15.4 Test mode functionality TESTMODE

15.4.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Test mode functionality	TESTMODE	-	-

15.4.2 Functionality

When the TESTMODE function is activated, protection functions in the IED are automatically blocked. It is then possible to unblock the protection functions individually from the local HMI or PST to perform required tests.

When a binary input is used to set the IED in test mode and a parameter, that requires restart of the application, is changed, the IED will re-enter test mode and all functions will be blocked, also functions that were unblocked before the change. During the re-entering to test mode, all functions will be temporarily unblocked for a short time, which might lead to unwanted operations. This is only valid if the IED is put in TEST mode by a binary input, not by local HMI.

When leaving TESTMODE, all blockings are removed and the IED resumes normal operation. However, if during TESTMODE operation, power is removed and later restored, the IED will remain in TESTMODE with the same protection functions blocked or unblocked as before the power was removed. All testing will be done with actually set and configured values within the IED. No settings will be changed, thus mistakes are avoided.

Forcing of binary output signals is only possible when the IED is in test mode.

15.4.3 Function block

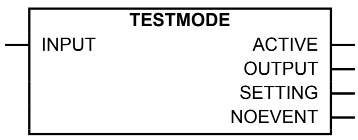

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Figure 240: TESTMODE function block

15.4.4 Signals

Table 428: TESTMODE Input signals

Name	Type	Default	Description
INPUT	BOOLEAN	0	Sets terminal in test mode when active

Table 429: TESTMODE Output signals

Name	Type	Description
ACTIVE	BOOLEAN	Terminal in test mode when active
OUTPUT	BOOLEAN	Test input is active
SETTING	BOOLEAN	Test mode setting is (On) or not (Off)
NOEVENT	BOOLEAN	Event disabled during testmode

15.4.5 Settings

Table 430: TESTMODE Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
TestMode	Off On	-	-	Off	Test mode in operation (On) or not (Off)
EventDisable	Off On	-	-	Off	Event disable during testmode
CmdTestBit	Off On	-	-	Off	Command bit for test required or not during testmode

15.4.6 Operation principle

To be able to test the functions in the IED, the IED shall be put in test mode. There are two ways of setting the IED in test mode:

- By configuration, activating the input signal of the function block TESTMODE.
- By setting *TestMode* to *On* in the local HMI, under the menu: **Tests/IED test mode/1:TESTMODE**.

While the IED is in test mode, the ACTIVE output of the function block TESTMODE is activated. The other outputs of the function block TESTMODE shows the generator of the “Test mode: On” state — input from configuration (OUTPUT output is activated) or setting from local HMI (SETTING output is activated).

While the IED is in test mode, the yellow START LED will flash and all functions are blocked. Any function can be unblocked individually regarding functionality and event signalling.

Forcing of binary output signals is only possible when the IED is in test mode.

Most of the functions in the IED can individually be blocked by means of settings from the local HMI. To enable these blockings the IED must be set in test mode (output ACTIVE is activated). When leaving the test mode, that is entering normal mode, these blockings are disabled and everything is set to normal operation. All testing will be done with actually set and configured values within the IED. No settings will be changed, thus no mistakes are possible.

The blocked functions will still be blocked next time entering the test mode, if the blockings were not reset.

The blocking of a function concerns all output signals from the actual function, so no outputs will be activated.

When a binary input is used to set the IED in test mode and a parameter, that requires restart of the application, is changed, the IED will re-enter test mode and all functions will be blocked, also functions that were unblocked before the change. During the re-entering to test mode, all functions will be temporarily unblocked for a short time, which might lead to unwanted operations. This is only valid if the IED is put in TEST mode by a binary input, not by local HMI.

The TESTMODE function block might be used to automatically block functions when a test handle is inserted in a test switch. A contact in the test switch (RTXP24 contact 29-30) can supply a binary input which in turn is configured to the TESTMODE function block.

Each of the protection functions includes the blocking from TESTMODE function block.

The functions can also be blocked from sending events over IEC 61850 station bus to prevent filling station and SCADA databases with test events, for example during a maintenance test.

15.5 Change lock function CHNGLCK

15.5.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Change lock function	CHNGLCK	-	-

15.5.2 Functionality

Change lock function (CHNGLCK) is used to block further changes to the IED configuration and settings once the commissioning is complete. The purpose is to block inadvertent IED configuration changes beyond a certain point in time.

When CHNGLCK has a logical one on its input, then all attempts to modify the IED configuration will be denied and the message "Error: Changes blocked" will be displayed on the LHMI; in PCM600 the message will be "Operation denied by active ChangeLock". The CHNGLCK function should be configured so that it is controlled by a signal from a binary input card. This guarantees that by setting that signal to a logical zero, CHNGLCK is deactivated. If any logic is included in the signal path to the CHNGLCK input, that logic must be designed so that it cannot permanently issue a logical one on the CHNGLCK input. If such a situation would occur in spite of these precautions, then please contact the local ABB representative for remedial action.

15.5.3 Function block

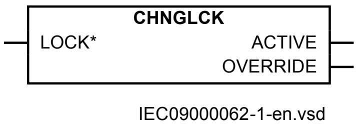

Figure 241: CHNGLCK function block

15.5.4 Signals

Table 431: CHNGLCK Input signals

Name	Type	Default	Description
LOCK	BOOLEAN	0	Activate change lock

Table 432: CHNGLCK Output signals

Name	Type	Description
ACTIVE	BOOLEAN	Change lock active
OVERRIDE	BOOLEAN	Change lock override

15.5.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600)

15.5.6 Operation principle

The Change lock function (CHNGLCK) is configured using ACT.

The function, when activated, will still allow the following changes of the IED state that does not involve reconfiguring of the IED:

- Monitoring
- Reading events
- Resetting events
- Reading disturbance data
- Clear disturbances
- Reset LEDs
- Reset counters and other runtime component states
- Control operations
- Set system time
- Enter and exit from test mode
- Change of active setting group

The binary input signal LOCK controlling the function is defined in ACT or SMT:

Binary input	Function
1	Activated
0	Deactivated

15.6 IED identifiers TERMINALID

15.6.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
IED identifiers	TERMINALID	-	-

15.6.2 Functionality

IED identifiers (TERMINALID) function allows the user to identify the individual IED in the system, not only in the substation, but in a whole region or a country.

Use only characters A-Z,a-z and 0-9 in station, object and unit names.

15.6.3 Settings

Table 433: TERMINALID Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
StationName	0 - 18	-	1	Station name	Station name
StationNumber	0 - 99999	-	1	0	Station number
ObjectName	0 - 18	-	1	Object name	Object name
ObjectNumber	0 - 99999	-	1	0	Object number
UnitName	0 - 18	-	1	Unit name	Unit name
UnitNumber	0 - 99999	-	1	0	Unit number
TechnicalKey	0 - 18	-	1	AA0J0Q0A0	Technical key

15.7 Product information

15.7.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Product information	PRODINF	-	-

15.7.2 Functionality

The Product identifiers function identifies the IED. The function has seven pre-set, settings that are unchangeable but nevertheless very important:

- IEDProdType
- ProductDef
- FirmwareVer
- SerialNo
- OrderingNo
- ProductionDate

The settings are visible on the local HMI , under:

Diagnostics/IED status/Product identifiers

They are very helpful in case of support process (such as repair or maintenance).

15.7.3 Settings

The function does not have any parameters available in Local HMIor Protection and Control IED Manager (PCM600).

15.8 Primary system values PRIMVAL

15.8.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Primary system values	PRIMVAL	-	-

15.8.2 Functionality

The rated system frequency and phasor rotation are set under **Main menu/ Configuration/ Power system/ Primary values/PRIMVAL** in PCM600 parameter setting tree.

15.8.3 Settings

Table 434: PRIMVAL Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
Frequency	50.0 - 60.0	Hz	10.0	50.0	Rated system frequency
PhaseRotation	Normal=L1L2L3 Inverse=L3L2L1	-	-	Normal=L1L2L3	System phase rotation

15.9 Signal matrix for analog inputs SMAI

15.9.1 Functionality

Signal matrix for analog inputs (SMAI) function (or the pre-processing function) is used within PCM600 in direct relation with SMT or ACT (see the overview of the engineering process in the *Engineering manual*). SMT represents the way analog inputs are brought in for one IED configuration.

15.9.2 Signal matrix for analog inputs SMAI_20_1

15.9.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Signal matrix for analog inputs	SMAI_20_1	-	-

15.9.2.2 Function block

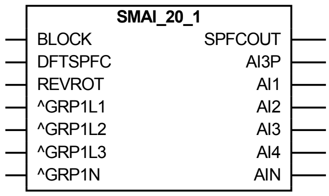

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Figure 242: SMAI_20_1 function block

15.9.2.3 Signals

Table 435: SMAI_20_1 Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block group 1
DFTSPFC	REAL	20.0	Number of samples per fundamental cycle used for DFT calculation
REVROT	BOOLEAN	0	Reverse rotation group 1
GRP1L1	STRING	-	First analog input used for phase L1 or L1-L2 quantity
GRP1L2	STRING	-	Second analog input used for phase L2 or L2-L3 quantity
GRP1L3	STRING	-	Third analog input used for phase L3 or L3-L1 quantity
GRP1N	STRING	-	Fourth analog input used for residual or neutral quantity

Table 436: SMAI_20_1 Output signals

Name	Type	Description
SPFCOUT	REAL	Number of samples per fundamental cycle from internal DFT reference function
AI3P	GROUP SIGNAL	Grouped three phase signal containing data from inputs 1-4
AI1	GROUP SIGNAL	Quantity connected to the first analog input
AI2	GROUP SIGNAL	Quantity connected to the second analog input
AI3	GROUP SIGNAL	Quantity connected to the third analog input
AI4	GROUP SIGNAL	Quantity connected to the fourth analog input
AIN	GROUP SIGNAL	Calculated residual quantity if inputs 1-3 are connected

15.9.2.4 Settings

Table 437: SMAI_20_1 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
DFTRefExtOut	InternalDFTRef DFTRefGrp1 DFTRefGrp2 DFTRefGrp3 DFTRefGrp4 DFTRefGrp5 DFTRefGrp6 DFTRefGrp7 DFTRefGrp8 DFTRefGrp9 DFTRefGrp10 DFTRefGrp11 DFTRefGrp12 External DFT ref	-	-	InternalDFTRef	DFT reference for external output
DFTReference	InternalDFTRef DFTRefGrp1 DFTRefGrp2 DFTRefGrp3 DFTRefGrp4 DFTRefGrp5 DFTRefGrp6 DFTRefGrp7 DFTRefGrp8 DFTRefGrp9 DFTRefGrp10 DFTRefGrp11 DFTRefGrp12 External DFT ref	-	-	InternalDFTRef	DFT reference
ConnectionType	Ph-N Ph-Ph	-	-	Ph-N	Input connection type
AnalogInputType	Voltage Current	-	-	Voltage	Analog input signal type

Table 438: SMAI_20_1 Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
Negation	Off NegateN Negate3Ph Negate3Ph+N	-	-	Off	Negation
MinValFreqMeas	5 - 200	%	1	10	Limit for frequency calculation in % of UBase

15.9.3 Signal matrix for analog inputs SMAI_20_2

15.9.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Signal matrix for analog inputs	SMAI_20_2	-	-

15.9.3.2 Function block

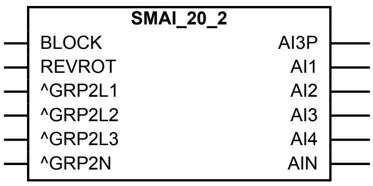

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Figure 243: SMAI_20_2 to SMAI_20_12 function block

Note that input and output signals on SMAI_20_2 to SMAI_20_12 are the same except for input signals GRPxL1 to GRPxN where x is equal to instance number (2 to 12).

15.9.3.3 Signals

Table 439: SMAI_20_2 Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block group 2
REVROT	BOOLEAN	0	Reverse rotation group 2
GRP2L1	STRING	-	First analog input used for phase L1 or L1-L2 quantity
GRP2L2	STRING	-	Second analog input used for phase L2 or L2-L3 quantity
GRP2L3	STRING	-	Third analog input used for phase L3 or L3-L1 quantity
GRP2N	STRING	-	Fourth analog input used for residual or neutral quantity

Table 440: SMAI_20_2 Output signals

Name	Type	Description
AI3P	GROUP SIGNAL	Grouped three phase signal containing data from inputs 1-4
AI1	GROUP SIGNAL	Quantity connected to the first analog input
AI2	GROUP SIGNAL	Quantity connected to the second analog input
AI3	GROUP SIGNAL	Quantity connected to the third analog input
AI4	GROUP SIGNAL	Quantity connected to the fourth analog input
AIN	GROUP SIGNAL	Calculated residual quantity if inputs 1-3 are connected

15.9.3.4 Settings

Table 441: SMAI_20_2 Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
DFTReference	InternalDFTRef DFTRefGrp1 DFTRefGrp2 DFTRefGrp3 DFTRefGrp4 DFTRefGrp5 DFTRefGrp6 DFTRefGrp7 DFTRefGrp8 DFTRefGrp9 DFTRefGrp10 DFTRefGrp11 DFTRefGrp12 External DFT ref	-	-	InternalDFTRef	DFT reference
ConnectionType	Ph-N Ph-Ph	-	-	Ph-N	Input connection type
AnalogInputType	Voltage Current	-	-	Voltage	Analog input signal type

Table 442: SMAI_20_2 Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
Negation	Off NegateN Negate3Ph Negate3Ph+N	-	-	Off	Negation
MinValFreqMeas	5 - 200	%	1	10	Limit for frequency calculation in % of UBase

15.9.4 Operation principle

Every Signal matrix for analog inputs function (SMAI) can receive four analog signals (three phases and one neutral value), either voltage or current, see figure 242 and figure 243. SMAI outputs give information about every aspect of the 3ph analog signals acquired (phase angle, RMS value, frequency and frequency derivates etc. – 244 values in total). The BLOCK input will reset all outputs to 0.

The output signals AI1 to AI4 in SMAI_20_x function block are direct outputs of the, in SMT or ACT, connected input group signals to GRPxL1, GRPxL2, GRPxL3 and GRPxN, x=1-12. GRPxN is always the neutral current. If GRPxN is not connected, the AI4 output is all zero. The AIN output is the calculated residual sum of inputs GRPxL1, GRPxL2 and GRPxL3 and is equal to output AI4 if all inputs, including GRPxN, are connected. Note that function block will always calculate the residual sum of current/voltage if the input is not connected in SMT or ACT. Applications with a few exceptions shall always be connected to AI3P.

The input signal REVROT is used to reverse the phase order.

15.10 Summation block 3 phase 3PHSUM

15.10.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Summation block 3 phase	3PHSUM	-	-

15.10.2 Functionality

Summation block 3 phase function (3PHSUM) is used in order to get the sum of two sets of 3 phase analog signals (of the same type) for those IED functions that might need it.

15.10.3 Function block

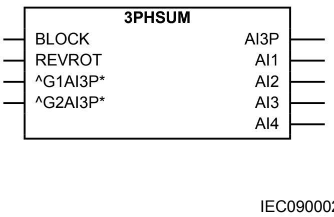

Figure 244: 3PHSUM function block

15.10.4 Signals

Table 443: 3PHSUM Input signals

Name	Type	Default	Description
BLOCK	BOOLEAN	0	Block
REVROT	BOOLEAN	0	Reverse rotation
G1AI3P	GROUP SIGNAL	-	Group 1 three phase analog input from first SMAI
G2AI3P	GROUP SIGNAL	-	Group 2 three phase analog input from second SMAI

Table 444: 3PHSUM Output signals

Name	Type	Description
AI3P	GROUP SIGNAL	Linear combination of two connected three phase inputs
AI1	GROUP SIGNAL	Linear combination of input 1 signals from both SMAI blocks
AI2	GROUP SIGNAL	Linear combination of input 2 signals from both SMAI blocks
AI3	GROUP SIGNAL	Linear combination of input 3 signals from both SMAI blocks
AI4	GROUP SIGNAL	Linear combination of input 4 signals from both SMAI blocks

15.10.5 Settings

Table 445: 3PHSUM Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
GlobalBaseSel	1 - 6	-	1	1	Selection of one of the Global Base Value groups
SummationType	Group1+Group2 Group1-Group2 Group2-Group1 -(Group1+Group2)	-	-	Group1+Group2	Summation type
DFTReference	InternalDFTRef DFTRefGrp1 External DFT ref	-	-	InternalDFTRef	DFT reference

Table 446: 3PHSUM Non group settings (advanced)

Name	Values (Range)	Unit	Step	Default	Description
FreqMeasMinVal	5 - 200	%	1	10	Amplitude limit for frequency calculation in % of Ubase

15.10.6 Operation principle

Summation block 3 phase (3PHSUM) receives the 3 phase signals from Signal matrix for analog inputs function (SMAI). In the same way, the BLOCK input will reset to 0 all the outputs of the function.

15.11 Global base values GBASVAL

15.11.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Global base values	GBASVAL	-	-

15.11.2 Functionality

Global base values function (GBASVAL) is used to provide global values, common for all applicable functions within the IED. One set of global values consists of values for current, voltage and apparent power and it is possible to have six different sets.

This is an advantage since all applicable functions in the IED use a single source of base values. This facilitates consistency throughout the IED and also facilitates a single point for updating values when necessary.

Each applicable function in the IED has a parameter, *GlobalBaseSel*, defining one out of the six sets of Global base value functions.

15.11.3 Settings

Table 447: GBASVAL Non group settings (basic)

Name	Values (Range)	Unit	Step	Default	Description
UBase	0.05 - 2000.00	kV	0.05	132.00	Global base voltage
IBase	1 - 99999	A	1	1000	Global base current
SBase	1 - 50000	MVA	1	229	Global base apparent power

15.12 Authority check ATHCHCK

15.12.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Authority check	ATHCHCK	-	-

15.12.2 Functionality

To safeguard the interests of our customers, both the IED and the tools that are accessing the IED are protected, subject of authorization handling. The concept of authorization, as it is implemented in the IED and in PCM600 is based on the following facts:

There are two types of access points to the IED:

- local, through the local HMI
- remote, through the communication ports

15.12.3 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM 600).

15.12.4 Operation principle

There are different levels (or types) of users that can access or operate different areas of the IED and tools functionality; the pre-defined user types are defined as follows:

User type	Access rights
SystemOperator	Control from local HMI, no bypass
ProtectionEngineer	All settings
DesignEngineer	Application configuration (including SMT, GDE and CMT)
UserAdministrator	User and password administration for the IED

The IED users can be created, deleted and edited only with the User Management Tool (UMT) within PCM600. The user can only LogOn or LogOff on the local HMI on the IED, there are no users, groups or functions that can be defined on local HMI.

Only characters A - Z, a - z and 0 - 9 should be used in user names and passwords.

15.12.4.1 Authorization handling in the IED

At delivery the default user is the SuperUser. No Log on is required to operate the IED until a user has been created with the User Management Tool (UMT).

Once a user is created and downloaded into the IED, that user can perform a Log on, using the password assigned in the tool. Then the default user will be Guest.

If there is no user created, an attempt to log on will display a message box: “No user defined!”

If one user leaves the IED without logging off, then after the timeout (set in **Main menu/Configuration/HMI/Screen/1:SCREEN**) elapses, the IED will return to a Guest state, when only reading is possible. By factory default, the display timeout is set to 60 minutes.

If one or more users are created with the UMT and downloaded into the IED, then, when a user attempts a Log on by pressing the key or when the user attempts to perform an operation that is password protected, the Log on window will appear.

The cursor is focused on the “User identity” field, so upon pressing the key, one can change the user name, by browsing the list of users, with the “up” and “down” arrows. After choosing the right user name, the user must press the key again. When it comes to password, upon pressing the key, the following characters will show up: “∗∗∗∗∗∗∗∗”. The user must scroll for every letter in the password. After all the letters are introduced (passwords are case sensitive) choose OK and press key again.

At successful Log on the local HMI shows the new username in the statusbar at the bottom of the LCD. If the Log on is OK, when required to change for example a password protected setting, the local HMI returns to the actual setting folder. If the LogOn has failed, an "Error Access Denied" message will pop-up. If a user enters an incorrect password three times, that user will be blocked for ten minutes before a new attempt to log in can be performed. The user will be blocked from logging in, both from the local HMI as well as, from PCM600 tool. However, other users will be able to log in during this period.

15.13 Authority status ATHSTAT

15.13.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Authority status	ATHSTAT	-	-

15.13.2 Functionality

Authority status (ATHSTAT) function is an indication function block for user log on activity.

15.13.3 Function block

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Figure 245: ATHSTAT function block

15.13.4 Signals

Table 448: ATHSTAT Output signals

Name	Type	Description
USRBLKED	BOOLEAN	At least one user is blocked by invalid password
LOGGEDON	BOOLEAN	At least one user is logged on

15.13.5 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600)

15.13.6 Operation principle

Authority status (ATHSTAT) function informs about two events related to the IED and the user authorization:

- the fact that at least one user has tried to log on wrongly into the IED and it was blocked (the output USRBLKED)
- the fact that at least one user is logged on (the output LOGGEDON)

Whenever one of the two events occurs, the corresponding output (USRBLKED or LOGGEDON) is activated.

15.14 Denial of service

15.14.1 Functionality

The Denial of service functions (DOSLAN1 and DOSFRNT) are designed to limit overload on the IED produced by heavy Ethernet network traffic. The communication facilities must not be allowed to compromise the primary functionality of the device. All inbound network traffic will be quota controlled so that too heavy network loads can be controlled. Heavy network load might for instance be the result of malfunctioning equipment connected to the network.

15.14.2 Denial of service, frame rate control for front port DOSFRNT

15.14.2.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Denial of service, frame rate control for front port	DOSFRNT	-	-

15.14.2.2 Function block

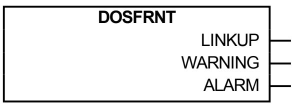

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Figure 246: DOSFRNT function block

15.14.2.3 Signals

Table 449: DOSFRNT Output signals

Name	Type	Description
LINKUP	BOOLEAN	Ethernet link status
WARNING	BOOLEAN	Frame rate is higher than normal state
ALARM	BOOLEAN	Frame rate is higher than throttle state

15.14.2.4 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600)

15.14.2.5 Monitored data

Table 450: DOSFRNT Monitored data

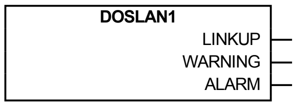
Name	Type	Values (Range)	Unit	Description
State	INTEGER	0=Off 1=Normal 2=Throttle 3=DiscardLow 4=DiscardAll 5=StopPoll	-	Frame rate control state
Quota	INTEGER	-	%	Quota level in percent 0-100
IPPackRecNorm	INTEGER	-	-	Number of IP packets received in normal mode
IPPackRecPoll	INTEGER	-	-	Number of IP packets received in polled mode
IPPackDisc	INTEGER	-	-	Number of IP packets discarded
NonIPPackRecNorm	INTEGER	-	-	Number of non IP packets received in normal mode
NonIPPackRecPoll	INTEGER	-	-	Number of non IP packets received in polled mode
NonIPPackDisc	INTEGER	-	-	Number of non IP packets discarded

15.14.3 Denial of service, frame rate control for LAN1 port DOSLAN1

15.14.3.1 Identification

Function description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE C37.2 device number
Denial of service, frame rate control for LAN1 port	DOSLAN1	-	-

15.14.3.2 Function block



IEC09000134-1-en.vsd

Figure 247: DOSLAN1 function block

15.14.3.3 Signals

Table 451: DOSLAN1 Output signals

Name	Type	Description
LINKUP	BOOLEAN	Ethernet link status
WARNING	BOOLEAN	Frame rate is higher than normal state
ALARM	BOOLEAN	Frame rate is higher than throttle state

15.14.3.4 Settings

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600)

15.14.3.5 Monitored data

Table 452: DOSLAN1 Monitored data

Name	Type	Values (Range)	Unit	Description
State	INTEGER	0=Off 1=Normal 2=Throttle 3=DiscardLow 4=DiscardAll 5=StopPoll	-	Frame rate control state
Quota	INTEGER	-	%	Quota level in percent 0-100
IPPackRecNorm	INTEGER	-	-	Number of IP packets received in normal mode
IPPackRecPoll	INTEGER	-	-	Number of IP packets received in polled mode
IPPackDisc	INTEGER	-	-	Number of IP packets discarded

Table continues on next page

Name	Type	Values (Range)	Unit	Description
NonIPPackRecNorm	INTEGER	-	-	Number of non IP packets received in normal mode
NonIPPackRecPoll	INTEGER	-	-	Number of non IP packets received in polled mode
NonIPPackDisc	INTEGER	-	-	Number of non IP packets discarded

15.14.4 Operation principle

The Denial of service functions (DOSLAN1 and DOSFRNT) measures the IED load from communication and, if necessary, limit it for not jeopardizing the IEDs control and protection functionality due to high CPU load. The function has the following outputs:

- LINKUP indicates the ethernet link status
- WARNING indicates that communication (frame rate) is higher than normal
- ALARM indicates that the IED limits communication

Section 16 IED physical connections

16.1 Protective earth connections

The IED shall be earthed with a 16.0 mm^2 flat copper cable.

The earth lead should be as short as possible, less than 1500 mm. Additional length is required for door mounting.

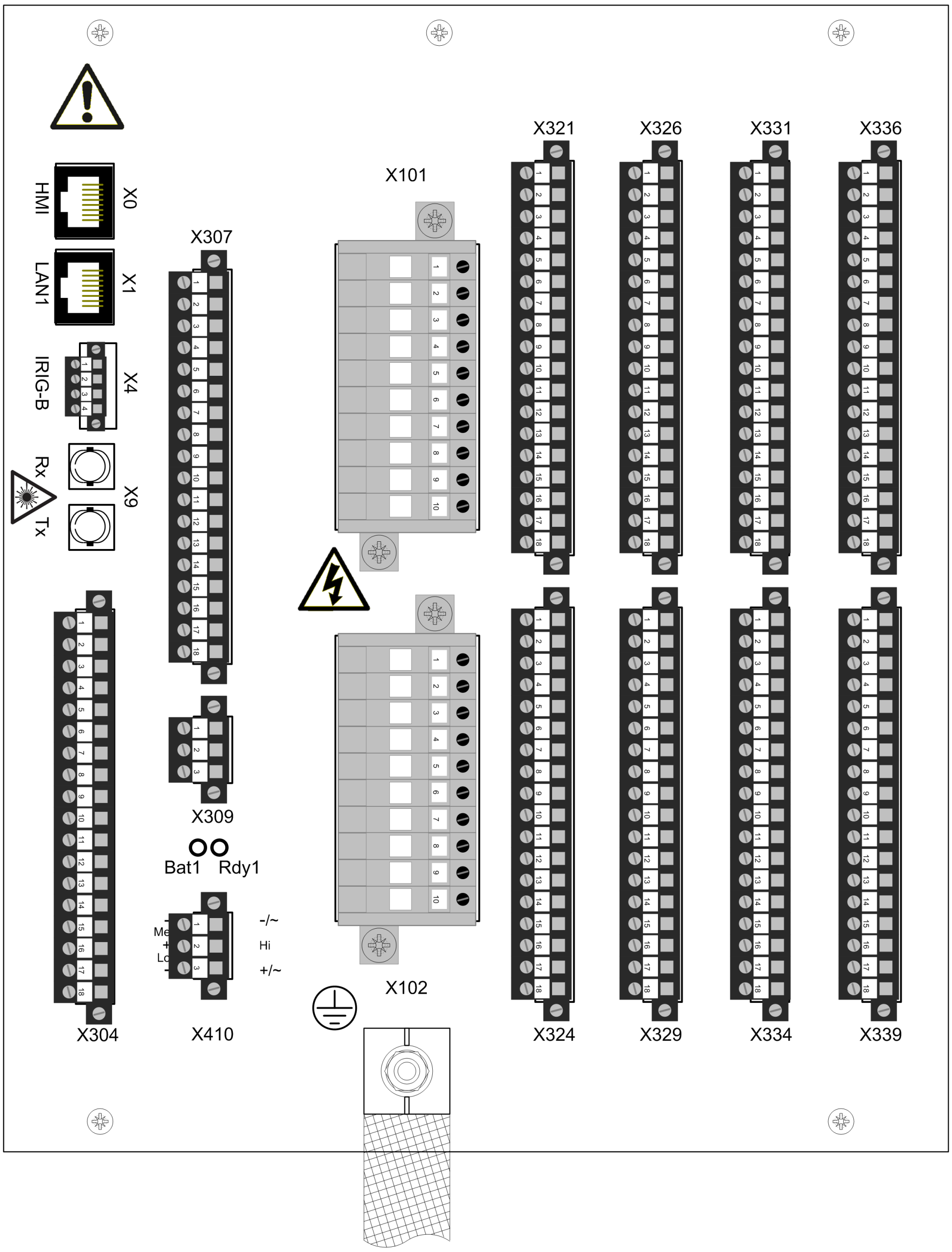


Figure 248: Protective earth pin is located below connector X102 on the 6U half 19” case

16.2 Inputs

16.2.1 Measuring inputs

Each terminal for CTs/VTs is dimensioned for one 0.5...6.0 mm^2 wire or for two wires of maximum 2.5 mm^2.

Table 453: Analog input modules

Terminal	TRM 6I + 4U	TRM 8I + 2U	TRM 4I + 1I + 5U	AIM 6I + 4U	AIM 4I + 1I + 5U
X101-1, 2	1/5A	1/5A	1/5A	1/5A	1/5A
X101-3, 4	1/5A	1/5A	1/5A	1/5A	1/5A
X101-5, 6	1/5A	1/5A	1/5A	1/5A	1/5A
X101-7, 8	1/5A	1/5A	1/5A	1/5A	1/5A
X101-9, 10	1/5A	1/5A	0.1/0.5A	1/5A	0.1/0.5A
X102-1, 2	1/5A	1/5A	100/220V	1/5A	100/220V
X102-3, 4	100/220V	1/5A	100/220V	100/220V	100/220V
X102-5, 6	100/220V	1/5A	100/220V	100/220V	100/220V
X102-7, 8	100/220V	100/220V	100/220V	100/220V	100/220V
X102-9, 10	100/220V	100/220V	100/220V	100/220V	100/220V

See the connection diagrams for information on the analog input module variant included in a particular configured IED.

16.2.2 Auxiliary supply voltage input

The auxiliary voltage of the IED is connected to terminals X410-1 and X410-2/3. The terminals used depend on the power supply.

The permitted auxiliary voltage range of the IED is marked on top of the IED's LHMI.

Table 454: Auxiliary voltage supply of 110...250 V DC or 100...240 V AC

Case	Terminal	Description
6U half 19”	X410-1	- Input
	X410–3	+ Input

Table 455: Auxiliary voltage supply of 48-125 V DC

Case	Terminal	Description
6U half 19”	X410-1	- Input
	X410–2	+ Input

16.2.3 Binary inputs

The binary inputs can be used, for example, to generate a blocking signal, to unlatch output contacts, to trigger the disturbance recorder or for remote control of IED settings.

Each signal connector terminal is connected with one 0.5...2.5 mm^2 wire or with two 0.5...1.0 mm^2 wires.

Table 456: Binary inputs X304, 6U half 19"

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X304-1	Common - for inputs 1-4		
X304-2	Binary input 1 +	COM_101	BI1
X304-3	Binary input 2 +	COM_101	BI2
X304-4	Binary input 3 +	COM_101	BI3
X304-5	Binary input 4 +	COM_101	BI4
X304-6	Common - for inputs 5-8		
X304-7	Binary input 5 +	COM_101	BI5
X304-8	Binary input 6 +	COM_101	BI6
X304-9	Binary input 7 +	COM_101	BI7
X304-10	Binary input 8 +	COM_101	BI8
X304-11	Common - for inputs 9-11		
X304-12	Binary input 9 +	COM_101	BI9
X304-13	Binary input 10 +	COM_101	BI10
X304-14	Binary input 11 +	COM_101	BI11
X304-15	Common - for inputs 12-14		
X304-16	Binary input 12 +	COM_101	BI12
X304-17	Binary input 13 +	COM_101	BI13
X304-18	Binary input 14 +	COM_101	BI14

Table 457: Binary inputs X324, 6U half 19"

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X324-1	- for input 1	BIO_3	BI1
X324-2	Binary input 1 +	BIO_3	BI1
X324-3	-		
X324-4	Common - for inputs 2-3		
X324-5	Binary input 2 +	BIO_3	BI2
X324-6	Binary input 3 +	BIO_3	BI3
X324-7	-		
Table continues on next page			

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X324-8	Common - for inputs 4-5		
X324-9	Binary input 4 +	BIO_3	BI4
X324-10	Binary input 5 +	BIO_3	BI5
X324-11	-		
X324-12	Common - for inputs 6-7		
X324-13	Binary input 6 +	BIO_3	BI6
X324-14	Binary input 7 +	BIO_3	BI7
X324-15	-		
X324-16	Common - for inputs 8-9		
X324-17	Binary input 8 +	BIO_3	BI8
X324-18	Binary input 9 +	BIO_3	BI9

Table 458: Binary inputs X329, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X329-1	- for input 1	BIO_4	BI1
X329-2	Binary input 1 +	BIO_4	BI1
X329-3	-		
X329-4	Common - for inputs 2-3		
X329-5	Binary input 2 +	BIO_4	BI2
X329-6	Binary input 3 +	BIO_4	BI3
X329-7	-		
X329-8	Common - for inputs 4-5		
X329-9	Binary input 4 +	BIO_4	BI4
X329-10	Binary input 5 +	BIO_4	BI5
X329-11	-		
X329-12	Common - for inputs 6-7		
X329-13	Binary input 6 +	BIO_4	BI6
X329-14	Binary input 7 +	BIO_4	BI7
X329-15	-		
X329-16	Common - for inputs 8-9		
X329-17	Binary input 8 +	BIO_4	BI8
X329-18	Binary input 9 +	BIO_4	BI9

Table 459: *Binary inputs X334, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X334-1	- for input 1	BIO_5	BI1
X334-2	Binary input 1 +	BIO_5	BI1
X334-3	-		
X334-4	Common - for inputs 2-3		
X334-5	Binary input 2 +	BIO_5	BI2
X334-6	Binary input 3 +	BIO_5	BI3
X334-7	-		
X334-8	Common - for inputs 4-5		
X334-9	Binary input 4 +	BIO_5	BI4
X334-10	Binary input 5 +	BIO_5	BI5
X334-11	-		
X334-12	Common - for inputs 6-7		
X334-13	Binary input 6 +	BIO_5	BI6
X334-14	Binary input 7 +	BIO_5	BI7
X334-15	-		
X334-16	Common - for inputs 8-9		
X334-17	Binary input 8 +	BIO_5	BI8
X334-18	Binary input 9 +	BIO_5	BI9

Table 460: *Binary inputs X339, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X339-1	- for input 1	BIO_6	BI1
X339-2	Binary input 1 +	BIO_6	BI1
X339-3	-		
X339-4	Common - for inputs 2-3		
X339-5	Binary input 2 +	BIO_6	BI2
X339-6	Binary input 3 +	BIO_6	BI3
X339-7	-		
X339-8	Common - for inputs 4-5		
X339-9	Binary input 4 +	BIO_6	BI4
X339-10	Binary input 5 +	BIO_6	BI5
X339-11	-		
X339-12	Common - for inputs 6-7		
X339-13	Binary input 6 +	BIO_6	BI6
X339-14	Binary input 7 +	BIO_6	BI7
Table continues on next page			

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X339-15	-		
X339-16	Common - for inputs 8-9		
X339-17	Binary input 8 +	BIO_6	BI8
X339-18	Binary input 9 +	BIO_6	BI9

16.3 Outputs

16.3.1 Outputs for tripping, controlling and signalling

Output contacts PO1, PO2 and PO3 are power output contacts used, for example, for controlling circuit breakers.

Each signal connector terminal is connected with one 0.5...2.5 mm^2 wire or with two 0.5...1.0 mm^2 wires.

The connected DC voltage to outputs with trip circuit supervision (TCS) must have correct polarity or the trip circuit supervision TCSSCBR function will not operate properly.

Table 461: Output contacts X307, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
 X307-1 X307-2	Power output 1, normally open (TCS) - +	PSM_102	BO1_PO_TCS
 X307-3 X307-4	Power output 2, normally open (TCS) - +	PSM_102	BO2_PO_TCS
 X307-5 X307-6	Power output 3, normally open (TCS) - +	PSM_102	BO3_PO_TCS
X307-7 X307-8	Power output 4, normally open	PSM_102	BO4_PO
X307-9 X307-10	Power output 5, normally open	PSM_102	BO5_PO
X307-11 X307-12	Power output 6, normally open	PSM_102	BO6_PO

Table 462: *Output contacts X321, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X321-1 X321-2	Power output 1, normally open	BIO_3	BO1_PO
X321-3 X321-4	Power output 2, normally open	BIO_3	BO2_PO
X321-5 X321-6	Power output 3, normally open	BIO_3	BO3_PO

Table 463: *Output contacts X326, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X326-1 X326-2	Power output 1, normally open	BIO_4	BO1_PO
X326-3 X326-4	Power output 2, normally open	BIO_4	BO2_PO
X326-5 X326-6	Power output 3, normally open	BIO_4	BO3_PO

Table 464: *Output contacts X331, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X331-1 X331-2	Power output 1, normally open	BIO_5	BO1_PO
X331-3 X331-4	Power output 2, normally open	BIO_5	BO2_PO
X331-5 X331-6	Power output 3, normally open	BIO_5	BO3_PO

Table 465: *Output contacts X336, 6U half 19”*

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X336-1 X336-2	Power output 1, normally open	BIO_6	BO1_PO
X336-3 X336-4	Power output 2, normally open	BIO_6	BO2_PO
X336-5 X336-6	Power output 3, normally open	BIO_6	BO3_PO

16.3.2 Outputs for signalling

Signal output contacts are used for signalling on starting and tripping of the IED. On delivery from the factory, the start and alarm signals from all the protection stages are routed to signalling outputs. See connection diagrams.

Each signal connector terminal is connected with one 0.5...2.5 mm^2 wire or with two 0.5...1.0 mm^2 wires.

Table 466: Output contacts X307, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X307-13 X307-14	Signal output 1, normally open	PSM_102	BO7_SO
X307-15 X307-16	Signal output 2, normally open	PSM_102	BO8_SO
X307-17 X307-18	Signal output 3, normally open	PSM_102	BO9_SO

Table 467: Output contacts X321, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X321-7 X321-8	Signal output 1, normally open Signal output 1	BIO_3	BO4_SO
X321-9 X321-10	Signal output 2, normally open Signal output 2	BIO_3	BO5_SO
X321-11 X321-12	Signal output 3, normally open Signal output 3	BIO_3	BO6_SO
X321-13 X321-14 X321-15	Signal output 4, normally open Signal output 5, normally open Signal outputs 4 and 5, common	BIO_3 BIO_3	BO7_SO BO8_SO
X321-16 X321-17 X321-18	Signal output 6, normally closed Signal output 6, normally open Signal output 6, common	BIO_3	BO9_SO

Table 468: Output contacts X326, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X326-7	Signal output 1, normally open	BIO_4	BO4_SO
X326-8	Signal output 1		
X326-9	Signal output 2, normally open	BIO_4	BO5_SO
X326-10	Signal output 2		
X326-11	Signal output 3, normally open	BIO_4	BO6_SO
X326-12	Signal output 3		
X326-13	Signal output 4, normally open	BIO_4	BO7_SO
X326-14	Signal output 5, normally open	BIO_4	BO8_SO
X326-15	Signal outputs 4 and 5, common		
X326-16	Signal output 6, normally closed	BIO_4	BO9_SO
X326-17	Signal output 6, normally open		
X326-18	Signal output 6, common		

Table 469: Output contacts X331, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X331-7	Signal output 1, normally open	BIO_5	BO4_SO
X331-8	Signal output 1		
X331-9	Signal output 2, normally open	BIO_5	BO5_SO
X331-10	Signal output 2		
X331-11	Signal output 3, normally open	BIO_5	BO6_SO
X331-12	Signal output 3		
X331-13	Signal output 4, normally open	BIO_5	BO7_SO
X331-14	Signal output 5, normally open	BIO_5	BO8_SO
X331-15	Signal outputs 4 and 5, common		
X331-16	Signal output 6, normally closed	BIO_5	BO9_SO
X331-17	Signal output 6, normally open		
X331-18	Signal output 6, common		

Table 470: Output contacts X336, 6U half 19”

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X336-7	Signal output 1, normally open	BIO_6	BO4_SO
X336-8	Signal output 1		
X336-9	Signal output 2, normally open	BIO_6	BO5_SO
X336-10	Signal output 2		
Table continues on next page			

Terminal	Description	PCM600 info	
		Hardware module instance	Hardware channel
X336-11 X336-12	Signal output 3, normally open Signal output 3	BIO_6	BO6_SO
X337-13 X336-14 X336-15	Signal output 4, normally open Signal output 5, normally open Signal outputs 4 and 5, common	BIO_6 BIO_6	BO7_SO BO8_SO
X336-16 X336-17 X336-18	Signal output 6, normally closed Signal output 6, normally open Signal output 6, common	BIO_6	BO9_SO

16.3.3 IRF

The IRF contact functions as a change-over output contact for the self-supervision system of the IED. Under normal operating conditions, the IED is energized and one of the two contacts is closed. When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the closed contact drops off and the other contact closes.

Each signal connector terminal is connected with one 0.5...2.5 mm^2 wire or with two 0.5...1.0 mm^2 wires.

Table 471: IRF contact X309

Case	Terminal	Description
6U half 19”	X309-1	Closed; no IRF, and U_{aux} connected
	X309-2	Closed; IRF, or U_{aux} disconnected
	X309-3	IRF, common

16.4 Communication connections

The IED's LHMI is provided with an RJ-45 connector. The connector is mainly for configuration and setting purposes.

Rear communication via the X1/LAN1 connector uses a communication module with the optical LC Ethernet connection.

The HMI connector X0 is used for connecting an external HMI to the IED. The X0/HMI connector must not be used for any other purpose.

16.4.1 Ethernet RJ-45 front connection

The IED's LHMI is provided with an RJ-45 connector designed for point-to-point use. The connector is mainly for configuration and setting purposes. The interface on the PC has to be configured in a way that it obtains the IP address automatically if the DHCPServer is enabled in LHMI. There is a DHCP server inside IED for the front interface only.

The events and setting values and all input data such as memorized values and disturbance records can be read via the front communication port.

Only one of the possible clients can be used for parametrization at a time.

- PCM600
- LHMI

The default IP address of the IED through this port is 10.1.150.3.

The front port supports TCP/IP protocol. A standard Ethernet CAT 5 crossover cable is used with the front port.

16.4.2 Station communication rear connection

The default IP address of the IED through the Ethernet connection is 192.168.1.10. The physical connector is X1/LAN1. The interface speed is 100 Mbps for the 100BASE-FX LC alternative.

16.4.3 Communication interfaces and protocols

Table 472: Supported communication interfaces and protocols

Protocol	Ethernet 100BASE-FX LC
IEC 61850-8-1	●
DNP3	●
● = Supported	

16.4.4 Recommended industrial Ethernet switches

ABB recommends three third-party industrial Ethernet switches.

- RuggedCom RS900
- RuggedCom RS1600
- RuggedCom RSG2100

16.5 Connection diagrams

Connection diagrams are valid for configured REL650 variants A01 and A05

Table of contents

Part of product	Sheets
Designations for 6U, 1/2x19" casing with 1 TRM slot	2
Communication module (COM)	3
Power supply module 48-125 VDC (PSM)	4
Power supply module 110-250 VDC, 100-240 VAC (PSM)	5
Transformer module (TRM)	6
Binary input/output module (BIO)	7
Binary input/output module (BIO)	8

Prep.	PSTP/ TPLA	Agneta Rydh	2009-06-09
Appr.	PSTP/	Nyback Patrik	2009-09-01
Resp. dept	PSTP/ TPLA		

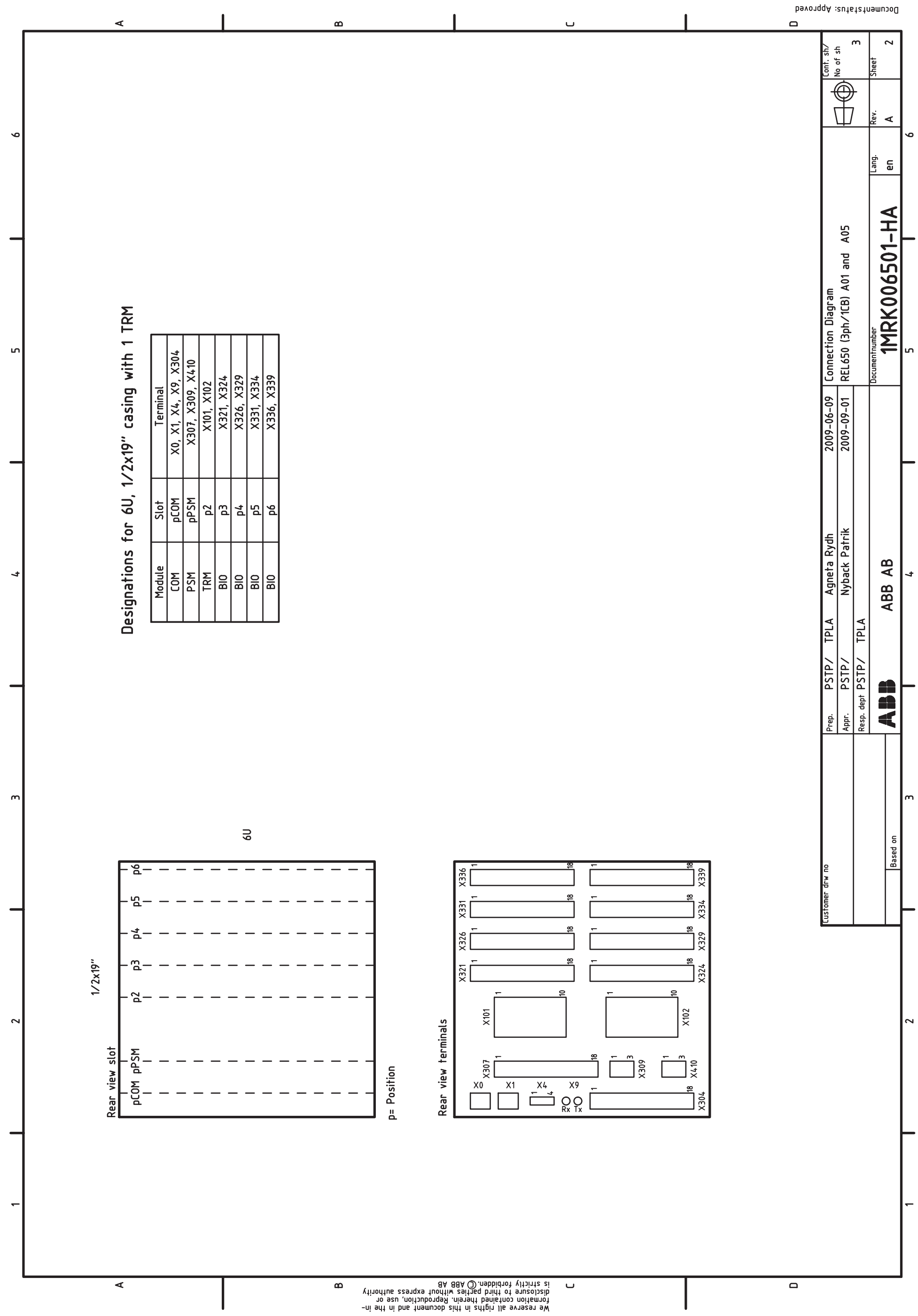
Connection Diagram
REL650 (3ph/1CB) A01 and A05

ABB AB

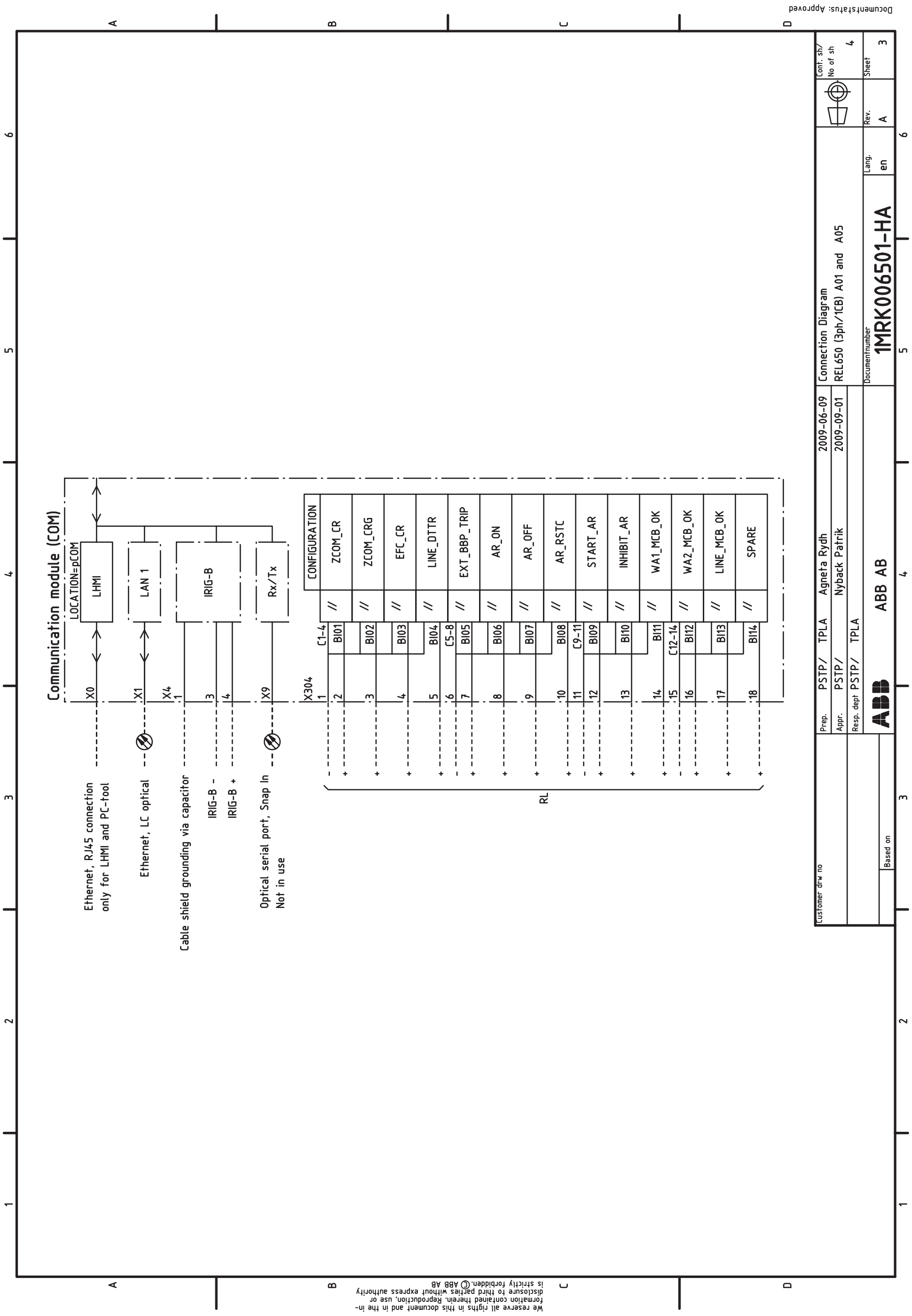
Documentnumber 1MRK006501-HA

Lang. en | Rev. A | Sheet 1 | Cont. sh/No of sh 2

Documentstatus: Approved



Module	Slot	Terminal
COM	pCOM	X0, X1, X4, X9, X304
PSM	pPSM	X307, X309, X410
TRM	p2	X101, X102
BIO	p3	X321, X324
BIO	p4	X326, X329
BIO	p5	X331, X334
BIO	p6	X336, X339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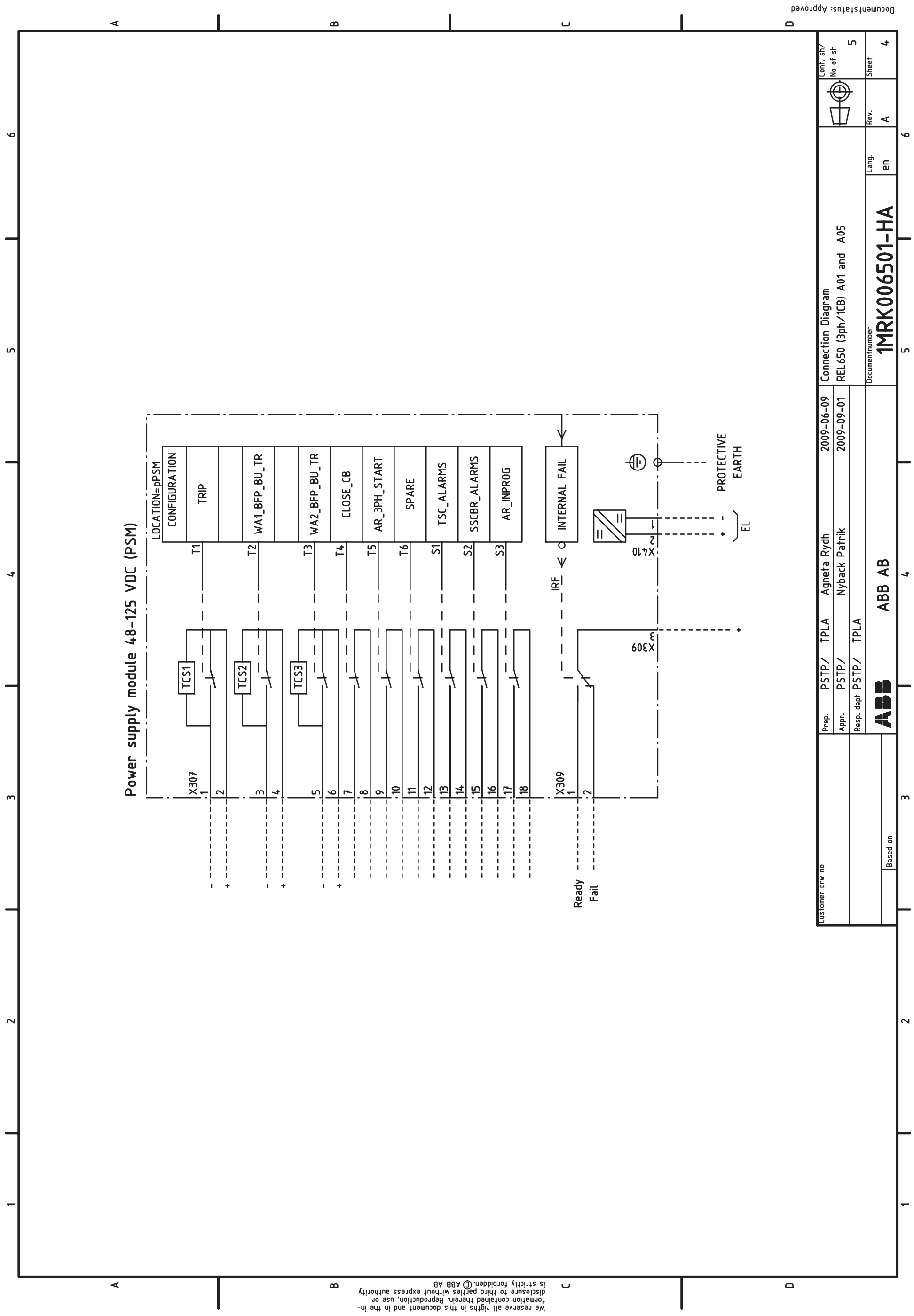
LOCATION=pCOM
LHMI
LAN 1
IRIG-B
Rx/Tx
CONFIGURATION
ZCOM_CR
ZCOM_CRG
EFC_CR
LINE_DTTR
EXT_BBP_TRIP
AR_ON
AR_OFF
AR_RSTC
START_AR
INHIBIT_AR
WA1_MCB_OK
WA2_MCB_OK
LINE_MCB_OK
SPARE
Ethernet, RJ45 connection only for LHMI and PC-tool
Ethernet, LC optical
Cable shield grounding via capacitor
IRIG-B -
IRIG-B +
Optical serial port, Snap In Not in use
RL
Connection Diagram
REL650 (3ph/1CB) A01 and A05
1MRK006501-HA
ABB AB
Agneta Rydh 2009-06-09
Nyback Patrik 2009-09-01
DocumentStatus: Approved


DocumentStatus: Approved
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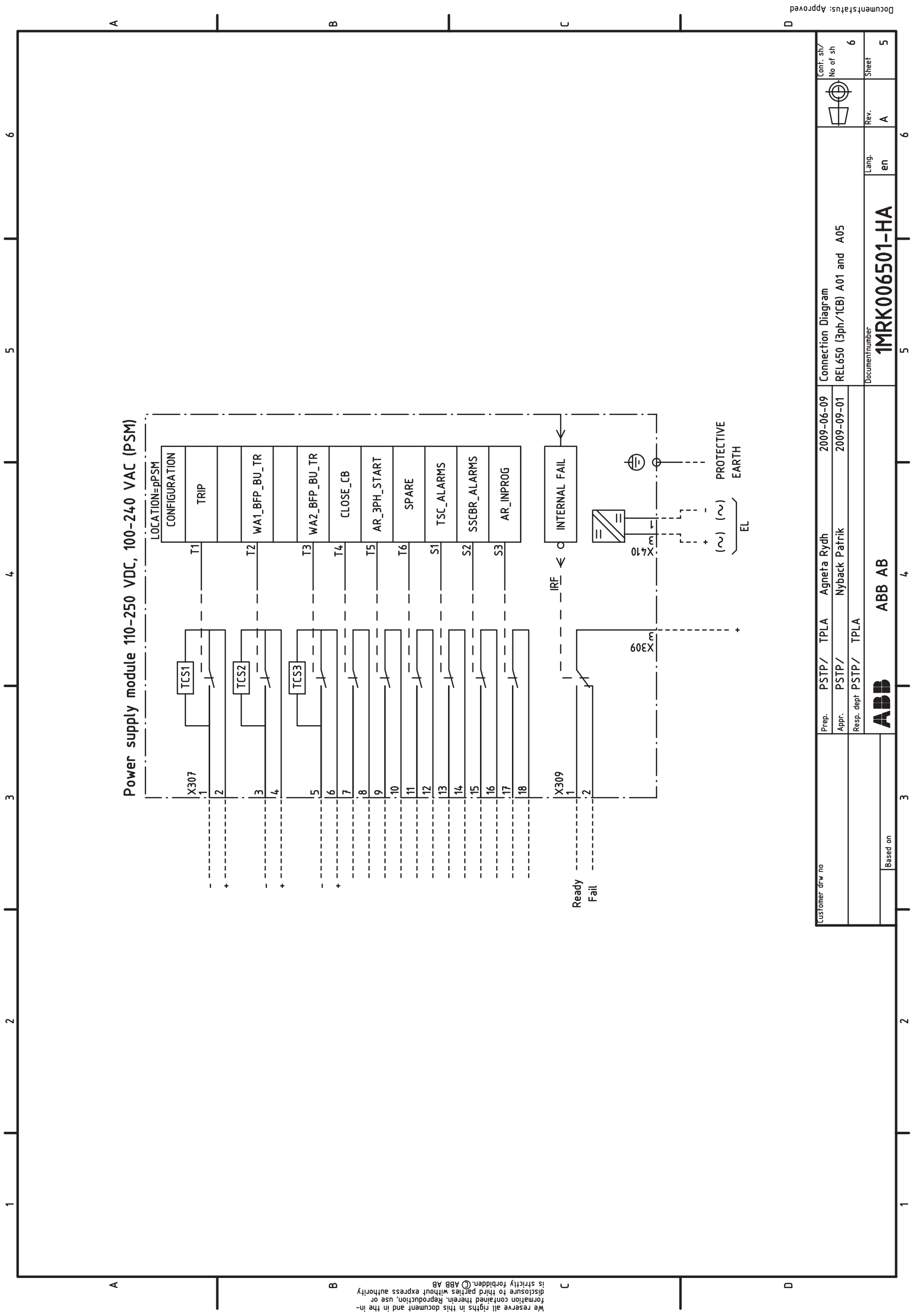
LOCATION=pPSM
CONFIGURATION
TRIP
WA1_BFP_BU_TR
WA2_BFP_BU_TR
CLOSE_CB
AR_3PH_START
SPARE
TSC_ALARMS
SSCBR_ALARMS
AR_INPROG
INTERNAL FAIL
IRF
PROTECTIVE EARTH
EL
TCS1
TCS2
TCS3
X307
X309
X410
Ready
Fail
Connection Diagram
REL650 (3ph/1CB) A01 and A05
1MRK006501-HA
ABB AB
Agneta Rydh
Nyback Patrik
2009-06-09
2009-09-01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LOCATION=pSM
CONFIGURATION
TRIP
WA1_BFP_BU_TR
WA2_BFP_BU_TR
CLOSE_CB
AR_3PH_START
SPARE
TSC_ALARMS
SSCBR_ALARMS
AR_INPROG
INTERNAL FAIL
IRF
T1
T2
T3
T4
T5
T6
S1
S2
S3
TCS1
TCS2
TCS3
X307
X309
X410
Ready
Fail
PROTECTIVE EARTH
EL
Connection Diagram
REL650 (3ph/1CB) A01 and A05
1MRK006501-HA
Prep. PSTP/ TPLA Agneta Rydh 2009-06-09
Appr. PSTP/ Nyback Patrik 2009-09-01
Resp. dept PSTP/ TPLA
ABB AB
Customer drw no
Based on
Lang. en
Rev. A
Sheet 5
Cont. sh/ No of sh 6
DocumentStatus: Approved
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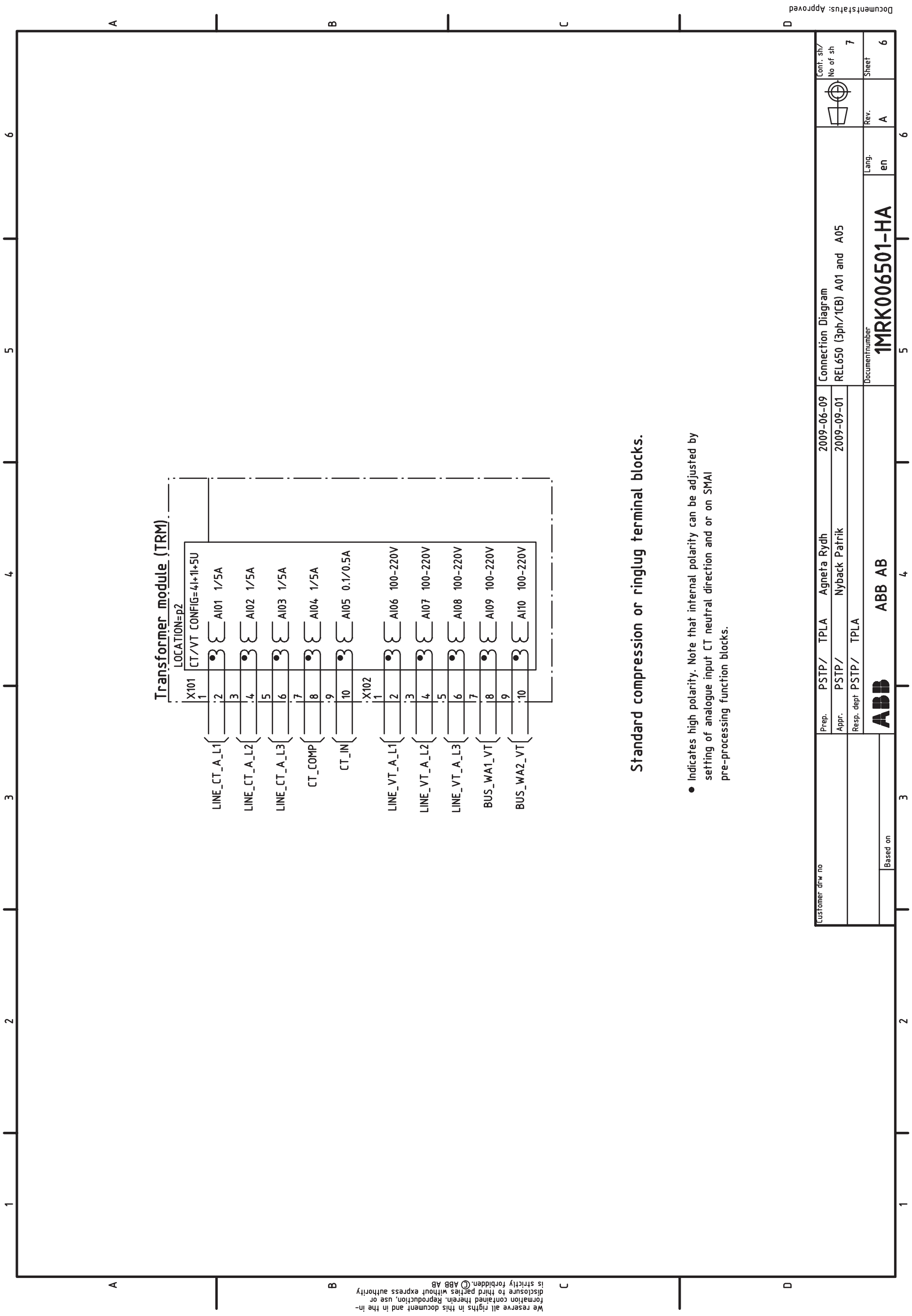
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CT/VT CONFIG=4I+1I+5U
X101
AI01 1/5A
AI02 1/5A
AI03 1/5A
AI04 1/5A
AI05 0.1/0.5A
X102
AI06 100-220V
AI07 100-220V
AI08 100-220V
AI09 100-220V
AI10 100-220V
LINE_CT_A_L1
LINE_CT_A_L2
LINE_CT_A_L3
CT_COMP
CT_IN
LINE_VT_A_L1
LINE_VT_A_L2
LINE_VT_A_L3
BUS_WA1_VT
BUS_WA2_VT
Standard compression or ringlug terminal blocks.
● Indicates high polarity. Note that internal polarity can be adjusted by setting of analogue input CT neutral direction and or on SMAI pre-processing function blocks.
Customer drw no
Prep. PSTP/ TPLA Agneta Rydh 2009-06-09
Appr. PSTP/ Nyback Patrik 2009-09-01
Resp. dept PSTP/ TPLA
Connection Diagram
REL650 (3ph/1CB) A01 and A05
ABB AB
Documentnumber
1MRK006501-HA
Lang. en
Rev. A
Sheet 6
No of sh 7
Based on
DocumentStatus: Approved
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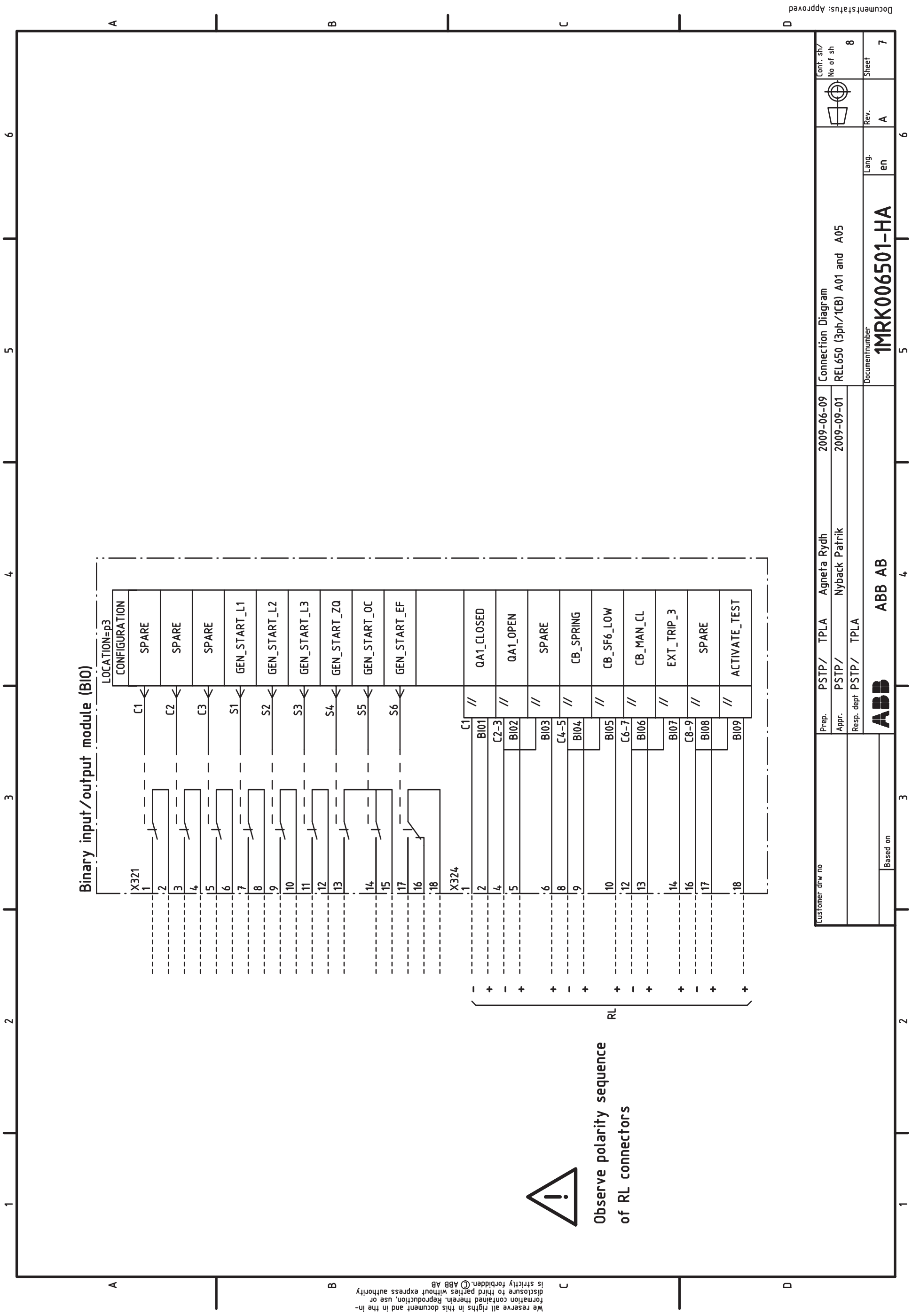
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SPARE
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GEN_START_ZQ
GEN_START_OC
GEN_START_EF
QA1_CLOSED
QA1_OPEN
SPARE
CB_SPRING
CB_SF6_LOW
CB_MAN_CL
EXT_TRIP_3
SPARE
ACTIVATE_TEST
X321
X324
RL
Observe polarity sequence
of RL connectors
Connection Diagram
REL650 (3ph/1CB) A01 and A05
1MRK006501-HA
ABB AB
Agneta Rydh
Nyback Patrik
2009-06-09
2009-09-01
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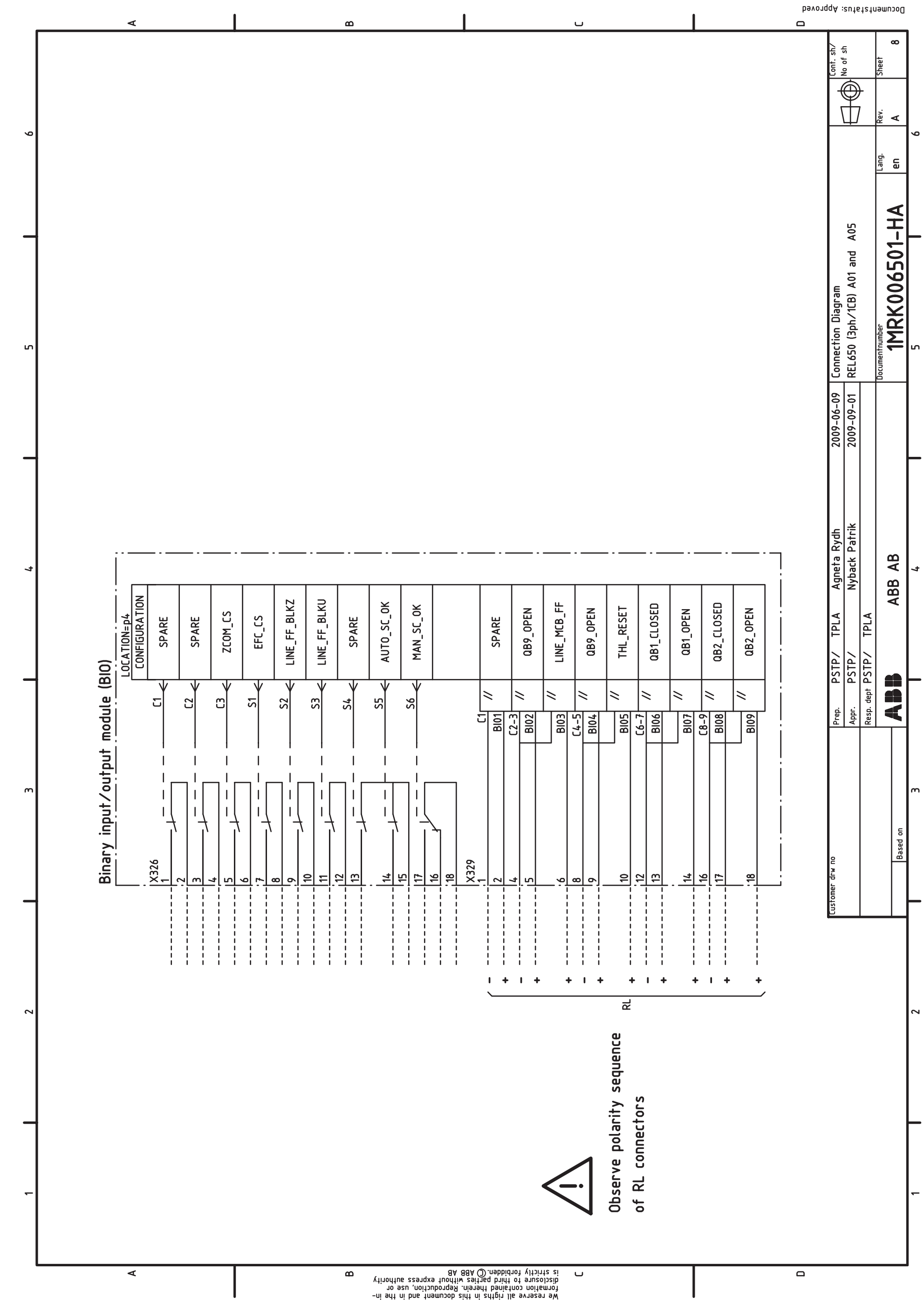
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C2
C3
S1
S2
S3
S4
S5
S6
X329
SPARE
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LINE_MCB_FF
QB9_OPEN
THL_RESET
QB1_CLOSED
QB1_OPEN
QB2_CLOSED
QB2_OPEN
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BI02
BI03
BI04
BI05
BI06
BI07
BI08
BI09
C2-3
C4-5
C6-7
C8-9
RL
Observe polarity sequence
of RL connectors
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Based on
Prep. PSTP/ TPLA Agneta Rydh 2009-06-09
Appr. PSTP/ Nyback Patrik 2009-09-01
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Connection Diagram
REL650 (3ph/1CB) A01 and A05
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Section 17 Technical data

17.1 Dimensions

Table 473: Dimensions of the IED

Description	Type	Value
Width	half 19"	220 mm
Height	half 19"	265.9 mm (6U)
Depth	half 19"	249.5 mm
Weight	half 19" box	<10 kg (6U)
	half 19" LHMI	1.3 kg (6U)

17.2 Power supply

Table 474: Power supply

Description	Type 1	Type 2
U_{aux}nominal	100, 110, 120, 220, 240 V AC, 50 and 60 Hz	48, 60, 110, 125 V DC
	110, 125, 220, 250 V DC	
U_{aux}variation	85...110% of U_n (85...264 V AC)	80...120% of U_n (38.4...150 V DC)
	80...120% of U_n (88...300 V DC)	
Maximum load of auxiliary voltage supply	35 W	
Ripple in the DC auxiliary voltage	Max 15% of the DC value (at frequency of 100 Hz)	
Maximum interruption time in the auxiliary DC voltage without resetting the IED	50 ms at U_{aux}	

17.3 Energizing inputs

Table 475: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz	
Operating range		Rated frequency ± 5 Hz	
Current inputs	Rated current, I_n	0.1/0.5 A[1)]	1/5 A[2)]
	Thermal withstand capability: • Continuously • For 1 s • For 10 s	 4 A 100 A 25 A	 20 A 500 A 100 A
	Dynamic current withstand: • Half-wave value	 250 A	 1250 A
	Input impedance	<100 mΩ	<10 mΩ
Voltage inputs	Rated voltage	100 V/ 110 V/ 115 V/ 120 V (Parametrization)	
	Voltage withstand: • Continuous • For 10 s	 2 x U_n (240 V) 3 x U_n (360 V)	
	Burden at rated voltage	<0.05 VA	

1) Residual current
2) Phase currents or residual current

17.4 Binary inputs

Table 476: Binary inputs

Description	Value
Operating range	Maximum input voltage 300 V DC
Rated voltage	24...250 V DC
Current drain	1.6...1.8 mA
Power consumption/input	<0.3 W
Threshold voltage	15...221 V DC (parametrizable in the range in steps of 1% of the rated voltage)

17.5 Signal outputs

Table 477: Signal output and IRF output

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A
Make and carry 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at U< 48/110/220 V DC	≤0.5 A/≤0.1 A/≤0.04 A
Minimum contact load	100 mA at 24 V AC/DC

17.6 Power outputs

Table 478: Power output relays, with or without TCS function

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 U< 48/110/220 V DC	≤1 A/≤0.3 A/≤0.1 A
Minimum contact load	100 mA at 24 V AC/DC

Table 479: Power output relays with TCS function

Description	Value
Control voltage range	20...250 V DC
Current drain through the supervision circuit	~1.0 mA
Minimum voltage over the TCS contact	20 V DC

17.7 Data communication interfaces

Table 480: Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
LAN/HMI port (X0)[1)]	-	CAT 6 S/FTP or better	100 MBits/s
LAN1 (X1)	TCP/IP protocol	Fibre-optic cable with LC connector	100 MBits/s

1) Only available for the external HMI option.

Table 481: Fibre-optic communication link

Wave length	Fibre type	Connector	Permitted path attenuation[1]	Distance
1300 nm	MM 62.5/125 µm glass fibre core	LC	<8 dB	2 km

1) Maximum allowed attenuation caused by connectors and cable together

Table 482: X4/IRIG-B interface

Type	Protocol	Cable
Screw terminal, pin row header	IRIG-B	Shielded twisted pair cable Recommended: CAT 5, Belden RS-485 (9841-9844) or Alpha Wire (Alpha 6222-6230)

Table 483: Serial rear interface

Type	Counter connector
Serial port (X9)	Optical serial port, snap-in (not in use)

17.8 Enclosure class

Table 484: Degree of protection of flush-mounted IED

Description	Value
Front side	IP 40
Rear side, connection terminals	IP 20

Table 485: Degree of protection of the LHMI

Description	Value
Front and side	IP 42

17.9 Environmental conditions and tests

Table 486: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)
Short-time service temperature range	-40...+85ºC (<16h) Note: Degradation in MTBF and HMI performance outside the temperature range of -25...+55ºC
Relative humidity	<93%, non-condensing
Table continues on next page	

Description	Value
Atmospheric pressure	86...106 kPa
Altitude	up to 2000 m
Transport and storage temperature range	-40...+85ºC

Table 487: Environmental tests

Description	Type test value	Reference
Dry heat test (humidity <50%)	• 96 h at +55ºC • 16 h at +85ºC	IEC 60068-2-2
Cold test	• 96 h at -25ºC • 16 h at -40ºC	IEC 60068-2-1
Damp heat test, cyclic	• 6 cycles at +25…55°C, humidity 93…95%	IEC 60068-2-30
Storage test	• 96 h at -40ºC • 96 h at +85ºC	IEC 60068-2-48

Section 18 IED and functionality tests

18.1 Electromagnetic compatibility tests

Table 488: Electromagnetic compatibility tests

Description	Type test value	Reference
100 kHz and 1 MHz burst disturbance test		IEC 61000-4-18 IEC 60255-22-1, level 3
• Common mode	2.5 kV	
• Differential mode	1.0 kV	
Electrostatic discharge test		IEC 61000-4-2 IEC 60255-22-2, level 4
• Contact discharge	8 kV	
• Air discharge	15 kV	
Radio frequency interference tests		
• Conducted, common mode OK	10 V (emf), f=150 kHz...80 MHz	IEC 61000-4-6 IEC 60255-22-6, level 3
• Radiated, amplitude-modulated	20 V/m (rms), f=80...1000 MHz and f=1.4...2.7 GHz	IEC 61000-4-3 IEC 60255-22-3
Fast transient disturbance tests		IEC 61000-4-4 IEC 60255-22-4, class A
• Communication ports	2 kV	
• Other ports	4 kV	
Surge immunity test		IEC 61000-4-5 IEC 60255-22-5, level 4/3
• Binary inputs	2 kV line-to-earth, 1kV line-to-line	
• Communication	1 kV line-to-earth	
• Other ports	4 kV line-to-earth, 2 kV line-to-line	
Power frequency (50 Hz) magnetic field		IEC 61000-4-8, level 5
• 3 s	1000 A/m	
• Continuous	100 A/m	

Table continues on next page

Description	Type test value	Reference
Power frequency immunity test • Common mode • Differential mode	300 V rms 150 V rms	IEC 60255-22-7, class A IEC 61000-4-16
Voltage dips and short interruptions	Dips: 40%/200 ms 70%/500 ms Interruptions: 0-50 ms: No restart 0...∞ s : Correct behaviour at power down	IEC 60255-11 IEC 61000-4-11
Electromagnetic emission tests • Conducted, RF-emission (mains terminal) OK 0.15...0.50 MHz 0.5...30 MHz • Radiated RF -emission 0...230 MHz 230...1000 MHz	< 79 dB(µV) quasi peak < 66 dB(µV) average < 73 dB(µV) quasi peak < 60 dB(µV) average < 40 dB(µV/m) quasi peak, measured at 10 m distance < 47 dB(µV/m) quasi peak, measured at 10 m distance	EN 55011, class A IEC 60255-25

18.2 Insulation tests

Table 489: Insulation tests

Description	Type test value	Reference
Dielectric tests: • Test voltage	2 kV, 50 Hz, 1 min 1 kV, 50 Hz, 1min, communication	IEC 60255-5
Impulse voltage test: • Test voltage	5 kV, unipolar impulses, waveform 1.2/50 µs, source energy 0.5 J 1 kV, unipolar impulses, waveform 1.2/50 µs, source energy 0.5 J, communication	IEC 60255-5
Insulation resistance measurements • Isolation resistance	>100 MΩ, 500 V DC	IEC 60255-5
Protective bonding resistance • Resistance	<0.1 Ω (60 s)	IEC 60255-27

18.3 Mechanical tests

Table 490: Mechanical tests

Description	Reference	Requirement
Vibration response tests (sinusoidal)	IEC 60255-21-1	Class 2
Vibration endurance test	IEC60255-21-1	Class 1
Shock response test	IEC 60255-21-2	Class 1
Shock withstand test	IEC 60255-21-2	Class 1
Bump test	IEC 60255-21-2	Class 1
Seismic test	IEC 60255-21-3	Class 2

18.4 Product safety

Table 491: Product safety

Description	Reference
LV directive	2006/95/EC
Standard	EN 60255-27 (2005)

18.5 EMC compliance

Table 492: EMC compliance

Description	Reference
EMC directive	2004/108/EC
Standard	EN 50263 (2000) EN 60255-26 (2007)

Section 19 Time inverse characteristics

19.1 Application

In order to assure time selectivity between different overcurrent protections in different points in the network different time delays for the different relays are normally used. The simplest way to do this is to use definite time delay. In more sophisticated applications current dependent time characteristics are used. Both alternatives are shown in a simple application with three overcurrent protections connected in series.

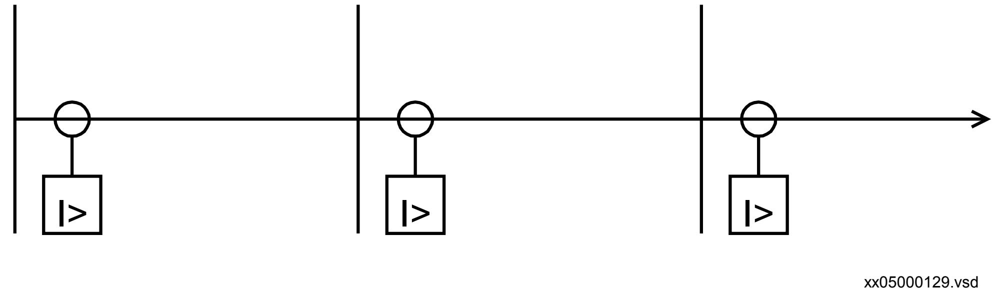

Figure 249: Three overcurrent protections connected in series

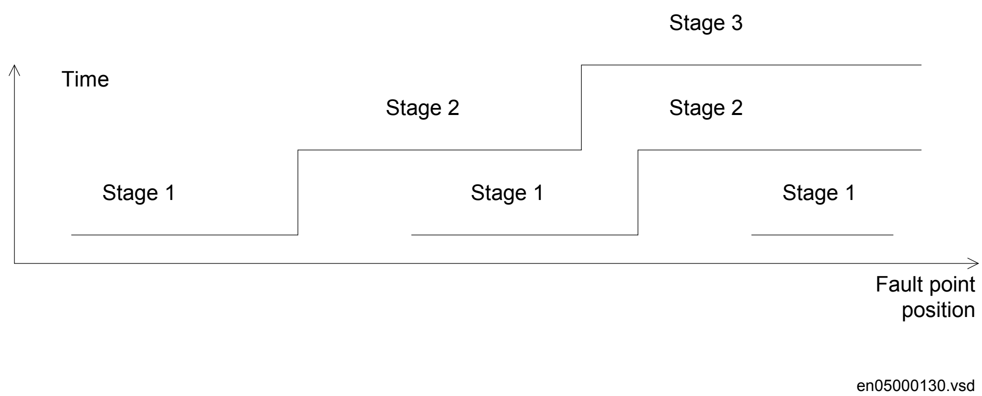

Figure 250: Definite time overcurrent characteristics

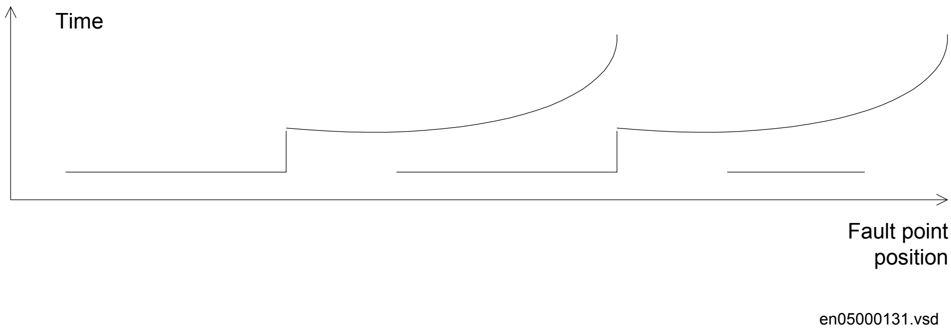

Figure 251: Inverse time overcurrent characteristics with inst. function

The inverse time characteristic makes it possible to minimize the fault clearance time and still assure the selectivity between protections.

To assure selectivity between protections there must be a time margin between the operation time of the protections. This required time margin is dependent of following factors, in a simple case with two protections in series:

- Difference between pick-up time of the protections to be co-ordinated
- Opening time of the breaker closest to the studied fault
- Reset time of the protection
- Margin dependent of the time-delay inaccuracy of the protections

Assume we have the following network case.

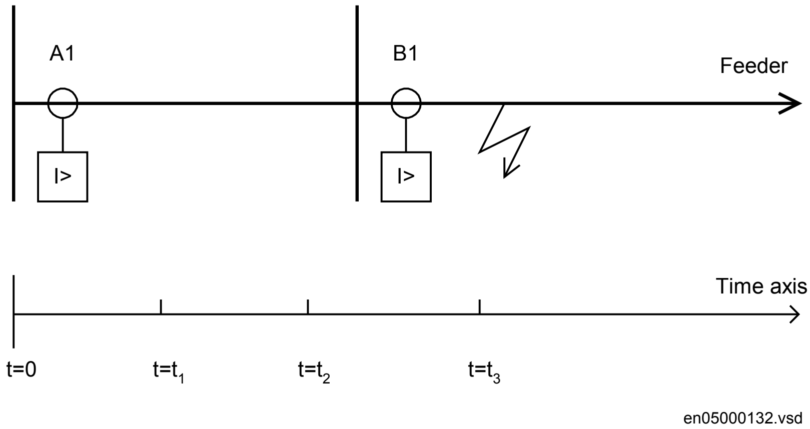

Figure 252: Selectivity steps for a fault on feeder B1

where:

t=0	is The fault occurs
$t=t_1$	is Protection B1 trips
$t=t_2$	is Breaker at B1 opens
$t=t_3$	is Protection A1 resets

In the case protection B1 shall operate without any intentional delay (instantaneous). When the fault occurs the protections start to detect the fault current. After the time t_1 the protection B1 send a trip signal to the circuit breaker. The protection A1 starts its delay timer at the same time, with some deviation in time due to differences between the two protections. There is a possibility that A1 will start before the trip is sent to the B1 circuit breaker.

At the time t_2 the circuit breaker B1 has opened its primary contacts and thus the fault current is interrupted. The breaker time (t2 - t1) can differ between different faults. The maximum opening time can be given from manuals and test protocols. Still at t_2 the timer of protection A1 is active.

At time t_3 the protection A1 is reset, i.e. the timer is stopped.

In most applications it is required that the delay times shall reset as fast as possible when the current fed to the protection drops below the set current level, the reset time shall be minimized. In some applications it is however beneficial to have some type of delayed reset time of the overcurrent function. This can be the case in the following applications:

- If there is a risk of intermittent faults. If the current relay, close to the faults, starts and resets there is a risk of unselective trip from other protections in the system.
- Delayed resetting could give accelerated fault clearance in case of automatic reclosing to a permanent fault.
- Overcurrent protection functions are sometimes used as release criterion for other protection functions. It can often be valuable to have a reset delay to assure the release function.

19.2 Operation principle

19.2.1 Mode of operation

The function can operate in a definite time-lag mode or in a current dependent inverse time mode. For the inverse time characteristic both ANSI and IEC based standard curves are available.

If current in any phase exceeds the set start current value , a timer, according to the selected operating mode, is started. The component always uses the maximum of the three phase current values as the current level used in timing calculations.

In case of definite time-lag mode the timer will run constantly until the time is reached or until the current drops below the reset value (start value minus the hysteresis) and the reset time has elapsed.

The general expression for inverse time curves is according to equation 109.

$$t[s] = \left(\frac{A}{\left(\frac{i}{in>}\right)^{p} - C} + B \right) \cdot k$$

(Equation 109)

where:	
p, A, B, C	are constants defined for each curve type,
in>	is the set start current for step n,
k	is set time multiplier for step n and
i	is the measured current.

For inverse time characteristics a time will be initiated when the current reaches the set start level. From the general expression of the characteristic the following can be seen:

$$(t_{op} - B \cdot k) \cdot \left(\left(\frac{i}{in >} \right)^{p} - C \right) = A \cdot k$$

(Equation 110)

where:

t_{op}	is the operating time of the protection

The time elapsed to the moment of trip is reached when the integral fulfils according to equation 111, in addition to the constant time delay:

$$\int_{0}^{t} \left(\left(\frac{i}{in >} \right)^{p} - C \right) \cdot dt \geq A \cdot k$$

(Equation 111)

For the numerical protection the sum below must fulfil the equation for trip.

$$\Delta t \cdot \sum_{j=1}^{n} \left(\left(\frac{i(j)}{in >} \right)^{p} - C \right) \geq A \cdot k$$

(Equation 112)

where:

j = 1	is the first protection execution cycle when a fault has been detected, i.e. when $\frac{i}{in >} > 1$
Δt	is the time interval between two consecutive executions of the protection algorithm,
n	is the number of the execution of the algorithm when the trip time equation is fulfilled, i.e. when a trip is given and
i (j)	is the fault current at time j

For inverse time operation, the inverse time characteristic is selectable. Both the IEC and ANSI/IEEE standardized inverse time characteristics are supported.

For the IEC curves there is also a setting of the minimum time-lag of operation, see figure 253.

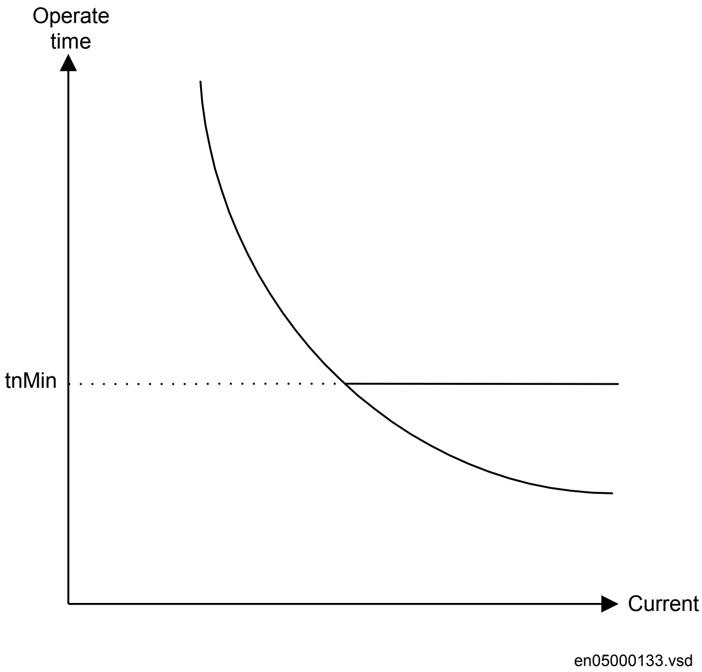

Figure 253: Minimum time-lag operation for the IEC curves

In order to fully comply with IEC curves definition setting parameter tMin shall be set to the value which is equal to the operating time of the selected IEC inverse time curve for measured current of twenty times the set current pickup value. Note that the operating time value is dependent on the selected setting value for time multiplier k.

In addition to the ANSI and IEC standardized characteristics, there are also two additional inverse curves available; the RI curve and the RD curve.

The RI inverse time curve emulates the characteristic of the electromechanical ASEA relay RI. The curve is described by equation 114:

$$t[s] = \left(\frac{k}{0.339 - 0.235 \cdot \frac{in>}{i}} \right)$$

(Equation 114)

where:

in>	is the set start current for step n
k	is set time multiplier for step n
i	is the measured current

The RD inverse curve gives a logarithmic delay, as used in the Combiflex protection RXIDG. The curve enables a high degree of selectivity required for sensitive residual earth fault current protection, with ability to detect high resistive earth faults. The curve is described by equation 115:

$$t[s] = 5.8 - 1.35 \cdot \ln\left(\frac{i}{k \cdot in >}\right)$$

(Equation 115)

where:

in>	is the set start current for step n,
k	is set time multiplier for step n and
i	is the measured current

The timer will be reset directly when the current drops below the set start current level minus the hysteresis.

19.3 Inverse time characteristics

Table 493: ANSI Inverse time characteristics

Function	Range or value	Accuracy
Operating characteristic: $$t = \left(\frac{A}{\left(I^P - 1\right)} + B\right) \cdot k$$ (Equation 116) $I = I_{measured}/I_{set}$	k = 0.05-999 in steps of 0.01 unless otherwise stated	-
ANSI Extremely Inverse	A=28.2, B=0.1217, P=2.0	ANSI/IEEE C37.112, class 5 + 40 ms
ANSI Very inverse	A=19.61, B=0.491, P=2.0	
ANSI Normal Inverse	A=0.0086, B=0.0185, P=0.02, tr=0.46	
ANSI Moderately Inverse	A=0.0515, B=0.1140, P=0.02	
ANSI Long Time Extremely Inverse	A=64.07, B=0.250, P=2.0	
ANSI Long Time Very Inverse	A=28.55, B=0.712, P=2.0	
ANSI Long Time Inverse	k=(0.01-1.20) in steps of 0.01 A=0.086, B=0.185, P=0.02	

Table 494: IEC Inverse time characteristics

Function	Range or value	Accuracy
Operating characteristic: $$t = \left(\frac{A}{\left(I^P - 1 \right)} \right) \cdot k$$ (Equation 117) $I = I_{measured}/I_{set}$	k = (0.05-1.10) in steps of 0.01	-
IEC Normal Inverse	A=0.14, P=0.02	IEC 60255-3, class 5 + 40 ms
IEC Very inverse	A=13.5, P=1.0	
IEC Inverse	A=0.14, P=0.02	
IEC Extremely inverse	A=80.0, P=2.0	
IEC Short time inverse	A=0.05, P=0.04	
IEC Long time inverse	A=120, P=1.0	

Table 495: RI and RD type inverse time characteristics

Function	Range or value	Accuracy
RI type inverse characteristic $$t = \frac{1}{0.339 - \frac{0.236}{I}} \cdot k$$ (Equation 118) $I = I_{measured}/I_{set}$	k=(0.05-999) in steps of 0.01	IEC 60255-3, class 5 + 40 ms
RD type logarithmic inverse characteristic $$t = 5.8 - \left(1.35 \cdot \ln \frac{I}{k} \right)$$ (Equation 119) $I = I_{measured}/I_{set}$	k=(0.05-1.10) in steps of 0.01	IEC 60255-3, class 5 + 40 ms

Table 496: *Inverse time characteristics for Two step undervoltage protection UV2PTUV*

Function	Range or value	Accuracy
Type A curve: $$t = \frac{k}{\left(\frac{U< - U}{U<}\right)}$$ (Equation 120) U< = U_{set} U = $UV_{measured}$	k = (0.05-1.10) in steps of 0.01	Class 5 +40 ms
Type B curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U< - U}{U<} - 0.5\right)^{2.0}} + 0.055$$ (Equation 121) U< = U_{set} U = $U_{measured}$	k = (0.05-1.10) in steps of 0.01	

Table 497: *Inverse time characteristics for Two step overvoltage protection OV2PTOV*

Function	Range or value	Accuracy
Type A curve: $$t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$$ (Equation 122) U> = U_{set} U = $U_{measured}$	k = (0.05-1.10) in steps of 0.01	Class 5 +40 ms
Type B curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0} - 0.035}$$ (Equation 123)	k = (0.05-1.10) in steps of 0.01	
Type C curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0} - 0.035}$$ (Equation 124)	k = (0.05-1.10) in steps of 0.01	

Table 498: Inverse time characteristics for Two step residual overvoltage protection ROV2PTOV

Function	Range or value	Accuracy
Type A curve: $$t = \frac{k}{\left(\frac{U - U>}{U>}\right)}$$ (Equation 125) U> = U_{set} U = $U_{measured}$	k = (0.05-1.10) in steps of 0.01	Class 5 +40 ms
Type B curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{2.0} - 0.035}$$ (Equation 126)	k = (0.05-1.10) in steps of 0.01	
Type C curve: $$t = \frac{k \cdot 480}{\left(32 \cdot \frac{U - U>}{U>} - 0.5\right)^{3.0} - 0.035}$$ (Equation 127)	k = (0.05-1.10) in steps of 0.01	

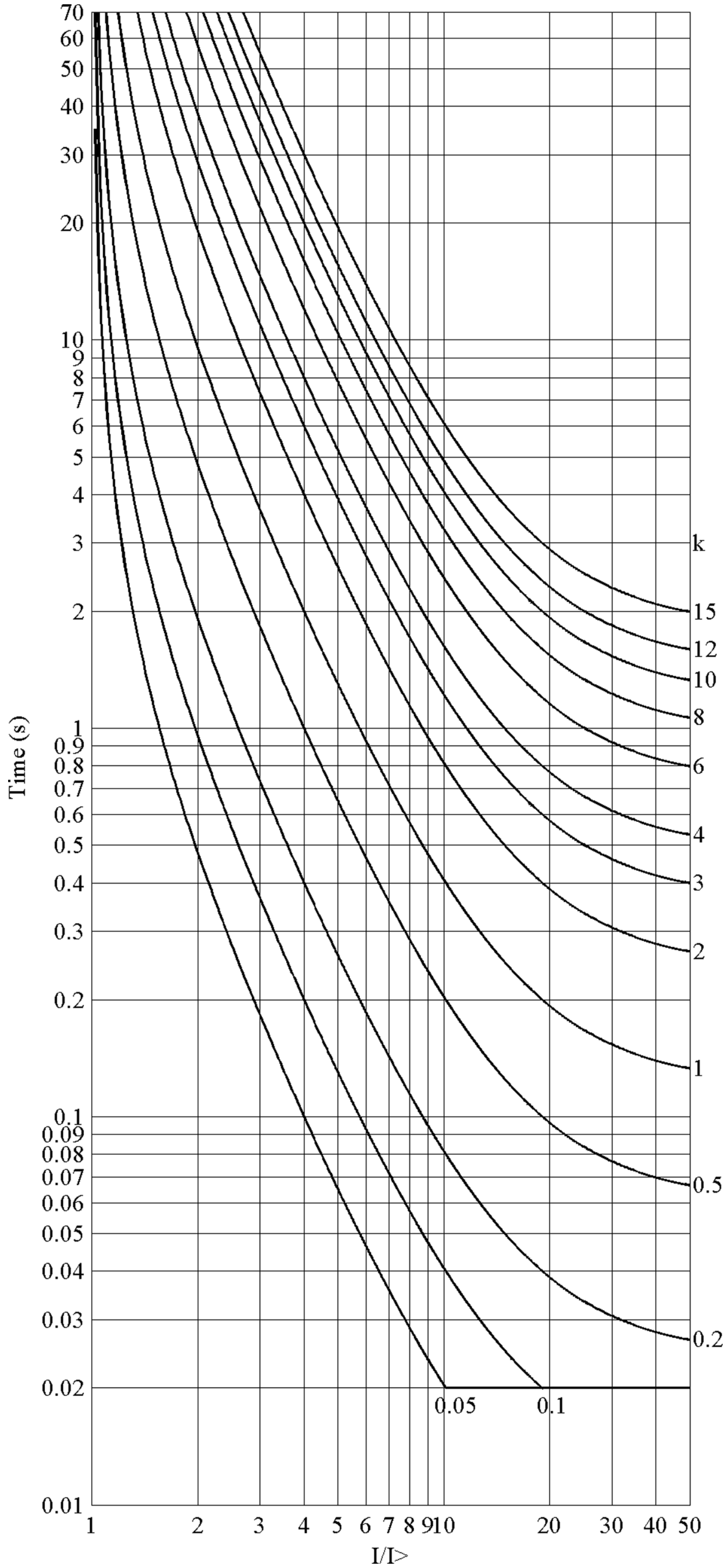

Figure 254: ANSI Extremely inverse time characteristics

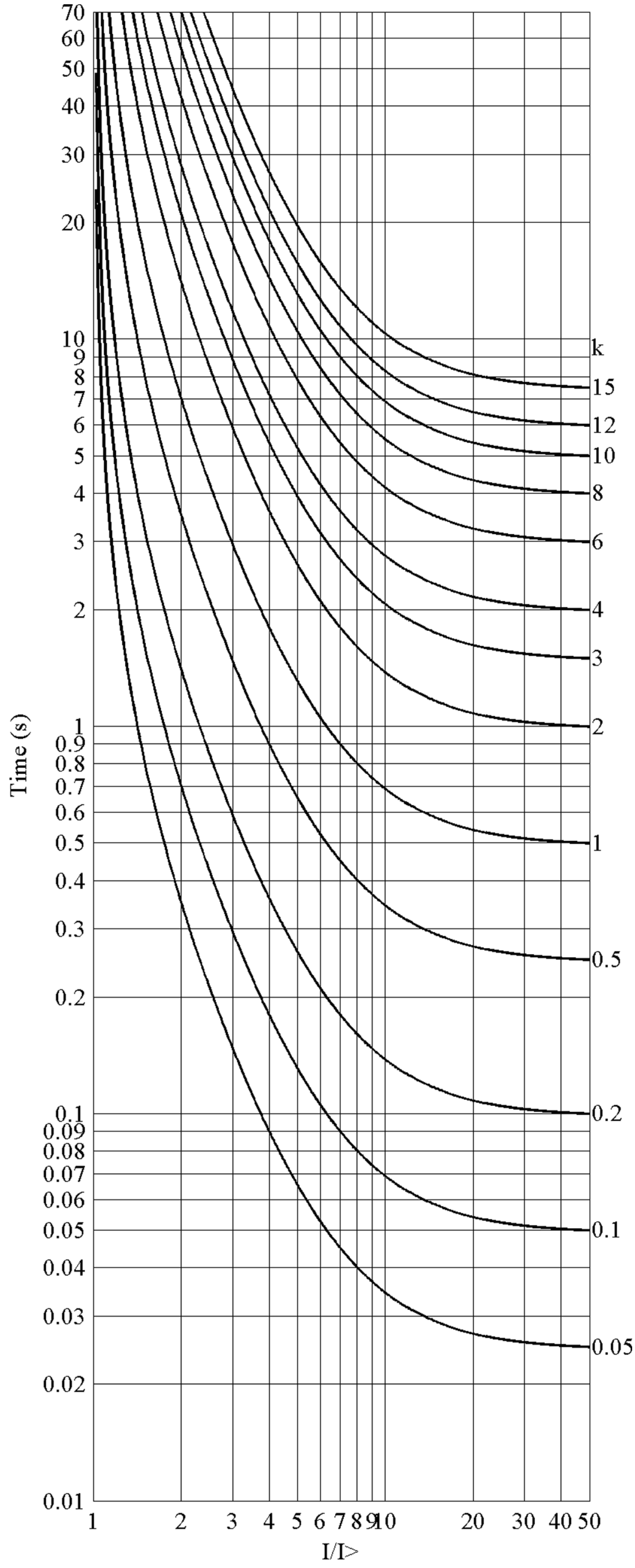

Figure 255: ANSI Very inverse time characteristics

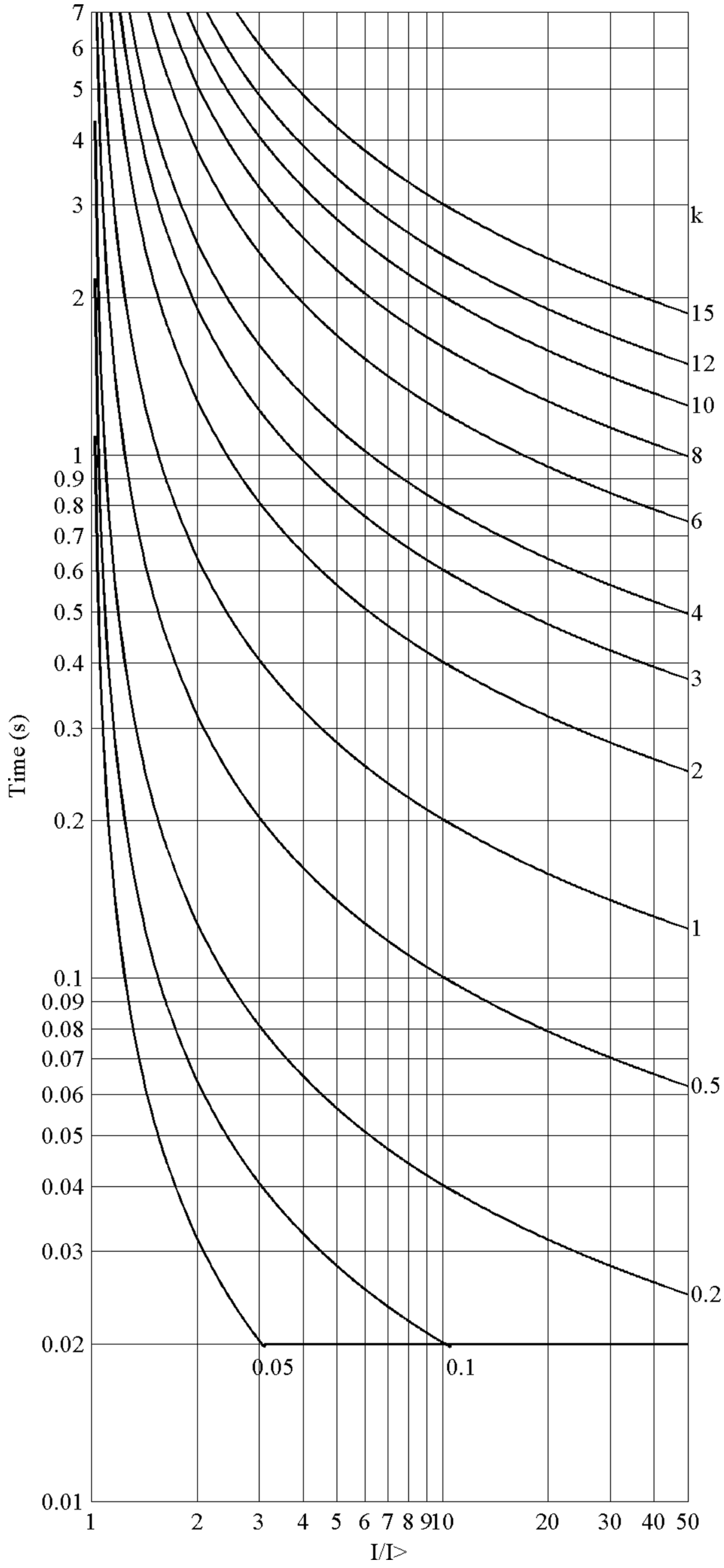

Figure 256: ANSI Normal inverse time characteristics

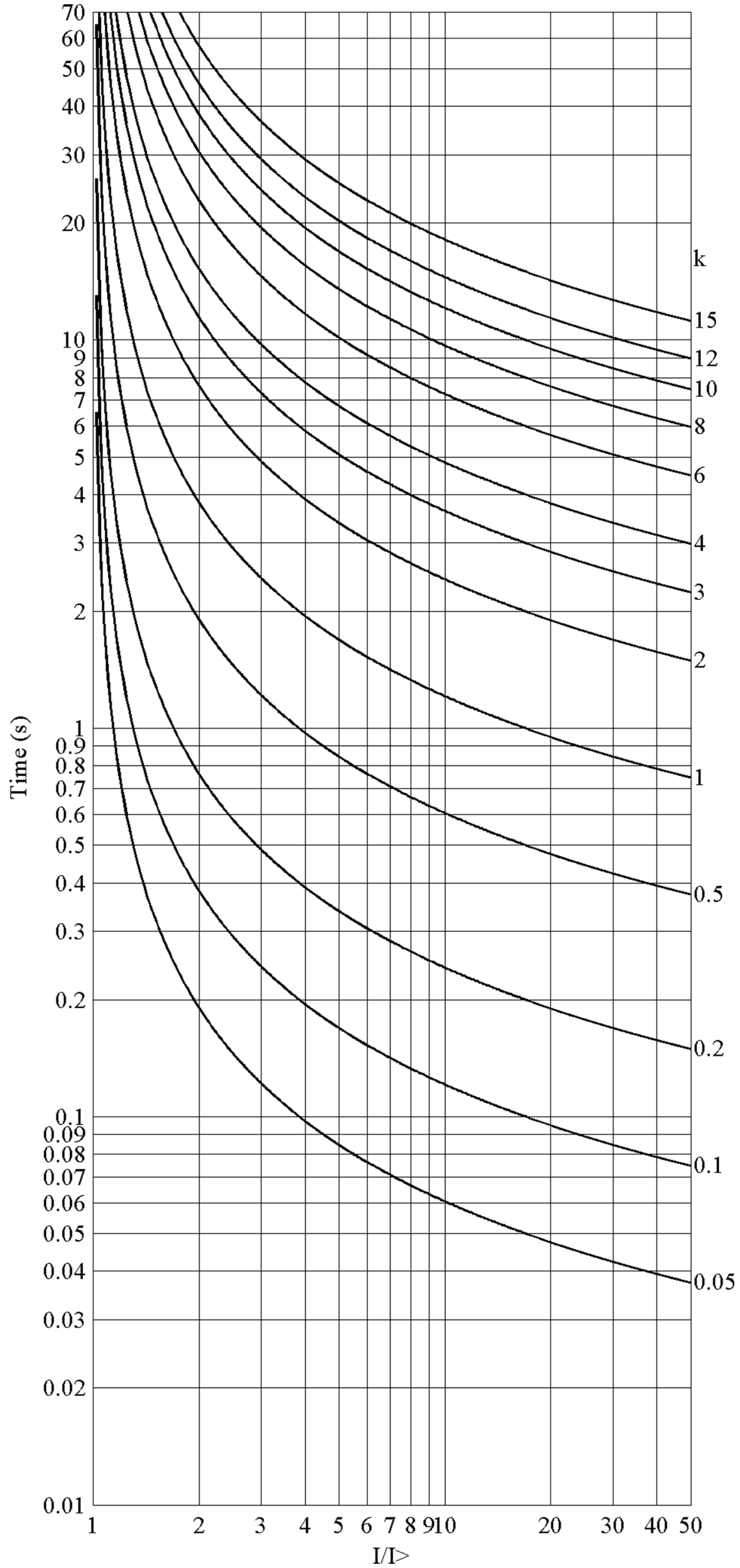

Figure 257: ANSI Moderately inverse time characteristics

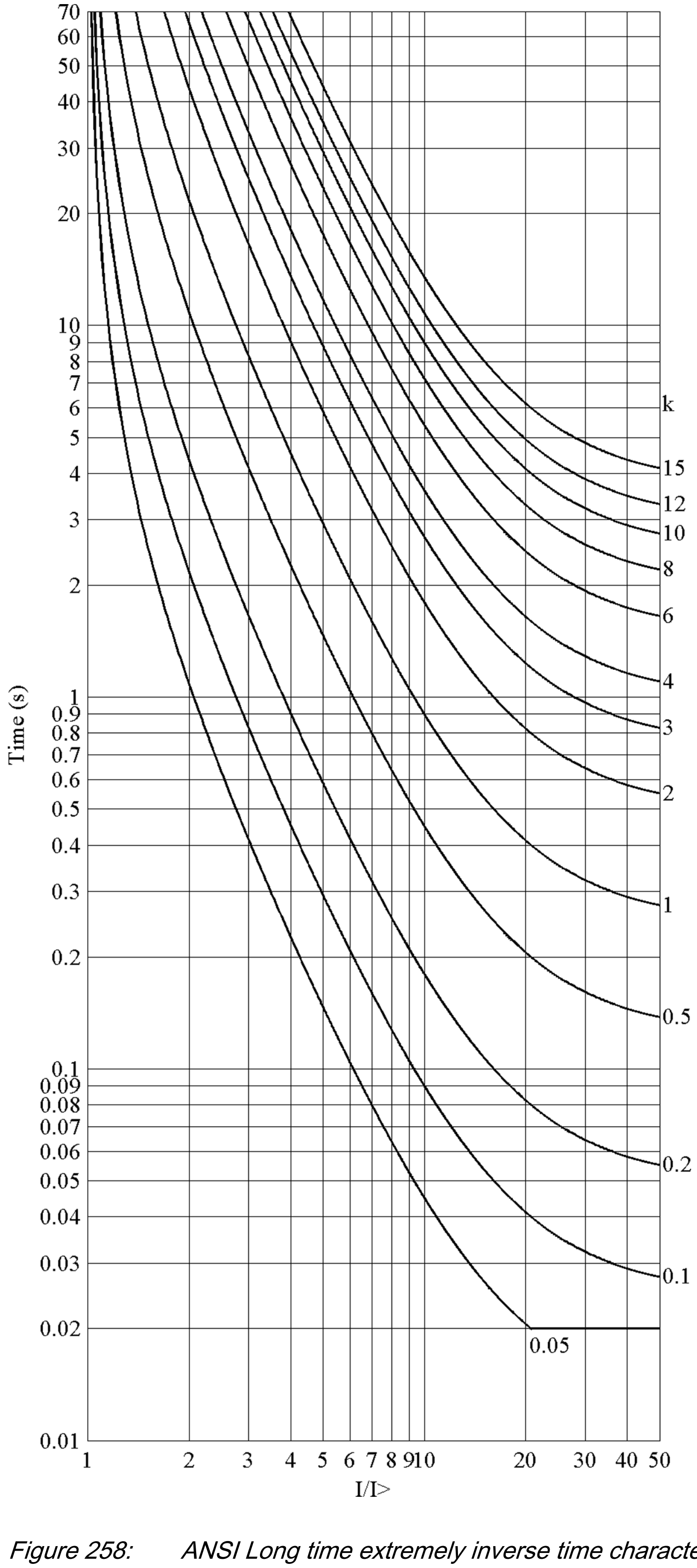

Figure 258: ANSI Long time extremely inverse time characteristics

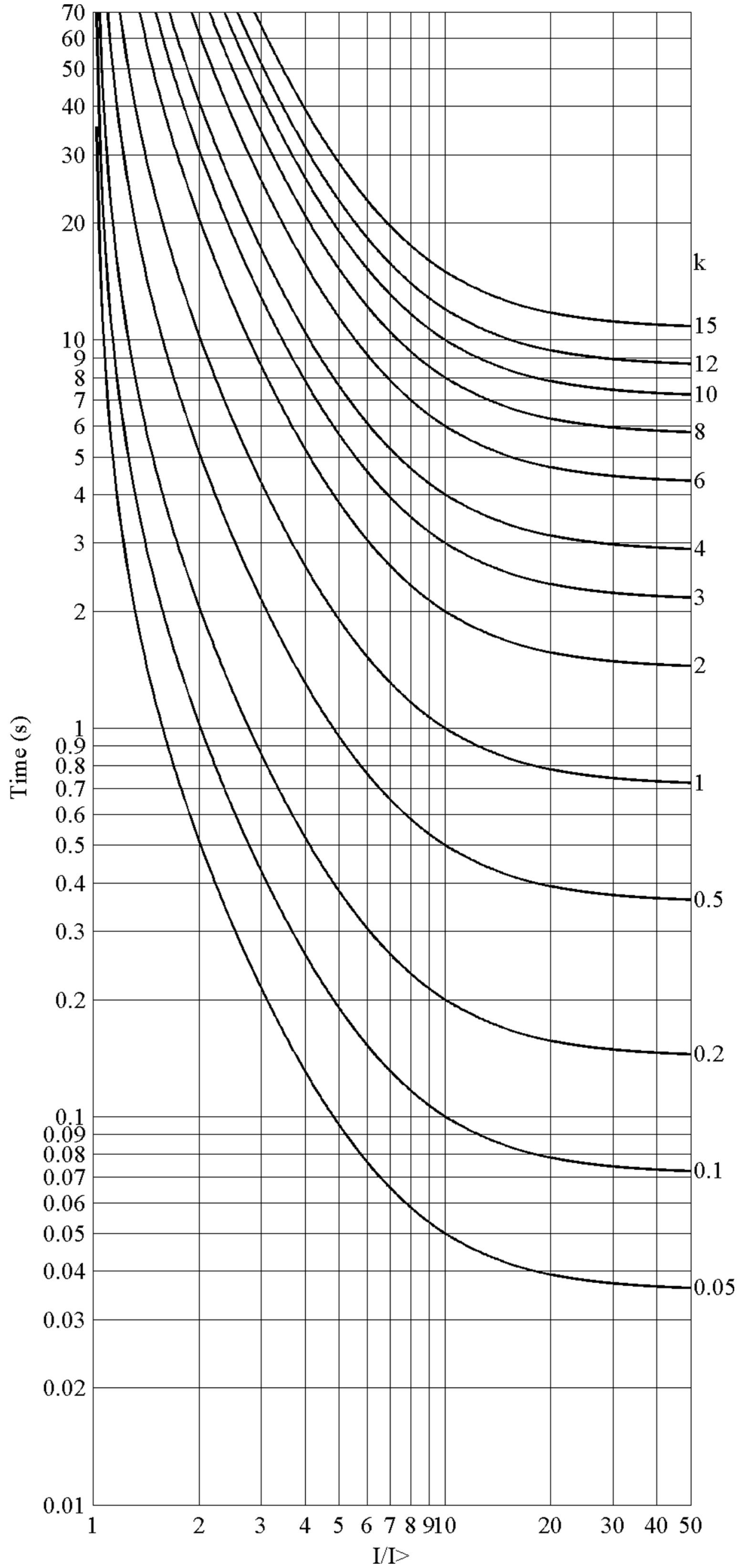

Figure 259: ANSI Long time very inverse time characteristics

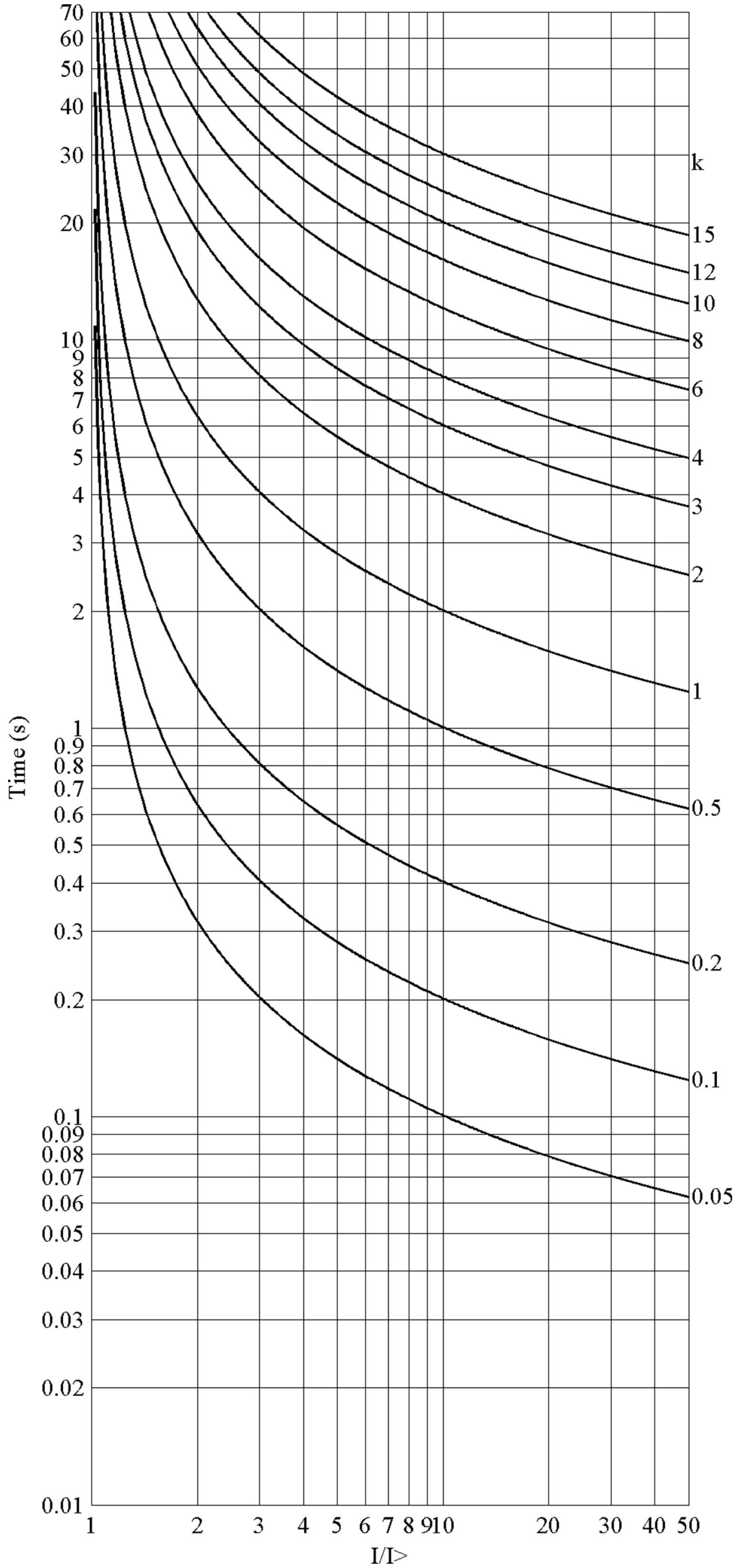

Figure 260: ANSI Long time inverse time characteristics

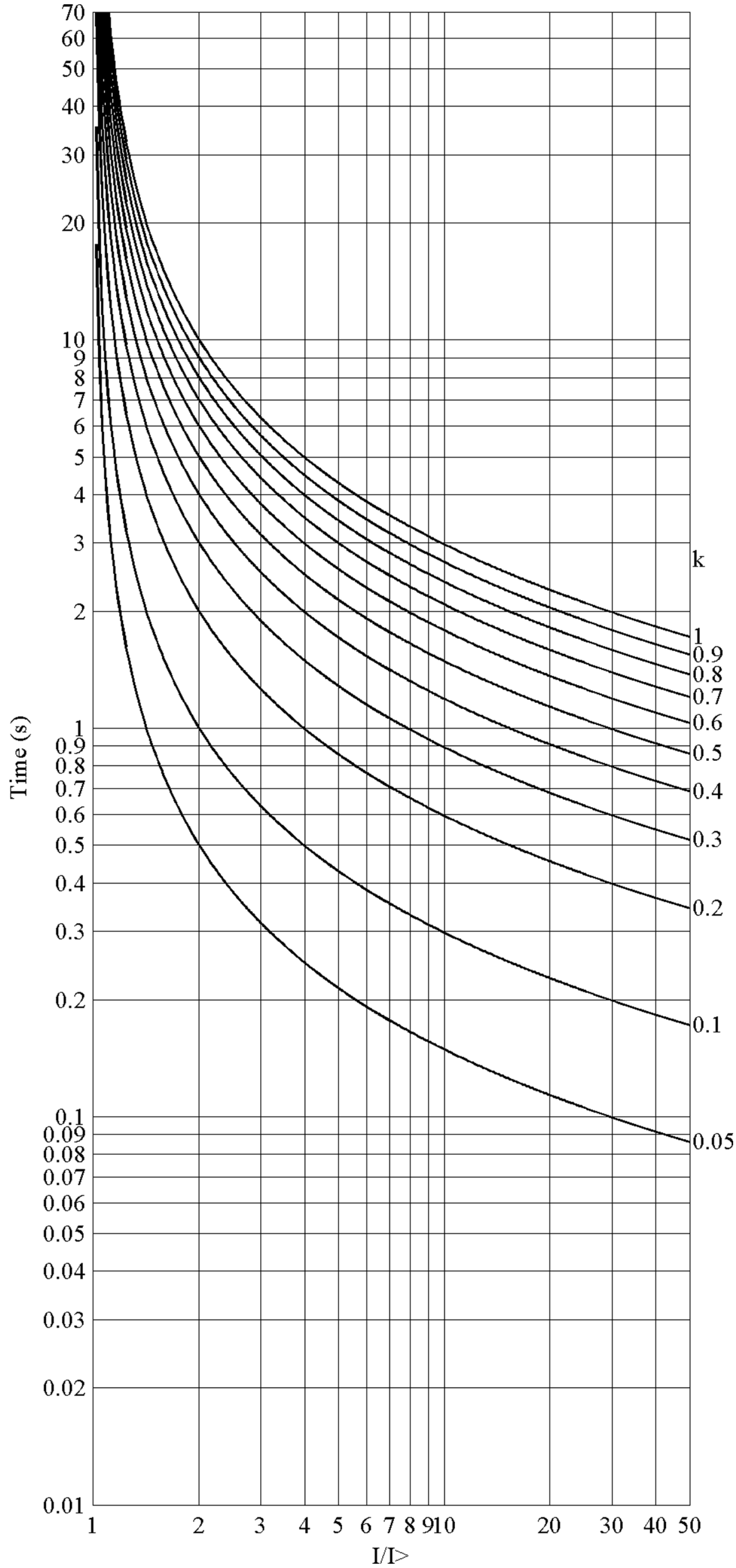

Figure 261: IEC Normal inverse time characteristics

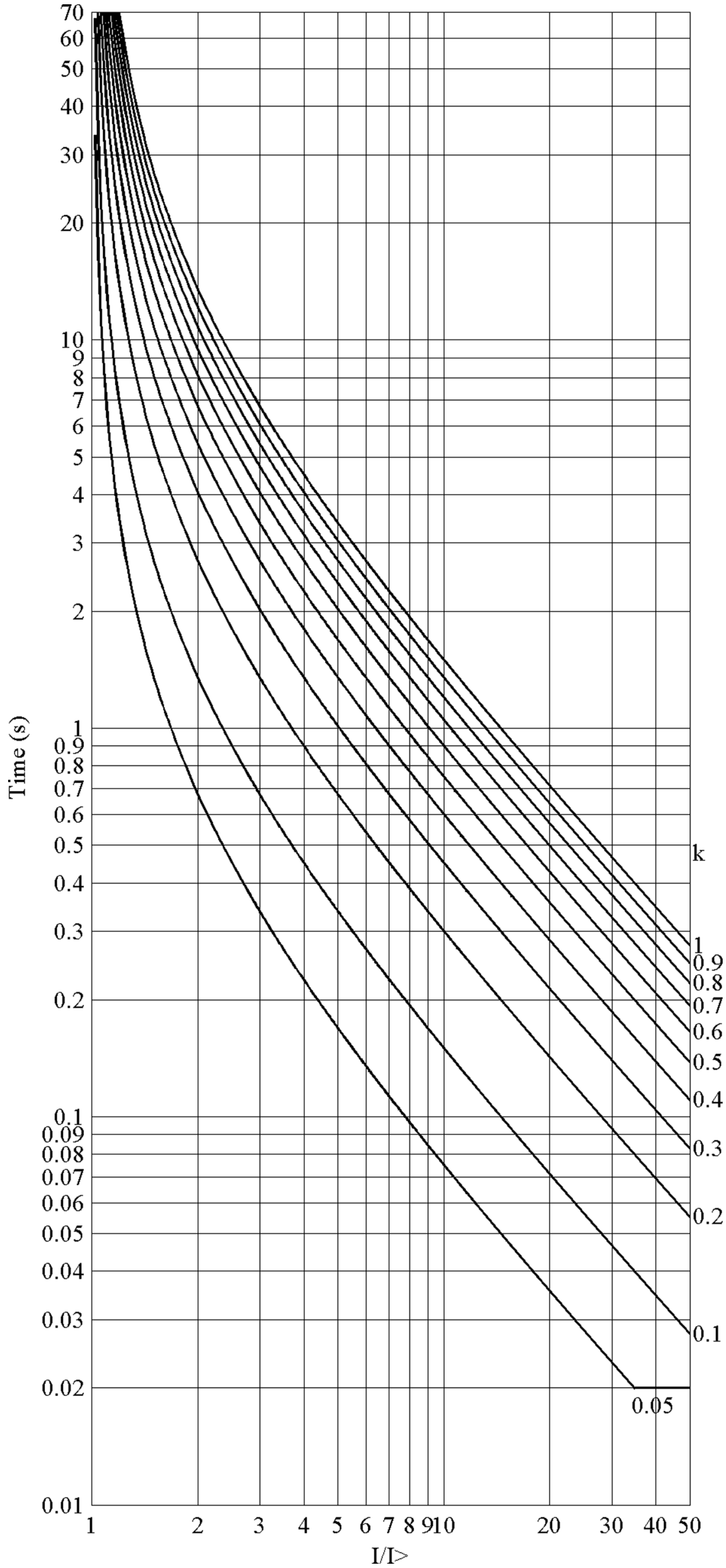

Figure 262: IEC Very inverse time characteristics

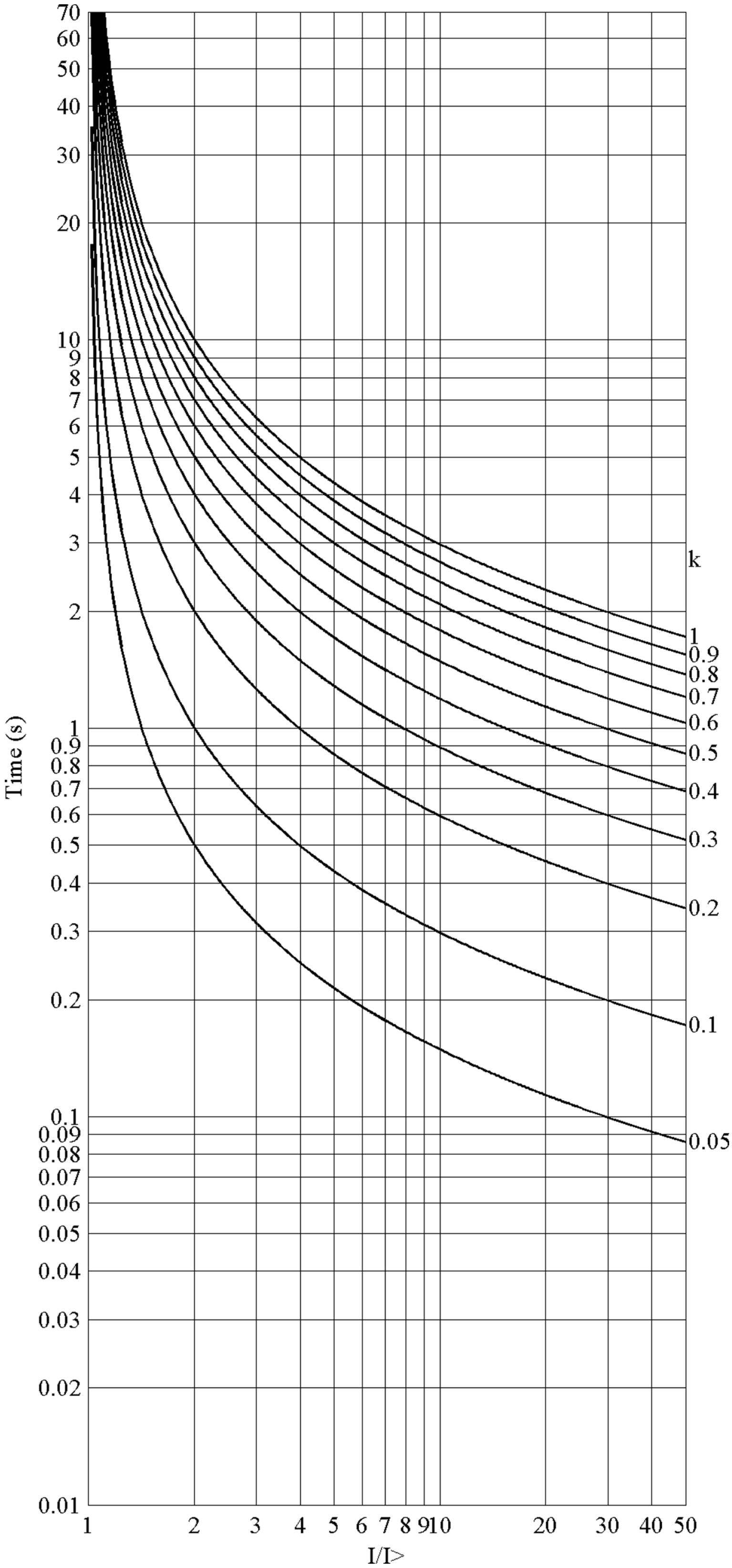

Figure 263: IEC Inverse time characteristics

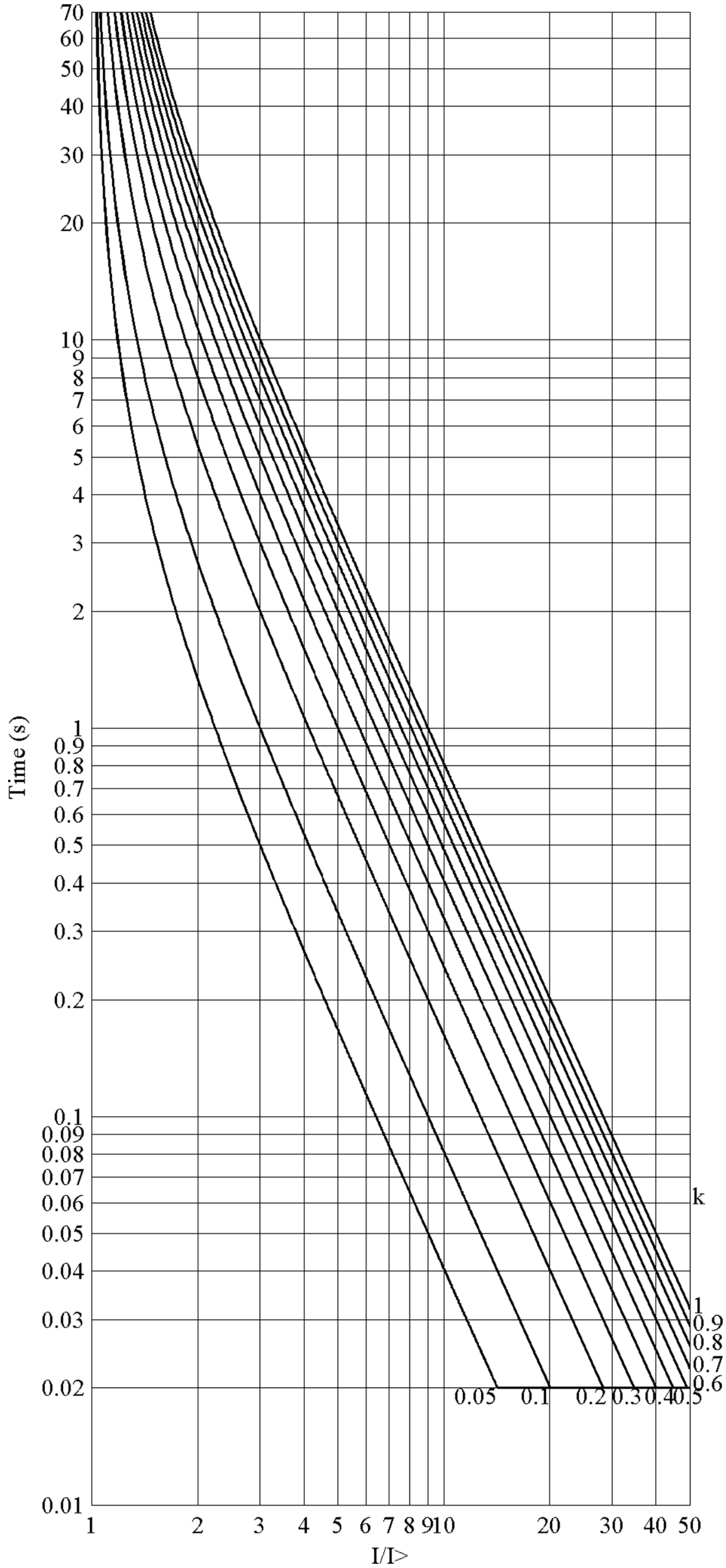

Figure 264: IEC Extremely inverse time characteristics

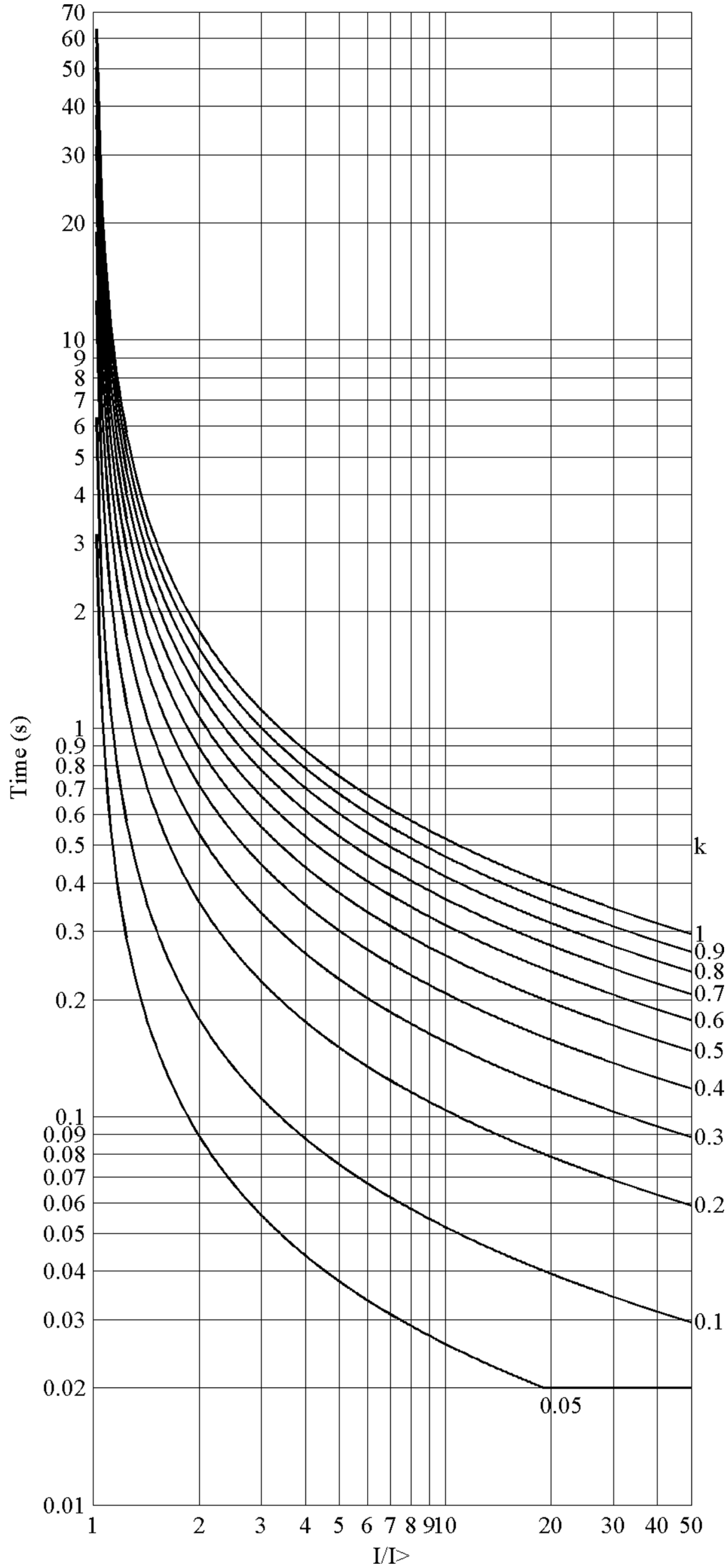

Figure 265: IEC Short time inverse time characteristics

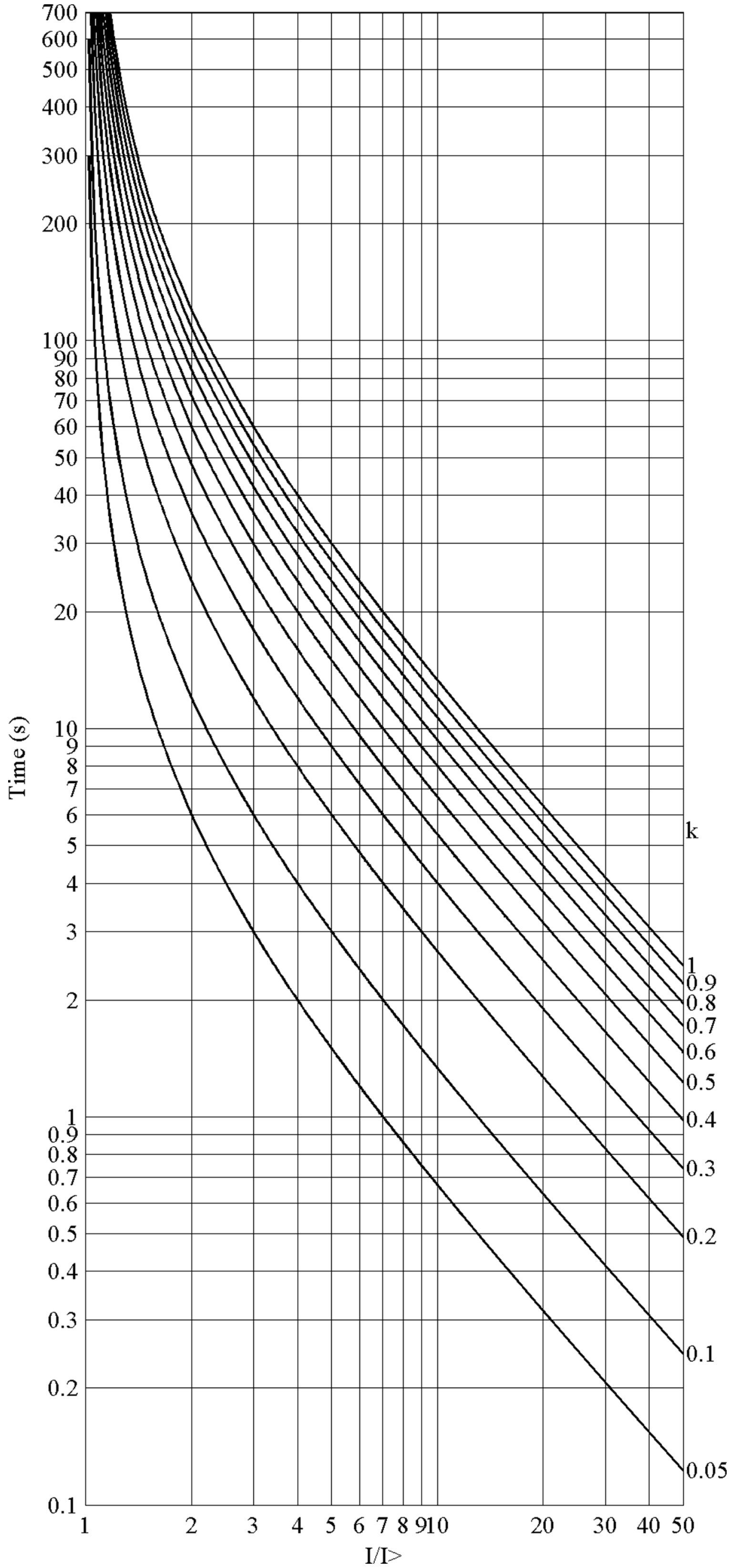

Figure 266: IEC Long time inverse time characteristics

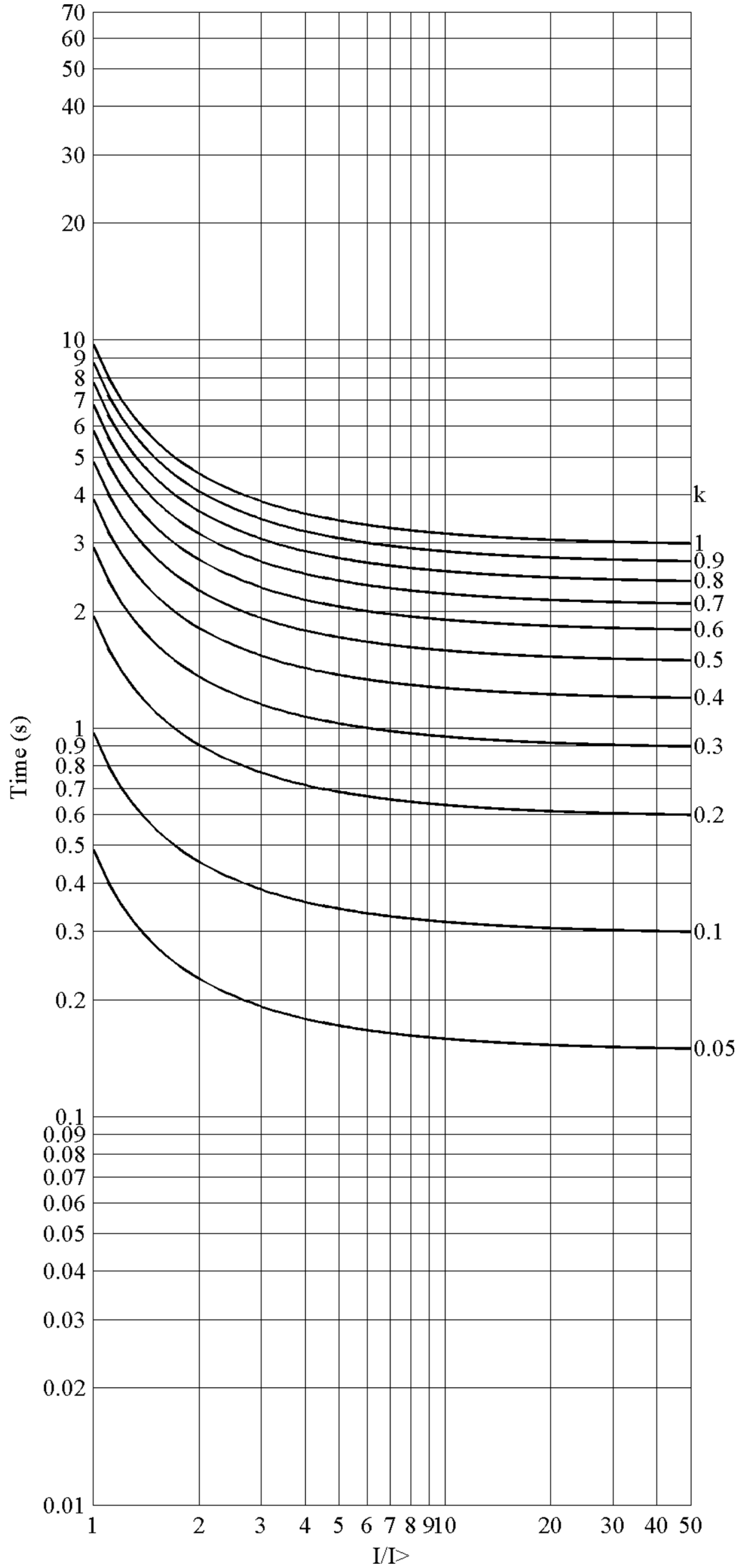

Figure 267: RI-type inverse time characteristics

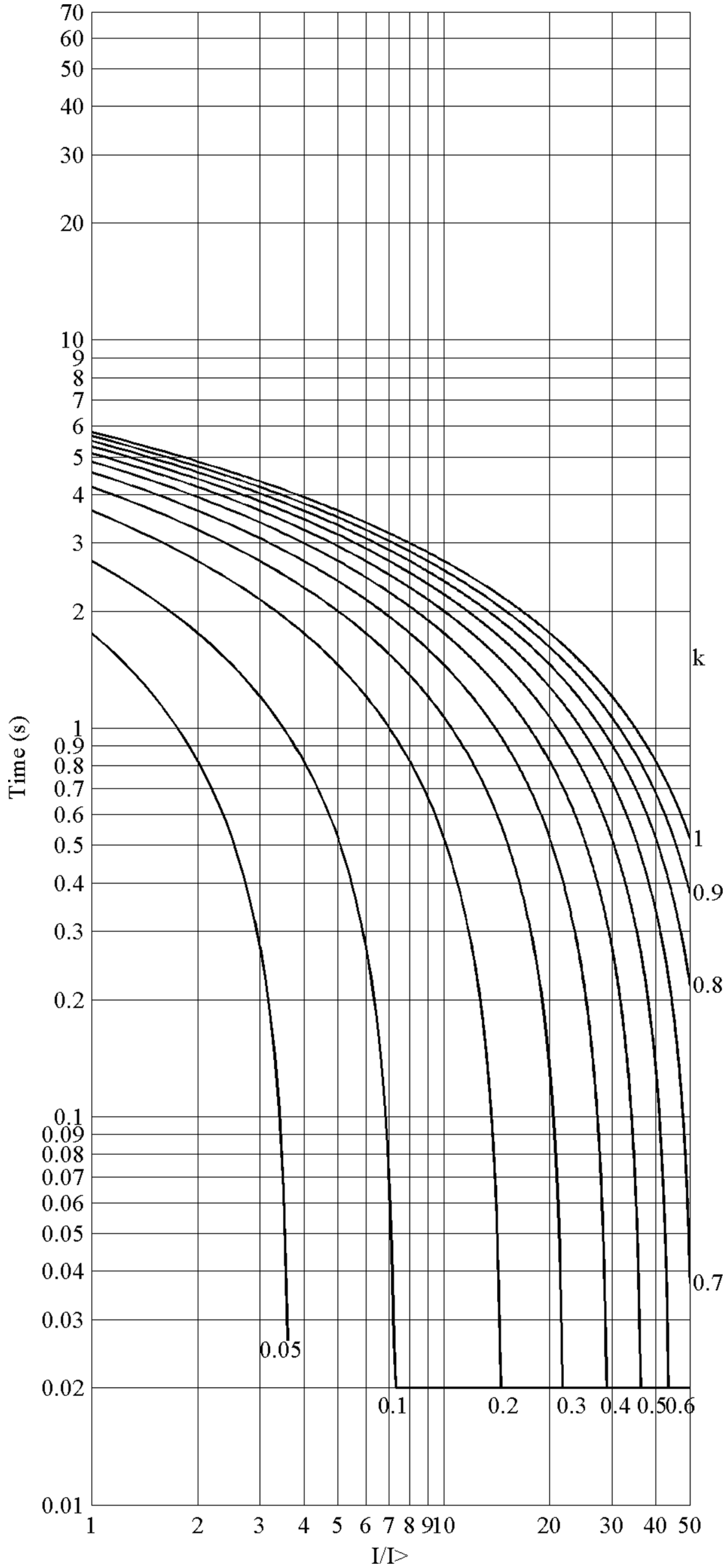

Figure 268: RD-type inverse time characteristics

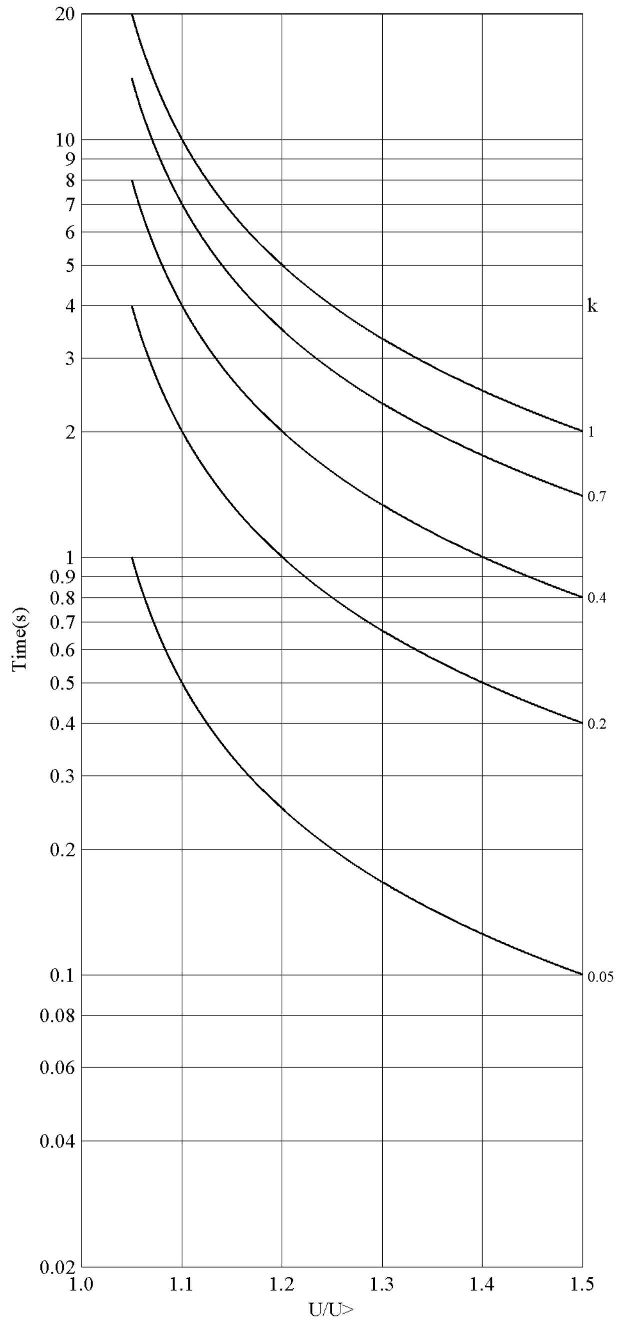

Figure 269: Inverse curve A characteristic of overvoltage protection

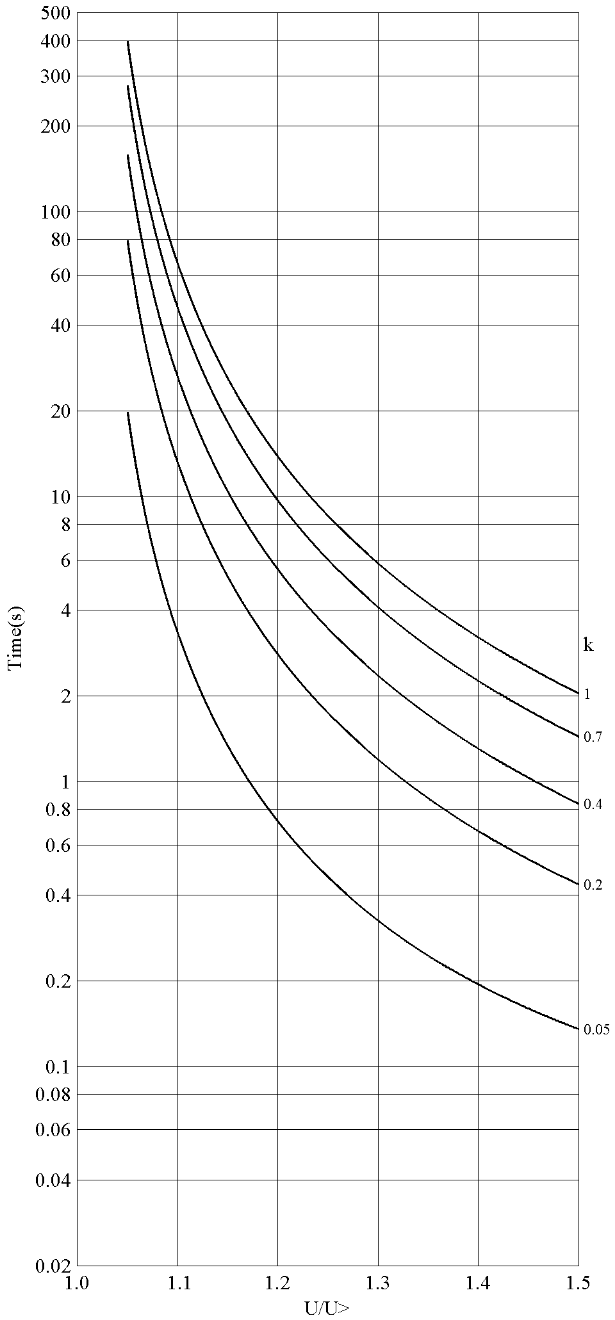

Figure 270: Inverse curve B characteristic of overvoltage protection

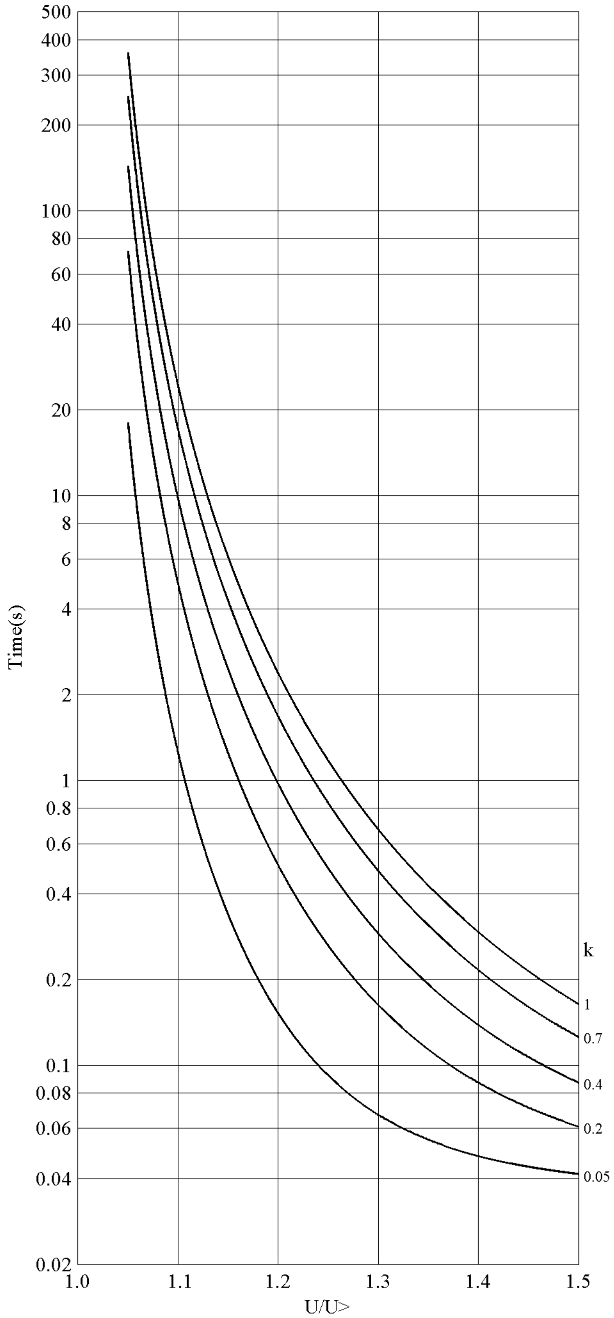

Figure 271: Inverse curve C characteristic of overvoltage protection

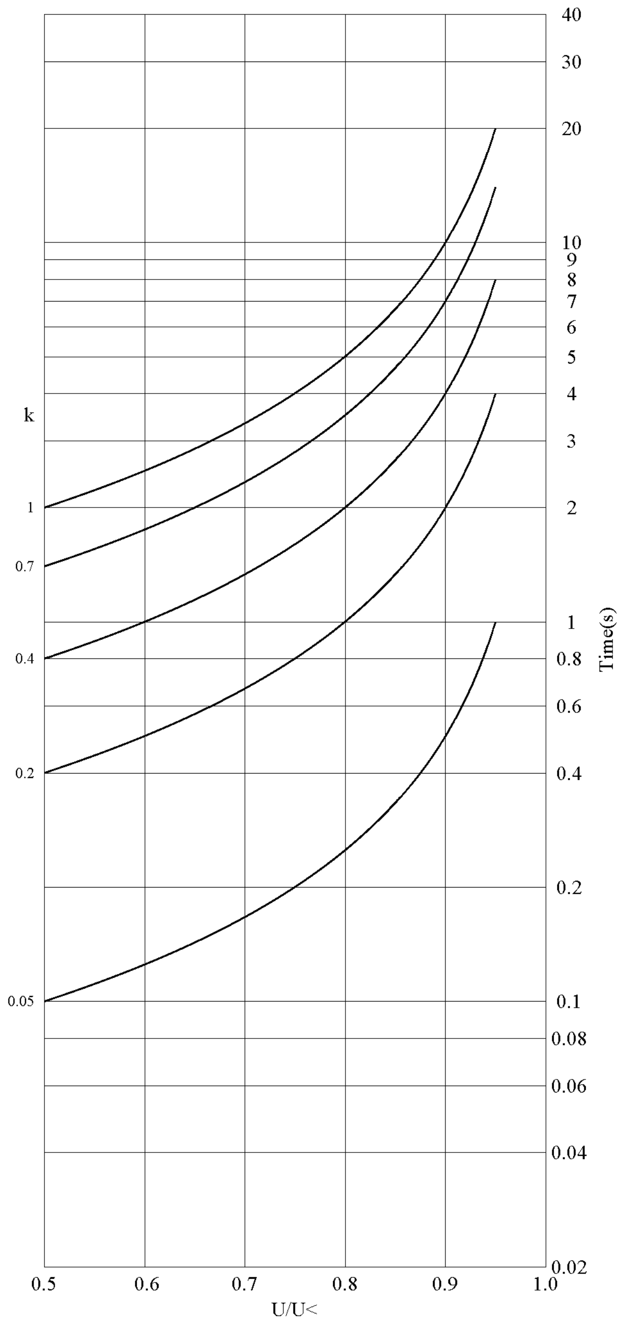

Figure 272: Inverse curve A characteristic of undervoltage protection

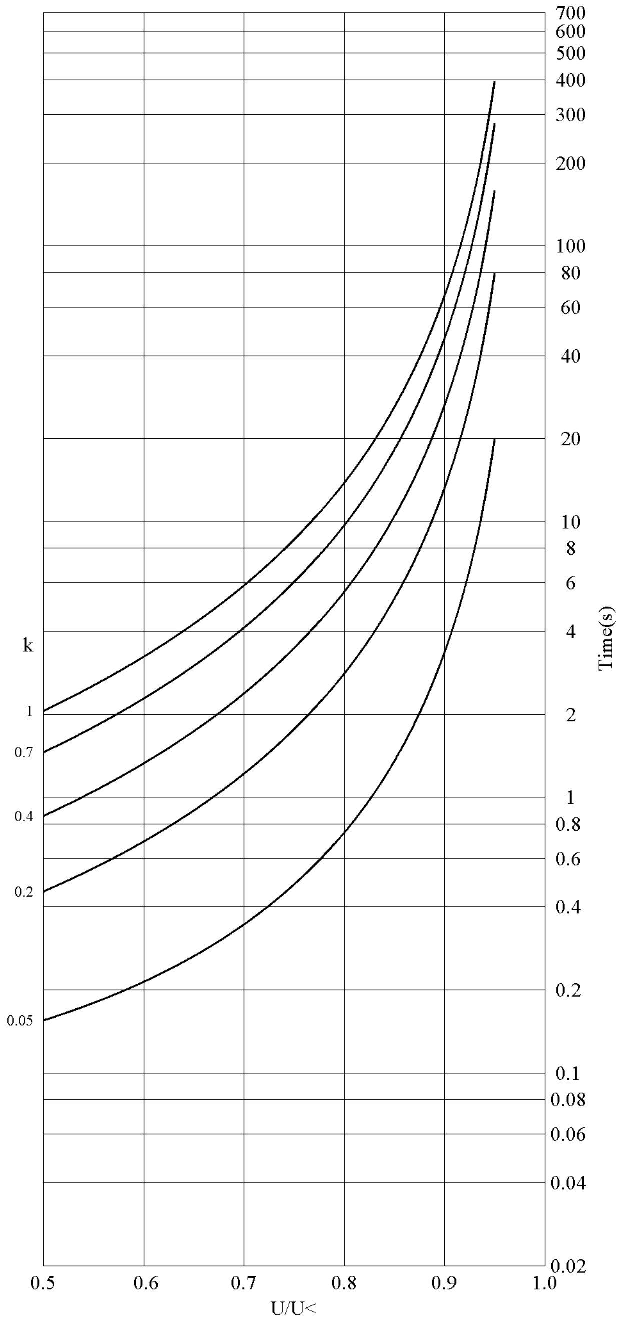

Figure 273: Inverse curve B characteristic of undervoltage protection

Section 20 Glossary

AC	Alternating current
ACT	Application configuration tool within PCM600
A/D converter	Analog to digital converter
ADBS	Amplitude dead-band supervision
ANSI	American National Standards Institute
AR	Autoreclosing
ASCT	Auxiliary summation current transformer
ASD	Adaptive signal detection
AWG	American Wire Gauge standard
BR	External bi-stable relay
BS	British standard
CAN	Controller Area Network. ISO standard (ISO 11898) for serial communication
CB	Circuit breaker
CCITT	Consultative Committee for International Telegraph and Telephony. A United Nations sponsored standards body within the International Telecommunications Union.
CCVT	Capacitive Coupled Voltage Transformer
Class C	Protection Current Transformer class as per IEEE/ ANSI
CMPPS	Combined mega pulses per second
CO cycle	Close-open cycle
Co-directional	Way of transmitting G.703 over a balanced line. Involves two twisted pairs making it possible to transmit information in both directions
COMTRADE	Standard format according to IEC 60255-24
Contra-directional	Way of transmitting G.703 over a balanced line. Involves four twisted pairs of with two are used for transmitting data in both directions, and two pairs for transmitting clock signals
CPU	Central processor unit
CR	Carrier receive
CRC	Cyclic redundancy check
CS	Carrier send

CT	Current transformer
CVT	Capacitive voltage transformer
DAR	Delayed auto-reclosing
DARPA	Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)
DBDL	Dead bus dead line
DBLL	Dead bus live line
DC	Direct current
DFT	Discrete Fourier transform
DIP-switch	Small switch mounted on a printed circuit board
DLLB	Dead line live bus
DNP	Distributed Network Protocol as per IEEE/ANSI Std. 1379-2000
DR	Disturbance recorder
DRAM	Dynamic random access memory
DRH	Disturbance report handler
DSP	Digital signal processor
DTT	Direct transfer trip scheme
EHV network	Extra high voltage network
EIA	Electronic Industries Association
EMC	Electro magnetic compatibility
EMF	Electro motive force
EMI	Electro magnetic interference
EnFP	End fault protection
ESD	Electrostatic discharge
FOX 20	Modular 20 channel telecommunication system for speech, data and protection signals
FOX 512/515	Access multiplexer
FOX 6Plus	Compact, time-division multiplexer for the transmission of up to seven duplex channels of digital data over optical fibers
G.703	Electrical and functional description for digital lines used by local telephone companies. Can be transported over balanced and unbalanced lines
GCM	Communication interface module with carrier of GPS receiver module
GDE	Graphical display editor within PCM600

GI	General interrogation command
GIS	Gas insulated switchgear
GOOSE	Generic object oriented substation event
GPS	Global positioning system
HDLC protocol	High level data link control, protocol based on the HDLC standard
HFBR connector type	Plastic fiber connector
HMI	Human machine interface
HSAR	High speed auto reclosing
HV	High voltage
HVDC	High voltage direct current
IDBS	Integrating dead band supervision
IEC	International Electrical Committee
IEC 60044-6	IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance
IEC 61850	Substation Automation communication standard
IEEE	Institute of Electrical and Electronics Engineers
IEEE 802.12	A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable
IEEE P1386.1	PCI Mezzanine card (PMC) standard for local bus modules. References the CMC (IEEE P1386, also known as Common mezzanine card) standard for the mechanics and the PCI specifications from the PCI SIG (Special Interest Group) for the electrical EMF Electro Motive Force.
IED	Intelligent electronic device
I-GIS	Intelligent gas insulated switchgear
Instance	When several occurrences of the same function are available in the IED they are referred to as instances of that function. One instance of a function is identical to another of the same kind but will have a different number in the IED user interfaces. The word instance is sometimes defined as an item of information that is representative of a type. In the same way an instance of a function in the IED is representative of a type of function.
IP	1. Internet protocol. The network layer for the TCP/IP protocol suite widely used on Ethernet networks. IP is a connectionless, best-effort packet switching protocol. It

	provides packet routing, fragmentation and re-assembly through the data link layer.
	2. Ingression protection according to IEC standard
IP 20	Ingression protection, according to IEC standard, level 20
IP 40	Ingression protection, according to IEC standard, level 40
IP 54	Ingression protection, according to IEC standard, level 54
IRF	Internal fail signal
IRIG-B:	InterRange Instrumentation Group Time code format B, standard 200
ITU	International Telecommunications Union
LAN	Local area network
LIB 520	High voltage software module
LCD	Liquid crystal display
LDD	Local detection device
LED	Light emitting diode
MCB	Miniature circuit breaker
MCM	Mezzanine carrier module
MVB	Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.
NCC	National Control Centre
OCO cycle	Open-close-open cycle
OCP	Overcurrent protection
OLTC	On load tap changer
OV	Over voltage
Overreach	A term used to describe how the relay behaves during a fault condition. For example a distance relay is over-reaching when the impedance presented to it is smaller than the apparent impedance to the fault applied to the balance point, i.e. the set reach. The relay “sees” the fault but perhaps it should not have seen it.
PCI	Peripheral component interconnect, a local data bus
PCM	Pulse code modulation
PCM600	Protection and control IED manager
PC-MIP	Mezzanine card standard
PISA	Process interface for sensors & actuators
PMC	PCI Mezzanine card
POTT	Permissive overreach transfer trip

Process bus	Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components
PSM	Power supply module
PST	Parameter setting tool within PCM600
PT ratio	Potential transformer or voltage transformer ratio
PUTT	Permissive underreach transfer trip
RASC	Synchrocheck relay, COMBIFLEX
RCA	Relay characteristic angle
REVAL	Evaluation software
RFPP	Resistance for phase-to-phase faults
RFPE	Resistance for phase-to-earth faults
RISC	Reduced instruction set computer
RMS value	Root mean square value
RS422	A balanced serial interface for the transmission of digital data in point-to-point connections
RS485	Serial link according to EIA standard RS485
RTC	Real time clock
RTU	Remote terminal unit
SA	Substation Automation
SC	Switch or push-button to close
SCS	Station control system
SCT	System configuration tool according to standard IEC 61850
SMA connector	Subminiature version A, A threaded connector with constant impedance.
SMT	Signal matrix tool within PCM600
SMS	Station monitoring system
SNTP	Simple network time protocol – is used to synchronize computer clocks on local area networks. This reduces the requirement to have accurate hardware clocks in every embedded system in a network. Each embedded node can instead synchronize with a remote clock, providing the required accuracy.
SRY	Switch for CB ready condition
ST	Switch or push-button to trip
Starpoint	Neutral point of transformer or generator
SVC	Static VAr compensation
TC	Trip coil

TCS	Trip circuit supervision
TCP	Transmission control protocol. The most common transport layer protocol used on Ethernet and the Internet.
TCP/IP	Transmission control protocol over Internet Protocol. The de facto standard Ethernet protocols incorporated into 4.2BSD Unix. TCP/IP was developed by DARPA for internet working and encompasses both network layer and transport layer protocols. While TCP and IP specify two protocols at specific protocol layers, TCP/IP is often used to refer to the entire US Department of Defense protocol suite based upon these, including Telnet, FTP, UDP and RDP.
TNC connector	Threaded Neill Concelman, A threaded constant impedance version of a BNC connector
TPZ, TPY, TPX, TPS	Current transformer class according to IEC
Underreach	A term used to describe how the relay behaves during a fault condition. For example a distance relay is under-reaching when the impedance presented to it is greater than the apparent impedance to the fault applied to the balance point, i.e. the set reach. The relay does not “see” the fault but perhaps it should have seen it. See also Overreach.
U/I-PISA	Process interface components that deliver measured voltage and current values
UTC	Coordinated universal time. A coordinated time scale, maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated dissemination of standard frequencies and time signals. UTC is derived from International Atomic Time (TAI) by the addition of a whole number of "leap seconds" to synchronize it with Universal Time 1 (UT1), thus allowing for the eccentricity of the Earth"s orbit, the rotational axis tilt (23.5 degrees), but still showing the Earth"s irregular rotation, on which UT1 is based. The Coordinated Universal Time is expressed using a 24-hour clock and uses the Gregorian calendar. It is used for aeroplane and ship navigation, where it also sometimes known by the military name, "Zulu time". "Zulu" in the phonetic alphabet stands for "Z" which stands for longitude zero.
UV	Undervoltage
WEI	Weak end infeed logic
VT	Voltage transformer
X.21	A digital signalling interface primarily used for telecom equipment

$3I_O$	Three times zero-sequence current. Often referred to as the residual or the earth-fault current
$3U_O$	Three times the zero sequence voltage. Often referred to as the residual voltage or the neutral point voltage

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