Relion® 615 series

Feeder Protection and Control REF615 Application 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 the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

Table of contents

Section 1 Introduction

1.1 This manual

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.

1.2 Intended audience

This manual addresses the protection and control engineer responsible for planning, pre-engineering and engineering.

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as protection schemes and principles.

1.3 Product documentation

1.3.1 Product documentation set

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

The engineering guide provides information for IEC 61850 engineering of the 615 series protection IEDs with PCM600 and IET600. This guide concentrates especially on the configuration of GOOSE communication with these tools. The guide can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. For more details on tool usage, see the PCM600 documentation.

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

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

The 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 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 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.

1.3.2 Document revision history

Document revision/date	Product version	History
A/2007-12-20	1.0	First release
B/2008-02-08	1.0	Content updated
C/2008-07-02	1.1	Content updated to correspond to the product version
D/2009-03-04	2.0	Content updated to correspond to the product version
E/2009-07-03	2.0	Content updated
F/2010-06-11	3.0	Content updated to correspond to the product version
G/2010-06-29	3.0	Terminology updated
H/2010-09-24	3.0	Content updated
K/2012-05-11	4.0	Content updated to correspond to the product version

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS756468
DNP3 Communication Protocol Manual	1MRS756709
IEC 60870-5-103 Communication Protocol Manual	1MRS756710
IEC 61850 Engineering Guide	1MRS756475
Engineering Manual	1MRS757121
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

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

1.4.3 Functions, codes and symbols

Table 1: REF615 functions, codes and symbols

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

Function	IEC 61850	IEC 60617	IEC-ANSI
Admittance based earth-fault protection	EFPADM1	Yo> -> (1)	21YN (1)
	EFPADM2	Yo> -> (2)	21YN (2)
	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection	WPWDE1	Po> -> (1)	32N (1)
	WPWDE2	Po> -> (2)	32N (2)
	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)
	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
	FRPFRQ3	f>/f<,df/dt (3)	81 (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQM3I (1)
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQM3V (1)
Voltage variation	PHQVVR1	PQMU (1)	PQMV (1)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Synchronism and energizing check	SECRSYN1	SYNC	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
Frequency measurement	FMMXU1	f	f

Section 2 REF615 overview

2.1 Overview

REF615 is a dedicated feeder IED (intelligent electronic device) designed for the protection, control, measurement and supervision of utility substations and industrial power systems including radial, looped and meshed distribution networks with or without distributed power generation. REF615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series IEDs are characterized by their compactness and withdrawable-unit design.

Re-engineered from the ground up, the 615 series has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices.

The IED provides main protection for overhead lines and cable feeders in distribution networks. The IED is also used as back-up protection in applications, where an independent and redundant protection system is required.

Depending on the chosen standard configuration, the IED is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance earthed, compensated and solidly earthed networks. Once the standard configuration IED has been given the application-specific settings, it can directly be put into service.

The 615 series IEDs support a range of communication protocols including IEC 61850 with GOOSE messaging, IEC 60870-5-103, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
1.0	Product released
1.1	• IRIG-B • Support for parallel protocols added: IEC 61850 and Modbus • X130 BIO added: optional for variants B and D • CB interlocking functionality enhanced • TCS functionality in HW enhanced • Non-volatile memory added
2.0	• Support for DNP3 serial or TCP/IP • Support for IEC 60870-5-103 • Voltage measurement and protection • Power and energy measurement • New standard configurations E and F • Disturbance recorder upload via WHMI • Fuse failure supervision
3.0	• New configurations G and H • Additions to configurations A, B, E and F • Application configurability support • Analog GOOSE support • Large display with single line diagram • Enhanced mechanical design • Increased maximum amount of events and fault records • Admittance-based earth-fault protection • Frequency measurement and protection • Synchronism and energizing check • Combi sensor inputs • Multi-port Ethernet option
4.0	• New configuration J • Additions/changes for configurations A-H • Dual fibre optic Ethernet communication option (COM0032) • Generic control point (SPCGGIO) function blocks • Additional logic blocks • Button object for SLD • Controllable disconnector and earth switch objects for SLD • Wattmetric based E/F • Harmonics based E/F • Power Quality functions • Increased maximum amount of events and fault records

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.4 SP1 or later
- REF615 Connectivity Package Ver. 4.0 or later
    - Parameter Setting
    - Firmware Update
    - Disturbance Handling
    - Signal Monitoring
    - Lifecycle Traceability
    - Signal Matrix
    - Communication Management
    - Configuration Wizard

- Label Printing
- IED User Management
- Application Configuration
- Graphical Display Editor
- Event Viewer

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

2.2 Operation functionality

2.2.1 Optional functions

- Arc protection
- Autoreclosing
- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Admittance based earth-fault (configuration A, B, E, F, G and J only)
- Watt-metric based earth-fault (configuration A, B, E, F, G and J only)
- Harmonics based earth-fault (configuration B, D, F and J only)
- Power quality functions (configuration J only)

2.3 Physical hardware

The IED consists of two main parts: plug-in unit and case. The content depends on the ordered functionality.

Table 2: Plug-in unit and case

Main unit	Slot ID	Content options	
Plug-in unit	-	HMI	Small (4 lines, 16 characters) Large (8 lines, 16 characters)
	X100	Auxiliary power/BO module	48-250 V DC/100-240 V AC; or 24-60 V DC 2 normally-open PO contacts 1 change-over SO contacts 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BI/O module	Only with configurations B, D, E, F, G, H and J: 8 binary inputs 4 SO contacts
	X120	AI/BI module	Only with configurations A and B: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1] 1 residual voltage input (60-120 V) 3 binary inputs
			Only with configurations C, D, E, F, H and J: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1] 4 binary inputs
Case	X130	AI/BI module	Only with configurations E and F: 3 phase voltage inputs (60-120 V) 1 residual voltage input (60-120 V) 4 binary inputs
		Sensor input module	Only with configuration G: 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)[1]
		AI/BI module	Only with configuration H and J: 3 phase voltage inputs (60-210 V) 1 residual voltage input (60-210 V) 1 reference voltage input for SECRSYN1 (60-210 V) 4 binary inputs
		Optional BI/O module	Optional for configurations B and D: 6 binary inputs 3 SO contacts
	X000	Optional communication module	See technical manual for details about different type of communication modules.

1) The 0.2/1 A input is normally used in applications requiring sensitive earth-fault protection and featuring core-balance current transformers.

Rated values of the current and voltage inputs are basic setting parameters of the IED. The binary input thresholds are selectable within the range 18…176 V DC by adjusting the binary input setting parameters.

The connection diagrams of different hardware modules are presented in this manual.

See the installation manual for more information about the case and the plug-in unit.

Table 3: Number of physical connections in standard configurations

Conf.	Analog channels			Binary channels	
	CT	VT	Combi sensor	BI	BO
A	4	1	-	3	6
B	4	-	-	11 (17)[1)]	10 (13)[1)]
C	4	1	-	4	6
D	4	-	-	12 (18)[1)]	10 (13)[1)]
E	4	5[2)]	-	16	10
F	4	5[2)]	-	16	10
G	1	-	3[3)]	8	10
H	4	5	-	16	10
J	4	5	-	16	10

1) With optional BIO module
2) One of the five channels reserved for future applications
3) Combi sensor inputs for three-phase current and voltage

2.4 Local HMI

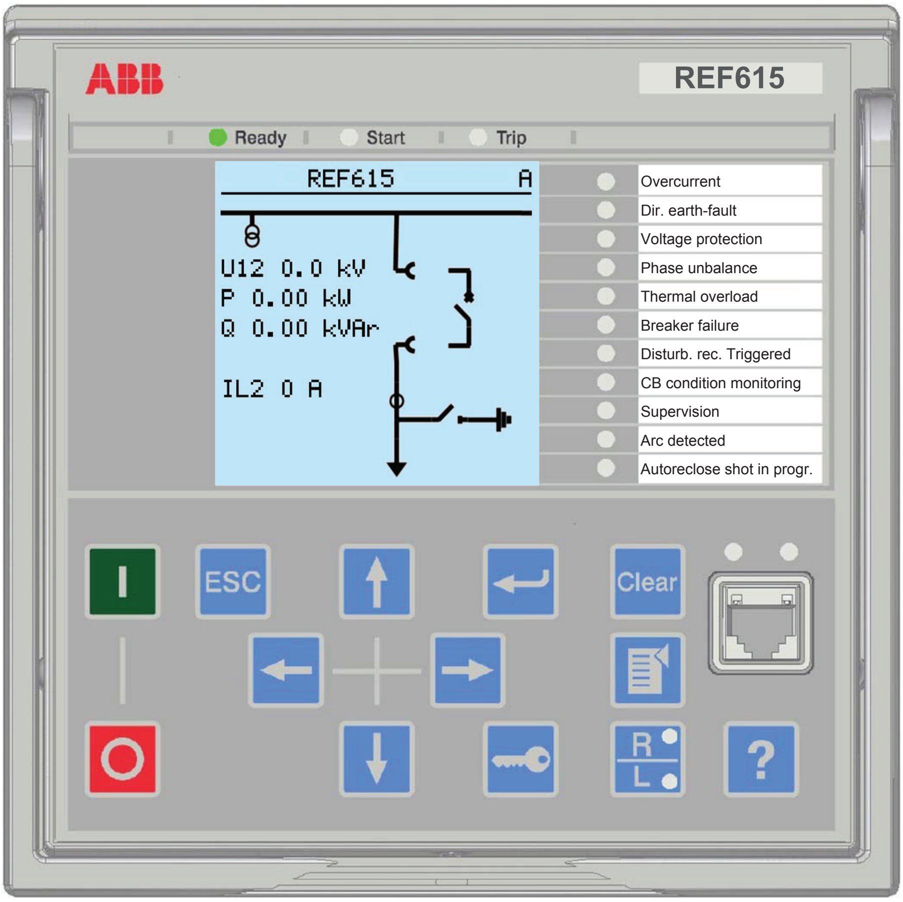


Figure 1: Example of 615 series LHMI

The LHMI of the IED contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

2.4.1 Display

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

Table 4: Characters and rows on the view

Character size	Rows in view	Characters on row
Small, mono-spaced (6x12 pixels)	5 rows 10 rows with large screen	20
Large, variable width (13x14 pixels)	4 rows 8 rows with large screen	min 8

The display view is divided into four basic areas.

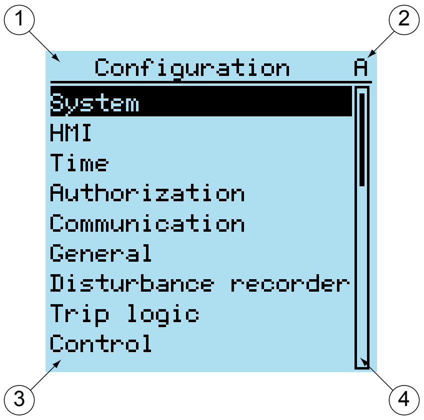


Figure 2: Display layout

1 Header

2 Icon

3 Content

4 Scroll bar (displayed when needed)

2.4.2 LEDs

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

There are also 11 matrix programmable LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

2.4.3 Keypad

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

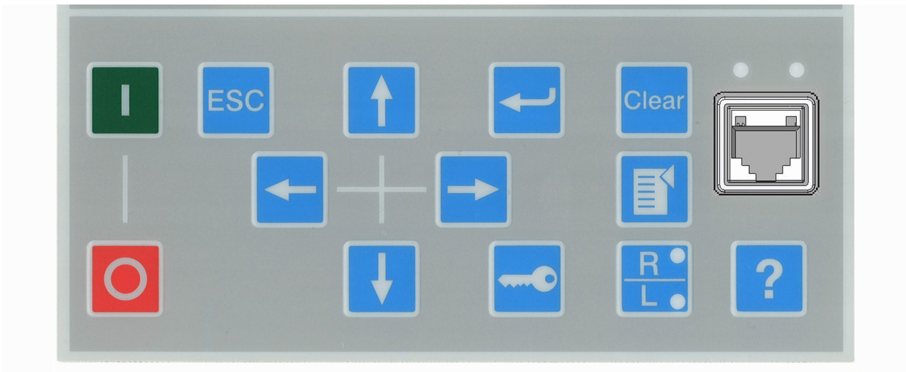


Figure 3: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.5 Web HMI

The WHMI enables the user to access the IED via a Web browser. The supported Web browser versions are Internet Explorer 7.0, 8.0 or 9.0.

WHMI is disabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Phasor diagram
- Single-line diagram

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

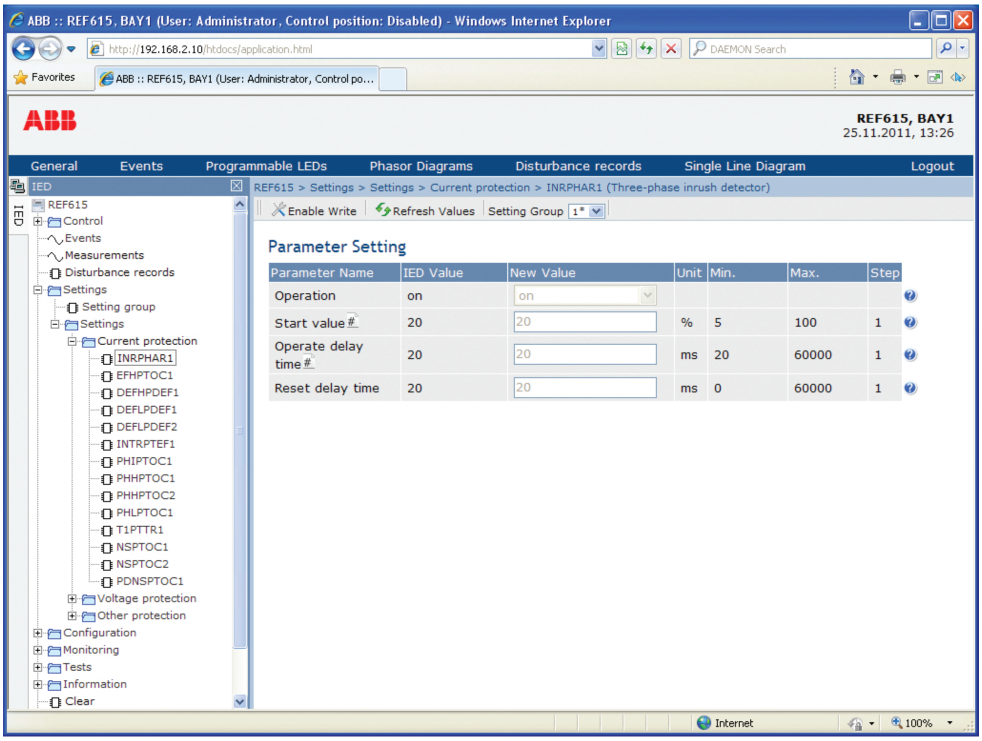


Figure 4: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

The default passwords can be changed with Administrator user rights.

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

Table 5: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.6.1 Audit trail

615 series IEDs offer a large set of event logging functions. Normal process related events can be viewed by the normal user with Event Viewer in PCM600. Critical system and IED security related events are logged to a separate non-volatile audit trail for the administrator.

Audit trail is a chronological record of system activities that enable the reconstruction and examination of the sequence of events and/or changes in an event. Past user and process events can be examined and analyzed in a consistent method with the help of Event List and Event Viewer in PCM600. The IED stores 2048 system events to non-volatile audit trail. Additionally, 1024 process events are stored in non-volatile event list. Both audit trail and event list work according to the FIFO principle.

User audit trail is defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined usernames or user categories. The user audit trail events are supported in IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 6: Audit trail events

Enum	Explanation/note
Configuration change	Configuration files changed
Firmware change	
Setting group remote	User changed setting group remotely

Table continues on next page

Enum	Explanation/note
Setting group local	User changed setting group locally
Control remote	DPC object control remote
Control local	DPC object control local
Test on	Test mode on
Test off	Test mode off
Setting commit	Settings has been changed
Time change	
View audit log	Administrator accessed audit trail
Login	
Logout	
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period

PCM600 Event Viewer can be used to view the audit trail events together with normal events. Since only the administrator has the right to read audit trail, authorization must be properly configured in PCM600. The audit trail cannot be reset but PCM600 Event Viewer can filter data. Some of the audit trail events are interesting also as normal process events.

To expose the audit trail events also as normal process events, define the level parameter via **Configuration/Authorization/ Authority logging.**

Table 7: Audit trail events

Audit trail event	Authority logging				
	None	Configuration change	Setting group	Setting group, control	Settings edit
Configuration change		x	x	x	x
Firmware change		x	x	x	x
Setting group remote			x	x	x
Setting group local			x	x	x
Control remote				x	x
Control local				x	x
Test on				x	x
Test off				x	x
Setting commit					x
Time change					
View audit log					
Login					

Table continues on next page

Audit trail event	Authority logging				
Logout					
Firmware reset					
Audit overflow					

2.7 Communication

The IED supports a range of communication protocols including IEC 61850, IEC 60870-5-103, Modbus® and DNP3. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the IEDs, is only enabled by the IEC 61850 communication protocol.

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

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

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The IED can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fibre-optic LC connector (100Base-FX). An optional serial interface is available for RS-232/RS-485 communication.

For the correct operation of redundant loop topology, it is essential that the external switches in the network support the RSTP protocol and that it is enabled in the switches. Otherwise, connecting the loop topology can cause problems to the network. The IED itself does not support link-down detection or RSTP. The ring recovery process is based on the aging of MAC addresses and link-up/link-down events can cause temporary breaks in communication. For better performance of the self-healing loop, it is recommended that the external switch furthest from the 615 IED loop is assigned as the root switch (bridge priority = 0) and the bridge priority increases towards the IED loop. The end links of the IED loop can be attached to the same external switch or to two adjacent external switches. Self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all IEDs.

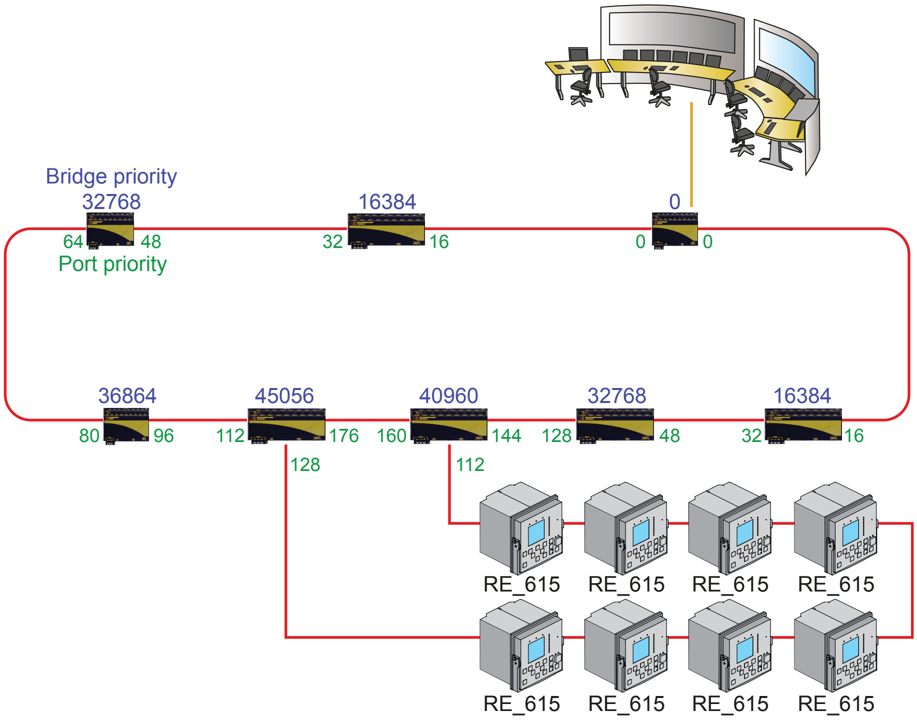


Figure 5: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to thirty 615 series IEDs. If more than 30 IEDs are to be connected, it is recommended that the network is split into several rings with no more than 30 IEDs per ring.

Section 3 REF615 standard configurations

3.1 Standard configurations

REF615 is available in nine alternative standard configurations. The standard signal configuration can be altered by means of the graphical signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions using various logical elements, including timers and flip-flops. By combining protection functions with logic function blocks, the IED configuration can be adapted to user-specific application requirements.

Table 8: Standard configurations

Description	Std. conf.
Non-directional overcurrent and directional earth-fault protection and CB control	A
Non-directional overcurrent and directional earth-fault protection, CB condition monitoring, CB control and with the optional I/O module control of two network objects	B
Non-directional overcurrent and non-directional earth-fault protection and CB control	C
Non-directional overcurrent and non-directional earth-fault protection, CB condition monitoring, CB control and with the optional I/O module control of two network objects	D
Non-directional overcurrent and directional earth-fault protection with phase-voltage based measurements, CB condition monitoring and CB control	E
Directional overcurrent and directional earth-fault protection with phase-voltage based measurements, undervoltage and overvoltage protection, CB condition monitoring and CB control	F
Directional overcurrent and directional earth-fault protection, phase-voltage based protection and measurement functions, CB condition monitoring, CB control and sensor inputs	G
Non-directional overcurrent and non-directional earth-fault protection, phase-voltage and frequency based protection and measurement functions, synchro-check , CB condition monitoring and CB control	H
Directional overcurrent and directional earth-fault protection, phase-voltage and frequency based protection and measurement functions, synchro check, CB condition monitoring and CB control	J

Table 9: Supported functions

Functionality	A	B	C	D	E	F	G	H	J
Protection									
Three-phase non-directional overcurrent protection, low stage, instance 1	●	●	●	●	●	-	-	●	-
Three-phase non-directional overcurrent protection, high stage, instance 1	●	●	●	●	●	-	-	●	-
Three-phase non-directional overcurrent protection, high stage, instance 2	●	●	●	●	●	-	-	●	-
Table continues on next page									

Functionality	A	B	C	D	E	F	G	H	J
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	●	●	●	●	●	●	●	●	●
Three-phase directional overcurrent protection, low stage, instance 1	-	-	-	-	-	●	●	-	●
Three-phase directional overcurrent protection, low stage, instance 2	-	-	-	-	-	●	●	-	●
Three-phase directional overcurrent protection, high stage	-	-	-	-	-	●	●	-	●
Non-directional earth-fault protection, low stage, instance 1	-	-	● 1)	● 1)	-	-	-	● 1)	-
Non-directional earth-fault protection, low stage, instance 2	-	-	● 1)	● 1)	-	-	-	● 1)	-
Non-directional earth-fault protection, high stage, instance 1	-	-	● 1)	● 1)	-	-	-	● 1)	-
Non-directional earth-fault protection, instantaneous stage	-	-	● 1)	● 1)	-	-	-	● 1)	-
Directional earth-fault protection, low stage, instance 1	● 1)2)	● 1)2)	-	-	● 1)4)	● 1)4)	● 1)3)	-	● 1)4)
Directional earth-fault protection, low stage, instance 2	● 1)2)	● 1)2)	-	-	● 1)4)	● 1)4)	● 1)3)	-	● 1)4)
Directional earth-fault protection, high stage	● 1)2)	● 1)2)	-	-	● 1)4)	● 1)4)	● 1)3)	-	● 1)4)
Admittance based earth-fault protection, instance 1	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Admittance based earth-fault protection, instance 2	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Admittance based earth-fault protection, instance 3	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Wattmetric based earth-fault protection, instance 1	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Wattmetric based earth-fault protection, instance 2	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Wattmetric based earth-fault protection, instance 3	o 1)2)5)	o 1)2)5)	-	-	o 1)4)5)	o 1)4)5)	o 1)5)6)	-	o 1)4)5)
Transient / intermittent earth-fault protection	● 2)7)	● 2)7)	-	-	● 2)7)	● 2)7)	-	-	● 2)7)
Harmonics based earth-fault protection	-	o 5)7)8)	-	o 5)7)8)	-	o 5)7)8)	-	-	o 5)7)8)
Non-directional (cross-country) earth fault protection, using calculated Io	● 9)	● 9)	-	-	● 9)	● 9)	● 9)	-	● 9)
Negative-sequence overcurrent protection, instance 1	●	●	●	●	●	●	●	●	●
Negative-sequence overcurrent protection, instance 2	●	●	●	●	●	●	●	●	●
Phase discontinuity protection	●	●	●	●	●	●	●	●	●
Residual overvoltage protection, instance 1	● 2)	● 2)	-	-	● 4)	● 4)	● 6)	● 4)	● 4)
Residual overvoltage protection, instance 2	● 2)	● 2)	-	-	● 4)	● 4)	● 6)	● 4)	● 4)
Residual overvoltage protection, instance 3	● 2)	● 2)	-	-	● 4)	● 4)	● 6)	● 4)	● 4)
Three-phase undervoltage protection, instance 1	-	-	-	-	-	●	●	●	●
Table continues on next page									

Functionality	A	B	C	D	E	F	G	H	J
Three-phase undervoltage protection, instance 2	-	-	-	-	-	●	●	●	●
Three-phase undervoltage protection, instance 3	-	-	-	-	-	●	●	●	●
Three-phase overvoltage protection, instance 1	-	-	-	-	-	●	●	●	●
Three-phase overvoltage protection, instance 2	-	-	-	-	-	●	●	●	●
Three-phase overvoltage protection, instance 3	-	-	-	-	-	●	●	●	●
Positive-sequence undervoltage protection, instance 1	-	-	-	-	-	●	●	-	●
Negative-sequence overvoltage protection, instance 1	-	-	-	-	-	●	●	-	●
Frequency protection, instance 1	-	-	-	-	-	-	-	●	●
Frequency protection, instance 2	-	-	-	-	-	-	-	●	●
Frequency protection, instance 3	-	-	-	-	-	-	-	●	●
Three-phase thermal protection for feeders, cables and distribution transformers	●	●	●	●	●	●	●	-	●
Circuit breaker failure protection	●	●	●	●	●	●	●	●	●
Three-phase inrush detector	●	●	●	●	●	●	●	●	●
Master trip, instance 1	●	●	●	●	●	●	●	●	●
Master trip, instance 2	●	●	●	●	●	●	●	●	●
Arc protection, instance 1	o	o	o	o	o	o	o	o	o
Arc protection, instance 2	o	o	o	o	o	o	o	o	o
Arc protection, instance 3	o	o	o	o	o	o	o	o	o
Control									
Circuit-breaker control	●	●	●	●	●	●	●	●	●
Disconnector control, instance 1	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Disconnector control, instance 2	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Earthing switch control	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Disconnector position indication, instance 1	-	●	-	●	●	●	●	●	●
Disconnector position indication, instance 2	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Disconnector position indication, instance 3	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Earthing switch indication, instance 1	-	●	-	●	●	●	●	●	●
Earthing switch indication, instance 2	-	●[8)]	-	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]	●[8)]
Auto-reclosing	o	o	o	o	o	o	o	o	o
Synchronism and energizing check	-	-	-	-	-	-	-	●	●
Condition Monitoring									
Circuit-breaker condition monitoring	-	●	-	●	●	●	●	●	●
Trip circuit supervision, instance 1	●	●	●	●	●	●	●	●	●
Trip circuit supervision, instance 2	●	●	●	●	●	●	●	●	●
Current circuit supervision	-	-	-	-	●	●	●	●	●
Fuse failure supervision	-	-	-	-	●	●	●	●	●
Power Quality									
Table continues on next page									

Functionality	A	B	C	D	E	F	G	H	J
Current total demand distortion, instance 1	-	-	-	-	-	-	-	-	o [10)]
Voltage total harmonic distortion, instance 1	-	-	-	-	-	-	-	-	o [10)]
Voltage variation, instance 1	-	-	-	-	-	-	-	-	o [10)]
Measurement									
Disturbance recorder	●	●	●	●	●	●	●	●	●
Three-phase current measurement, instance 1	●	●	●	●	●	●	●	●	●
Sequence current measurement	●	●	●	●	●	●	●	●	●
Residual current measurement, instance 1	●	●	●	●	●	●	●	●	●
Three-phase voltage measurement	-	-	-	-	●	●	●	●	●
Residual voltage measurement	●	●	-	-	●	●	-	●	●
Sequence voltage measurement	-	-	-	-	●	●	●	●	●
Three-phase power and energy measurement, including power factor	-	-	-	-	●	●	●	●	●
Frequency measurement	-	-	-	-	-	-	-	●	●
● = Included,○ = Optional at the time of the order									

1) I_0 selectable by parameter, I_0 measured as default.
2) U_0 measured is always used
3) U_0 calculated and negative sequence voltage selectable by parameter, U_0 calculated as default.
4) U_0 selectable by parameter, U_0 measured as default.
5) One of the following can be ordered as an option: Admittance based E/F, Wattmetric based E/F or Harmonics based E/F. The option is an addition to the existing E/F of the original configuration. The Admittance based and Wattmetric based optional E/F has also a predefined configuration in the relay. The optional E/F can be set on or off.
6) U_0 calculated is always used.
7) I_0 measured is always used.
8) Available in IED and SMT but not connected to anything in logic.
9) Io selectable by parameter, Io calculated as default.
10) This option includes Current total demand distrortion, Voltage total harmonic distortion and Voltage variation.

3.1.1 Addition of control functions for primary devices and the use of binary inputs and outputs

If extra control functions intended for controllable primary devices are added to the configuration, additional binary inputs and/or outputs are needed to complement the standard configuration.

If the number of inputs and/or outputs in a standard configuration is not sufficient, it is possible either to modify the chosen IED standard configuration in order to release some binary inputs or binary outputs which have originally been configured for other purposes, or to integrate an external input/output module, for example RIO600, to the IED.

The external I/O module’s binary inputs and outputs of can be used for the less time-critical binary signals of the application. The integration enables releasing some initially reserved binary inputs and outputs of the IED’s standard configuration.

The suitability of the IED’s binary outputs which have been selected for primary device control should be carefully verified, for example make and carry and breaking capacity. If the requirements for the primary device control circuit are not met, using external auxiliary relays should be considered.

3.2 Connection diagrams

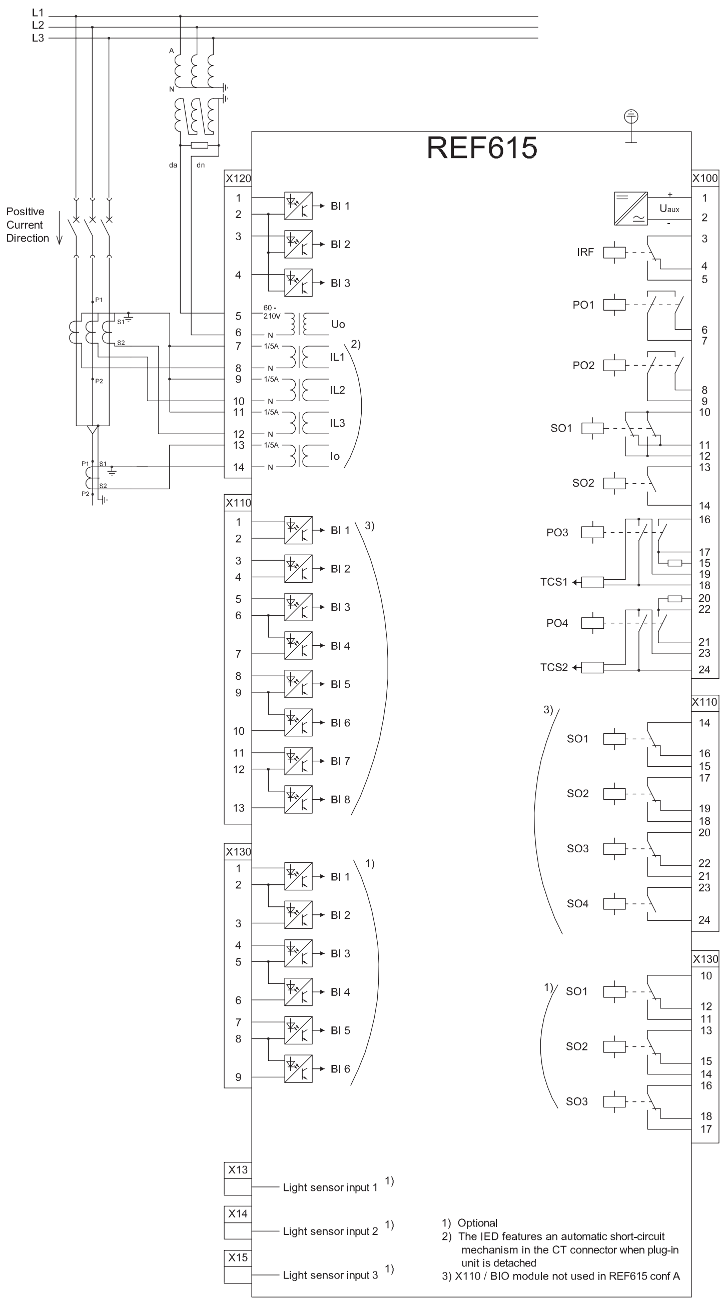


Figure 6: Connection diagram for the A and B configurations [1]

[1] Additional BIO-module (X110 in the diagram) is included in the IED variant B

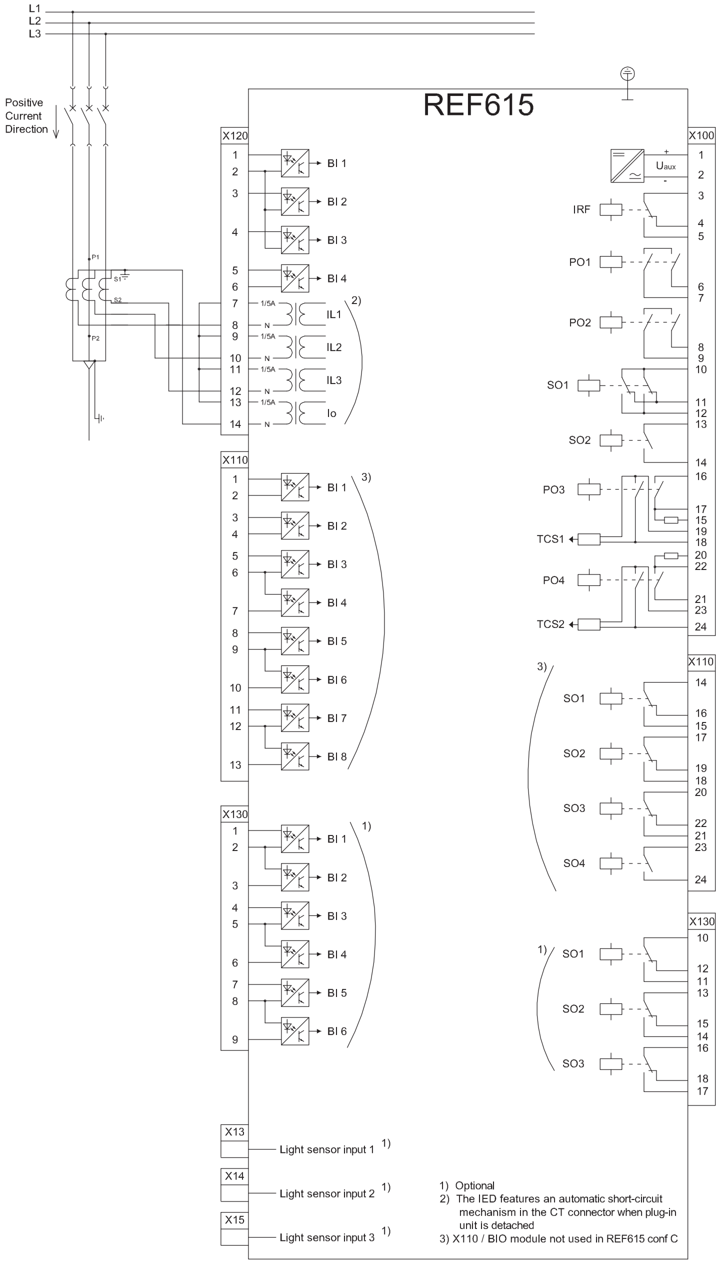


Figure 7: Connection diagram for the C and D configurations [2]

[2] Additional BIO-module (X110 in the diagram) is included in the IED variant D

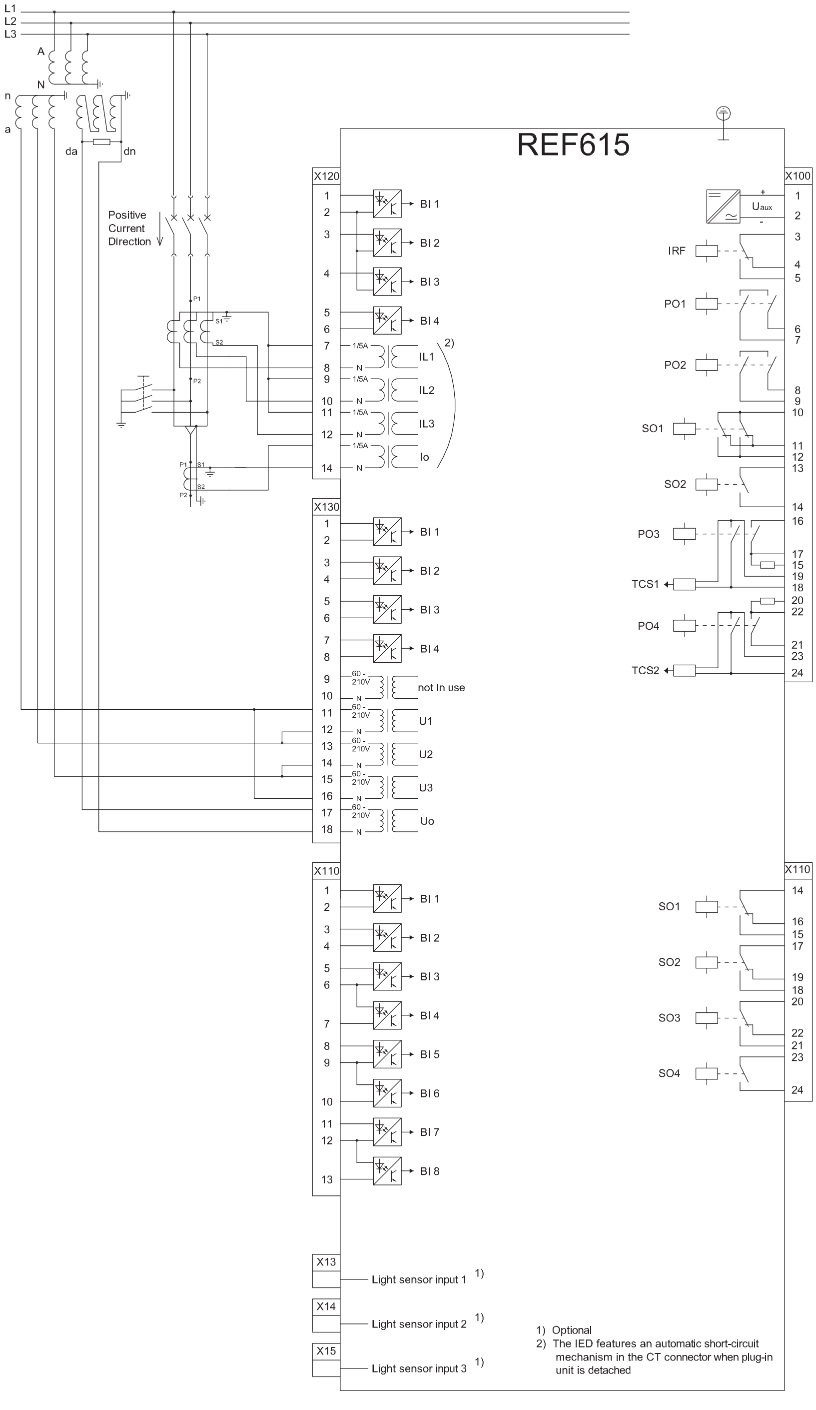


Figure 8: Connection diagram for the E and F configurations

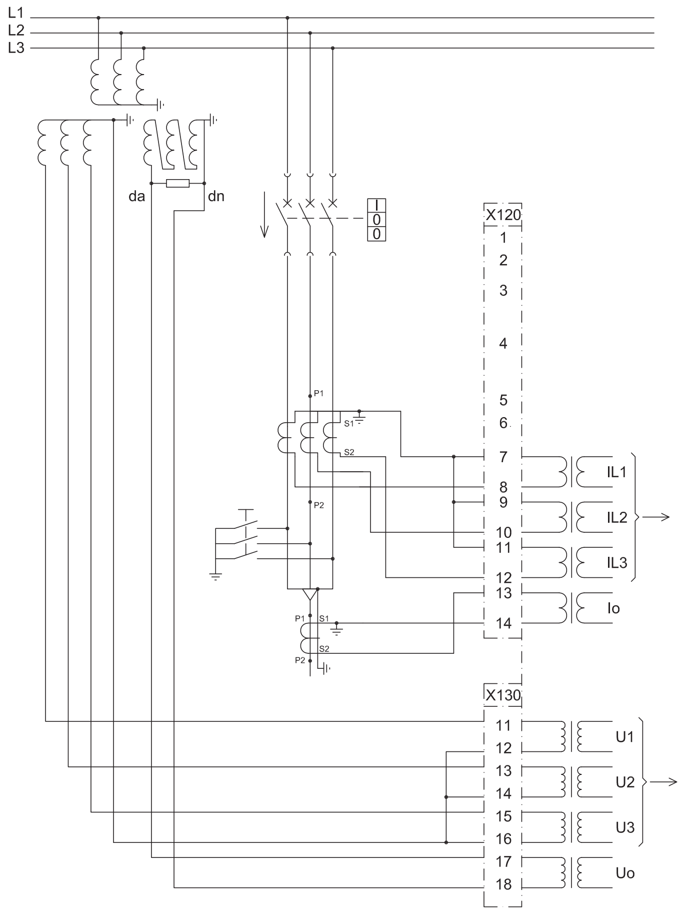


Figure 9: Connection diagram for the E and F configurations

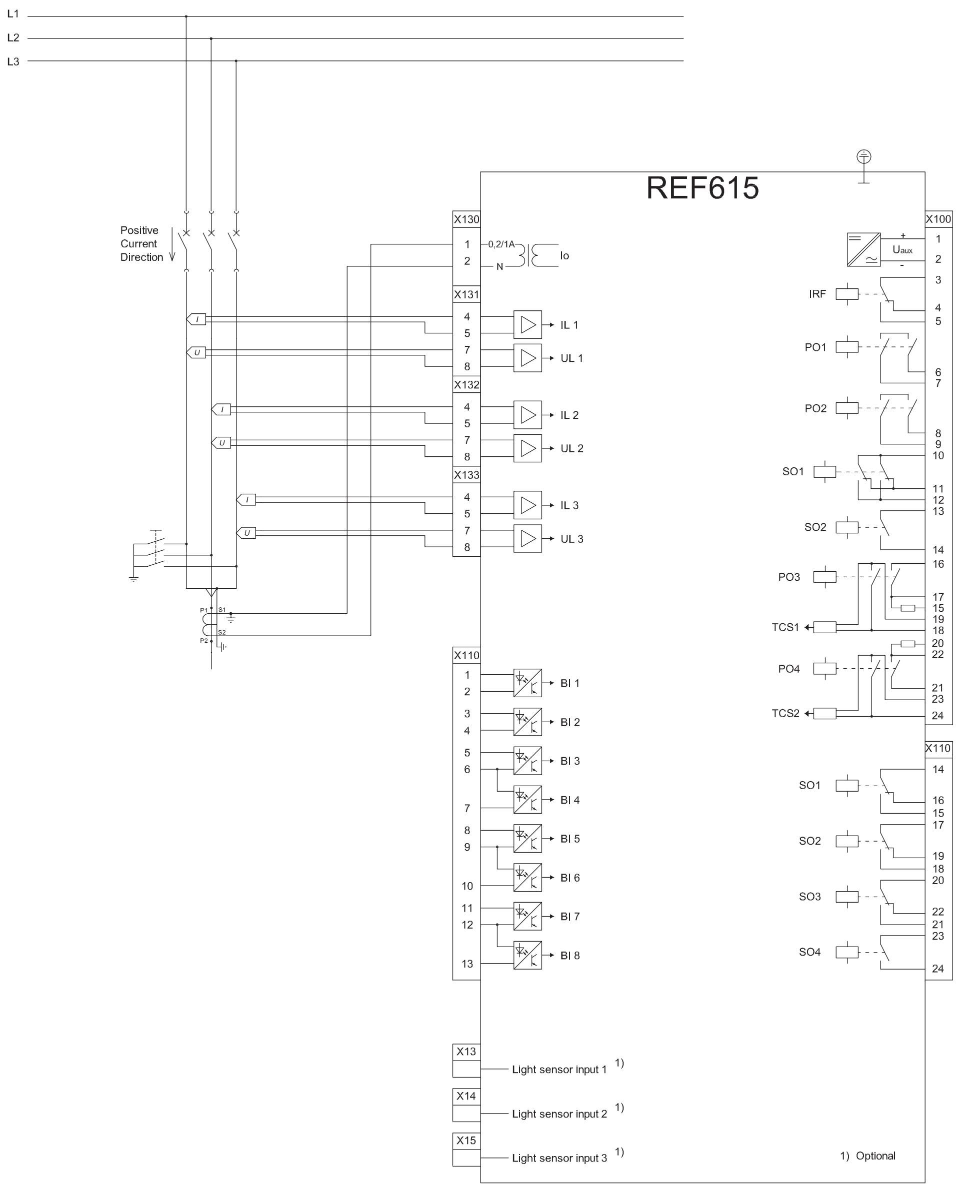


Figure 10: Connection diagram for the G configuration

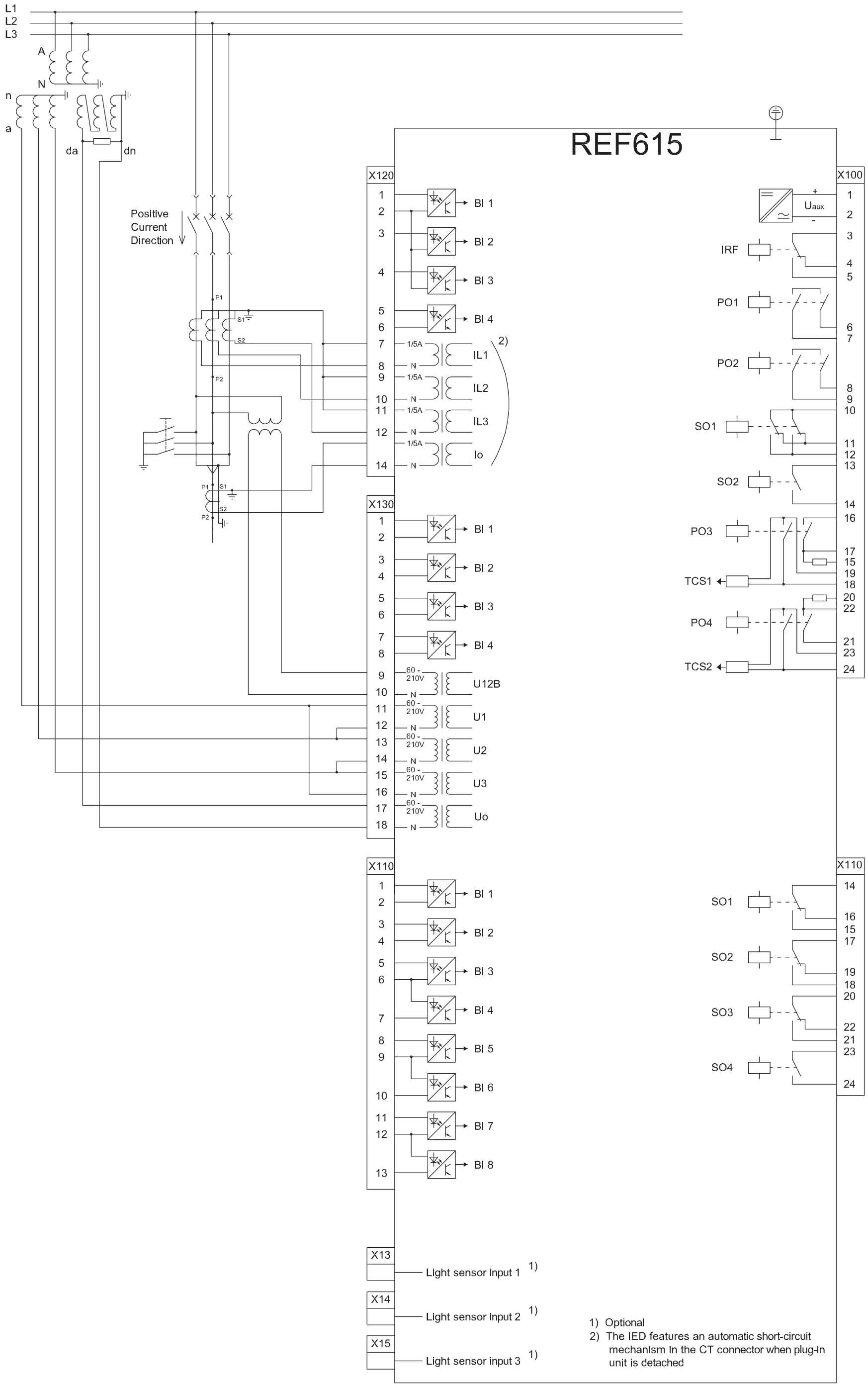


Figure 11: Connection diagram for the H and J configuration

3.3 Presentation of standard configurations

Functional diagrams

The functional diagrams describe the IED's functionality from the protection, measuring, condition monitoring, disturbance recording, control and interlocking perspective. Diagrams show the default functionality with simple symbol logics forming principle diagrams. The external connections to primary devices are also shown, stating the default connections to measuring transformers. The positive measuring direction of directional protection functions is towards the outgoing feeder.

The functional diagrams are divided into sections with each section constituting one functional entity. The external connections are also divided into sections. Only the relevant connections for a particular functional entity are presented in each section.

Protection function blocks are part of the functional diagram. They are identified based on their IEC 61850 name but the IEC based symbol and the ANSI function number are also included. Some function blocks, such as PHHPTOC, are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name, IEC symbol and ANSI function number are appended with a running number, that is an instance number, from one upwards. If the block has no suffix after the IEC or ANSI symbol, the function block has been used, that is, instantiated, only once. The IED’s internal functionality and the external connections are separated with a dashed line presenting the IED’s physical casing.

Signal Matrix and Application Configuration

With Signal Matrix and Application Configuration in PCM600, it is possible to modify the standard configuration according to the actual needs. The IED is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. The Signal Matrix is used for GOOSE signal input engineering and for making cross-references between the physical I/O signals and the function blocks. The Signal Matrix tool cannot be used for adding or removing function blocks, for example, GOOSE receive function blocks. The Application Configuration tool is used for these kind of operations. If a function block is removed with Application Configuration, the function related data disappears from the menus as well as from the 61850 data model, with the exception of some basic function blocks, which are mandatory and thus cannot be removed from the IED configuration by removing them from the Application Configuration.

3.4 Standard configuration A

3.4.1 Applications

The standard configuration for non-directional overcurrent and directional earthfault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance or wattmetric based principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.4.2 Functions

Table 10: Functions included in the standard configuration A

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Auto-reclosing	DARREC1	O -> I	79
Condition Monitoring			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Residual voltage measurement	RESVMMXU1	Uo	Vn

3.4.2.1 Default I/O connections

Table 11: Default connections for binary inputs

Binary input	Default usage	Connector pins
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed position indication	X120-3,2
X120-BI3	Circuit breaker open position indication	X120-4,2

Table 12: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100-8,9
X100-PO3	Open circuit breaker/trip coil 1	X100-15,16,17,18,19
X100-PO4	Open circuit breaker/trip coil 2	X100-20,21,22,23,24
X100-SO1	General start indication	X100-10,11,12
X100-SO2	General operate indication	X100-13,14,15

Table 13: Default connections for LEDs

LED	Default usage
1	Non-directional overcurrent operate
2	Directional/intermittent earth fault operate
3	Double (cross country) earth fault or residual overvoltage operate
4	Negative seq. overcurrent/phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Not connected
9	Trip circuit supervision alarm
10	Arc protection operate
11	Auto reclose in progress

3.4.2.2 Default disturbance recorder settings

Table 14: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	-
7	-
8	-
9	-
Table continues on next page	

Channel	Selection and text
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.4.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.4.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

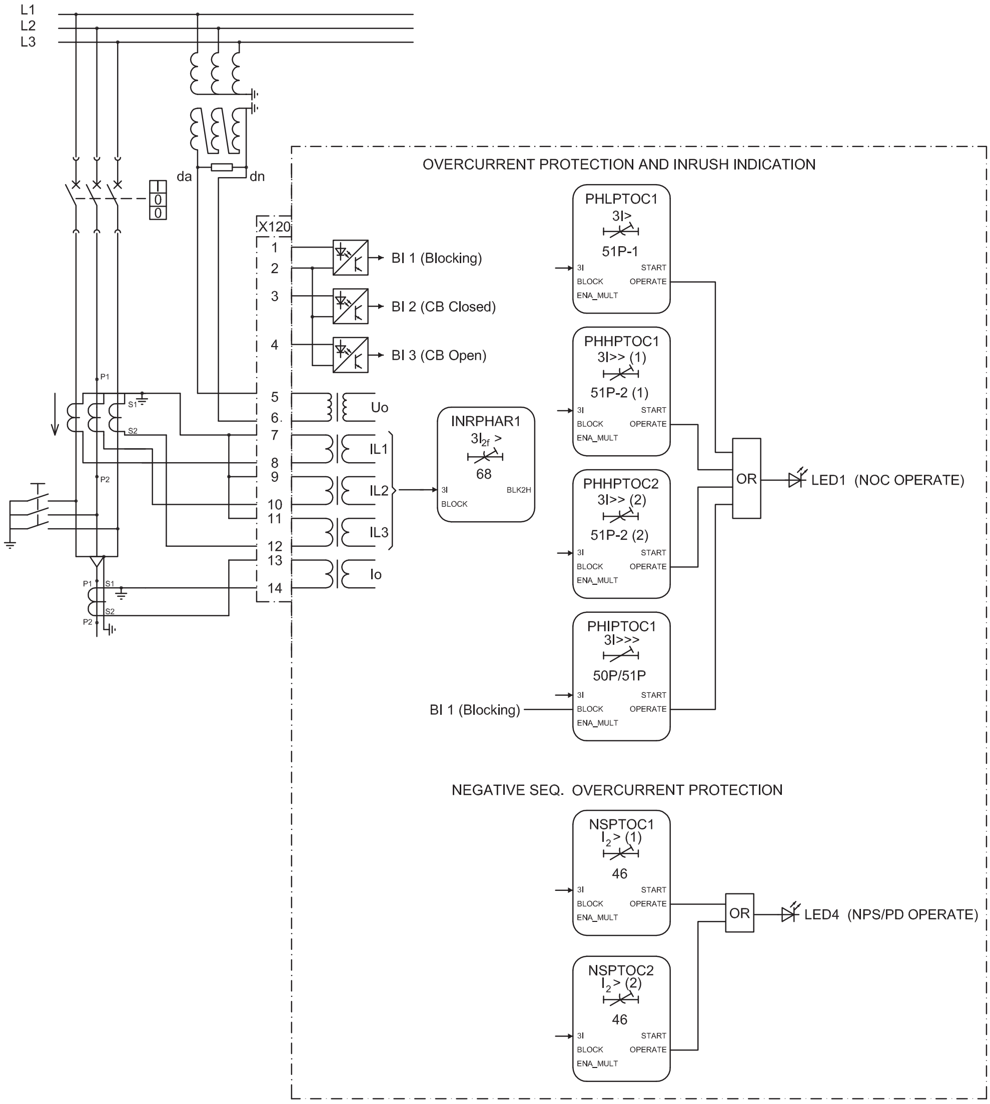


Figure 12: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

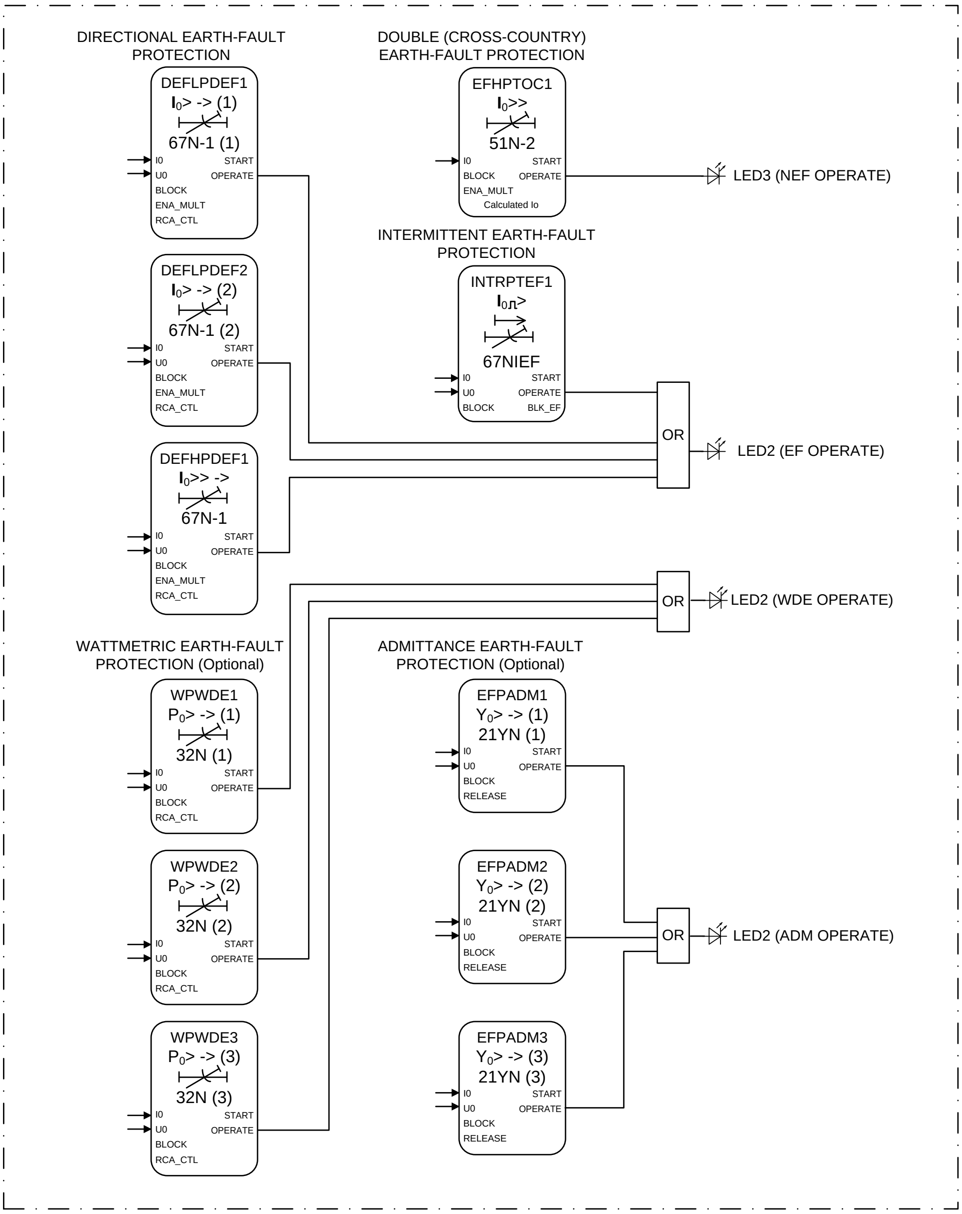


Figure 13: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only, or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE). In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault and LED 3 for double earth-fault protection operate indication.

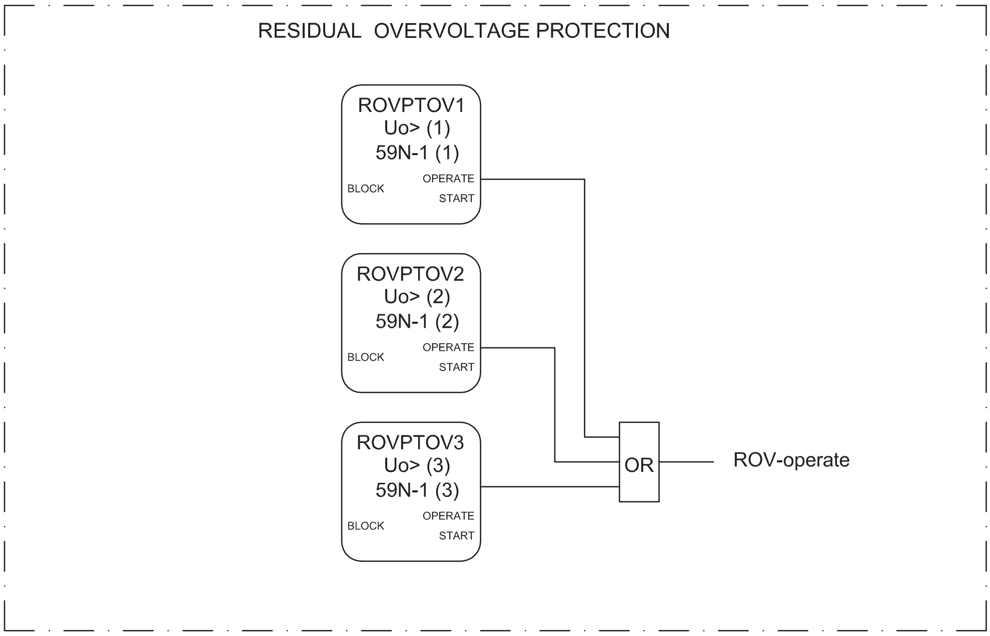


Figure 14: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 3.

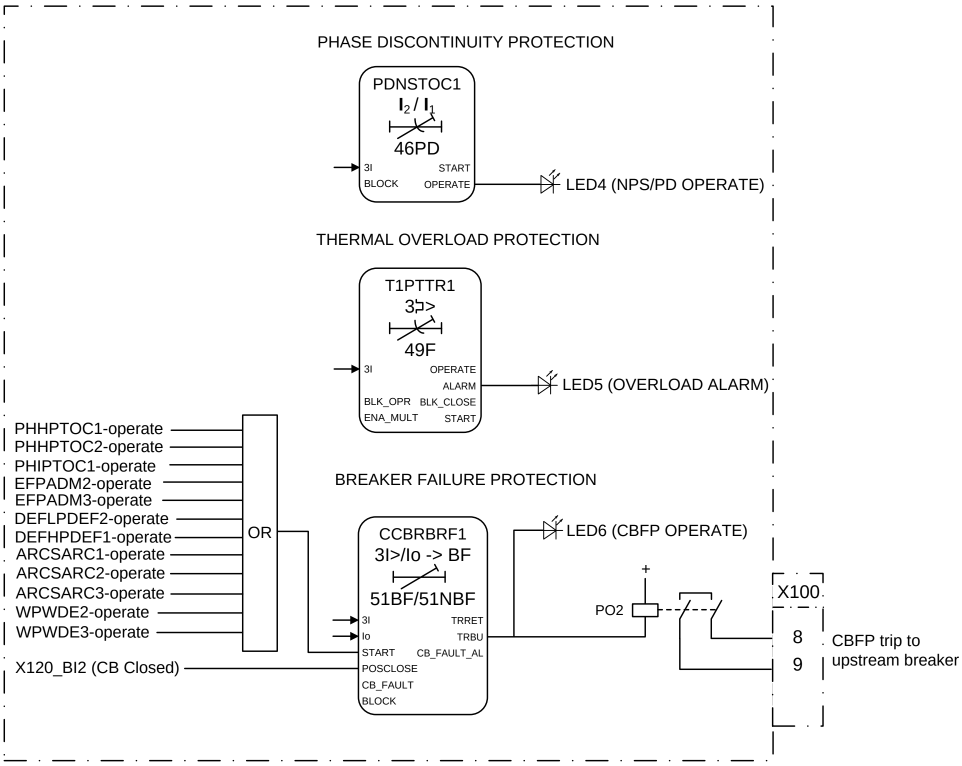


Figure 15: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

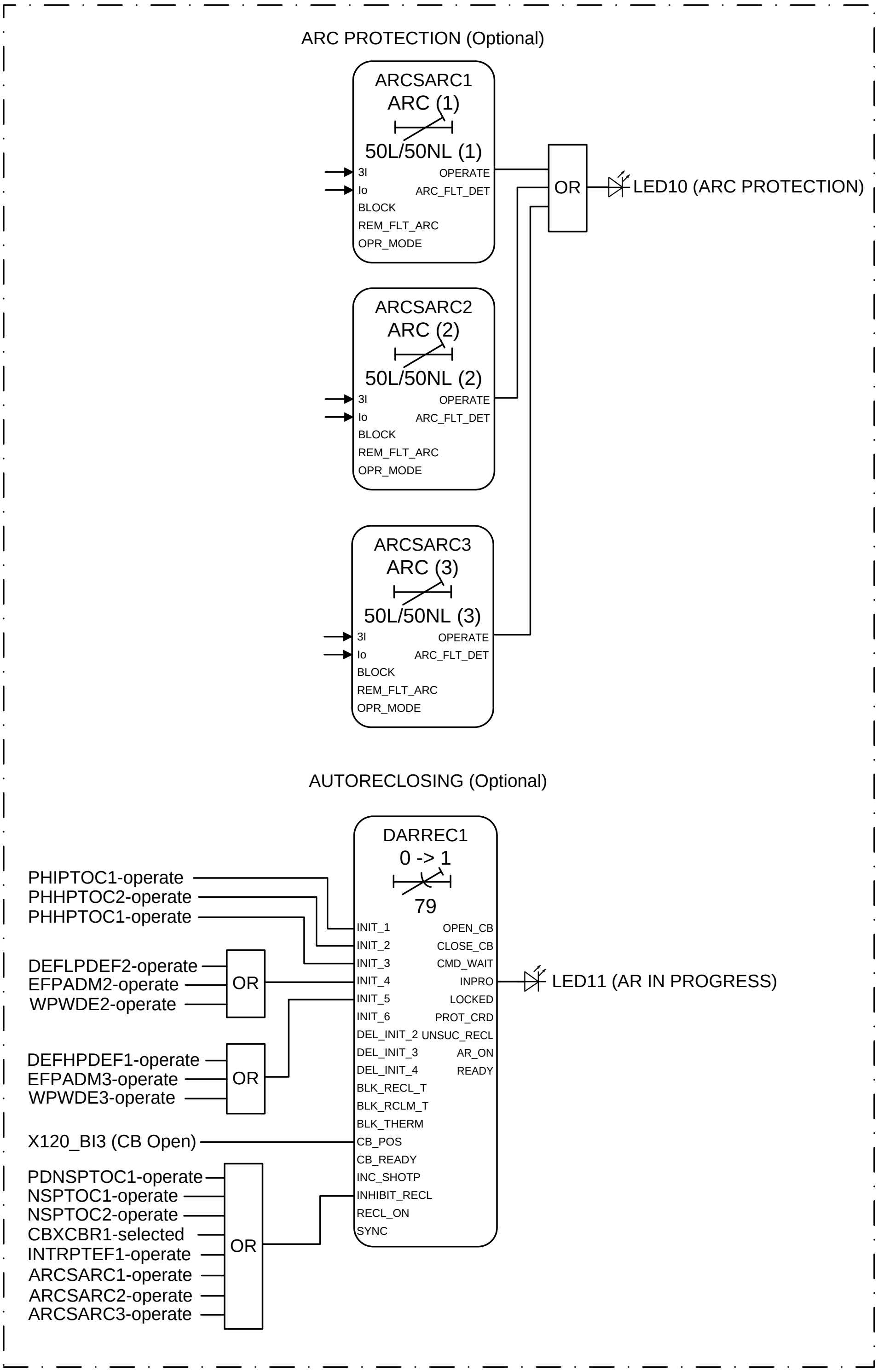


Figure 16: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

3.4.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

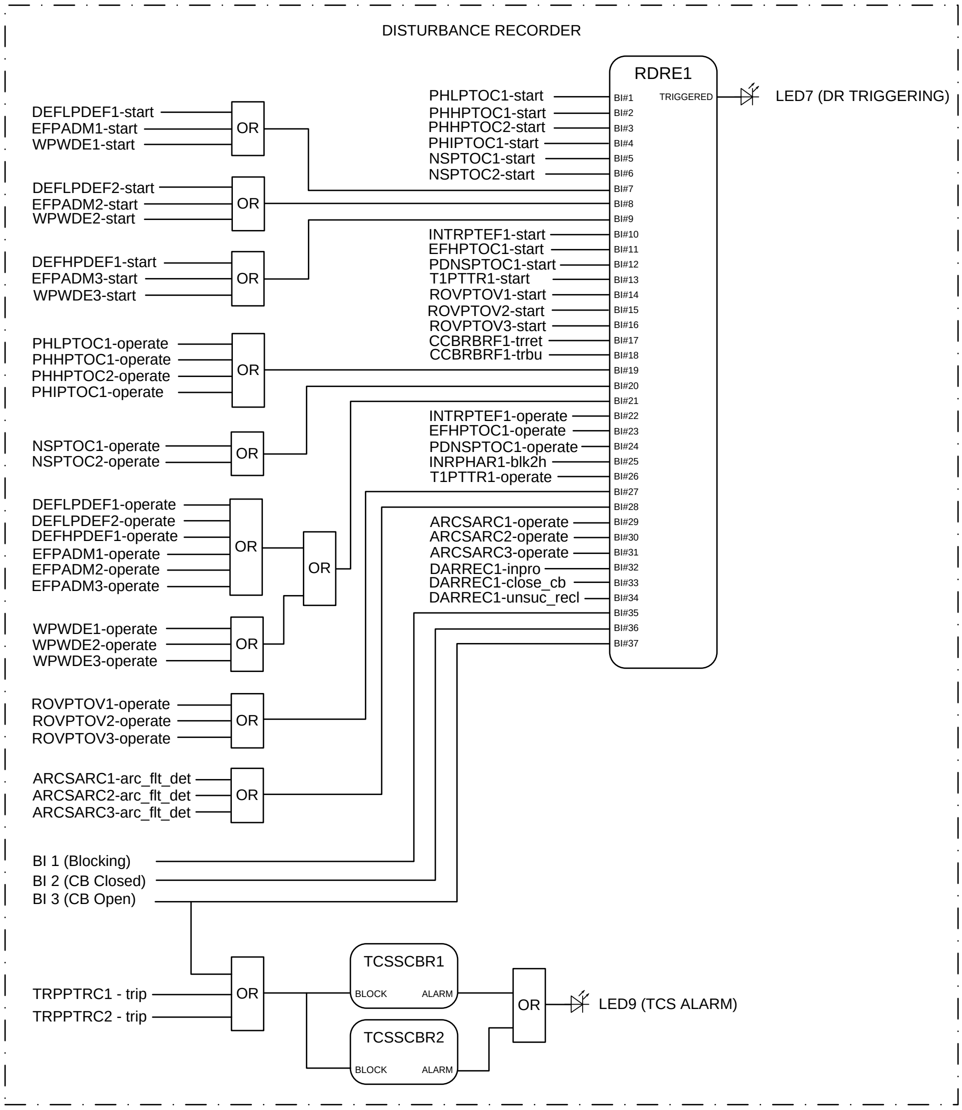


Figure 17: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.4.3.3 Functional diagrams for control and interlocking

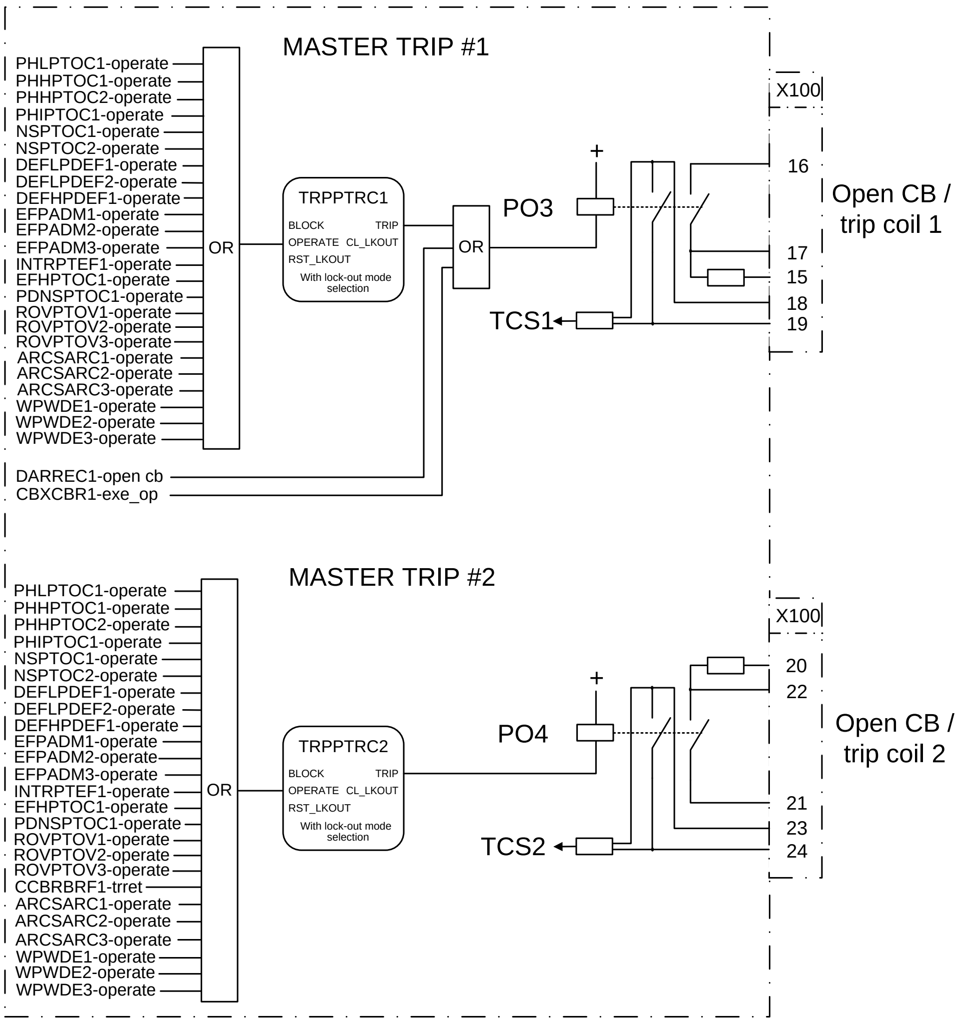


Figure 18: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary

input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

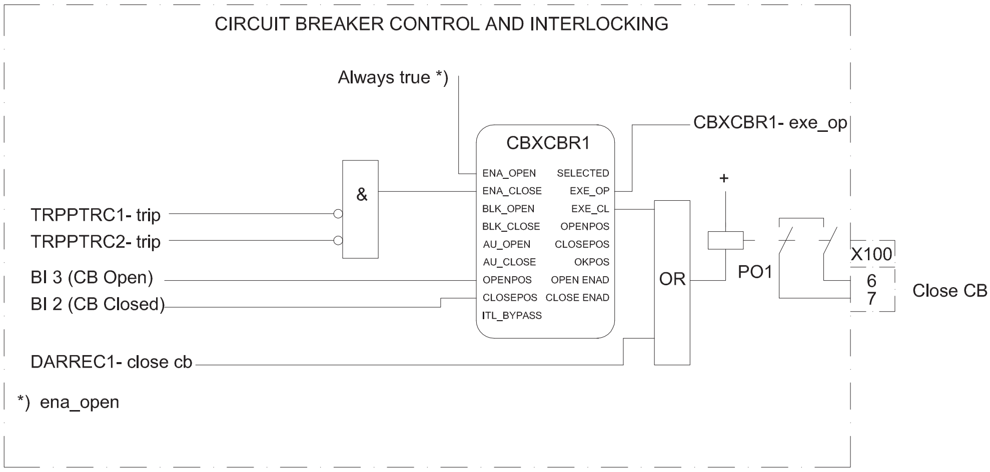


Figure 19: Circuit breaker control

The ENA_CLOSE input, which enables the closing of the circuit breaker, is a status of the Master Trip in the breaker control function block CBXCBR. The open operation is always enabled.

If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

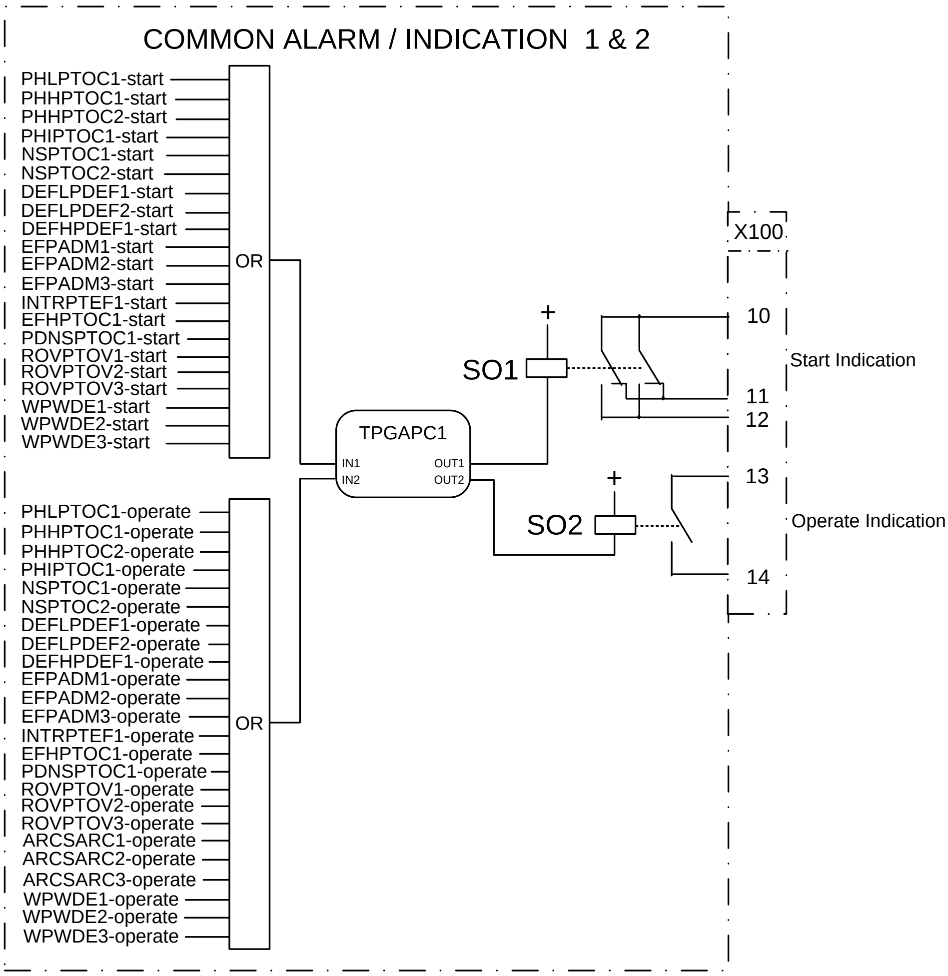


Figure 20: Alarm indication

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100: 13-15)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.5 Standard configuration B

3.5.1 Applications

The standard configuration for non-directional overcurrent and directional earthfault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance, wattmetric or harmonic based principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.5.2 Functions

Table 15: Functions included in the standard configuration B

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Residual voltage measurement	RESVMMXU1	Uo	Vn

3.5.2.1 Default I/O connections

Table 16: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI2	Directional earth fault protection's basic angle control	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-6,7
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2

Table 17: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100-8,9
X100-PO3	Open circuit breaker/trip coil 1	X100-15,16,17,18,19
X100-PO4	Open circuit breaker/trip coil 2	X100-20,21,22,23,24
X100-SO1	General start indication	X100-10,11,12
X100-SO2	General operate indication	X100-13,14,15
X110-SO1	Upstream overcurrent blocking	X110-14,15,16
X110-SO2	Overcurrent operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22

Table 18: Default connections for LEDs

LED	Default usage
1	Non-directional overcurrent operate
2	Directional/intermittent earth fault operate
3	Double (cross country) earth fault or residual overvoltage operate

Table continues on next page

LED	Default usage
4	Negative seq. overcurrent/phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Trip circuit supervision alarm
10	Arc protection operate
11	Auto reclose in progress

3.5.2.2 Default disturbance recorder settings

Table 19: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.5.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.5.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

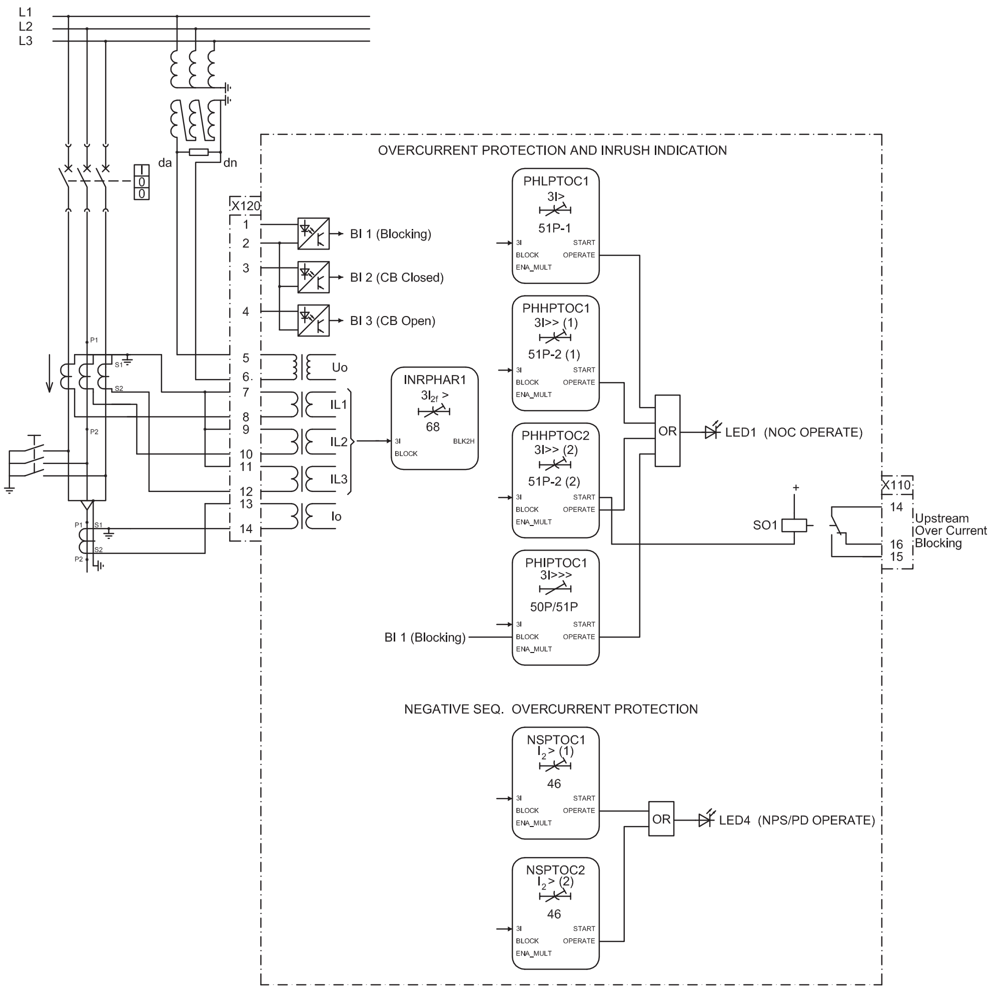


Figure 21: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block’s (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

The upstream blocking from the start of the overcurrent second high stage (PHHPTOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

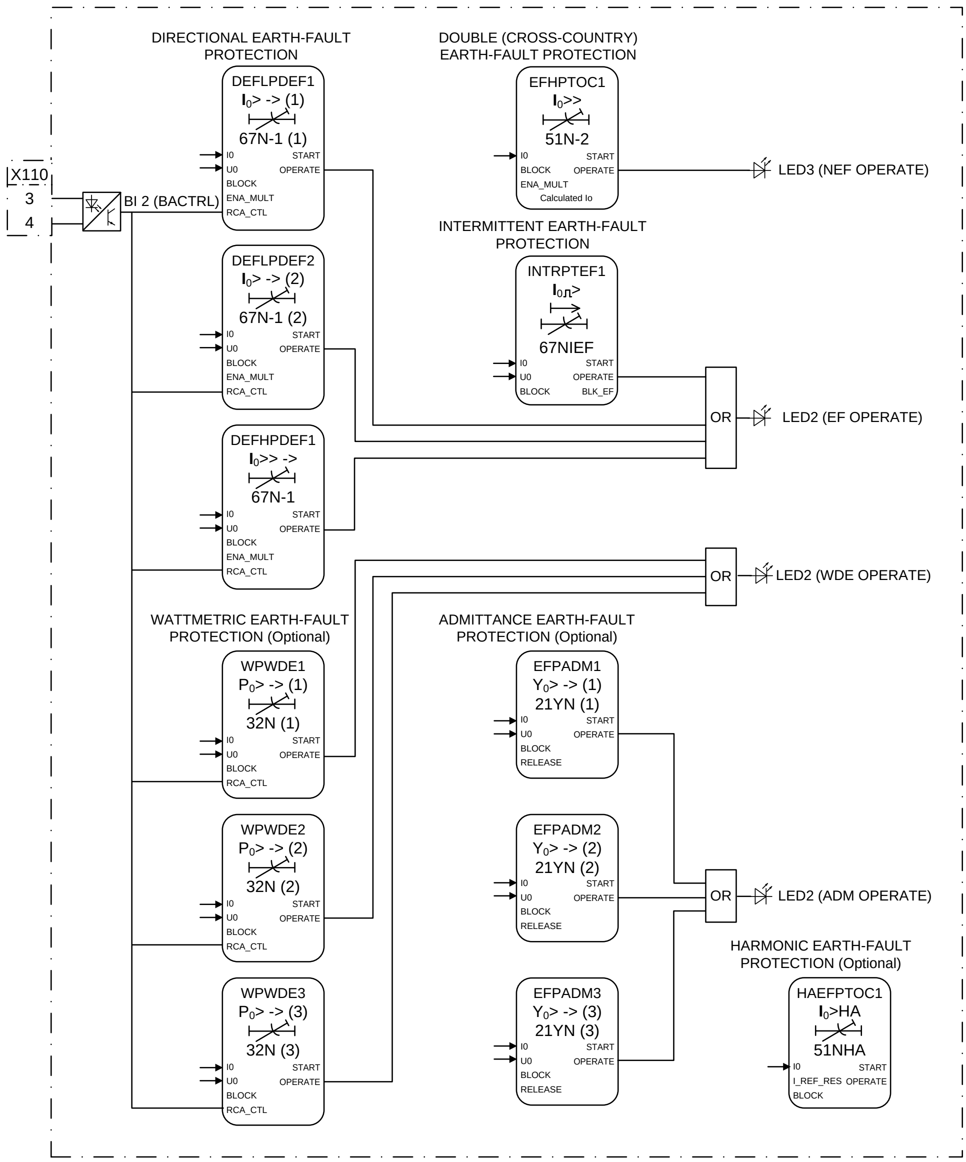


Figure 22: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE) or harmonic based earth-fault protection (HAEFPTOC). In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

The binary input 2 (X110:3-4) is intended for directional earth-fault protection blocks' relay characteristic angle (RCA: 0°/-90°) or operation mode (I_0Sinφ/ I_0Cosφ) change. All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault and LED 3 for double earth-fault protection operate indication.

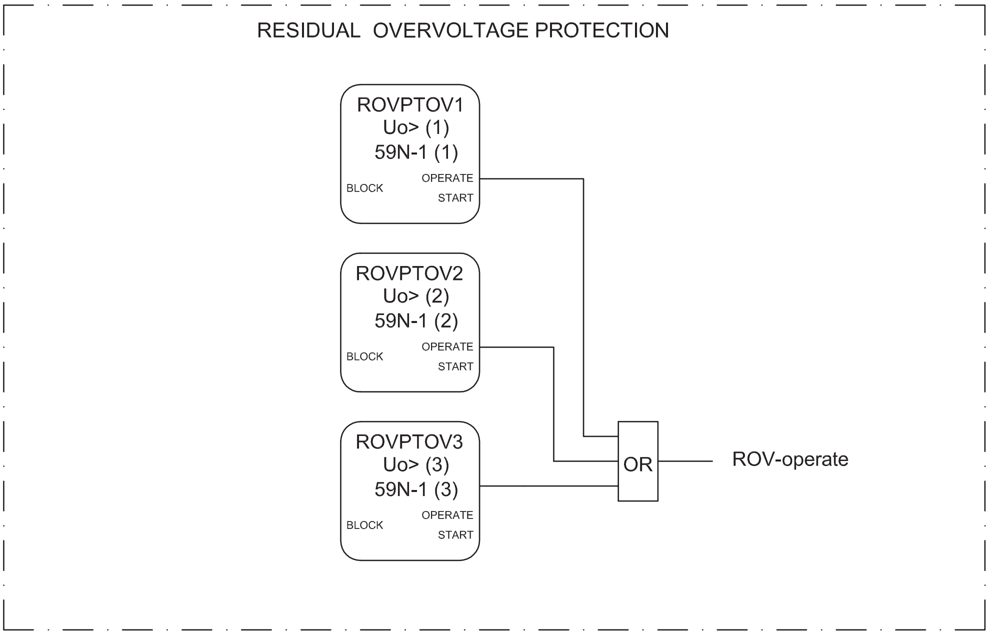


Figure 23: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 3.

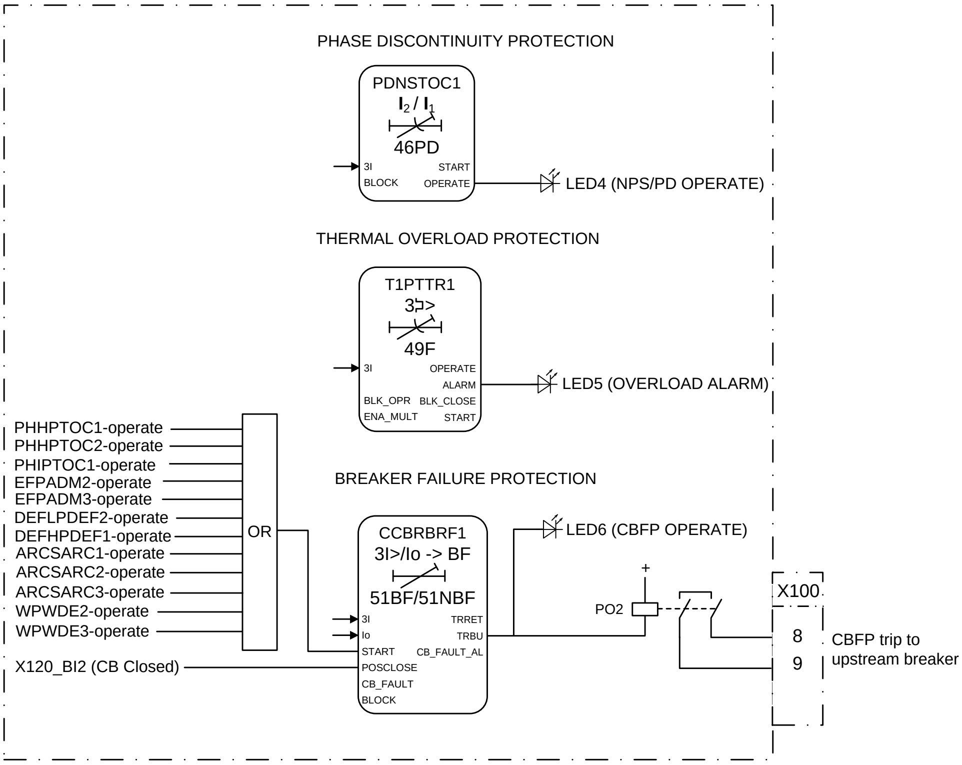


Figure 24: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

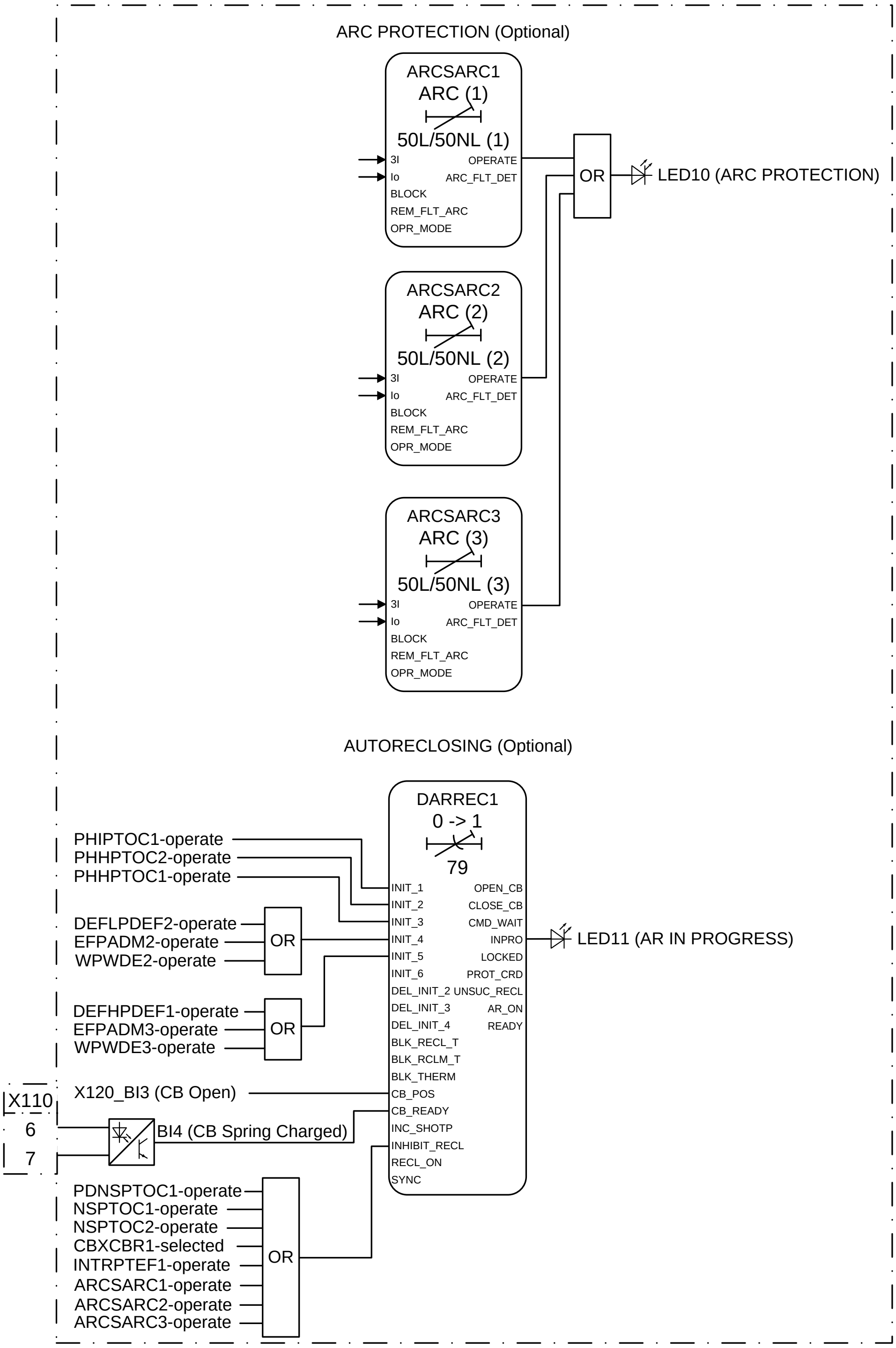


Figure 25: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

3.5.3.2 Functional diagram for disturbance recorder and trip circuit supervision

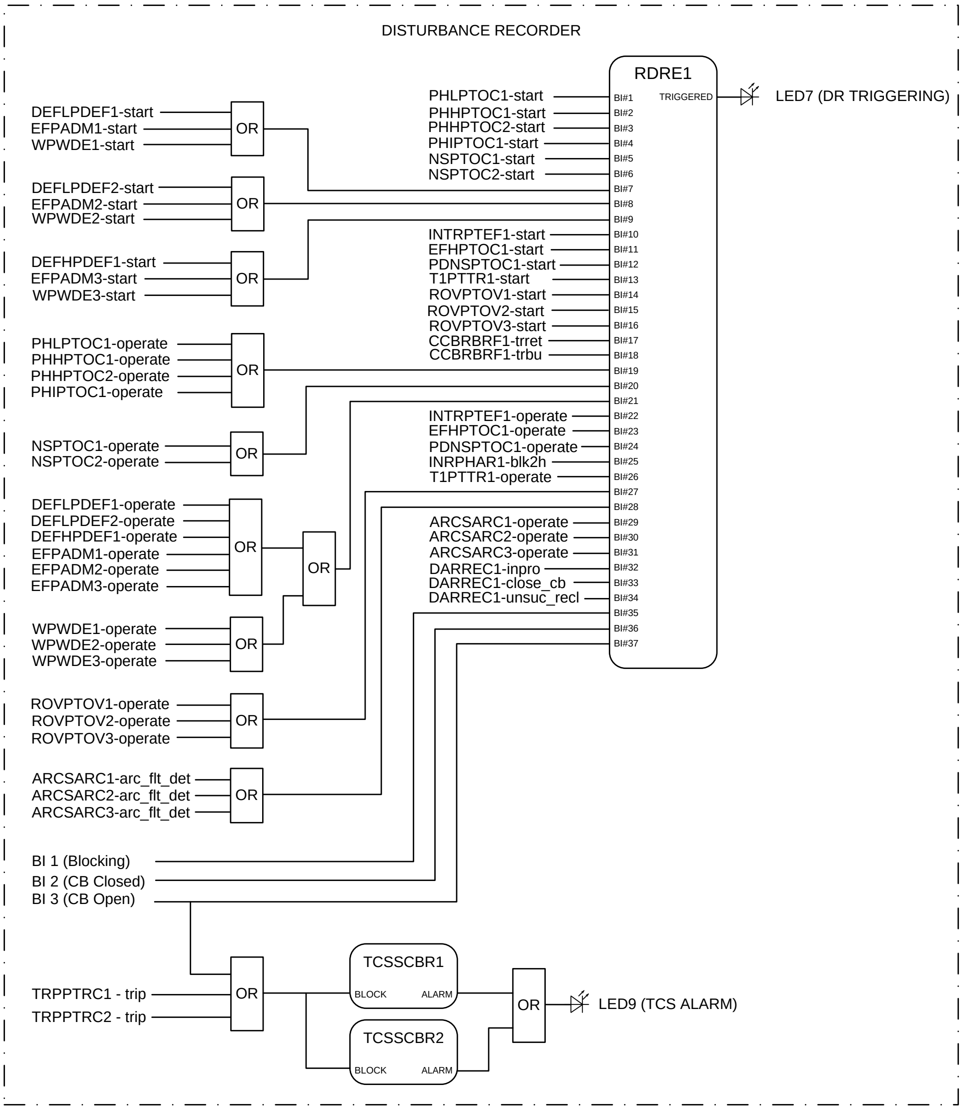


Figure 26: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.5.3.3 Functional diagrams for control and interlocking

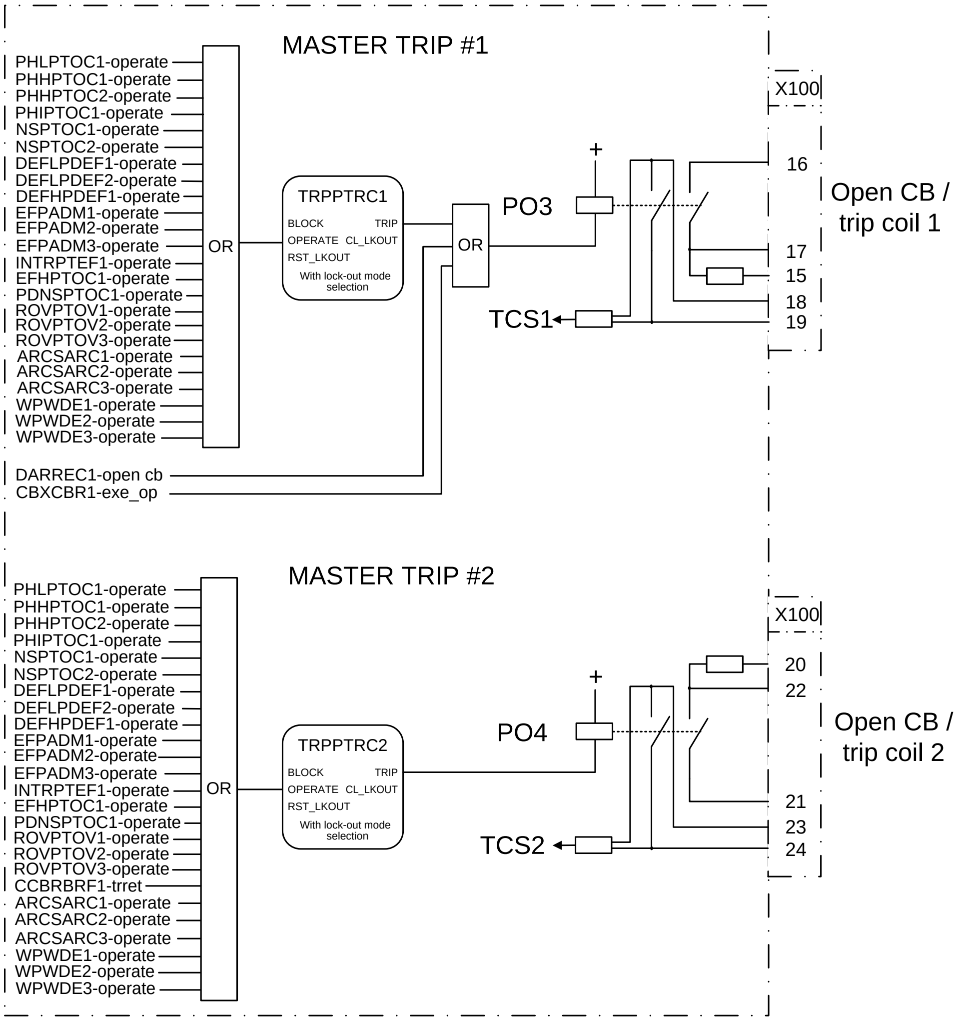


Figure 27: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary

input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

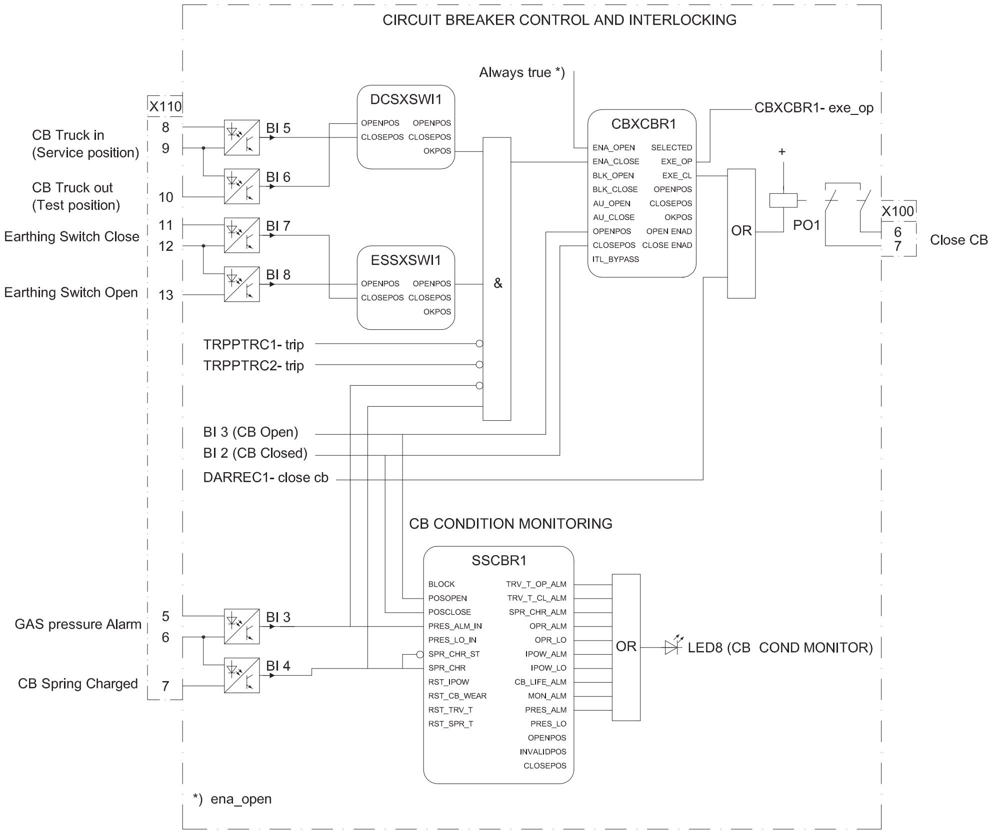


Figure 28: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 20: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

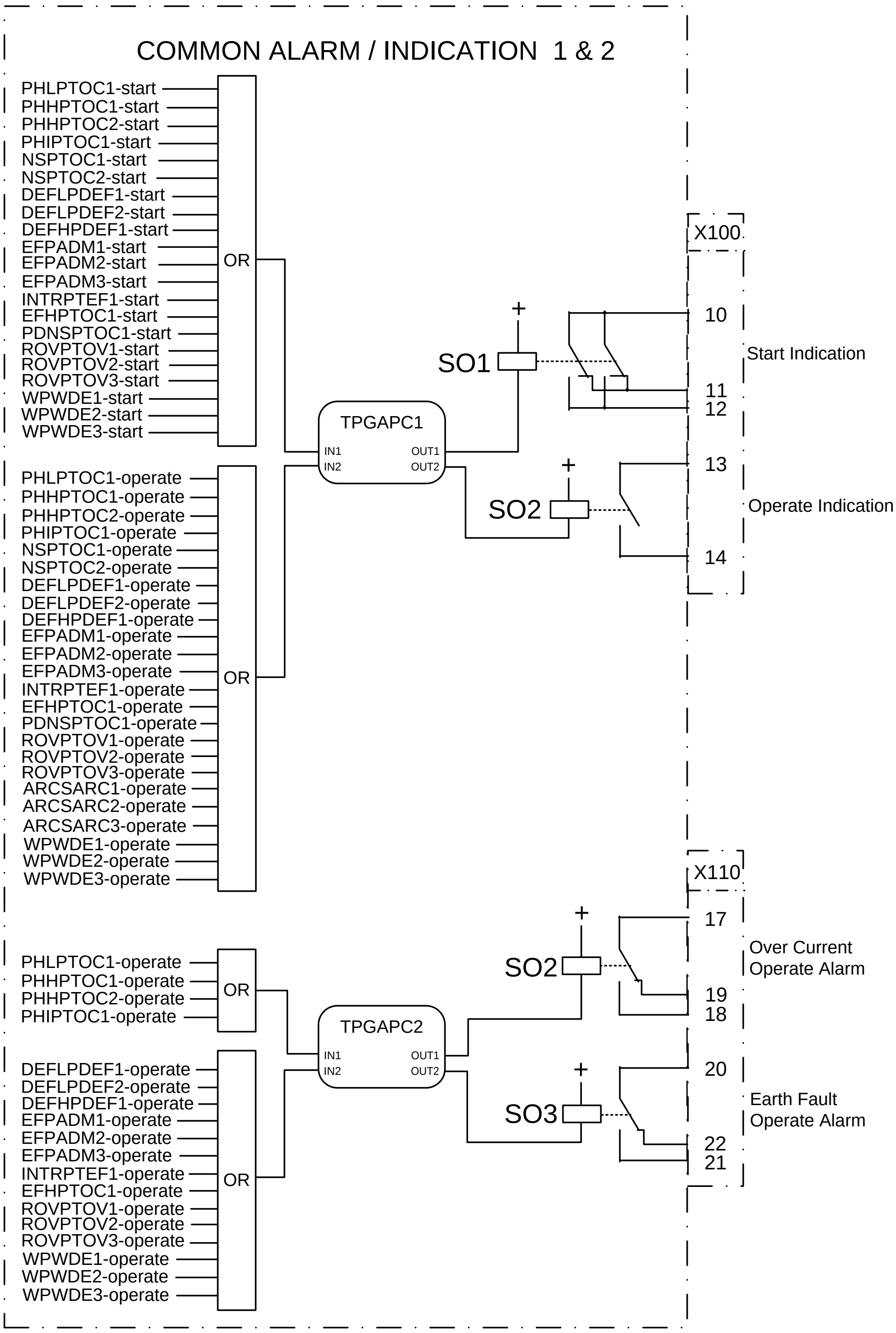


Figure 29: Alarm indication

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100: 13-15)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.6 Standard configuration C

3.6.1 Applications

The standard configuration for non-directional overcurrent and non-directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in directly or resistance earthed distribution networks.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.6.2 Functions

Table 21: Functions included in the standard configuration C

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In

3.6.2.1 Default I/O connections

Table 22: Default connections for binary inputs

Binary input	Default usage	Connector pins
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Reset of master trip lockout	X120-5,6

Table 23: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100-8,9
X100-PO3	Open circuit breaker/trip coil 1	X100-15,16,17,18,19
X100-PO4	Open circuit breaker/trip coil 2	X100-20,21,22,23,24
X100-SO1	General start indication	X100-10,11,12
X100-SO2	General operate indication	X100-13,14,15

Table 24: Default connections for LEDs

LED	Default usage
1	Non-directional overcurrent operate
2	Non-directional earth fault operate
3	Sensitive earth fault operate
4	Negative seq. overcurrent/phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Not connected
9	Trip circuit supervision alarm
10	Arc protection operate
11	Auto reclose in progress

3.6.2.2 Default disturbance recorder settings

Table 25: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.6.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a summation connection of the phase current transformers.

3.6.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

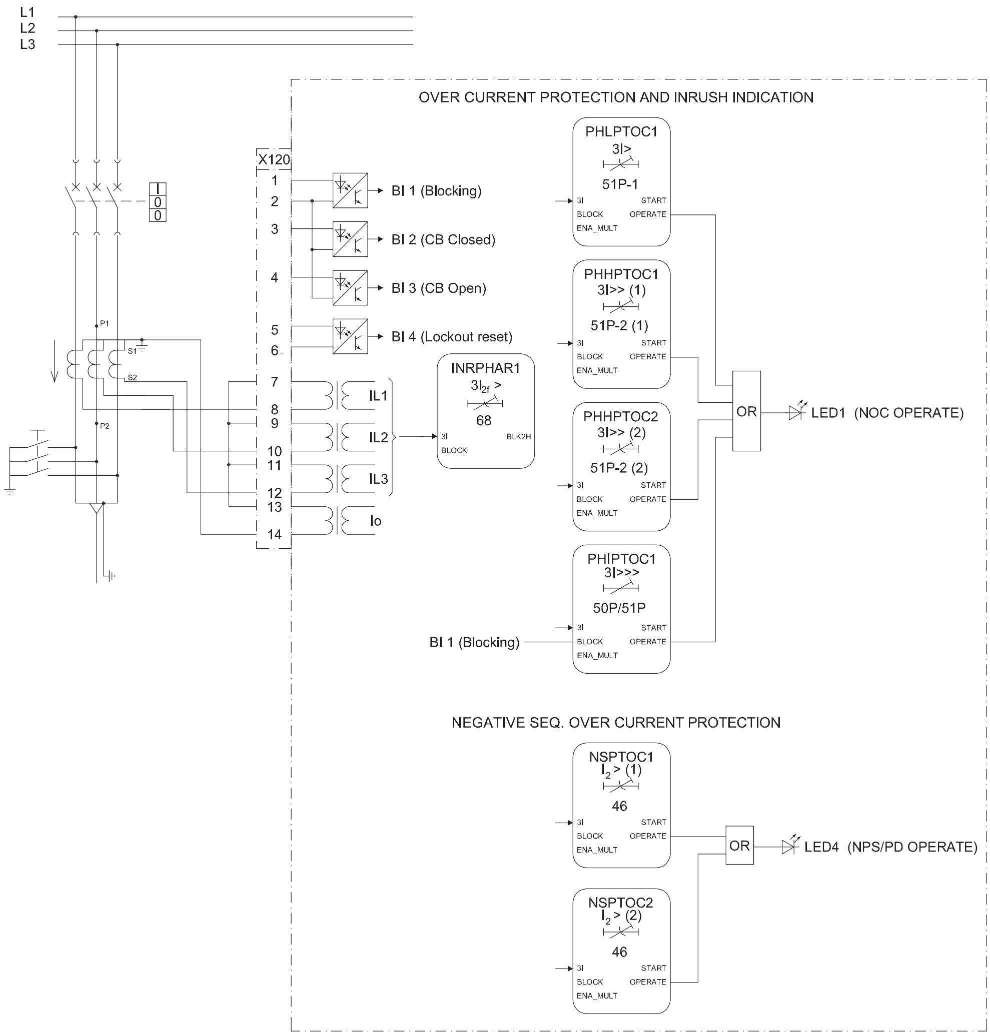


Figure 30: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

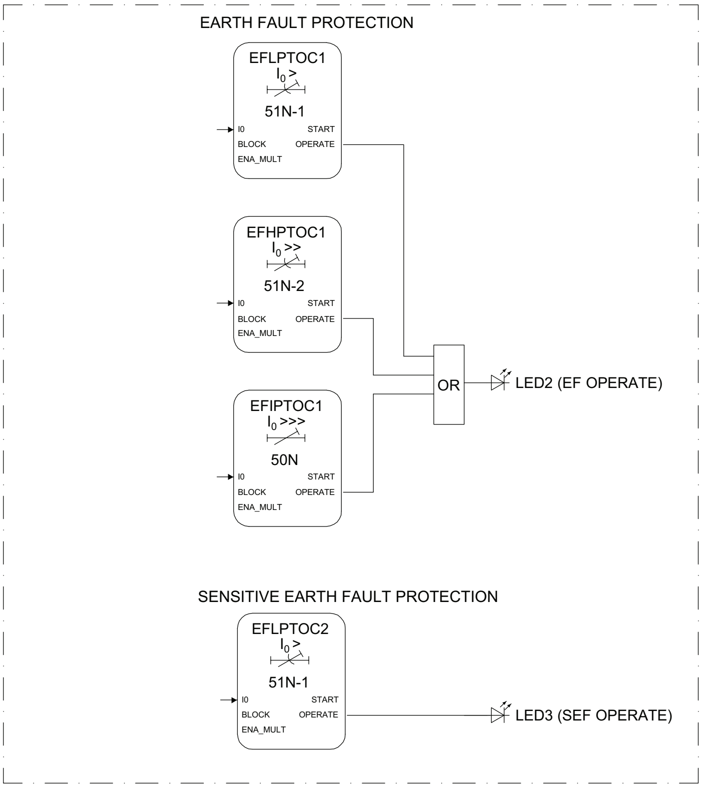


Figure 31: Non-directional earth-fault protection

Four stages are offered for non-directional earth-fault protection. One stage is dedicated to sensitive earth-fault protection.

All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault and LED 3 for the sensitive earth-fault protection operate indication.

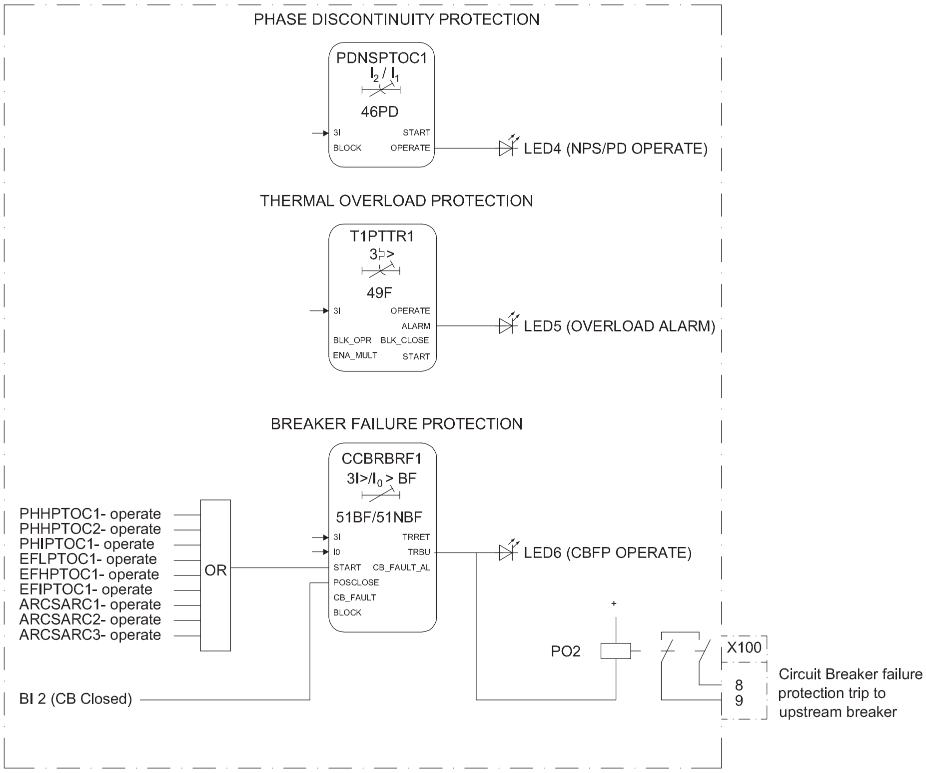


Figure 32: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

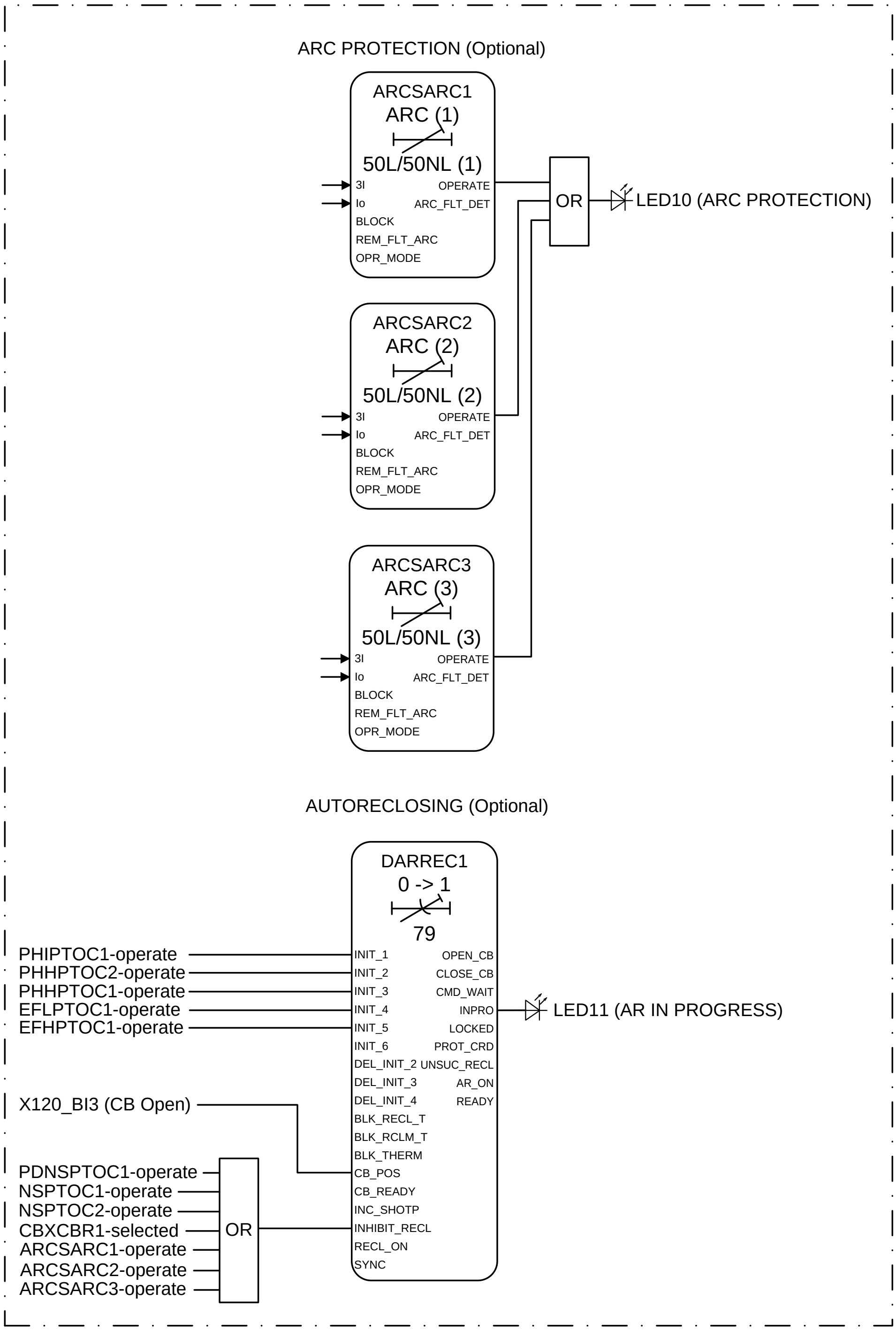


Figure 33: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

3.6.3.2 Functional diagram for disturbance recorder and trip circuit supervision

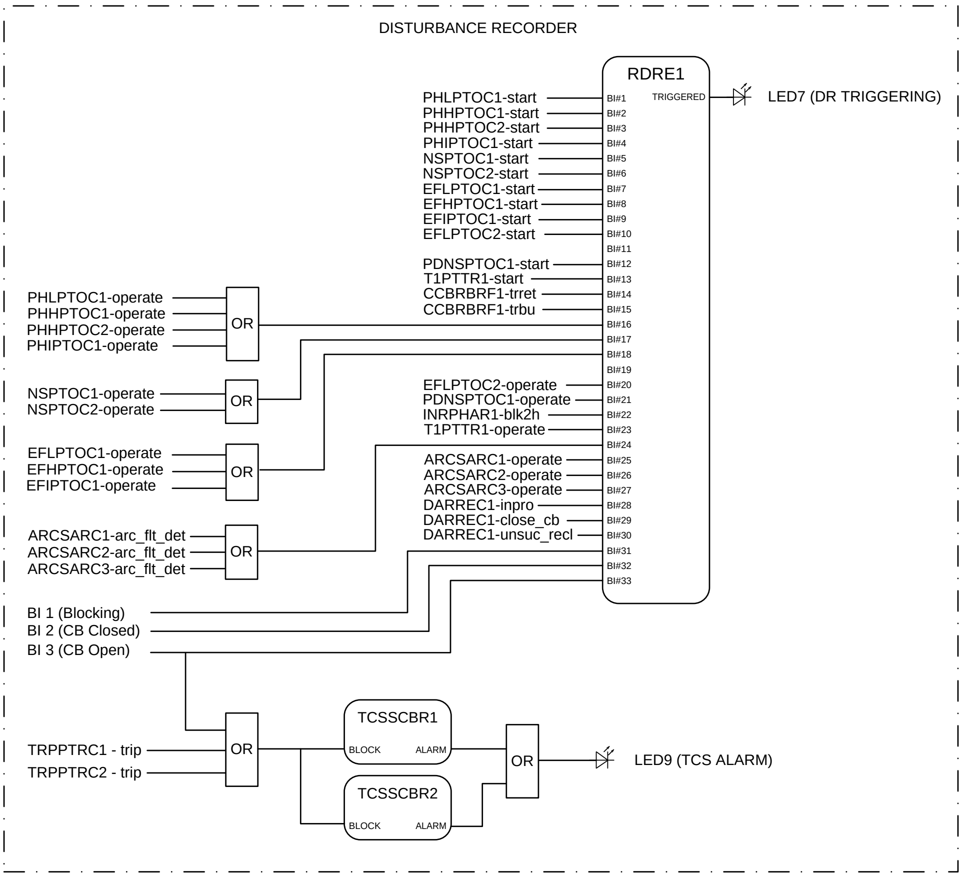


Figure 34: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.6.3.3 Functional diagrams for control and interlocking

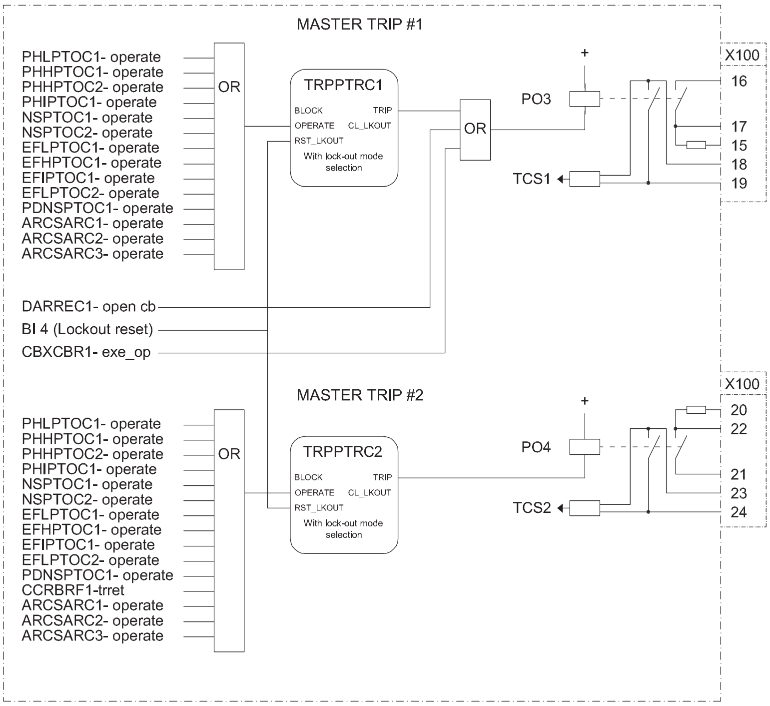


Figure 35: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary

input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

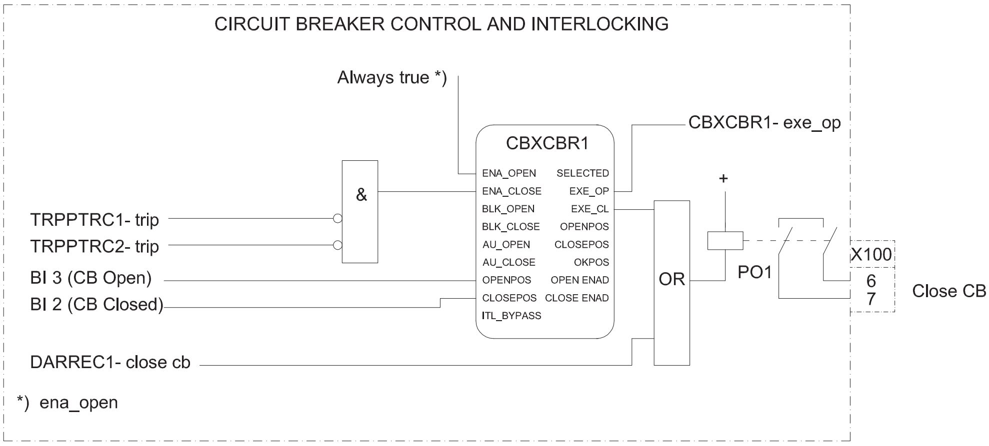


Figure 36: Circuit breaker control

The ENA_CLOSE input, which enables the closing of the circuit breaker, is a status of the Master Trip in the breaker control function block CBXCBR. The open operation is always enabled.

If the ENA_CLOSE signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

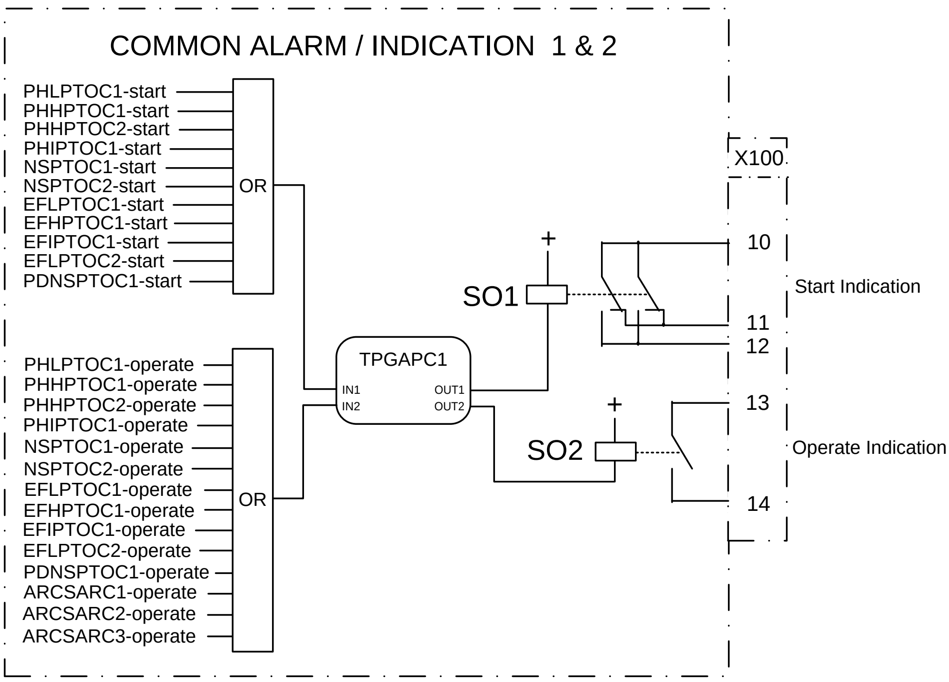


Figure 37: Alarm indication

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.7 Standard configuration D

3.7.1 Applications

The standard configuration for non-directional overcurrent and non-directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in directly or resistance earthed distribution networks.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.7.2 Functions

Table 26: Functions included in the standard configuration D

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In

3.7.2.1 Default I/O connections

Table 27: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI2	Auto reclose external start command	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-6,7
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Reset of master trip lockout	X120-5,6

Table 28: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100-8,9
X100-PO3	Open circuit breaker/trip coil 1	X100-15,16,17,18,19
X100-PO4	Open circuit breaker/trip coil 2	X100-20,21,22,23,24
X100-SO1	General start indication	X100-10,11,12
X100-SO2	General operate indication	X100-13,14,15

Table continues on next page

Binary output	Default usage	Connector pins
X110-SO1	Upstream overcurrent blocking	X110-14,15,16
X110-SO2	Overcurrent operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22

Table 29: Default connections for LEDs

LED	Default usage
1	Non-directional overcurrent operate
2	Non-directional earth fault operate
3	Sensitive earth fault operate
4	Negative seq. overcurrent/phase discontinuity operate
5	Thermal overload alarm
6	Breaker failure operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	Trip circuit supervision alarm
10	Arc protection operate
11	Auto reclose in progress

3.7.2.2 Default disturbance recorder settings

Table 30: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	-
6	-
7	-
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.7.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a summation connection of the phase current transformers.

3.7.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

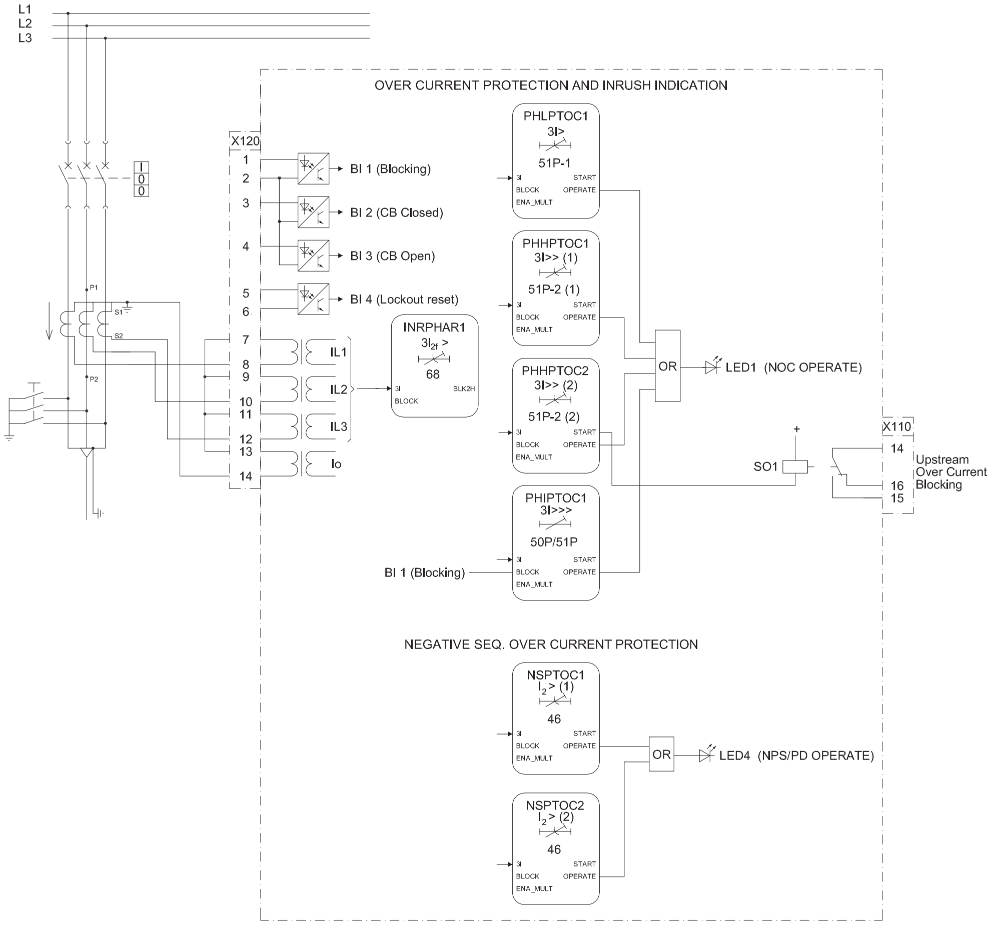


Figure 38: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

The upstream blocking from the start of the overcurrent second high stage (PHHPTOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

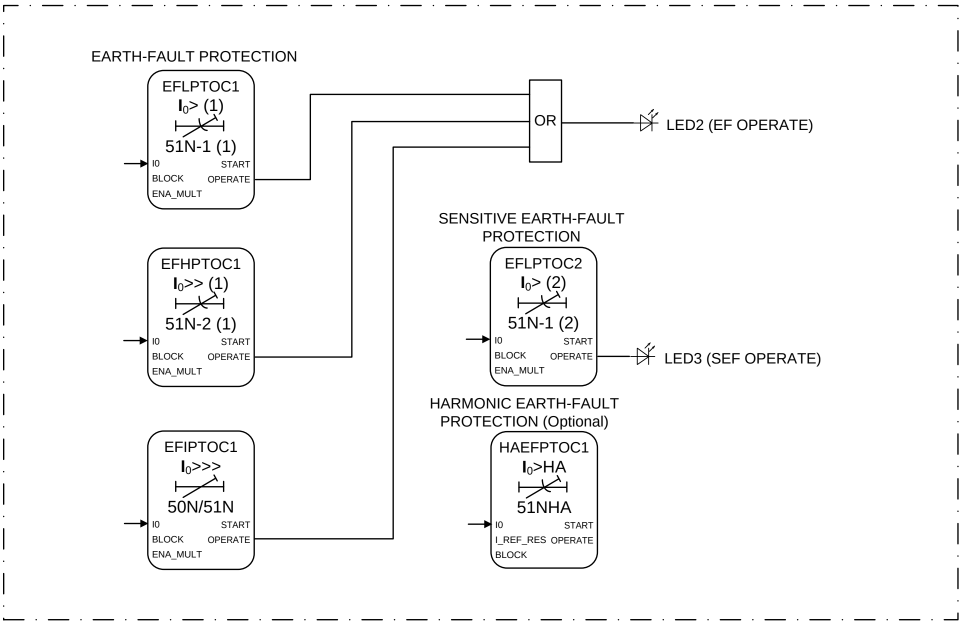


Figure 39: Non-directional earth-fault protection

Four stages are offered for non-directional earth-fault protection. One stage is dedicated to sensitive earth-fault protection. Based on the order code, the configuration can also include an optional harmonic-based earth-fault (HAEFPTOC) protection.

All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault and LED 3 for the sensitive earth-fault protection operate indication.

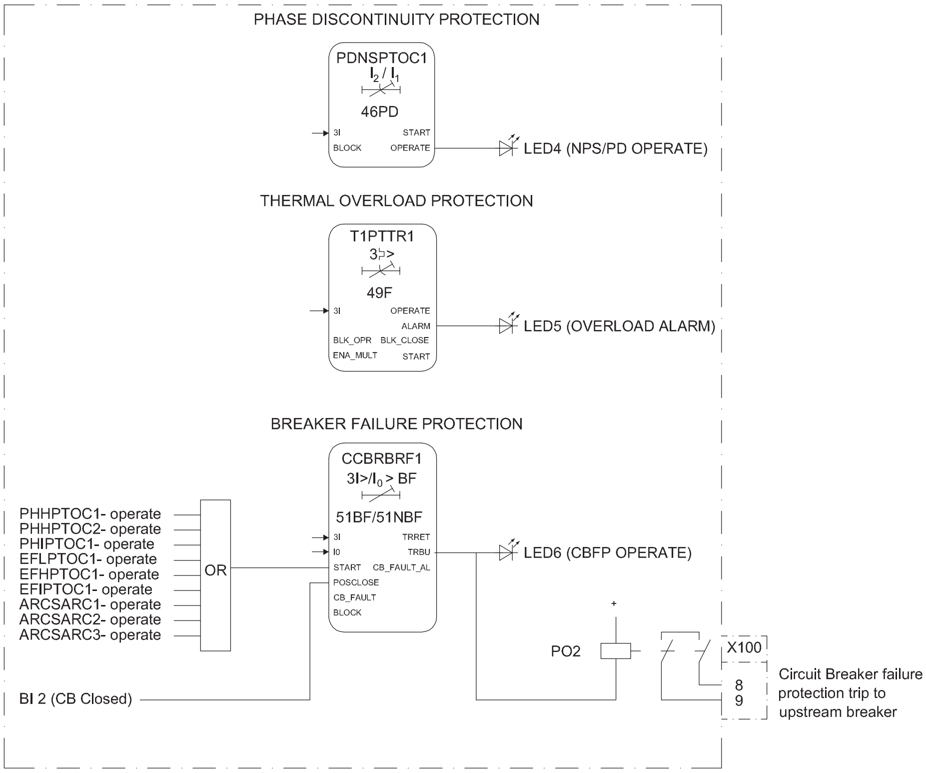


Figure 40: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

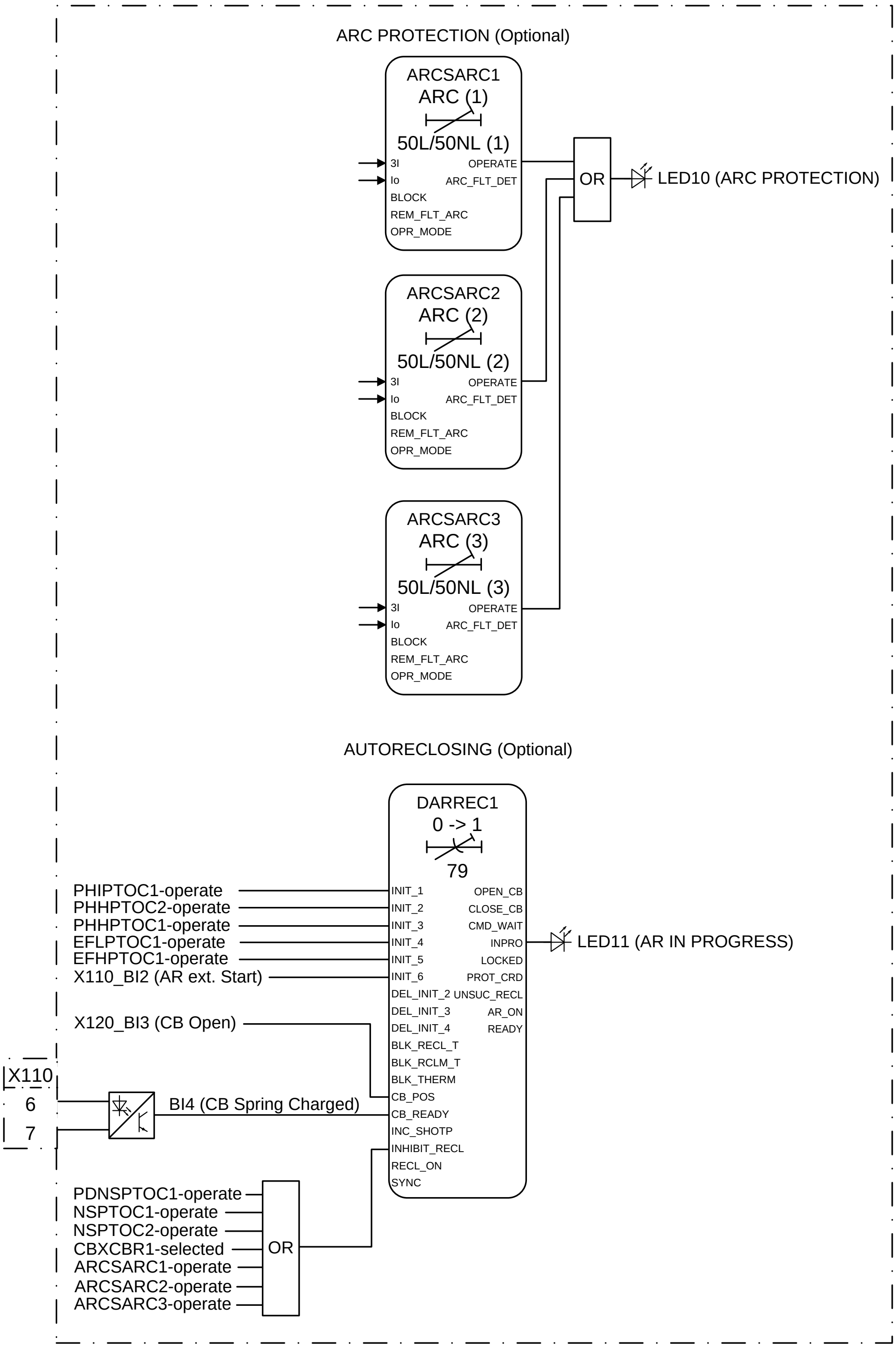


Figure 41: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. The INIT6 input in the autorecloser function block is controlled by a binary input 2 (X110:3-4) enabling the use of the external start command. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

3.7.3.2 Functional diagram for disturbance recorder and trip circuit supervision

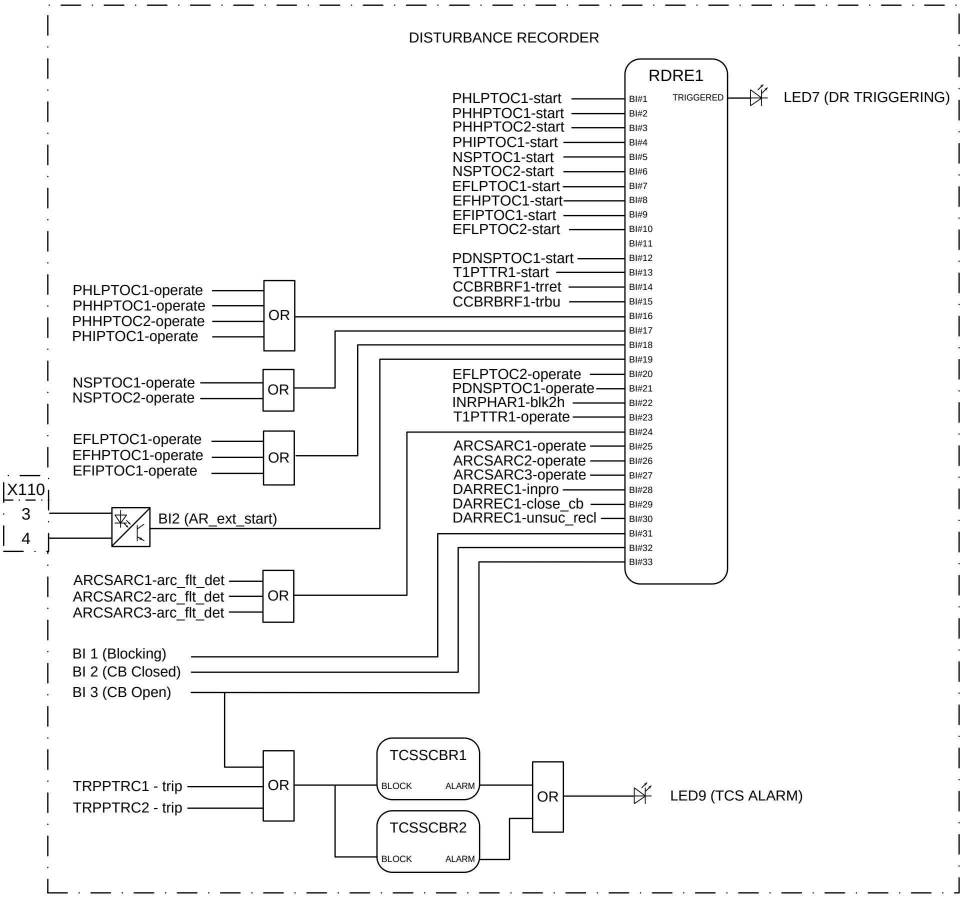


Figure 42: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected, as well as the autorecloser external start command from the binary input 2 (X110:3-4).

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

3.7.3.3 Functional diagrams for control and interlocking

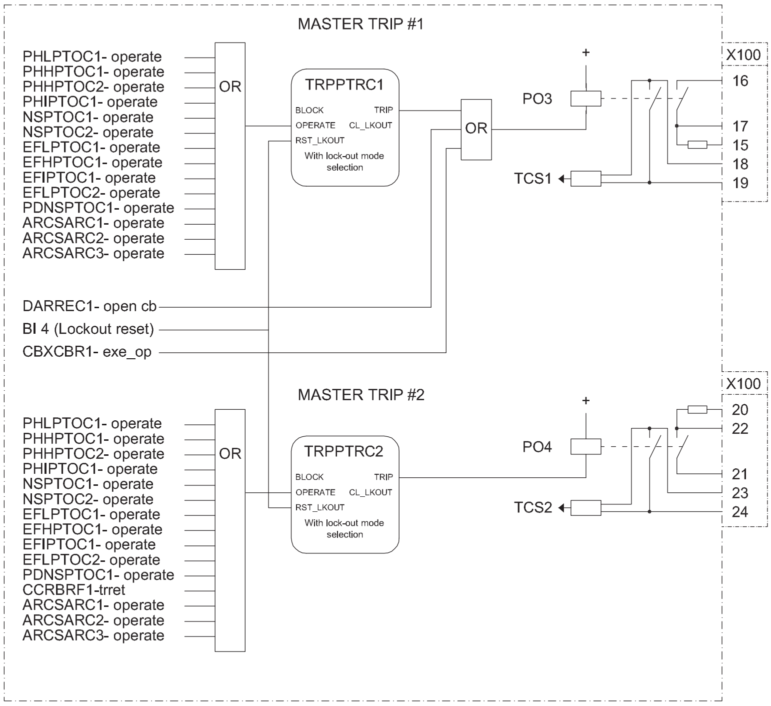


Figure 43: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

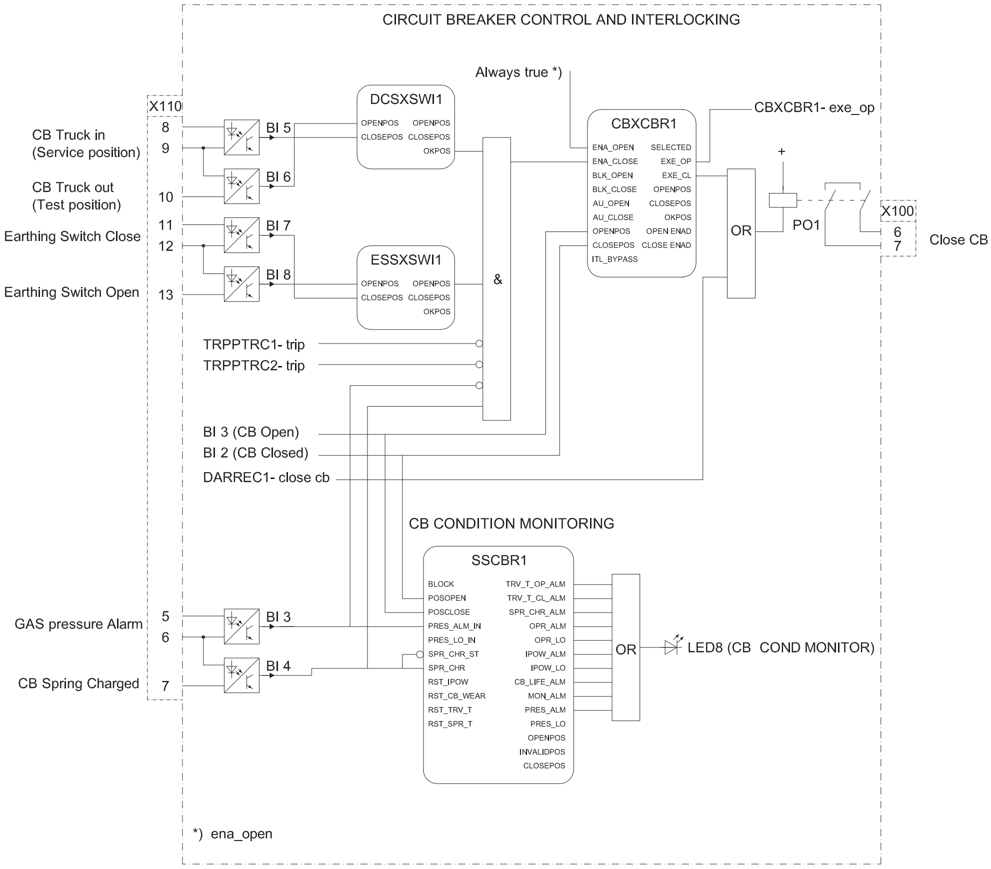


Figure 44: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 31: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

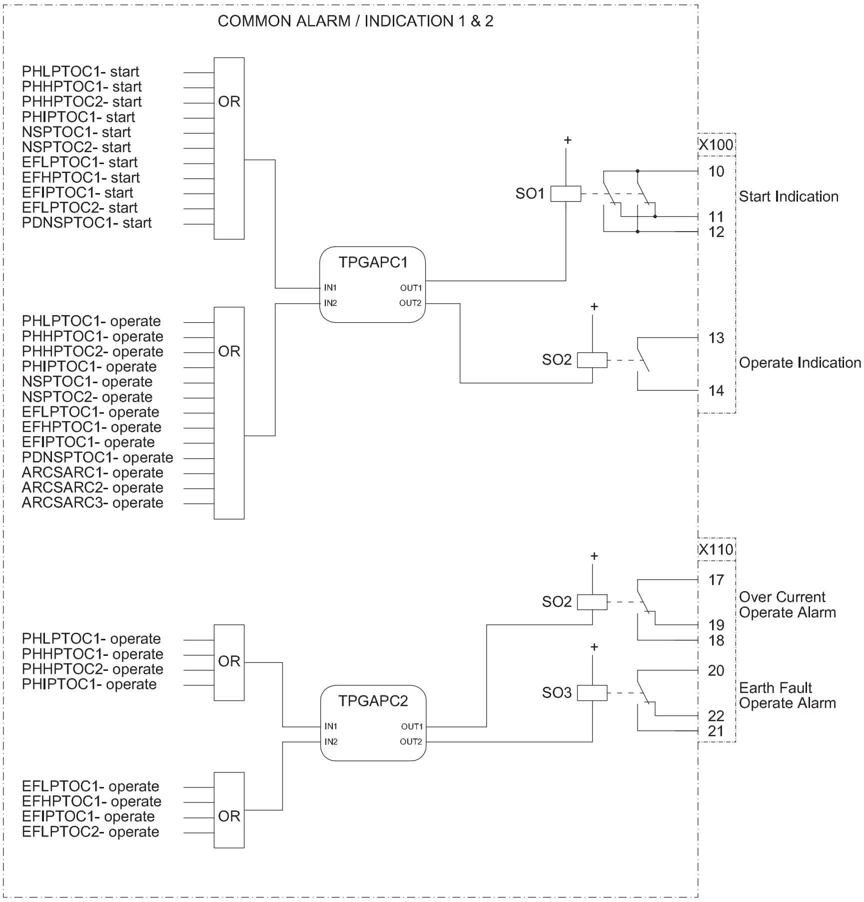


Figure 45: Alarm indication

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.8 Standard configuration E

3.8.1 Applications

The standard configuration for non-directional overcurrent and directional earthfault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance or wattmetric based principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.8.2 Functions

Table 32: Functions included in the standard configuration E

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E

3.8.2.1 Default I/O connections

Table 33: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	MCB open	X110-1,2
X110-BI2	Directional earth fault protection's basic angle control	X110-3,4
X110-BI3	Circuit breaker low gas pressure alarm	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Lock-out reset	X120-5,6

Table 34: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15
X110-SO2	Overcurrent operate alarm	X110-17,18
X110-SO3	Earth fault operate alarm	X110-20,21

Table 35: Default connections for LEDs

LED	Default usage
1	Non-directional overcurrent protection operated
2	Directional earth-fault protection operated
3	Double (cross country) earth fault or residual overvoltage protection operated
4	Negative-sequence overcurrent or phase discontinuity protection operated
5	Thermal overload protection operated
6	Circuit-breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit-breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.8.2.2 Default disturbance recorder settings

Table 36: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.8.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.8.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

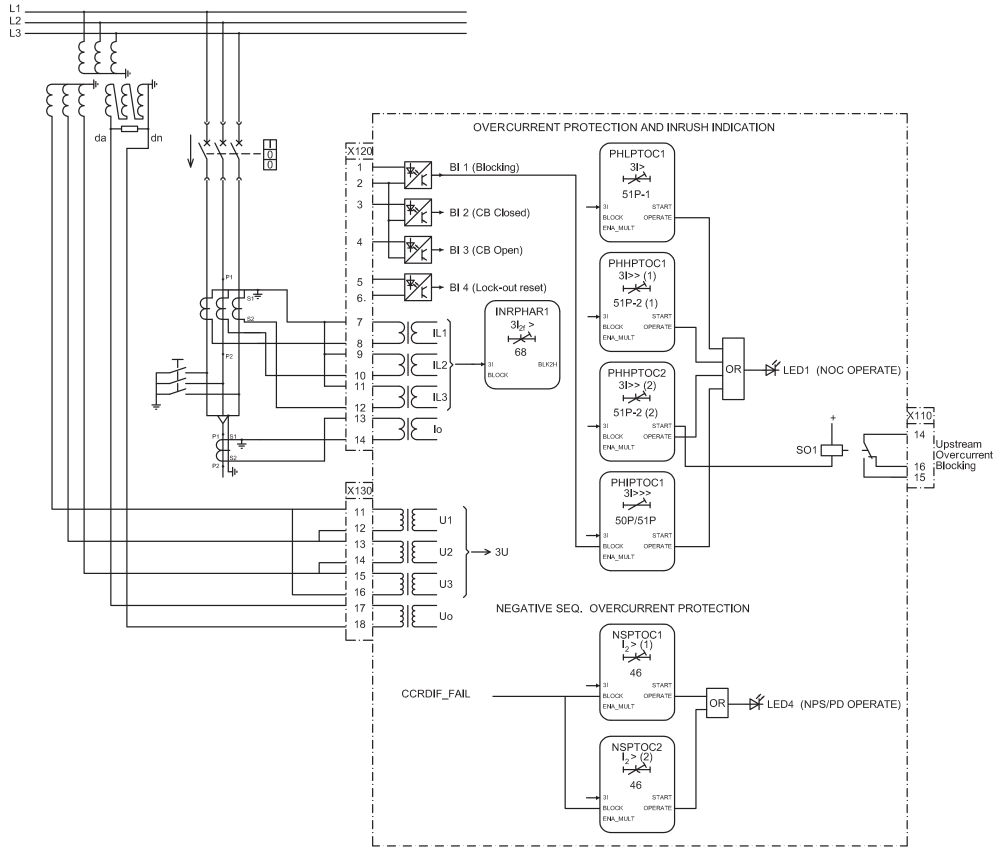


Figure 46: Overcurrent protection

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

The upstream blocking from the start of the overcurrent second high stage (PHHPTOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

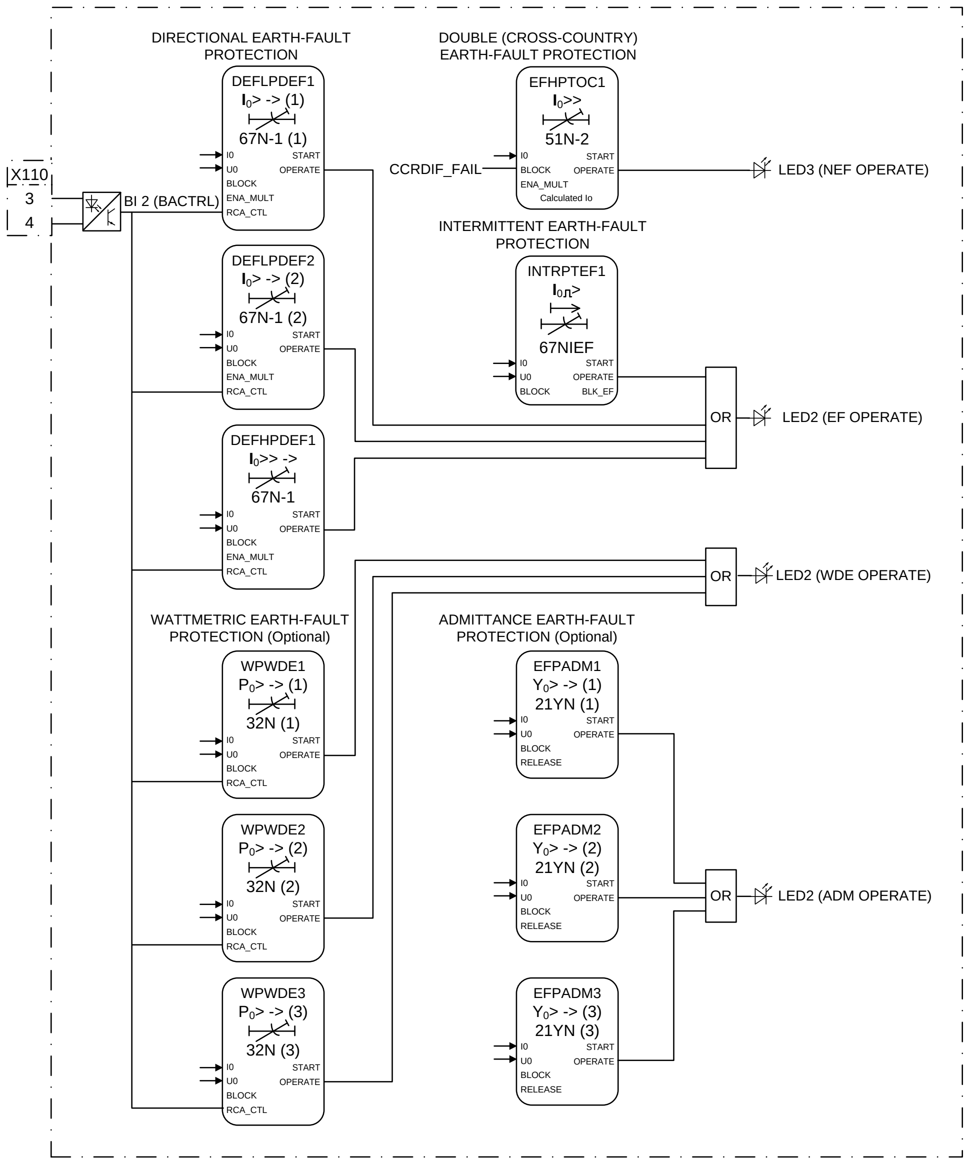


Figure 47: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE) or harmonic based earth-fault protection (HAEFPTOC). In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

The binary input 2 (X110:3-4) is intended for directional earth-fault protection blocks' relay characteristic angle (RCA: 0°/-90°) or operation mode (I_0Sinφ/ I_0Cosφ) change. All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault and LED 3 for double earth-fault protection operate indication.

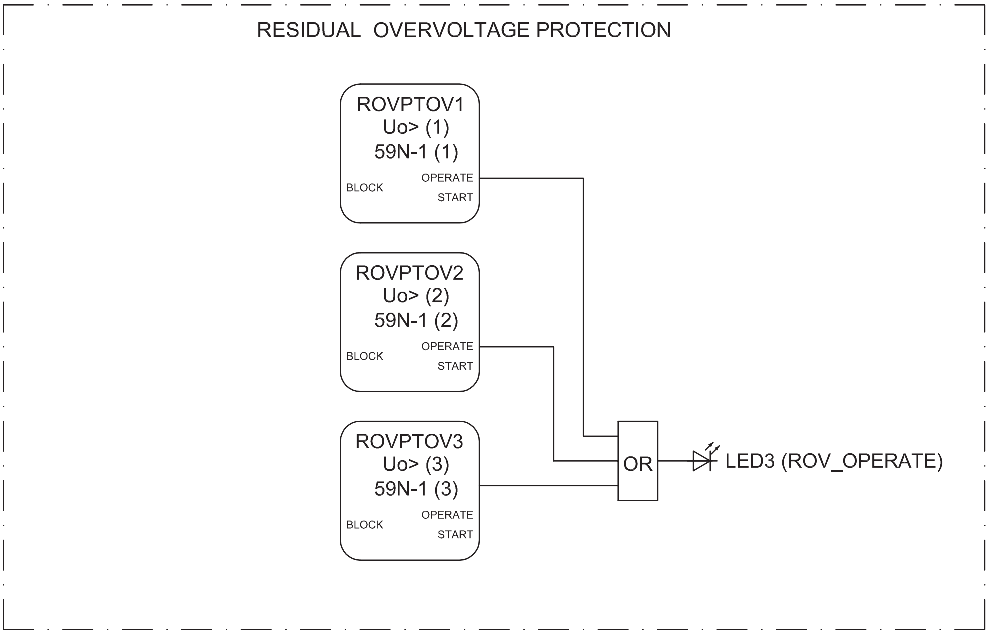


Figure 48: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 3.

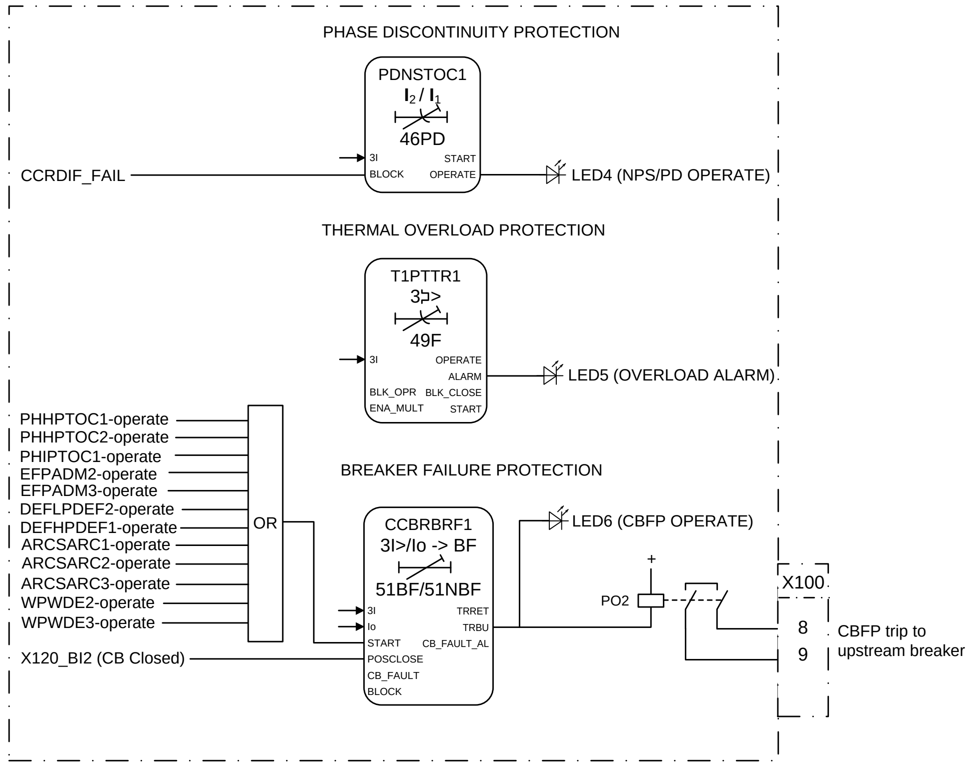


Figure 49: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

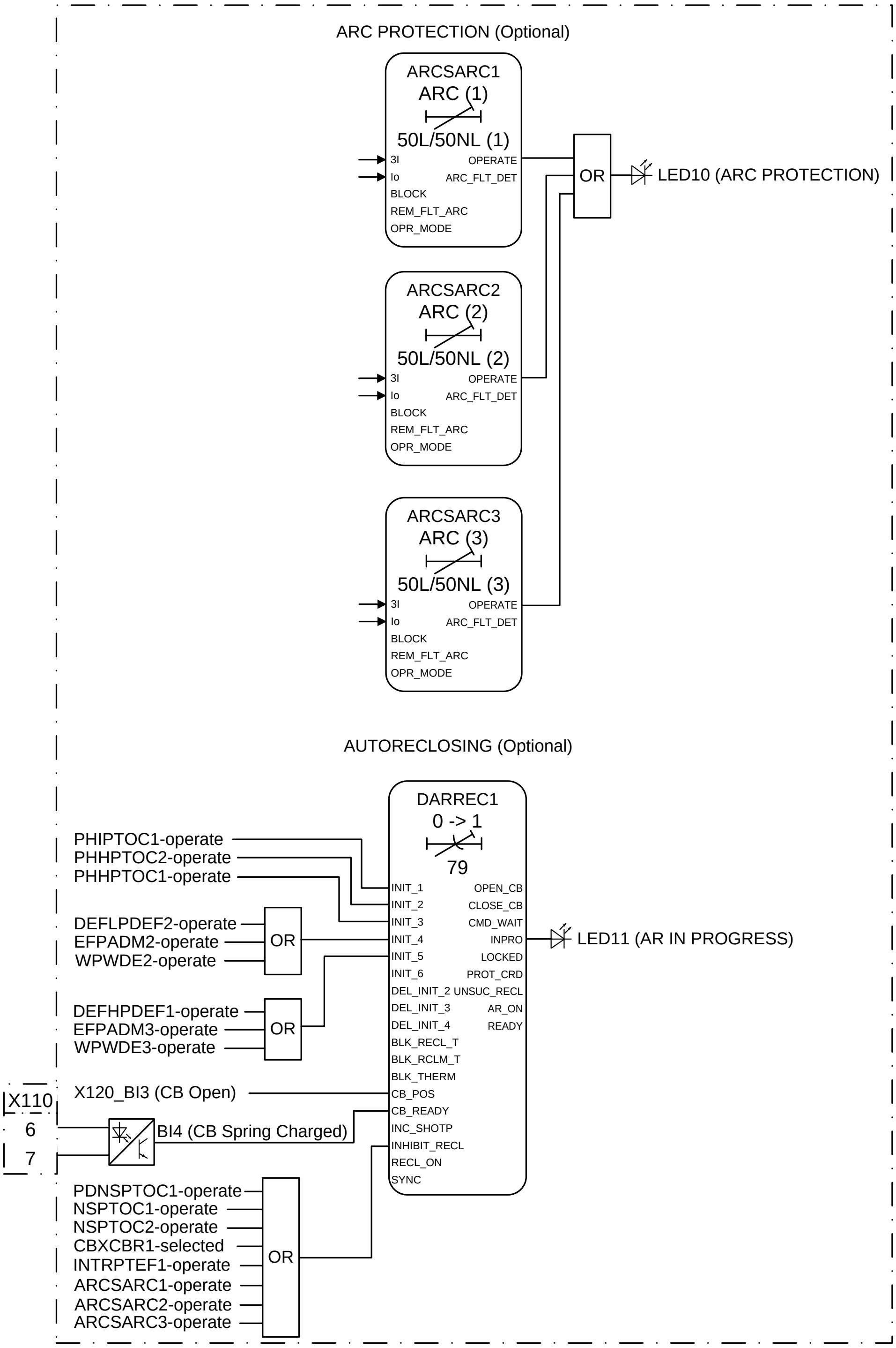


Figure 50: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

3.8.3.2 Functional diagram for disturbance recorder and trip circuit supervision

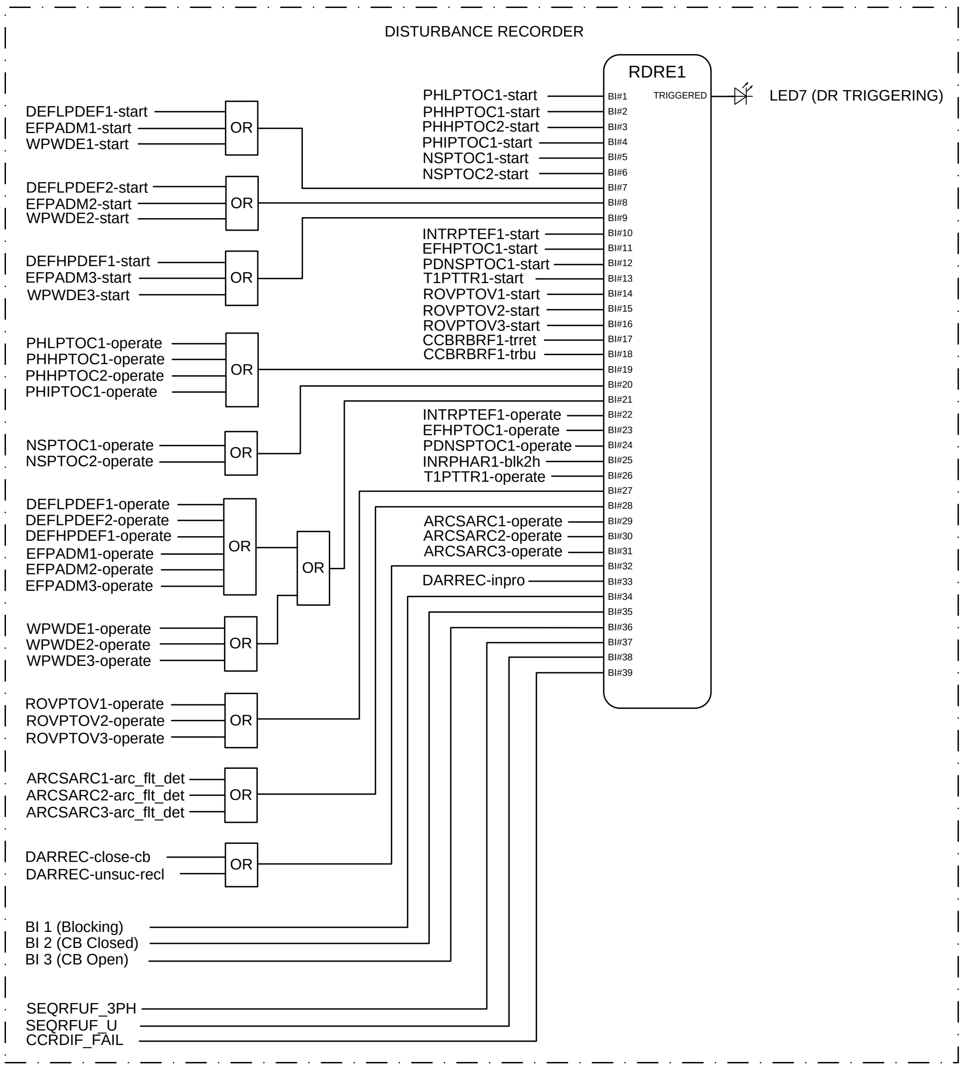


Figure 51: Disturbance recorder

All start and operate signals from the protection stages are routed either to trigger the disturbance recorder or to be recorded by the disturbance recorder, depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

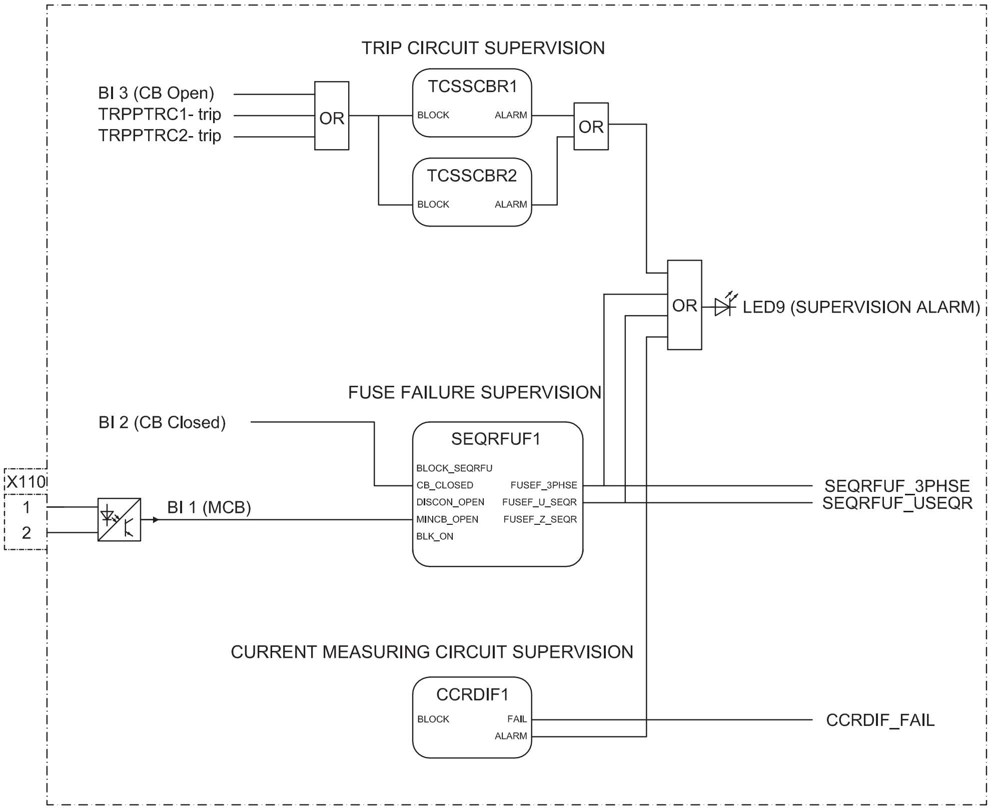


Figure 52: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.8.3.3 Functional diagrams for control and interlocking

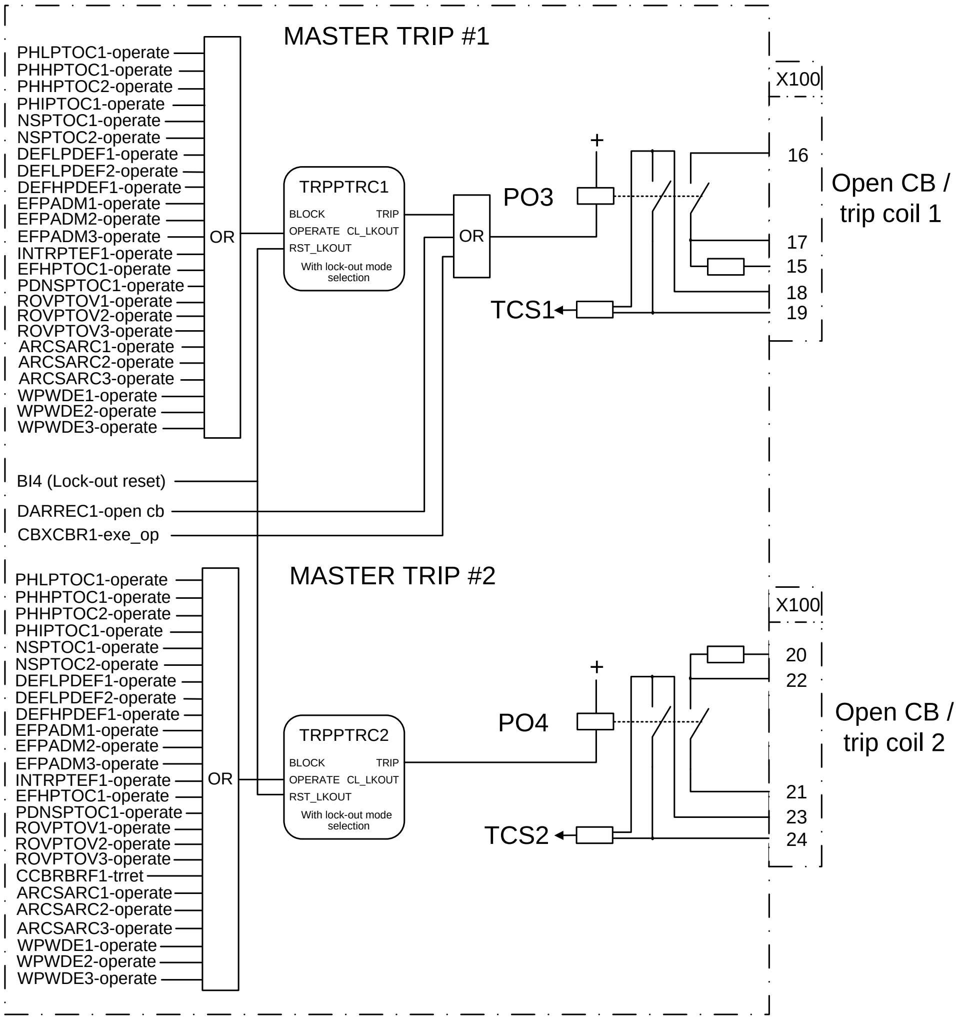


Figure 53: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

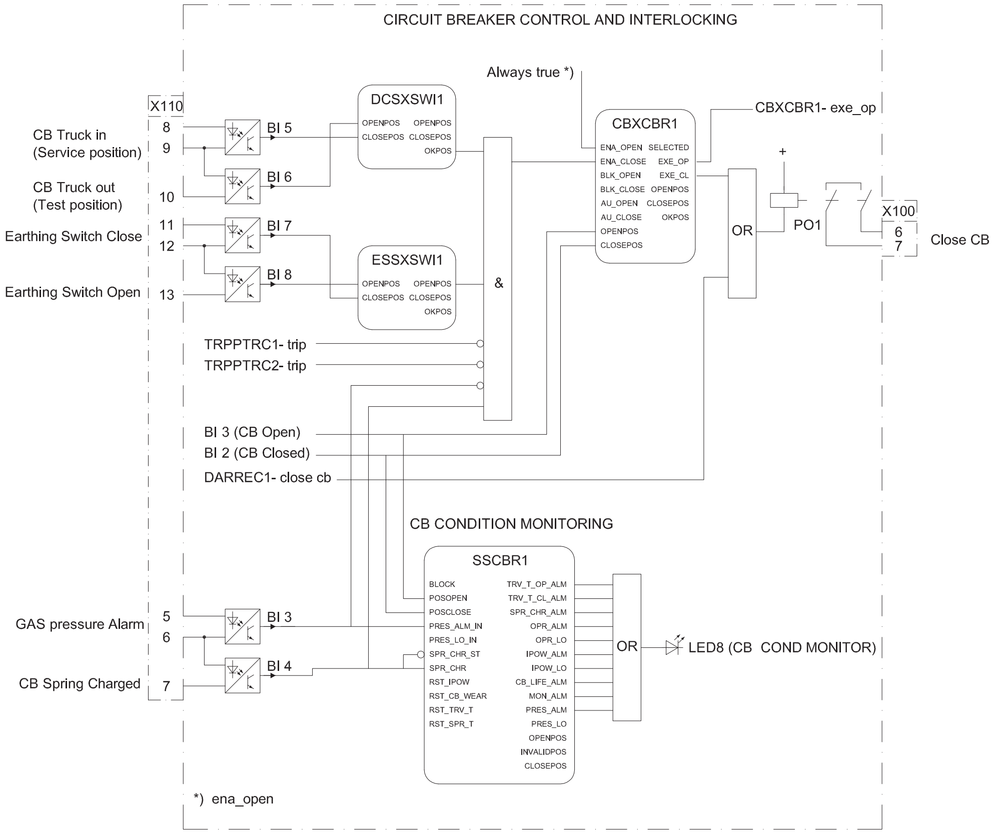


Figure 54: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 37: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

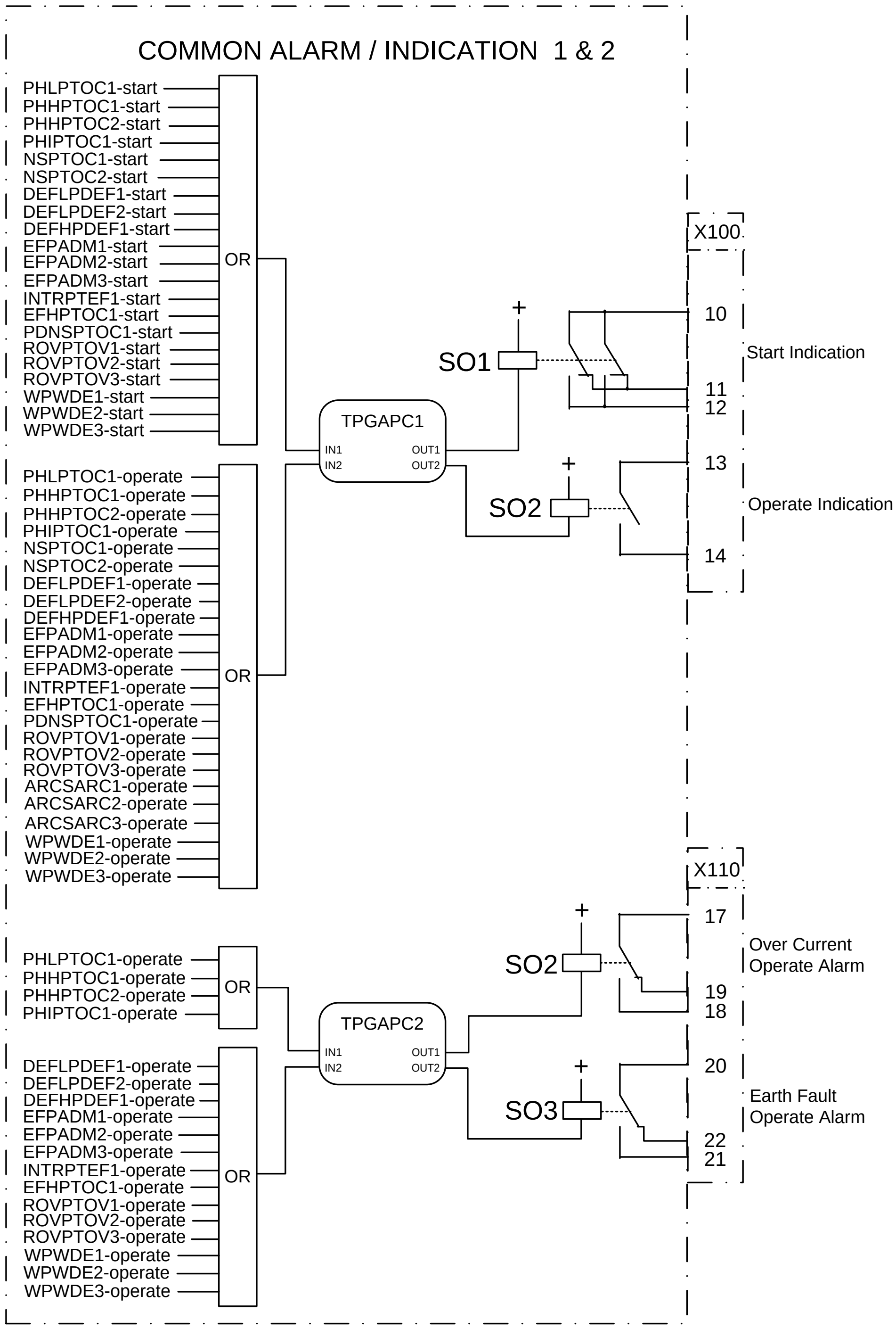


Figure 55: Alarm indication

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.9 Standard configuration F

3.9.1 Applications

The standard configuration for directional overcurrent and directional earth-fault protection with phase-voltage based measurements, undervoltage and overvoltage protection is mainly intended for comprehensive protection and control functionality of circuit breaker controlled asynchronous motors. With minor modifications this standard configuration can be applied also for contactor controlled motors. The configuration also includes additional options to select earth-fault protection based on admittance, wattmetric or harmonic based principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.9.2 Functions

Table 38: Functions included in the standard configuration F

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67-1 (1)
Three-phase directional overcurrent protection, low stage, instance 2	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> ->	67-2
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27 (2)
Three-phase undervoltage protection, instance 3	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59 (1)
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59 (2)
Three-phase overvoltage protection, instance 3	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O- (1)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E

3.9.2.1 Default I/O connections

Table 39: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	MCB open	X110-1,2
X110-BI2	Directional earth fault protection's basic angle control	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Lock-out reset	X120-5,6

Table 40: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15
X110-SO2	Overcurrent operate alarm	X110-17,18
X110-SO3	Earth fault operate alarm	X110-20,21
X110-SO4	Voltage protection operate alarm	X110-23,24

Table 41: Default connections for LEDs

LED	Default usage
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Voltage protection operated
4	Negative-sequence overcurrent or phase discontinuity protection operated
5	Thermal overload protection operated
6	Circuit-breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit-breaker condition monitoring alarm

Table continues on next page

LED	Default usage
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.9.2.2 Default disturbance recorder settings

Table 42: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.9.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED’s standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder’s parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.9.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

Four overcurrent stages are available for overcurrent and short-circuit protection. Three of them include directional functionality (DPHxPDOC). The non-directional instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative-sequence overcurrent stages (NSPTOC1 and NSPTOC2) are available for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the shown protection function blocks.

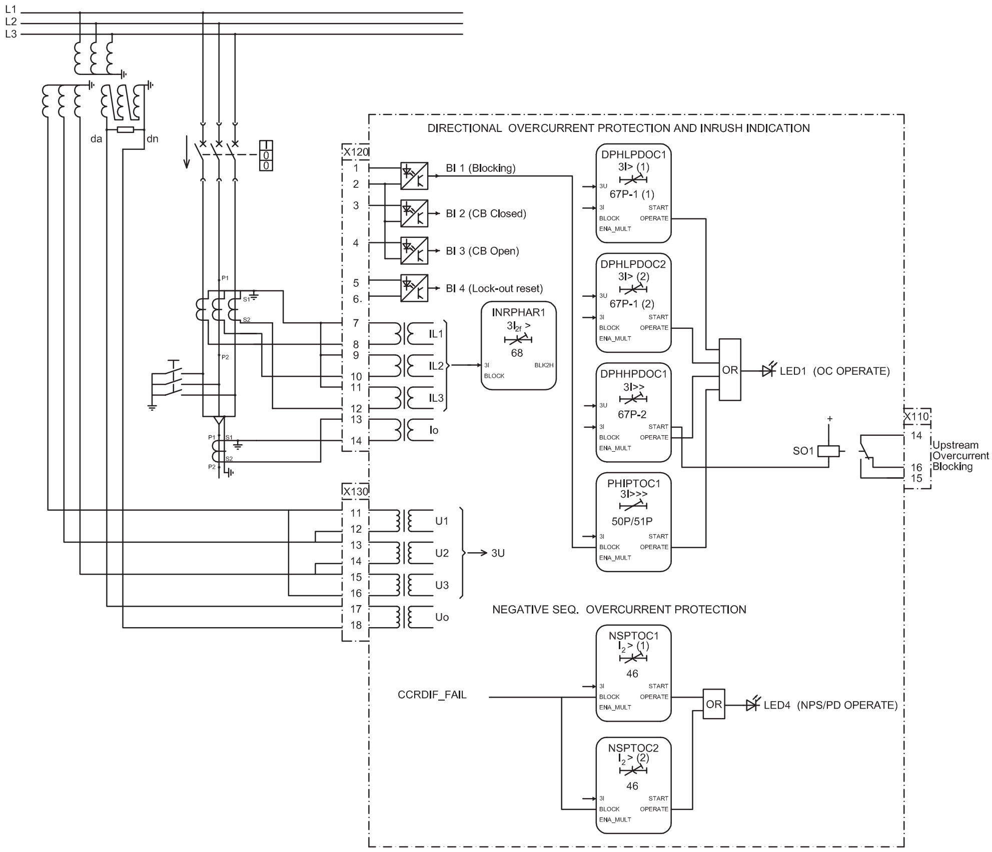


Figure 56: Directional overcurrent protection

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

The upstream blocking from the start of the directional overcurrent second low stage (DPHLPDOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

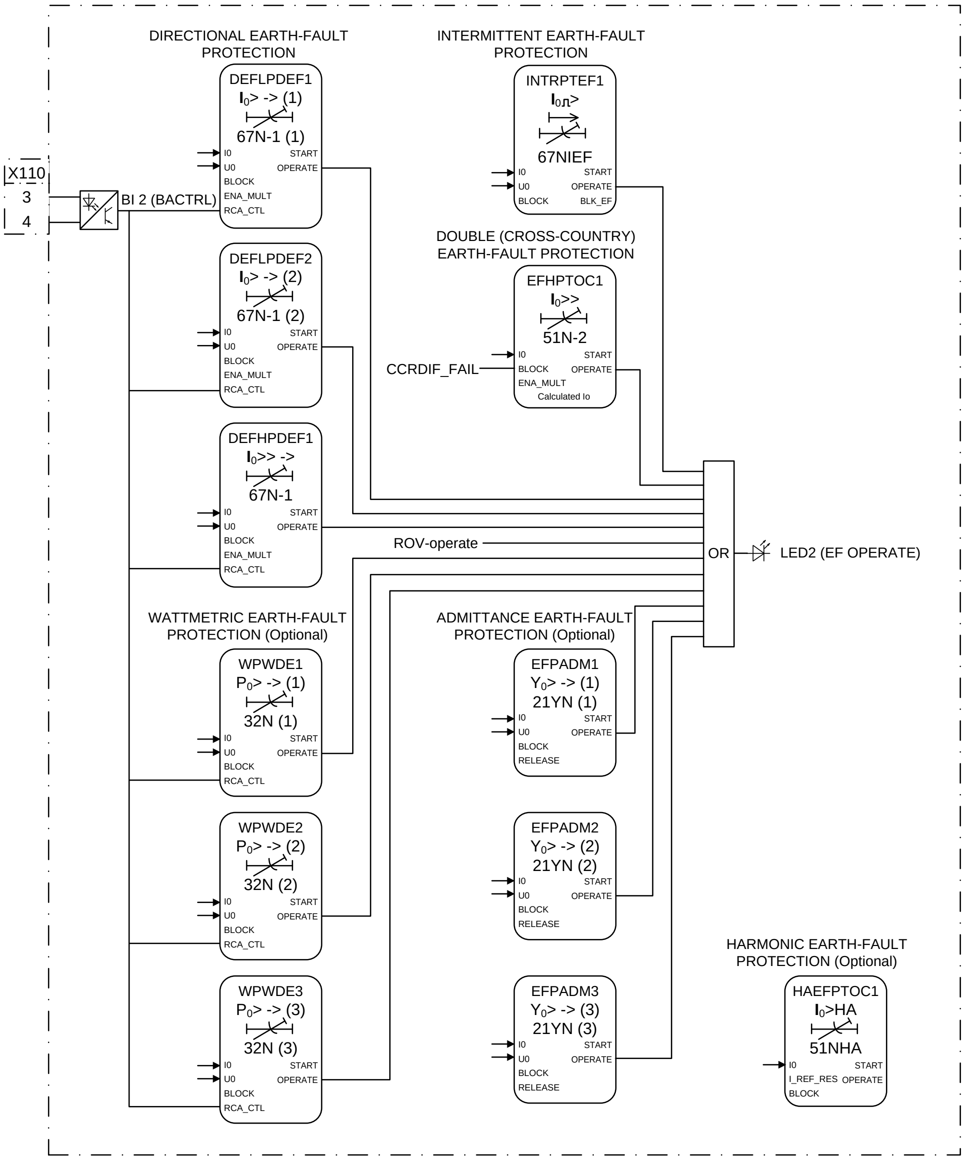


Figure 57: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE) or harmonic based earth-fault protection (HAEFPTOC). In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

The binary input 2 (X110:3-4) is intended for directional earth-fault protection blocks' relay characteristic angle (RCA: 0°/-90°) or operation mode (I_0Sinφ/ I_0Cosφ) change. All operate signals are connected to the Master Trip as well as to the alarm LED 2.

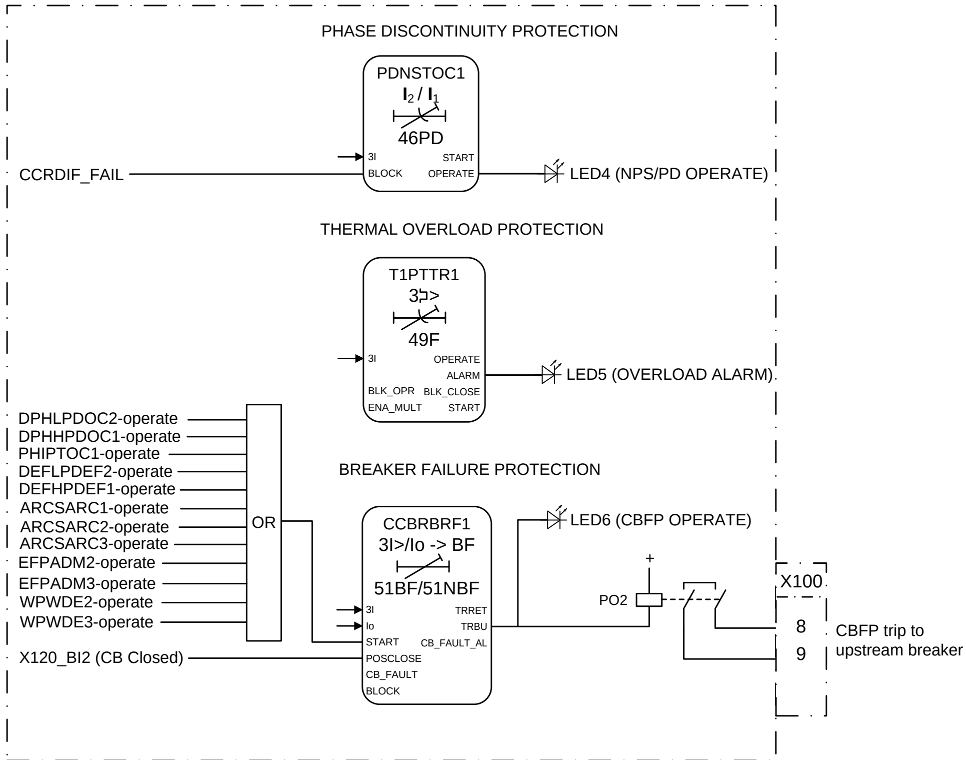


Figure 58: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication, and LED 5 is used for the thermal overload protection alarm indication.

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

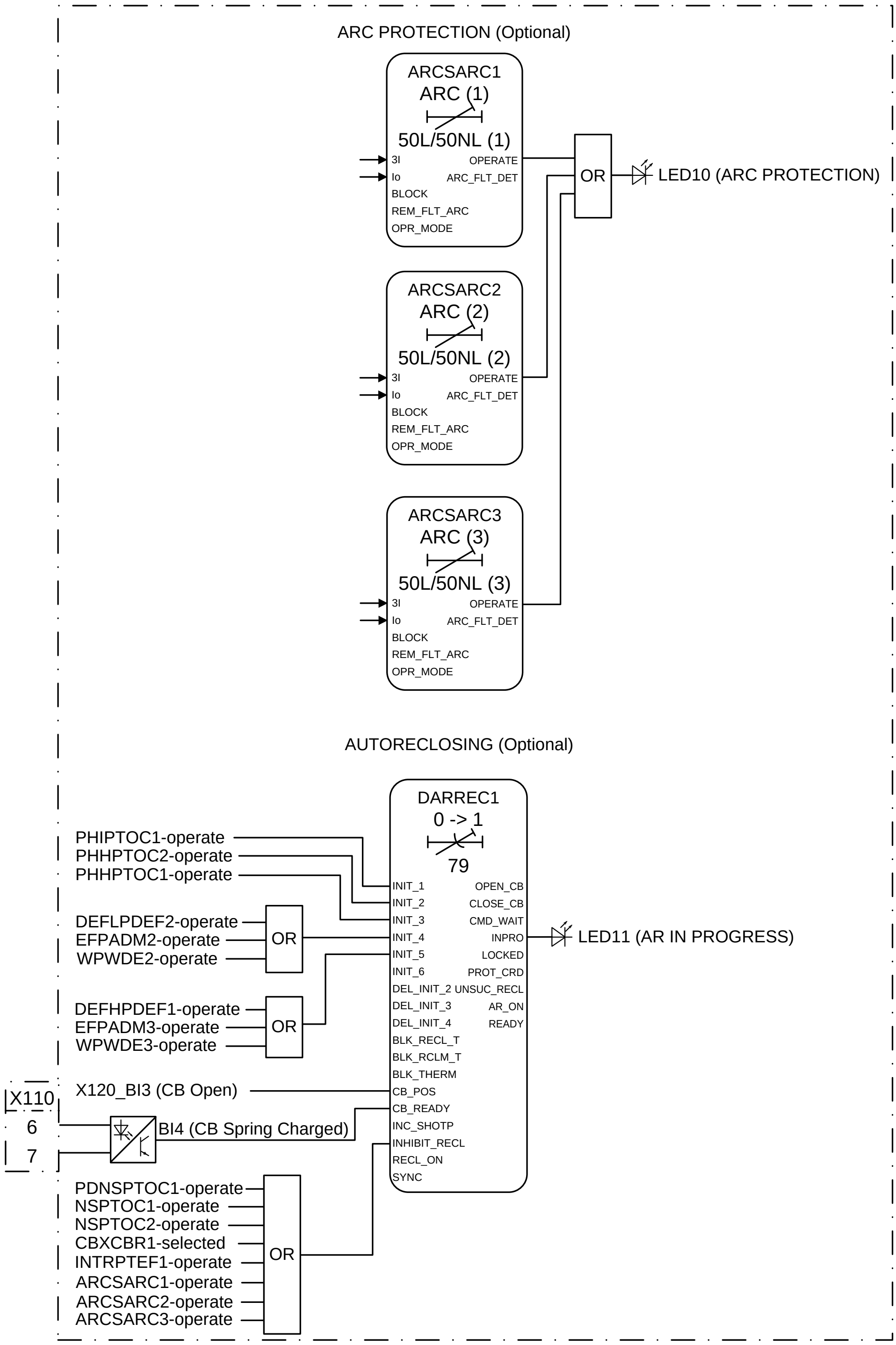


Figure 59: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

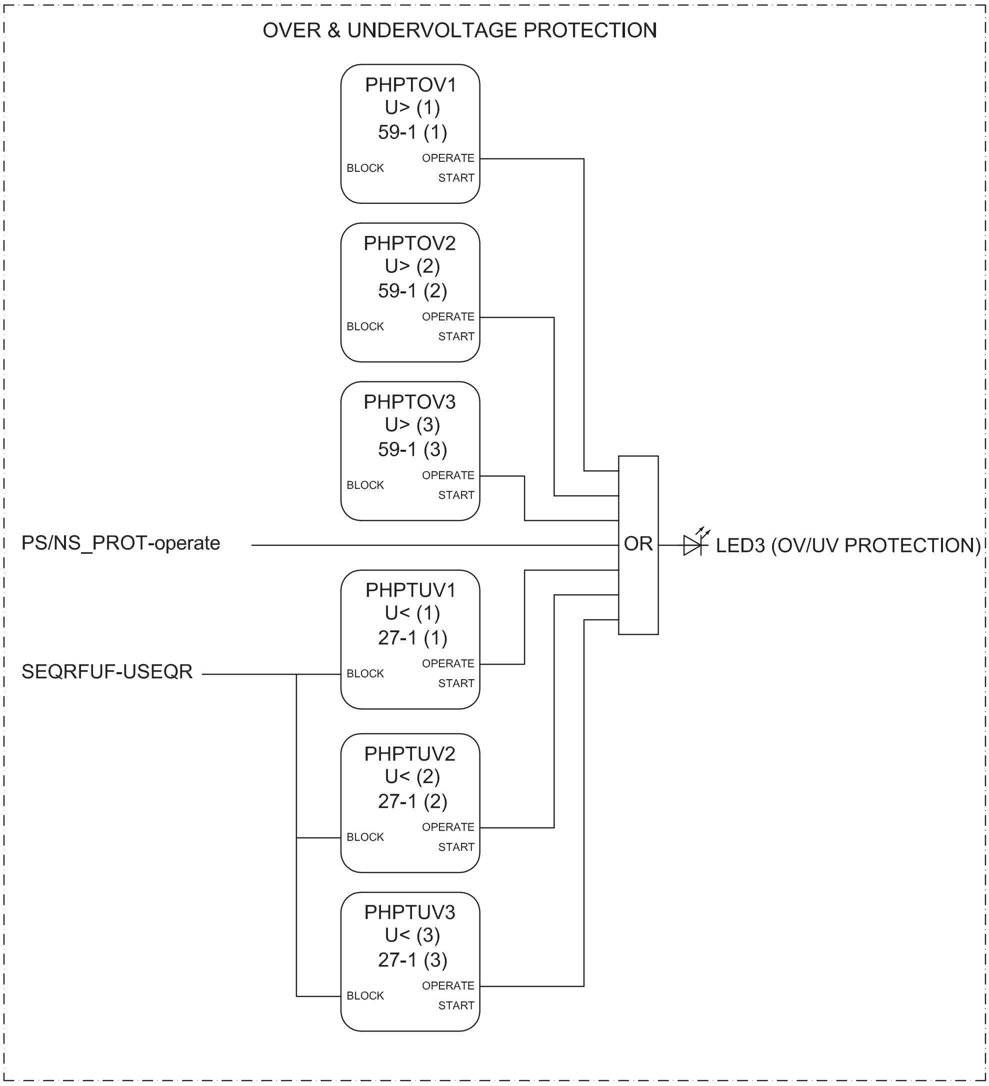


Figure 60: Overvoltage and undervoltage protection

Three overvoltage and undervoltage protection stages (PHxPTOV and PHxPTUV) offer protection against abnormal phase voltage conditions. The operation of voltage functions is connected to alarm LED 3. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

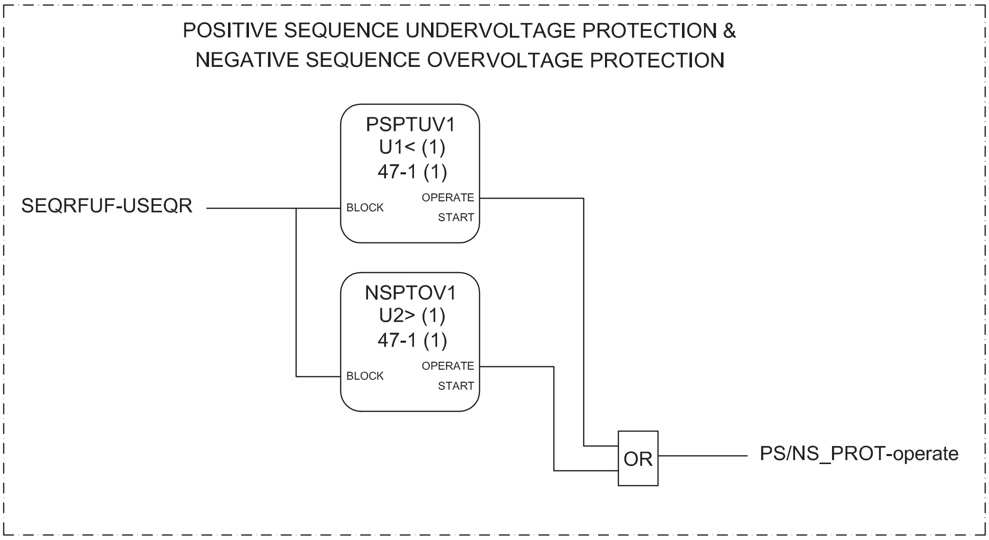


Figure 61: Positive-sequence undervoltage and negative-sequence overvoltage protection

Positive-sequence undervoltage (PSPTUV) and negative-sequence overvoltage (NSPTOV) protection functions enable voltage-based unbalance protection. The operation signals of voltage-sequence functions are connected to alarm LED 3, which is a combined voltage protection alarm LED.

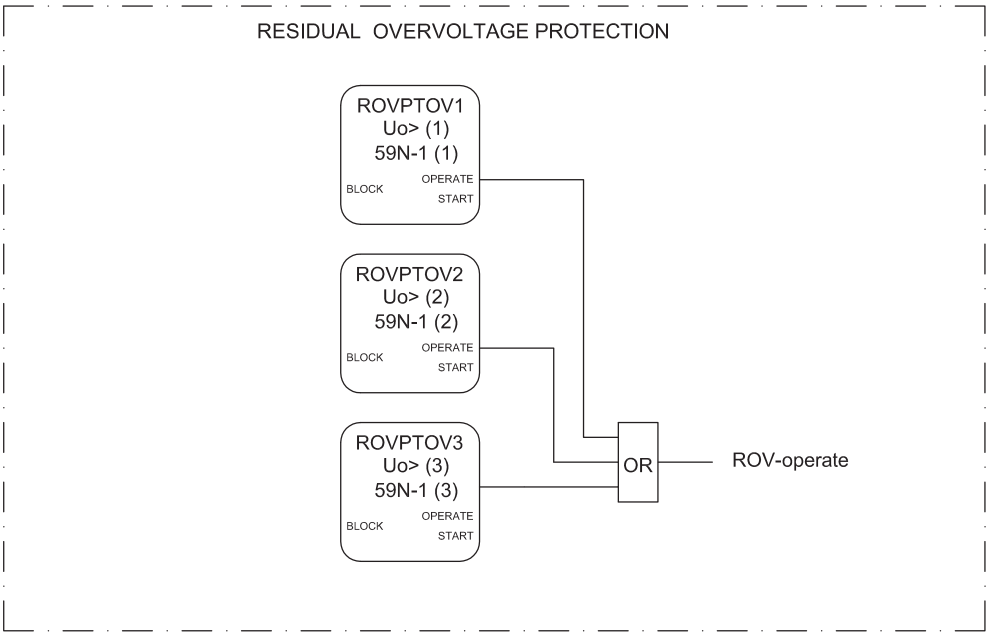


Figure 62: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 2.

3.9.3.2 Functional diagram for disturbance recorder and trip circuit supervision

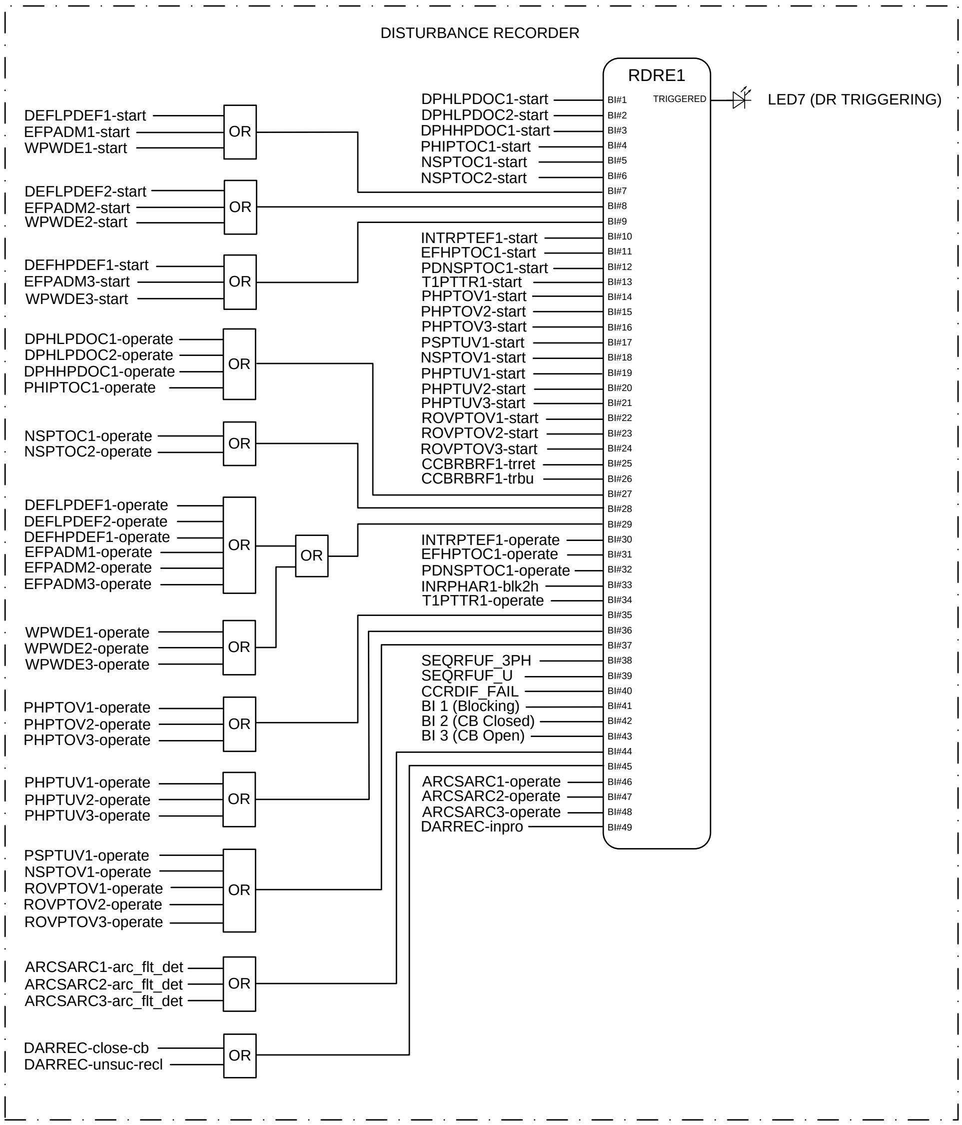


Figure 63: Disturbance recorder

All start and operate signals from the protection stages are routed either to trigger the disturbance recorder or to be recorded by the disturbance recorder, depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

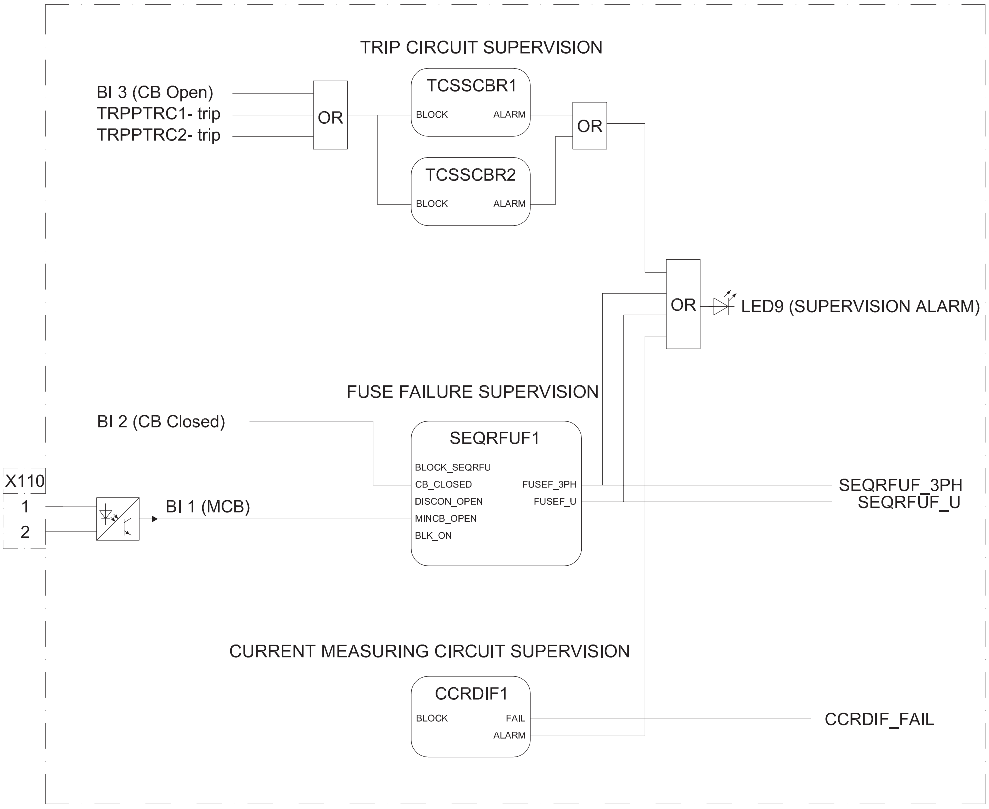


Figure 64: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.9.3.3 Functional diagrams for control and interlocking

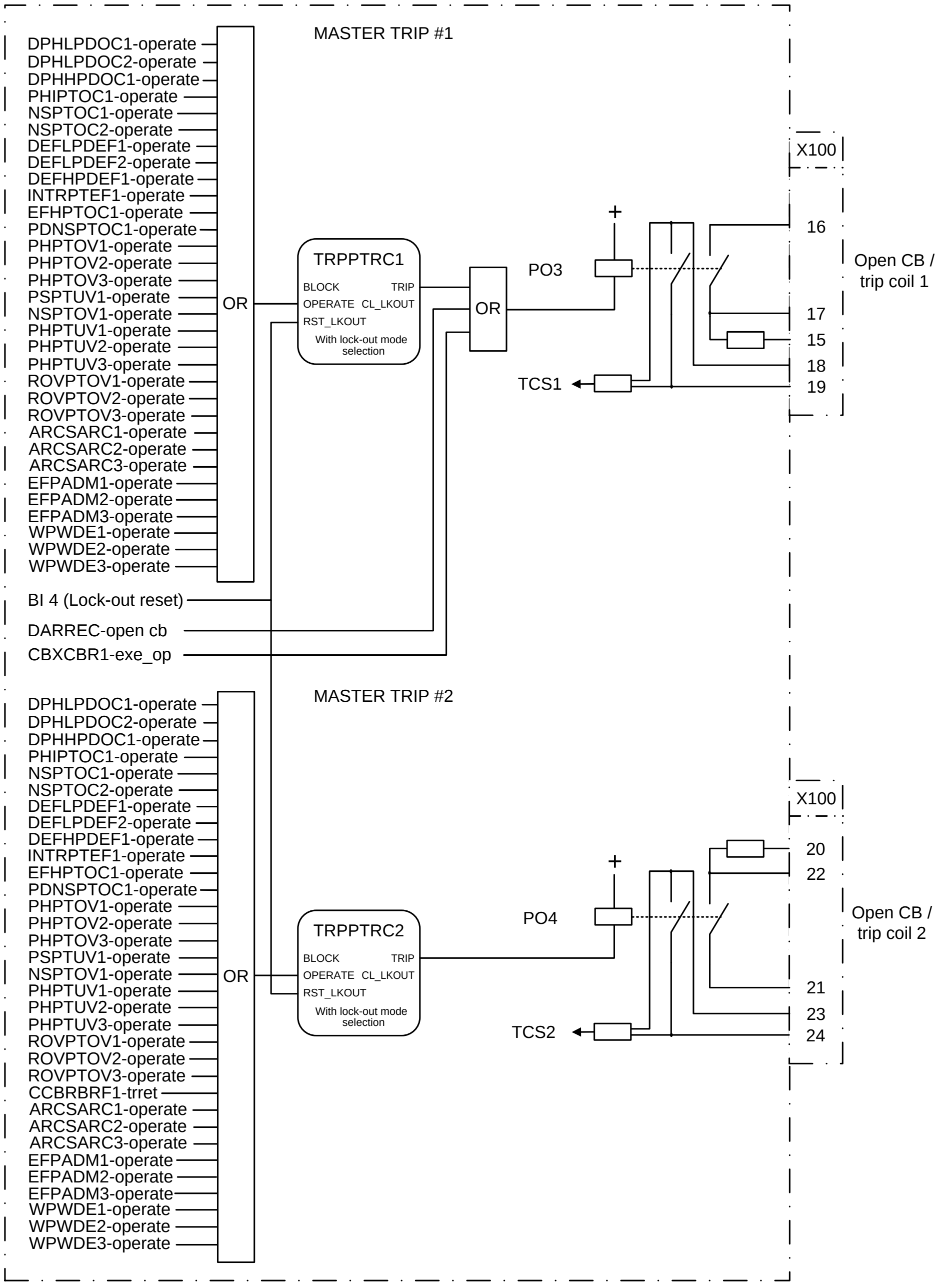


Figure 65: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

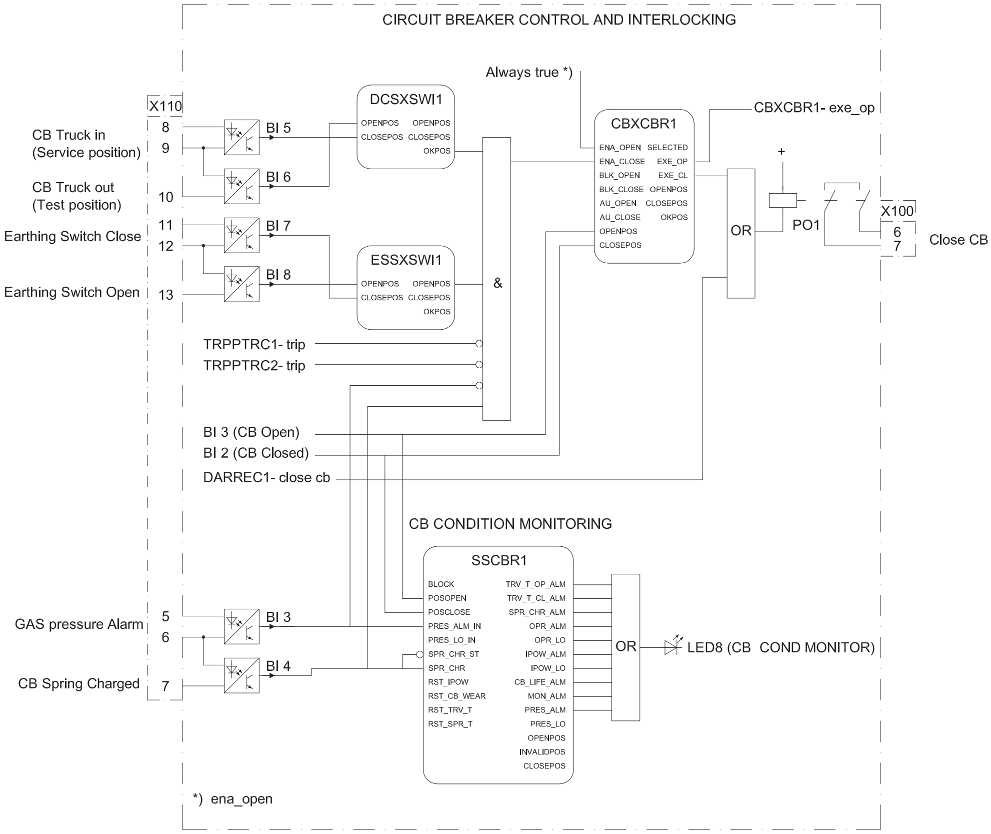


Figure 66: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 43: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

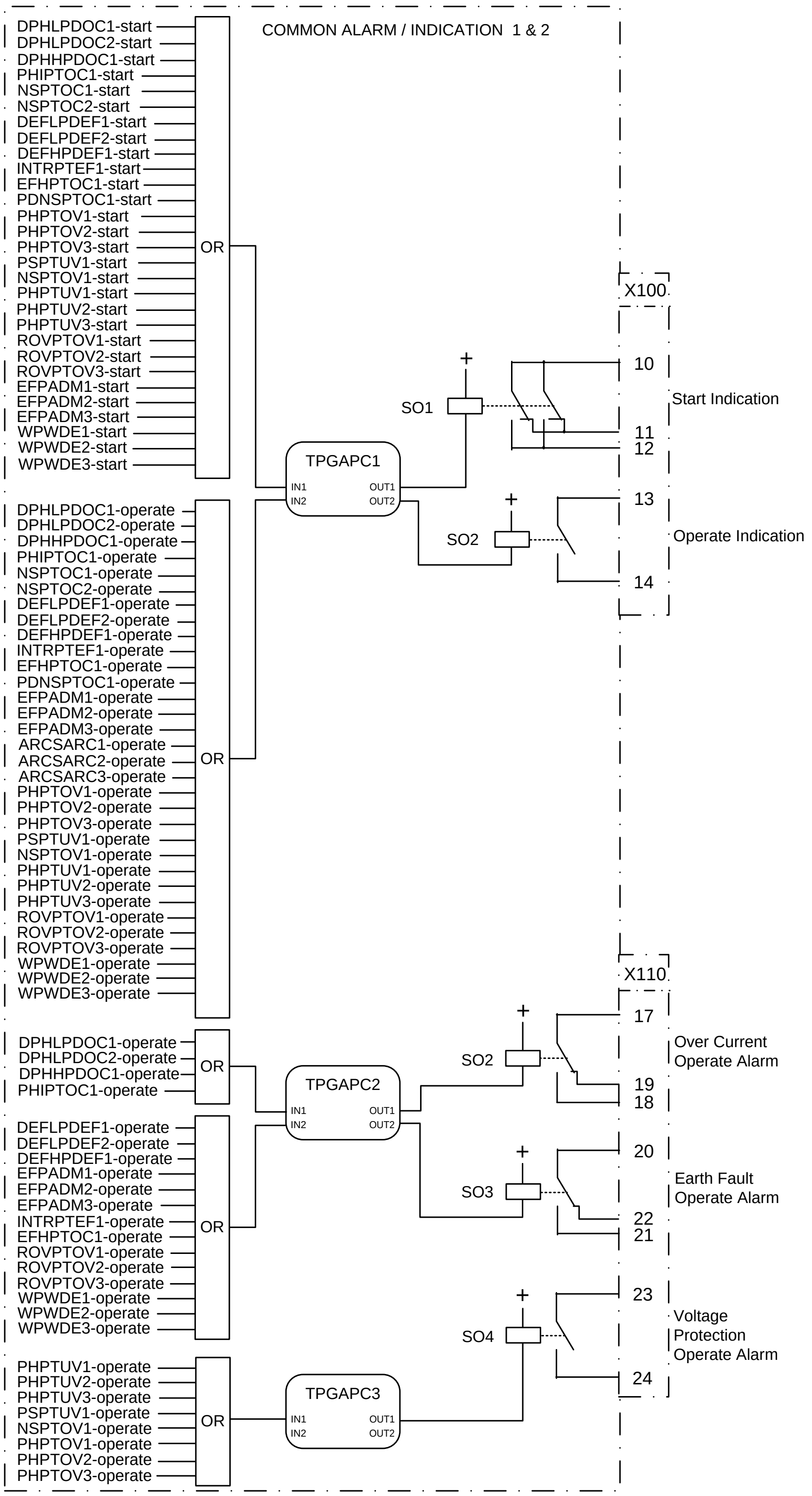


Figure 67: Alarm indication

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)

TPGAPC 1...3 are timers used for setting the minimum pulse length for the outputs. Four generic timers (TPGAPC1..4) are available in the IED. The remaining one not described in the functional diagram is available in PCM600 for connection where applicable.

3.10 Standard configuration G

3.10.1 Applications

The standard configuration for non-directional earth-fault, voltage and frequency protection is mainly intended for cable and overhead-line feeder applications in direct or resistance earthed distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance or wattmetric principle

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.10.2 Functions

Table 44: Functions included in the standard configuration G

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67-1 (1)
Three-phase directional overcurrent protection, low stage, instance 2	DPHLPDOC2	3I> -> (2)	67-1 (2)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> ->	67-2
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27 (2)
Three-phase undervoltage protection, instance 3	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59 (1)
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59 (2)
Three-phase overvoltage protection, instance 3	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O- (1)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E

3.10.2.1 Default I/O connections

Table 45: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	Circuit breaker closed indication	X110-1,2
X110-BI2	Circuit breaker open indication	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
Table continues on next page		

Binary input	Default usage	Connector pins
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12

Table 46: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15,16
X110-SO2	Overcurrent operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Voltage protection operate alarm	X110-23,24

Table 47: Default connections for LEDs

LED	Default usage
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Voltage protection operated
4	Negative-sequence overcurrent or phase discontinuity protection operated
5	Thermal overload protection operated
6	Circuit-breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	Circuit-breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.10.2.2 Default disturbance recorder settings

Table 48: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	U1
6	U2
7	U3
8	-
9	-
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.10.2.3 Sensor settings

Rogowski sensor setting example

In this example, a **80 A/0.150 V at 50 Hz** sensor is used and the application has a **150 A** nominal current (In). As the Rogowski sensor is linear and does not saturate, the 80 A/0.150 V at 50 Hz sensor also works as a 150 A/0.28125 V at 50 Hz sensor. When defining another primary value for the sensor, also the nominal voltage has to be redefined to maintain the same transformation ratio. However, the setting in the IED (*Rated Secondary Value*) is not in V but in mV/Hz, which makes the same setting value valid for both 50 and 60 Hz nominal frequency. *Rated Secondary Value* is calculated with the formula:

$$\frac{\frac{I_n}{I_{pr}} * K_r}{f_n} = RSV$$

I_n	the application nominal current
I_{pr}	the sensor rated primary current
f_n	network nominal frequency
K_r	the sensor rated voltage (in mV) at the rated current
RSV	the *Rated Secondary Value* in mV/Hz

In this example, this is then:

$$\frac{\frac{150A}{80A} * 150mV}{50Hz} = 5.625\frac{mV}{Hz}$$

With this information, the IED Rogowski sensor settings can be set.

Table 49: Example setting values

Primary Current	150 A
Rated Secondary Value	5.625 mV/Hz
Nominal Current	150 A

Unless otherwise specified, the *Nominal Current* setting should always be the same as the *Primary Current* setting.

3.10.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.10.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail and picture the factory set default connections.

Four overcurrent stages are available for overcurrent and short-circuit protection. Three of them include directional functionality (DPHxPDOC) and one non-directional instantaneous stage (PHIPTOC1). The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the shown protection function blocks.

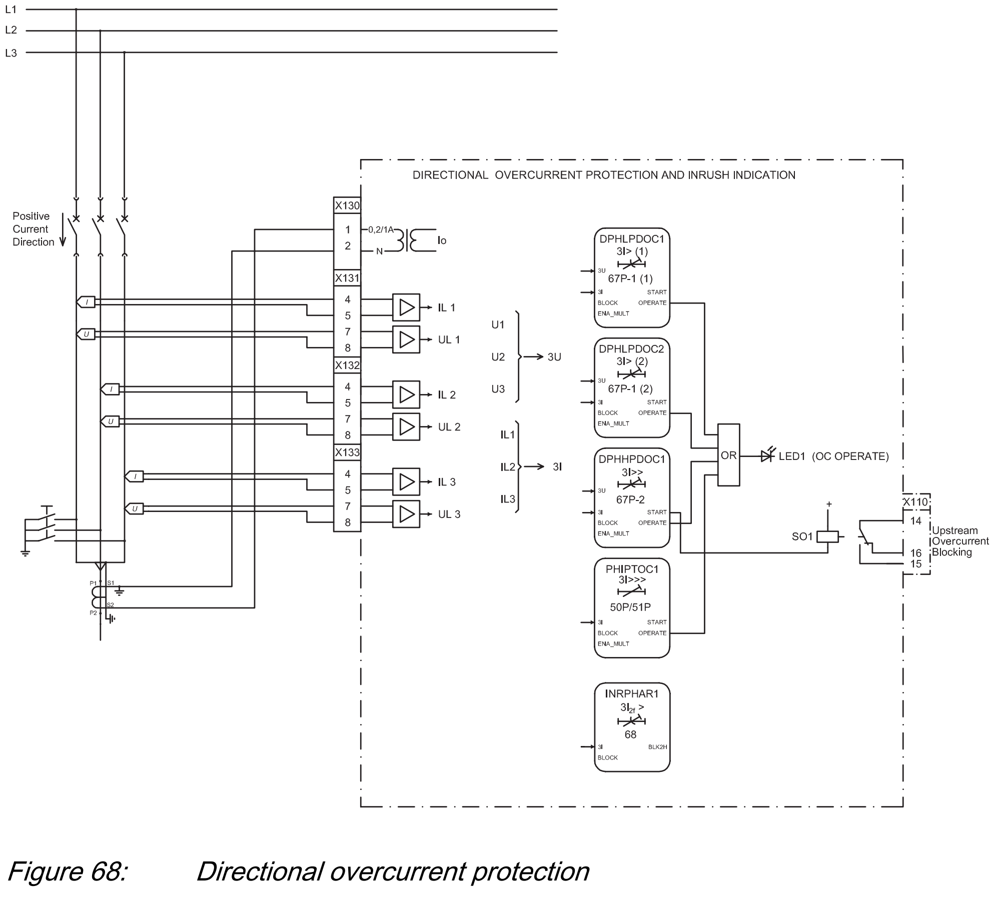


Figure 68: Directional overcurrent protection

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent protection.

The upstream blocking from the start of the directional overcurrent second low stage (DPHLPDOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

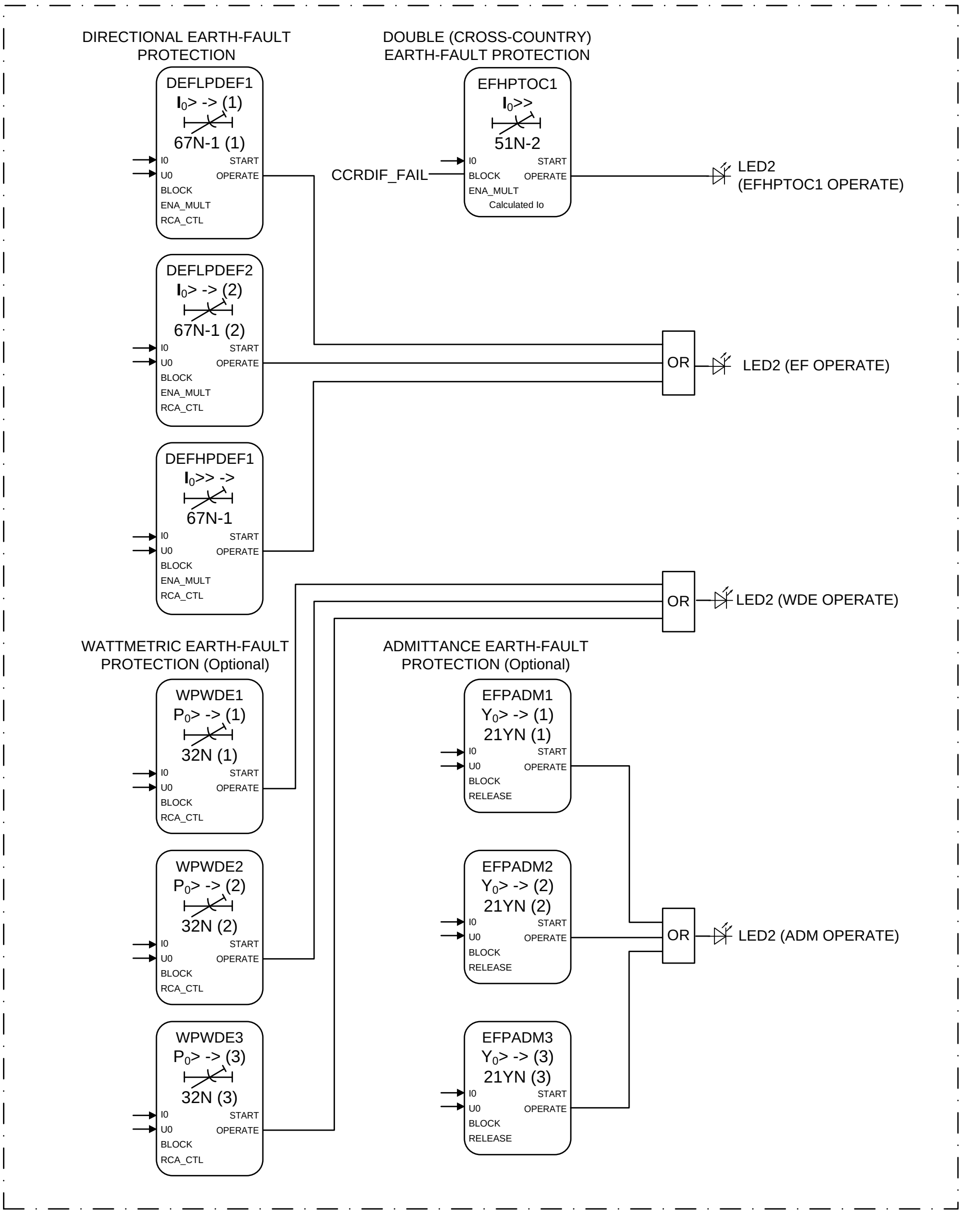


Figure 69: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only, or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE).

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

All operate signals are connected to the Master Trip and also to the alarm LEDs. LED 2 is used for directional earth-fault.

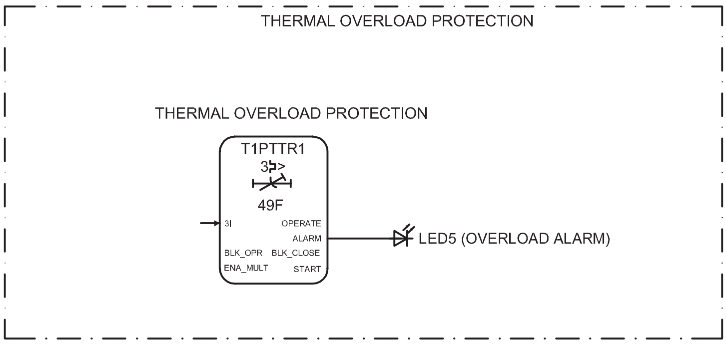


Figure 70: Thermal overload protection

The thermal overload protection (T1PTTR1) provides indication on overload situations. LED 5 is used for the thermal overload protection alarm indication.

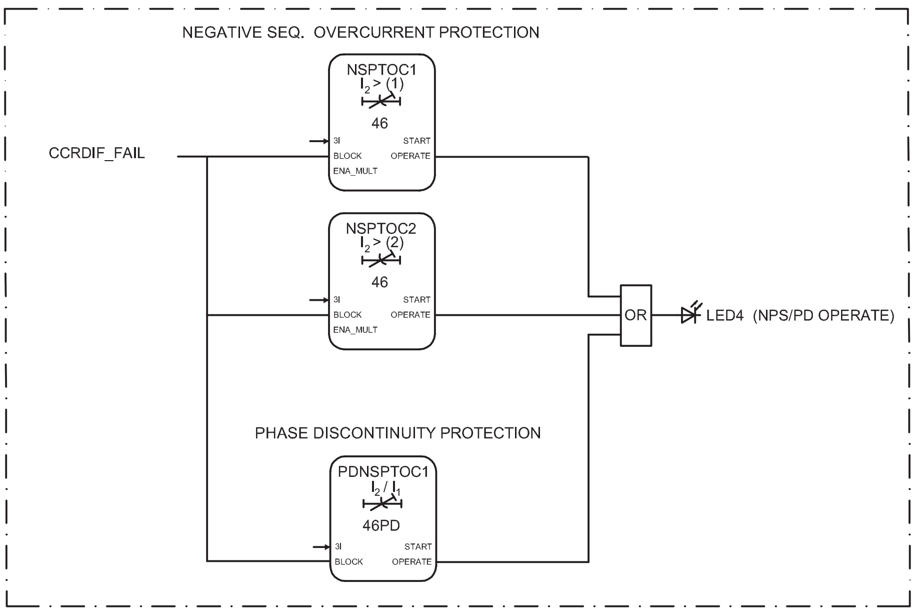


Figure 71: Negative sequence and phase discontinuity protection

Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED. LED 4 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication.

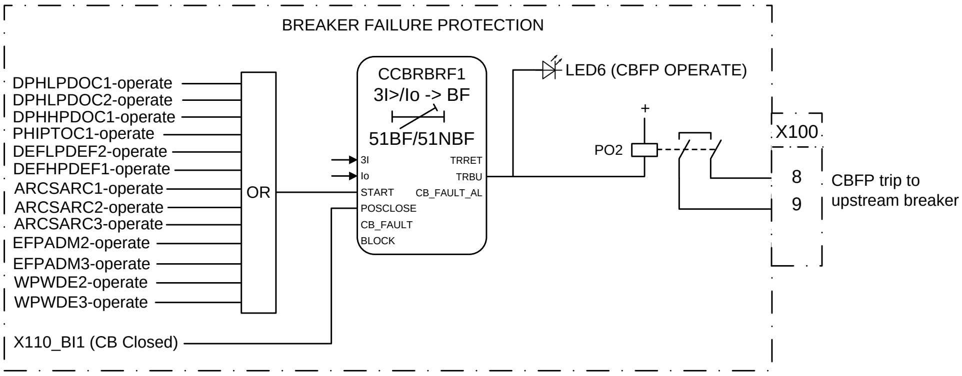


Figure 72: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip Logic 2. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

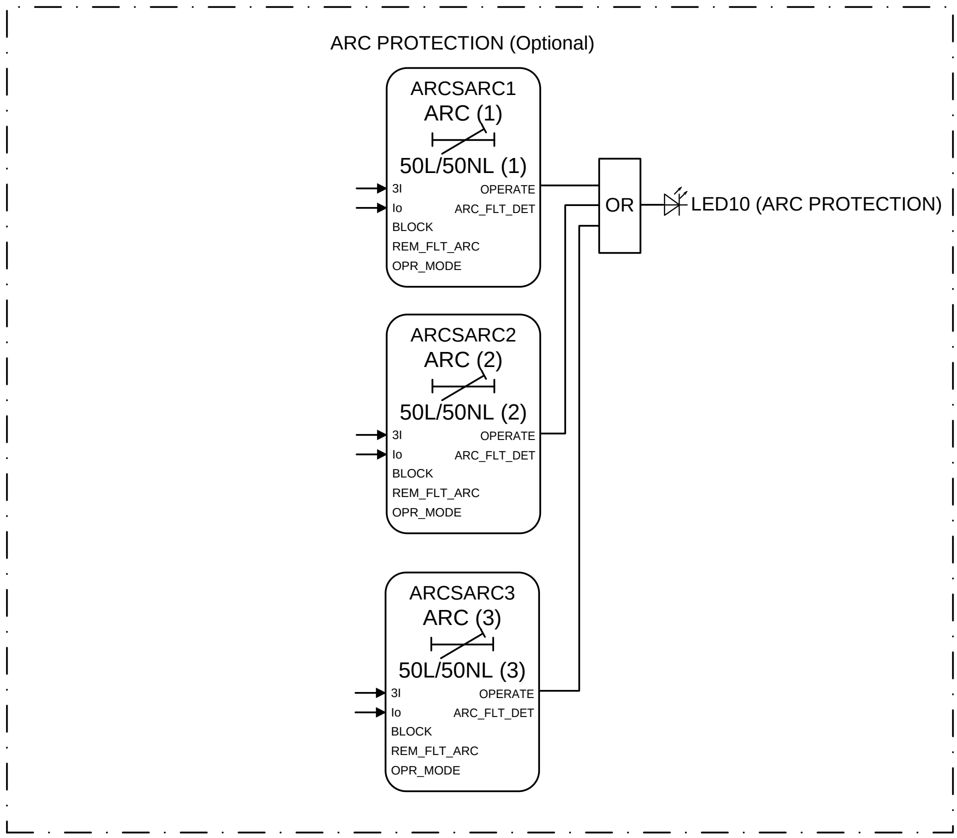


Figure 73: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

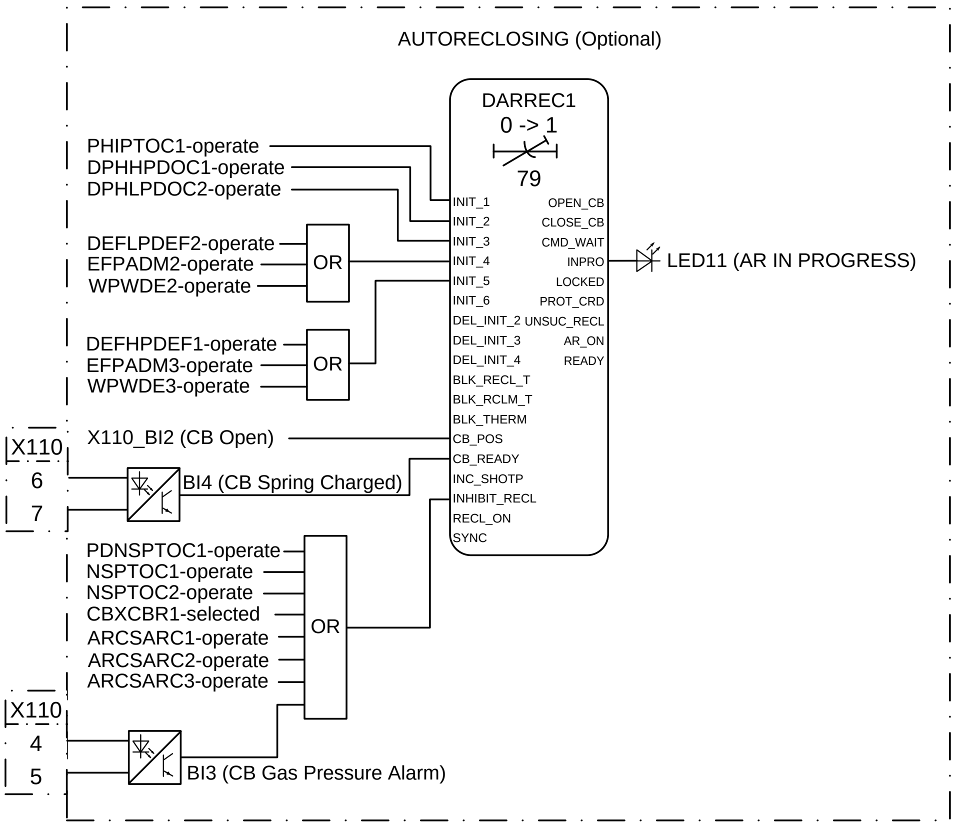


Figure 74: Autoreclosing

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

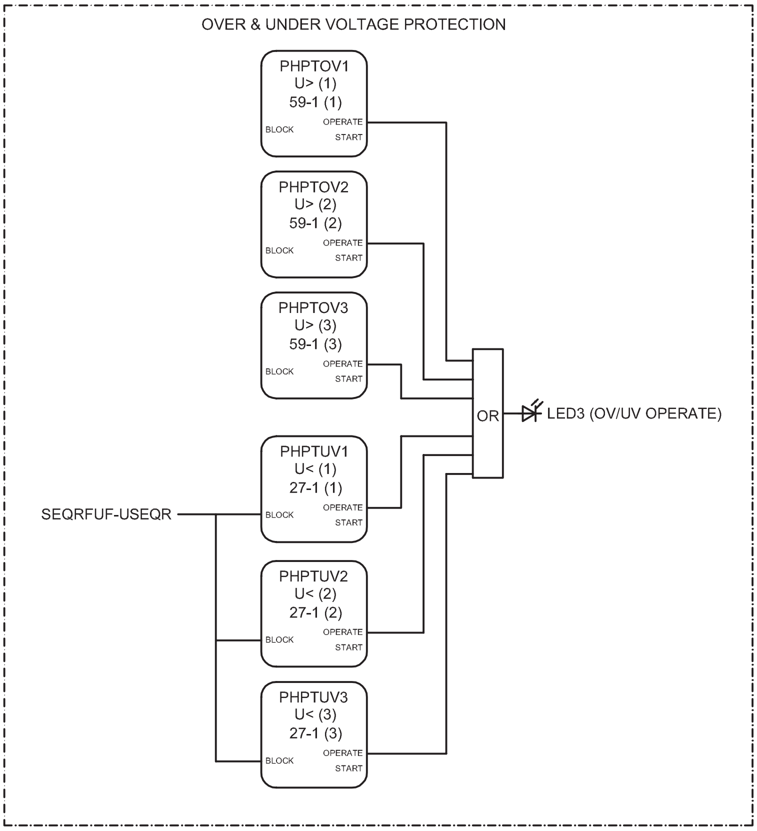


Figure 75: Overvoltage and undervoltage protection

Three overvoltage and undervoltage protection stages (PHxPTOV and PHxPTUV) offer protection against abnormal phase voltage conditions. The operation of voltage functions is connected to alarm LED 3. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

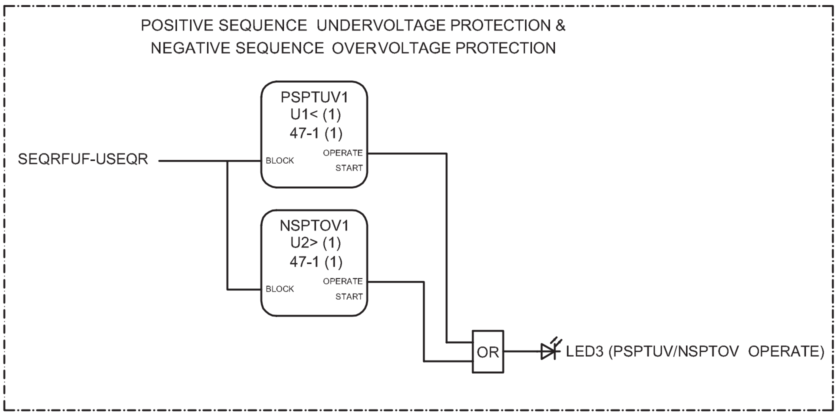


Figure 76: Positive-sequence undervoltage and negative-sequence overvoltage protection

Positive-sequence undervoltage (PSPTUV) and negative-sequence overvoltage (NSPTOV) protection functions enable voltage-based unbalance protection. The operation signals of voltage-sequence functions are connected to alarm LED 3, which is a combined voltage protection alarm LED.

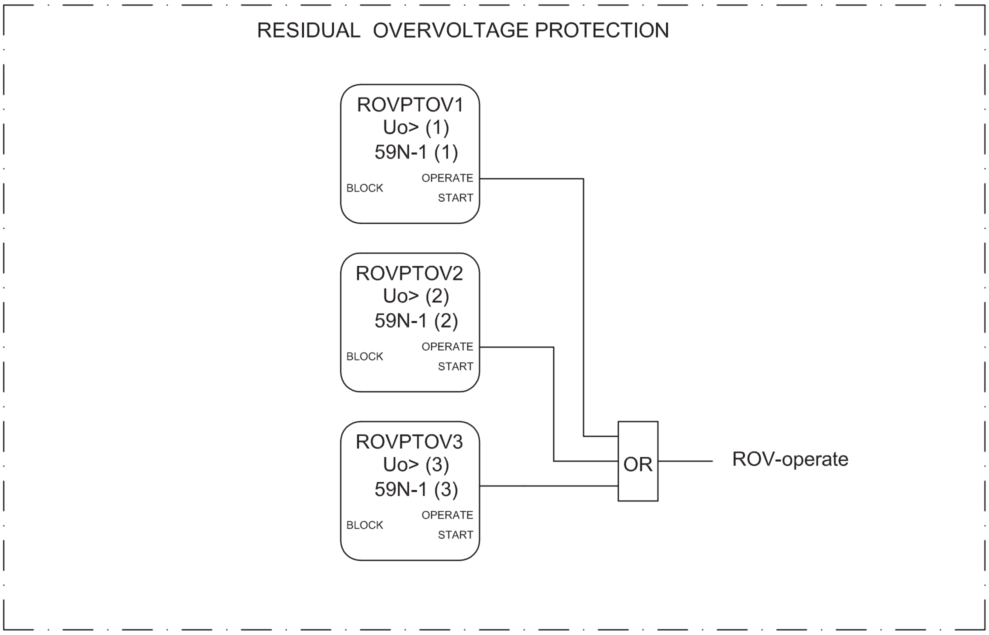


Figure 77: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 2.

3.10.3.2 Functional diagram for disturbance recorder and trip circuit supervision

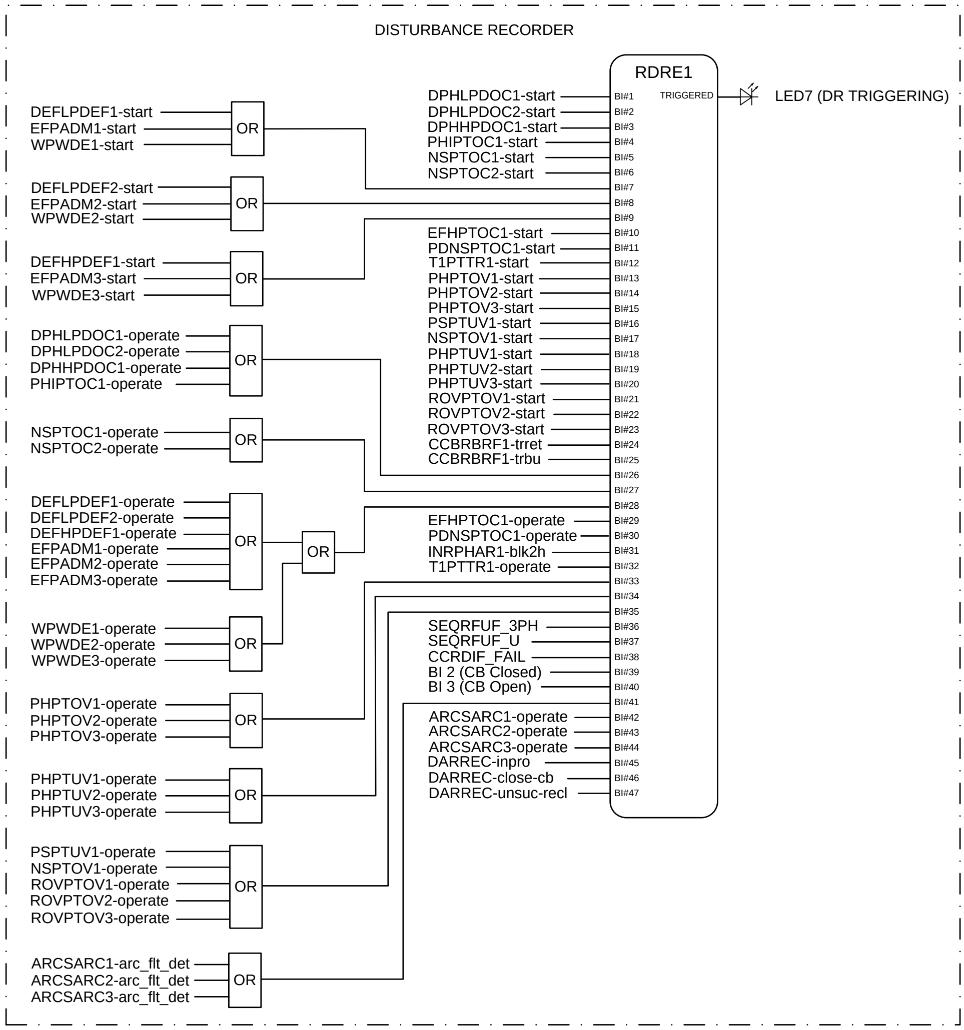


Figure 78: Disturbance recorder

All start and operate signals from the protection stages are routed either to trigger the disturbance recorder or to be recorded by the disturbance recorder, depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the two binary inputs from X110 are also connected.

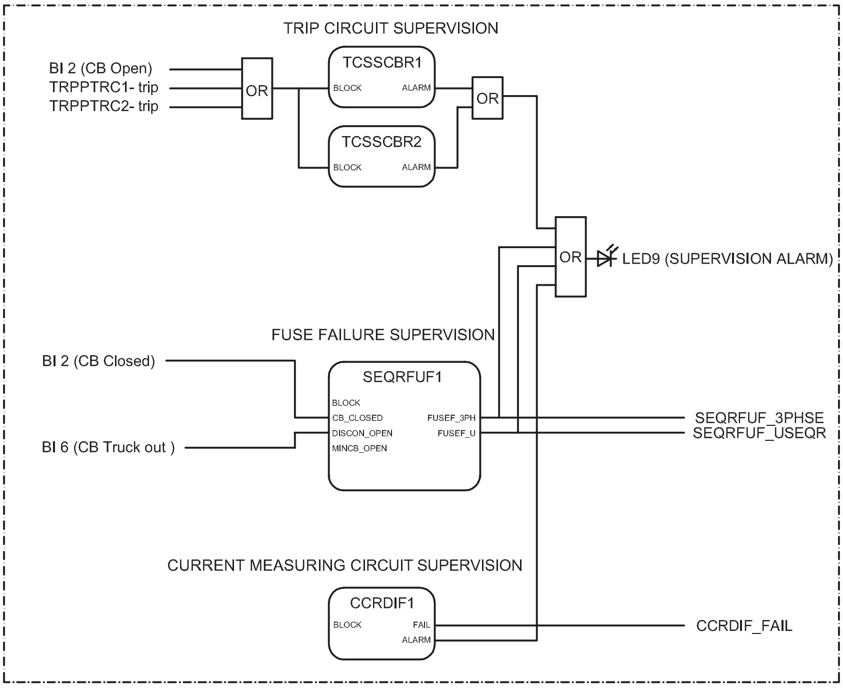


Figure 79: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.10.3.3 Functional diagrams for control and interlocking

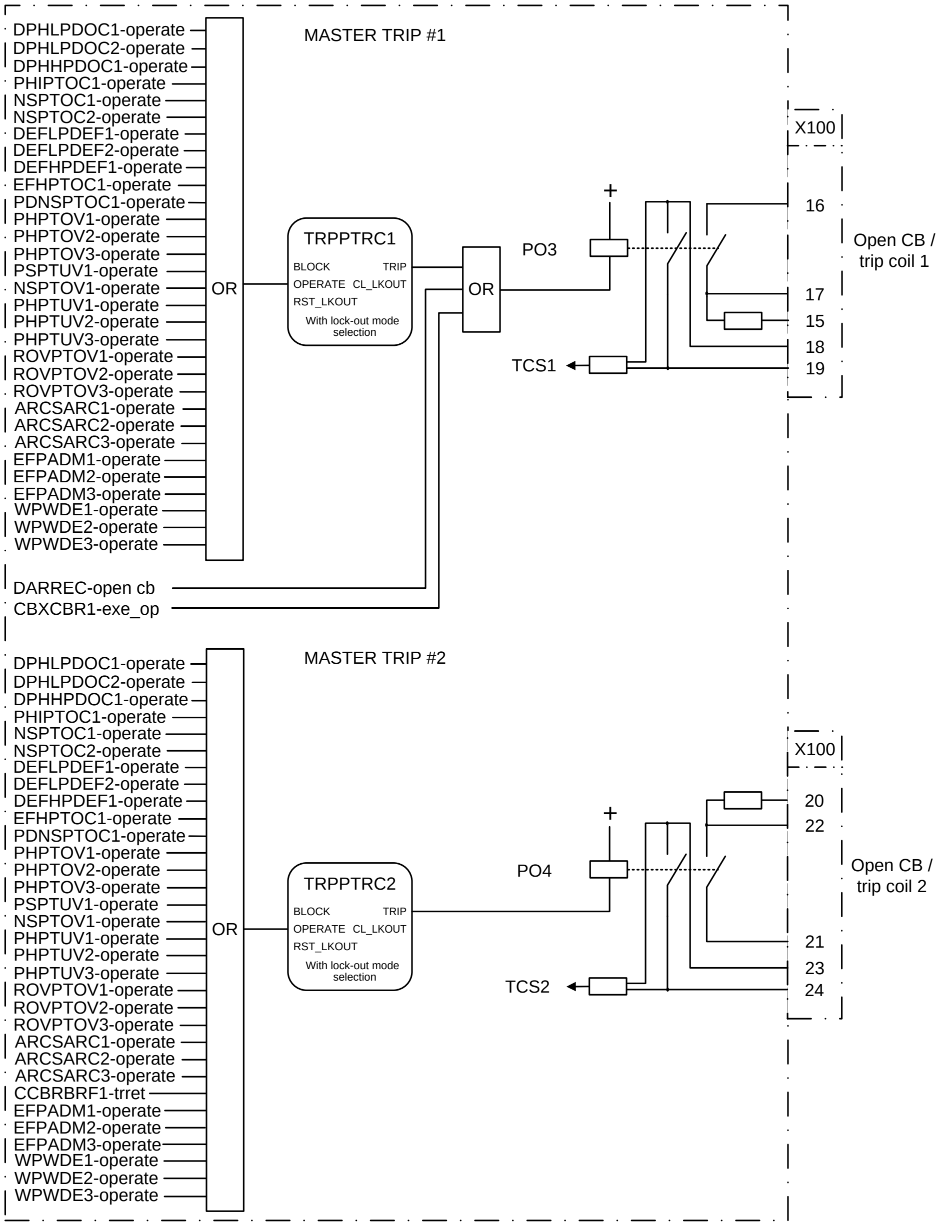


Figure 80: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary

input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

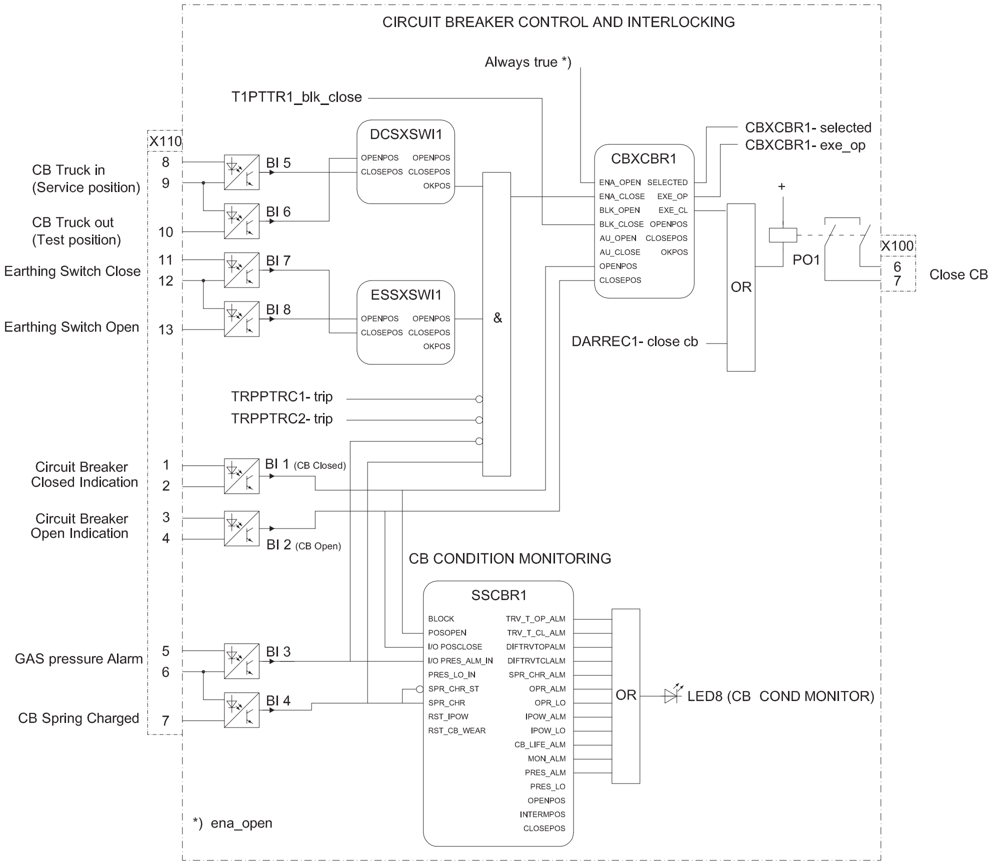


Figure 81: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 50: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

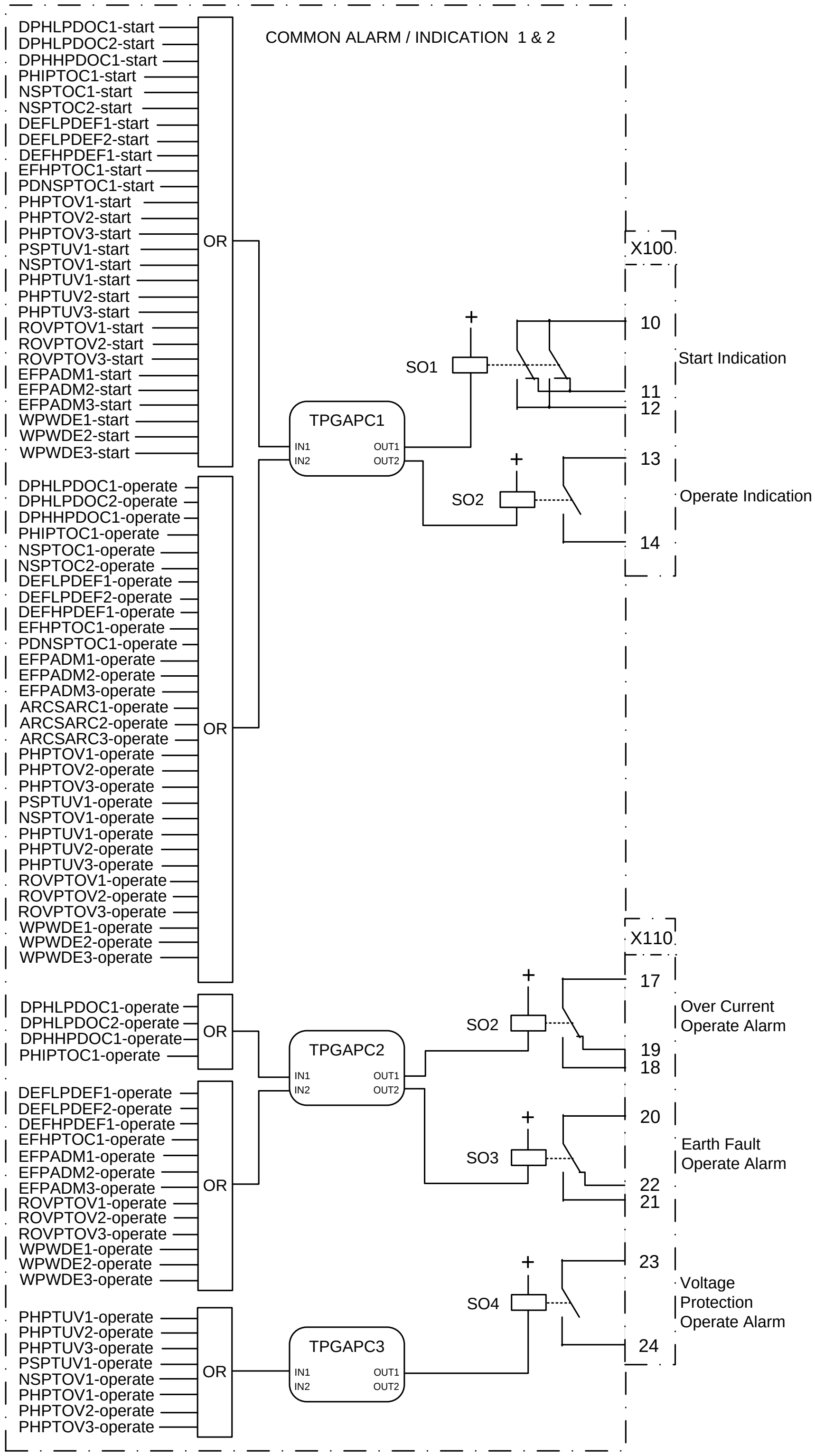


Figure 82: Alarm indication

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)
- Operation (trip) of any stage of the voltage protection function SO4 (X110:23-24)

TPGAPC 1...3 are timers used for setting the minimum pulse length for the outputs. Four generic timers (TPGAPC1..4) are available in the IED. The remaining one not described in the functional diagram is available in PCM600 for connection where applicable.

3.11 Standard configuration H

3.11.1 Applications

The standard configuration for non-directional overcurrent and non-directional earth-fault, phase-voltage and frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in directly or resistance-earthed distribution networks.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.11.2 Functions

Table 51: Functions included in the standard configuration H

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27 (2)
Three-phase undervoltage protection, instance 3	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59 (1)
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59 (2)
Three-phase overvoltage protection, instance 3	PHPTOV3	3U> (3)	59 (3)
Frequency protection, instance 1	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
Frequency protection, instance 2	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
Frequency protection, instance 3	FRPFRQ3	f>/f<,df/dt (3)	81 (3)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Synchronism and energizing check	SECRSYN1	SYNC	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
Frequency measurement	FMMXU1	f	f

3.11.2.1 Default I/O connections

Table 52: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	Busbar VT secondary MCB open	X110-1,2
X110-BI2	Line VT secondary MCB open	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2

Table continues on next page

Binary input	Default usage	Connector pins
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Lock-out reset	X120-5,6

Table 53: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15,16
X110-SO2	Overcurrent operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Voltage protection operate alarm	X110-23,24

Table 54: Default connections for LEDs

LED	Default usage
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Combined protection operated indication
4	Synchronism or energizing check OK
5	Frequency protection
6	Circuit-breaker failure protection backup protection operated
8	Circuit-breaker condition monitoring alarm
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.11.2.2 Default disturbance recorder settings

Table 55: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3

Table continues on next page

Channel	Selection and text
4	Io
5	Uo
6	U1
7	U2
8	U3
9	U1B
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.11.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED’s standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder’s parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.11.3.1 Functional diagrams for protection

The functional diagrams describe the IED’s protection functionality in detail and picture the factory set default connections.

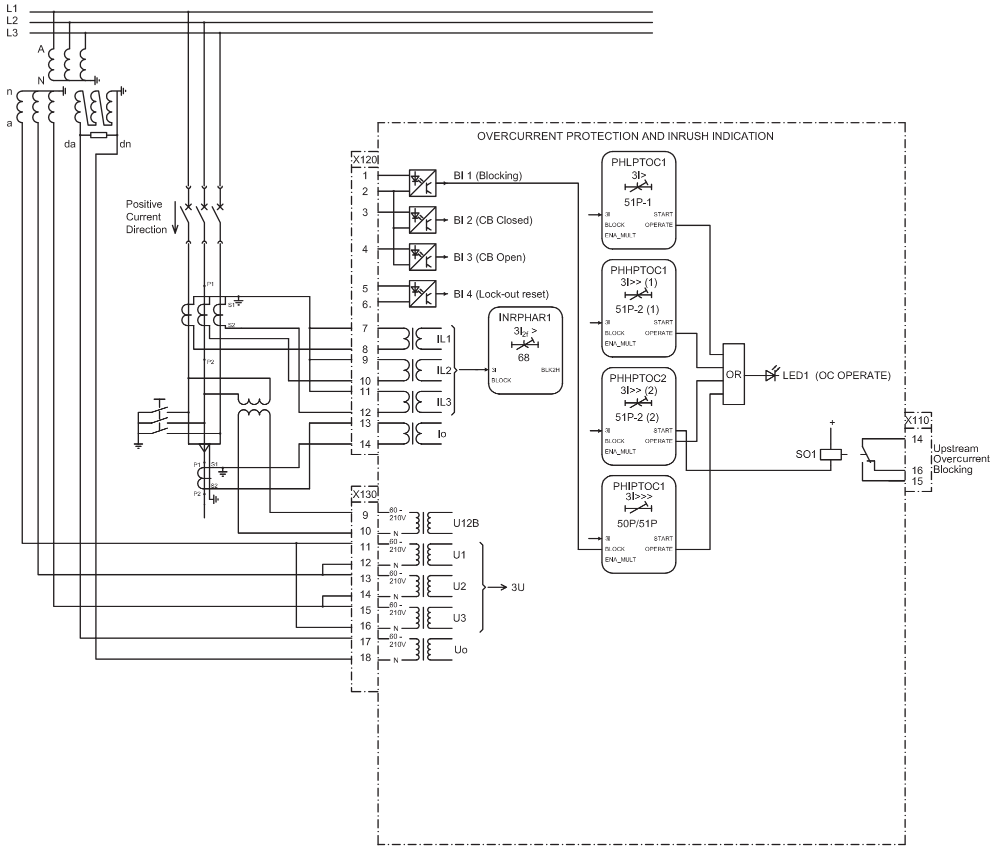


Figure 83: Non-directional overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LEDs. LED 1 is used for overcurrent and LED 4 for negative-sequence overcurrent protection operate indication. LED 4 is also used for phase discontinuity protection operate indication.

The upstream blocking from the start of the overcurrent second high stage (PHHPTOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

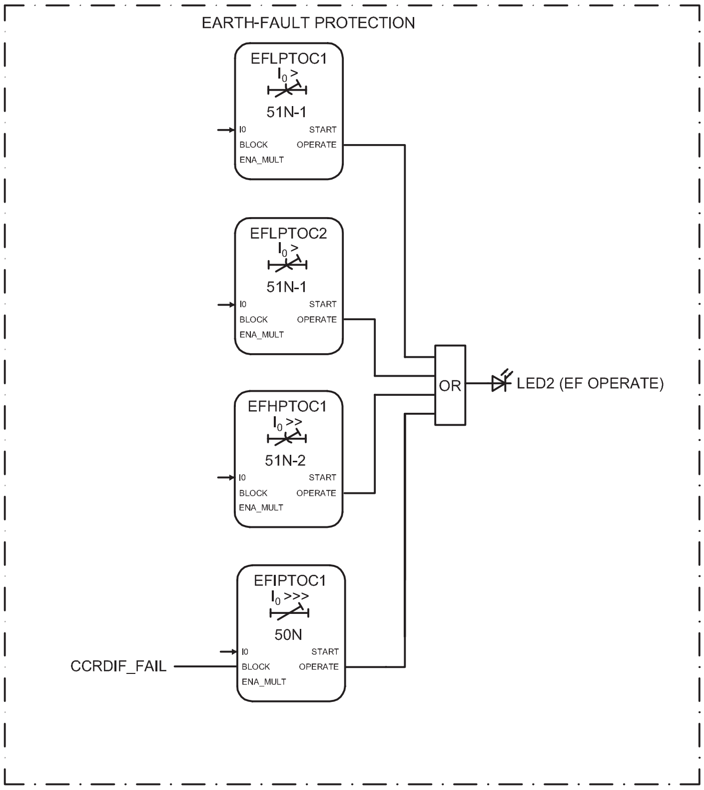


Figure 84: Non-directional earth-fault protection

Four stages are offered for non-directional earth-fault protection. One stage is dedicated to sensitive earth-fault protection.

All operate signals are connected to the Master Trip as well as to the alarm LEDs. LED 2 is used for directional earth-fault.

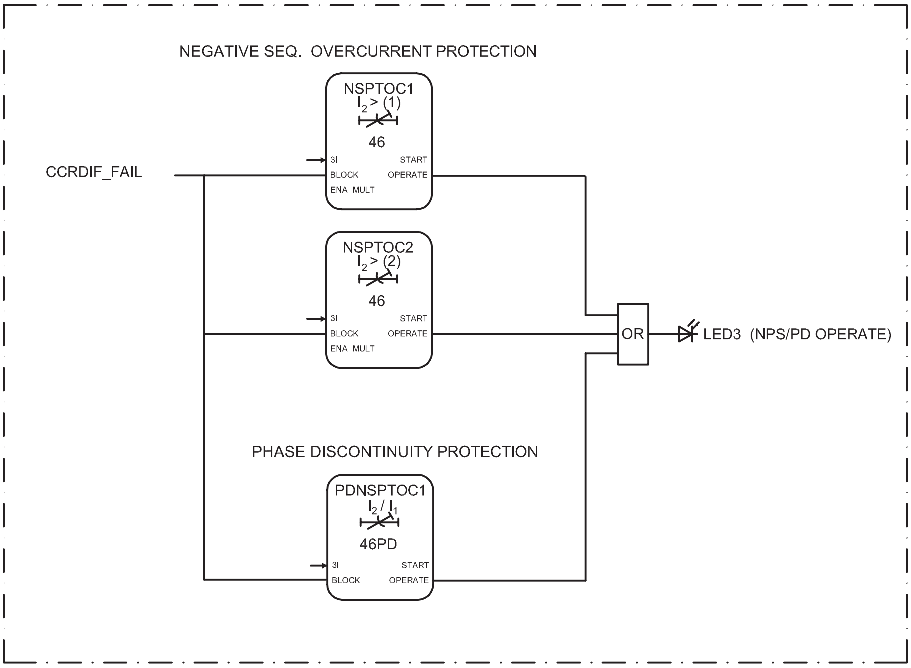


Figure 85: Negative sequence and phase discontinuity protection

Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection.

The phase discontinuity protection (PDNPSTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED. LED 3 is used for the phase discontinuity protection operate indication, the same as for negative sequence overcurrent protection operate indication.

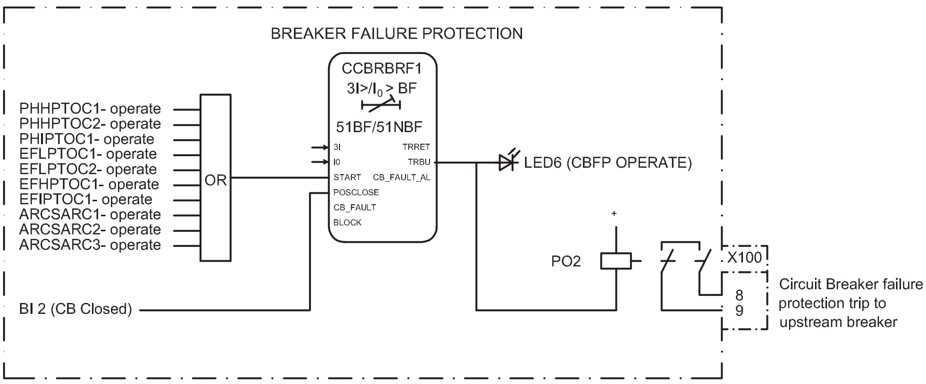


Figure 86: Circuit breaker failure protection

The breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for back-up (TRBU) operate indication.

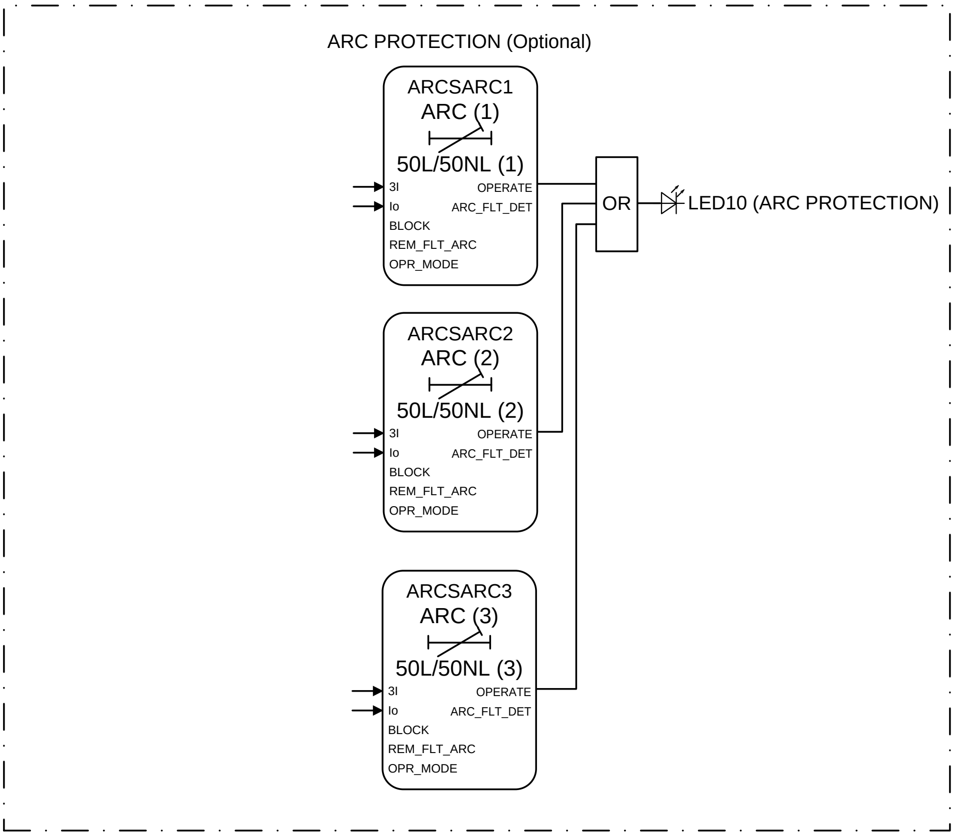


Figure 87: Arc protection

Arc protection (ARCSARC1...3) and autoreclosing (DARREC1) are included as optional functions.

The arc protection offers individual function blocks for three arc sensors that can be connected to the IED. Each arc protection function block has two different operation modes, with or without the phase and residual current check. Operate signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

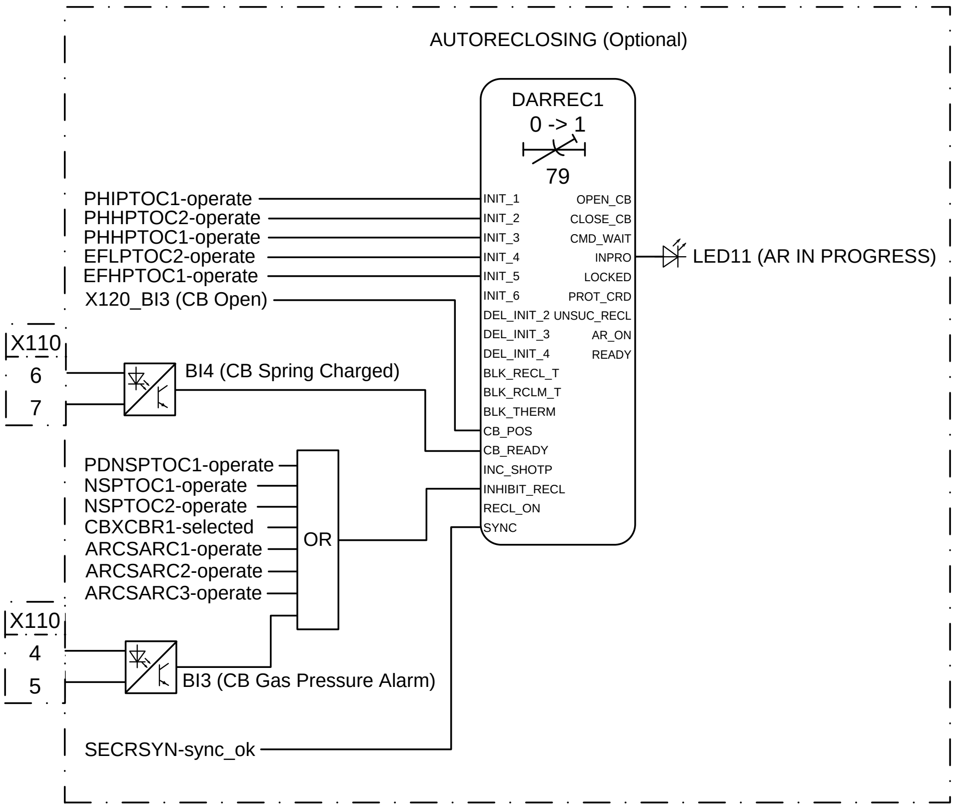


Figure 88: Autoreclosing

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

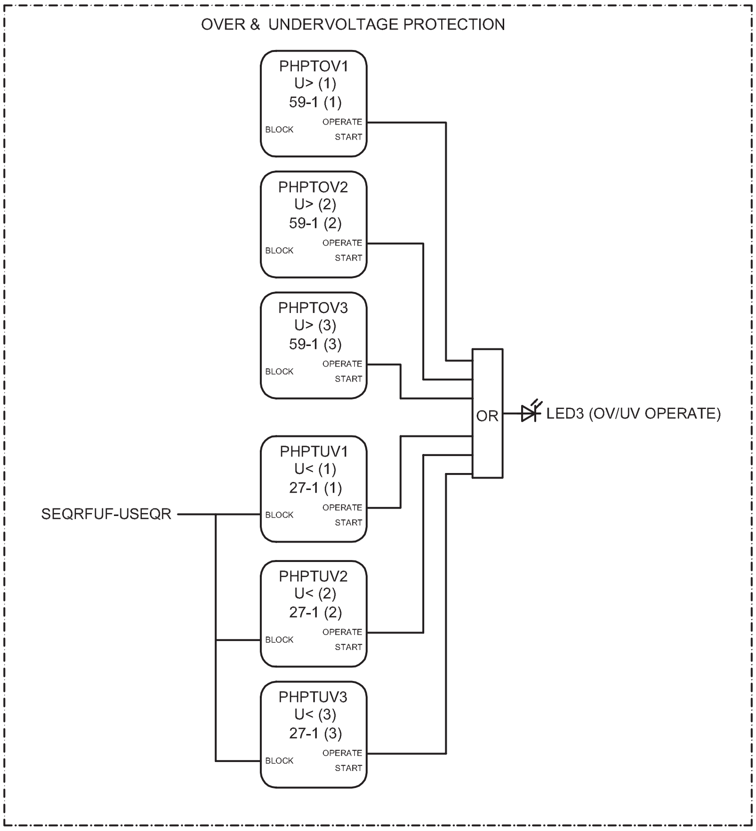


Figure 89: Overvoltage and undervoltage protection

Three overvoltage and undervoltage protection stages (PHxPTOV and PHxPTUV) offer protection against abnormal phase voltage conditions. The operation of voltage functions is connected to alarm LED 3. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

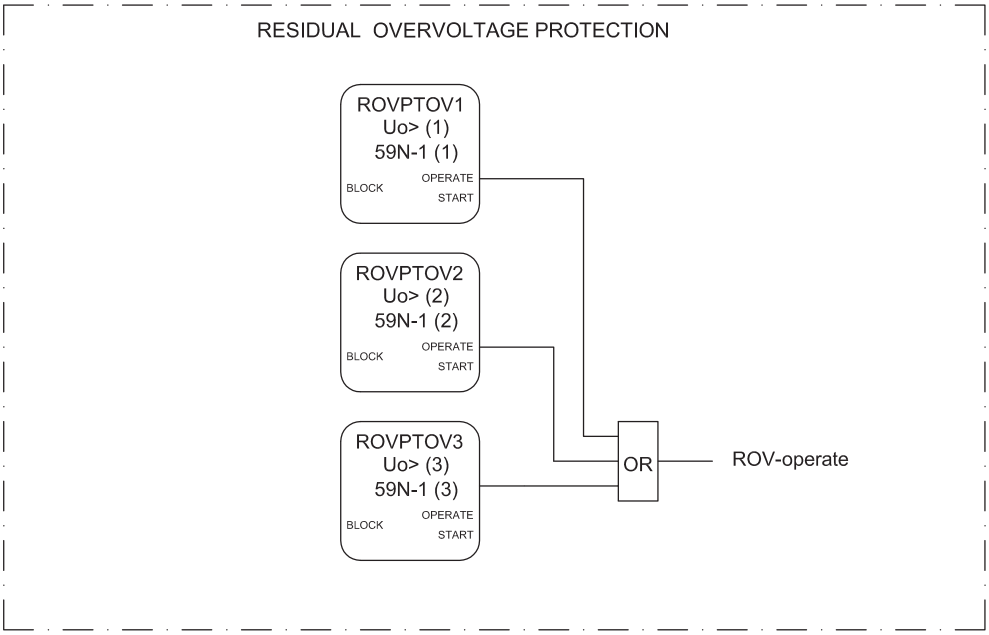


Figure 90: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is connected to alarm LED 2.

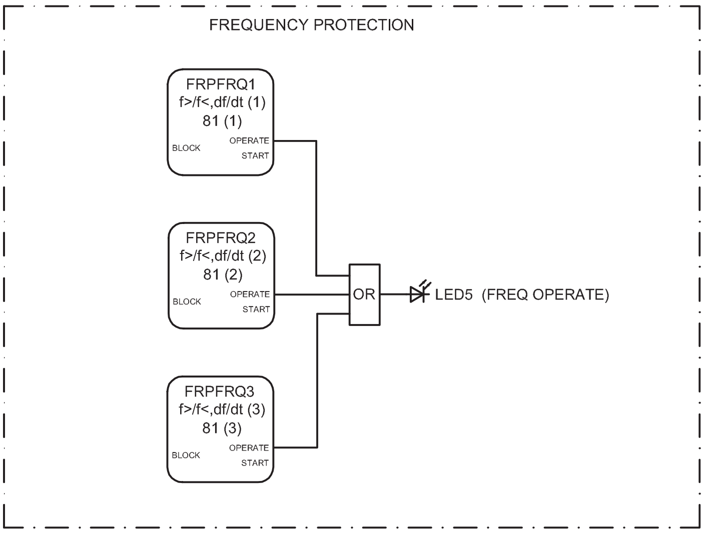


Figure 91: Frequency protection

The selectable underfrequency or overfrequency protection (FRPFRQ) prevents damage to network components under unwanted frequency conditions.

The function contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. The operation signal is connected to alarm LED 5.

3.11.3.2 Functional diagram for disturbance recorder and trip circuit supervision

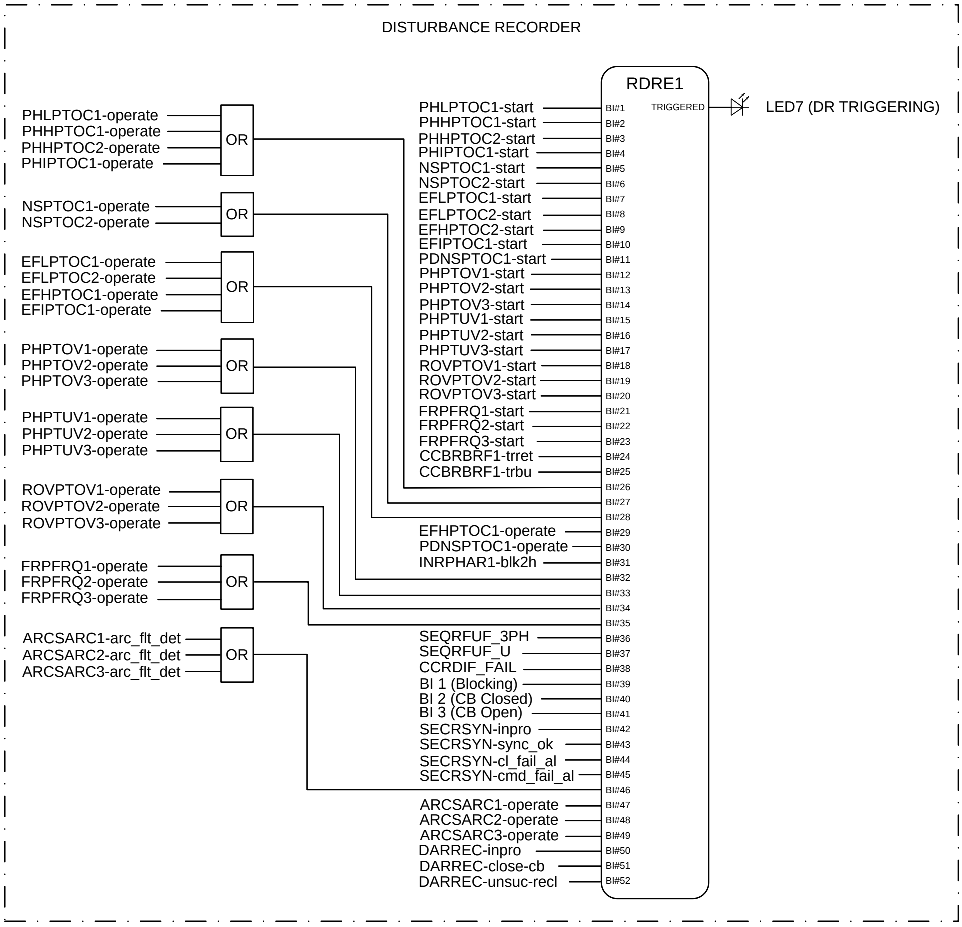


Figure 92: Disturbance recorder

All start and operate signals from the protection stages are routed either to trigger the disturbance recorder or to be recorded by the disturbance recorder, depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals, the synchrocheck signals and the three binary inputs from X120 are also connected.

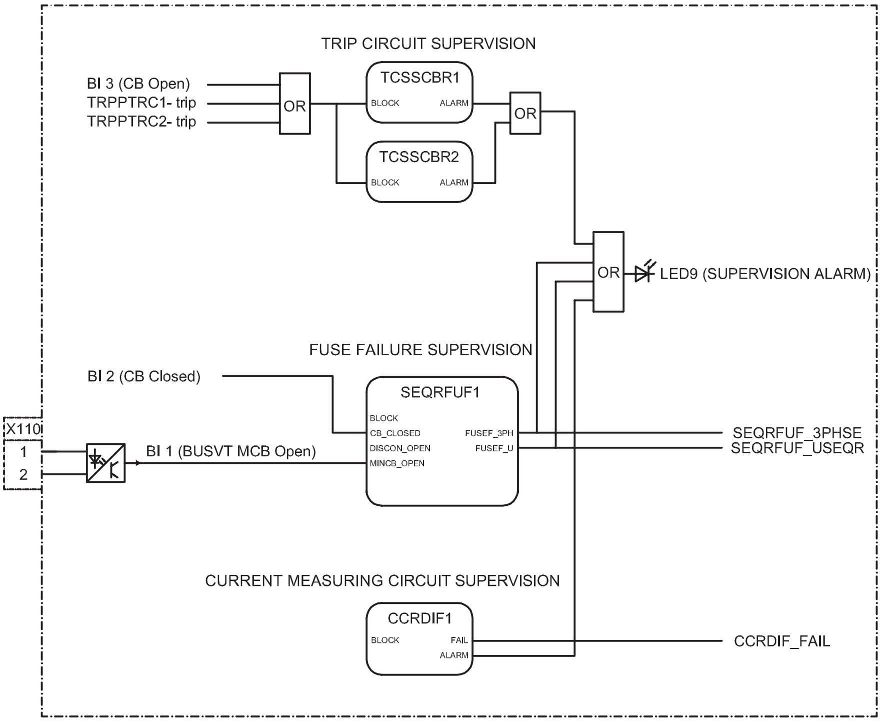


Figure 93: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.11.3.3 Functional diagrams for control and interlocking

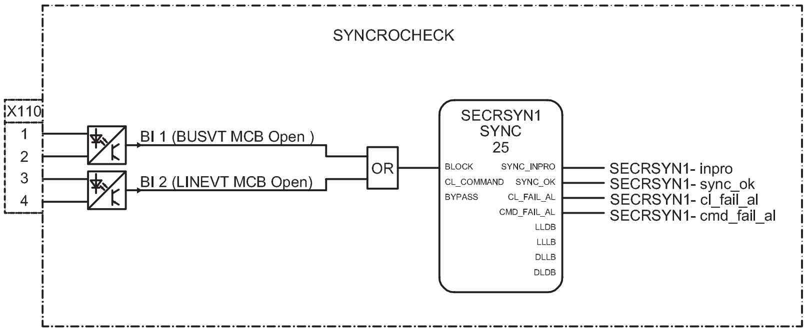


Figure 94: Synchrocheck

The main purpose of the synchronism and energizing check (SECRSYN) is to provide control over the closing of the circuit breakers in power networks to prevent the closing if the conditions for synchronism are not detected. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN measures the bus and line voltages and compares them to set conditions. When all the measured quantities are within set limits, the output SYNC_OK is activated for allowing closing or closing the circuit breaker. The SYNC_OK output signal of SECRSYN is connected to ENA_CLOSE input of CBXCBR through control logic.

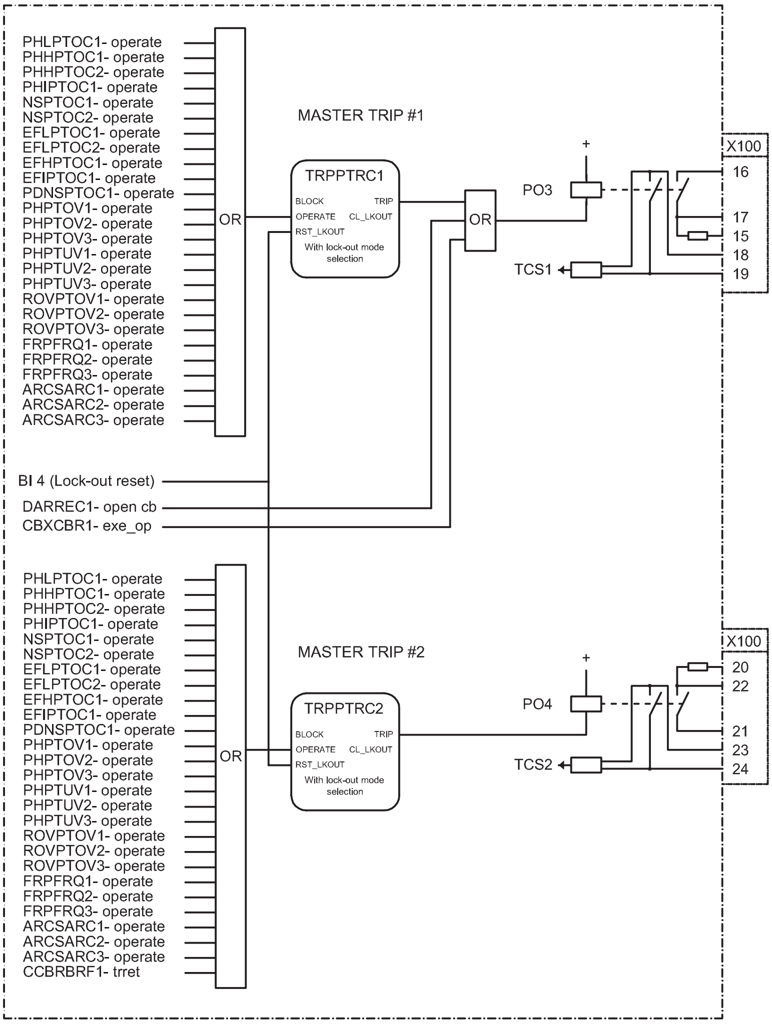


Figure 95: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

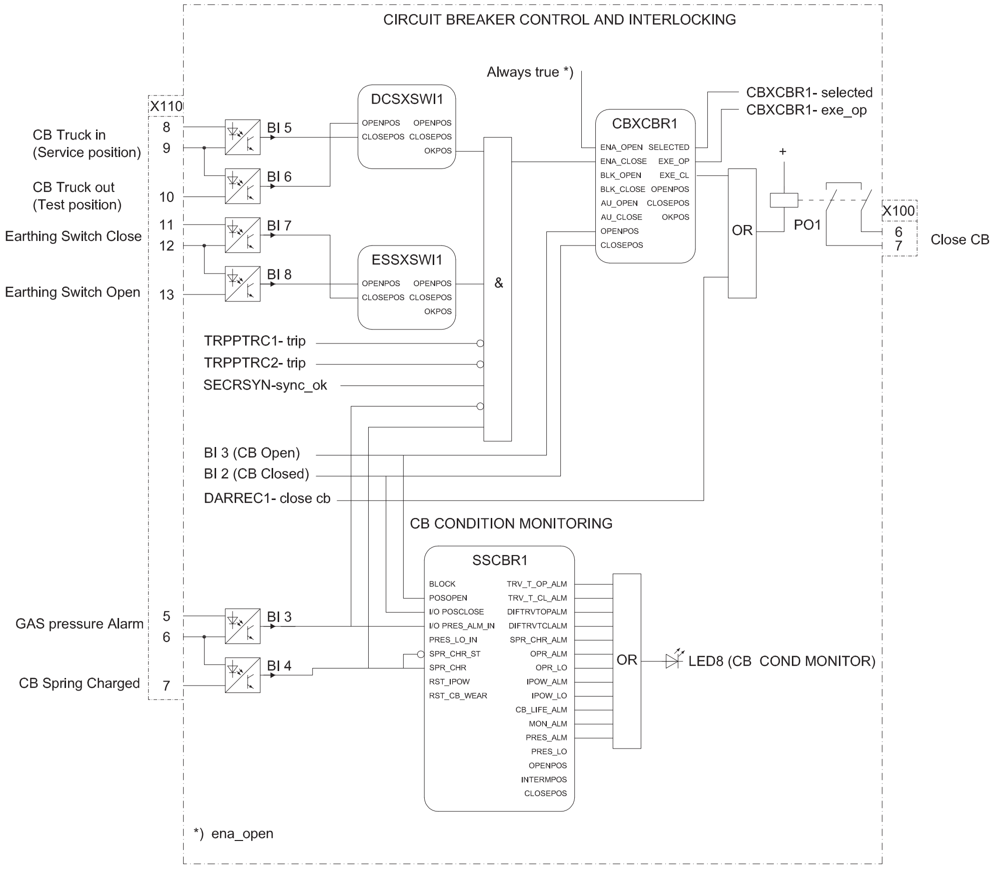


Figure 96: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 56: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

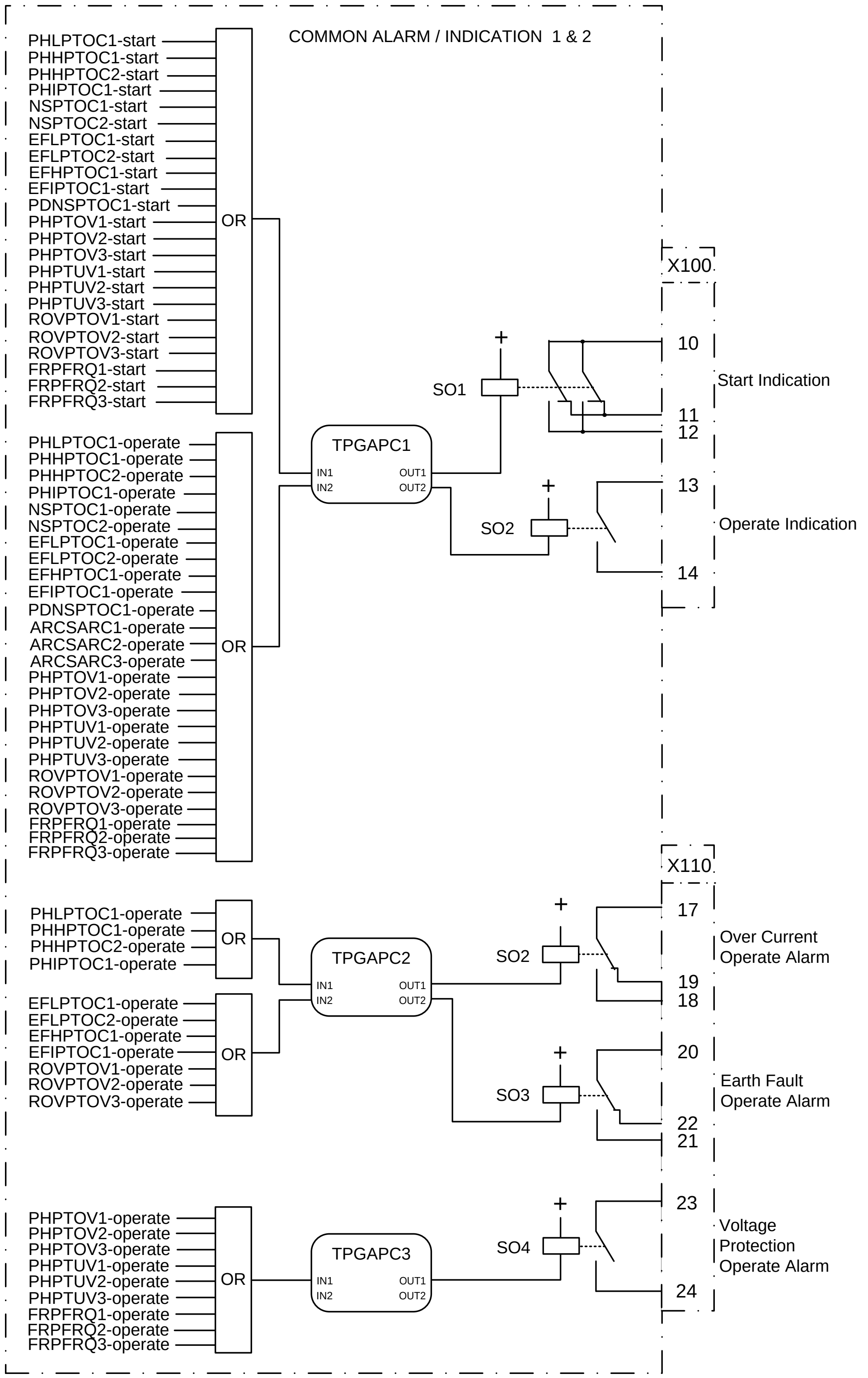


Figure 97: Alarm indication

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)
- Operation (trip) of any stage of the voltage or frequency protection function SO4 (X110:23-24)

TPGAPC 1...3 are timers used for setting the minimum pulse length for the outputs. Four generic timers (TPGAPC1..4) are available in the IED. The remaining one not described in the functional diagram is available in PCM600 for connection where applicable.

3.12 Standard configuration J

3.12.1 Applications

The standard configuration for directional overcurrent and directional earth-fault protection with phase-voltage based measurements, undervoltage and overvoltage protection, and frequency protection and measurement functions is mainly intended for cable and overhead-line feeder applications in isolated or resonant-earthed distribution networks. The configuration also includes additional options to select earth-fault protection based on admittance, wattmetric or harmonic based principle.

The IED with a standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the IED enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.12.2 Functions

Table 57: Functions included in the standard configuration J

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67-1 (1)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase directional overcurrent protection, low stage, instance 2	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> ->	67-2
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Admittance based earth-fault protection, instance 1	EFPADM1	Yo> -> (1)	21YN (1)
Admittance based earth-fault protection, instance 2	EFPADM2	Yo> -> (2)	21YN (2)
Admittance based earth-fault protection, instance 3	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric based earth-fault protection, instance 1	WPWDE1	Po> -> (1)	32N (1)
Wattmetric based earth-fault protection, instance 2	WPWDE2	Po> -> (2)	32N (2)
Wattmetric based earth-fault protection, instance 3	WPWDE3	Po> -> (3)	32N (3)
Transient / intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Harmonics based earth-fault protection	HAEFPTOC1	Io>HA	51NHA
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Three-phase undervoltage protection, instance 2	PHPTUV2	3U< (2)	27 (2)
Three-phase undervoltage protection, instance 3	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection, instance 1	PHPTOV1	3U> (1)	59 (1)
Three-phase overvoltage protection, instance 2	PHPTOV2	3U> (2)	59 (2)
Three-phase overvoltage protection, instance 3	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O- (1)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Frequency protection, instance 1	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
Frequency protection, instance 2	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
Frequency protection, instance 3	FRPFRQ3	f>/f<,df/dt (3)	81 (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Power quality			
Current total demand distortion	CMHAI1	PQM3I	PQM3I
Voltage total harmonic distortion	VMHAI1	PQM3U	PQM3V
Voltage variation	PHQVVR1	PQMU	PQMV
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Auto-reclosing	DARREC1	O -> I	79
Synchronism and energizing check	SECRSYN1	SYNC	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
Frequency measurement	FMMXU1	f	f

3.12.2.1 Default I/O connections

Table 58: Default connections for binary inputs

Binary input	Default usage	Connector pins
X110-BI1	Busbar VT secondary MCB open	X110-1,2
X110-BI2	Line VT secondary MCB open	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	Circuit breaker truck in (service position) indication	X110-8,9
X110-BI6	Circuit breaker truck out (test position) indication	X110-10,9
X110-BI7	Earthing switch closed indication	X110-11,12
X110-BI8	Earthing switch open indication	X110-13,12
X120-BI1	Blocking of overcurrent instantaneous stage	X120-1,2
X120-BI2	Circuit breaker closed indication	X120-3,2
X120-BI3	Circuit breaker open indication	X120-4,2
X120-BI4	Lock-out reset	X120-5,6

Table 59: Default connections for binary outputs

Binary output	Default usage	Connector pins
X100-PO1	Close circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2	X100-20-24
X110-SO1	Upstream overcurrent blocking	X110-14,15
X110-SO2	Overcurrent operate alarm	X110-17,18
X110-SO3	Earth fault operate alarm	X110-20,21
X110-SO4	Voltage and frequency protection operate alarm	X110-23,24

Table 60: Default connections for LEDs

LED	Default usage
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Combined protection operated indication
4	Synchronism or energizing check OK
5	Thermal overload protection operated
6	Circuit-breaker failure protection backup protection operated
7	Disturbance recorder triggered
8	CB condition monitoring
9	Supervision alarm
10	Arc fault detected
11	Autoreclose in progress

3.12.2.2 Default disturbance recorder settings

Table 61: Default analog channel selection and text settings

Channel	Selection and text
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	U1B
10	-
11	-
12	-

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.12.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.12.3.1 Functional diagrams for protection

The functional diagrams describe the IED's protection functionality in detail, and the factory-set default connections.

Four overcurrent stages are available for overcurrent and short-circuit protection. Three of them include directional functionality (DPHxPDOC). The non-directional instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative-sequence overcurrent stages (NSPTOC1 and NSPTOC2) are available for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables either blocking the function or multiplying the active settings for any of the shown protection function blocks.

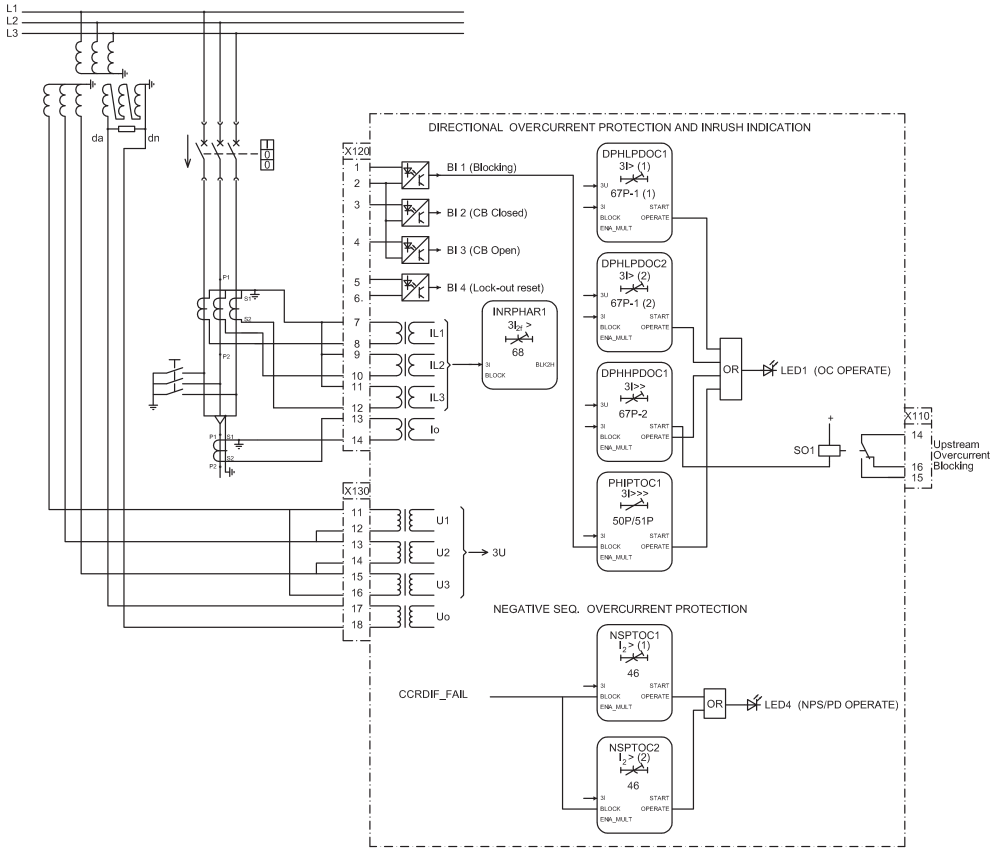


Figure 98: Directional overcurrent protection and inrush indication

All operate signals are connected to the Master Trip and to the alarm LEDs. The LED 1 is used for overcurrent and the LED 3 for negative-sequence overcurrent protection operate indication. The LED 3 is also used for phase discontinuity protection operate indication and for voltage protection indication.

The upstream blocking from the start of the directional overcurrent second low stage (DPHLPDOC2) is connected to the output SO1 (X110:14-16). This output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

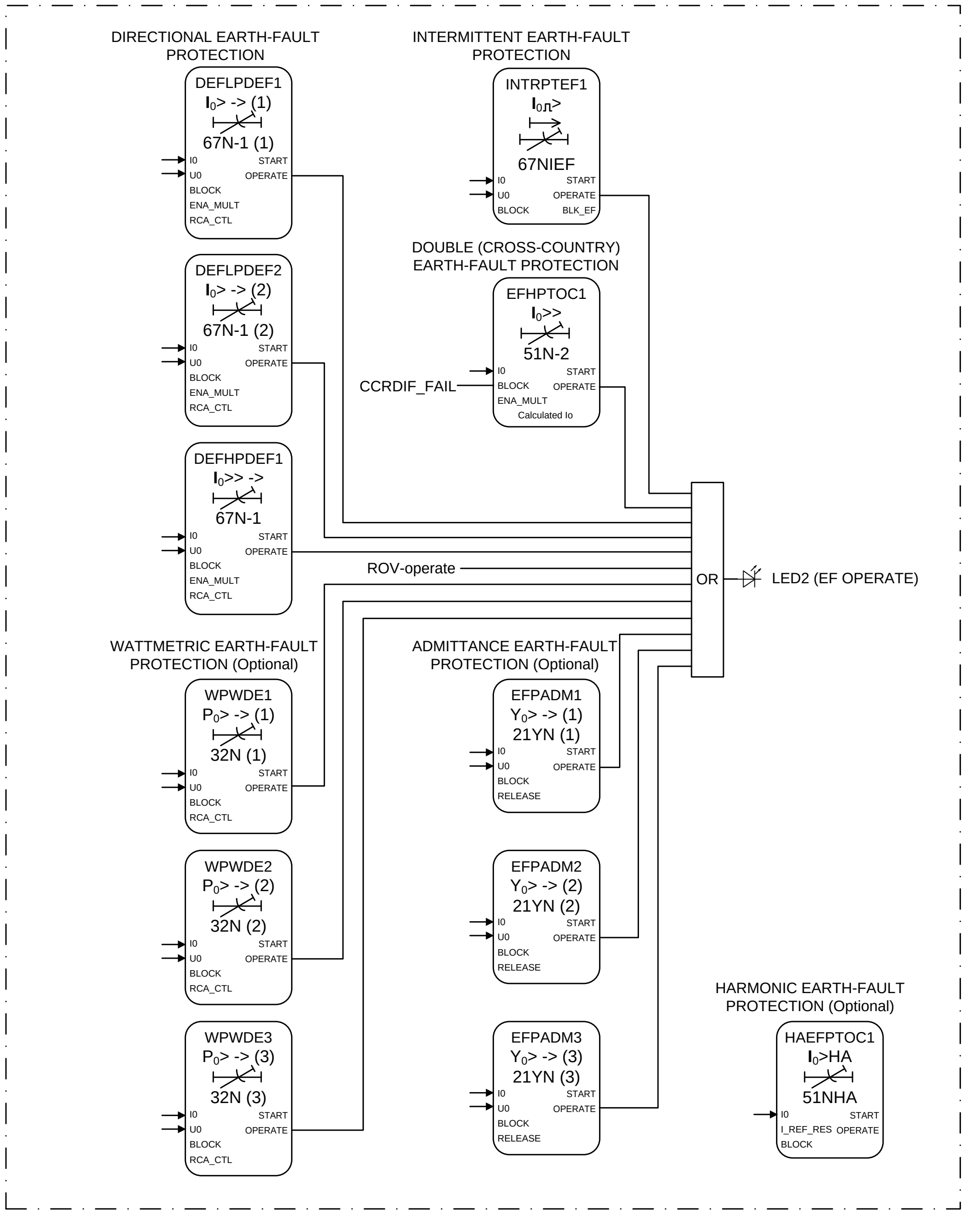


Figure 99: Directional earth-fault protection

Three stages are offered for directional earth-fault protection. According to the order code, the directional earth-fault protection method can be based on conventional directional earth-fault (DEFxPDEF) only or alternatively together with admittance criteria (EFPADM) or wattmetric earth-fault protection (WPWDE) or harmonic based earth-fault protection (HAEFPTOC). In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) protects against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

All operate signals are connected to the Master Trip and also to the alarm LED 2.

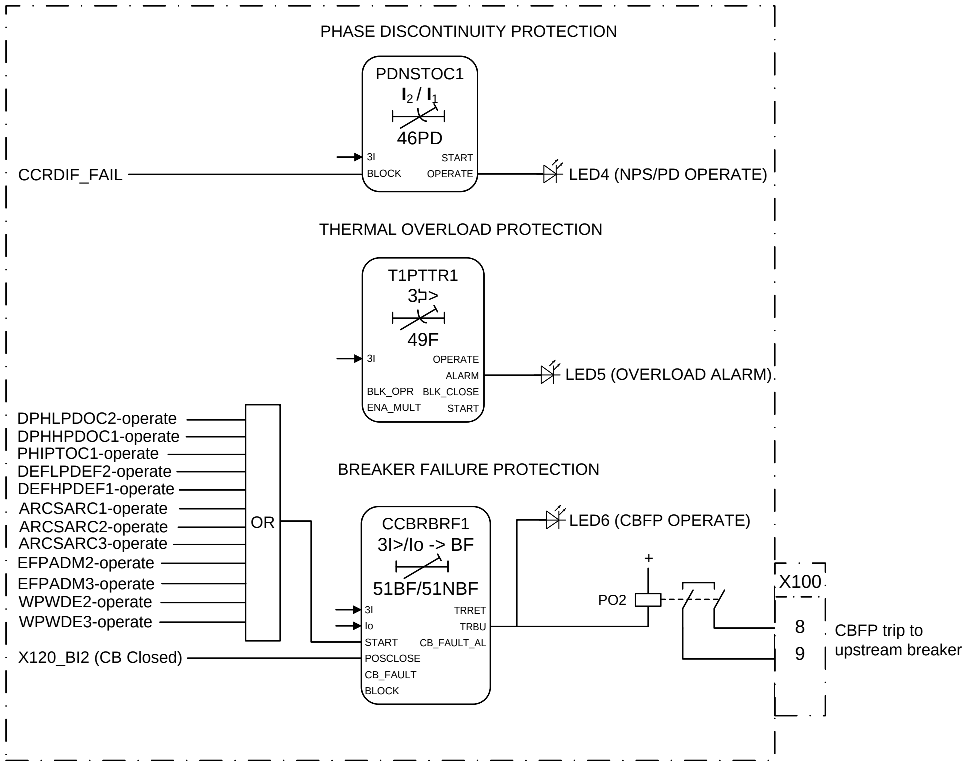


Figure 100: Phase discontinuity, thermal overload and circuit breaker failure protection

The phase discontinuity protection (PDNSPTOC1) protects for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED and the disturbance recorder. The thermal overload protection (T1PTTR1) provides indication on overload situations. The operate signal of the phase discontinuity protection is connected to the Master Trip and also to an alarm LED. The LED 3 is used for the phase discontinuity protection operate indication, the same as for negative-sequence overcurrent protection operate indication, and the LED 5 is used for the thermal overload protection alarm indication.

The breaker-failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase- and residual currents. The breaker failure protection has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through the Master Trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). The LED 6 is used for back-up (TRBU) operate indication.

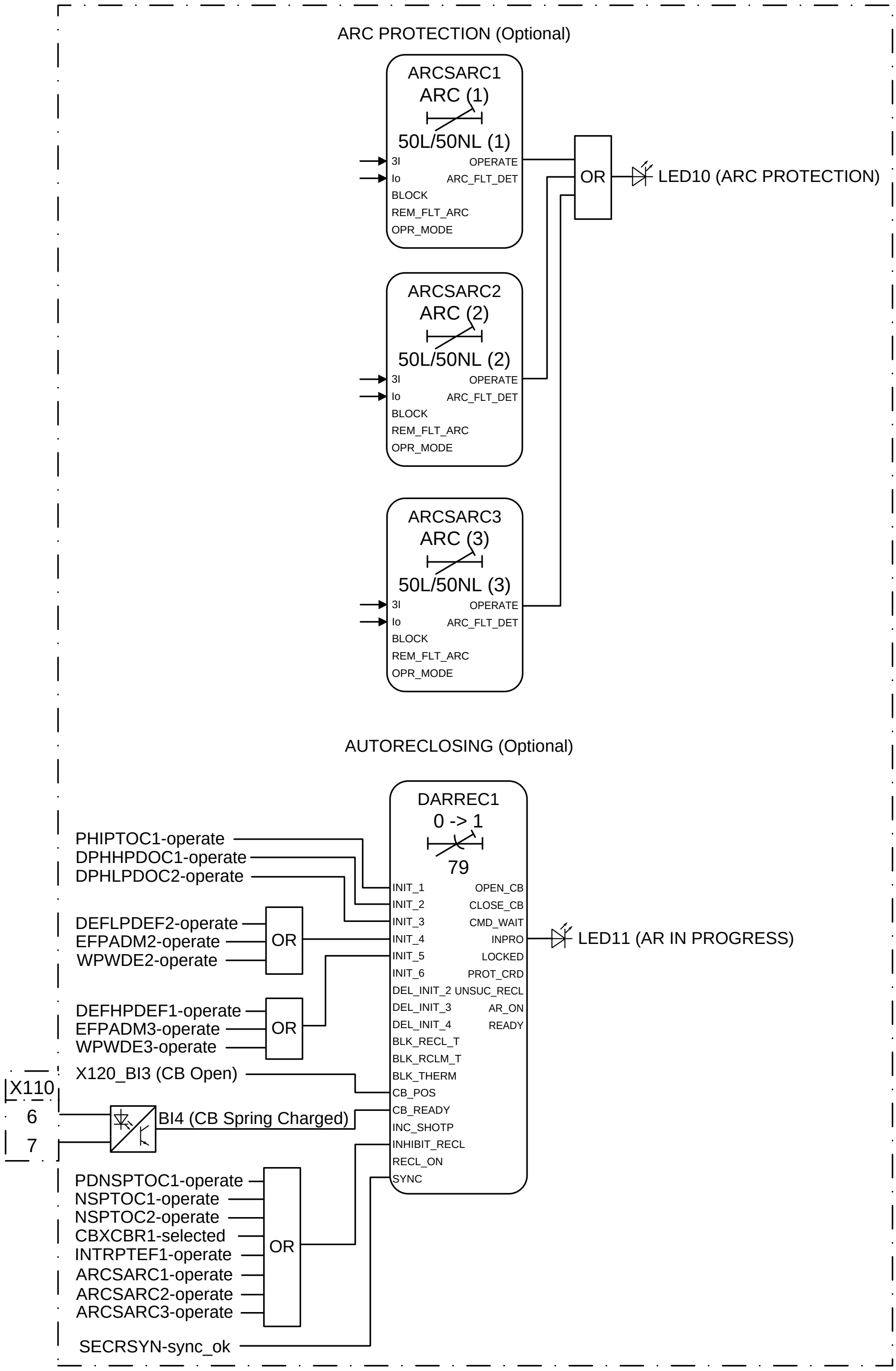


Figure 101: Arc protection

ARC protection (ARCSARC1...3) and autorreclosing (DARREC1) are included as optional functions.

The ARC protection offers individual function blocks for three ARC sensors that can be connected to the IED. Each ARC protection function block has two different operation modes, with or without the phase and residual current check. The operate signals from the ARC protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

The autorecloser is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, some selected protection function operations are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is not connected to any of the binary inputs. As a result, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to the alarm LED 11.

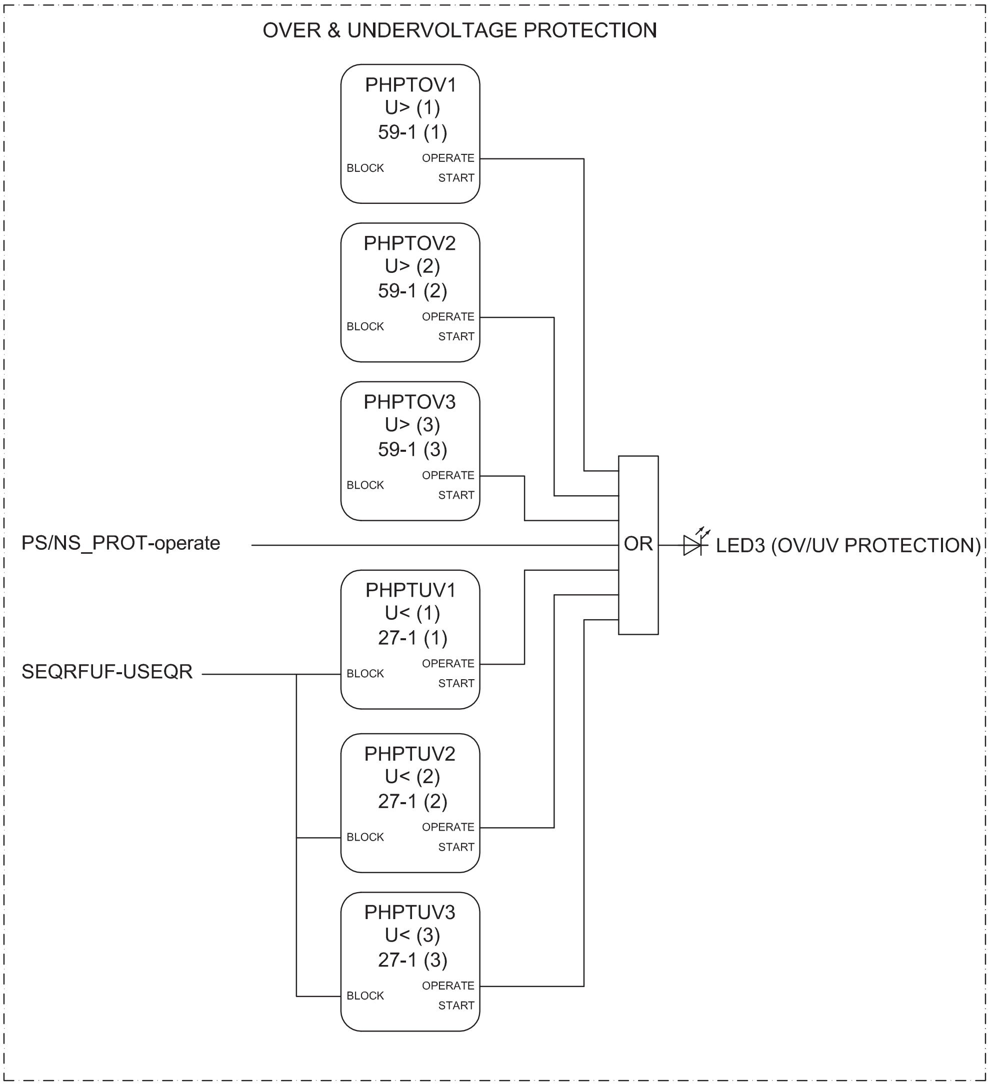


Figure 102: Overvoltage and undervoltage protection

Three overvoltage and undervoltage protection stages (PHxPTOV and PHxPTUV) protect against abnormal phase voltage conditions. The voltage function operation is connected to the alarm LED 3. A failure in the voltage measuring circuit is detected by the fuse failure function, and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

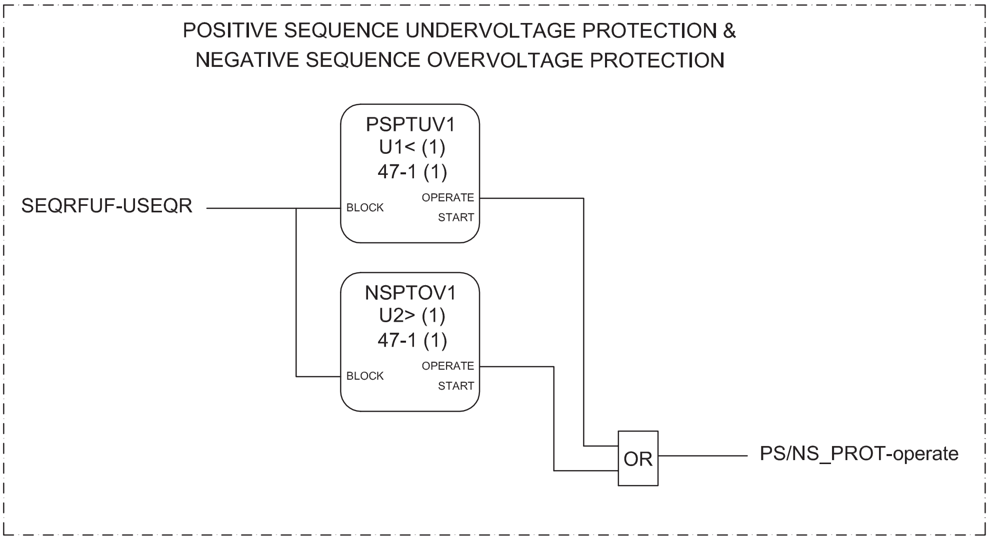


Figure 103: Positive-sequence undervoltage and negative-sequence overvoltage protection

Positive-sequence undervoltage (PSPTUV) and negative-sequence overvoltage (NSPTOV) protection functions enable voltage-based unbalance protection. The operation signals of the voltage-sequence functions are connected to the alarm LED 3, which is a combined voltage protection alarm LED.

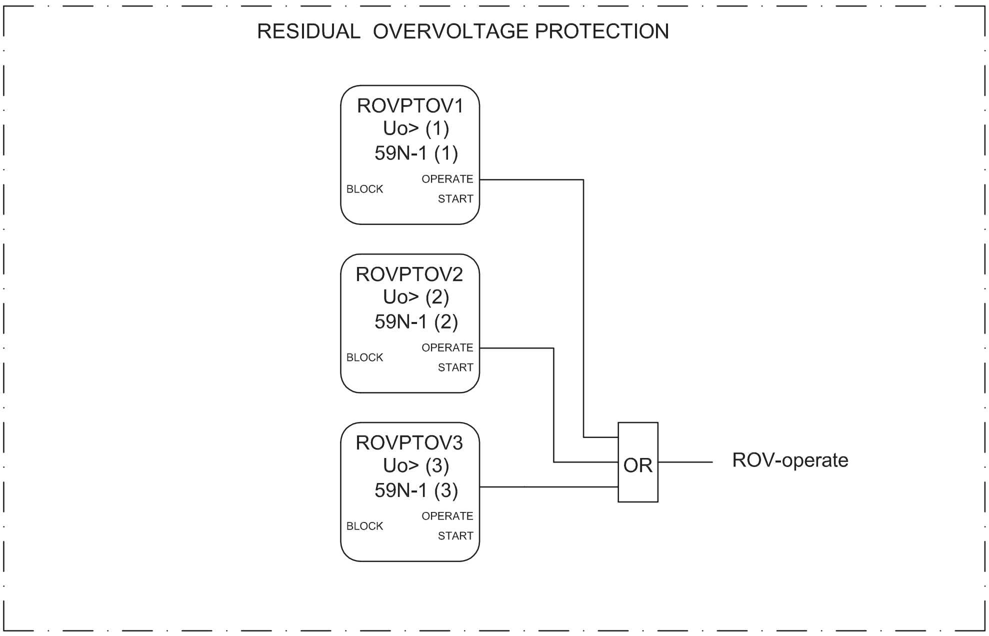


Figure 104: Residual overvoltage protection

The residual overvoltage protection (ROVPTOV) provides earth fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is connected to the alarm LED 2.

The selectable underfrequency or overfrequency protection (FRPFRQ) prevents damage to network components under unwanted frequency conditions. The function contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. The operation signal is connected to the alarm LED 3.

3.12.3.2 Functional diagram for disturbance recorder and trip circuit supervision

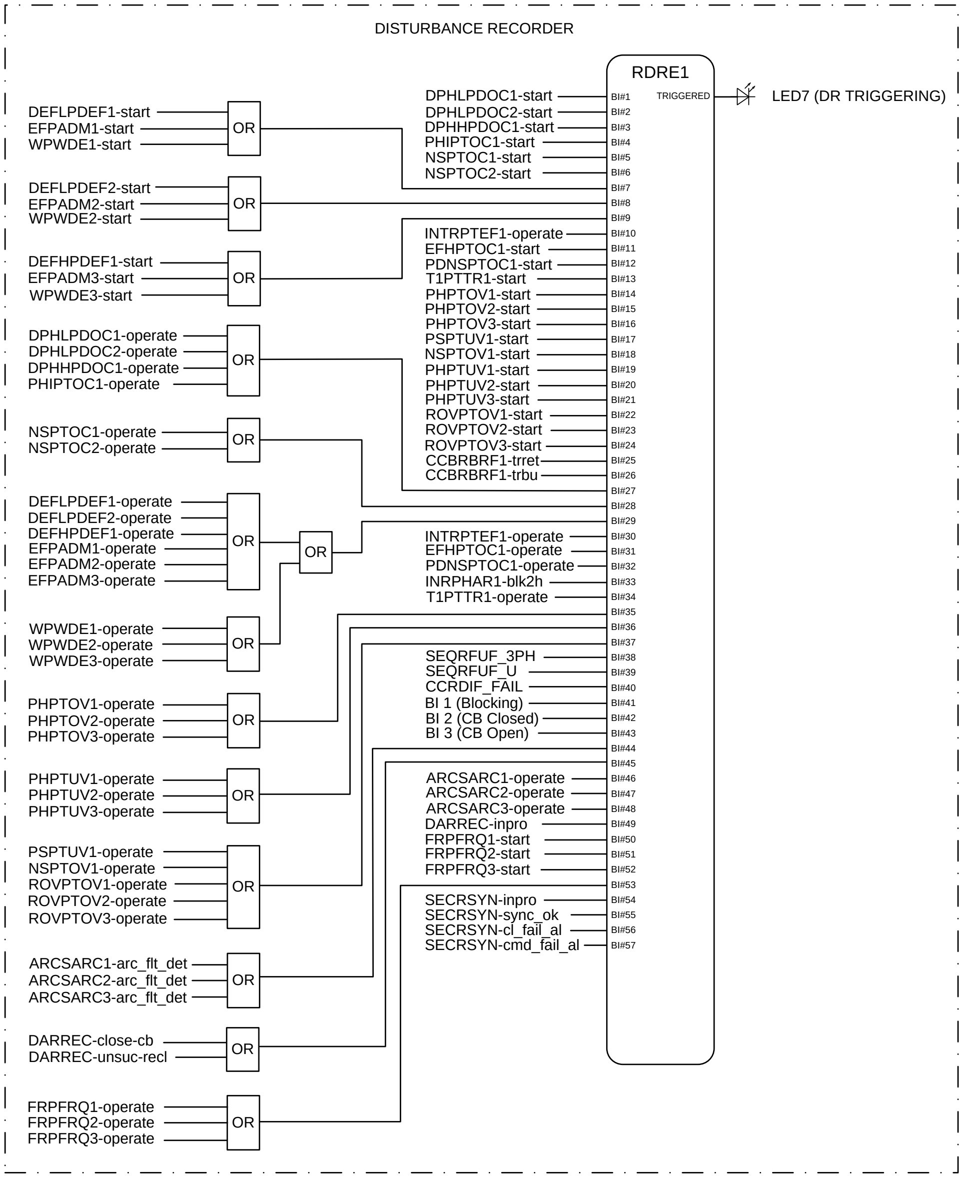


Figure 105: Disturbance recorder

All start and operate signals from the protection stages are routed either to trigger the disturbance recorder or to be recorded by the disturbance recorder, depending on the parameter settings. Additionally, the selected autorecloser, the ARC protection signals and the three binary inputs from X120 are also connected.

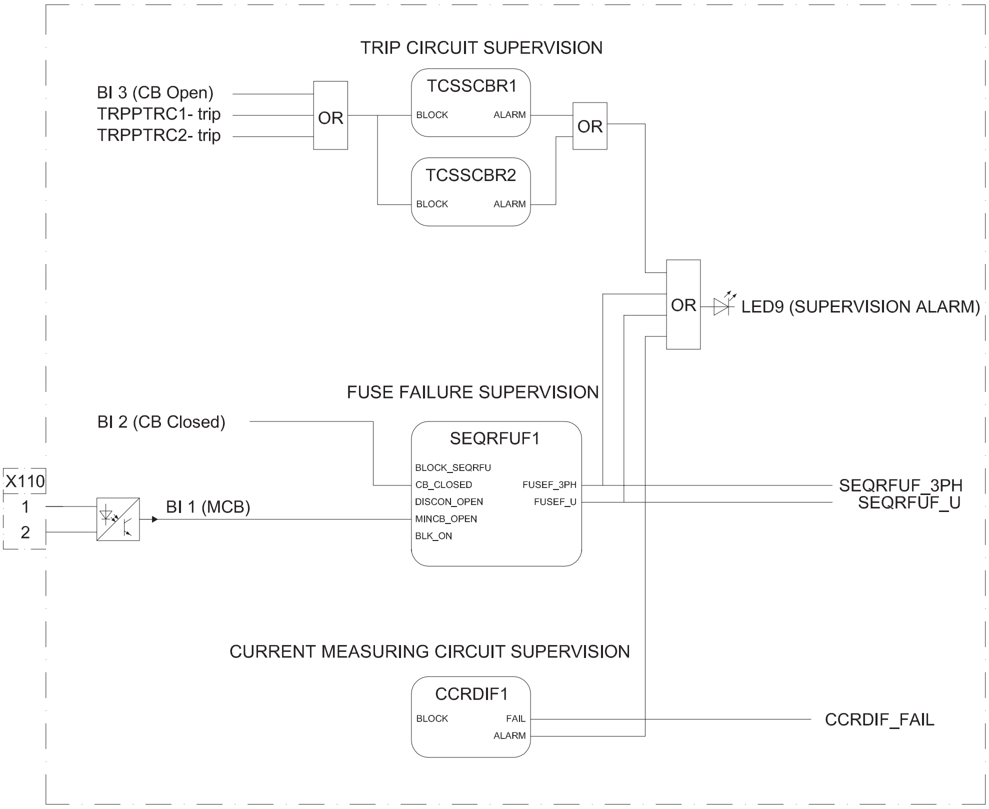


Figure 106: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

By default it is expected that there is no external resistor in the circuit breaker tripping coil circuit connected parallel with circuit breaker normally open auxiliary contact.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.12.3.3 Functional diagrams for control and interlocking

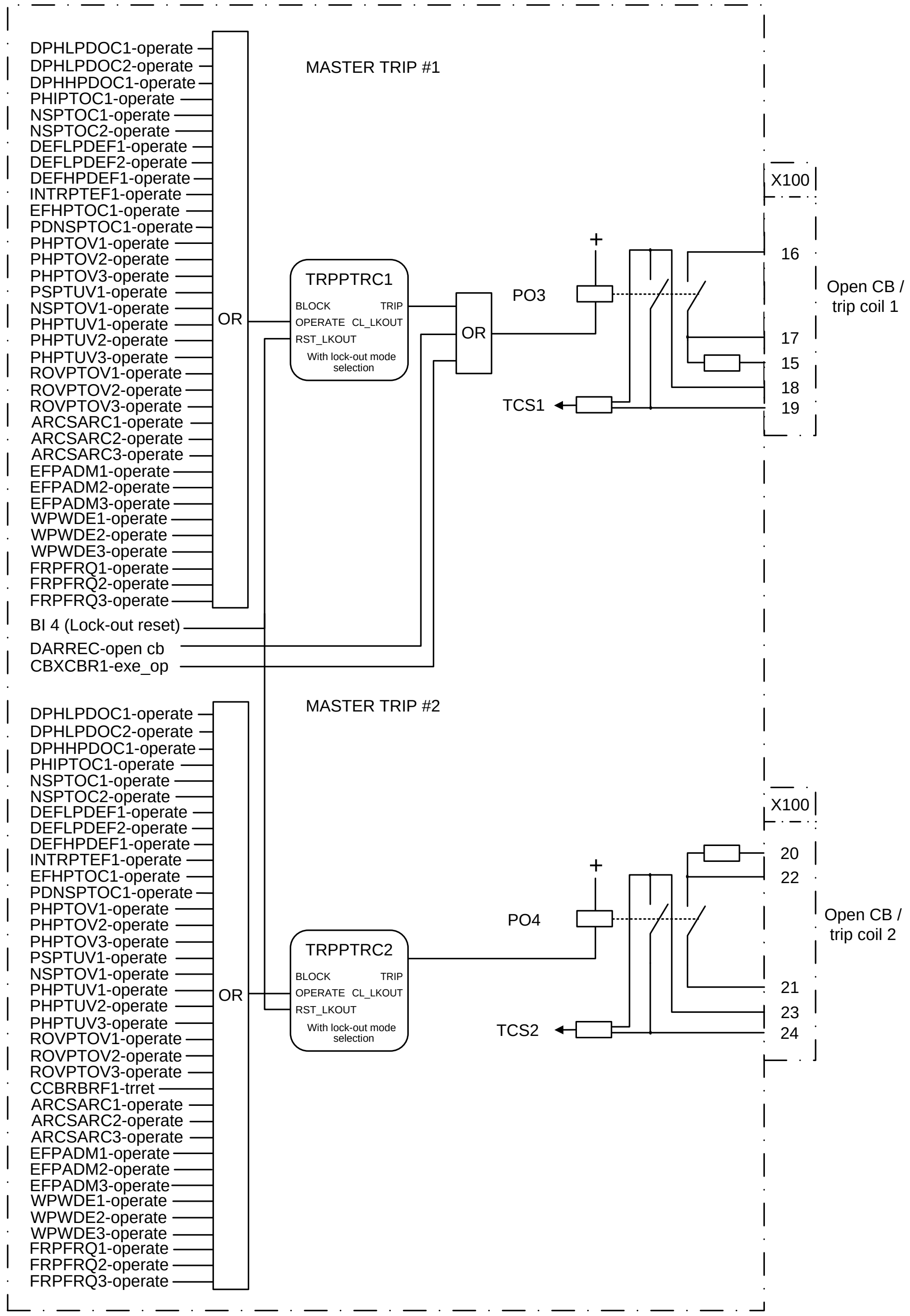


Figure 107: Master trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op or from the auto-recloser DARREC1-open_cb are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 and 2 provide the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

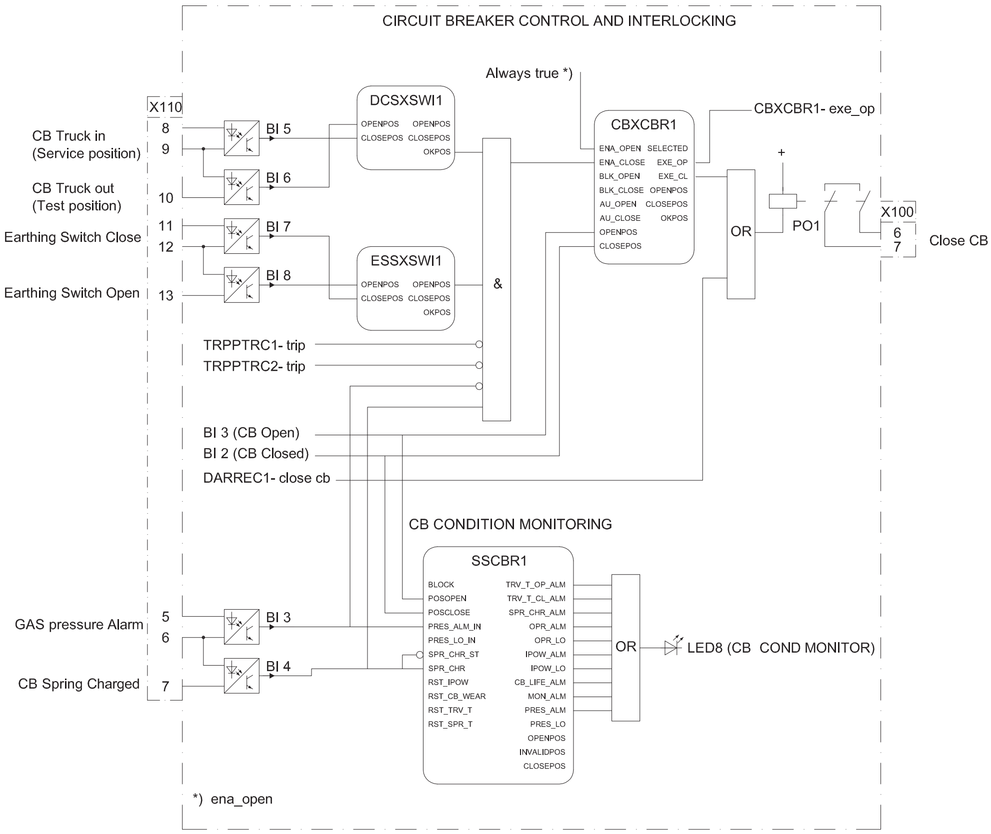


Figure 108: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 62: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.

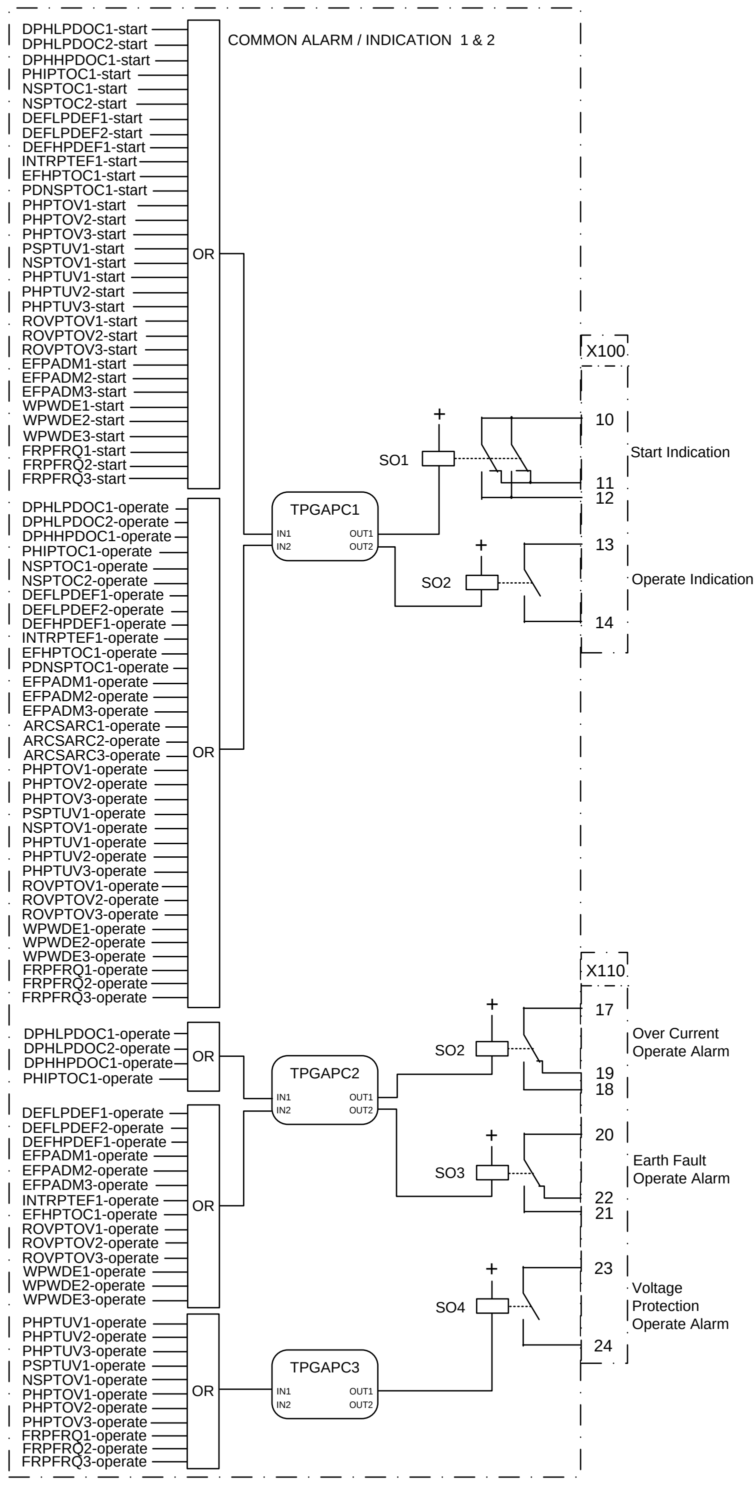


Figure 109: Alarm indication

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-22)

TPGAPC 1...3 are timers used for setting the minimum pulse length for the outputs. Four generic timers (TPGAPC1..4) are available in the IED. The remaining one not described in the functional diagram is available in PCM600 for connection where applicable.

3.12.3.4 Functional diagrams for power quality

The standard configuration offers a set of power quality functions. The total demand distortion of current can be supervised by CMHAI function, and correspondingly the total harmonics distortion of voltage can be supervised by VMHAI. The configuration also offers a short-duration voltage variation measurement function PHQVVR. This can be used for detecting voltage sags, swells and interruptions per-phase.

The power quality functions are not connected in the standard configuration by default. Depending on the application, the needed logic connections can be made by PCM600.

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for non-directional overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden. The protection settings of the IED should be defined in accordance with the CT performance as well as other factors.

4.1.1.1 Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (F_n) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection).

Table 63: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The 5P class provides a better accuracy. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering, and so on) of the IED.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it might have severe effects on the performance of the protection IED.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

Non-directional overcurrent protection does not set high requirements on the accuracy class or on the actual accuracy limit factor (F_a) of the CTs. It is, however, recommended to select a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the IED is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$,

I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the IED. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to operate, the start current should be set using the formula:

Current start value < 0.7 x (I_{kmin} / I_{1n})

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection IED inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The operate time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a.

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the start current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed IED operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive IEDs.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time the constant of the DC component of the fault current, when the current is only slightly higher than the starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the operate time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

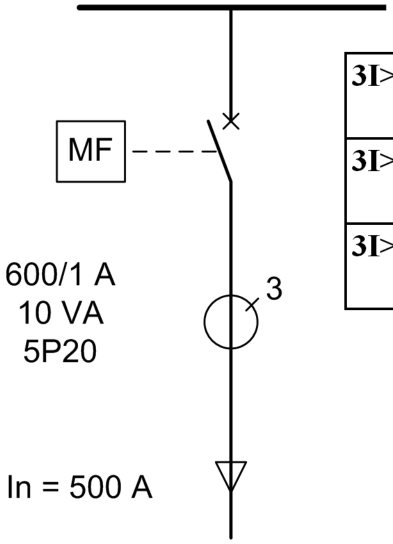
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

F_a > 20**Current start value* / I_{1n}

The *Current start value* is the primary pickup current setting of the IED.

4.1.1.3 Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three-stage definite time non-directional overcurrent protection.



3I>	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
3I>>	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
3I>>>	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 110: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next IED (not visible in the figure above). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the IED operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in the figure above.

For the application point of view, the suitable setting for instantaneous stage (I>>>) in this example is 3 500 A (5.83 x I_{2n}). For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the IED setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 IED physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

The IED can also be used in single or two-phase applications by leaving one or two energizing inputs unoccupied. However, at least terminals X120/7-8 must be connected.

Table 64: Phase current inputs included in configurations A, B, C, D, E, F, H and J

Terminal	Description
X120-7, 8	IL1
X120-9, 10	IL2
X120-11, 12	IL3

5.1.1.2 Residual current

Table 65: Residual current input included in configurations A, B, C, D, E, F, H and J

Terminal	Description
X120-13, 14	Io

Table 66: Residual current input included in configuration G

Terminal	Description
X130–1, 2	Io

5.1.1.3 Phase voltages

Table 67: Phase voltage input included in configurations E, F, H and J

Terminal	Description
X130-11, 12	U1
X130-13, 14	U2
X130-15, 16	U3

Table 68: Reference voltage input for SECRSYN1 included in configurations H and J

Terminal	Description
X130-9, 10	U12B

5.1.1.4 Residual voltage

Table 69: Additional residual voltage input included in configurations A and B

Terminal	Description
X120-5, 6	Uo

Table 70: Additional residual voltage input included in configurations E, F, H and J

Terminal	Description
X130-17, 18	Uo

5.1.1.5 Sensor inputs

Table 71: Combi sensor inputs included in configuration G

Terminal	Description
X131	IL1 U1
X132	IL2 U2
X133	IL3 U3

5.1.2 Auxiliary supply voltage input

The auxiliary voltage of the IED is connected to terminals X100/1-2. At DC supply, the positive lead is connected to terminal X100-1. The permitted auxiliary voltage range (AC/DC or DC) is marked on the top of the LHMI of the IED.

Table 72: Auxiliary voltage supply

Terminal	Description
X100-1	+ Input
X100-2	- Input

5.1.3 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.

Binary inputs of slot X110 are available with configurations B, D, E, F, G, H and J.

Table 73: Binary input terminals X110-1...13

Terminal	Description
X110-1 X110-2	BI1, + BI1, -
X110-3 X110-4	BI2, + BI2, -
X110-5 X110-6	BI3, + BI3, -
X110-6 X110-7	BI4, - BI4, +
X110-8 X110-9	BI5, + BI5, -
X110-9 X110-10	BI6, - BI6, +
X110-11 X110-12	BI7, + BI7, -
X110-12 X110-13	BI8, - BI8, +

Binary inputs of slot X120 are available with configurations C, D, E, F, H and J.

Table 74: Binary input terminals X120-1...6

Terminal	Description
X120-1 X120-2	BI1, + BI1, -
X120-3 X120-2	BI2, + BI2, -
X120-4 X120-2	BI3, + BI3, -
X120-5 X120-6	BI4, + BI4, -

Binary inputs of slot X120 are available with configurations A and B.

Table 75: Binary input terminals X120-1...4

Terminal	Description
X120-1 X120-2	BI1, + BI1, -
X120-3	BI2, +

Table continues on next page

Terminal	Description
X120-2	BI2, -
X120-4 X120-2	BI3, + BI3, -

Binary inputs of slot X130 are optional for configurations B and D.

Table 76: Binary input terminals X130-1...9

Terminal	Description
X130-1 X130-2	BI1, + BI1, -
X130-2 X130-3	BI2, - BI2, +
X130-4 X130-5	BI3, + BI3, -
X130-5 X130-6	BI4, - BI4, +
X130-7 X130-8	BI5, + BI5, -
X130-8 X130-9	BI6, - BI6, +

Binary inputs of slot X130 are available with configurations E, F, H and J.

Table 77: Binary input terminals X130-1...8

Terminal	Description
X130-1 X130-2	BI1, + BI1, -
X130-3 X130-4	BI2, + BI2, -
X130-5 X130-6	BI3, + BI3, -
X130-7 X130-8	BI4, + BI4, -

5.1.4 Optional light sensor inputs

If the IED is provided with the optional communication module with light sensor inputs, the pre-manufactured lens-sensor fibres are connected to inputs X13, X14 and X15, see the terminal diagrams.For further information, see arc protection.

The IED is provided with connection sockets X13, X14 and X15 only if the optional communication module with light sensor inputs has been installed. If the arc protection option is selected when ordering an IED, the light sensor inputs are included in the communication module.

Table 78: Light sensor input connectors

Terminal	Description
X13	Input Light sensor 1
X14	Input Light sensor 2
X15	Input Light sensor 3

5.2 Outputs

5.2.1 Outputs for tripping and controlling

Output contacts PO1, PO2, PO3 and PO4 are heavy-duty trip contacts capable of controlling most circuit breakers. On delivery from the factory, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 79: Output contacts

Terminal	Description
X100-6 X100-7	PO1, NO PO1, NO
X100-8 X100-9	PO2, NO PO2, NO
X100-15 X100-16 X100-17 X100-18 X100-19	PO3, NO (TCS resistor) PO3, NO PO3, NO PO3 (TCS1 input), NO PO3 (TCS1 input), NO
X100-20 X100-21 X100-22 X100-23 X100-24	PO4, NO (TCS resistor) PO4, NO PO4, NO PO4 (TCS2 input), NO PO4 (TCS2 input), NO

5.2.2 Outputs for signalling

Output contacts SO1 and SO2 in slot X100 or SO1, SO2, SO3 and SO4 in slot X110 or SO1, SO2 and SO3 in slot X130 (optional) can be used for signalling on start 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.

Table 80: Output contacts X100-10...14

Terminal	Description
X100-10	SO1, common
X100-11	SO1, NC
X100-12	SO1, NO
X100-13	SO2, NO
X100-14	SO2, NO

Output contacts of slot X110 are available with configurations B, D, E, F, G, H and J.

Table 81: Output contacts X110-14...24

Terminal	Description
X110-14	SO1, common
X110-15	SO1, NO
X110-16	SO1, NC
X110-17	SO2, common
X110-18	SO2, NO
X110-19	SO2, NC
X110-20	SO3, common
X110-21	SO3, NO
X110-22	SO3, NC
X110-23	SO4, common
X110-24	SO4, NO

Output contacts of slot X130 are available in the optional BIO module (BIOB02A).

Output contacts of slot X130 are optional for configurations B and D.

Table 82: Output contacts X130-10...18

Terminal	Description
X130-10	SO1, common
X130-11	SO1, NO
X130-12	SO1, NC
X130-13	SO2, common
X130-14	SO2, NO
X130-15	SO2, NC
X130-16	SO3, common
X130-17	SO3, NO
X130-18	SO3, NC

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection IED. Under normal operating conditions, the IED is energized and the contact is closed (X100/3-5). When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the output contact drops off and the contact closes (X100/3-4).

Table 83: IRF contact

Terminal	Description
X100-3	IRF, common
X100-4	Closed; IRF, or U_{aux} disconnected
X100-5	Closed; no IRF, and U_{aux} connected

Section 6 Glossary

615 series	Series of numerical IEDs for low-end protection and supervision applications of utility substations, and industrial switchgear and equipment
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
BI/O	Binary input/output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HW	Hardware
I/O	Input/output
IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IED	Intelligent electronic device
IET600	Integrated Engineering Toolbox in PCM600

IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fibre cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
PCM600	Protection and Control IED Manager
PO	Power output
RCA	Also known as MTA or base angle. Characteristic angle.
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RS-232	Serial interface standard
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
RTU	Remote terminal unit
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SO	Signal output
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
WAN	Wide area network
WHMI	Web human-machine interface

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