RELION® 615 SERIES

Capacitor Bank Protection and Control
REV615
Application Manual

Document ID: 1MRS757946
Issued: 2018-12-20
Revision: D
Product version: 5.0 FP1

Warranty

Please inquire about the terms of warranty from your nearest ABB representative.

www.abb.com/relion

Disclaimer

The data, examples and diagrams in this manual are included solely for the concept or product description and are not to be deemed as a statement of guaranteed properties. All persons responsible for applying the equipment addressed in this manual must satisfy themselves that each intended application is suitable and acceptable, including that any applicable safety or other operational requirements are complied with. In particular, any risks in applications where a system failure and/or product failure would create a risk for harm to property or persons (including but not limited to personal injuries or death) shall be the sole responsibility of the person or entity applying the equipment, and those so responsible are hereby requested to ensure that all measures are taken to exclude or mitigate such risks.

This product has been designed to be connected and communicate data and information via a network interface which should be connected to a secure network. It is the sole responsibility of the person or entity responsible for network administration to ensure a secure connection to the network and to take the necessary measures (such as, but not limited to, installation of firewalls, application of authentication measures, encryption of data, installation of anti virus programs, etc.) to protect the product and the network, its system and interface included, against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB is not liable for any such damages and/or losses.

This document has been carefully checked by ABB but deviations cannot be completely ruled out. In case any errors are detected, the reader is kindly requested to notify the manufacturer. Other than under explicit contractual commitments, in no event shall ABB be responsible or liable for any loss or damage resulting from the use of this manual or the application of the equipment.

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 standard 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

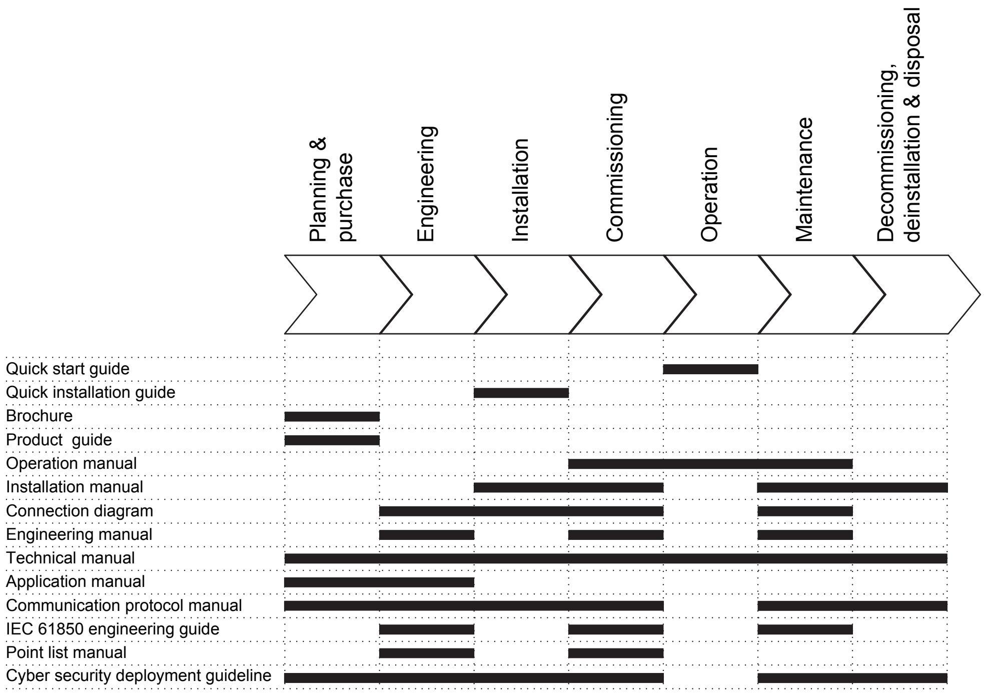


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2014-01-24	5.0	First release
B/2015-10-30	5.0 FP1	Content updated to correspond to the product version
C/2016-05-20	5.0 FP1	Content updated
D/2018-12-20	5.0 FP1	Content updated

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

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
Cyber Security Deployment Guideline	1MRS758280

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

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

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

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)
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>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
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)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T/G/C (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
	TRPPTRC3	Master Trip (3)	94/86 (3)
	TRPPTRC4	Master Trip (4)	94/86 (4)
	TRPPTRC5	Master Trip (5)	94/86 (5)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Multipurpose protection	MAPGAPC1	MAP (1)	MAP (1)
	MAPGAPC2	MAP (2)	MAP (2)
	MAPGAPC3	MAP (3)	MAP (3)
	MAPGAPC4	MAP (4)	MAP (4)
	MAPGAPC5	MAP (5)	MAP (5)
	MAPGAPC6	MAP (6)	MAP (6)
	MAPGAPC7	MAP (7)	MAP (7)
	MAPGAPC8	MAP (8)	MAP (8)
	MAPGAPC9	MAP (9)	MAP (9)
	MAPGAPC10	MAP (10)	MAP (10)
	MAPGAPC11	MAP (11)	MAP (11)
	MAPGAPC12	MAP (12)	MAP (12)
	MAPGAPC13	MAP (13)	MAP (13)
	MAPGAPC14	MAP (14)	MAP (14)
	MAPGAPC15	MAP (15)	MAP (15)
	MAPGAPC16	MAP (16)	MAP (16)
	MAPGAPC17	MAP (17)	MAP (17)
	MAPGAPC18	MAP (18)	MAP (18)
Three-phase overload protection for shunt capacitor banks	COLPTOC1	3I> 3I< (1)	51C/37 (1)
Current unbalance protection for shunt capacitor banks	CUBPTOC1	dI>C (1)	51NC-1 (1)
Three-phase current unbalance protection for shunt capacitor banks	HCUBPTOC1	3dI>C (1)	51NC-2 (1)
Shunt capacitor bank switching resonance protection, current based	SRCPTOC1	TD> (1)	55TD (1)
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)
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)
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 (1)	I <-> O ESC (1)
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)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60 (1)
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM (1)
Measurement			
Disturbance recorder	RDRE1	DR (1)	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
	RESVMMXU2	Uo (2)	Vn (2)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (1)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f (1)
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV	SMVRCV
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Time delay on (8 pcs)	TONGAPC1	TON (1)	TON (1)
	TONGAPC2	TON (2)	TON (2)
	TONGAPC3	TON (3)	TON (3)
	TONGAPC4	TON (4)	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)	SR (1)
	SRGAPC2	SR (2)	SR (2)
	SRGAPC3	SR (3)	SR (3)
	SRGAPC4	SR (4)	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)	MV (1)
	MVGAPC2	MV (2)	MV (2)
Generic control point (16 pcs)	SPCGAPC1	SPC (1)	SPC (1)
	SPCGAPC2	SPC (2)	SPC (2)
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4 (1)
	SCA4GAPC2	SCA4 (2)	SCA4 (2)
	SCA4GAPC3	SCA4 (3)	SCA4 (3)
	SCA4GAPC4	SCA4 (4)	SCA4 (4)
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4 (1)

Section 2 REV615 overview

2.1 Overview

REV615 is a dedicated capacitor bank relay designed for the protection, control, measurement and supervision of capacitor banks used for compensation of reactive power in utility substations and industrial power systems. REV615 can also be used for protection of harmonic filter circuits, if the highest significant harmonic component is the 11th. REV615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series relays 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 relay provides main protection for single star, double star, and H-bridge connected capacitor banks and harmonic filters in distribution networks.

Depending on the chosen standard configuration, the relay is adapted for the protection of H-bridge connected or double star connected shunt capacitor banks. Once the standard configuration relay has been given the application-specific settings, it can directly be put into service.

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302.

2.1.1 Product version history

Product version	Product history
5.0	Product released
5.0 FP1	• IEC 61850 Edition 2 • Currents sending support with IEC 61850-9-2 LE • Support for configuration migration (starting from Ver.3.0 to Ver.5.0 FP1) • Software closable Ethernet ports • Chinese language support • Report summary via WHMI • Voltage unbalance power quality option • Residual current input 0.2/1 A option • Transient/intermittent E/F • Additional timer, set-reset and analog value scaling functions

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- REV615 Connectivity Package Ver.5.1 or later
    - Parameter Setting
    - Signal Monitoring
    - Event Viewer
    - Disturbance Handling
    - Application Configuration
    - Signal Matrix
    - Graphical Display Editor
    - Communication Management
    - IED User Management
    - IED Compare
    - Firmware Update
    - Fault Record tool
    - Load Record Profile
    - Lifecycle Traceability
    - Configuration Wizard
    - AR Sequence Visualizer
    - Label Printing
    - IEC 61850 Configuration
    - IED Configuration Migration

Download connectivity packages from the ABB Web site http://www.abb.com/substationautomation or directly with Update Manager in PCM600.

2.2 Operation functionality

2.2.1 Optional functions

- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- Power quality functions
- IEC 61850-9-2 LE
- IEEE 1588 v2 time synchronization

2.3 Physical hardware

The protection relay 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	Slot ID	Content options	
Plug-in unit	-	HMI	Small (5 lines, 20 characters) Large (10 lines, 20 characters) with SLD
			Small Chinese (3 lines, 8 or more characters) Large Chinese (7 lines, 8 or more characters) with SLD
	X100	Auxiliary power/BO module	48-250V DC/100-240 V AC; or 24-60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BIO module	8 binary inputs 4 SO contacts
			8 binary inputs 3 HSO contacts
	X120	AI module	6 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A) [1)]
Case	X130	AI/BI module	Only with configuration B: 3 phase voltage inputs (60-210 V) 1 residual voltage input (60-210 V) 1 reference voltage input for ROV2 and ROV3 (60-210 V) 4 binary inputs
		AI/RTD/mA module	Only with configuration B: 3 phase voltage inputs (60-210 V) 1 residual voltage input (60-210 V) 1 reference voltage input for ROV2 and ROV3 (60-210 V) 1 generic mA input 2 RTD sensor inputs
		Optional BIOmodule	Optional for configuration A: 6 binary inputs 3 SO contacts
		Optional RTD/mA module	Optional for configuration A: 2 generic mA inputs 6 RTD sensor inputs
	X000	Optional communication module	See the technical manual for details about different types 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 protection relay. The binary input thresholds are selectable within the range 16…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: Input/output overview

Std. conf.	Order code digit		Analog channels		Binary channels			
	5-6	7-8	CT	VT	BI	BO	RTD	mA
A	BA	BA	7	-	8	4 PO + 6 SO	-	-
		BB	7	-	14	4 PO + 9 SO	-	-
		FD	7	-	8	4 PO + 2 SO + 3 HSO	-	-
		FF	7	-	14	4 PO + 5 SO + 3 HSO	-	-
	BG	BA	7	-	8	4 PO + 6 SO	6	2
		FD	7	-	8	4 PO + 2 SO + 3 HSO	6	2
B	BC	AD	7	5	12	4 PO + 6 SO	-	-
		FE	7	5	12	4 PO + 2 SO + 3 HSO	-	-
	BE	BA	7	5	8	4 PO + 6 SO	2	1
		FD	7	5	8	4 PO + 2 SO + 3 HSO	2	1

2.4 Local HMI

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

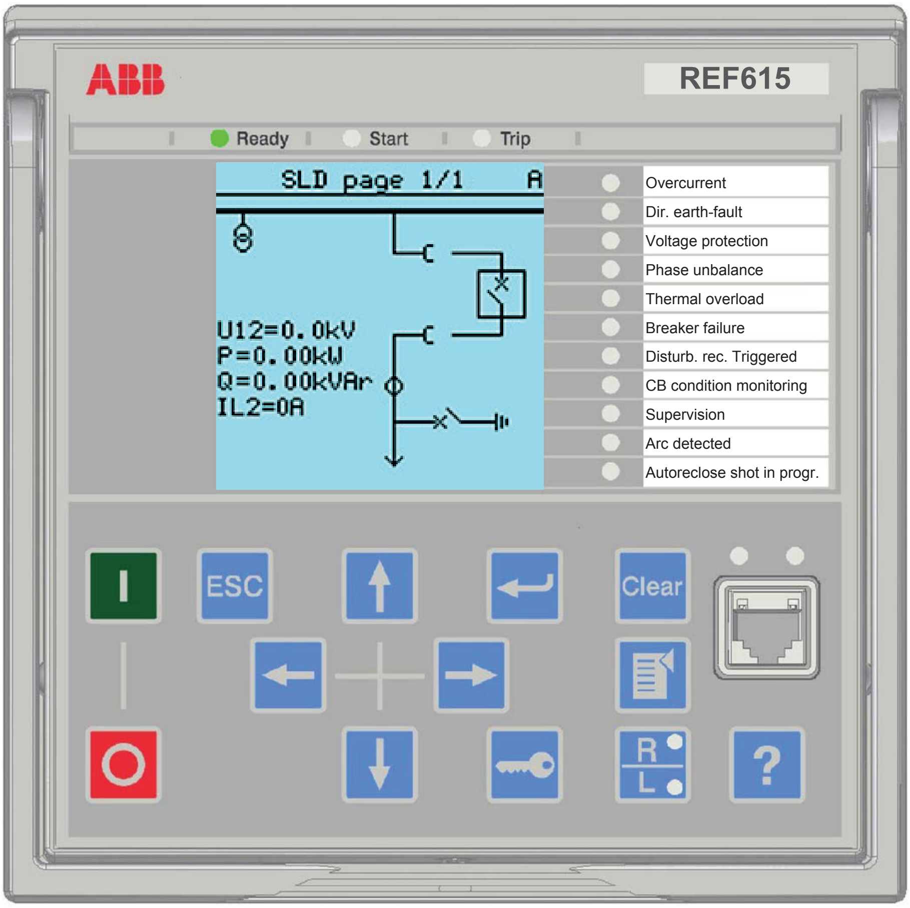


Figure 2: Example of the LHMI

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: Small display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

1) Depending on the selected language

Table 5: Large display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20
Large, variable width (13 × 14 pixels)	7	8 or more

1) Depending on the selected language

The display view is divided into four basic areas.

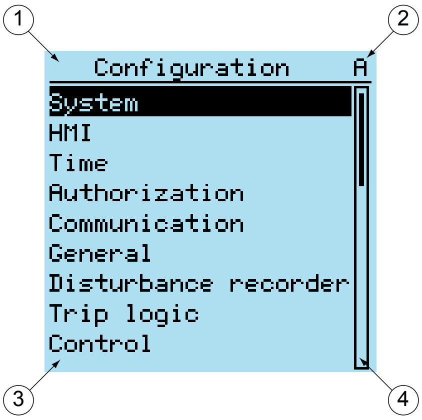


Figure 3: Display layout

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 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.

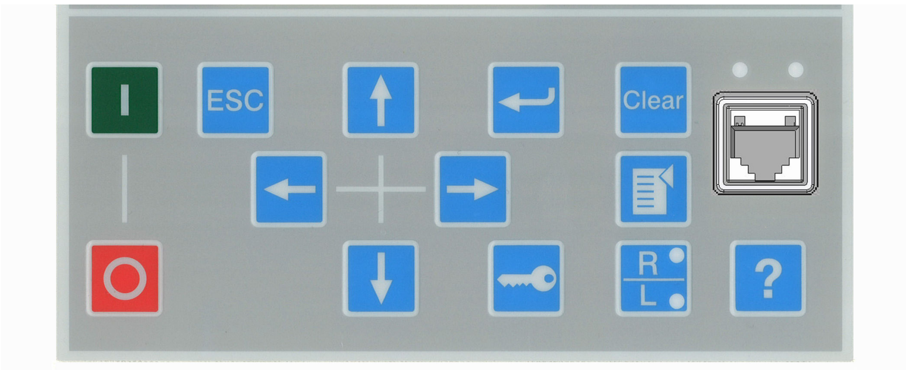


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. When the *Secure Communication* parameter in the protection relay is activated, the Web server is forced to take a secured (HTTPS) connection to WHMI using TLS encryption.The WHMI is verified with Internet Explorer 8.0, 9.0, 10.0 and 11.0.

WHMI is disabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Fault records
- Load profile record
- Phasor diagram
- Single-line diagram
- Importing/Exporting parameters
- Report summary

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

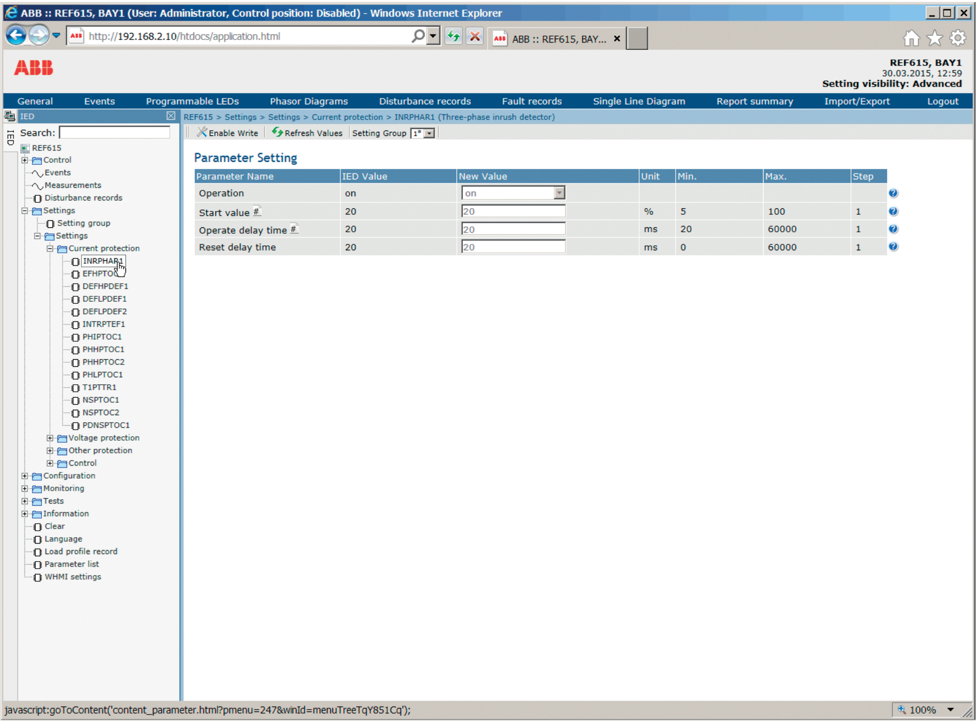


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

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

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

Table 6: 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 protection relay 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

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

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

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

Audit trail events related to user authorization (login, logout, violation remote and violation local) are defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined user names or user categories. The user audit trail events are accessible with IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 7: Audit trail events

Audit trail event	Description
Configuration change	Configuration files changed
Firmware change	Firmware changed
Firmware change fail	Firmware change failed
Attached to retrofit test case	Unit has been attached to retrofit case
Removed from retrofit test case	Removed from retrofit test case
Setting group remote	User changed setting group remotely
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
Reset trips	Reset latched trips (TRPPTRC*)
Setting commit	Settings have been changed
Time change	Time changed directly by the user. Note that this is not used when the protection relay is synchronised properly by the appropriate protocol (SNTP, IRIG-B, IEEE 1588 v2).
View audit log	Administrator accessed audit trail
Login	Successful login from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Logout	Successful logout from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Password change	Password changed
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period
Violation remote	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Violation local	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.

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

To expose the audit trail events through Event list, define the *Authority logging* level parameter via **Configuration/ Authorization/Security**. This exposes audit trail events to all users.

Table 8: Comparison of authority logging levels

Audit trail event	Authority logging level					
	None	Configuration change	Setting group	Setting group, control	Settings edit	All
Configuration change		•	•	•	•	•
Firmware change		•	•	•	•	•
Firmware change fail		•	•	•	•	•
Attached to retrofit test case		•	•	•	•	•
Removed from retrofit test case		•	•	•	•	•
Setting group remote			•	•	•	•
Setting group local			•	•	•	•
Control remote				•	•	•
Control local				•	•	•
Test on				•	•	•
Test off				•	•	•
Reset trips				•	•	•
Setting commit					•	•
Time change						•
View audit log						•
Login						•
Logout						•
Password change						•
Firmware reset						•
Violation local						•
Violation remote						•

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850, IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices (so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Furthermore, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard.

The protection relay can support 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.

2.7.1 Self-healing Ethernet ring

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

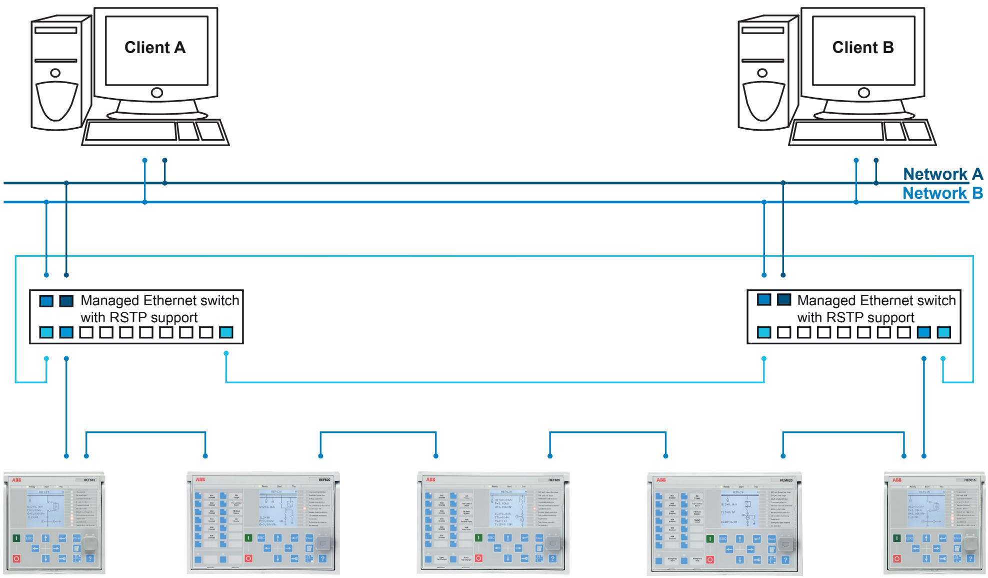


Figure 6: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to 30 protection relays. If more than 30 protection relays are to be connected, it is recommended that the network is split into several rings with no more than 30 protection relays per ring. Each protection relay has a 50-μs store-and-forward delay, and to fulfil the performance requirements for fast horizontal communication, the ring size is limited to 30 protection relays.

2.7.2 Ethernet redundancy

IEC 61850 specifies a network redundancy scheme that improves the system availability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3:2012 standard: parallel redundancy protocol PRP and high-availability seamless redundancy HSR protocol. Both protocols rely on the duplication of all transmitted information via two Ethernet ports for one logical network connection. Therefore, both are able to overcome the failure of a link or switch with a zero-switchover time, thus fulfilling the stringent real-time requirements for the substation automation horizontal communication and time synchronization.

PRP specifies that each device is connected in parallel to two local area networks. HSR applies the PRP principle to rings and to the rings of rings to achieve cost-effective redundancy. Thus, each device incorporates a switch element that forwards frames from port to port. The HSR/PRP option is available for all 615 series protection relays. However, RED615 supports this option only over fiber optics.

IEC 62439-3:2012 cancels and replaces the first edition published in 2010. These standard versions are also referred to as IEC 62439-3 Edition 1 and IEC 62439-3 Edition 2. The protection relay supports IEC 62439-3:2012 and it is not compatible with IEC 62439-3:2010.

PRP

Each PRP node, called a double attached node with PRP (DAN), is attached to two independent LANs operated in parallel. These parallel networks in PRP are called LAN A and LAN B. The networks are completely separated to ensure failure independence, and they can have different topologies. Both networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid communication failures. Non-PRP nodes, called single attached nodes (SANs), are either attached to one network only (and can therefore communicate only with DANs and SANs attached to the same network), or are attached through a redundancy box, a device that behaves like a DAN.

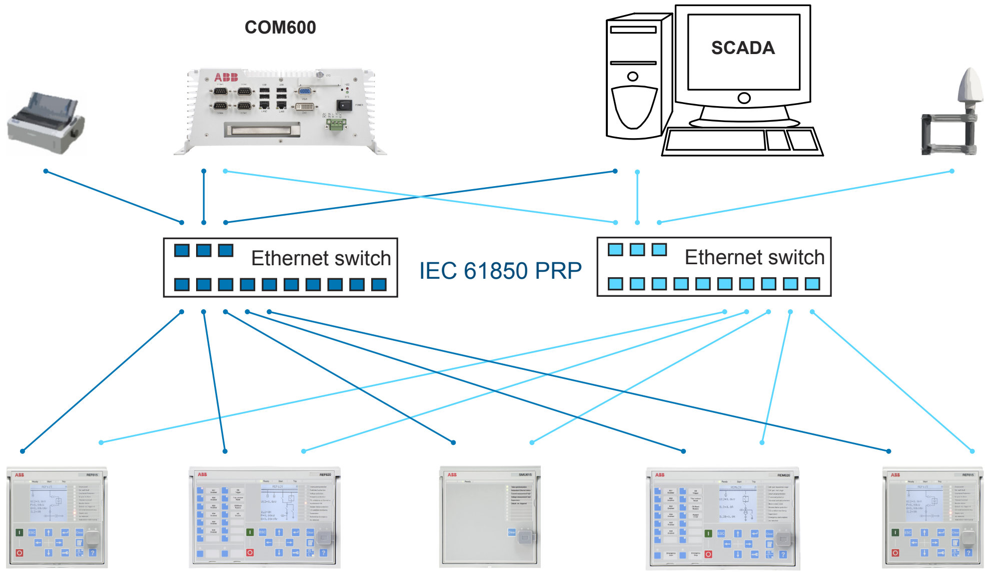


Figure 7: PRP solution

In case a laptop or a PC workstation is connected as a non-PRP node to one of the PRP networks, LAN A or LAN B, it is recommended to use a redundancy box device or an Ethernet switch with similar functionality between the PRP network and SAN to remove additional PRP information from the Ethernet frames. In some cases, default PC workstation adapters are not able to handle the maximum-length Ethernet frames with the PRP trailer.

There are different alternative ways to connect a laptop or a workstation as SAN to a PRP network.

- Via an external redundancy box (RedBox) or a switch capable of connecting to PRP and normal networks
- By connecting the node directly to LAN A or LAN B as SAN
- By connecting the node to the protection relay's interlink port

HSR

HSR applies the PRP principle of parallel operation to a single ring, treating the two directions as two virtual LANs. For each frame sent, a node, DAN, sends two frames, one over each port. Both frames circulate in opposite directions over the ring and each node forwards the frames it receives, from one port to the other. When the originating node receives a frame sent to itself, it discards that to avoid loops; therefore, no ring protocol is needed. Individually attached nodes, SANs, such as laptops and printers, must be attached through a “redundancy box” that acts as a ring element. For example, a 615 or 620 series protection relay with HSR support can be used as a redundancy box.

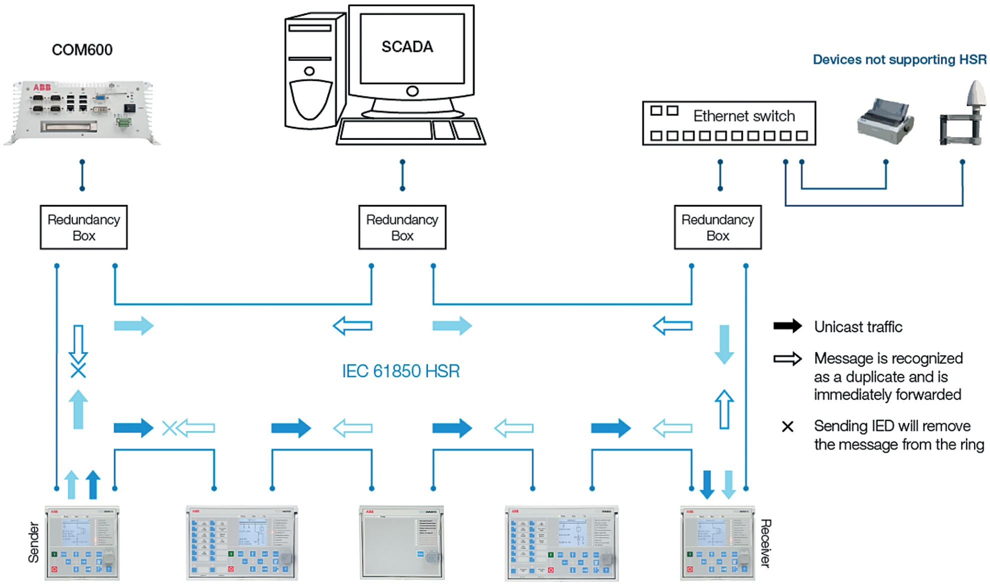


Figure 8: HSR solution

2.7.3 Process bus

Process bus IEC 61850-9-2 defines the transmission of Sampled Measured Values within the substation automation system. International Users Group created a guideline IEC 61850-9-2 LE that defines an application profile of IEC 61850-9-2 to facilitate implementation and enable interoperability. Process bus is used for distributing process data from the primary circuit to all process bus compatible devices in the local network in a real-time manner. The data can then be processed by any protection relay to perform different protection, automation and control functions.

UniGear Digital switchgear concept relies on the process bus together with current and voltage sensors. The process bus enables several advantages for the UniGear Digital like simplicity with reduced wiring, flexibility with data availability to all devices, improved diagnostics and longer maintenance cycles.

With process bus the galvanic interpanel wiring for sharing busbar voltage value can be replaced with Ethernet communication. Transmitting measurement samples over process bus brings also higher error detection because the signal transmission is automatically supervised. Additional contribution to the higher availability is the possibility to use redundant Ethernet network for transmitting SMV signals.

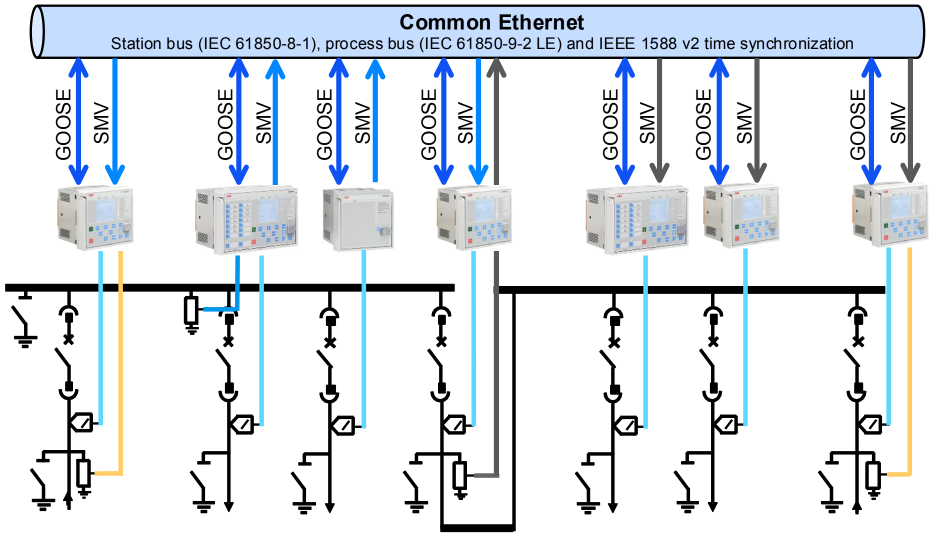


Figure 9: Process bus application of voltage sharing and synchrocheck

The 615 series supports IEC 61850 process bus with sampled values of analog currents and voltages. The measured values are transferred as sampled values using the IEC 61850-9-2 LE protocol which uses the same physical Ethernet network as the IEC 61850-8-1 station bus. The intended application for sampled values is sharing the measured voltages from one 615 series protection relay to other devices with phase voltage based functions and 9-2 support.

The 615 series protection relays with process bus based applications use IEEE 1588 v2 Precision Time Protocol (PTP) according to IEEE C37.238-2011 Power Profile for high accuracy time synchronization. With IEEE 1588 v2, the cabling infrastructure requirement is reduced by allowing time synchronization information to be transported over the same Ethernet network as the data communications.

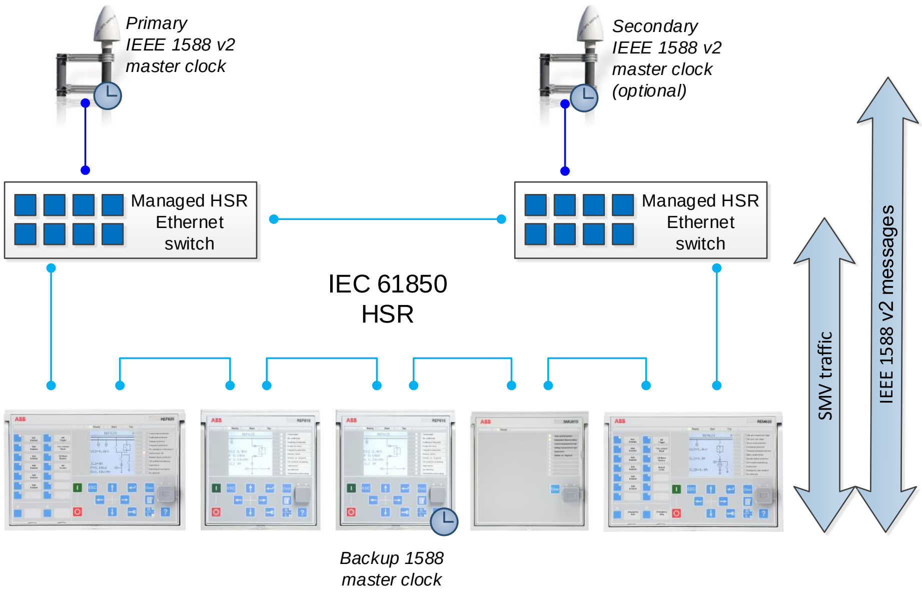


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

The process bus option is available for all 615 series protection relays equipped with phase voltage inputs. Another requirement is a communication card with IEEE 1588 v2 support (COM0031...COM0037). However, RED615 supports this option only with the communication card variant having fiber optic station bus ports. See the IEC 61850 engineering guide for detailed system requirements and configuration details.

2.7.4 Secure communication

The protection relay supports secure communication for WHMI and file transfer protocol. If the *Secure Communication* parameter is activated, protocols require TLS based encryption method support from the clients. In this case WHMI must be connected from a Web browser using the HTTPS protocol and in case of file transfer the client must use FTPS.

Section 3 REV615 standard configurations

3.1 Standard configurations

REV615 is available in two alternative standard configurations. The standard signal configuration can be altered by means of the 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 relay configuration can be adapted to user-specific application requirements.

The relay 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. Some of the supported functions in REV615 must be added with the Application Configuration tool to be available in the Signal Matrix tool and in the relay. The positive measuring direction of directional protection functions is towards the outgoing feeder.

Table 9: Standard configurations

Description	Std. conf.
Capacitor bank overload and unbalance protection, non-directional overcurrent and earth-fault protection and circuit-breaker condition monitoring	A
Capacitor bank overload and unbalance protection, non-directional overcurrent and directional earth-fault protection, voltage and frequency based protection and measurements, and circuit-breaker condition monitoring	B

Table 10: Supported functions

Function	IEC 61850	A	B
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1
Non-directional earth-fault protection, low stage	EFLPTOC	2	
Non-directional earth-fault protection, high stage	EFHPTOC	1	1
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	1	
Directional earth-fault protection, low stage	DEFLPDEF		2
Directional earth-fault protection, high stage	DEFHPDEF		1
Transient/intermittent earth-fault protection	INTRPTEF		1 [1)]
Negative-sequence overcurrent protection	NSPTOC	2	2
Residual overvoltage protection	ROVPTOV		1 2 [2)]
Three-phase undervoltage protection	PHPTUV		2
Three-phase overvoltage protection	PHPTOV		2

Table continues on next page

Function	IEC 61850	A	B
Positive-sequence undervoltage protection	PSPTUV		1
Negative-sequence overvoltage protection	NSPTOV		1
Three-phase thermal overload protection, two time constants	T2PTTR	1	1
Circuit breaker failure protection	CCBRBRF	1	1
Master trip	TRPPTRC	2 (3) 3)	2 (3) 3)
Arc protection	ARCSARC	(3)	(3)
Multipurpose protection	MAPGAPC	18	18
Three-phase overload protection for shunt capacitor banks	COLPTOC	1	1
Current unbalance protection for shunt capacitor banks	CUBPTOC	1 4)	1 4)
Three-phase current unbalance protection for shunt capacitor banks	HCUBPTOC	1 4)	1 4)
Shunt capacitor bank switching resonance protection, current based	SRCPTOC	1	1
Power quality			
Current total demand distortion	CMHAI	(1) 5)	(1) 6)
Voltage total harmonic distortion	VMHAI		(1) 6)
Voltage variation	PHQVVR		(1) 6)
Voltage unbalance	VSQVUB		(1) 6)
Control			
Circuit-breaker control	CBXCBR	1	1
Disconnector control	DCXSWI	2	2
Earthing switch control	ESXSWI	1	1
Disconnector position indication	DCSXSWI	3	3
Earthing switch indication	ESSXSWI	2	2
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR	1	1
Trip circuit supervision	TCSSCBR	2	2
Current circuit supervision	CCSPVC	1	1
Fuse failure supervision	SEQSPVC		1
Runtime counter for machines and devices	MDSOPT	1	1
Measurement			
Disturbance recorder	RDRE	1	1
Load profile record	LDPRLRC	1	1
Fault record	FLTRFRC	1	1
Three-phase current measurement	CMMXU	1	1
Sequence current measurement	CSMSQI	1	1
Residual current measurement	RESCMMXU	1	1
Three-phase voltage measurement	VMMXU		1
Residual voltage measurement	RESVMMXU		2
Sequence voltage measurement	VSMSQI		1
Three-phase power and energy measurement	PEMMXU		1
RTD/mA measurement	XRGGIO130	(1)	(1)
Frequency measurement	FMMXU		1
IEC 61850-9-2 LE sampled value sending 7)8)	SMVSENDER		(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) 7)8)	SMVRCV		(1)
Other			
Minimum pulse timer (2 pcs)	TPGAPC	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1
Pulse timer (8 pcs)	PTGAPC	2	2
Time delay off (8 pcs)	TOFGAPC	4	4
Time delay on (8 pcs)	TONGAPC	4	4
Set-reset (8 pcs)	SRGAPC	4	4

Table continues on next page

Function	IEC 61850	A	B
Move (8 pcs)	MVGAPC	2	2
Generic control point (16 pcs)	SPCGAPC	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = optional			

1) "Io measured" is always used.
2) "Uob measured" is always used.
3) Master trip is included and connected to the corresponding HSO in the configuration only when the BIO0007 module is used. If additionally the ARC option is selected, ARCSARC is connected to the corresponding master trip input in the configuration.
4) The Iunb measurement values are taken from this block and put in the Measurent view.
5) Power quality option includes only current total demand distortion.
6) Power quality option includes current total demand distortion, voltage total harmonic distortion, voltage variation and voltage unbalance.
7) Available only with IEC 61850-9-2
8) Available only with COM0031-0037

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 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 protection relay.

The external I/O module’s binary inputs and outputs 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 protection relay’s standard configuration.

The suitability of the protection relay’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

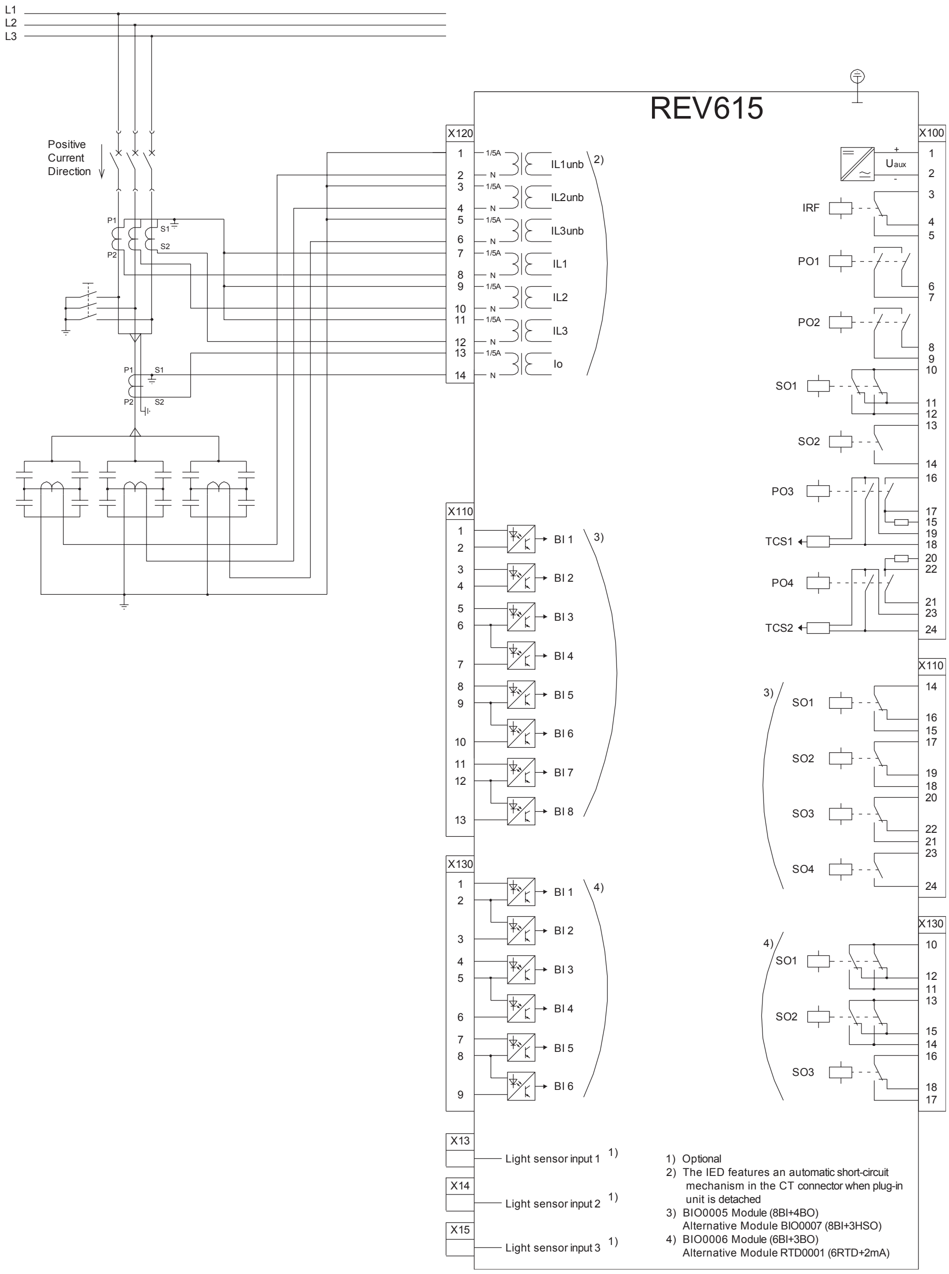


Figure 11: Connection diagram for the A configuration

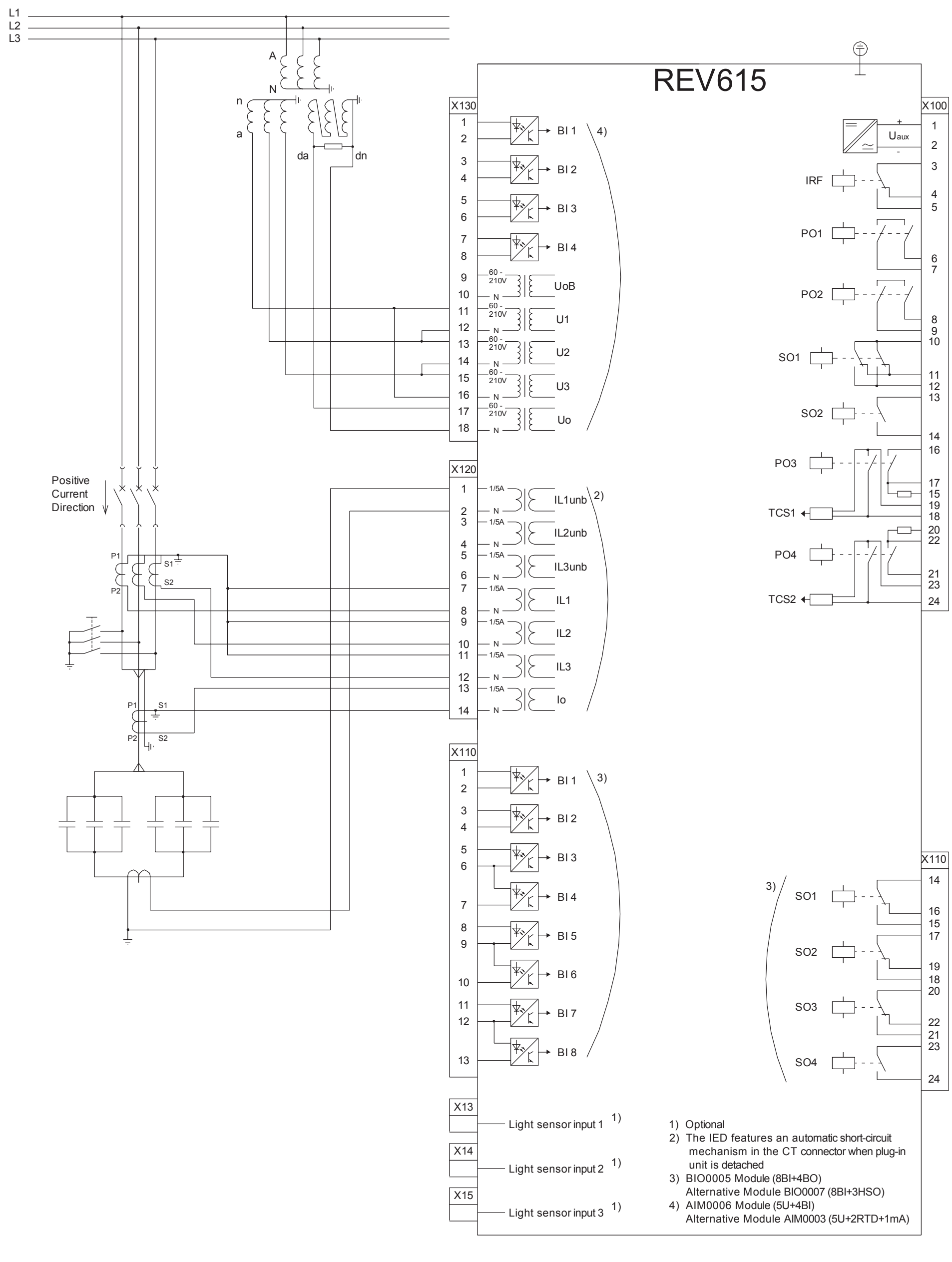


Figure 12: Connection diagram for the B configuration

3.3 Standard configuration A

3.3.1 Applications

The standard configuration offers three-phase overload protection, unbalance protection with compensation for natural unbalance and switching resonance protection for capacitor banks. An integrated undercurrent function in the overload protection function block detects the disconnection of a capacitor bank and inhibits the closing of the circuit breaker as long as the capacitor bank is still partially discharged. A three-phase thermal overload protection is available and can be used for the thermal protection of the reactors and resistors in the harmonic filter circuits.

The standard configuration is pre-configured for H-bridge connected capacitor banks. A three-phase current unbalance protection is used for unbalance protection.

The protection relay 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 protection relay enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.3.2 Functions

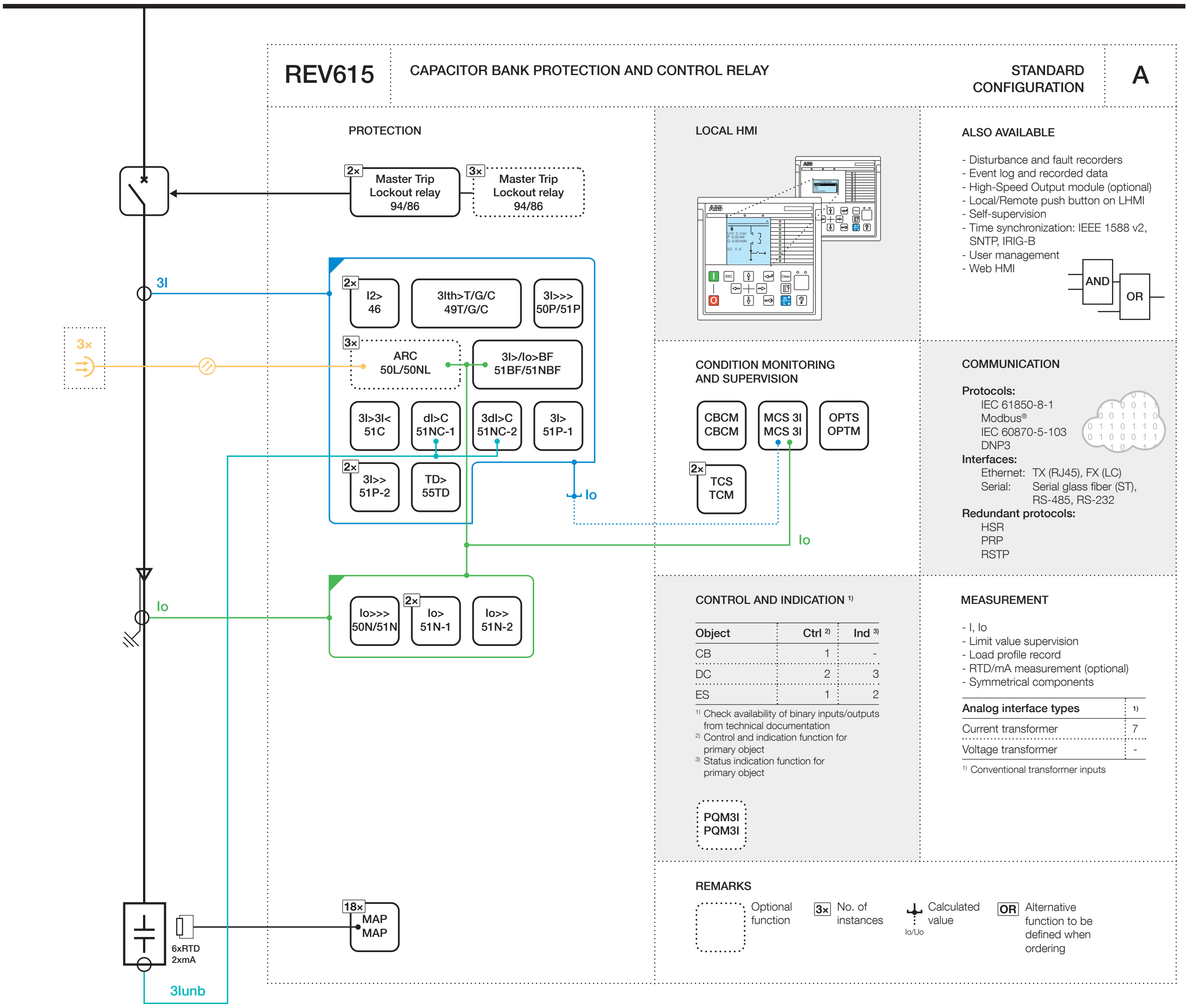


Figure 13: Functionality overview for standard configuration A

3.3.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 11: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker low gas pressure indication
X110-BI2	Circuit breaker spring charged indication
X110-BI3	Circuit breaker open indication
X110-BI4	Circuit breaker closed indication
X110-BI5	Circuit breaker truck out (test position) indication
X110-BI6	Circuit breaker truck in (service position) indication
X110-BI7	Earth switch open indication
X110-BI8	Earth switch closed indication

Table 12: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Capacitor bank reconnection enable
X110-SO1	Overcurrent operate alarm
X110-SO2	Earth-fault operate alarm
X110-SO3	Capacitor unbalance operate alarm
X110-SO4	Other capacitor operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 13: Default connections for LEDs

LED	Description
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Capacitor or thermal overload protection operated
4	Capacitor overload alarm
5	Capacitor unbalance or negative phase sequence protection operator
6	-
7	Undercurrent or resonance protection operated
8	Circuit breaker failure protection operated
9	Disturbance recorder triggered
10	Supervision alarms
11	Arc-fault detected

3.3.2.2 Default disturbance recorder settings

Table 14: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	IL1unb
5	IL2unb
6	IL3unb
7	Io
8	-
9	-
10	-
11	-
12	-

Table 15: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHLPTOC1 - start	Positive or Rising
5	EFHPTOC1 - start	Positive or Rising
6	EFIPTOC1 - start	Positive or Rising
7	EFLPTOC1 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	T2PTTR1 - start	Positive or Rising
12	COLPTOC1 - start ovload	Positive or Rising
13	COLPTOC1 - start un I	Positive or Rising
14	HCUBPTOC1 - start	Positive or Rising
15	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	

Table continues on next page

Channel	ID text	Level trigger mode
16	EFLPTOC1 - operate	Level trigger off
	EFLPTOC2 - operate	
	EFHPTOC1 - operate	
	EFIPTOC1 - operate	
17	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
18	T2PTTR1 - operate	Level trigger off
19	COLPTOC1 - operate ovload	Level trigger off
20	COLPTOC1 - operate un I	Level trigger off
21	HCUBPTOC1 - operate	Level trigger off
22	T2PTTR1 - alarm	Level trigger off
23	SRCPTOC1 - alarm	Positive or Rising
24	COLPTOC1 - alarm	Level trigger off
25	SRCPTOC1 - operate	Level trigger off
26	CCBRBRF1 - trret	Level trigger off
27	CCBRBRF1 - trbu	Level trigger off
28	CCSPVC1 - fail	Level trigger off
29	X110BI4 - CB closed	Level trigger off
30	X110BI3 - CB opened	Level trigger off
31	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
32	ARCSARC1 - operate	Positive or Rising
33	ARCSARC2 - operate	Positive or Rising
34	ARCSARC3 - operate	Positive or Rising

3.3.3 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.

The analog channels have fixed connections to the different function blocks inside the protection relay’s standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder’s parameter settings.

The capacitor phase currents as well as capacitor unbalance current to the protection relay are fed from a current transformer. The residual current to the protection relay is fed either from residually connected current transformers, an external core balance CT, neutral CT or internally calculated.

The protection relay offers six different setting groups which can be set based on the individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.3.3.1 Functional diagrams for protection

The functional diagrams describe the IEDs protection functionality in detail and according to the factory set default connections.

Four non-directional overcurrent stages are offered for capacitor overcurrent and short-circuit protection.

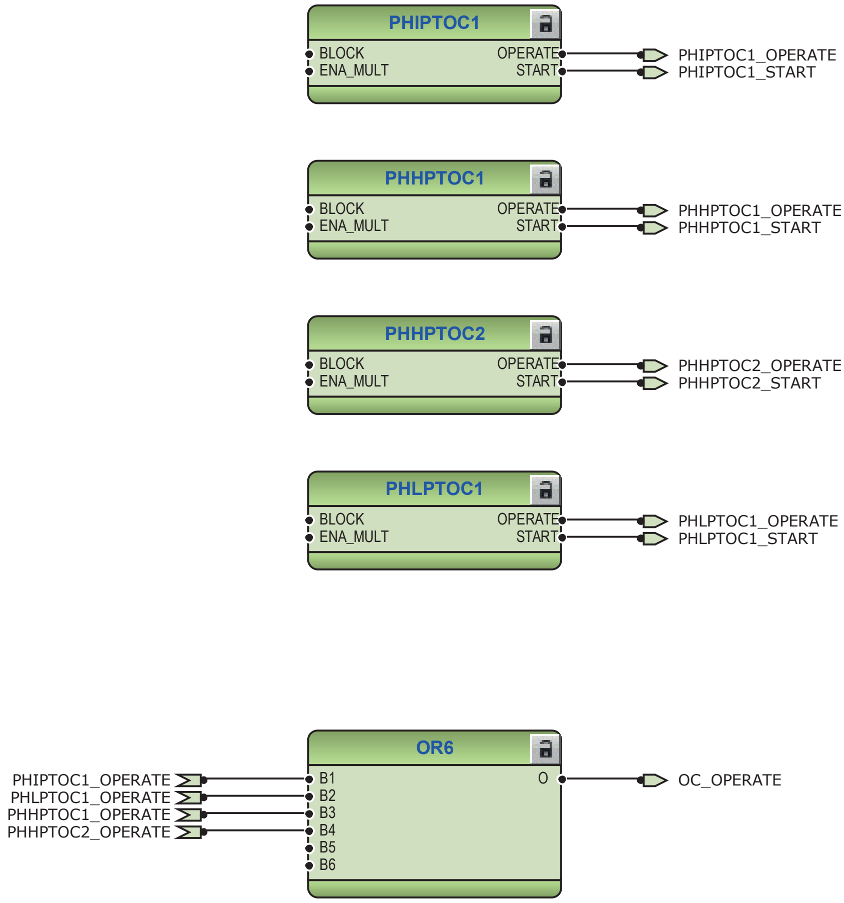


Figure 14: Overcurrent protection functions

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the capacitor against unbalance conditions. The negative-sequence overcurrent protection functions are blocked in case of detection of a failure in secondary circuit of the current transformer.

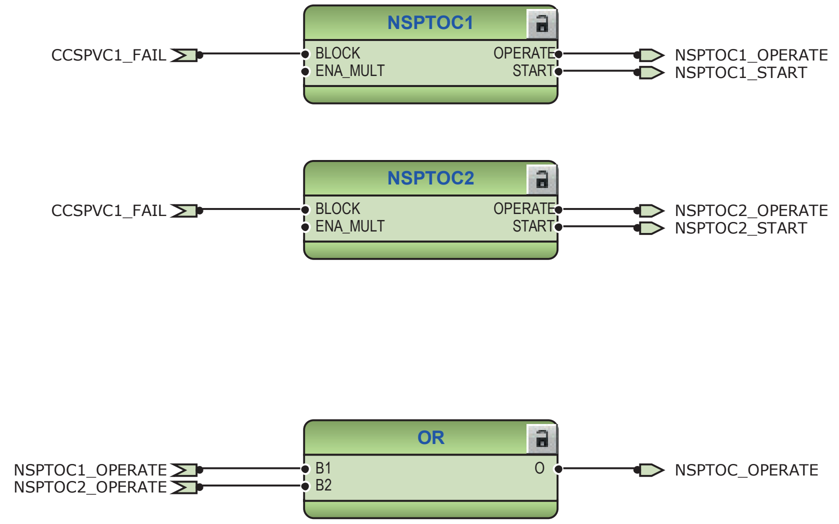


Figure 15: Negative-sequence overcurrent protection function

Four stages are provided for non-directional earth-fault protection.

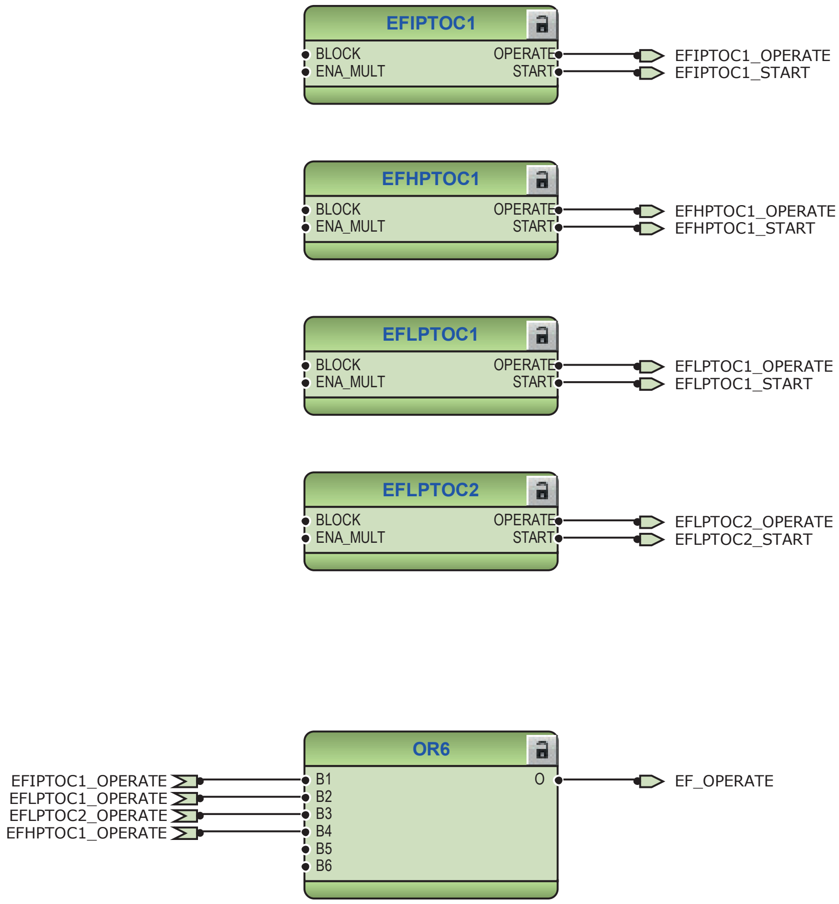


Figure 16: Earth-fault protection functions

The three-phase thermal overload protection T2PTTR1 with two time constants detects overload under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

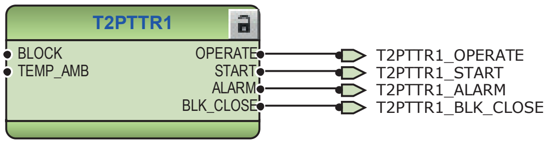


Figure 17: Thermal overcurrent protection function

The circuit breaker failure protection CCBRBRF1 is initiated via the START input by a number of different protection functions available in the IED. The circuit breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

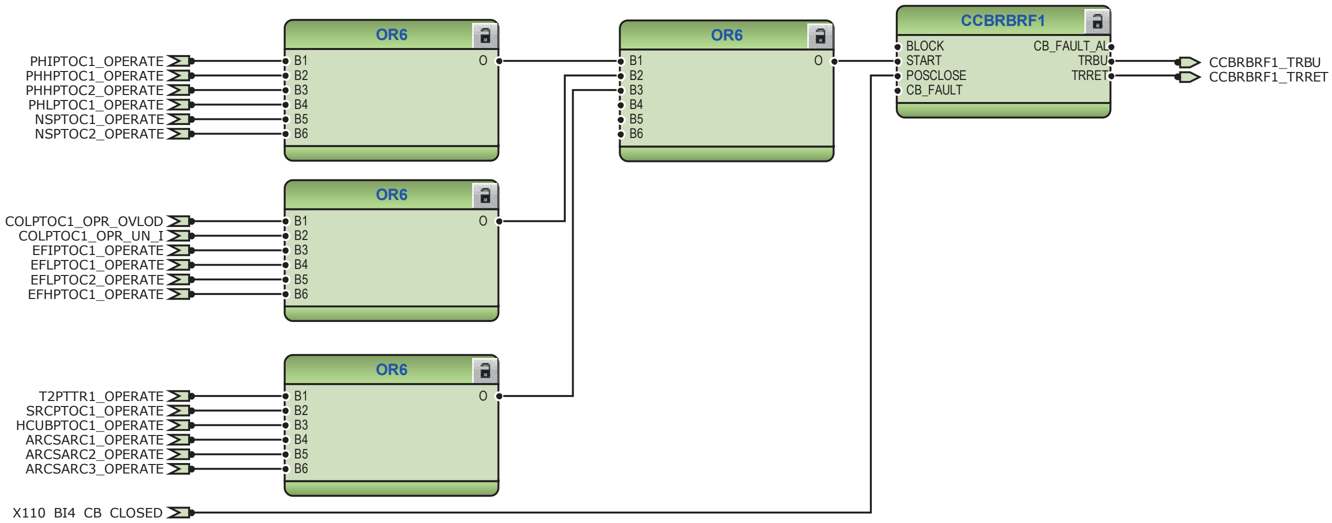


Figure 18: Circuit breaker failure protection function

Three arc protection stages ARCSARC1...3 are included as an optional function. 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, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The outputs of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

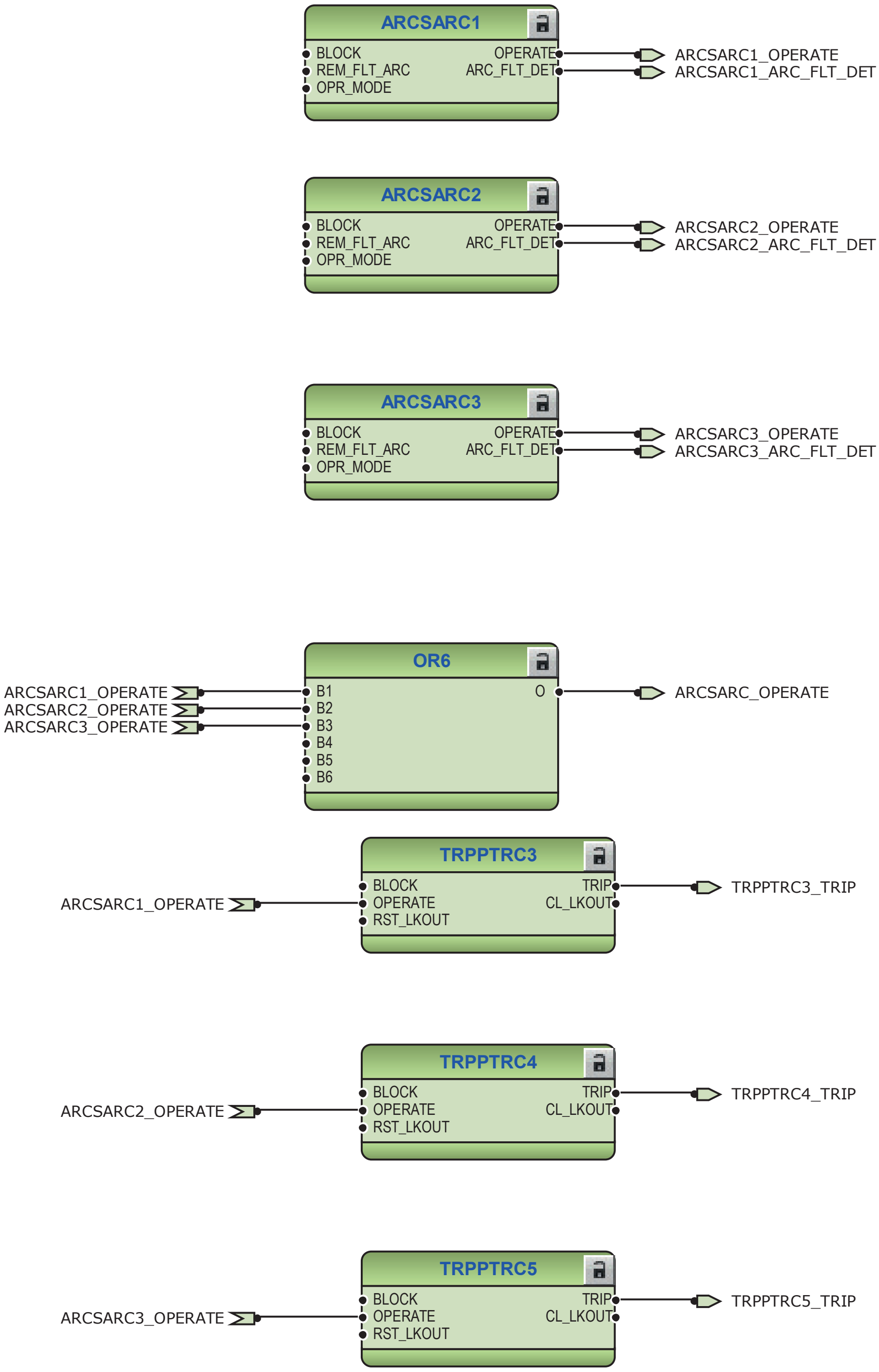


Figure 19: Arc protection with dedicated HSO

Three-phase overload protection for shunt capacitor banks COLPTOC1 provides protection against overloads caused due to harmonic currents and overvoltage in shunt capacitor banks. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

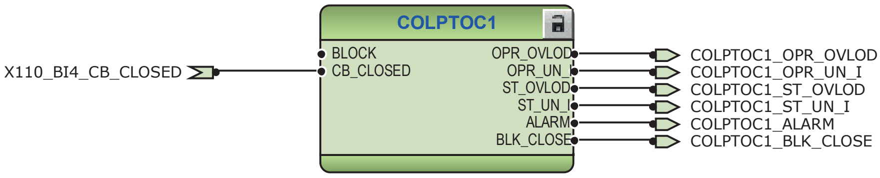


Figure 20: Capacitor bank overload protection function

Three-phase current unbalance protection for shunt capacitor banks HCUBPTOC1 is provided in the application configuration to protect H-bridge capacitor banks against internal faults. The function is suitable for protection of internally fused, externally fused and fuse-less capacitor bank applications. If the application contains a double-Y type connected capacitor bank, HCUBPTOC1 function can be replaced by CUBPTOC1 function which has been designed for double-Y type capacitor banks.

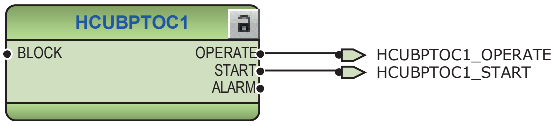


Figure 21: Unbalance protection for H-bridge shunt capacitor banks

Shunt capacitor bank switching resonance protection, current based, SRCPTOC1 is used for three-phase resonance detection caused by capacitor switching or due to topology changes in the network.

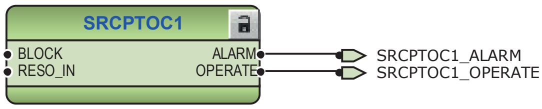


Figure 22: Capacitor bank resonance protection

General start and operate from all the functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

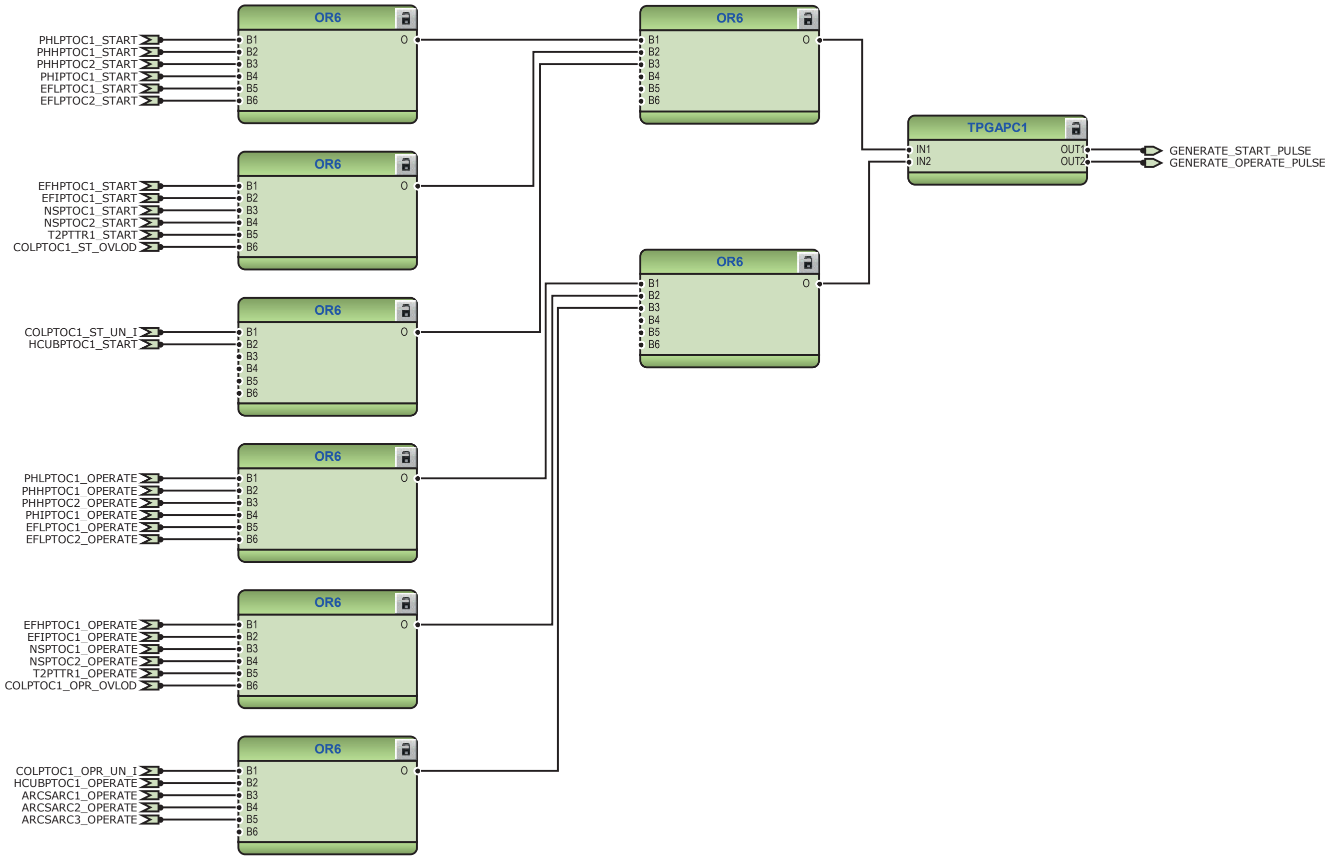


Figure 23: General start and operate signals

The operate signals from the protection functions are connected to two trip logics: TRPPTRC1 and TRPPTRC2. The output of TRPPTRC1 is available at binary output X100:PO3. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5 are also available if the IED is ordered with high speed binary outputs options.

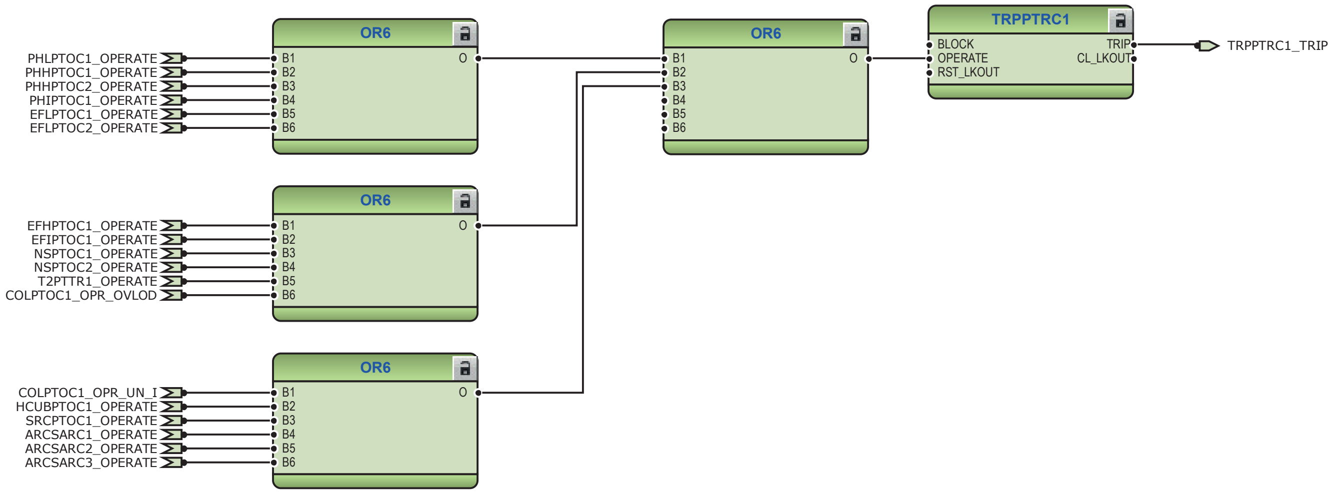


Figure 24: Trip logic TRPPTRC1

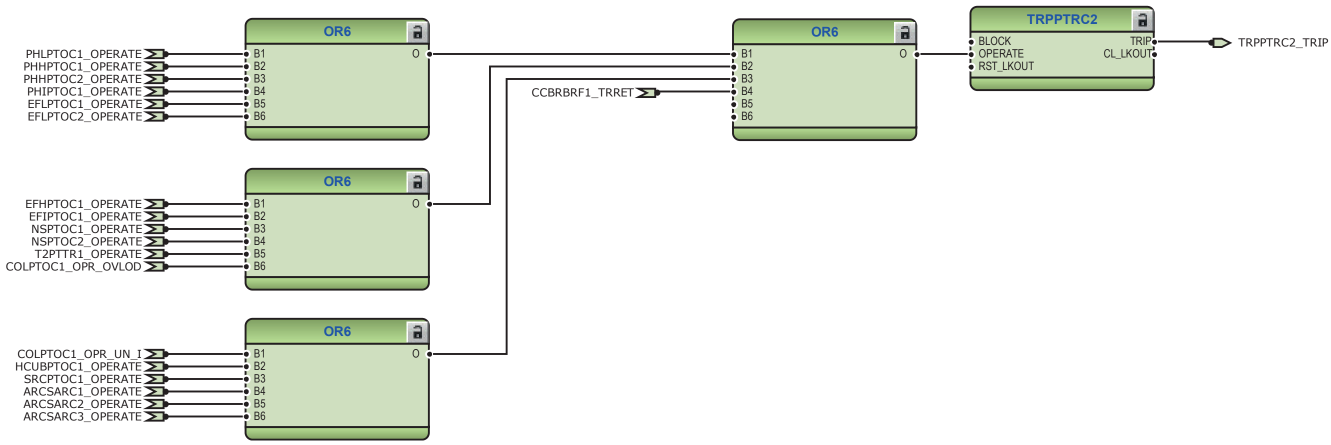


Figure 25: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

The `START` and the `OPERATE` outputs 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 signals from different functions and the few binary inputs are also connected to the disturbance recorder.

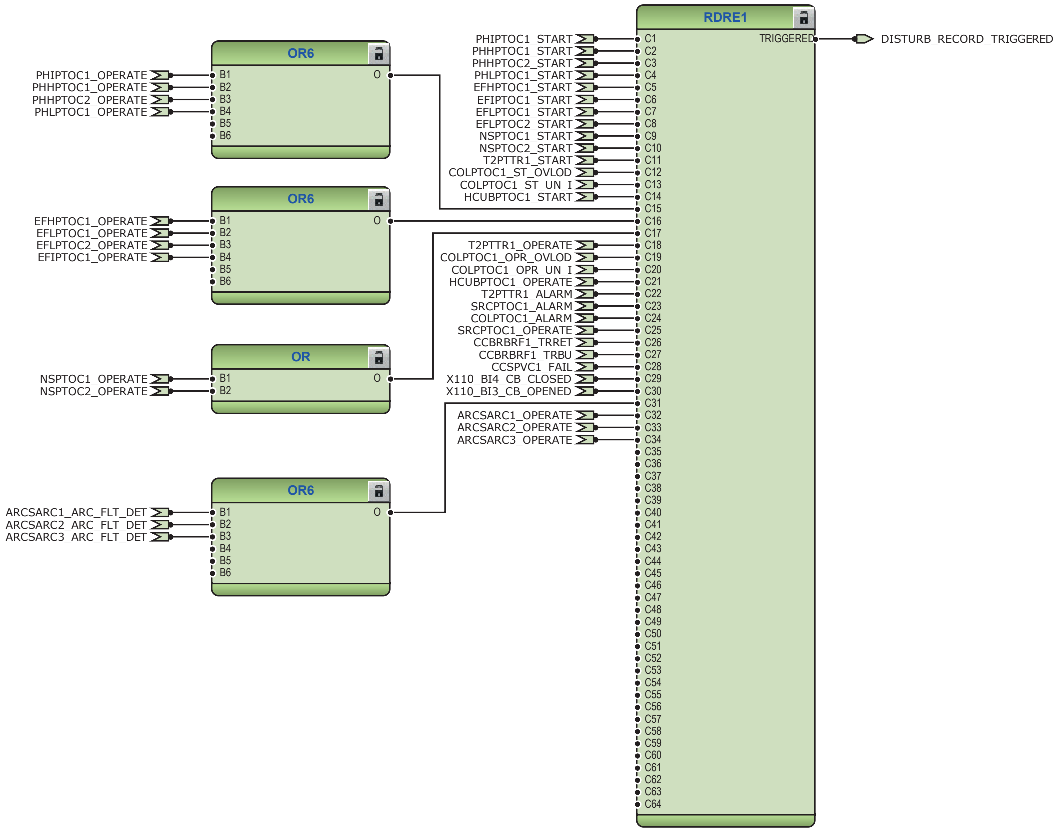


Figure 26: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it is used to block the current protection functions that measure the calculated sequence component currents or residual current to avoid unnecessary operation.

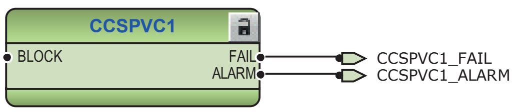


Figure 27: Current circuit supervision function

The circuit-breaker condition monitoring function SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

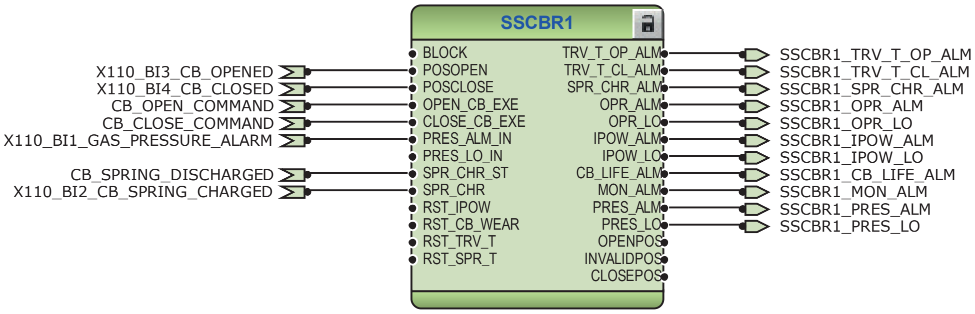


Figure 28: Circuit-breaker condition monitoring function

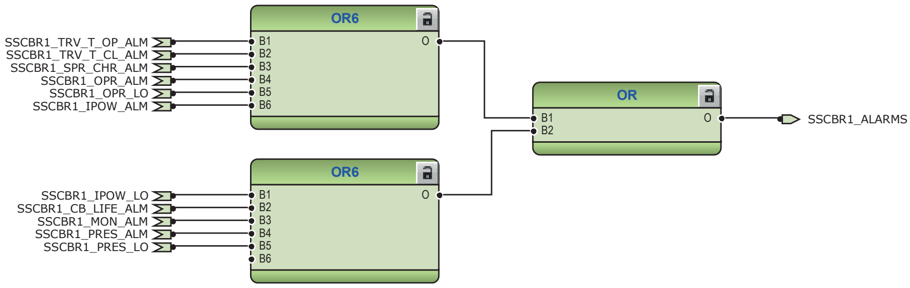


Figure 29: Logic for circuit breaker monitoring alarm

Figure 30: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. The functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 and the circuit breaker open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR1 properly.

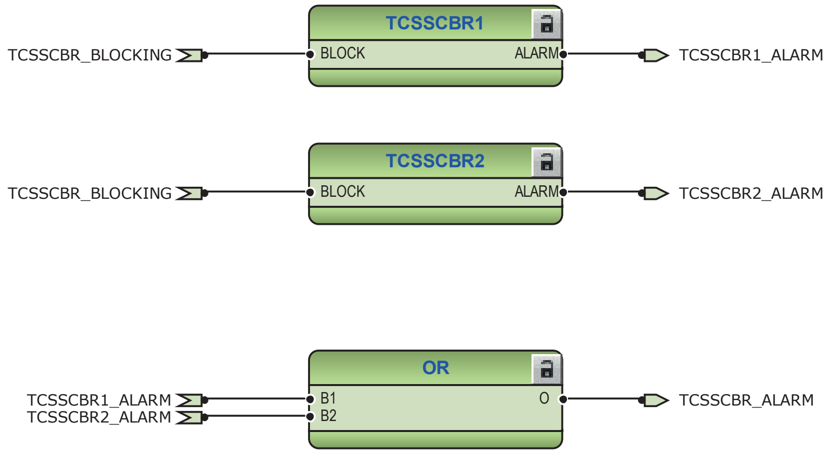


Figure 31: Trip circuit supervision function

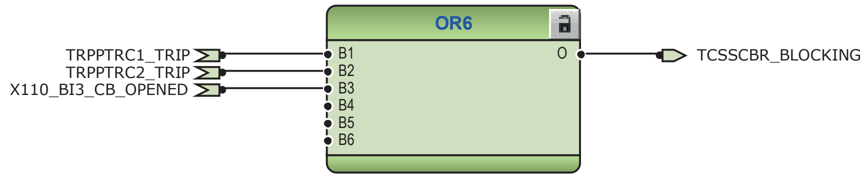


Figure 32: Logic for blocking trip logic circuit supervision

3.3.3.4 Functional diagrams for control and interlocking

There are two types of disconnector and earthing switch function blocks. 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. The disconnector (CB truck) and line side earthing switch status information are connected to DCSXSWI1 and ESSXSI1.

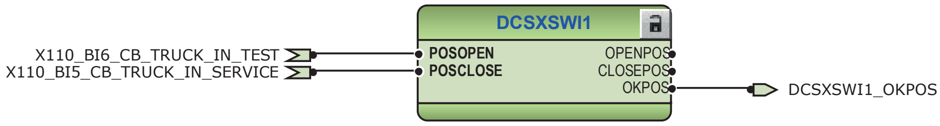


Figure 33: Disconnector 1 control logic

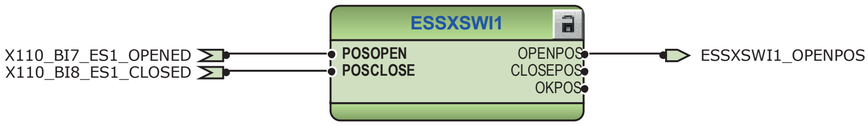


Figure 34: Earth-switch control logic

The circuit breaker closing is enabled when the `ENA_CLOSE` input is activated. The input can be activated using the configuration logic, which is a combination of the disconnector or breaker truck and earth-switch position status, status of the trip logics, gas pressure alarm and circuit-breaker spring charging status.

The `OKPOS` output from DCSXSWI defines whether the disconnector or breaker truck is either open (in test position) or close (in service position). This output, 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 for circuit breaker is always enabled.

The `SYNC_ITL_BYP` 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 the interlocking conditions being active when the circuit breaker truck is closed in service position.

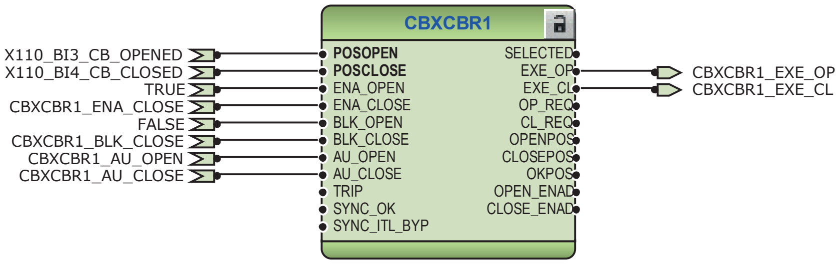


Figure 35: Circuit breaker control logic: Circuit breaker 1

Connect the additional signals required for the application for closing and opening of circuit breaker.

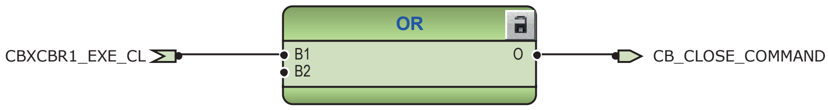


Figure 36: Circuit breaker control logic: Signals for closing coil of circuit breaker

Figure 37: Circuit breaker control logic: Signals for opening coil of circuit breaker

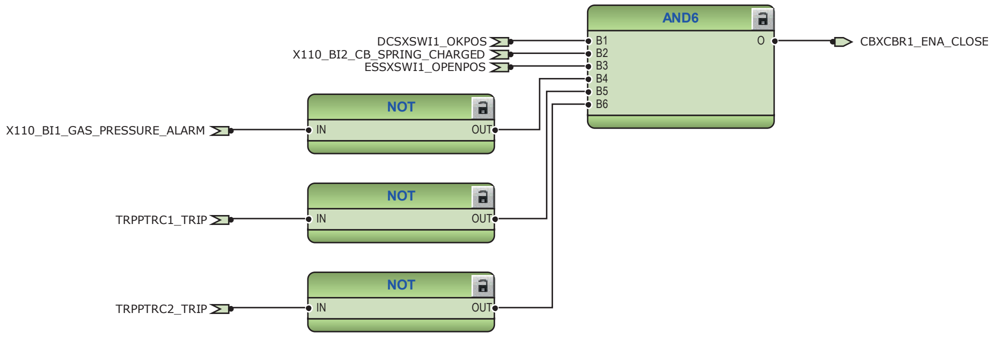


Figure 38: Circuit breaker close enable logic

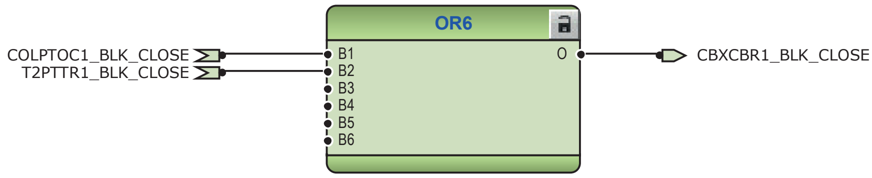


Figure 39: Circuit breaker close blocking logic

The configuration includes the logic for generating circuit breaker external closing and opening command with the IED in local or remote mode.

Check the logic for the external circuit breaker closing command and modify it according to the application.

Connect the additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration.

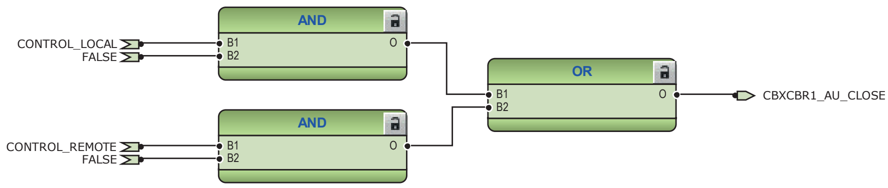


Figure 40: External closing command for circuit breaker

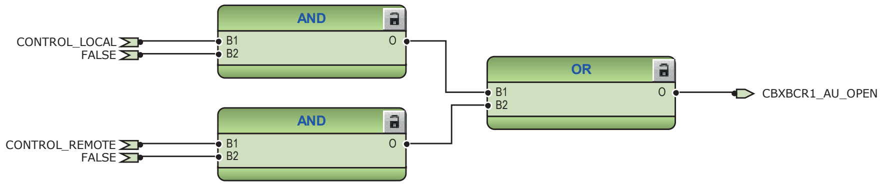


Figure 41: External opening command for circuit breaker

3.3.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

Three-phase capacitor unbalance current measurement is available in HCUBPTOC protection function.

Current total demand distortion CMHAI1 can be used to measure the harmonic contents of the phase current. By default these power quality functions are not included in the configuration. Depending on the application, the needed logic connections can be made by PCM600.

The measurements can be seen in the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The load profile record function LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

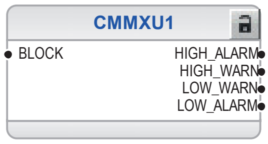


Figure 42: Current measurement : Three-phase current measurement

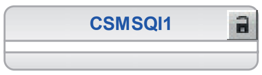


Figure 43: Current measurement : Sequence current measurement

Figure 44: Current measurement : Residual current measurement

Figure 45: Other measurement : Data monitoring

Figure 46: Other measurement : Load profile record

3.3.3.6 Functional diagrams for I/O and alarms LEDs

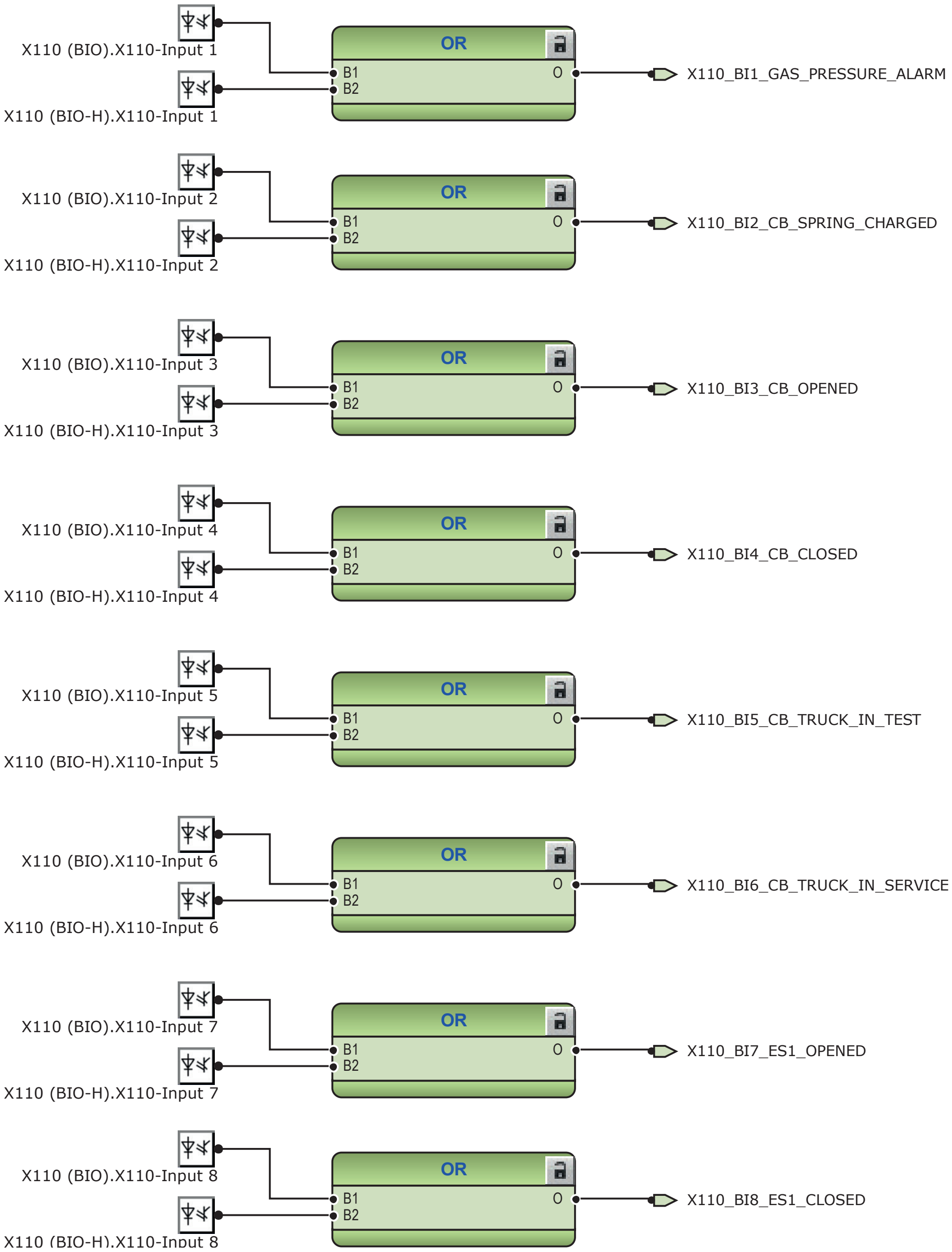


Figure 47: Default binary inputs - X110 terminal block

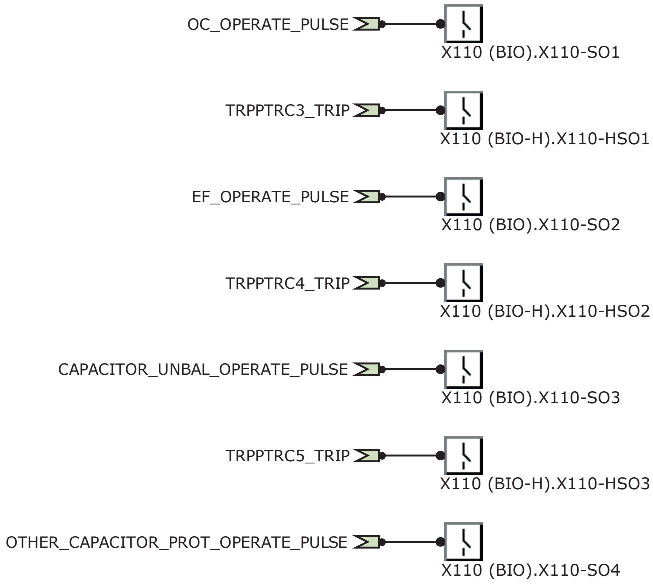


Figure 48: Binary outputs - X110 terminal block

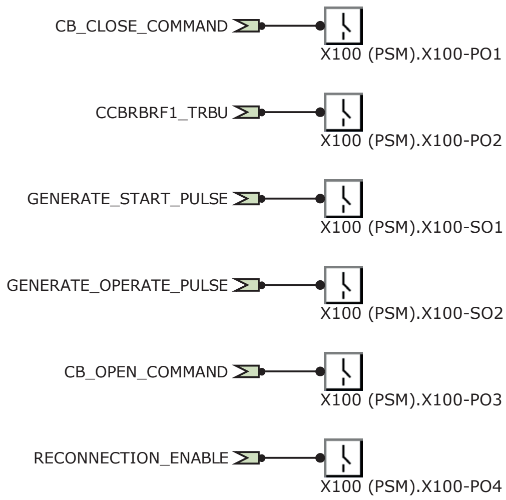
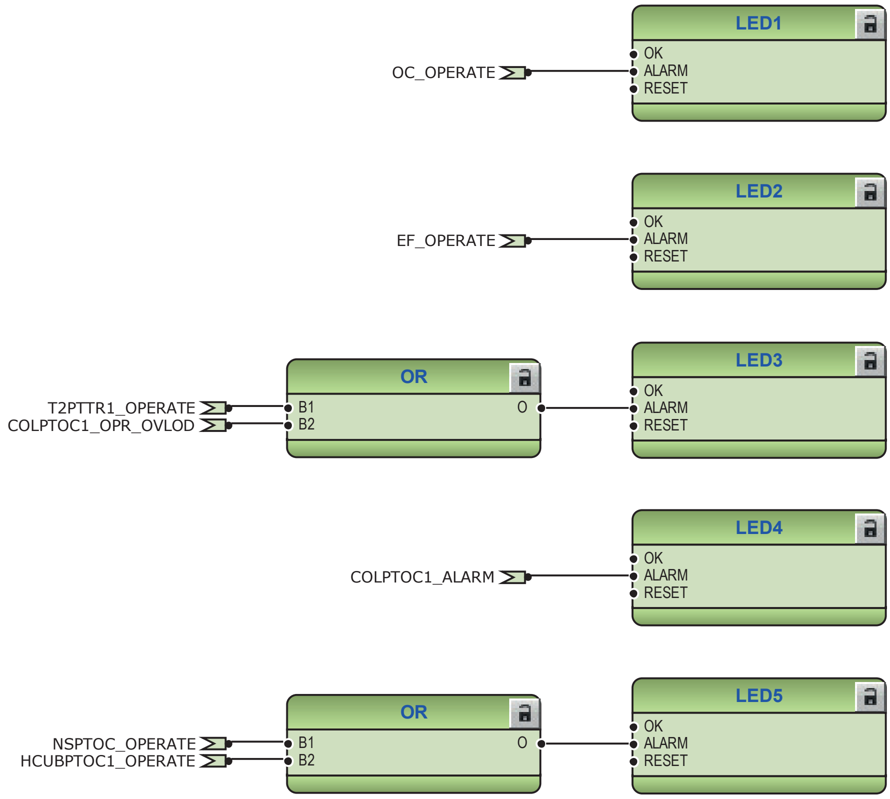


Figure 49: Binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
OC_OPERATE
LED2
OK
ALARM
RESET
EF_OPERATE
OR
B1
B2
O
T2PTTR1_OPERATE
COLPTOC1_OPR_OVLOD
LED3
OK
ALARM
RESET
LED4
OK
ALARM
RESET
COLPTOC1_ALARM
OR
B1
B2
O
NSPTOC_OPERATE
HCUBPTOC1_OPERATE
LED5
OK
ALARM
RESET

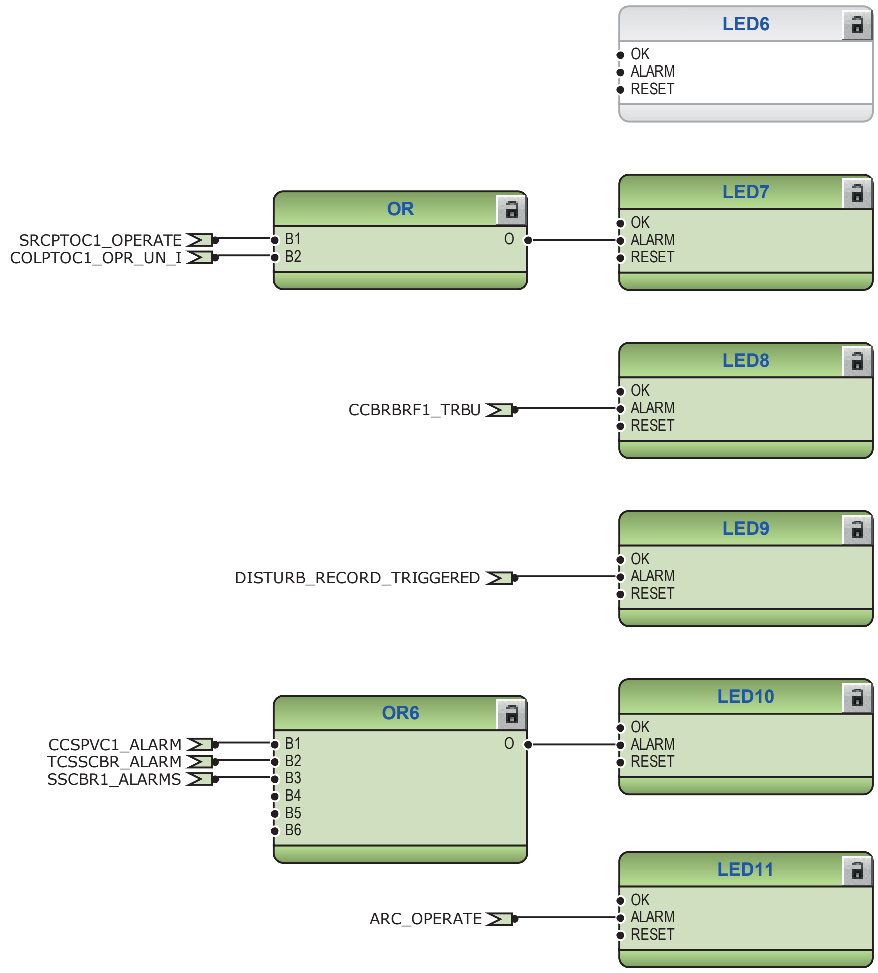


Figure 50: Default LED connection

3.3.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, earth-fault operate, capacitor unbalance operate and other combined capacitor operate logic. An additional reconnection enable logic is also provided, which is a NOT of circuit breaker close blocking (logic used in retrofitting applications). The operate logics are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

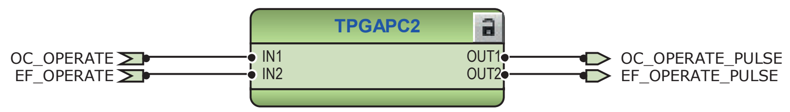


Figure 51: Timer logic for overcurrent and earth-fault operate pulse

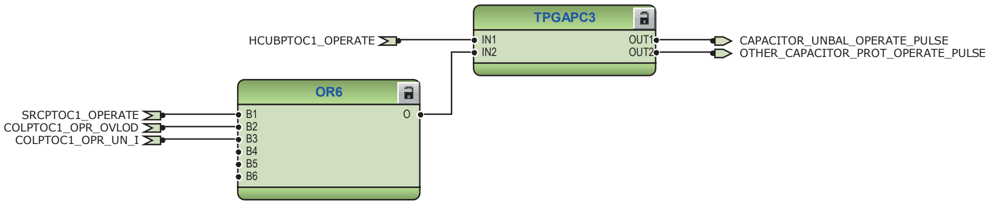


Figure 52: Timer logic for capacitor unbalance and other capacitor protection operate pulse

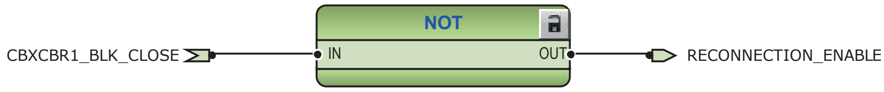


Figure 53: Reconnection enable logic

3.3.3.8 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, runtime counter for machines and devices MDSOPT and different types of timers and control functions. These functions are not included in application configuration but they can be added based on the system requirements.

3.4 Standard configuration B

3.4.1 Applications

The standard configuration offers three phase overload protection, unbalance protection with compensation for natural unbalance and switching resonance protection for capacitor banks. An integrated undercurrent function in the overload protection function block detects the disconnection of a capacitor bank and inhibits the closing of the circuit breaker as long as the capacitor bank is still partially discharged. A three-phase thermal overload protection is available and can be used for the thermal protection of the reactors and resistors in the harmonic filter circuits.

The standard configuration B is pre-configured for double-Y connected capacitor banks. A three-phase current unbalance protection is used for unbalance protection.

The second and third stage of the residual voltage protection in the standard configuration B can be used as voltage based unbalance protection mainly for single star-connected capacitor banks, with unearthed star point. A dedicated voltage input `Uob` is used for this purpose. This functionality needs to be configured before it can be taken into use.

The protection relay 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 protection relay 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

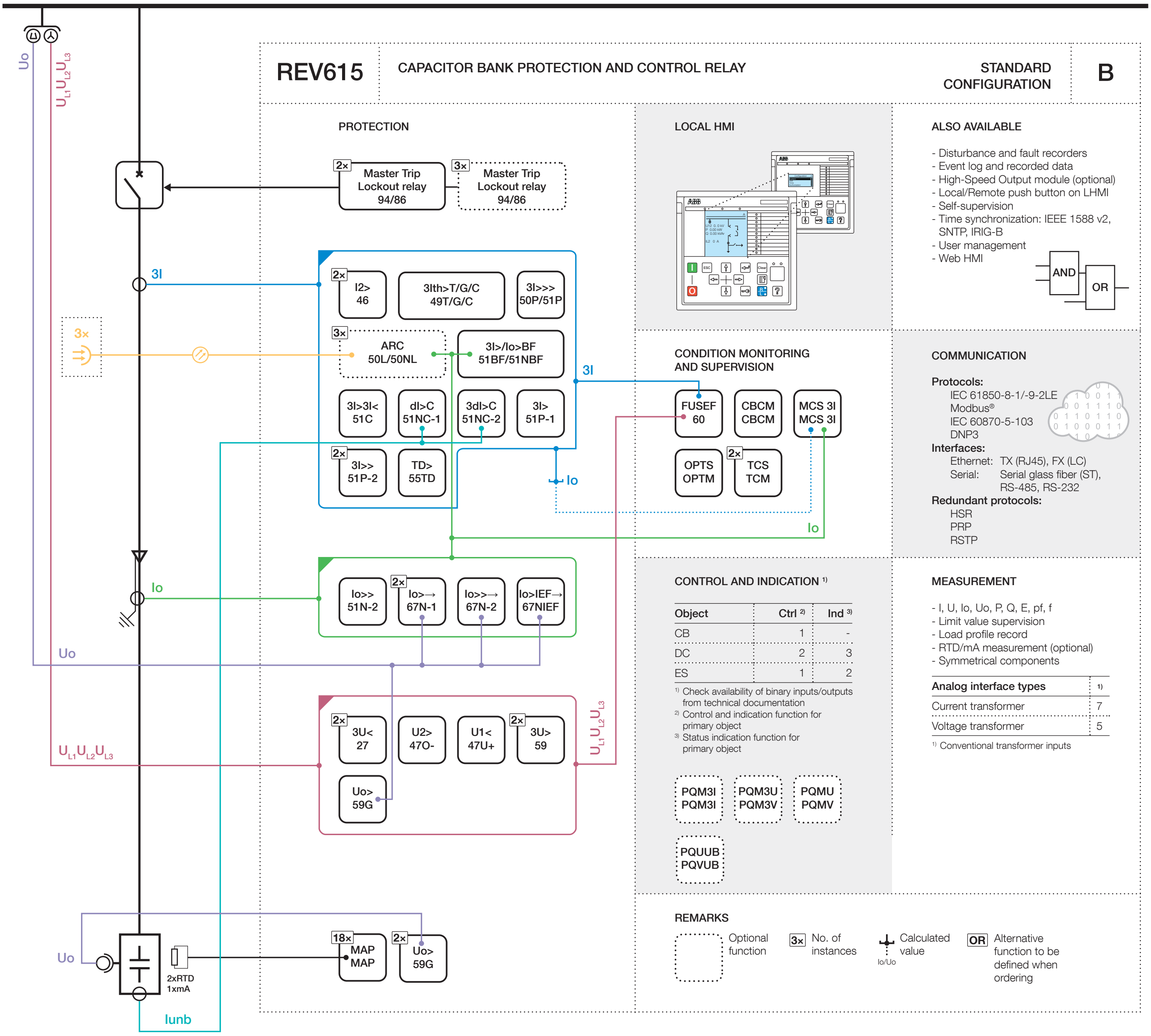


Figure 54: Functionality overview for standard configuration B

3.4.2.1 Default I/O connections

Connector pins for each input and output are presented in the IED physical connections section.

Table 16: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker low gas pressure indication
X110-BI2	Circuit breaker spring charged indication
X110-BI3	Circuit breaker open indication
X110-BI4	Circuit breaker closed indication
X110-BI5	Circuit breaker truck out (test position) indication
X110-BI6	Circuit breaker truck in (service position) indication
X110-BI7	Earth switch open indication
X110-BI8	Earth switch closed indication

Table 17: Default connections for binary outputs

Binary output	Description
X100-PO1	Close circuit breaker
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	General start indication
X100-SO2	General operate indication
X100-PO3	Open circuit breaker/trip coil 1
X100-PO4	Capacitor bank reconnection enable
X110-SO1	Overcurrent operate alarm
X110-SO2	Earth-fault operate alarm
X110-SO3	Capacitor protection operate alarm
X110-SO4	Voltage protection operate alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 18: Default connections for LEDs

LED	Description
1	Overcurrent protection operated
2	Earth-fault protection operated
3	Capacitor or thermal overload protection operated
4	Capacitor overload alarm
5	Capacitor unbalance or negative phase sequence protection operator
6	Voltage protection operated

Table continues on next page

LED	Description
7	Undercurrent or resonance protection operated
8	-
9	Disturbance recorder triggered
10	Supervision alarms
11	Arc-fault detected

3.4.2.2 Default disturbance recorder settings

Table 19: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Iunb
5	-
6	-
7	Io
8	Uo
9	U1
10	U2
11	U3
12	UoB

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHHPTOC2 - start	Positive or Rising
4	PHLPTOC1 - start	Positive or Rising
5	EFHPTOC1 - start	Positive or Rising
6	DEFHPDEF1 - start	Positive or Rising
7	DEFLPDEF1 - start	Positive or Rising
8	DEFLPDEF2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	T2PTTR1 - start	Positive or Rising
12	COLPTOC1 - start ovload	Positive or Rising
13	COLPTOC1 - start un I	Positive or Rising
14	CUBPTOC1 - start	Positive or Rising
Table continues on next page		

Channel	ID text	Level trigger mode
15	PSPTUV1 - start	Positive or Rising
16	NSPTOV1 - start	Positive or Rising
17	PHPTOV1 - start	Positive or Rising
18	PHPTOV2 - start	Positive or Rising
19	PHPTUV1 - start	Positive or Rising
20	PHPTUV2 - start	Positive or Rising
21	ROVPTOV1 - start	Positive or Rising
22	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHHPTOC2 - operate	
	PHLPTOC1 - operate	
23	EFLPTOC1 - operate	Level trigger off
	DEFLPDEF1 - operate	
	DEFLPDEF2 - operate	
	DEFHPDEF1 - operate	
24	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
25	T2PTTR1 - operate	Level trigger off
26	COLPTOC1 - operate ovload	Level trigger off
27	COLPTOC1 - operate un I	Level trigger off
28	CUBPTOC1 - operate	Level trigger off
29	PSPTUV1 - operate	Level trigger off
30	NSPTUV1 - operate	Level trigger off
31	PHPTOV1 - operate	Level trigger off
	PHPTPOV2 - operate	
32	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
33	ROVPTOV1 - operate	Level trigger off
34	T2PTTR1 - alarm	Level trigger off
35	SRCPTOC1 - alarm	Positive or Rising
36	COLPTOC1 - alarm	Level trigger off
37	SRCPTOC1 - operate	Level trigger off
38	CCBRBRF1 - trret	Level trigger off
39	CCBRBRF1 - trbu	Level trigger off
40	CCSPVC1 - fail	Level trigger off
41	SEQSPVC1 - fusef 3ph	Level trigger off
42	SEQSPVC - fusef u	Level trigger off
43	X110BI4 - CB closed	Level trigger off
44	X110BI3 - CB opened	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
45	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
46	ARCSARC1 - operate	Positive or Rising
47	ARCSARC2 - operate	Positive or Rising
48	ARCSARC3 - operate	Positive or Rising

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.

The analog channels have fixed connections to the different function blocks inside the protection relay's standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder's parameter settings.

The capacitor phase currents as well as capacitor unbalance current to the protection relay are fed from a current transformer. The residual current to the protection relay is fed either from residually connected current transformers, an external core balance CT, neutral CT or internally calculated.

The capacitor phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay is fed either from residually connected voltage transformers, an open delta connected VT or internally calculated.

The protection relay offers six different setting groups which can be set based on the individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.4.3.1 Functional diagrams for protection

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

Four non-directional overcurrent stages are offered for capacitor overcurrent and short-circuit protection.

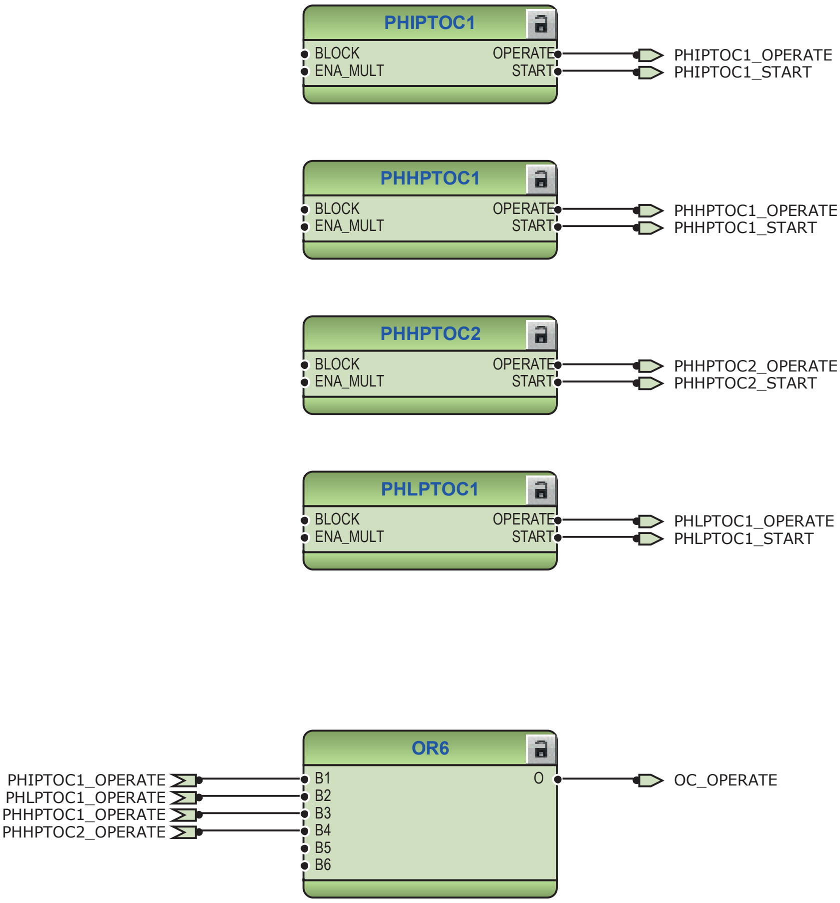


Figure 55: Overcurrent protection functions

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the capacitor against unbalance conditions. The negative-sequence overcurrent protection functions are blocked in case of detection of a failure in the secondary circuit of current transformer.

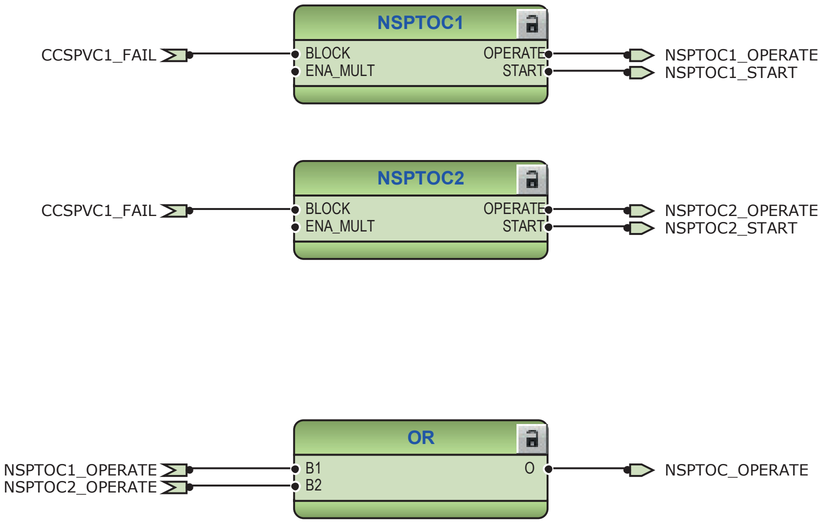


Figure 56: Negative-sequence overcurrent protection function

Four stages are provided for earth-fault protection. Three stages are dedicated for directional earth-fault protection.

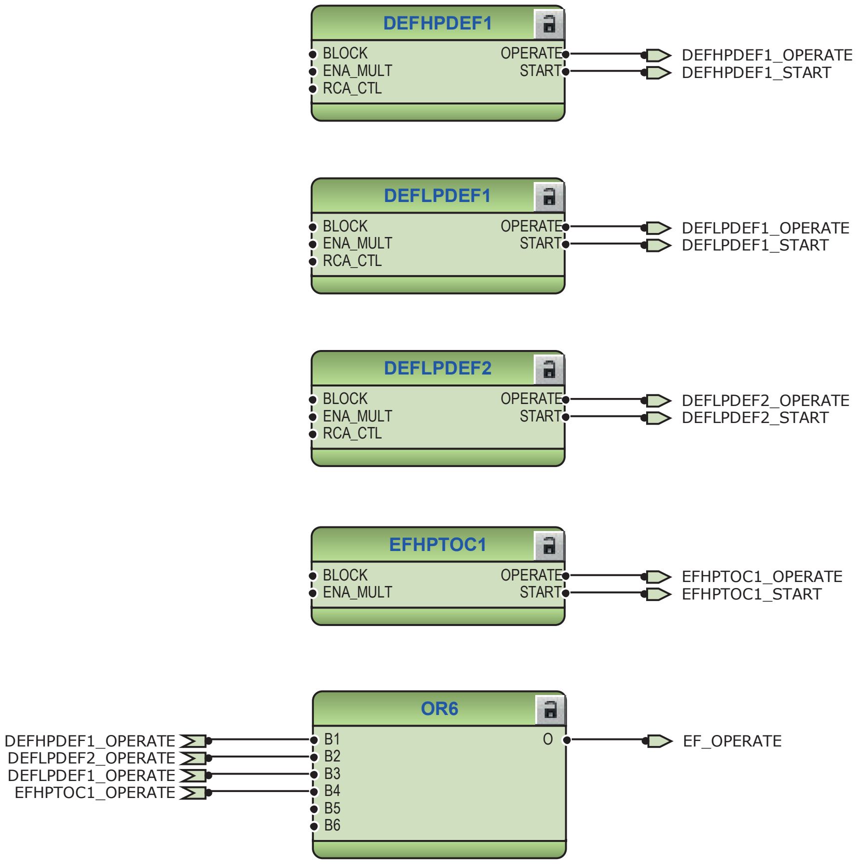


Figure 57: Earth-fault protection functions

The three-phase thermal overload protection T2PTTR1 with two time constants detects overload under varying load conditions. The BLK_CLOSE output of the function is used to block the closing operation of circuit breaker.

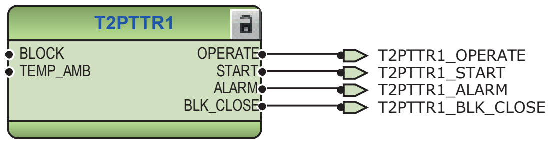


Figure 58: Thermal overcurrent protection function

The circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The circuit breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own breaker through TRPPTRC2_TRIP. The TRBU output is used to give a backup trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output X100:PO2.

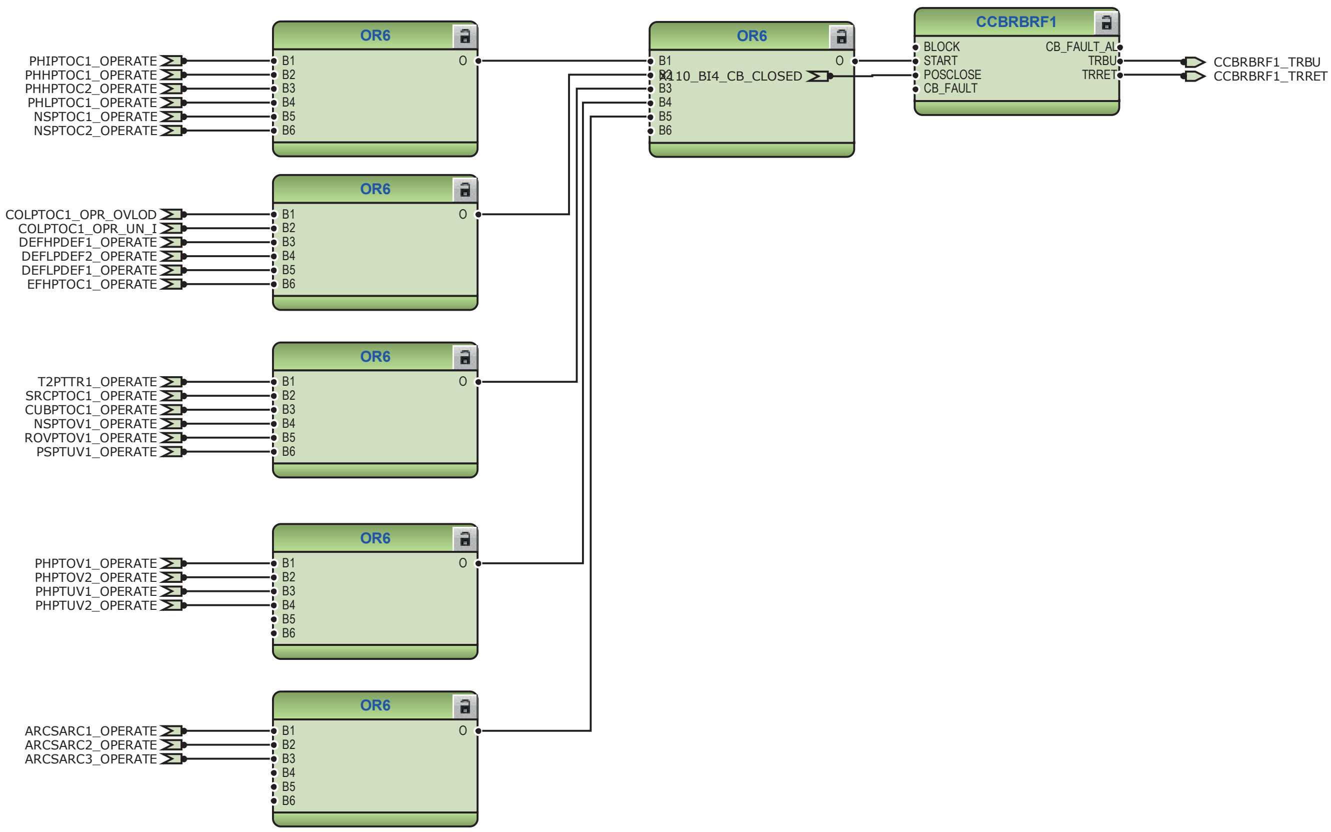


Figure 59: Circuit breaker failure protection function

Three arc protection stages ARCSARC1...3 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, that is, with or without the phase and residual current check.

The operate signals from ARCSARC1...3 are connected to both trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The outputs of TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

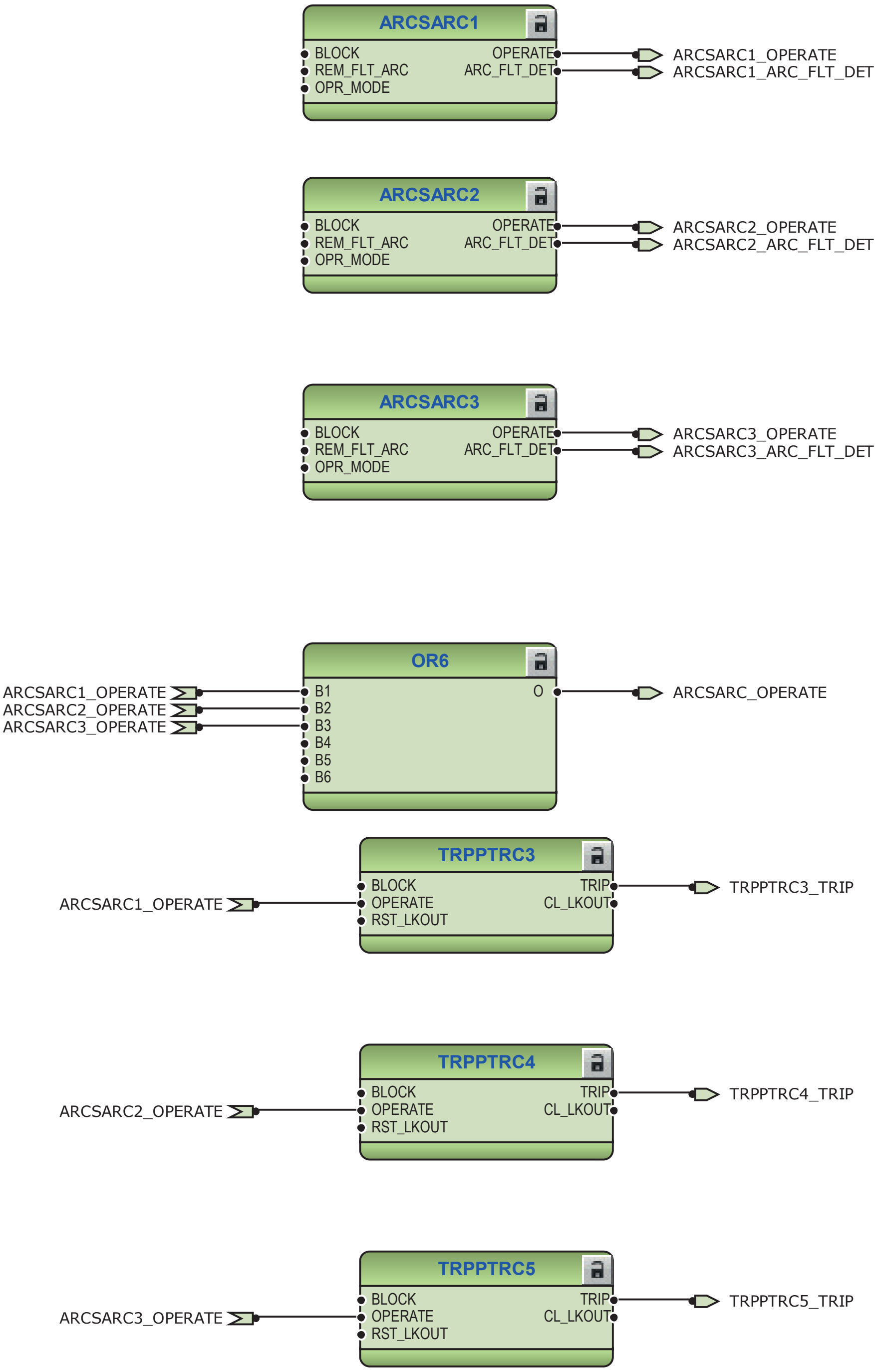


Figure 60: Arc protection with dedicated HSO

Three-phase overload protection for shunt capacitor banks COLPTOC1 provides protection against overloads caused due to harmonic currents and overvoltage in shunt capacitor banks. The `BLK_CLOSE` output of the function is used to block the closing operation of circuit breaker.

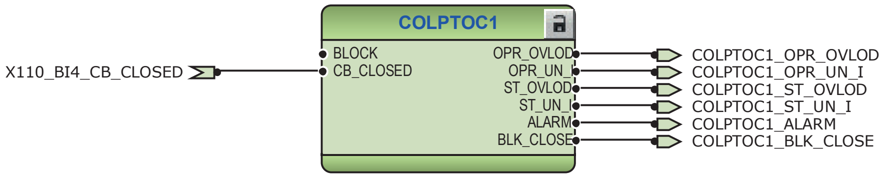


Figure 61: Capacitor bank overload protection function

Current unbalance protection for shunt capacitor banks CUBPTOC1 is provided in the application configuration to protect double-Y type connected capacitor banks against internal faults. The function is suitable for protection of internally fused, externally fused and fuse-less capacitor bank applications. If the application contains an H-bridge type capacitor bank, CUBPTOC1 function can be replaced by HCUBPTOC function which has been designed for H-bridge type capacitor banks.

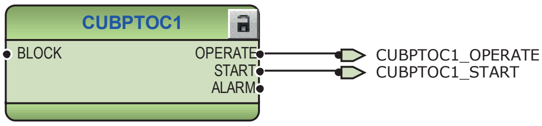


Figure 62: Unbalance protection for H-bridge shunt capacitor banks

Shunt capacitor bank switching resonance protection, current based, SRCPTOC1 is used for three-phase resonance detection caused by capacitor switching or due to topology changes in the network.

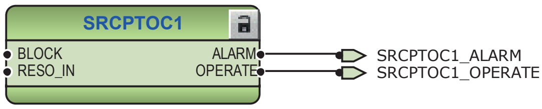


Figure 63: Capacitor bank resonance protection

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV1 and negative-sequence overvoltage protection NSPTOV1 functions enable voltage-based unbalance protection. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping.

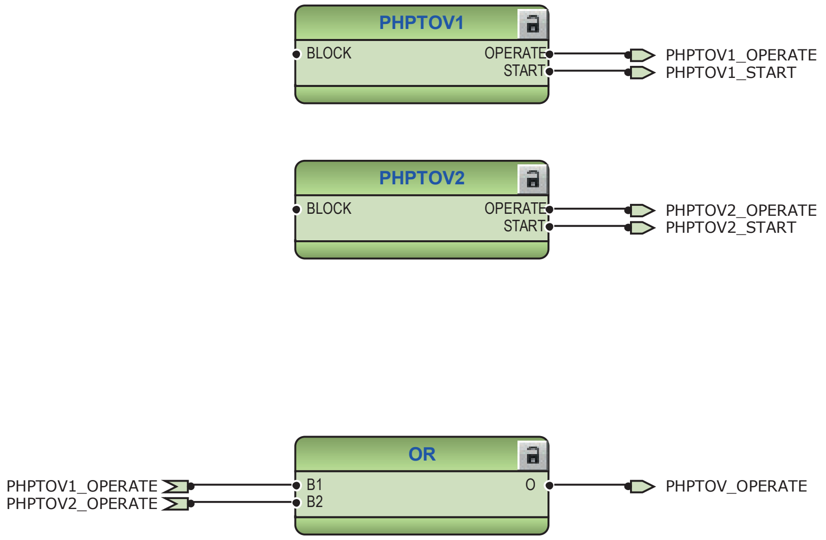


Figure 64: Overvoltage protection function

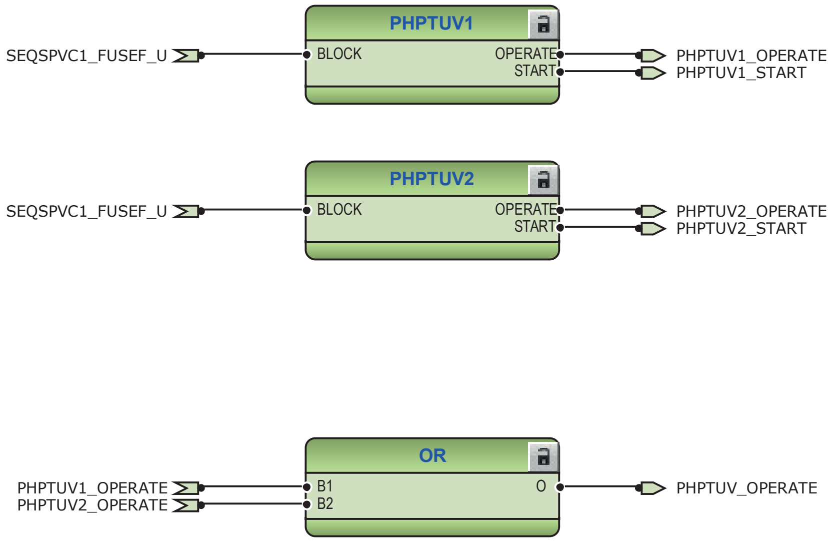


Figure 65: Undervoltage protection function

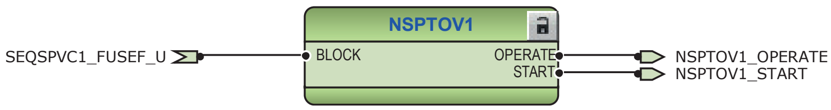


Figure 66: Negative-sequence overvoltage protection function

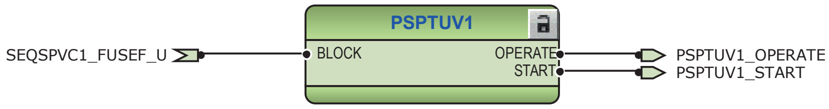


Figure 67: Negative-sequence undervoltage protection function

The residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the earth-fault functionality.

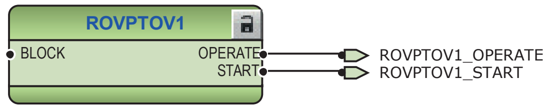


Figure 68: Residual voltage protection function

General start and operate from all the functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary outputs.

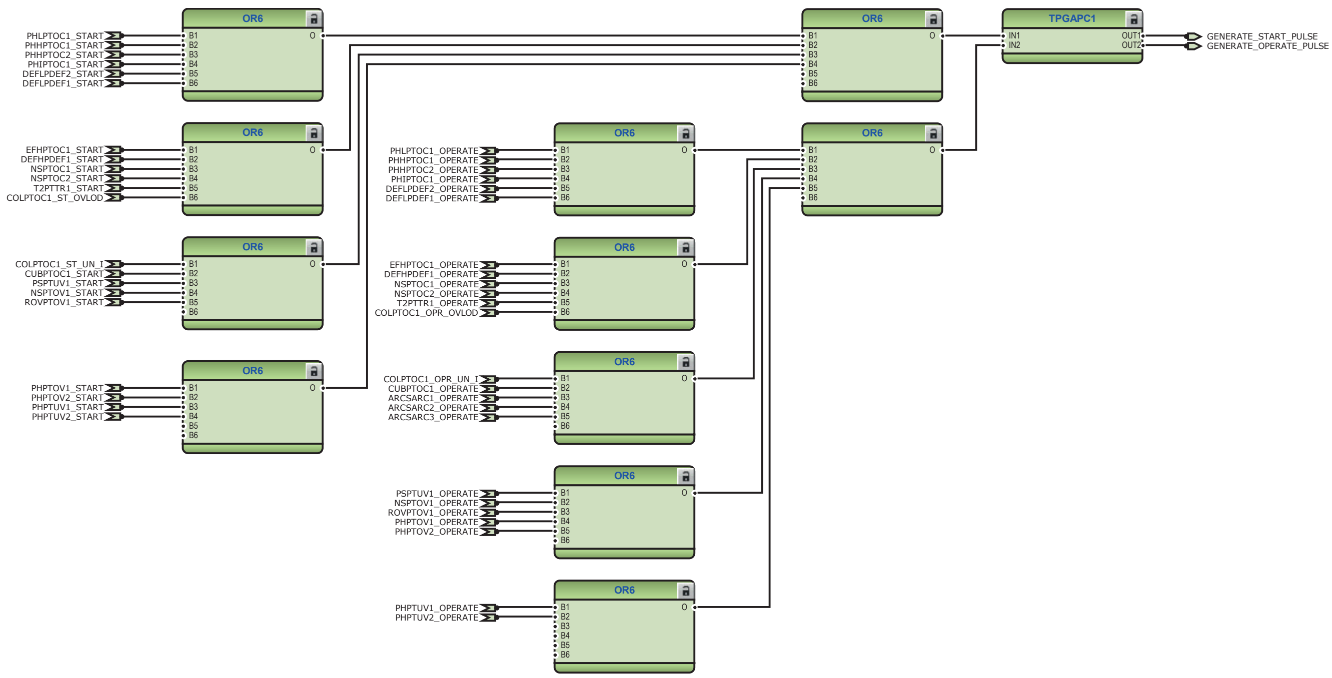


Figure 69: General start and operate signals

The operate signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of TRPPTRC1 is available at binary output X100:PO3. The trip logic functions are provided with lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can been assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5 are available if the IED is ordered with high speed binary outputs options.

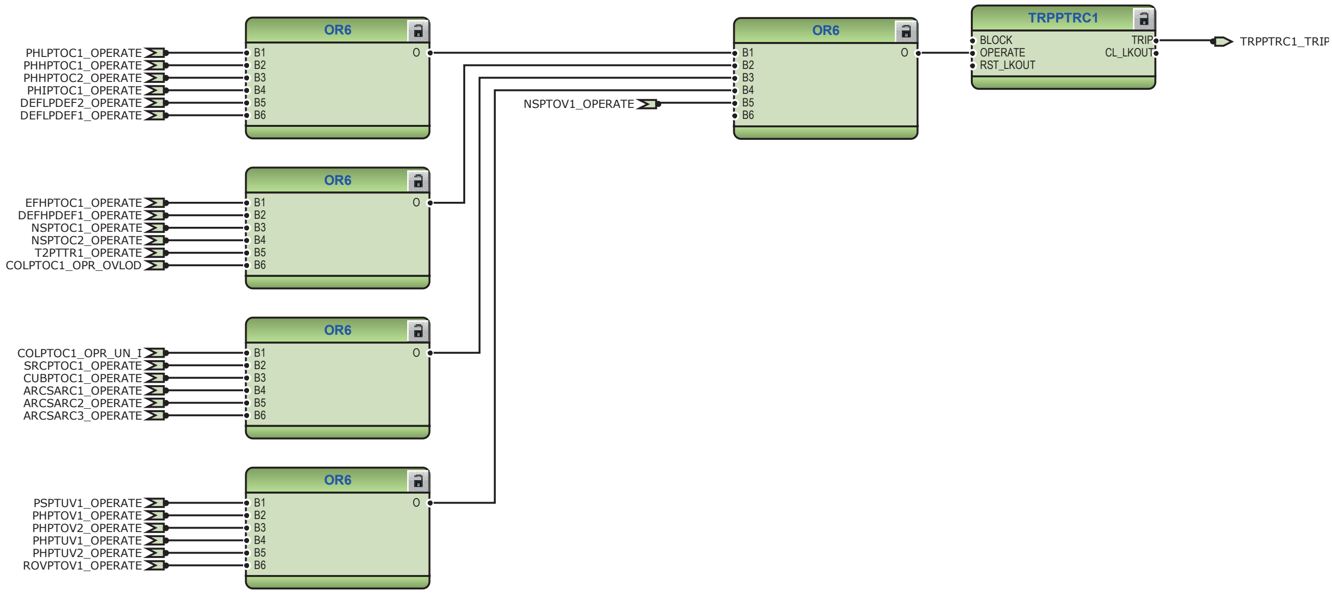


Figure 70: Trip logic TRPPTRC1

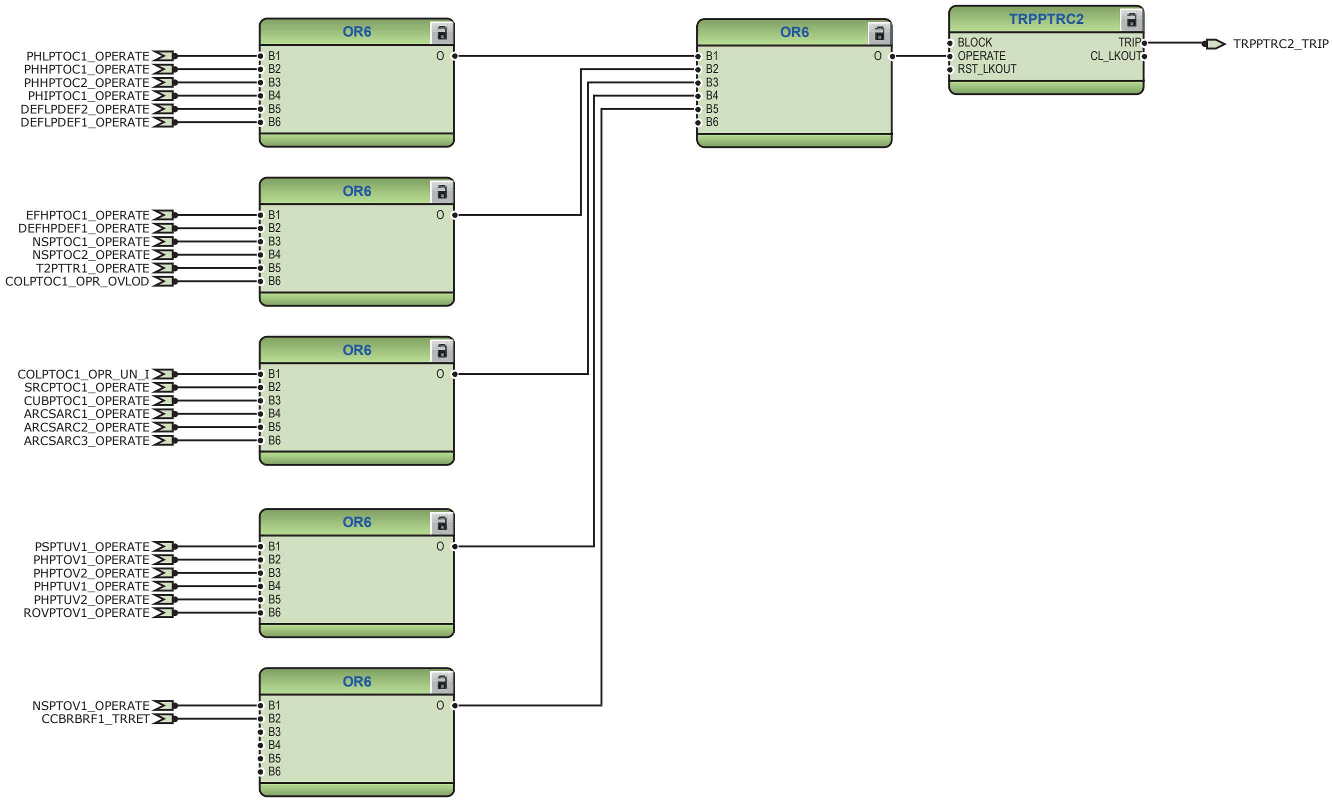


Figure 71: Trip logic TRPPTRC2

3.4.3.2 Functional diagrams for disturbance recorder

The START and the OPERATE outputs 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 signals from different functions and the few binary inputs are also connected to the disturbance recorder.

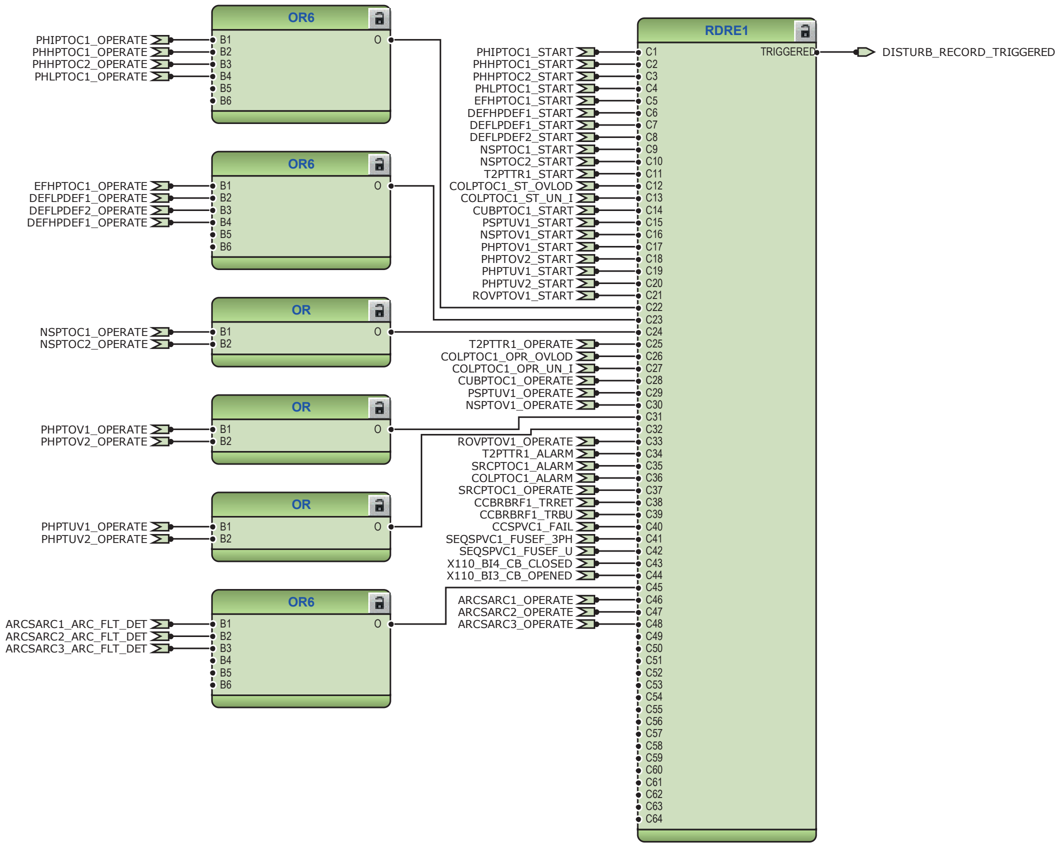


Figure 72: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

Failures in phase current measuring circuits are detected by CCSPVC1. When a failure is detected, it can be used to block current protection functions that are measuring calculated sequence component currents or residual current to avoid unnecessary operation.

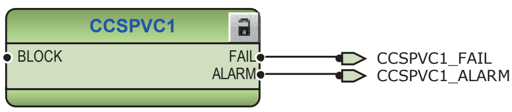


Figure 73: Current circuit supervision function

The fuse failure supervision SEQSPVC1 detects failures in the voltage measurement circuits at bus side. Failures, such as an open MCB, raise an alarm.

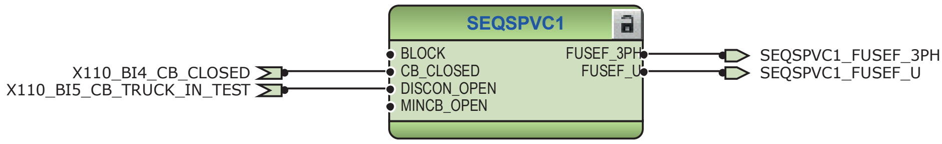


Figure 74: Fuse failure supervision function

The circuit-breaker condition monitoring function SSCBR1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1 introduces various supervision methods.

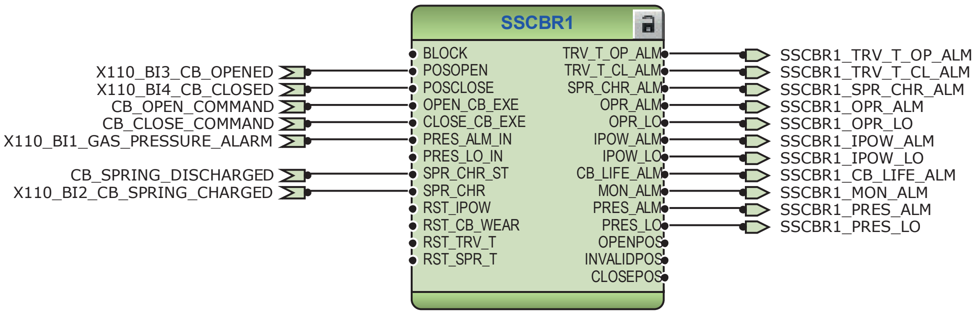


Figure 75: Condition monitoring function

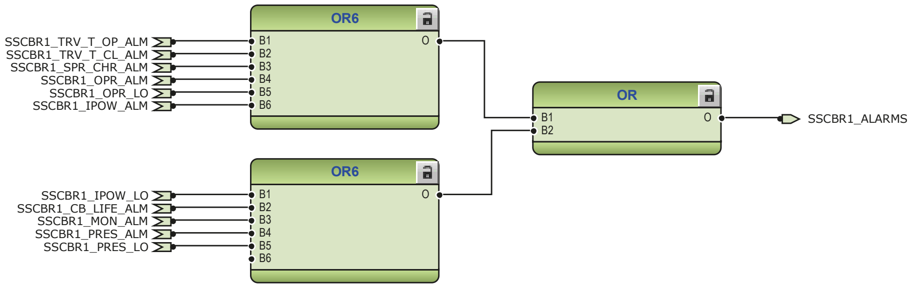


Figure 76: Logic for circuit breaker monitoring alarm

Figure 77: Logic for the start of circuit breaker spring charging

Two separate trip circuit supervision functions are included, TCSSCBR1 for power output X100:PO3 and TCSSCBR2 for power output X100:PO4. These functions are blocked by the master trip TRPPTRC1 and TRPPTRC2 and the circuit breaker open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

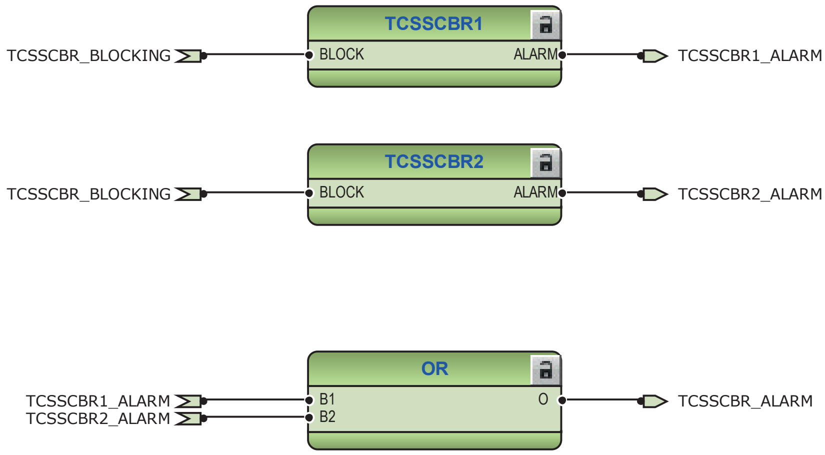


Figure 78: Trip circuit supervision function

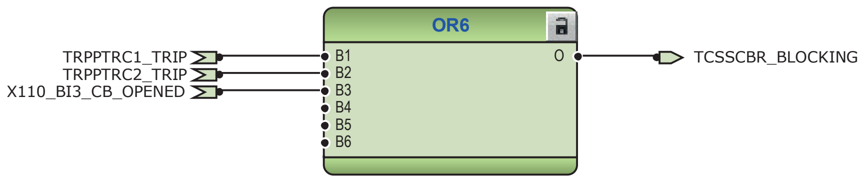


Figure 79: Logic for blocking trip circuit supervision function

3.4.3.4 Functional diagrams for control and interlocking

There are two types of disconnector and earthing switch function 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. The disconnector (CB truck) and line side earthing switch status information are connected to DCSXSWI1 and ESSXSI1.

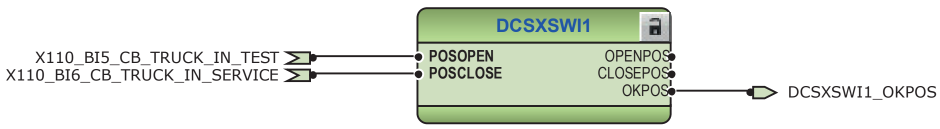


Figure 80: Disconnector control logic

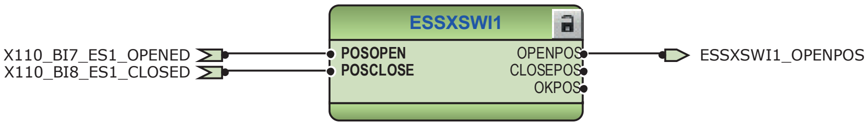


Figure 81: Earth-switch control logic

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 status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status.

The `OKPOS` output from DCSXSWI defines whether the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This output, 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 for circuit breaker is always enabled.

The `SYNC_ITL_BYP` 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 the interlocking conditions being active when the circuit breaker truck is closed in service position.

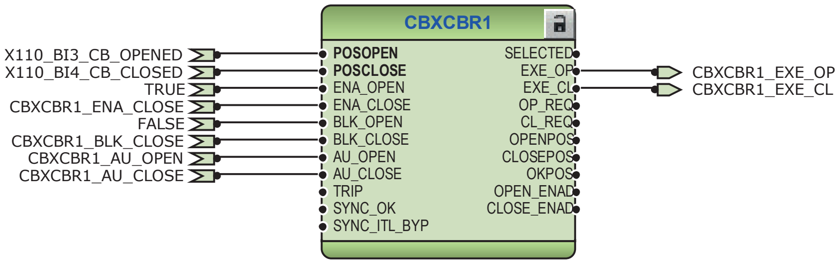


Figure 82: Circuit breaker control logic: Circuit breaker 1

Connect the additional signals required for the application for closing and opening of circuit breaker.

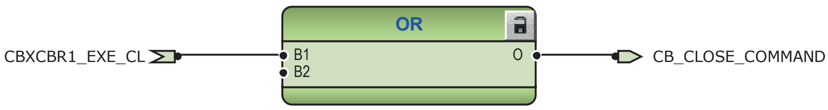


Figure 83: Circuit breaker control logic: Signals for closing coil of circuit breaker

Figure 84: Circuit breaker control logic: Signals for opening coil of circuit breaker

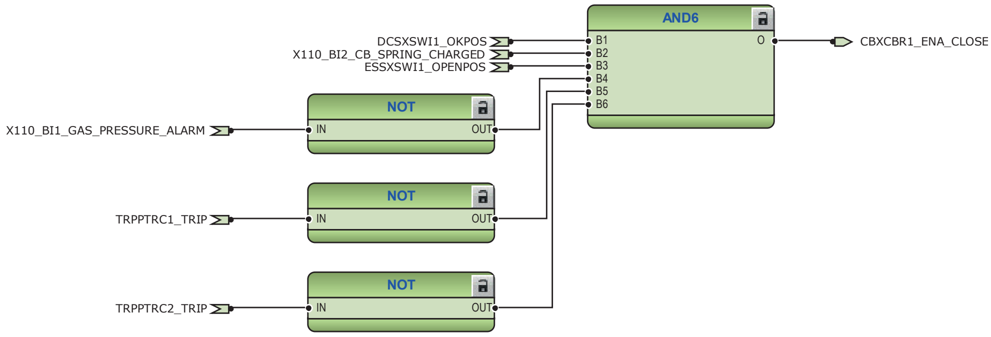


Figure 85: Circuit breaker close enable logic

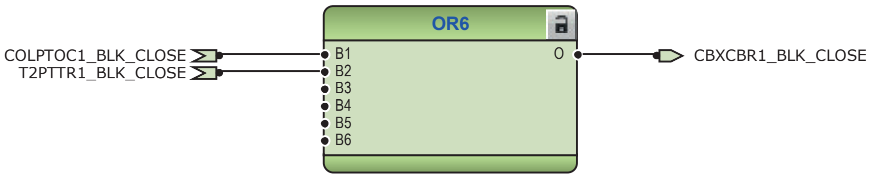


Figure 86: Circuit breaker close blocking logic

The configuration includes logic for generating circuit breaker external closing and opening command with IED in local or remote mode.

Check the logic for the external circuit breaker closing command and modify it according to the application.

Connect additional signals for opening and closing of circuit breaker in local or remote mode, if applicable for the configuration.

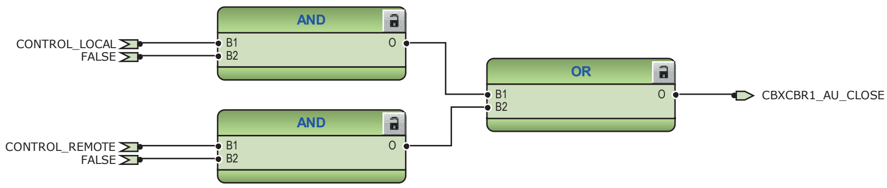


Figure 87: External closing command for circuit breaker

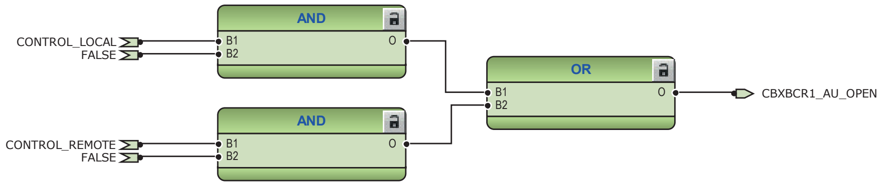


Figure 88: External opening command for circuit breaker

3.4.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

Three-phase capacitor unbalance current measurement is available in CUBPTOC protection function.

The three-phase capacitor phase voltage inputs to the IED are measured by three-phase voltage measurement VMMXU1. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESVMMXU1 measures the residual voltage. It is also possible to measure capacitor unbalance voltage by the residual voltage measurement RESVMMXU2.

The measurements can be seen in the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The frequency measurement FMMXU1 of the power system and three-phase power and energy measurement PEMMXU1 are available. The load profile function LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

Current total demand distortion CMHAI1 and voltage total harmonic distortion VMHAI1 can be used to measure the harmonic contents of the phase current and phase voltages. The voltage variation that is sage and swells can be measured by voltage variation PHQVVR1. By default these power quality functions are not included in the configuration. Depending on the application, the needed logic connections can be made by PCM600.

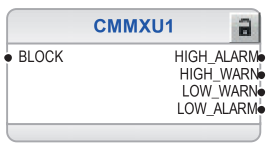


Figure 89: Current measurement: Three-phase current measurement

Figure 90: Current measurement: Sequence current measurement

Figure 91: Current measurement: Residual current measurement

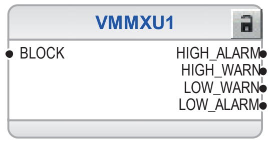


Figure 92: Voltage measurement: Three-phase voltage measurement

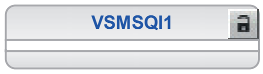


Figure 93: Voltage measurement: Sequence voltage measurement

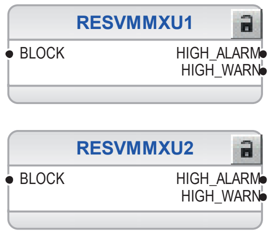


Figure 94: Voltage measurement: Residual voltage measurement

Figure 95: Other measurement: Frequency measurement

Figure 96: Other measurement: Three-phase power and energy measurement

Figure 97: Other measurement: Data monitoring

Figure 98: Other measurement: Load profile record

3.4.3.6 Functional diagrams for I/O and alarms LEDs

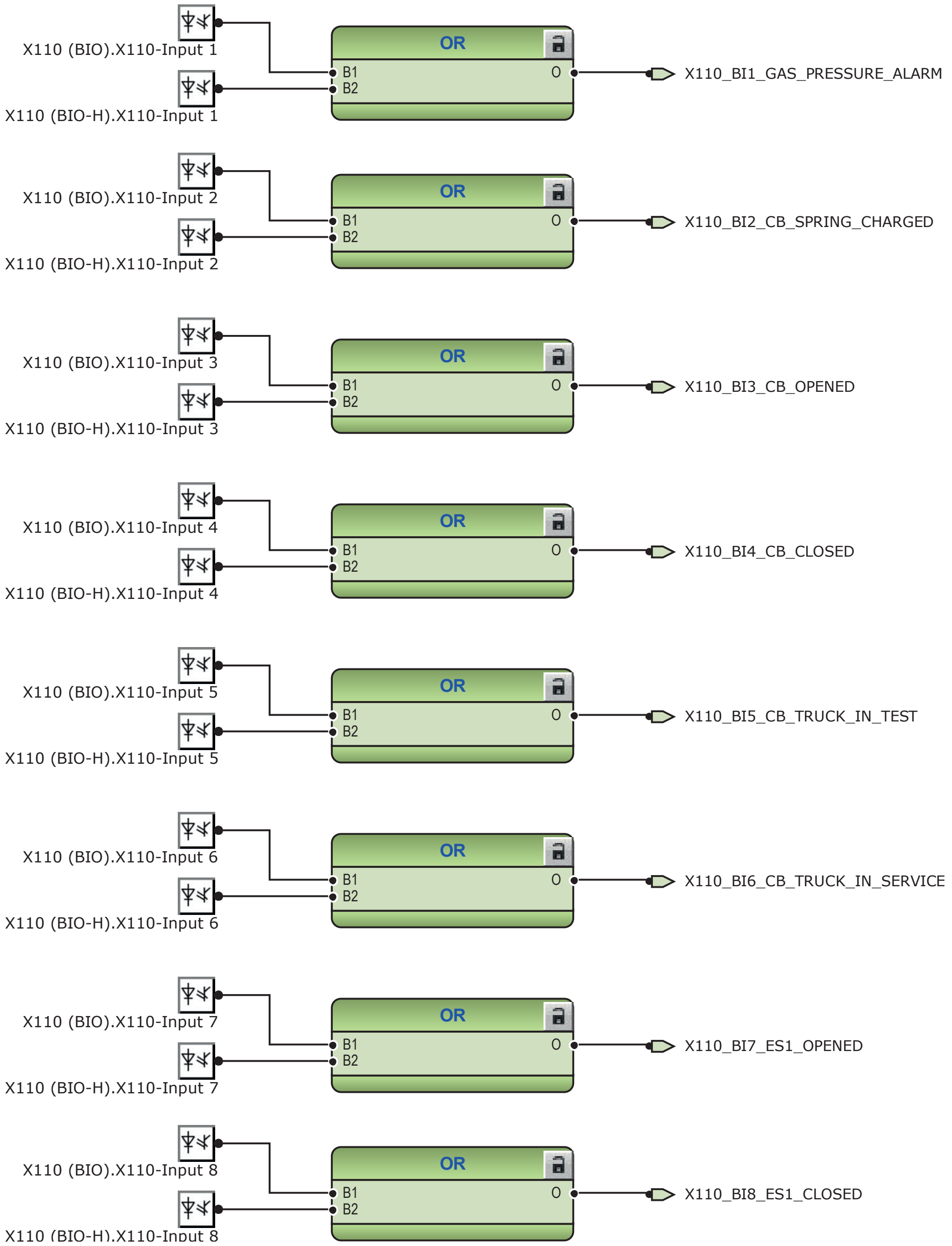


Figure 99: Default binary inputs - X110 terminal block

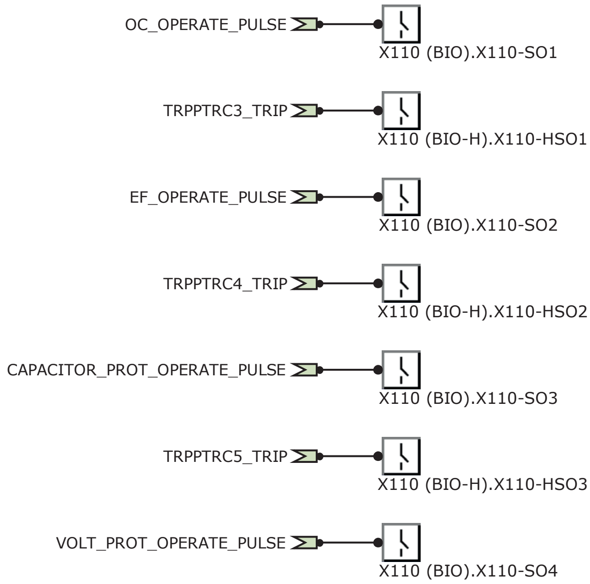


Figure 100: Binary outputs - X110 terminal block

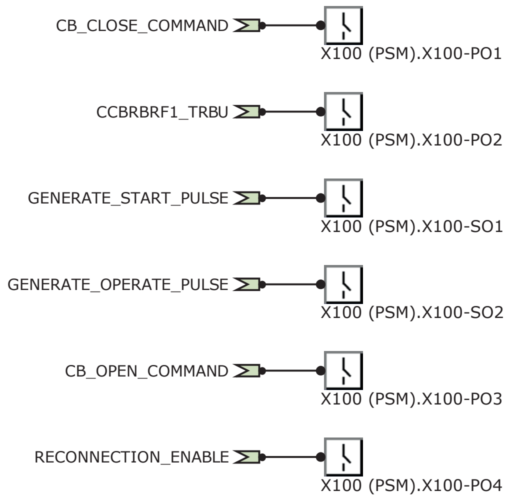
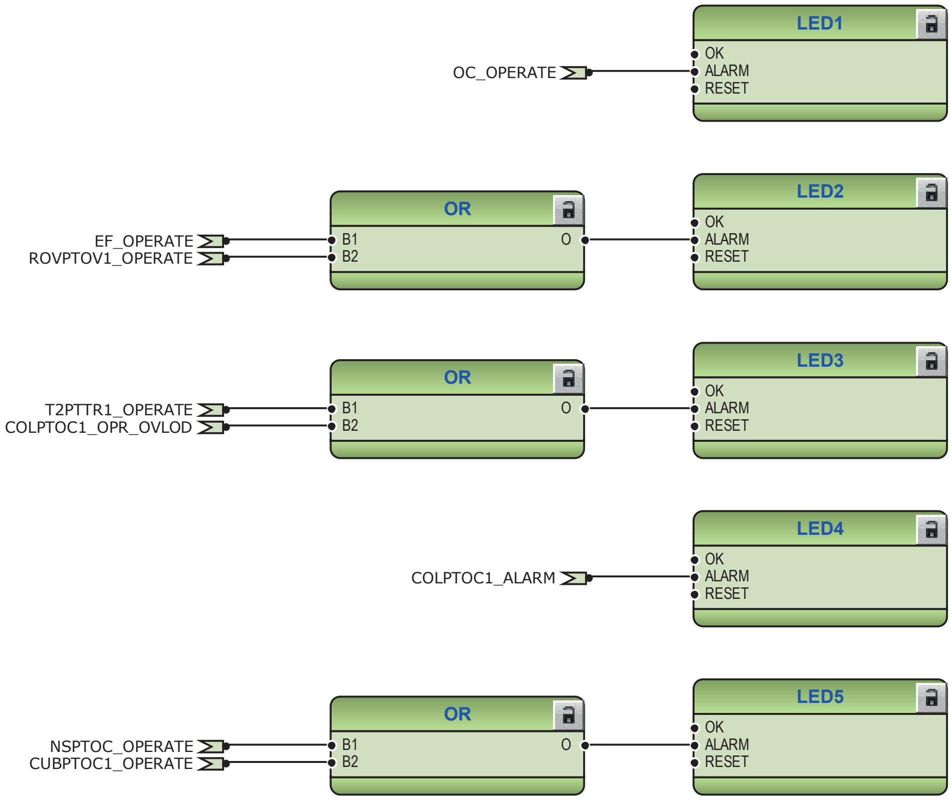


Figure 101: Binary outputs - X100 terminal block


LED1
OK
ALARM
RESET
OC_OPERATE
OR
B1
B2
O
LED2
OK
ALARM
RESET
EF_OPERATE
ROVPTOV1_OPERATE
OR
B1
B2
O
LED3
OK
ALARM
RESET
T2PTTR1_OPERATE
COLPTOC1_OPR_OVLOD
LED4
OK
ALARM
RESET
COLPTOC1_ALARM
OR
B1
B2
O
LED5
OK
ALARM
RESET
NSPTOC_OPERATE
CUBPTOC1_OPERATE

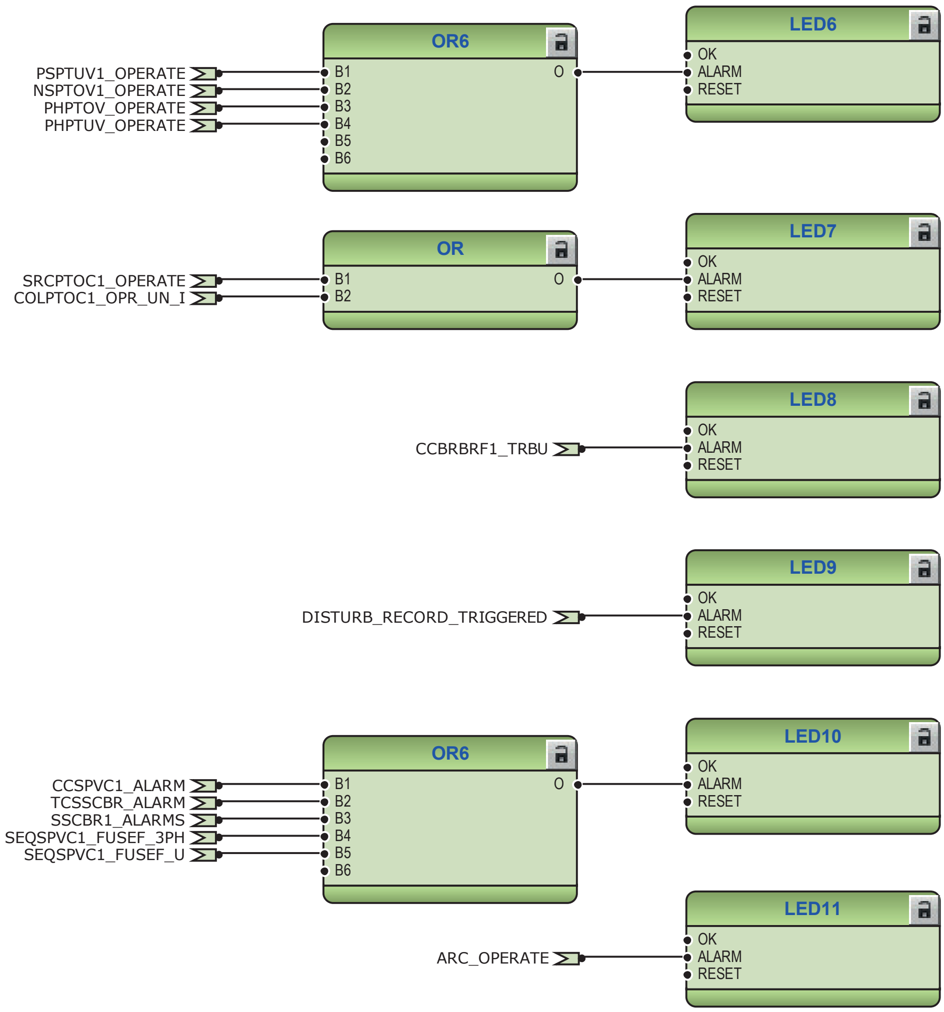


Figure 102: Default LED connection

3.4.3.7 Functional diagrams for other timer logics

The configuration also includes the overcurrent operate, earth-fault operate, combined capacitor operate logic and voltage protection operate logic. An additional reconnection enable logic is also provided, which is a NOT of circuit breaker close blocking (logic used in retrofitting applications). The operate logics are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

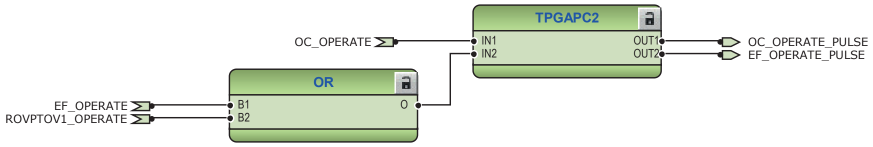


Figure 103: Timer logic for overcurrent and earth-fault operate pulse

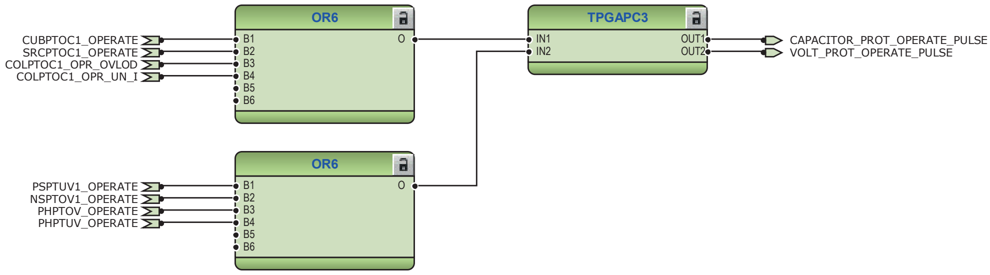


Figure 104: Timer logic for capacitor protection and voltage protection operate pulse

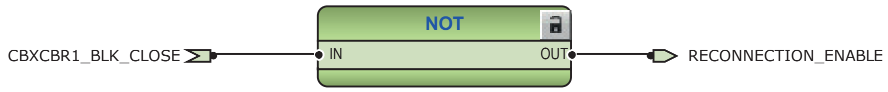


Figure 105: Reconnection enable logic

3.4.3.8 Other functions

The configuration includes few instances of multipurpose protection function MAPGAPC, runtime counter for machines and devices MDSOPT and different types of timers and control functions. These functions are not included in application configuration but they can be based on the system requirements.

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for overcurrent protection

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

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

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

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

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

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

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

The actual accuracy limit factor is calculated using the formula:

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

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 protection relay is not exceeded. This is always fulfilled when

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

I_{kmax} is the highest fault current.

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

Recommended start current settings

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

Current start value $< 0.7 \times (I_{kmin} / I_{1n})$

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

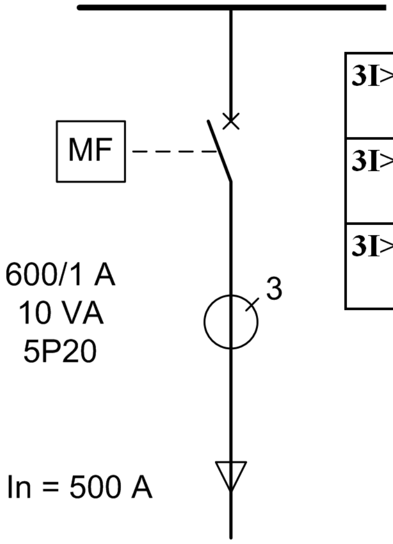
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

$F_a > 20 \times \textit{Current start value} / I_{1n}$

The *Current start value* is the primary start current setting of the protection relay.

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

Figure 106: Example of three-stage overcurrent protection

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 106). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 106.

For the application point of view, the suitable setting for instantaneous stage (I>>>) in this example is 3 500 A (5.83 × I_{2n}). I_{2n} is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 IED physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

The protection relay 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 22: Phase current inputs included in configurations A and B

Terminal	Description
X120:1-2	IL1 unb [1]
X120:3-4	IL2 unb [2]
X120:5-6	IL3 unb [2]
X120:7-8	IL1
X120:9-10	IL2
X120:11-12	IL3

1) Used only for HCUBPTOC1 and CUBPTOC1
2) Used only for HCUBPTOC1

5.1.1.2 Residual current

Table 23: Residual current input included in configurations A and B

Terminal	Description
X120:13-14	Io

5.1.1.3 Phase voltages

Table 24: Phase voltage inputs included in configuration B

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

5.1.1.4 Residual voltage

Table 25: Residual voltage input included in configurations A and B

Terminal	Description
X130:9-10	UoB[1)]
X130:17-18	Uo

1) Used only for ROVPTOV2 and ROVPTOV3

5.1.2 Auxiliary supply voltage input

The auxiliary voltage of the protection relay 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 protection relay.

Table 26: 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 protection relay's settings.

Binary inputs of slot X110 are optional with configurations A and B.

Table 27: Binary input terminals X110:1-13 with BIO0005 module

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	BI7, +

Table continues on next page

Terminal	Description
X110:12	BI7, -
X110:12 X110:13	BI8, - BI8, +

Table 28: Binary input terminals X110:1-10 with BIO0007 module

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

Optional binary inputs of slot X130 are available with configuration A.

Table 29: Optional binary input terminals X130:1-9 with BIO0006 module

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, +

Optional binary inputs of slot X130 are available with configuration B.

Table 30: Optional binary input terminals X130:1-8 with AIM0006 module

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

5.1.4 Optional light sensor inputs

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

The protection relay 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 a protection relay, the light sensor inputs are included in the communication module.

Table 31: Light sensor input connectors

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

5.1.5 RTD/mA inputs

It is possible to connect mA and RTD based measurement sensors to the protection relay, if the protection relay is provided with optional RTD0001 module in standard configuration A and with AIM0003 module in standard configuration B.

Table 32: Optional RTD/mA inputs for standard configuration A

Terminal	Description
X130:1 X130:2	mA1 (AI1), + mA1 (AI1), -
X130:3 X130:4	mA2 (AI2), + mA2 (AI2), -
X130:5 X130:6	RTD1 (AI3), + RTD1 (AI3), -
X130:7 X130:8	RTD2 (AI4), + RTD2 (AI4), -
X130:9 X130:10	RTD3 (AI5), + RTD3 (AI5), -
X130:11 X130:12	Common1) Common2)
X130:13 X130:14	RTD4 (AI6), + RTD4 (AI6), -
X130:15 X130:16	RTD5 (AI7), + RTD5 (AI7), -
X130:17 X130:18	RTD6 (AI8), + RTD6 (AI8), -

1) Common ground for RTD channels 1-3
2) Common ground for RTD channels 4-6

Table 33: Optional RTD/mA inputs for standard configuration B

Terminal	Description
X130:1 X130:2	mA 1 (AI1), + mA 1 (AI1), -
X130:3 X130:4 X130:5	RTD1 (AI2), + RTD1 (AI2), - RTD1 (AI2), ground
X130:6 X130:7 X130:8	RTD2 (AI3), + RTD2 (AI3), - RTD2 (AI3), ground

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.

Table 34: Output contacts

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

5.2.2 Outputs for signalling

SO output contacts can be used for signalling on start and tripping of the protection relay.

Table 35: 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

Table 36: Output contacts X110:14-24 with BIO0005

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

Table continues on next page

Terminal	Description
X110:22	SO3, NC
X110:23	SO4, common
X110:24	SO4, NO

Table 37: Optional high-speed output contacts X110:15-24 with BIO0007

Terminal	Description
X110:15	HSO1, NO
X110:16	HSO1, NO
X110:19	HSO2, NO
X110:20	HSO2, NO
X110:23	HSO3, NO
X110:24	HSO3, NO

Output contacts of slot X130 are available in the optional BIO module (BIO0006).

Output contacts of slot X130 are optional for configuration A.

Table 38: 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 relay. Under normal operating conditions, the protection relay 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 contact X100:3-5 drops off and the contact X100:3-4 closes.

Table 39: 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 protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
AC	Alternating current
AI	Analog input
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
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
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
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
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IED	Intelligent electronic device
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
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
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
MMS	1. Manufacturing message specification 2. Metering management system
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
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager

PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit
SAN	Single attached node
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
SMV	Sampled measured values
SNTP	Simple Network Time Protocol
SO	Signal output
TCS	Trip-circuit supervision
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

ABB Distribution Solutions
Distribution Automation
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

ABB Distribution Automation
Maneja Works
Vadodara-390013, India
Phone +91 265 2604386
Fax +91 265 2638922

www.abb.com/mediumvoltage
www.abb.com/relion
www.abb.com/substationautomation

1MRS757946 D