RELION® 615 SERIES

Transformer Protection and Control
RET615
Application Manual

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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

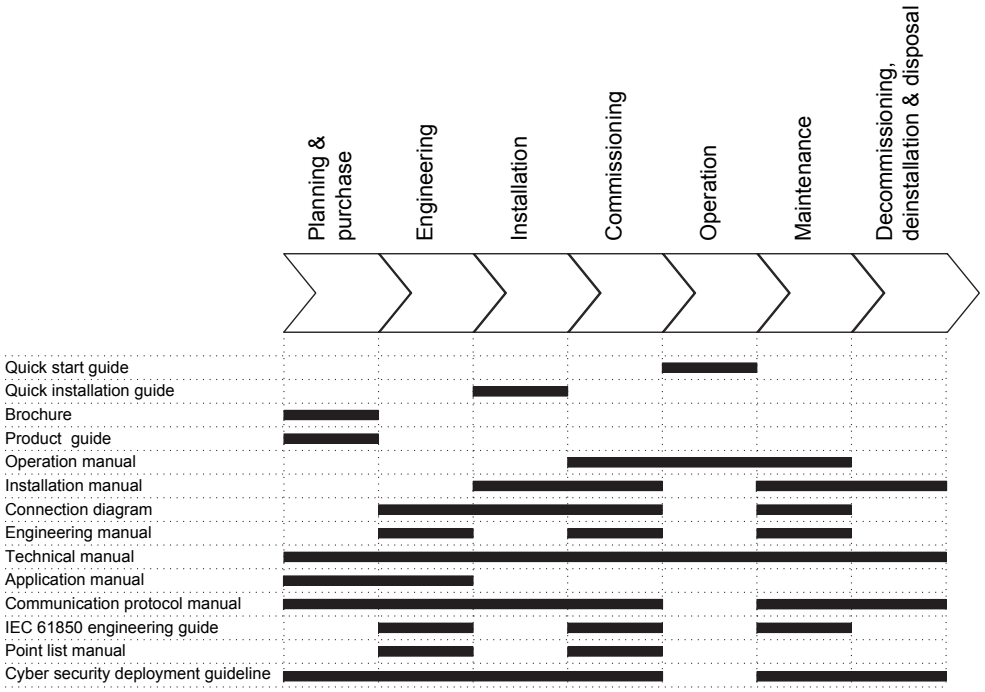


Figure 1: The intended use of documents during the product life cycle

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/2009-07-03	2.0	First release
B/2009-10-29	2.0	Content updated
C/2010-06-11	3.0	Content updated to correspond to the product version
D/2010-06-29	3.0	Terminology updated
E/2010-09-24	3.0	Content updated
F/2012-05-11	4.0	Content updated to correspond to the product version
G/2013-02-21	4.0 FP1	Content updated to correspond to the product version

Table continues on next page

Document revision/date	Product version	History
H/2014-01-24	5.0	Content updated to correspond to the product version
K/2015-10-30	5.0 FP1	Content updated to correspond to the product version
L/2016-05-20	5.0 FP1	Content updated
M/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)
	PHLPTOC2	3I> (2)	51P-1 (2)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
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)
	PHIPTOC2	3I>>> (2)	50P/51P (2)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
	EFHPTOC2	Io>> (2)	51N-2 (2)
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)
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)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T/G/C (1)
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF1	3dI>T (1)	87T (1)
Numerically stabilized low-impedance restricted earth-fault protection	LREFPNDF1	dIoLo> (1)	87NL (1)
High-impedance based restricted earth-fault protection	HREFPDIF1	dIoHi> (1)	87NH (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)
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)
Tap changer position indication	TPOSYLTC1	TPOSM (1)	84M (1)
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)
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)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
	CMMXU2	3I (2)	3I (2)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
	RESCMMXU2	Io (2)	In (2)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
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)
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)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
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 RET615 overview

2.1 Overview

RET615 is a dedicated transformer protection and control relay for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems. RET615 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. 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
2.0	Product released
3.0	• New configurations E, F, G and H • Additions to configuration A, B, C and D • Application configurability support • Analog GOOSE support • Large display with single line diagram • Enhanced mechanical design • Increased maximum amount of events and fault records • Frequency measurement and protection • RTD/mA measurement and protection • Voltage measurement and protection • Fuse failure supervision • Three-phase power and energy measurements • Multi-port Ethernet option
4.0	• Additions/changes for configurations A-H • Dual fiber optic Ethernet communication option (COM0032) • Generic control point (SPCGGIO) function blocks • Additional logic blocks • Button object for SLD • Controllable disconnector and earth switch objects for SLD • Additional multi-purpose protection instances • Increased maximum amount of events and fault records

Table continues on next page

Product version	Product history
4.0 FP1	• High-availability seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • Parallel use of IEC 61850 and DNP3 protocols • Parallel use of IEC 61850 and IEC 60870-5-103 protocols • Two selectable indication colors for LEDs (red or green) • Online binary signal monitoring with PCM600
5.0	• New layout in Application Configuration tool for all configurations • Support for IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • Load profile recorder • High-speed binary outputs • Optional RTD/mA inputs for configurations E-H • Profibus adapter support • Support for multiple SLD pages • Import/export of settings via WHMI • Setting usability improvements • HMI event filtering tool
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 • Additional timer, set-reset and analog value scaling functions • Frequency measurement

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) or later
- RET615 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
- Differential Characteristics Tool

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

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- RTD/mA measurements and multipurpose protection
- 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 unit	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...250 V 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)
Case	X130	AI/BI module	Only with configurations E, F, G and H: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
		AI/RTD/mA module	Only with configurations E, F, G and H: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA input 2 RTD sensor inputs
		Optional RTD/mA module	Optional for configurations A, B, C and D: 2 generic mA inputs 6 RTD sensor inputs
		Optional BIO module	Optional for configurations A, B, C and D: 6 binary inputs 3 SO contacts
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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 B C D	BA	BB	7	-	14	4 PO + 9 SO	-	-
		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
E F G H	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.

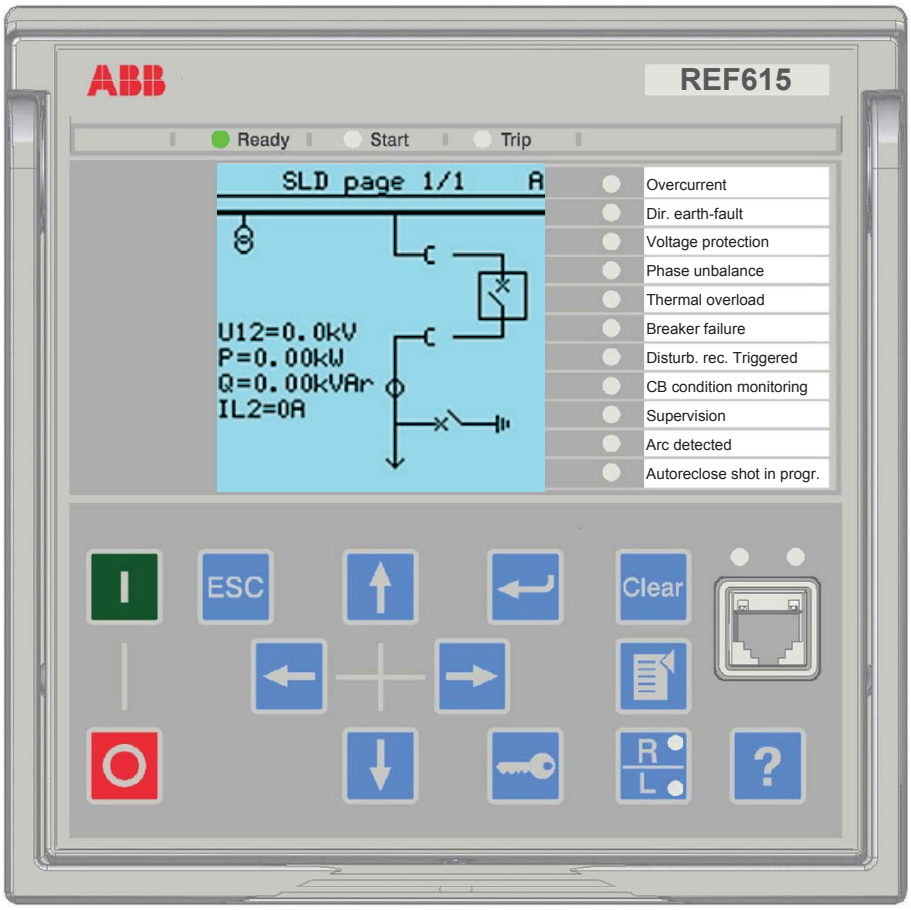


Figure 2: Example of the LHMI

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 size[1)]	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 size[1)]	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.

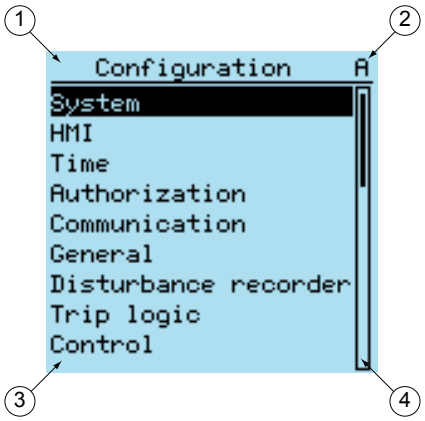


Figure 3: Display layout

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.

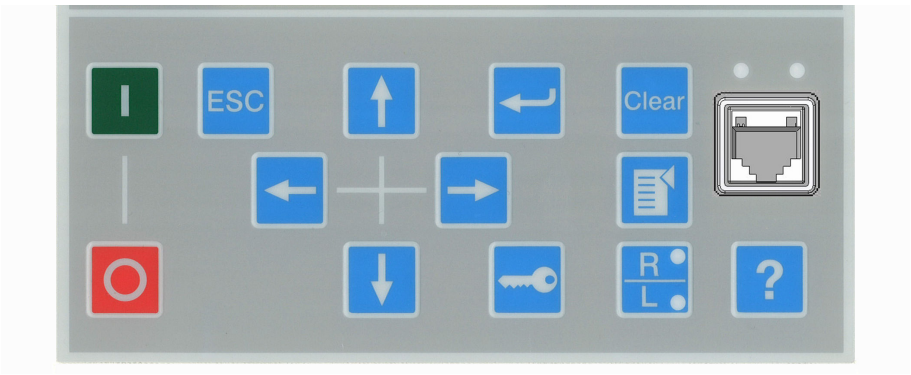


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

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.

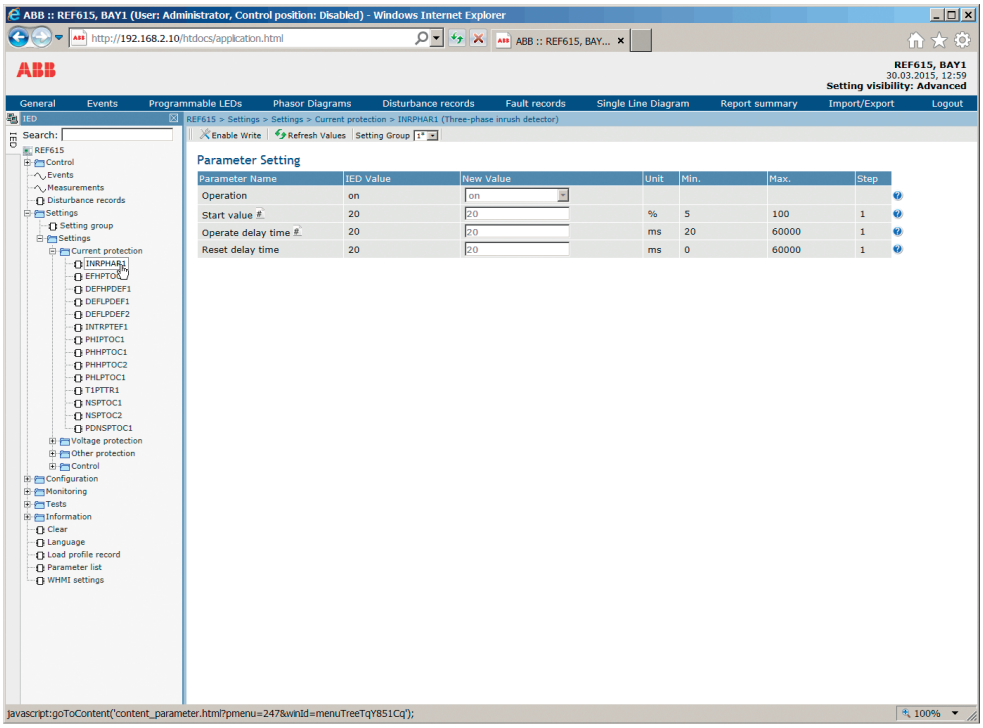


Figure 5: Example view of the WHMI

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. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber-optic LC connector (100Base-FX).

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.

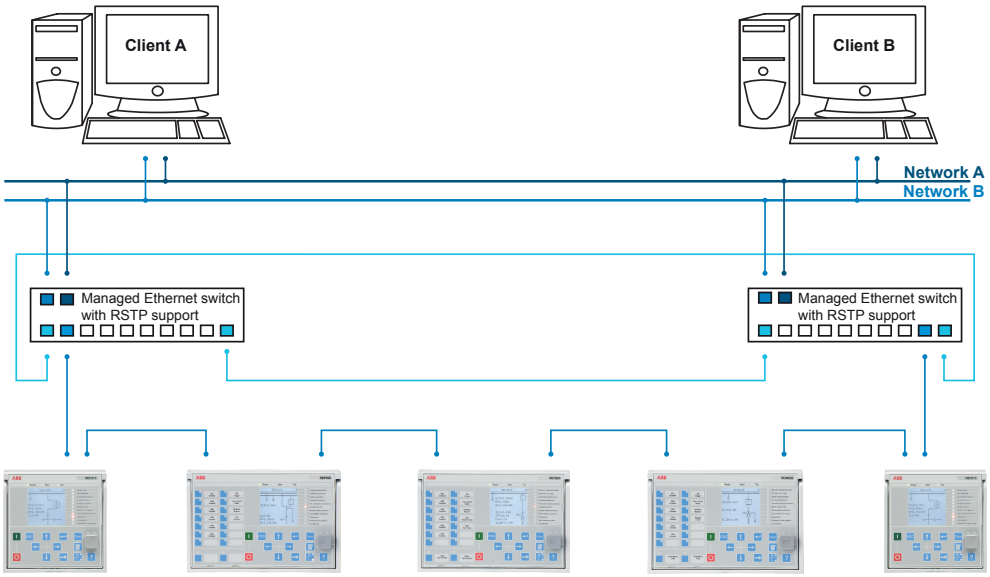


Figure 6: Self-healing Ethernet ring solution

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.

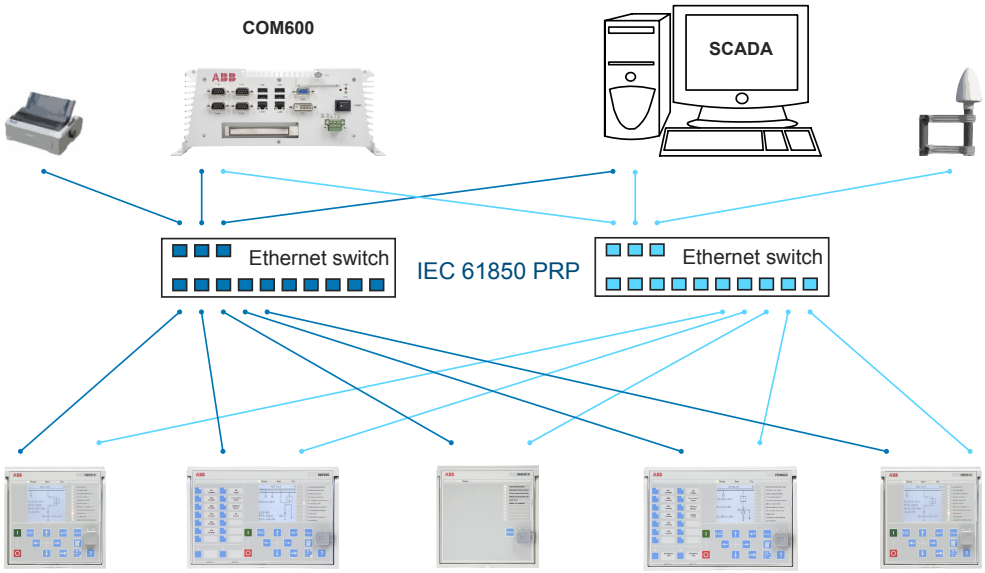


Figure 7: PRP solution

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.

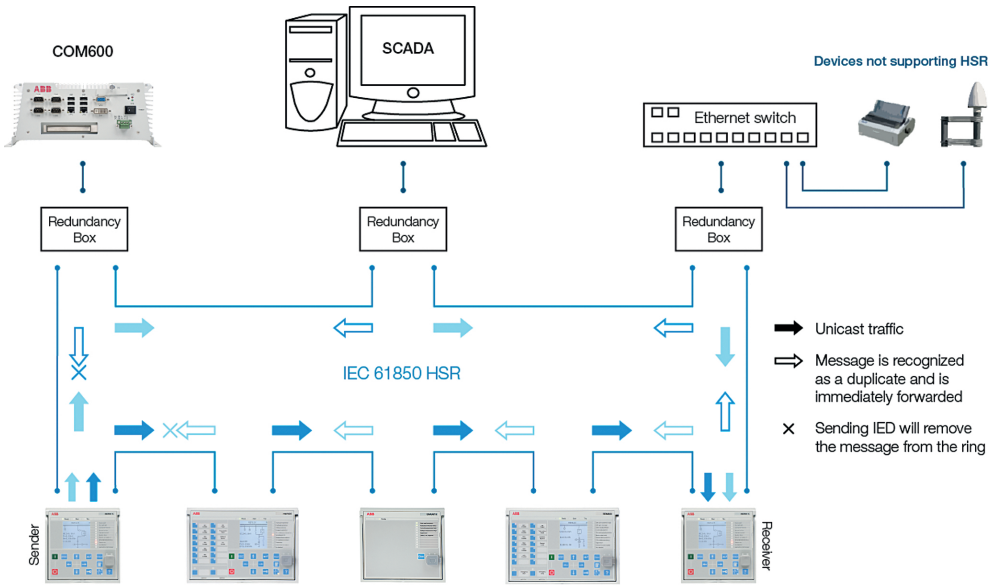


Figure 8: HSR solution

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.

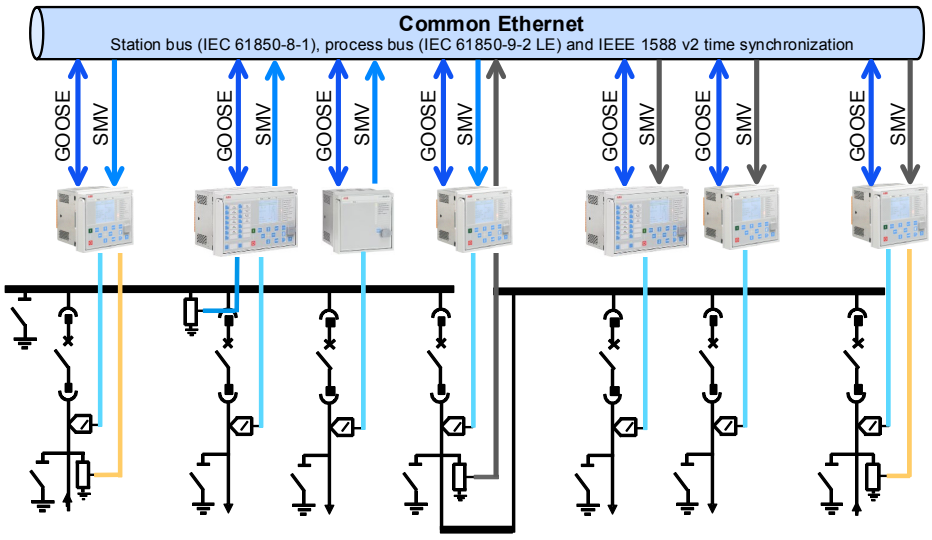


Figure 9: Process bus application of voltage sharing and synchrocheck

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.

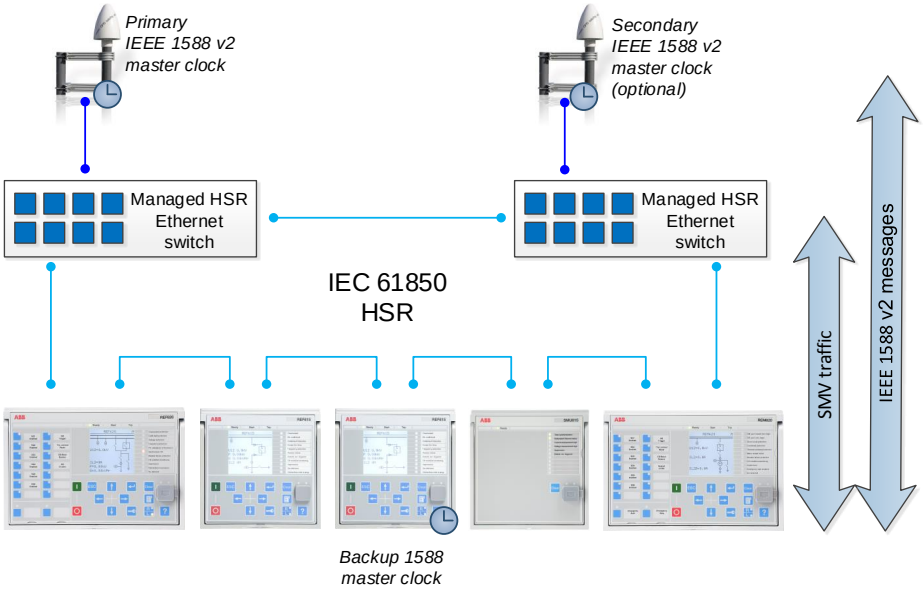


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

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 RET615 standard configurations

3.1 Standard configurations

RET615 is available with eight 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 utilizing 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 RET615 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.
Transformer differential with low-impedance restricted earth-fault protection on the HV side	A
Transformer differential with low-impedance restricted earth-fault protection on the LV side	B
Transformer differential with high-impedance restricted earth-fault protection on the HV side	C
Transformer differential with high-impedance restricted earth-fault protection on the LV side	D
Transformer differential with voltage protection and measurements, and low-impedance restricted earth-fault protection on the HV side	E
Transformer differential with voltage protection and measurements, and low-impedance restricted earth-fault protection on the LV side	F
Transformer differential with voltage protection and measurements, and high-impedance restricted earth-fault protection on the HV side	G
Transformer differential with voltage protection and measurements, and high-impedance restricted earth-fault protection on the LV side	H

Table 10: Supported functions

Function	IEC 61850	A	B	C	D	E	F	G	H
Protection									
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
	PHLPTOC2	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
	PHHPTOC2	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
	PHIPTOC2	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV
Non-directional earth-fault protection, low stage	EFLPTOC1	1 HV		1 HV 1)		1 HV		1 HV 1)	
	EFLPTOC2		1 LV		1 LV 2)		1 LV		1 LV 2)
Non-directional earth-fault protection, high stage	EFHPTOC1	1 HV		1 HV 1)		1 HV		1 HV 1)	
	EFHPTOC2		1 LV		1 LV 2)		1 LV		1 LV 2)
Negative-sequence overcurrent protection	NSPTOC1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
	NSPTOC2	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV
Residual overvoltage protection	ROVPTOV					2 HV	2 HV	2 HV	2 HV
Three-phase undervoltage protection	PHPTUV					2 HV	2 HV	2 HV	2 HV
Three-phase overvoltage protection	PHPTOV					2 HV	2 HV	2 HV	2 HV
Three-phase thermal overload protection, two time constants	T2PTTR	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF	1	1	1	1	1	1	1	1
Numerically stabilized low-impedance restricted earth-fault protection	LREFPNDF	1 HV	1 LV			1 HV	1 LV		
High-impedance based restricted earth-fault protection	HREFPDIF			1 HV	1 LV 3)			1 HV	1 LV 3)
Circuit breaker failure protection	CCBRBRF	1 HV 1)	1 HV 1)	1 HV 1)	1 HV 1)	1 HV 1)	1 HV 1)	1 HV 1)	1 HV 1)
Master trip	TRPPTRC	2 (3) 4)	2 (3) 4)	2 (3) 4)	2 (3) 4)	2 (3) 4)	2 (3) 4)	2 (3) 4)	2 (3) 4)
Arc protection	ARCSARC	(3) LV 5)	(3) LV 5)	(3) LV 5)	(3) LV 5)	(3) LV 5)	(3) LV 5)	(3) LV 5)	(3) LV 5)
Multipurpose protection	MAPGAPC	18	18	18	18	18	18	18	18
Control									
Circuit-breaker control	CBXCBR	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
Disconnector control	DCXSWI	2	2	2	2	2	2	2	2
Earthing switch control	ESXSWI	1	1	1	1	1	1	1	1
Disconnector position indication	DCSXSWI	3	3	3	3	3	3	3	3
Earthing switch indication	ESSXSWI	2	2	2	2	2	2	2	2
Tap changer position indication	TPOSYLTC	1	1	1	1	1	1	1	1
Condition monitoring and supervision									
Circuit-breaker condition monitoring	SSCBR	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
Trip circuit supervision	TCSSCBR	2	2	2	2	2	2	2	2
Fuse failure supervision	SEQSPVC					1	1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1	1	1	1	1	1
Measurement									
Disturbance recorder	RDRE	1	1	1	1	1	1	1	1
Load profile record	LDPRLRC	1	1	1	1	1	1	1	1
Fault record	FLTRFRC	1	1	1	1	1	1	1	1
Three-phase current measurement	CMMXU1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
	CMMXU2	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV	1 LV
Sequence current measurement	CSMSQI1	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV	1 HV
Residual current measurement	RESCMMXU1	1 HV		1 HV		1 HV		1 HV	
	RESCMMXU2		1 LV		1 LV		1 LV		1 LV
Three-phase voltage measurement	VMMXU					1 HV	1 HV	1 HV	1 HV

Table continues on next page

Function	IEC 61850	A	B	C	D	E	F	G	H
Residual voltage measurement	RESVMMXU					1 HV	1 HV	1 HV	1 HV
Sequence voltage measurement	VSMSQI					1 HV	1 HV	1 HV	1 HV
Three-phase power and energy measurement	PEMMXU					1 HV	1 HV	1 HV	1 HV
RTD/mA measurement	XRGGIO130	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Frequency measurement	FMMXU					1	1	1	1
IEC 61850-9-2 LE sampled value sending 6)7)	SMVSENDER					(1)	(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) 6)7)	SMVRCV					(1)	(1)	(1)	(1)
Other									
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4	4	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1	1	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1	1	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2	2	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4	4	4	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4	4	4	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4	4	4	4	4	4
Move (8 pcs)	MVGAPC	2	2	2	2	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2	2	2	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4	4	4	4	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1	1	1	1	1	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 HV = The function block is to be used on the high-voltage side in the application. LV = The function block is to be used on the low-voltage side in the application.									

1) "Io calculated" is always used.
2) IoB calculated is always used.
3) "IoB measured" is always used.
4) 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 in the configuration to the corresponding master trip input.
5) "IoB calculated" and "3IB" are always used.
6) Available only with IEC 61850-9-2
7) 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

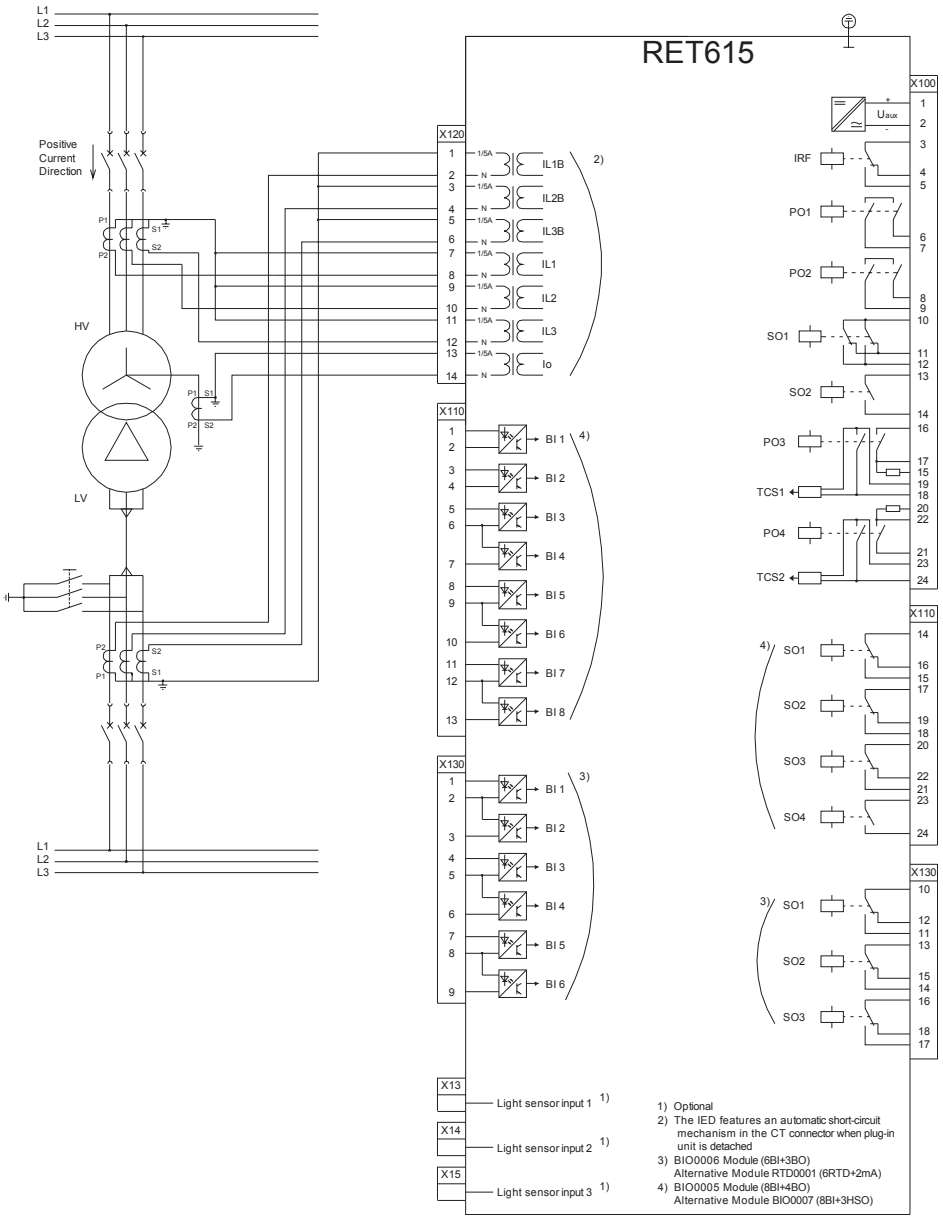


Figure 11: Connection diagram for the A configuration

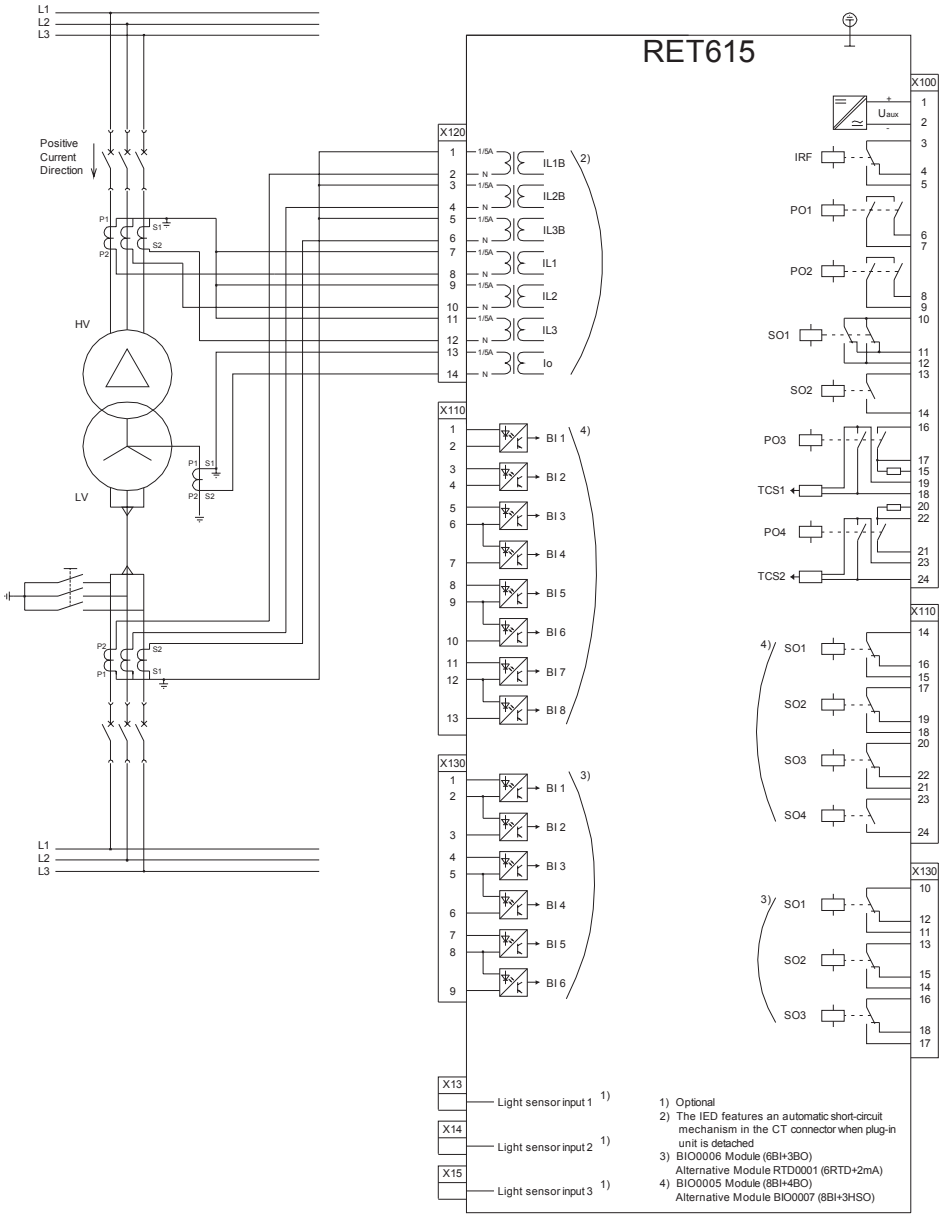


Figure 12: Connection diagram for the B configuration

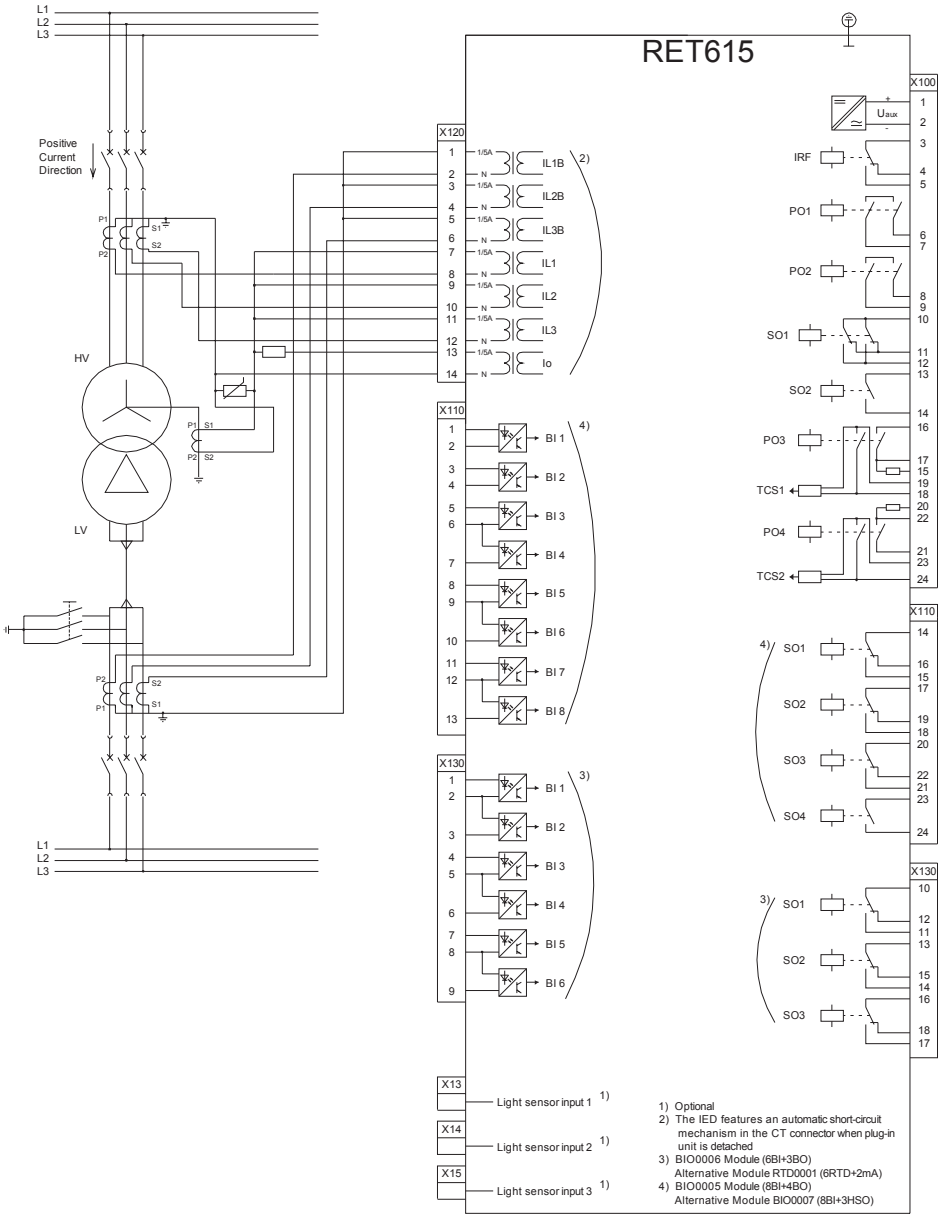


Figure 13: Connection diagram for the C configuration

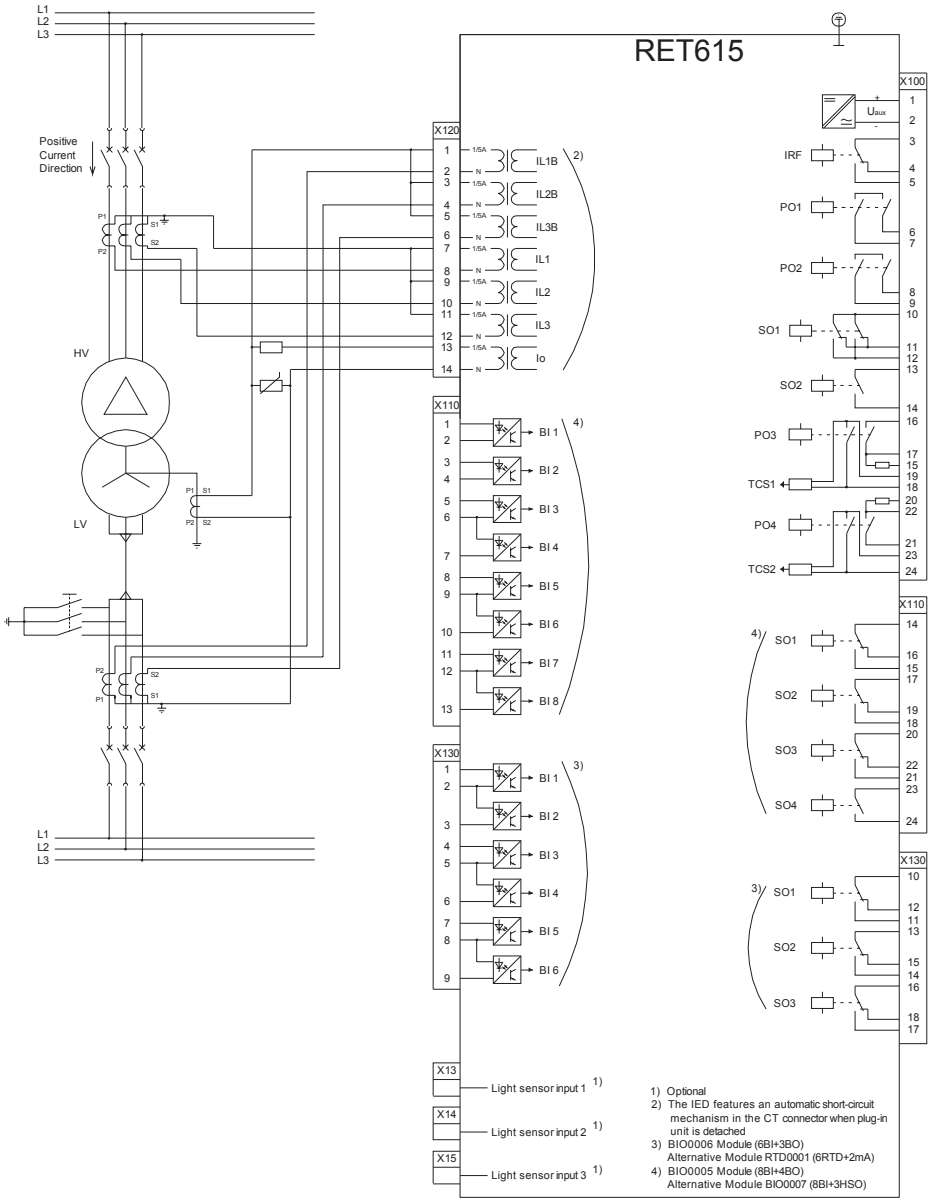


Figure 14: Connection diagram for the D configuration

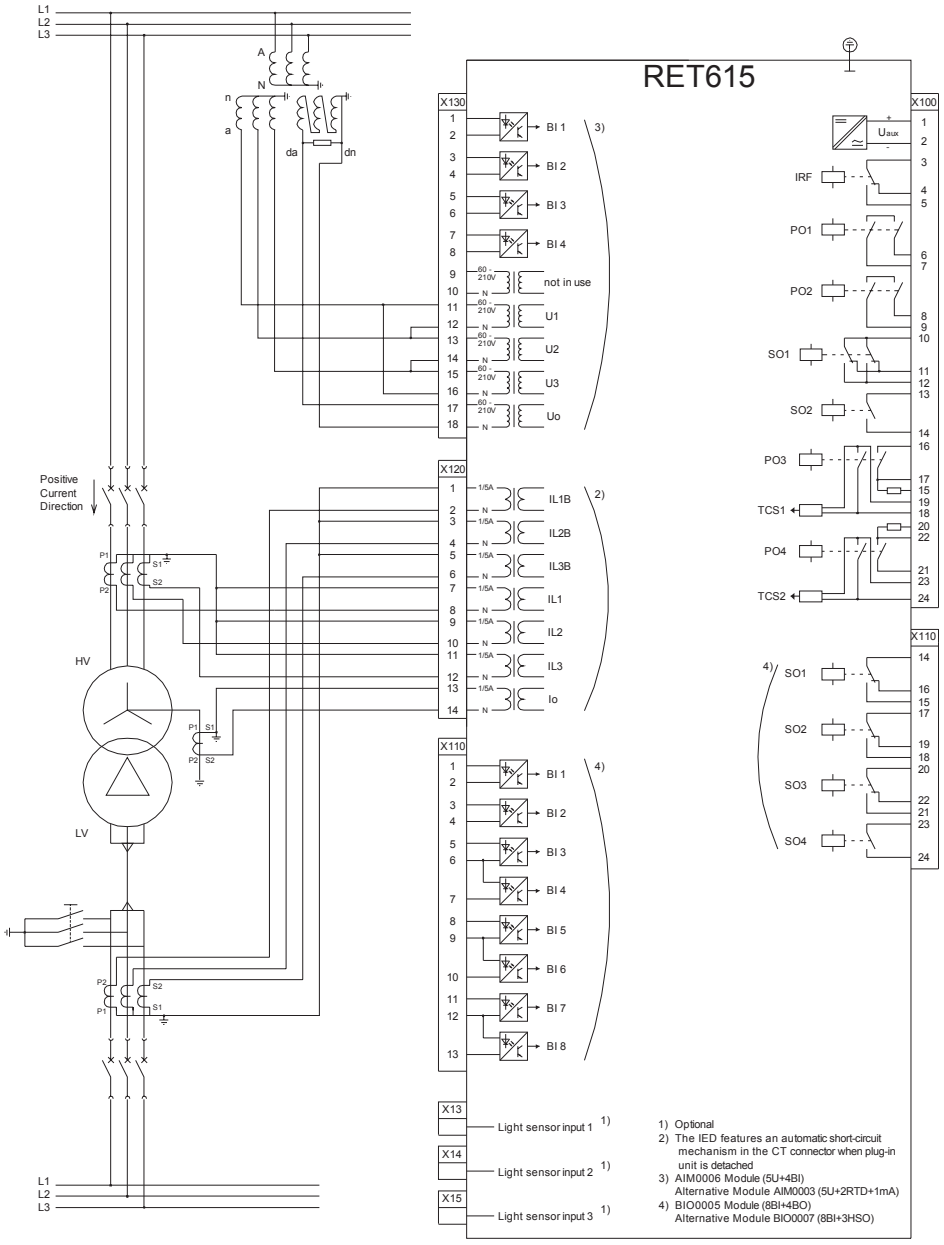


Figure 15: Connection diagram for the E configuration

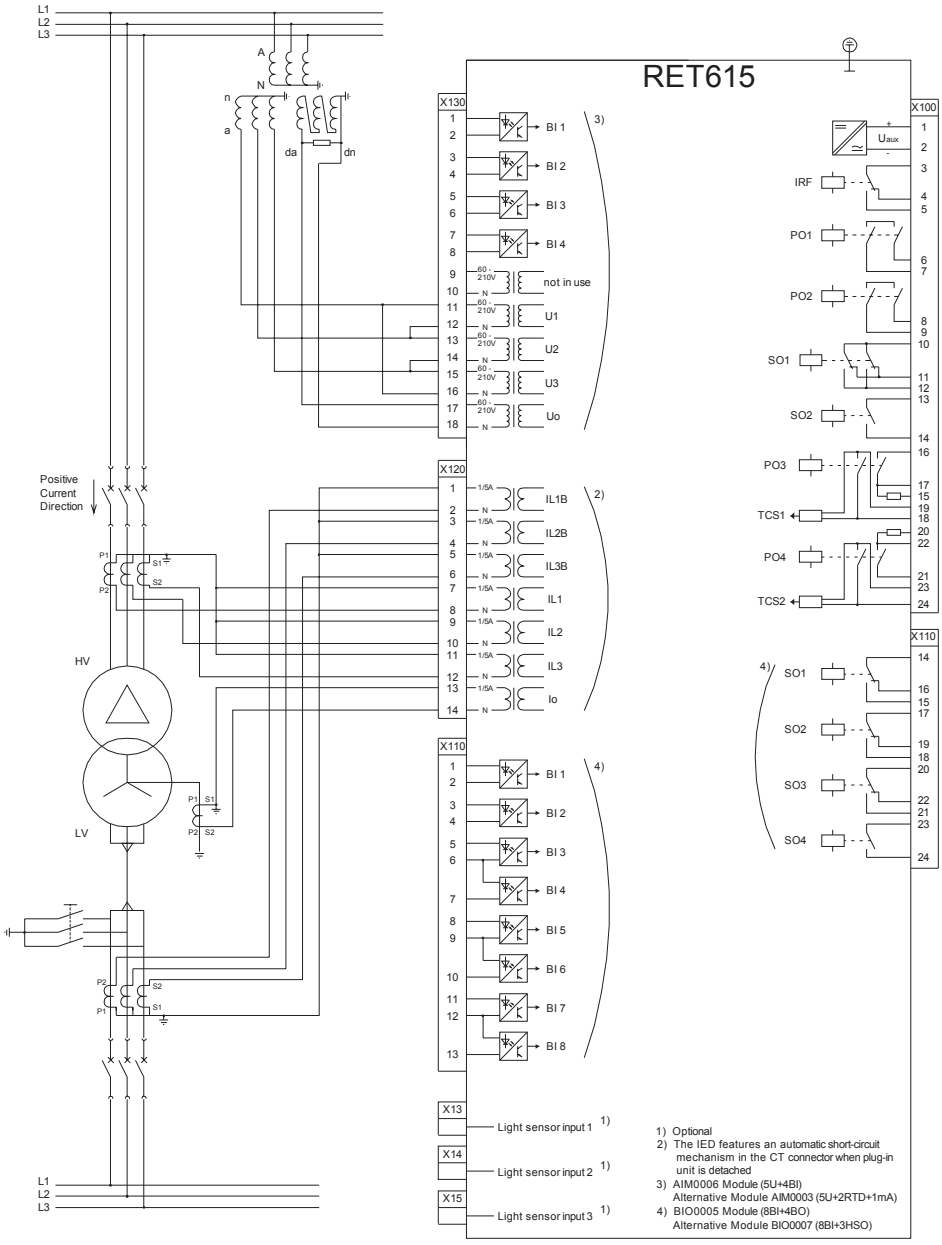


Figure 16: Connection diagram for the F configuration

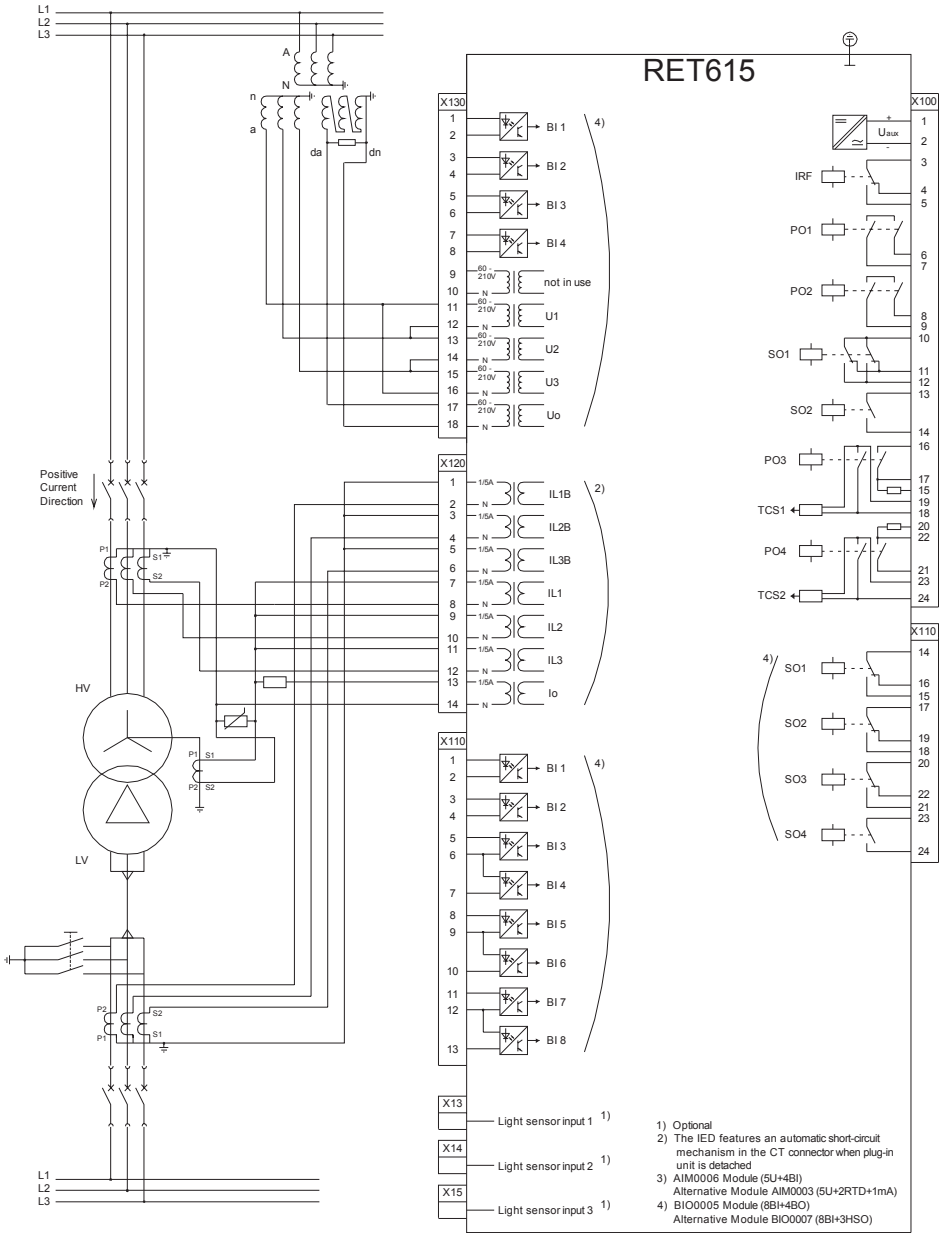


Figure 17: Connection diagram for the G configuration

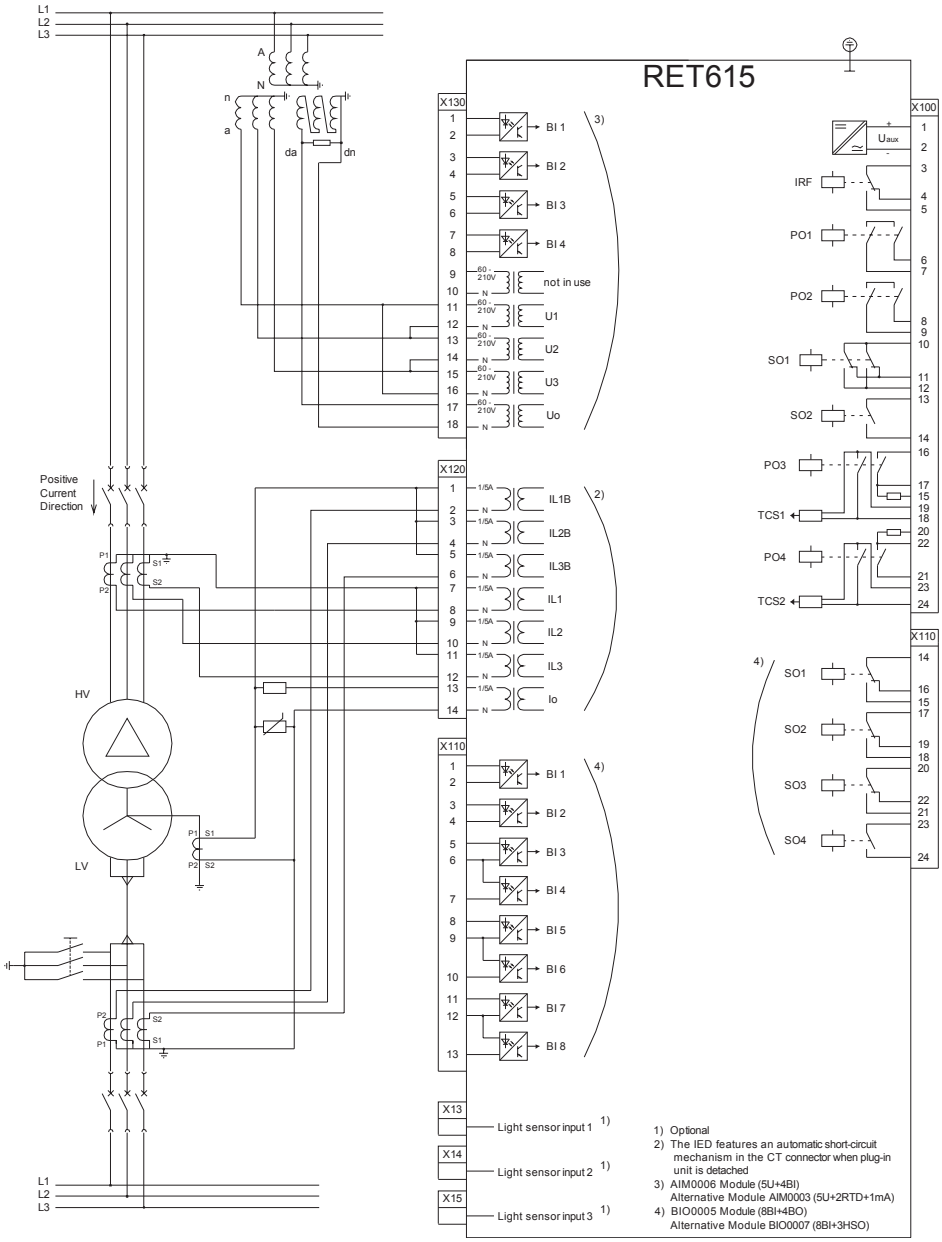


Figure 18: Connection diagram for the H configuration

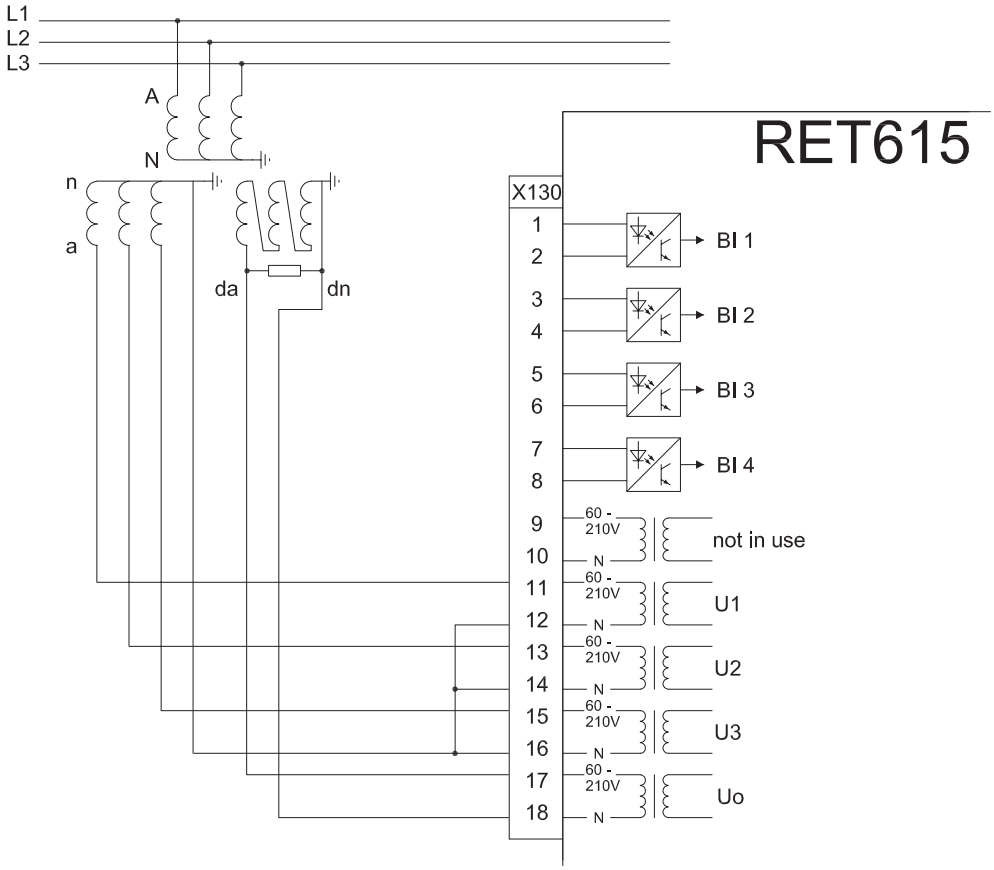


Figure 19: Connection diagram for the E, F, G and H configurations (transformer current differential protection with phase-to-earth voltage protection and measurement)

3.3 Standard configuration A

3.3.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and numerical restricted earth-fault protection for the high-voltage (HV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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

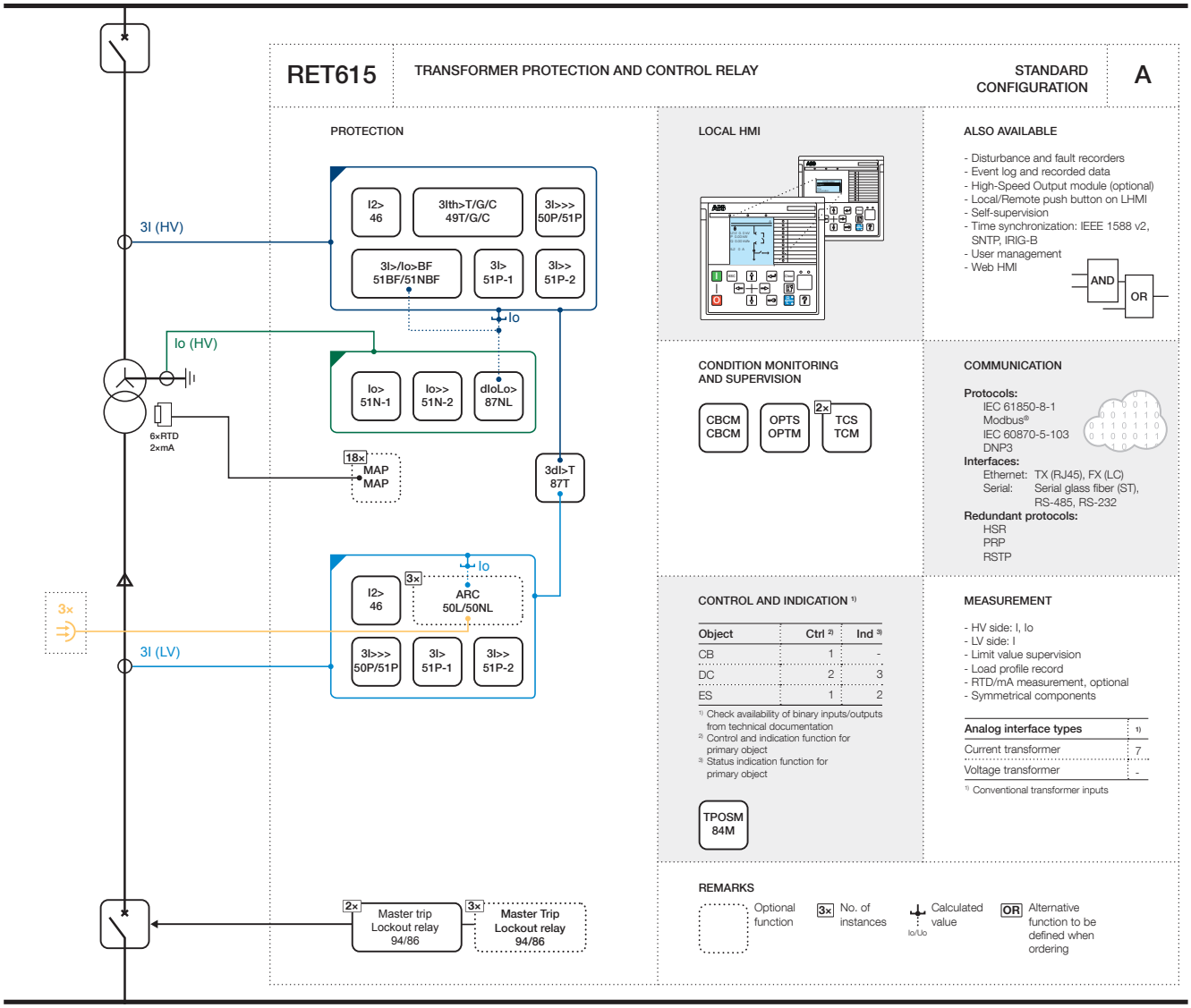


Figure 20: Functionality overview for standard configuration A

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	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	BCD sign bit (tap changer position)
X130-BI2	BCD bit 0 (LSB)
X130-BI3	BCD bit 1
X130-BI4	BCD bit 2
X130-BI5	BCD bit 3
X130-BI6	BCD bit 4 (MSB)

Table 12: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 13: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth-fault operate alarm

Table continues on next page

Binary output	Description
X110-SO4	Thermal overload and negative phase-sequence 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 14: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Non-directional overcurrent protection operate
4	Restricted earth-fault protection operate
5	Earth-fault protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.3.2.2 Default disturbance recorder settings

Table 15: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8	-
9	-
10	-
11	-
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 16: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC1 - start	Positive or Rising
8	EFLPTOC1 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	LREFPNDF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	CCBRBRF1 - trret	Level trigger off
14	CCBRBRF1 - trbu	Level trigger off
15	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
16	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
17	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
18	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
19	TR2PTDF1 - operate	Positive or Rising
20	TR2PTDF1 - opr LS	Level trigger off
21	TR2PTDF1 - opr HS	Level trigger off
22	TR2PTDF1 - blkd2h	Level trigger off
23	TR2PTDF1 - blkd5h	Level trigger off
24	TR2PTDF1 - blkdwav	Level trigger off
25	LREFPNDF1 - operate	Level trigger off
26	T2PTTR1 - operate	Level trigger off
27	T2PTTR1 - alarm	Level trigger off
28	T2PTTR1 - blk close	Level trigger off
29	X110BI1 - ext OC blocking	Level trigger off
30	X110BI2 - ext trip	Positive or Rising
31	X110BI7 - HVCB closed	Level trigger off
32	X110BI8 - HVCB opened	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	MDSOPT1 - alarm	Level trigger off
34	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
35	ARCSARC1 - operate	Positive or Rising
36	ARCSARC2 - operate	Positive or Rising
37	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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The protection relay offers six different setting groups which can be set based on 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 IED's protection functionality in detail and according to the factory set default connections.

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

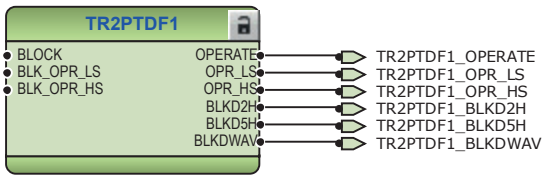


Figure 21: Differential protection

Three non-directional overcurrent stages are offered for each overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

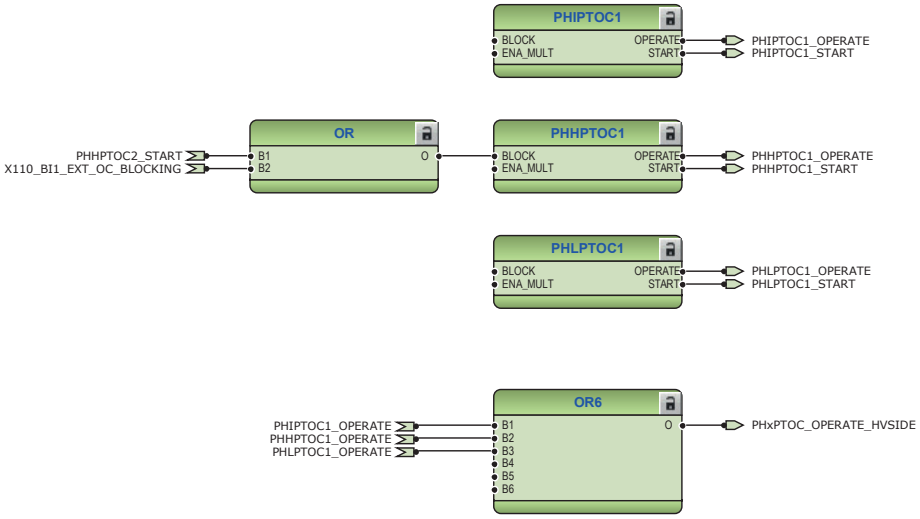


Figure 22: High-voltage side overcurrent protection function

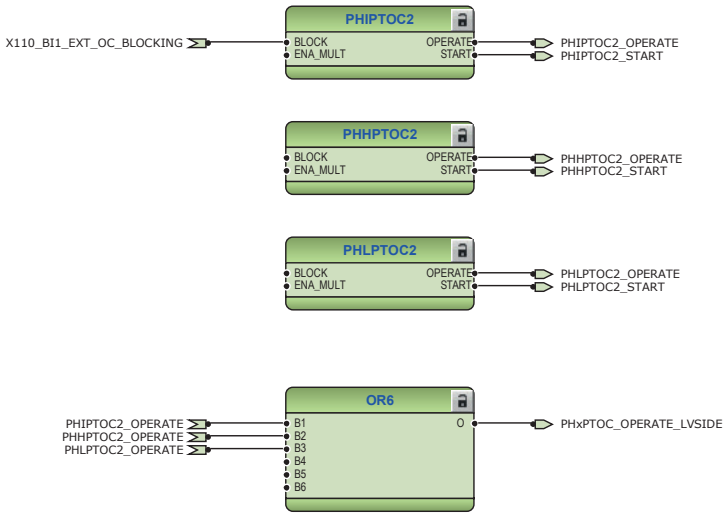


Figure 23: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from high-voltage side.

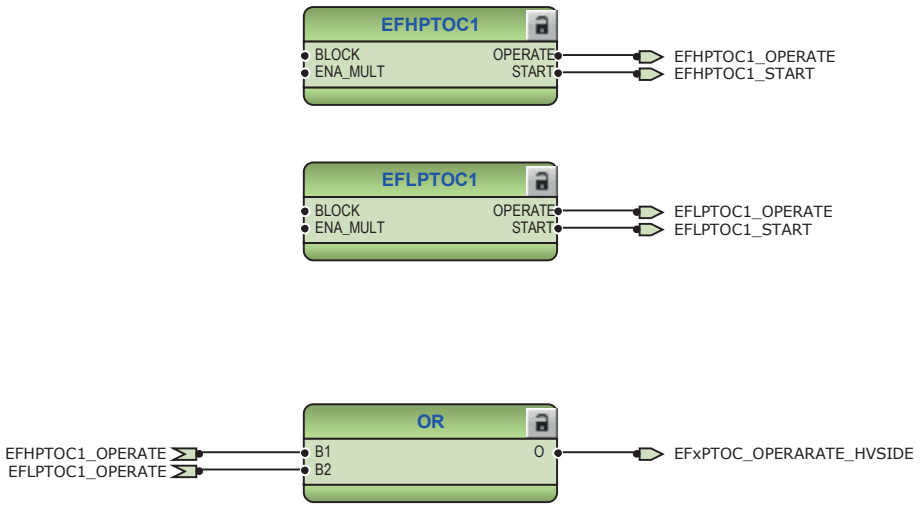


Figure 24: High-voltage side earth-fault protection

The configuration includes numerically stabilized low-impedance restricted earth-fault protection LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

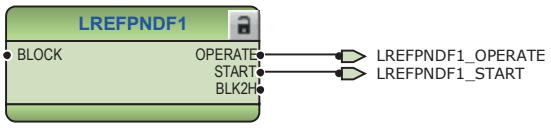


Figure 25: Restricted low-impedance earth-fault protection function

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

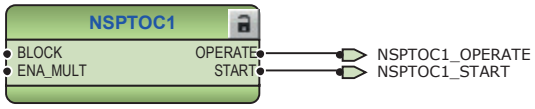


Figure 26: High-voltage side negative-sequence overcurrent protection function

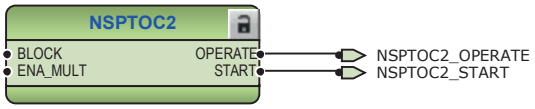


Figure 27: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overload conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. The disturbance recorder is connected in the configuration. If the IED is ordered with optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

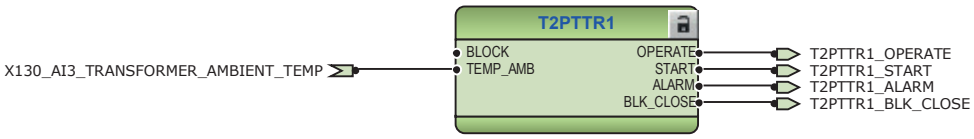


Figure 28: Thermal overcurrent protection function

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

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

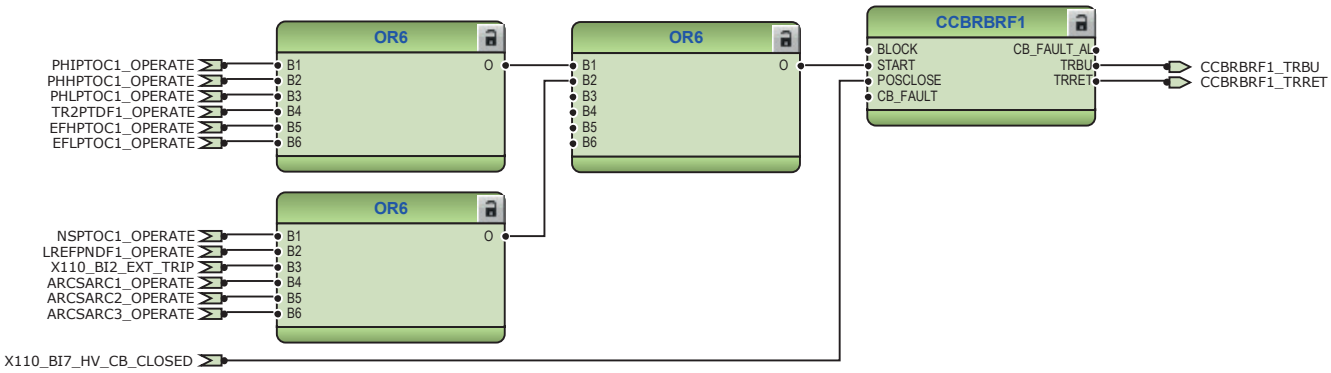


Figure 29: Circuit breaker failure protection function

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, with or without the phase and residual current check.

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

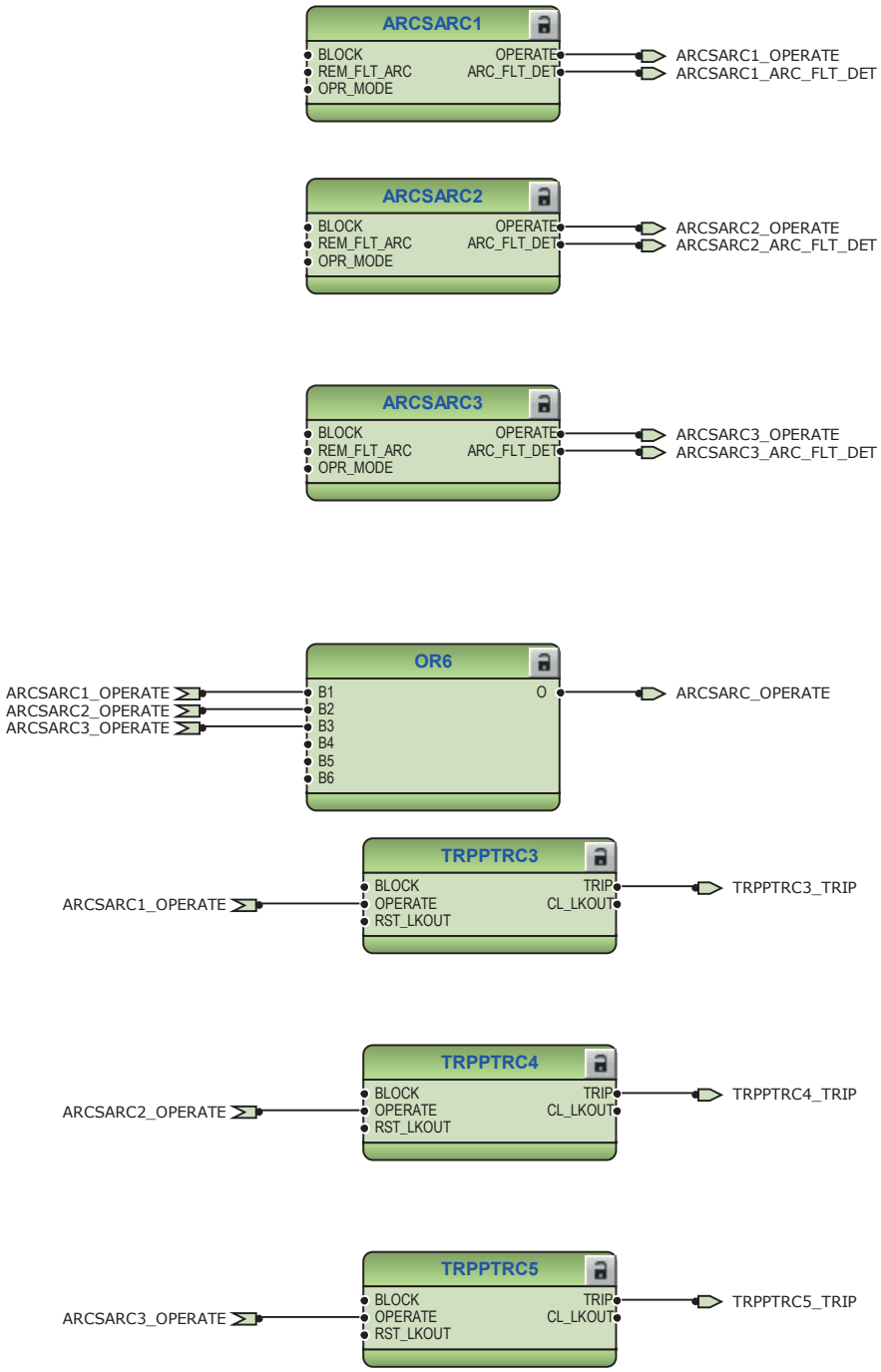


Figure 30: Arc protection with dedicated HSO

The generic operation time counter MDSOPT1 accumulates the operation time of the transformer.

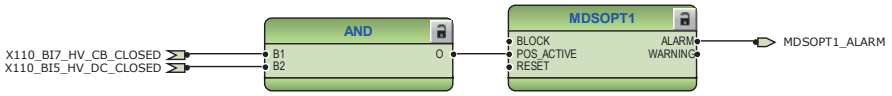


Figure 31: Operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

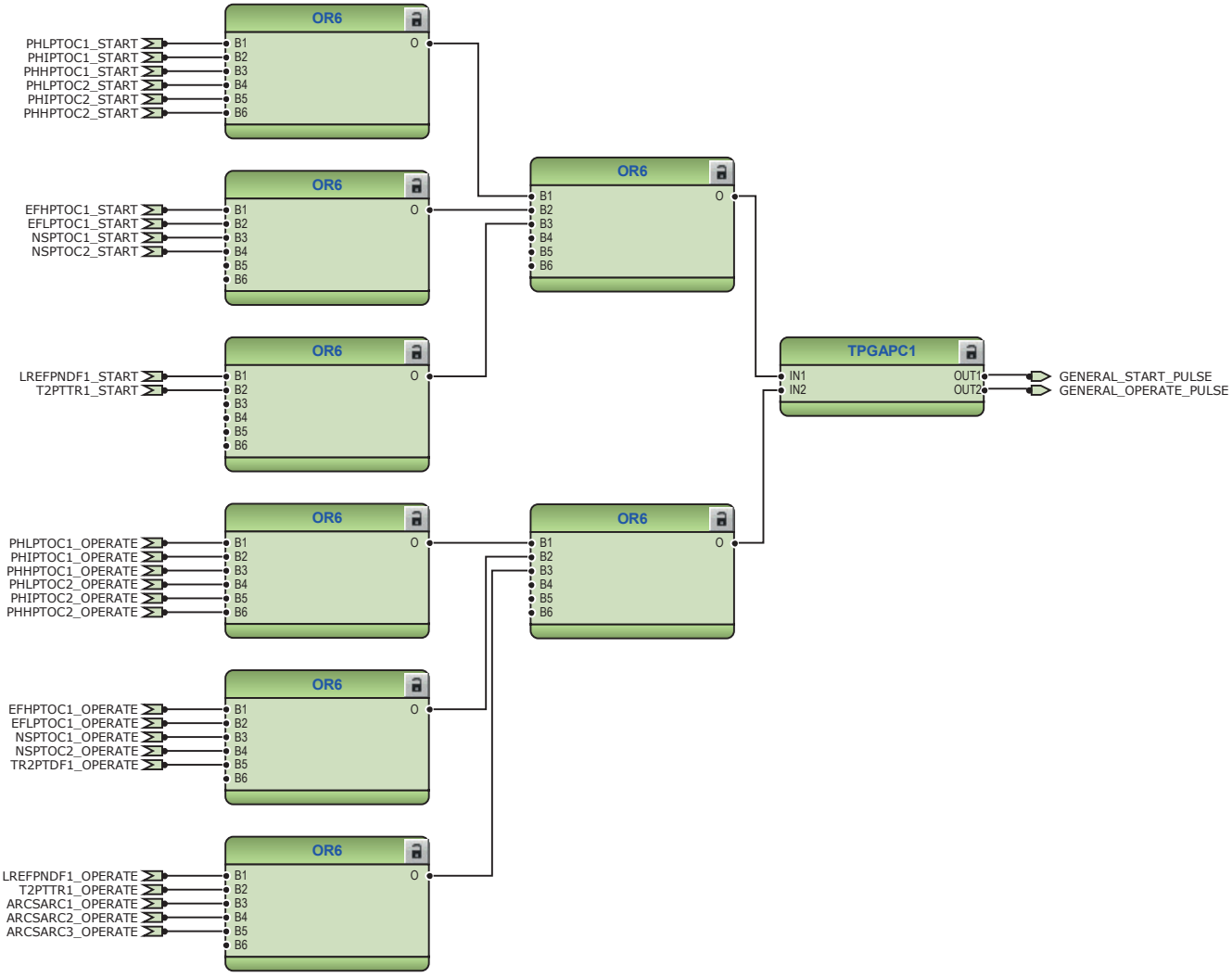


Figure 32: General start and operate signals

The operate signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open the circuit breaker on the high and low voltage sides respectively.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is

selected, binary input can be 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 IED is ordered with high speed binary outputs options.

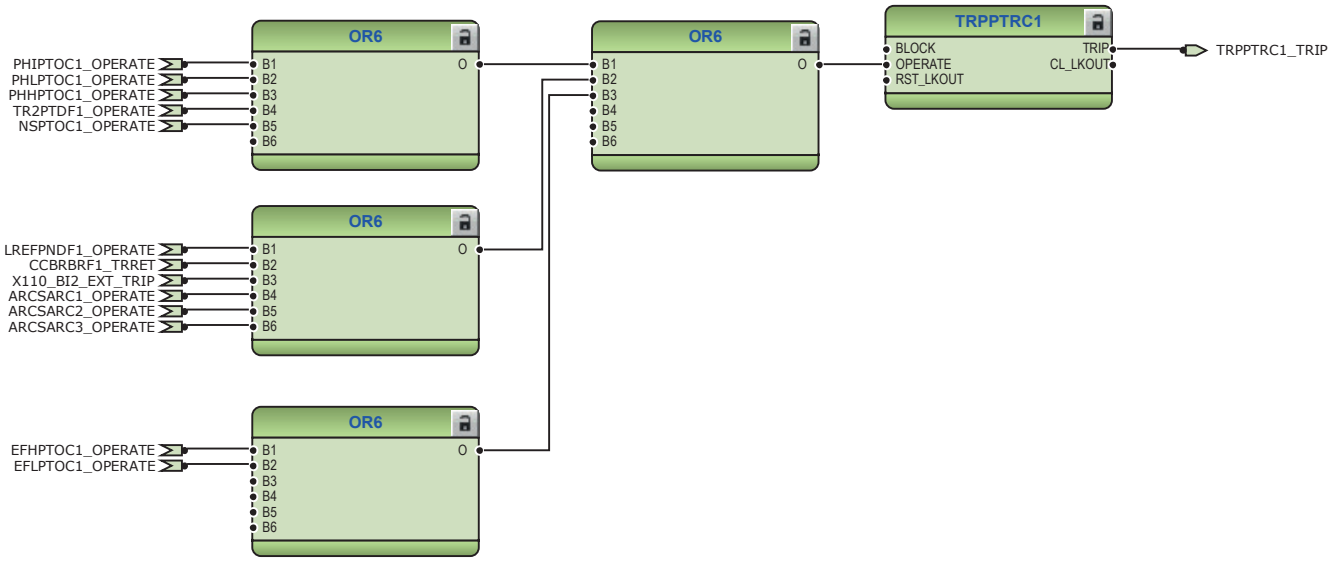


Figure 33: Trip logic TRPPTRC1

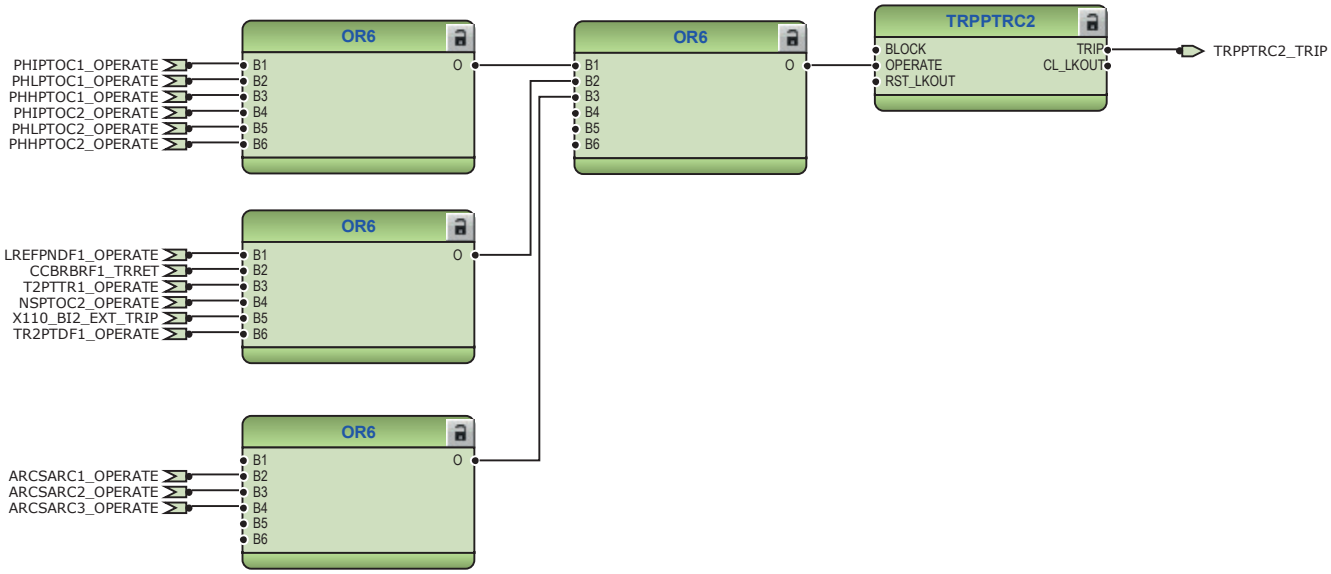


Figure 34: Trip logic TRPPTRC2

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 few binary inputs are also connected to the disturbance recorder.

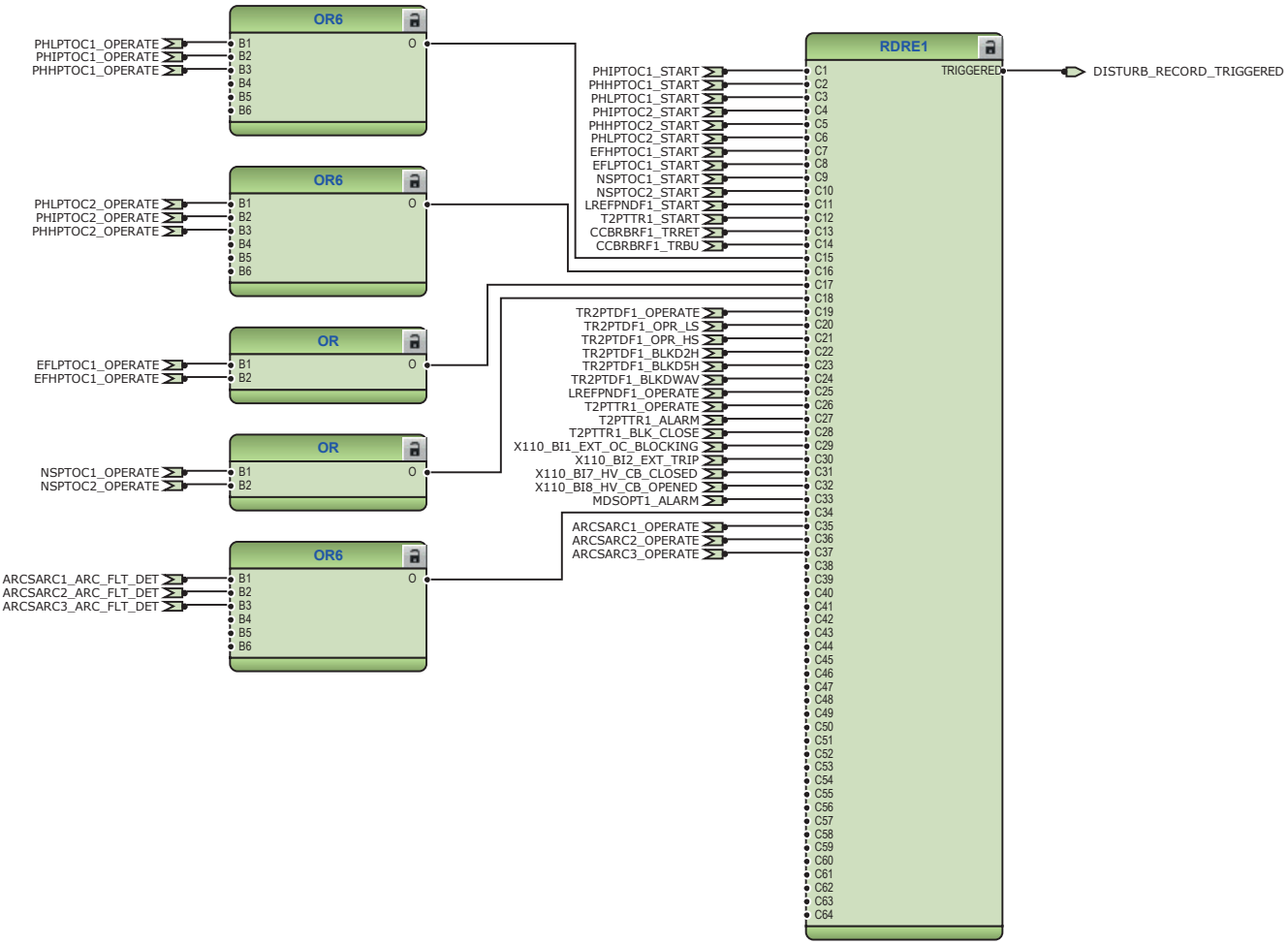


Figure 35: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

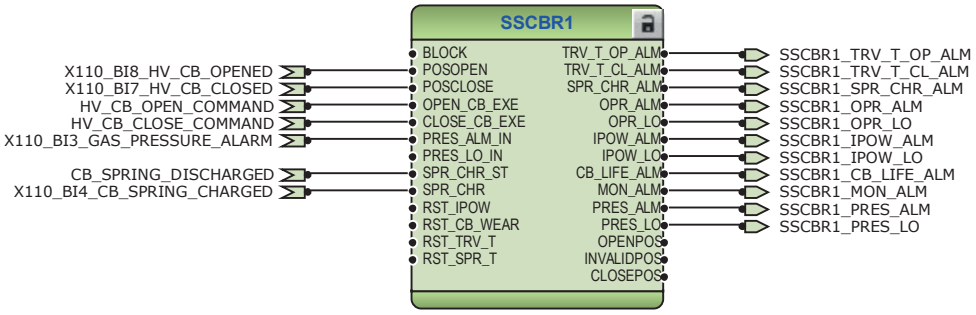


Figure 36: Circuit breaker condition monitoring function

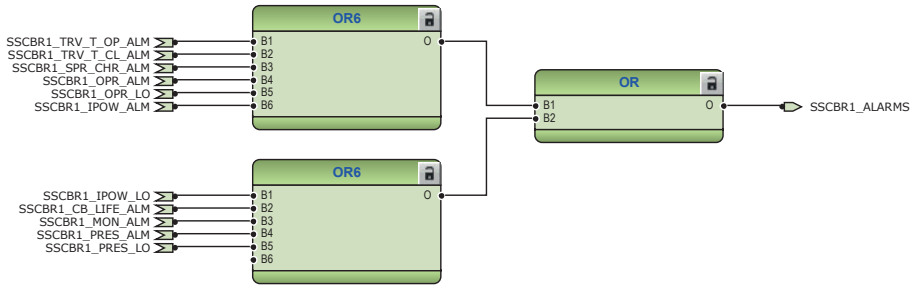


Figure 37: Logic for circuit-breaker monitoring alarm

Figure 38: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and the HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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.

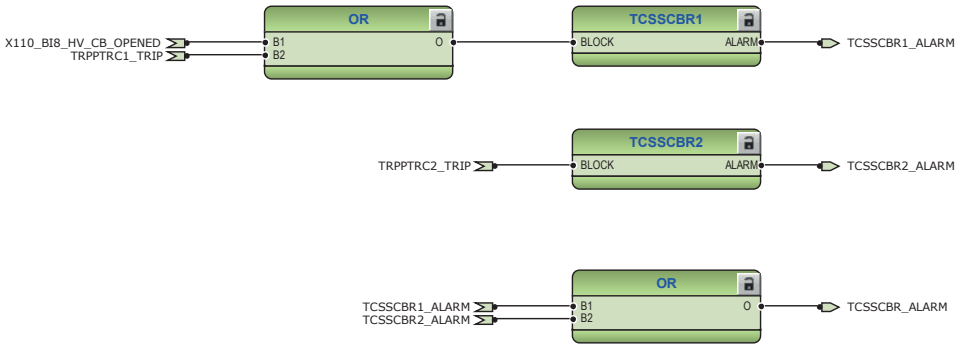


Figure 39: Trip circuit supervision function

3.3.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are 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) status information is connected to DCSXSWI1.

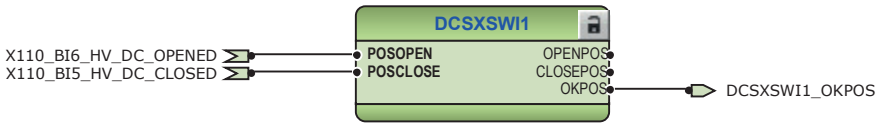


Figure 40: Disconnector control logic

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 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 closed (in service position). This output together with the 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

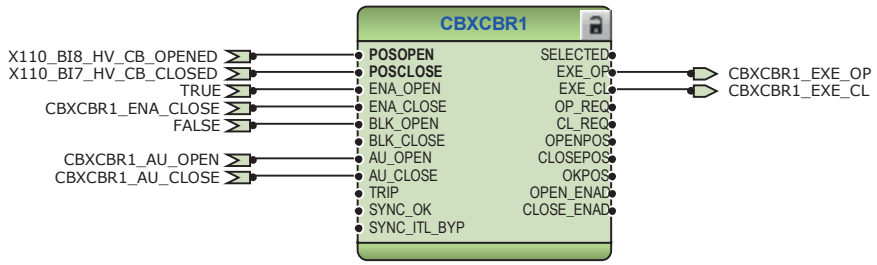


Figure 41: High-voltage side circuit breaker control logic: Circuit breaker 1

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

Figure 42: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker

Figure 43: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker

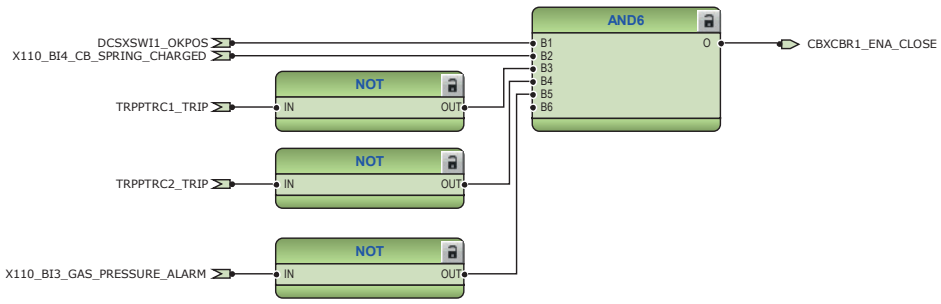


Figure 44: High-voltage side circuit breaker close enable logic

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.

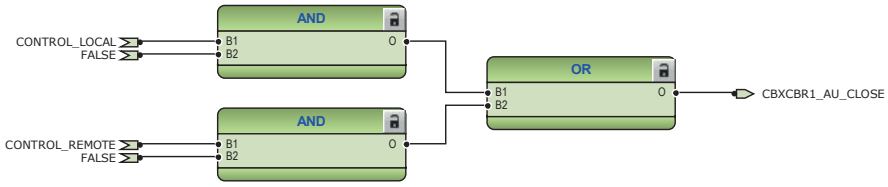


Figure 45: External closing command for circuit breaker

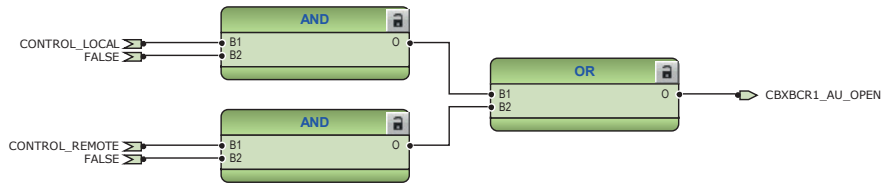


Figure 46: External opening command for circuit breaker

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used, TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters for TPOSYLTC1 properly.

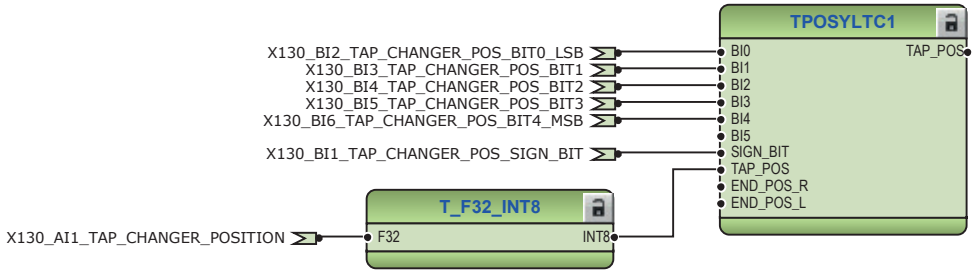


Figure 47: Tap changer position indicator

3.3.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. 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 from high-voltage side.

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.

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

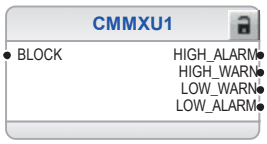


Figure 48: Current measurement: Three-phase current measurement (HV side)

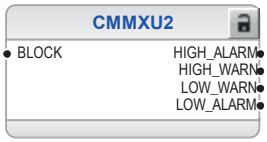


Figure 49: Current measurement: Three-phase current measurement (LV side)

Figure 50: Current measurement: Sequence current measurement (HV side)

Figure 51: Current measurement: Residual current measurement (HV side)

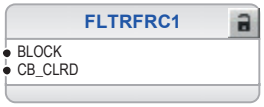


Figure 52: Other measurement: Data monitoring

Figure 53: Other measurement: Load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

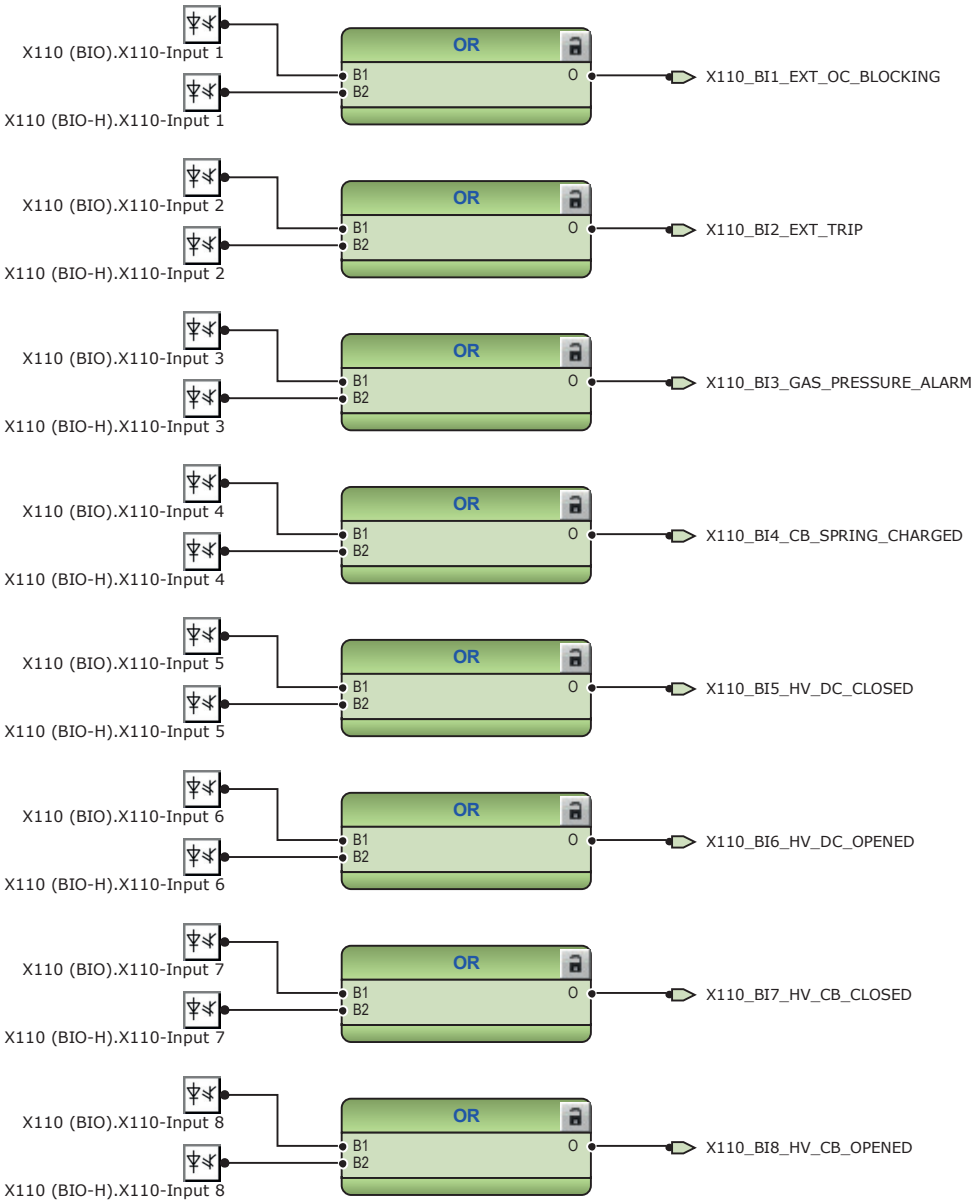


Figure 54: Binary inputs - X110 terminal block

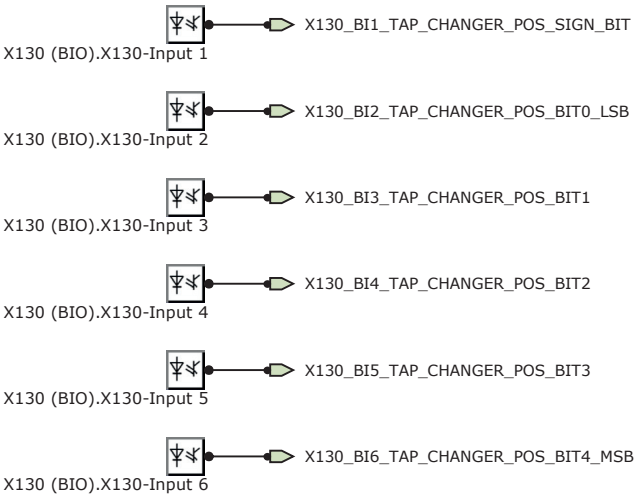


Figure 55: Binary inputs - X130 terminal block

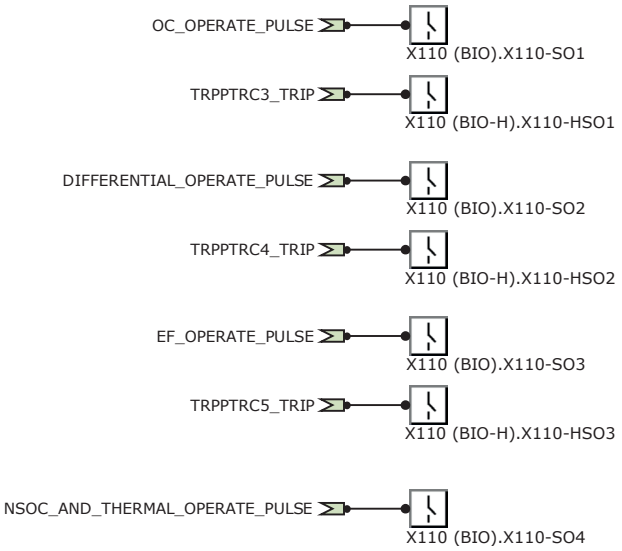


Figure 56: Binary outputs - X110 terminal block

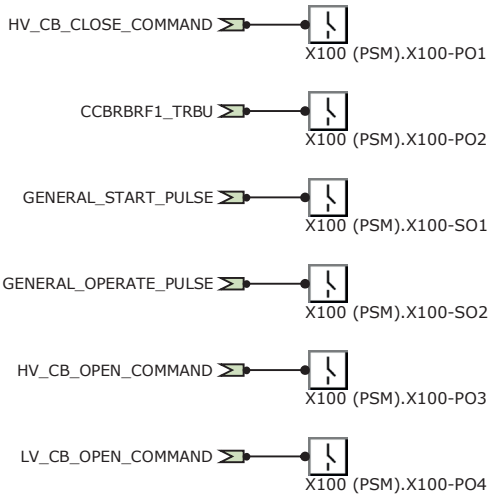


Figure 57: Binary outputs - X100 terminal block

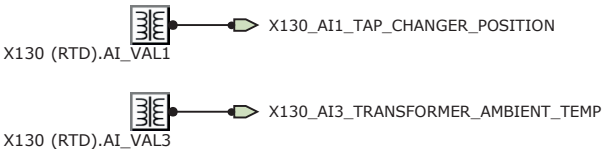


Figure 58: Default mA/RTD inputs X130

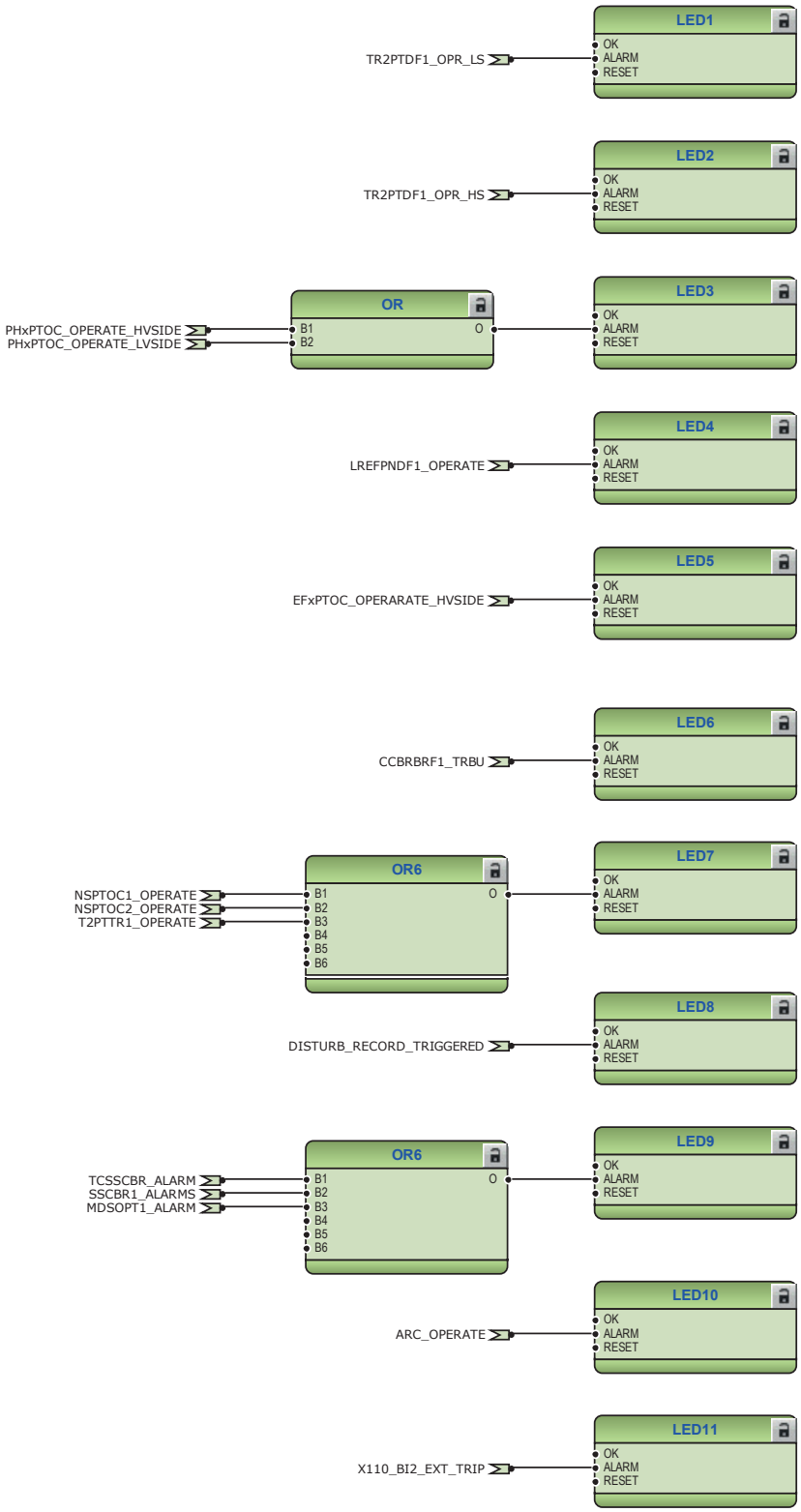


Figure 59: Default LED connection

3.3.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, differential operate, earth-fault operate and combined negative-sequence and thermal overload operate logic. 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.

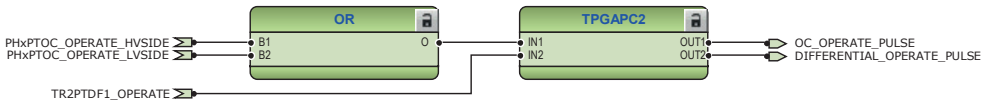


Figure 60: Timer logic for overcurrent and differential operate pulse

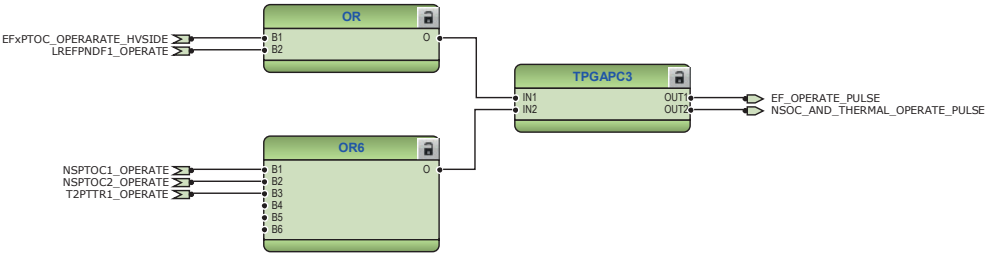


Figure 61: Timer logic for earth-fault and negative-sequence with thermal overload protection operate alarm

3.3.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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 includes three-phase transformer differential protection for two-winding transformers and numerical restricted earth-fault protection for the low-voltage (LV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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

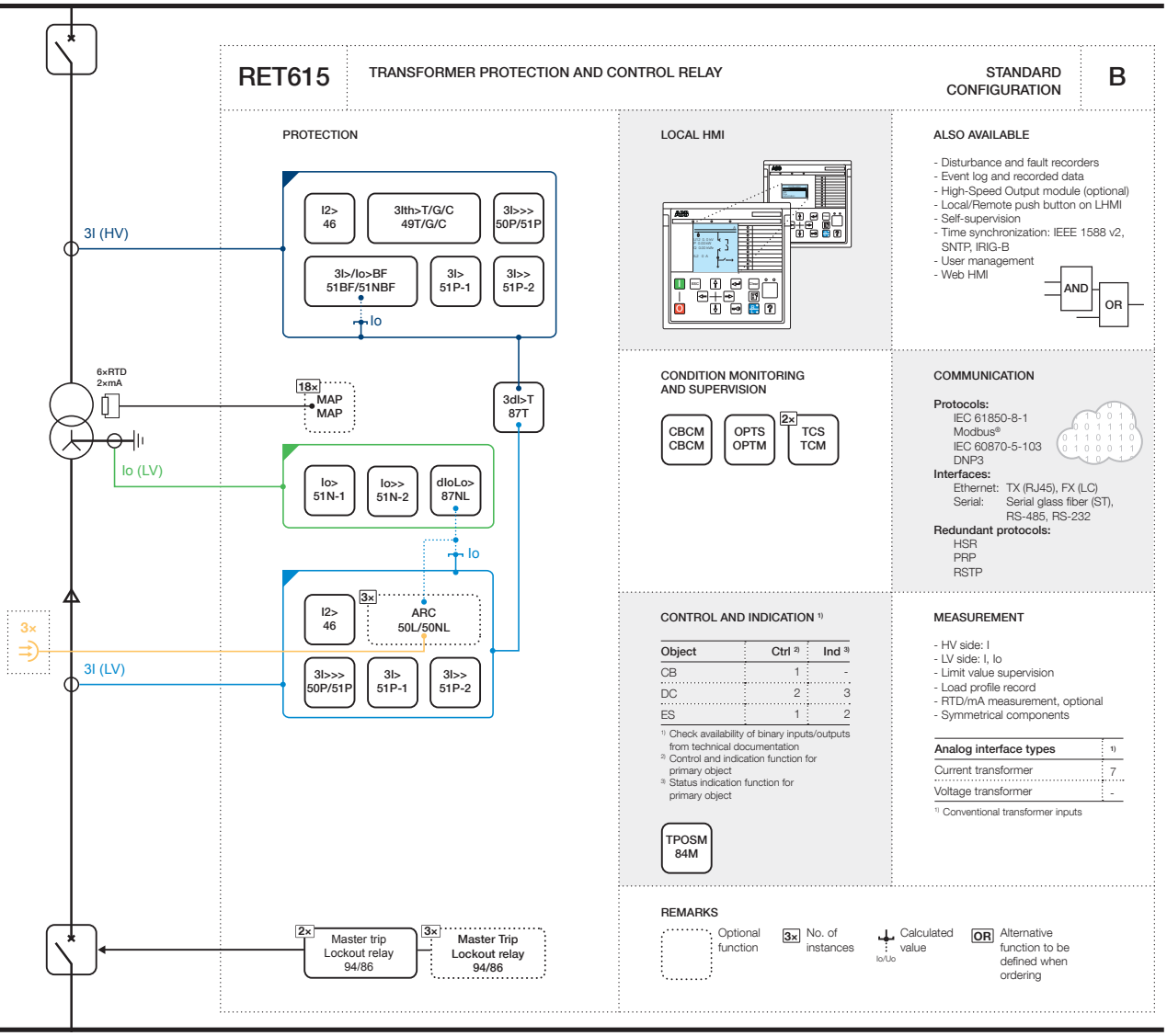


Figure 62: Functionality overview for standard configuration B

3.4.2.1 Default I/O connections

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

Table 17: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	BCD sign bit (tap changer position)
X130-BI2	BCD bit 0 (LSB)
X130-BI3	BCD bit 1
X130-BI4	BCD bit 2
X130-BI5	BCD bit 3
X130-BI6	BCD Bit 4 (MSB)

Table 18: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 19: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth-fault operate alarm
Table continues on next page	

Binary output	Description
X110-SO4	Thermal overload and negative phase-sequence 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 20: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Non-directional overcurrent protection operate
4	Restricted earth-fault protection operate
5	Earth-fault protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.4.2.2 Default disturbance recorder settings

Table 21: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io B
8	-
9	-
10	-
11	-
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 22: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC2 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	LREFPNDF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	CCBRBRF1 - trret	Level trigger off
14	CCBRBRF1 - trbu	Level trigger off
15	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
16	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
17	EFLPTOC2 - operate	Level trigger off
	EFHPTOC2 - operate	
18	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
19	TR2PTDF1 - operate	Positive or Rising
20	TR2PTDF1 - opr LS	Level trigger off
21	TR2PTDF1 - opr HS	Level trigger off
22	TR2PTDF1 - blkd2h	Level trigger off
23	TR2PTDF1 - blkd5h	Level trigger off
24	TR2PTDF1 - blkdwav	Level trigger off
25	LREFPNDF1 - operate	Level trigger off
26	T2PTTR1 - operate	Level trigger off
27	T2PTTR1 - alarm	Level trigger off
28	T2PTTR1 - blk close	Level trigger off
29	X110BI1 - ext OC blocking	Level trigger off
30	X110BI2 - ext trip	Positive or Rising
31	X110BI7 - HVCB closed	Level trigger off
32	X110BI8 - HVCB opened	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	MDSOPT1 - alarm	Level trigger off
34	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
35	ARCSARC1 - operate	Positive or Rising
36	ARCSARC2 - operate	Positive or Rising
37	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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The protection relay offers six different setting groups which can be set based on 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.

The stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

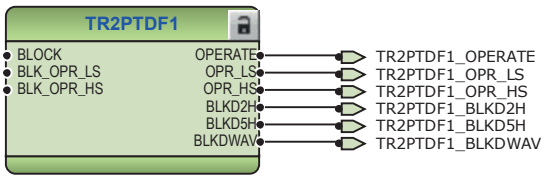


Figure 63: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

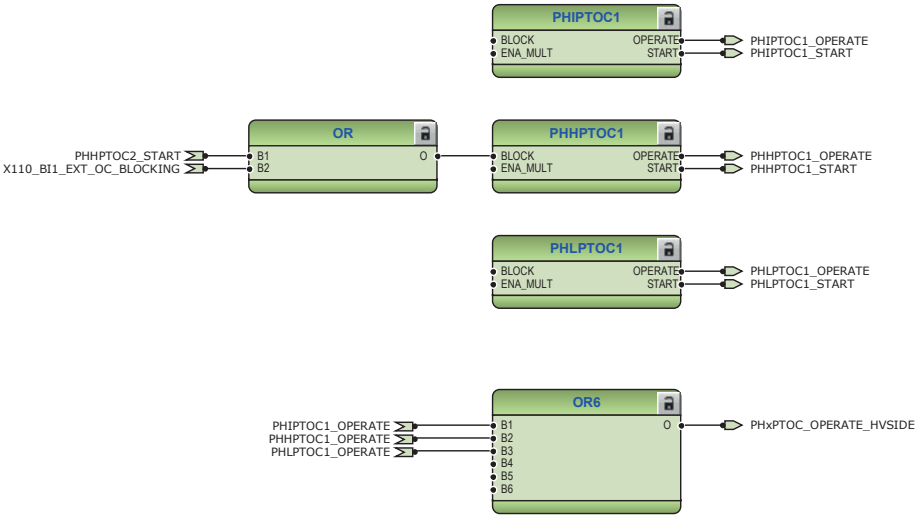


Figure 64: High-voltage side overcurrent protection function

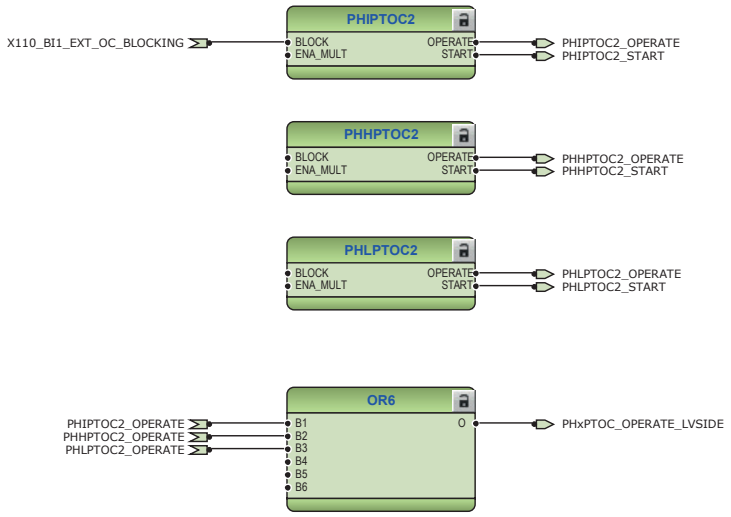


Figure 65: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection and this measures the neutral current from low-voltage side.

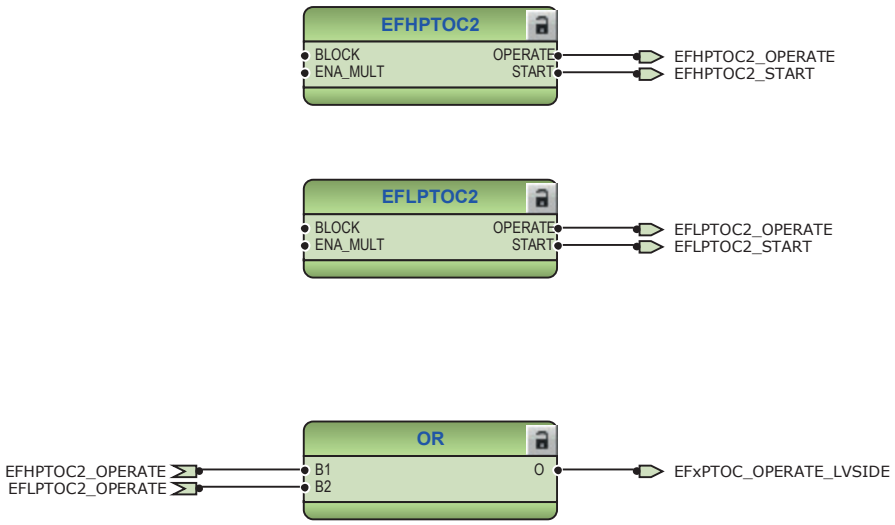


Figure 66: Low-voltage side earth-fault protection function

The configuration includes numerically stabilized low-impedance restricted earth-fault protection function for low-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

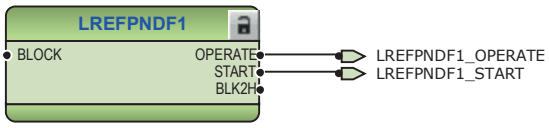


Figure 67: Restricted low-impedance earth-fault protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

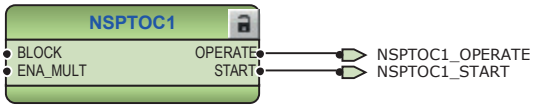


Figure 68: High-voltage side negative-sequence overcurrent protection function

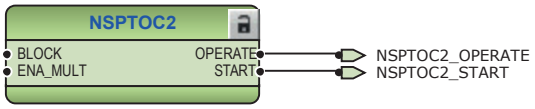


Figure 69: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

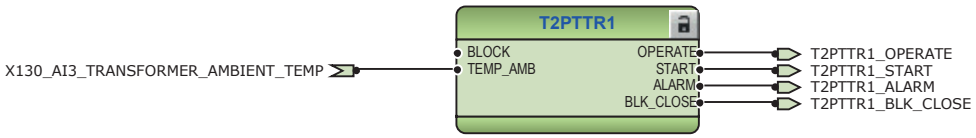


Figure 70: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

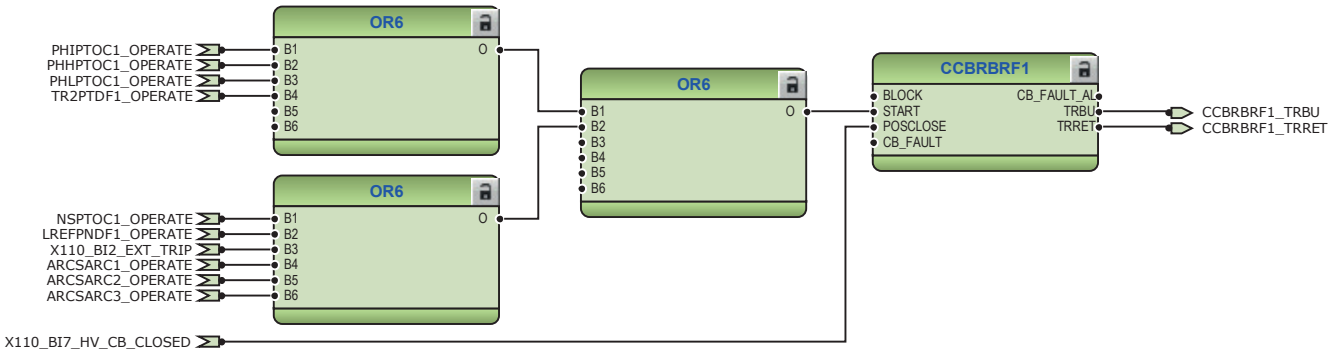


Figure 71: Circuit breaker failure protection function

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

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

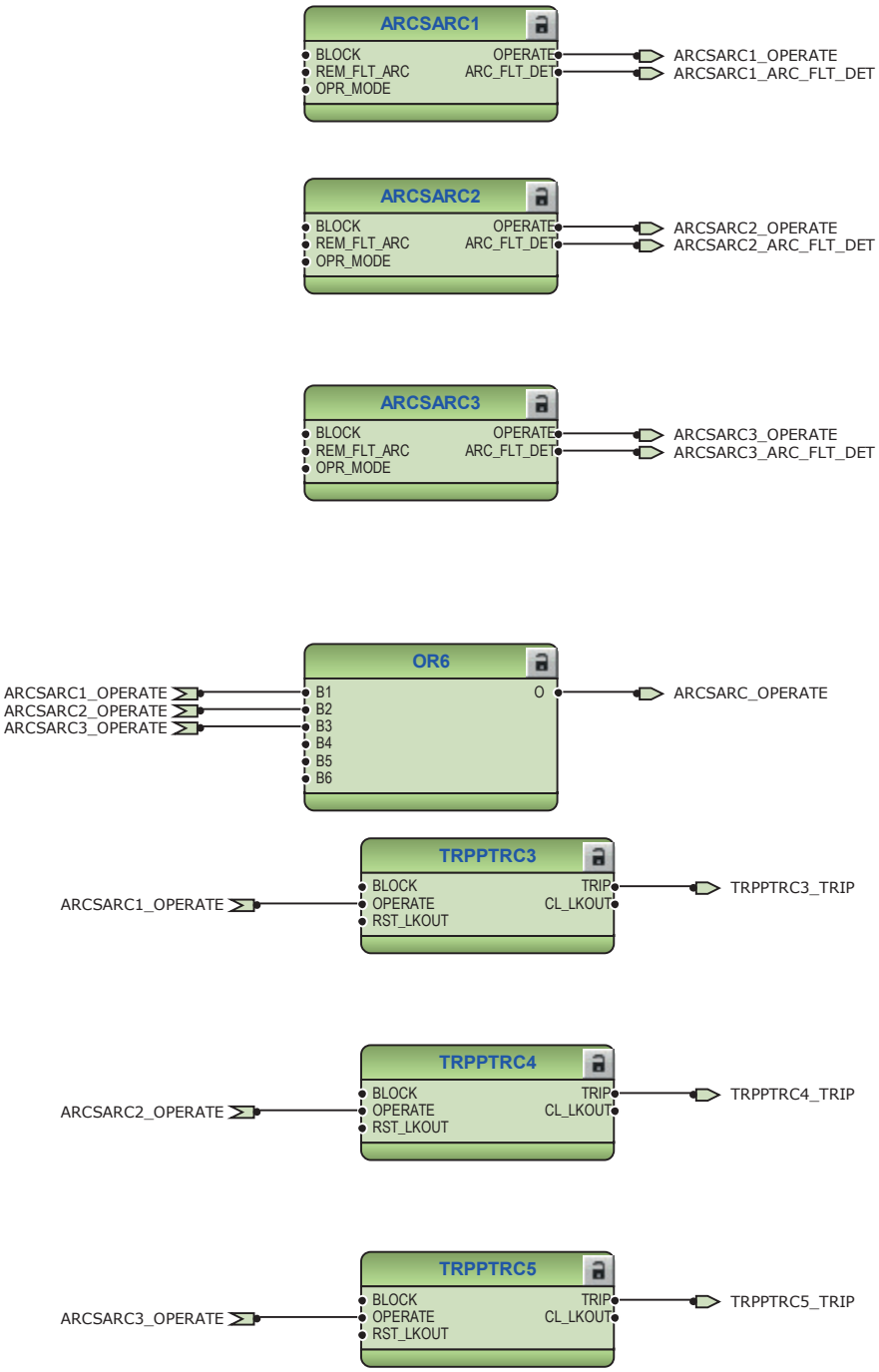


Figure 72: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

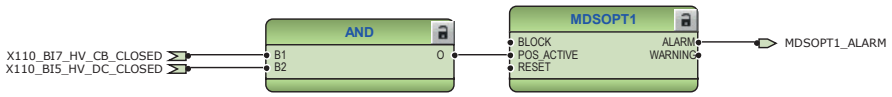


Figure 73: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

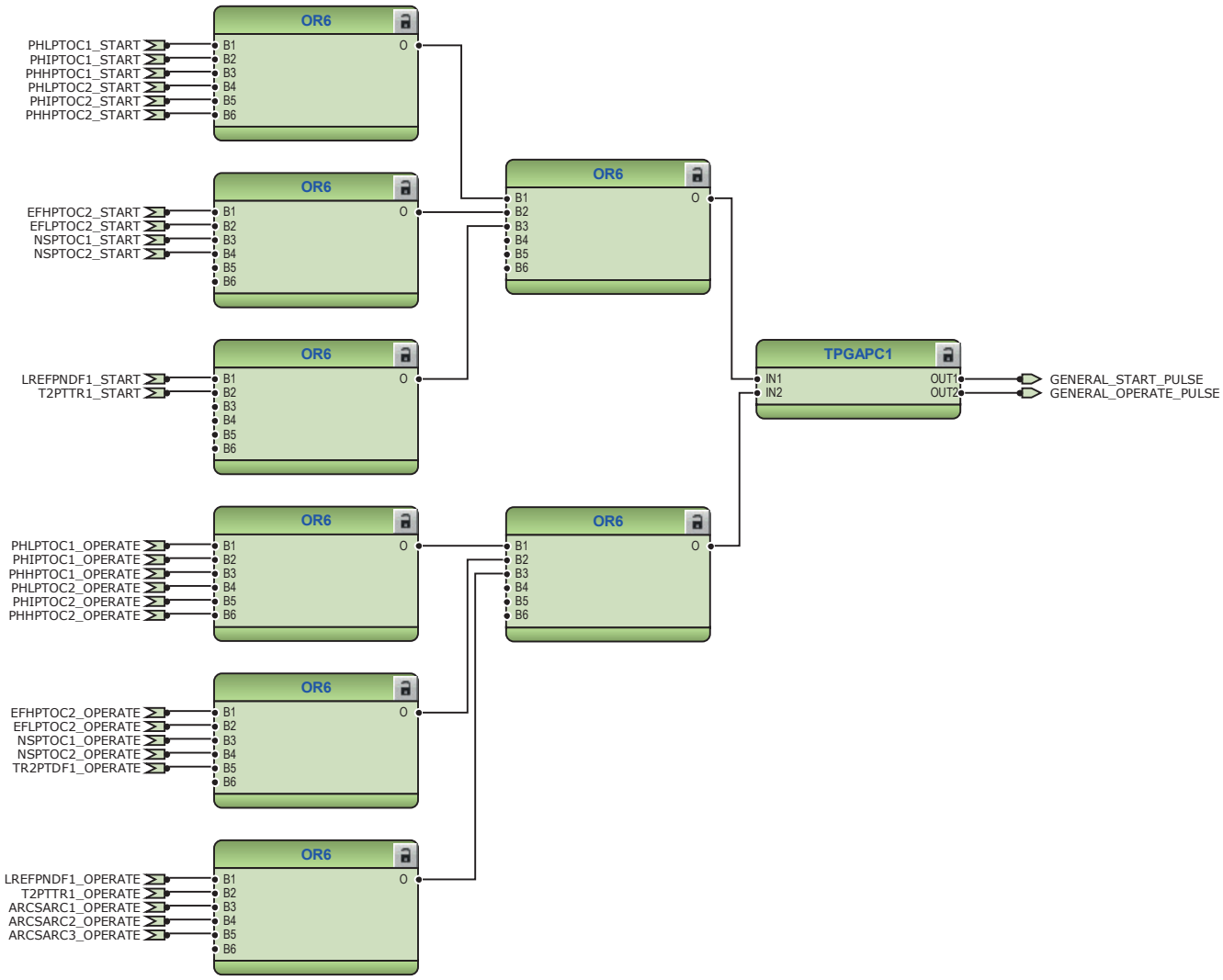


Figure 74: General start and operate signals

The operate signals from the protection are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which is further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

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

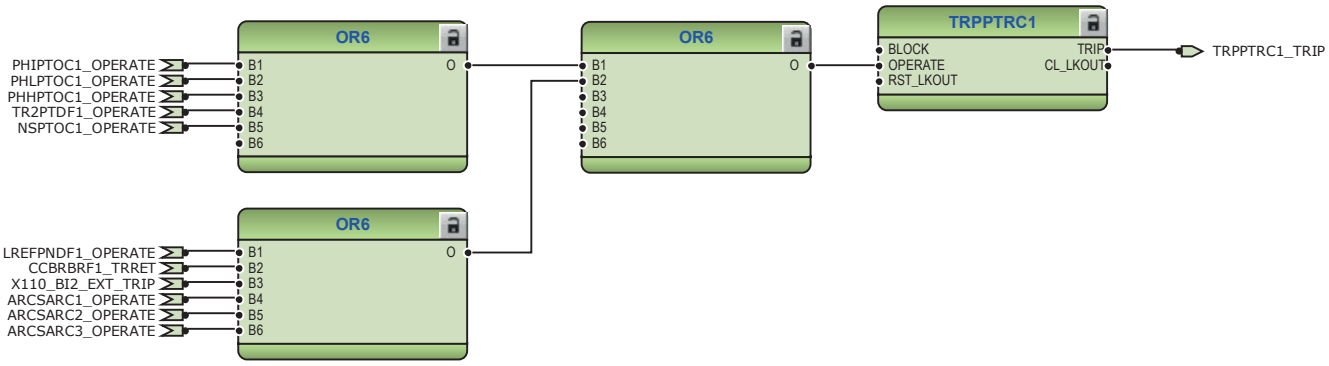


Figure 75: Trip logic TRPPTRC1

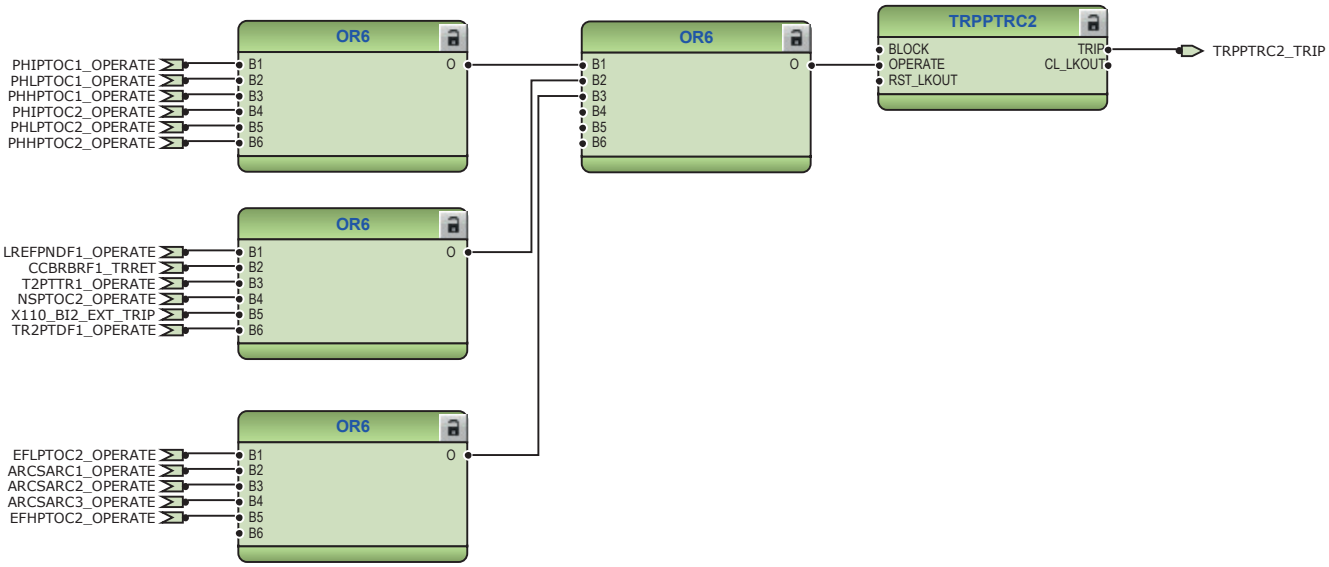


Figure 76: Trip logic TRPPTRC2

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 few binary inputs are also connected to the disturbance recorder.

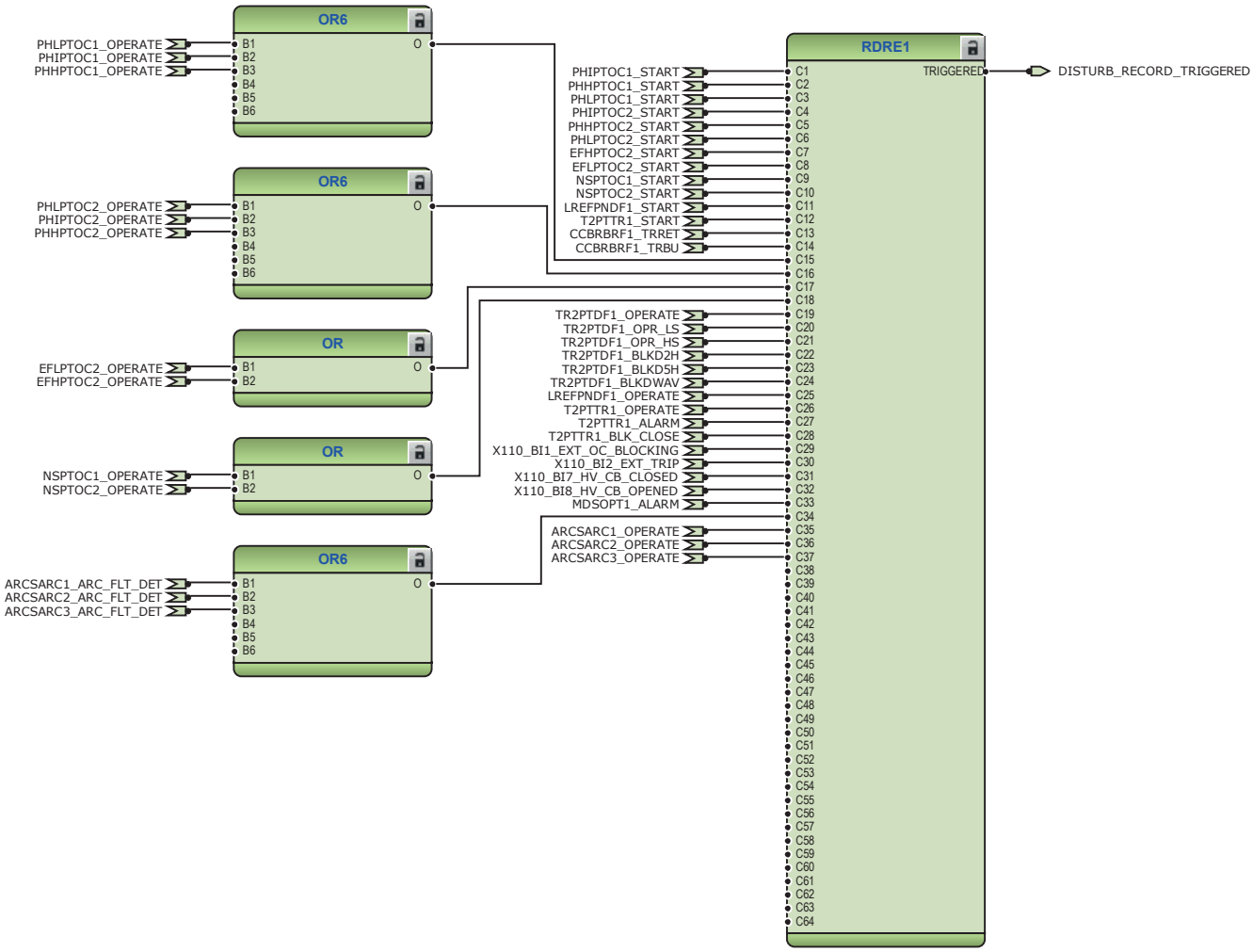


Figure 77: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

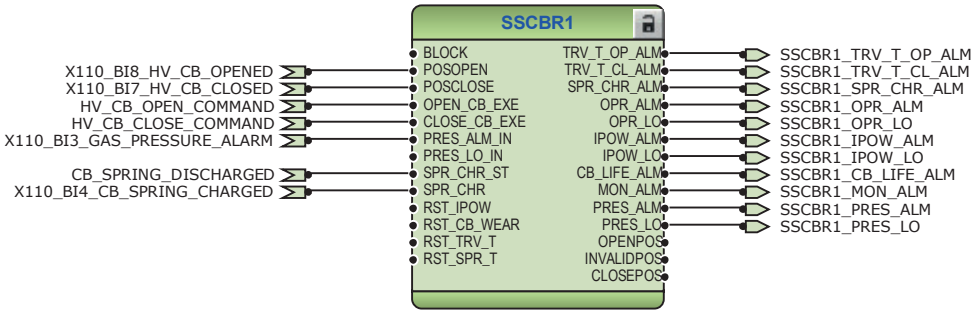


Figure 78: Circuit-breaker condition monitoring function

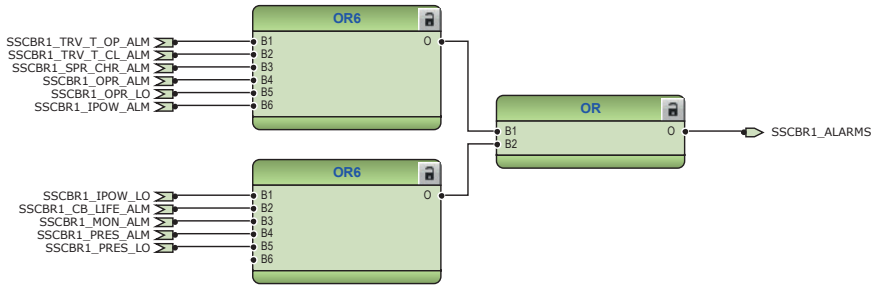


Figure 79: Logic for circuit-breaker monitoring alarm

Figure 80: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and the HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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.

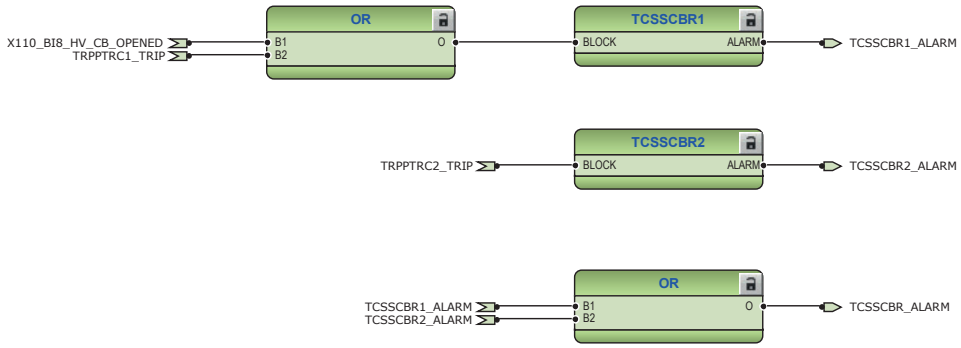


Figure 81: Trip circuit supervision function

3.4.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are 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) status information is connected to DCSXSWI1.

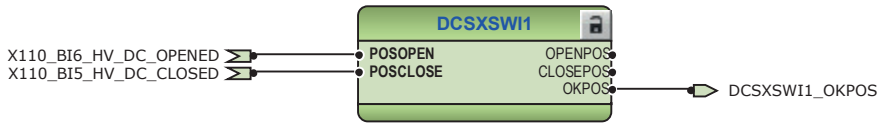


Figure 82: Disconnector control logic

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 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 closed (in service position). This output, together with the 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

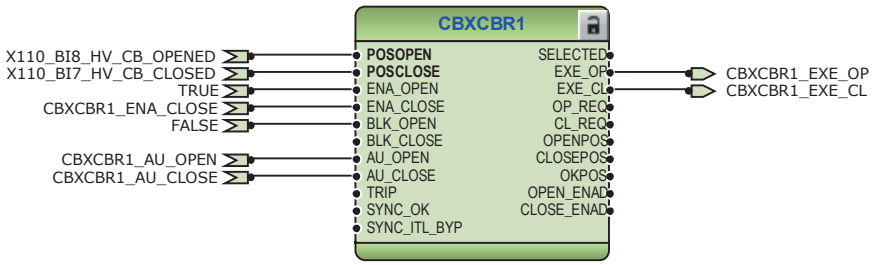


Figure 83: High-voltage side circuit breaker control logic: Circuit breaker 1

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

Figure 84: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker

Figure 85: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker

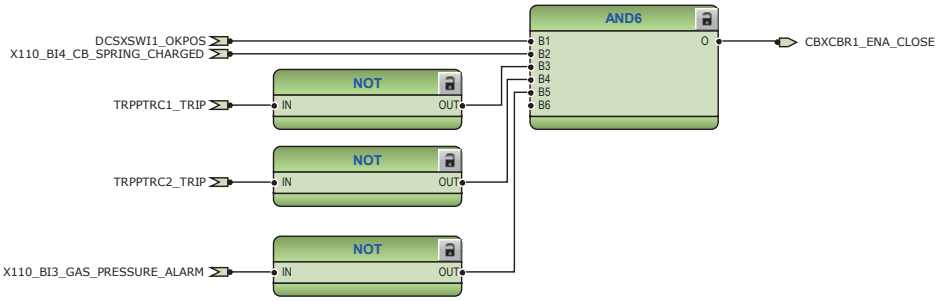


Figure 86: High-voltage side circuit breaker close enable logic

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

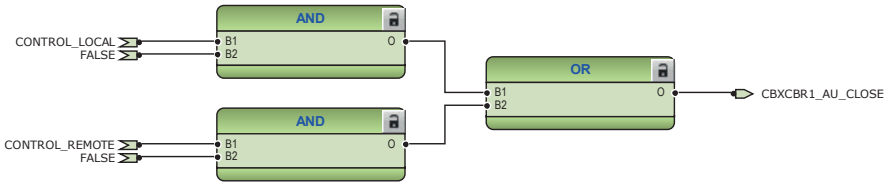


Figure 87: External closing command for circuit breaker

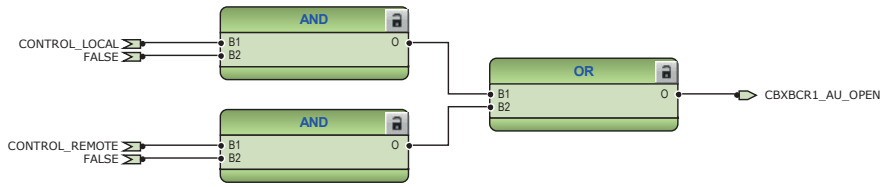


Figure 88: External opening command for circuit breaker

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used, TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters TPOSYLTC1 properly

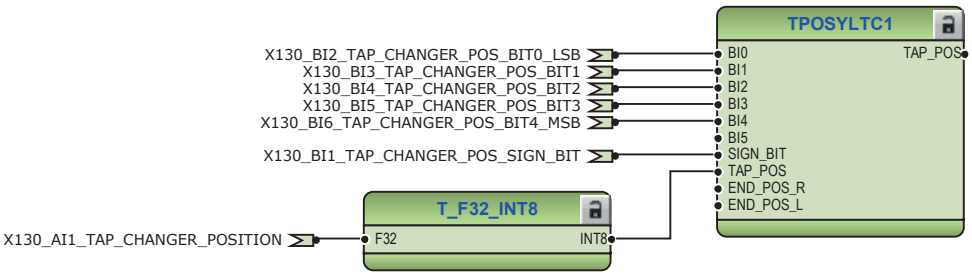


Figure 89: Tap changer position indicator

3.4.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The

current input is connected to the X120 card in the back panel. The sequence current measurement function CSMSQI1 measures the sequence current from high-voltage side and the residual current measurement function RESCMMXU2 measures the residual current from low-voltage side.

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

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

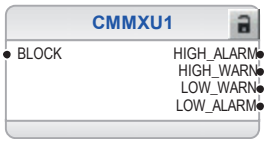


Figure 90: Current measurement: Three-phase current measurement (HV side)

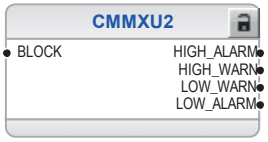


Figure 91: Current measurement: Three-phase current measurement (LV side)

Figure 92: Current measurement: Sequence current measurement (HV side)

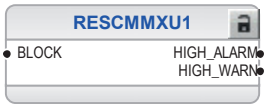


Figure 93: Current measurement: Residual current measurement (LV side)

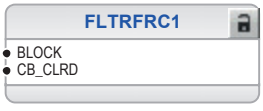


Figure 94: Other measurement: Data monitoring

Figure 95: Other measurement: Load profile record

3.4.3.6 Functional diagrams for I/O and alarms LEDs

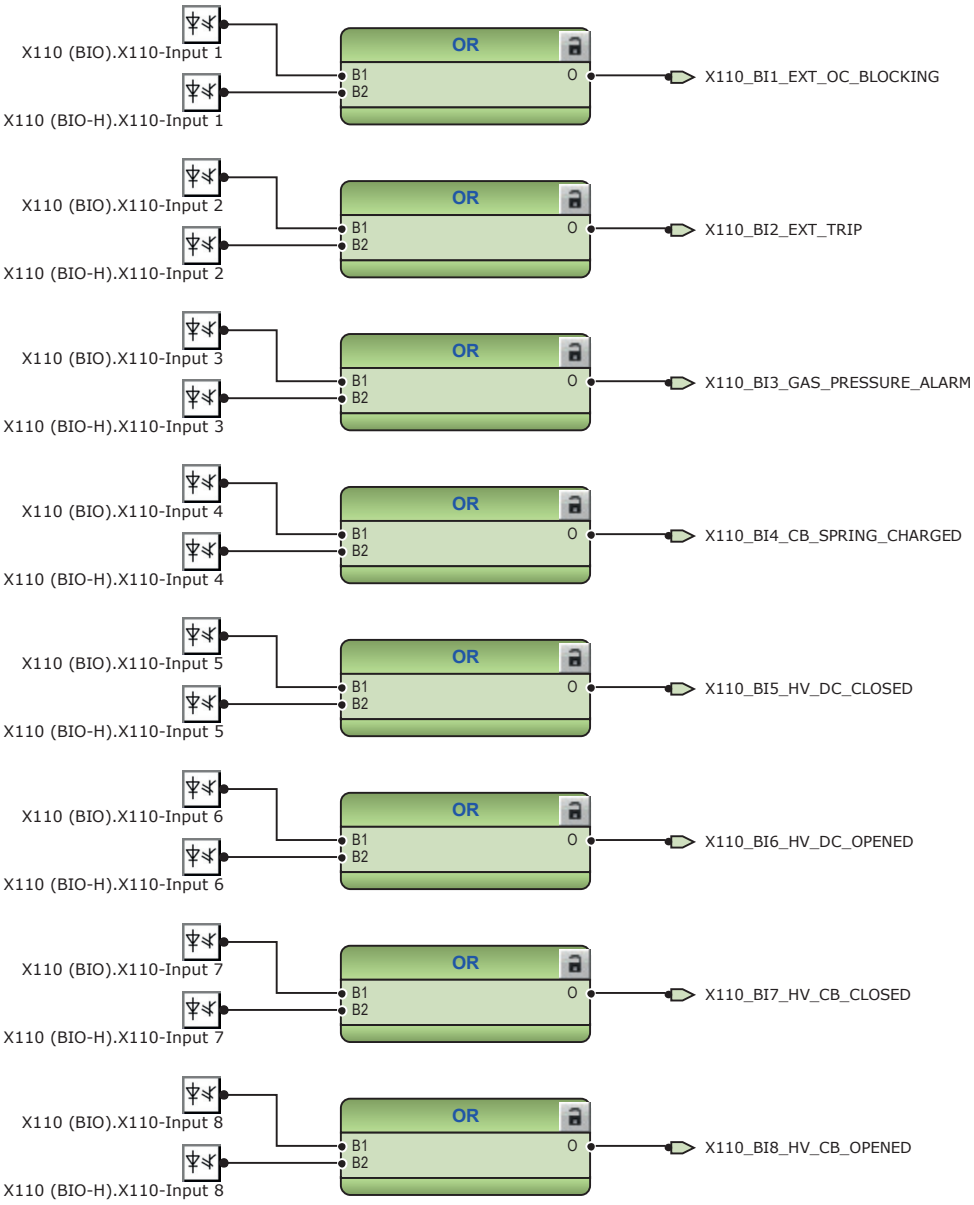


Figure 96: Binary inputs - X110 terminal block

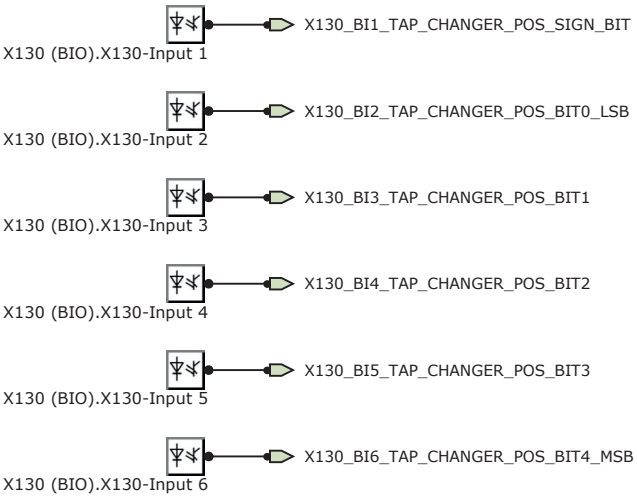


Figure 97: Binary inputs - X130 terminal block

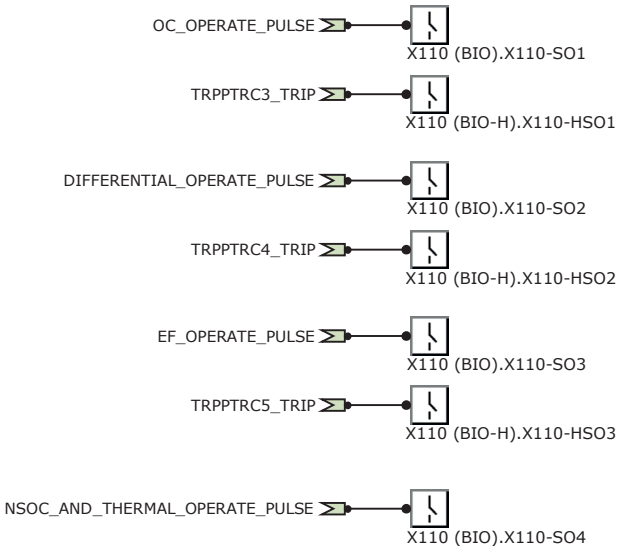


Figure 98: Binary outputs - X110 terminal block

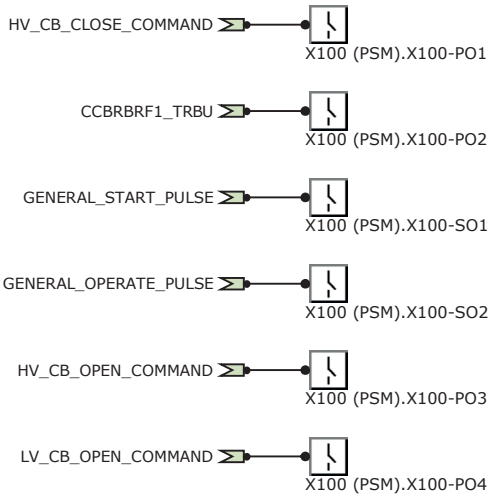


Figure 99: Binary outputs - X100 terminal block

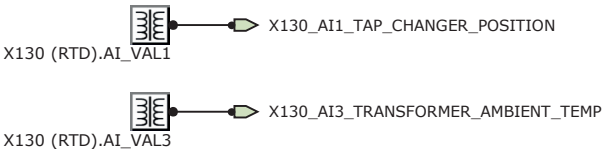


Figure 100: Default mA/RTD inputs X130

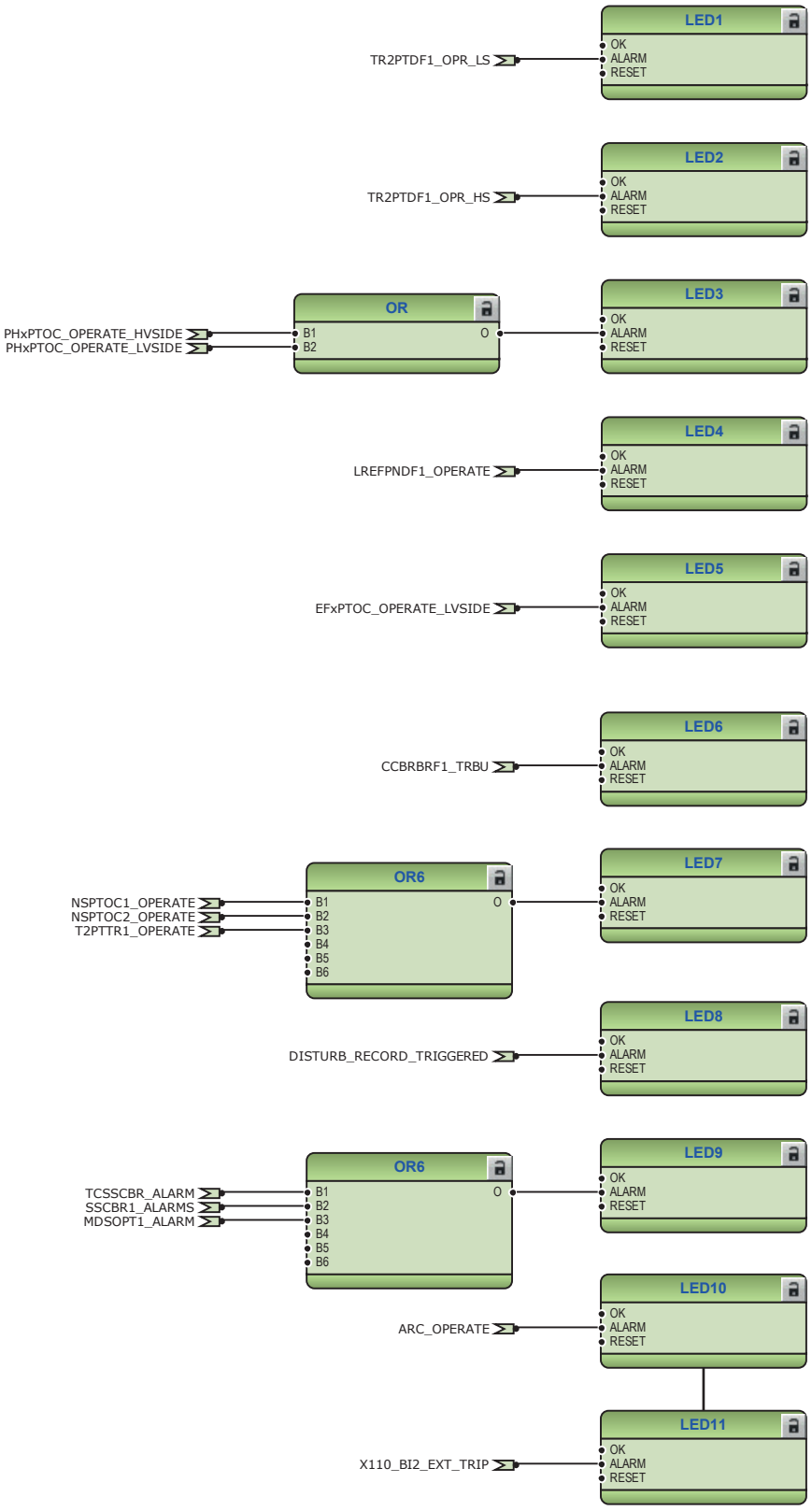


Figure 101: Default LED connection

3.4.3.7 Functional diagrams for other timer logics

The configuration also includes overcurrent operate, differential operate, earth-fault operate and combined negative-sequence and thermal overload operate logic. 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.

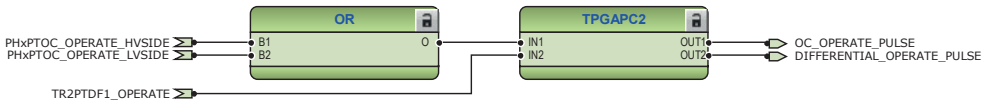


Figure 102: Timer logic for overcurrent and differential operate pulse

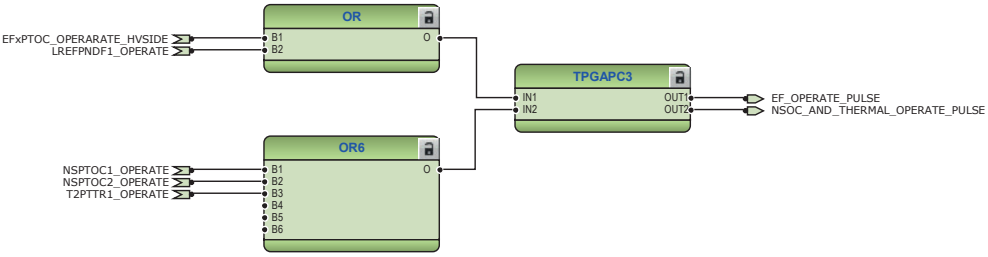


Figure 103: Timer logic for earth-fault and negative sequence with thermal overload protection operate alarm

3.4.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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.

3.5 Standard configuration C

3.5.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and high impedance based restricted earth-fault protection for the high-voltage (HV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.5.2 Functions

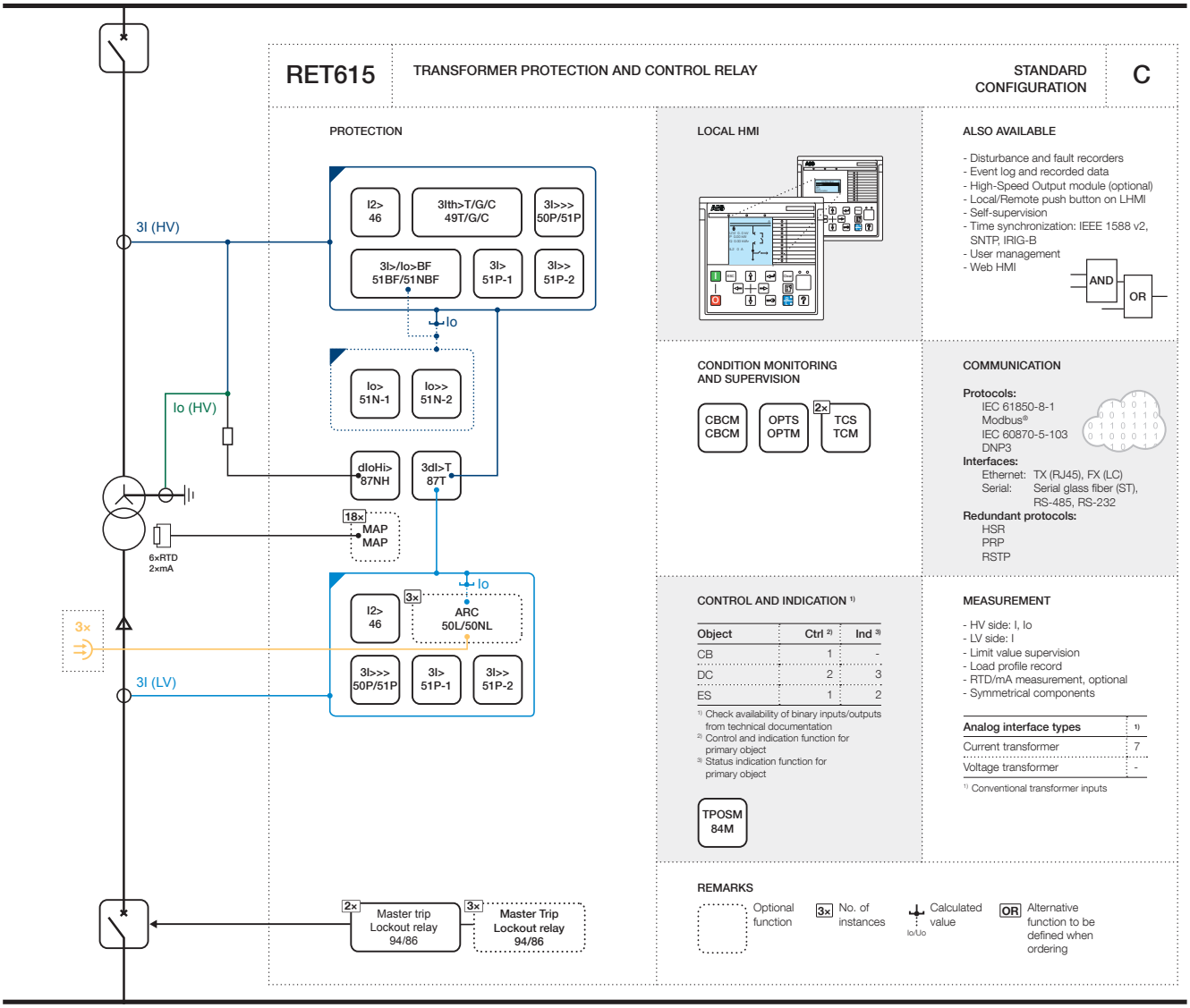


Figure 104: Functionality overview for standard configuration C

3.5.2.1 Default I/O connections

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

Table 23: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	BCD sign bit (tap changer position)
X130-BI2	BCD bit 0 (LSB)
X130-BI3	BCD bit 1
X130-BI4	BCD bit 2
X130-BI5	BCD bit 3
X130-BI6	BCD bit 4 (MSB)

Table 24: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 25: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
Table continues on next page	

Binary output	Description
X110-SO4	Thermal overload and negative phase-sequence 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 26: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Non-directional overcurrent protection operate
4	Restricted earth-fault protection operate
5	Earth-fault protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.5.2.2 Default disturbance recorder settings

Table 27: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8	-
9	-
10	-
11	-
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 28: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC1 - start	Positive or Rising
8	EFLPTOC1 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	HREFPDIF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	CCBRBRF1 - trret	Level trigger off
14	CCBRBRF1 - trbu	Level trigger off
15	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
16	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
17	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
18	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
19	TR2PTDF1 - operate	Positive or Rising
20	TR2PTDF1 - opr LS	Level trigger off
21	TR2PTDF1 - opr HS	Level trigger off
22	TR2PTDF1 - blkd2h	Level trigger off
23	TR2PTDF1 - blkd5h	Level trigger off
24	TR2PTDF1 - blkdwav	Level trigger off
25	HREFPDIF1 - operate	Level trigger off
26	T2PTTR1 - operate	Level trigger off
27	T2PTTR1 - alarm	Level trigger off
28	T2PTTR1 - blk close	Level trigger off
29	X110BI1 - ext OC blocking	Level trigger off
30	X110BI2 - ext trip	Positive or Rising
31	X110BI7 - HVCB closed	Level trigger off
32	X110BI8 - HVCB opened	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	MDSOPT1 - alarm	Level trigger off
34	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
35	ARCSARC1 - operate	Positive or Rising
36	ARCSARC2 - operate	Positive or Rising
37	ARCSARC3 - operate	Positive or Rising

3.5.3 Function 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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The protection relay offers six different setting groups which can be set based on 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.

3.5.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

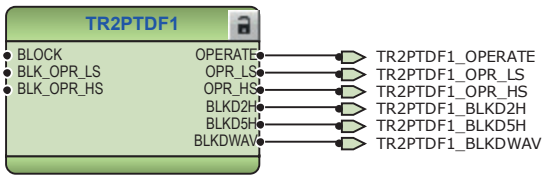


Figure 105: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110: BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

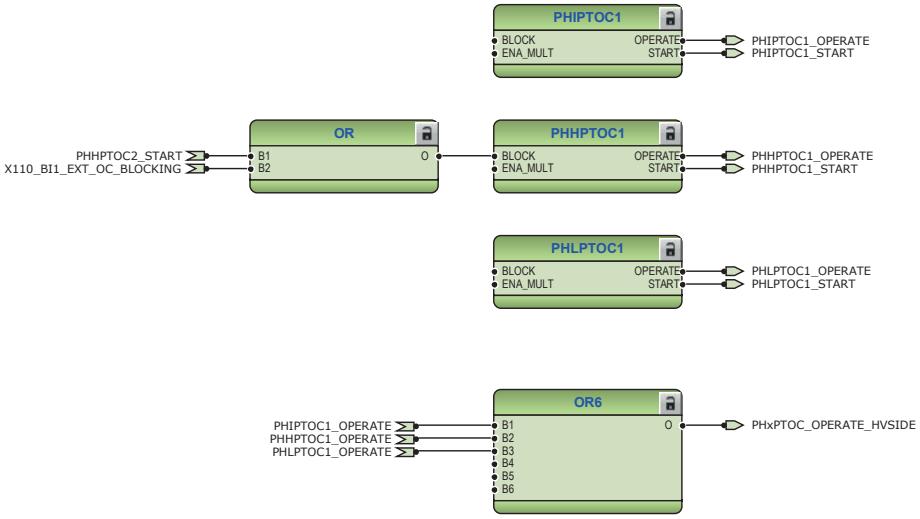


Figure 106: High-voltage side overcurrent protection function

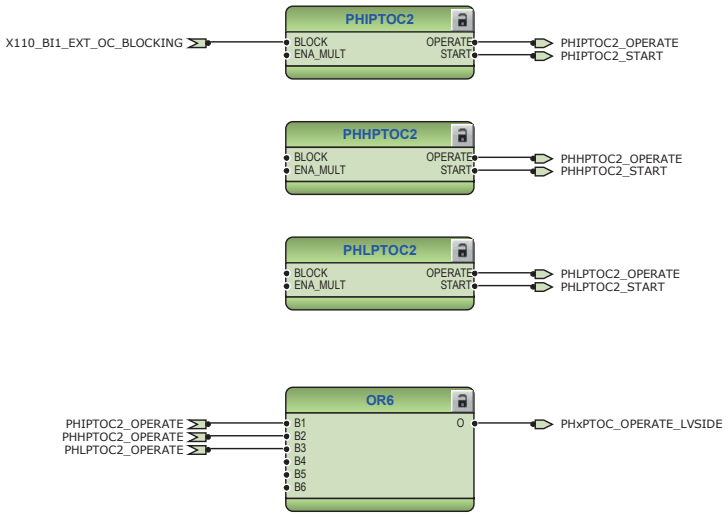


Figure 107: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection that uses the residual current calculated from phase current of high-voltage side.

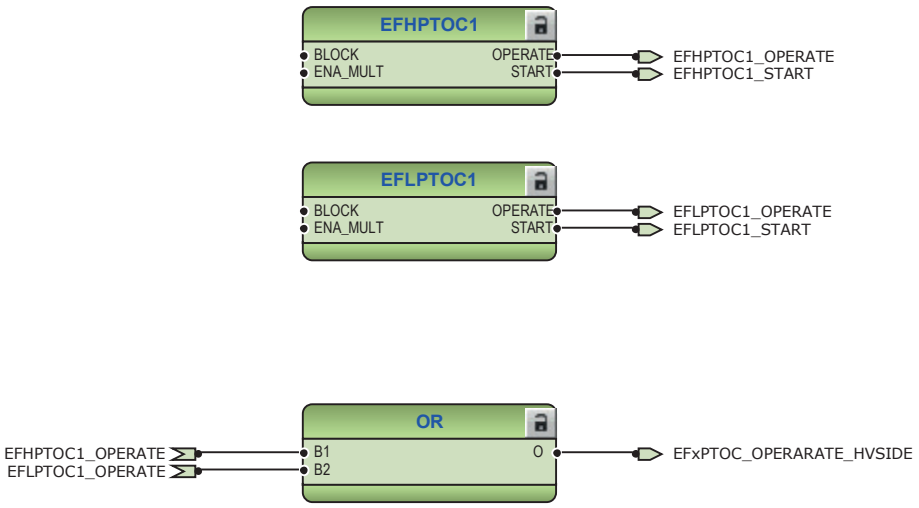


Figure 108: High-voltage side earth-fault protection function

Configuration also includes high-impedance based restricted earth-fault protection for high-voltage side of two-winding power transformers HREFPDIF1. The restricted earth-fault current stage operates exclusively on earth faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

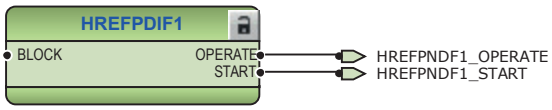


Figure 109: Restricted high-impedance earth-fault protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

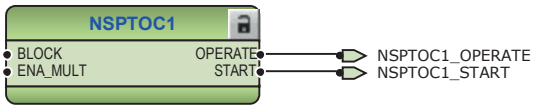


Figure 110: High-voltage side negative-sequence overcurrent protection function

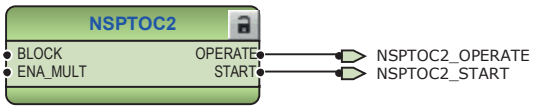


Figure 111: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

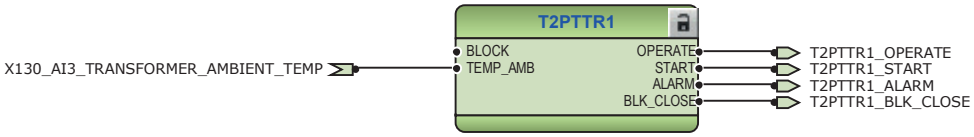


Figure 112: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

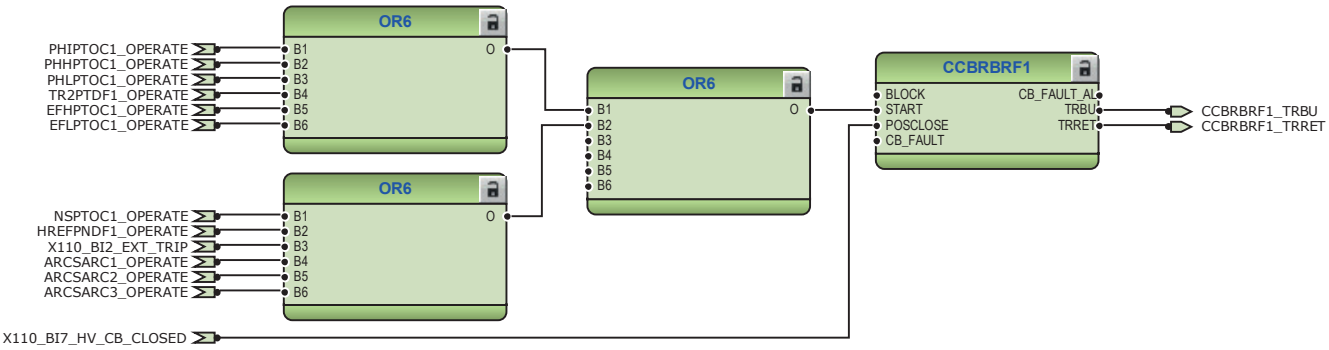


Figure 113: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages 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, 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 is ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of these TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

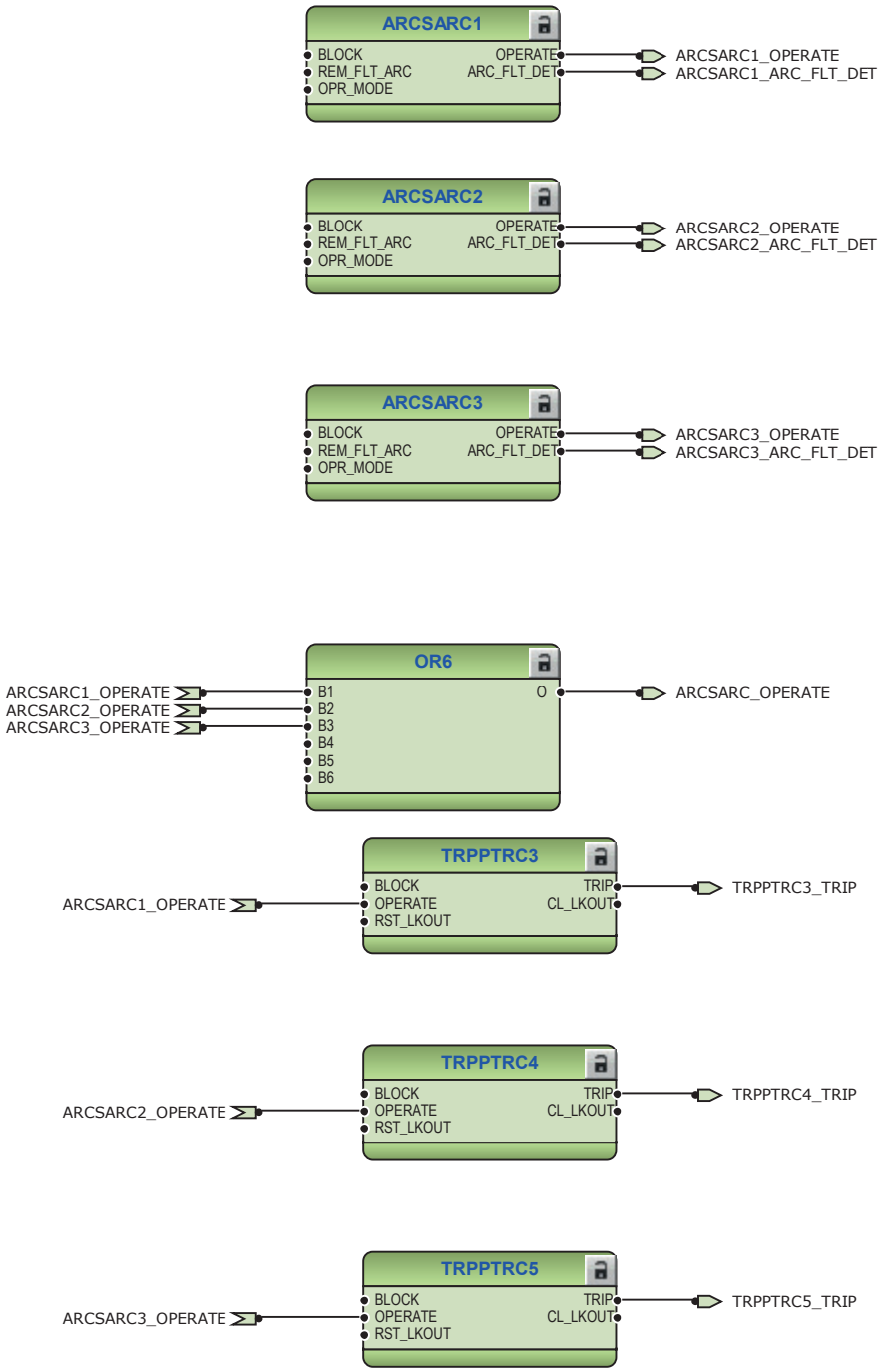


Figure 114: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

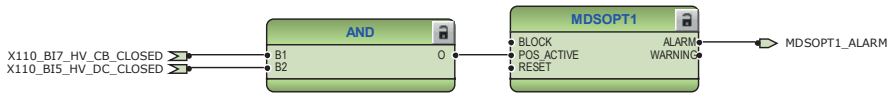


Figure 115: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

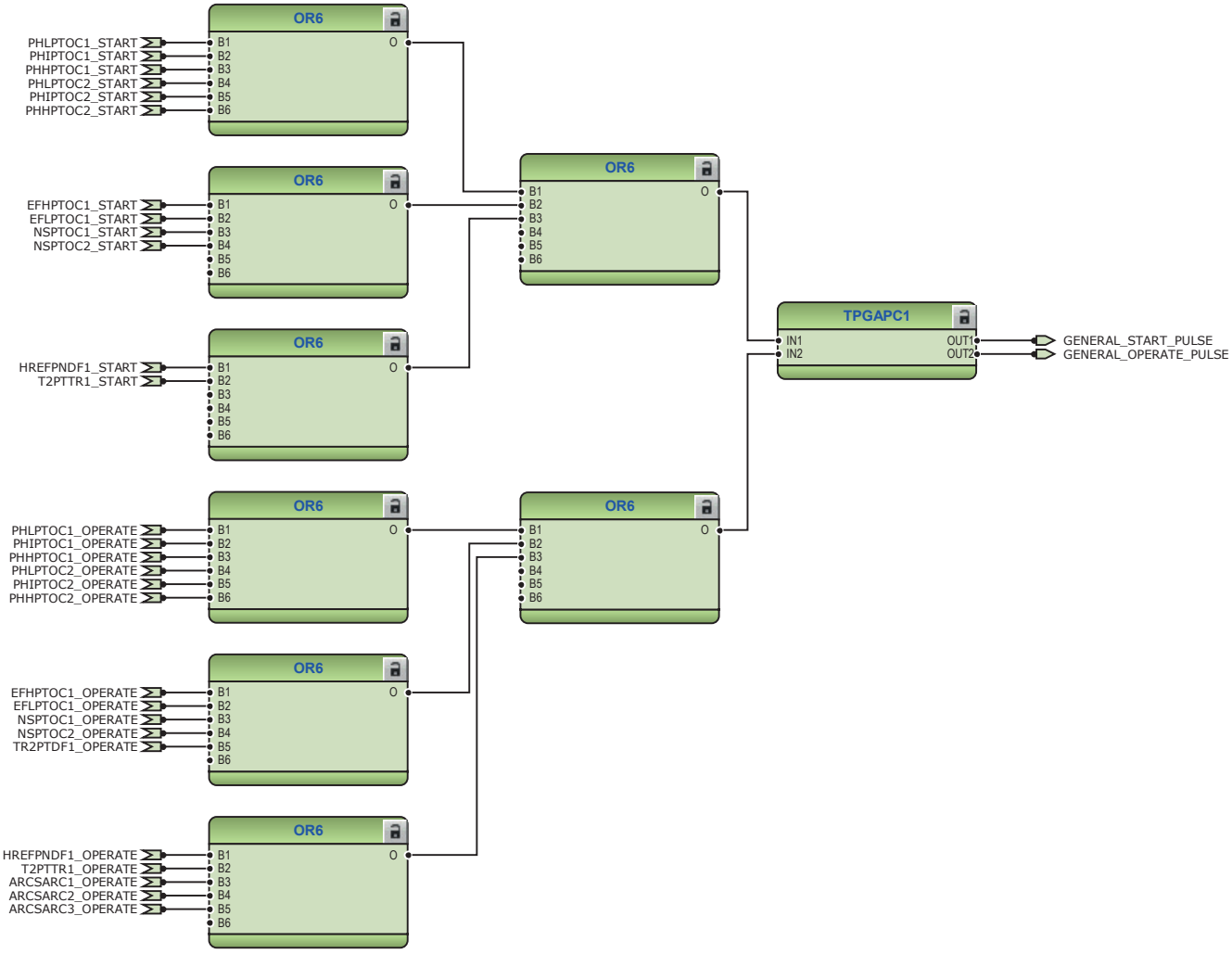


Figure 116: General start and operate signals

The operate signals from the protections are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is

selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

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

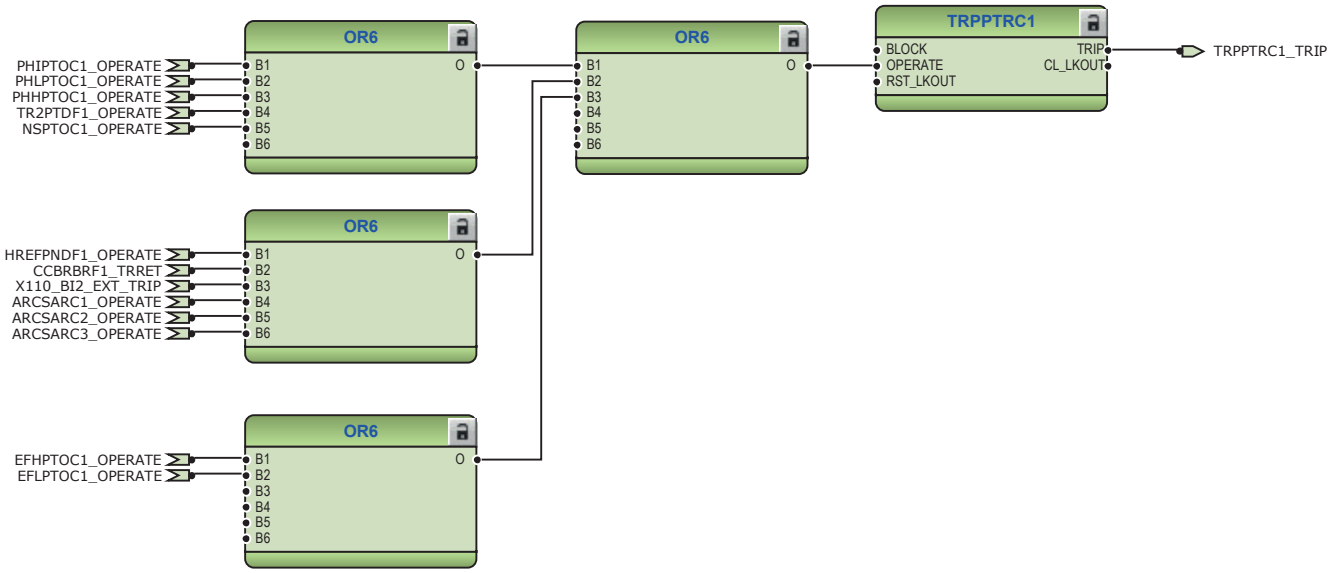


Figure 117: Trip logic TRPPTRC1

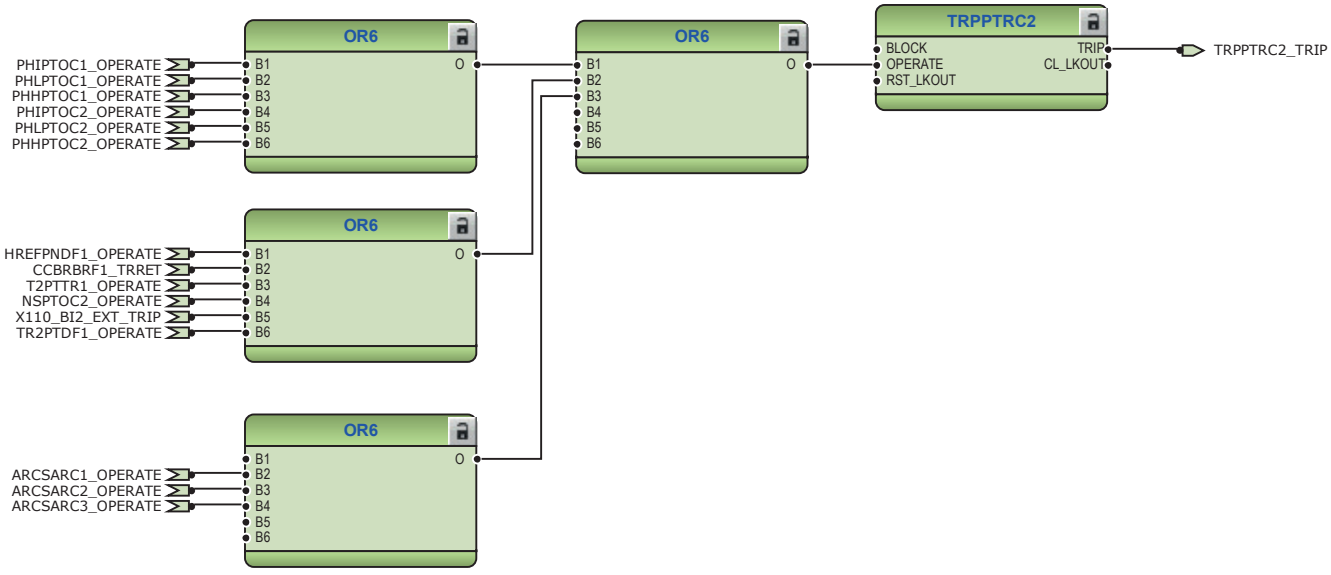


Figure 118: Trip logic TRPPTRC2

3.5.3.2 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.

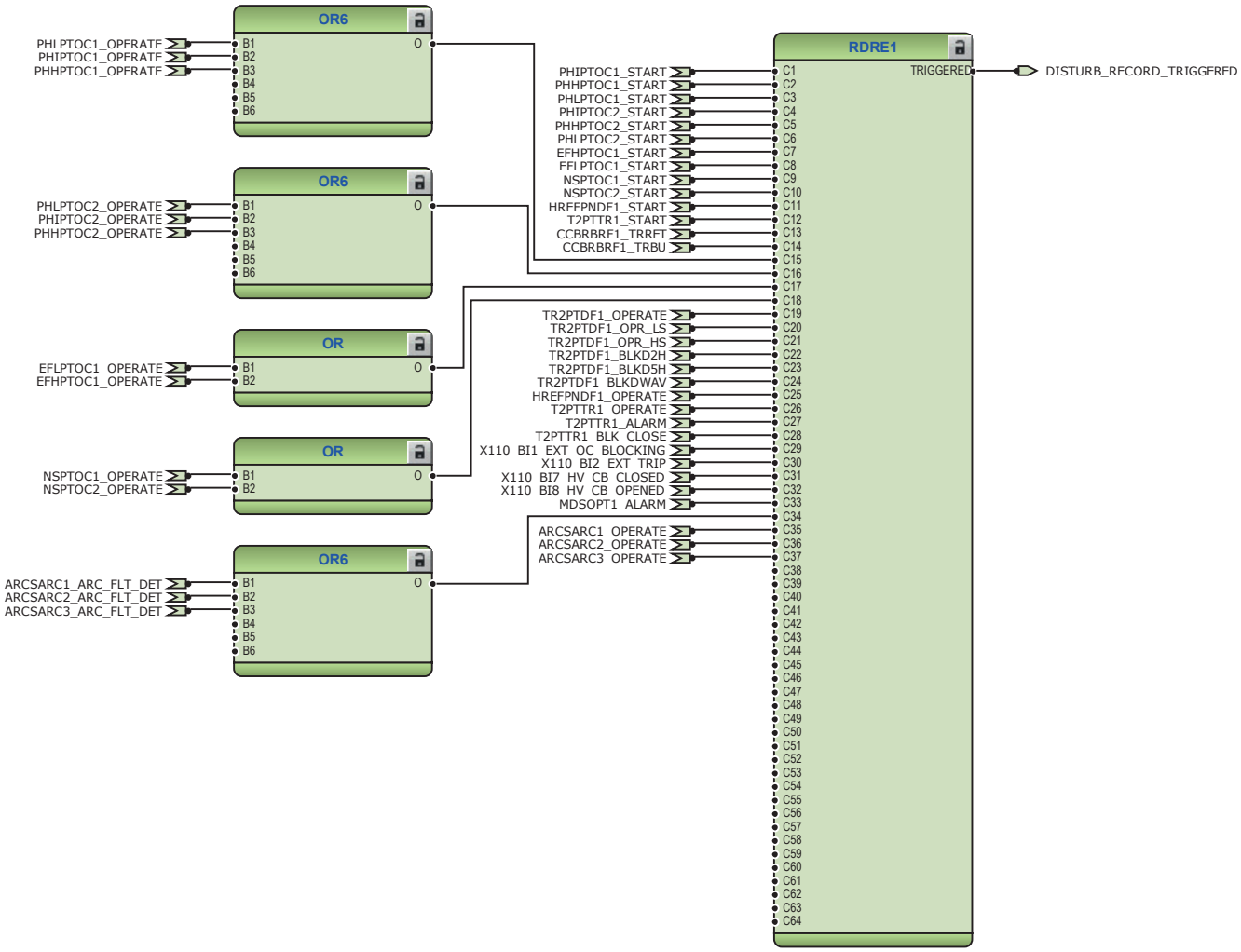


Figure 119: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

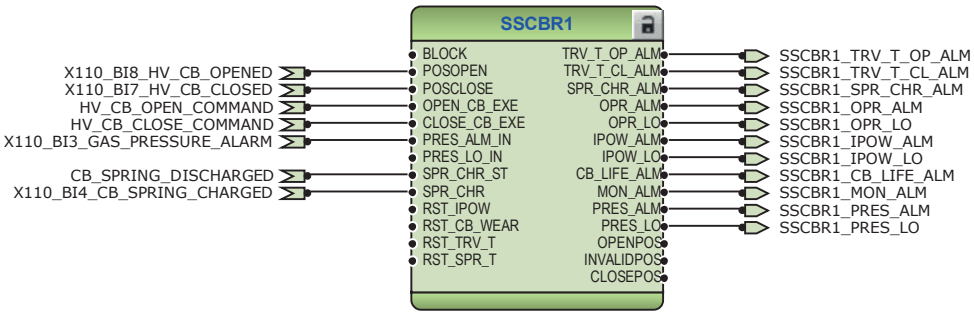


Figure 120: Circuit breaker-condition monitoring function

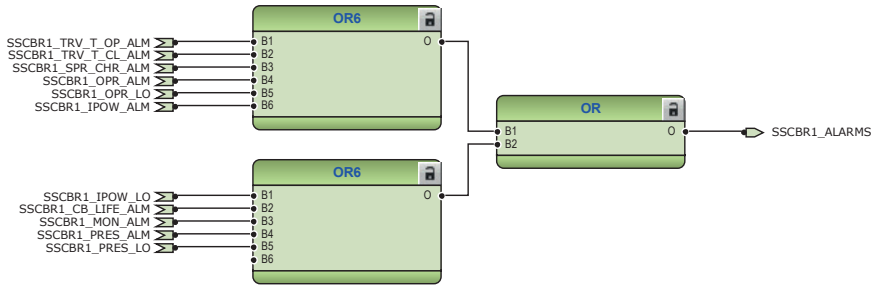


Figure 121: Logic for circuit-breaker monitoring alarm

Figure 122: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR1 properly.

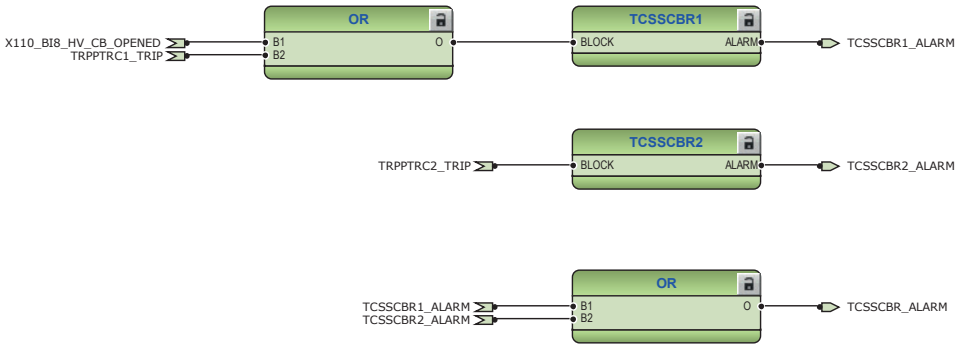


Figure 123: Trip circuit supervision function

3.5.3.4 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) status information is connected to DCSXSWI1.

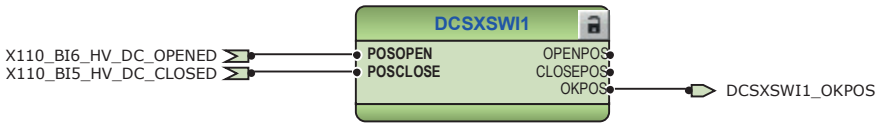


Figure 124: High-voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or closed (in service position). This output, together with 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

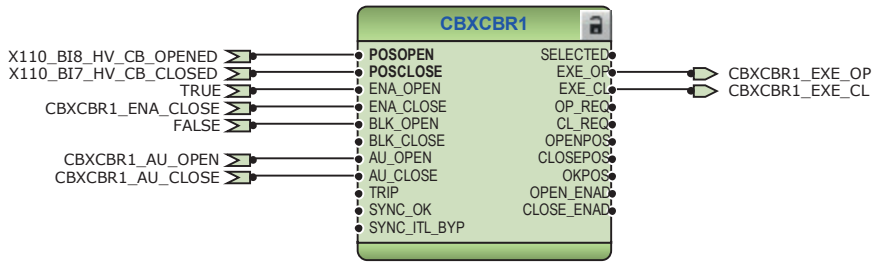


Figure 125: High-voltage side circuit breaker 1

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

Figure 126: Signals for closing coil of circuit breaker 1

Figure 127: Signals for opening coil of circuit breaker 1

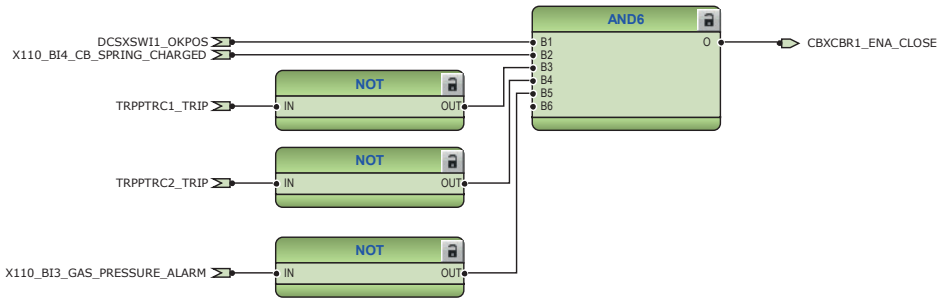


Figure 128: High-voltage side circuit breaker 1 close enable logic

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

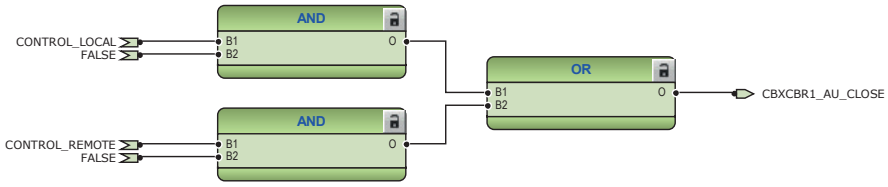


Figure 129: External closing command for circuit breaker 1

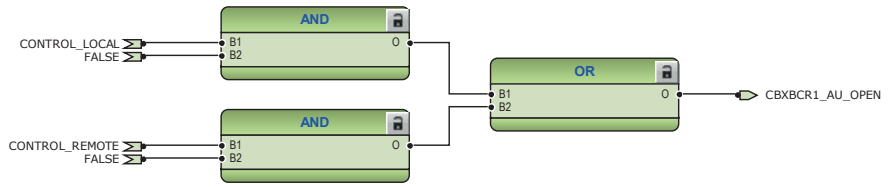


Figure 130: External opening command for circuit breaker 1

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters for TPOSYLTC1 properly.

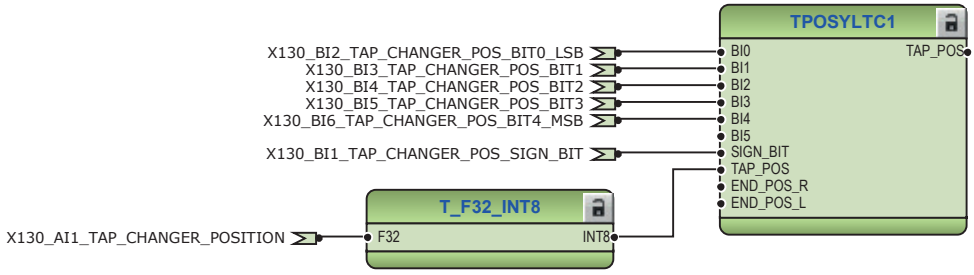


Figure 131: Tap changer position indicator

3.5.3.5 Functional diagrams for measurement functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The

current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current from high-voltage side.

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.

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

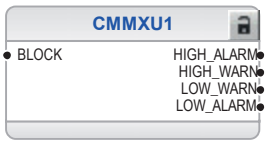


Figure 132: Current measurement: Three-phase current measurement (HV side)

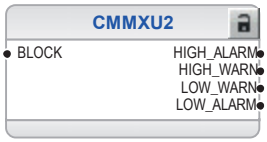


Figure 133: Current measurement: Three-phase current measurement (LV side)

Figure 134: Current measurement: Sequence current measurement (HV side)

Figure 135: Current measurement: Residual current measurement (HV side)

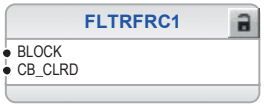


Figure 136: Other measurement: Data monitoring

Figure 137: Other measurement: Load profile record

3.5.3.6 Functional diagrams for I/O and alarms LEDs

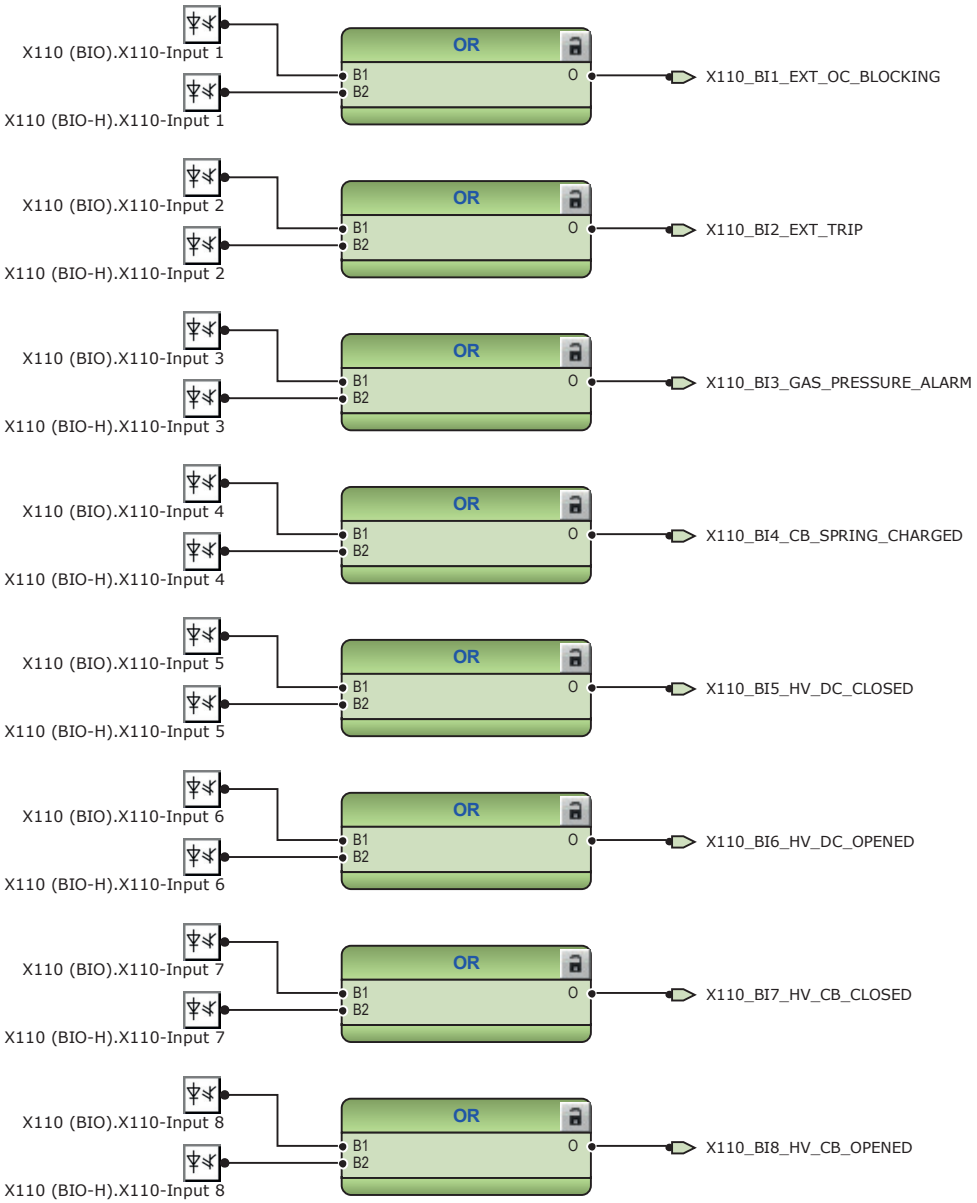


Figure 138: Binary inputs - X110 terminal block

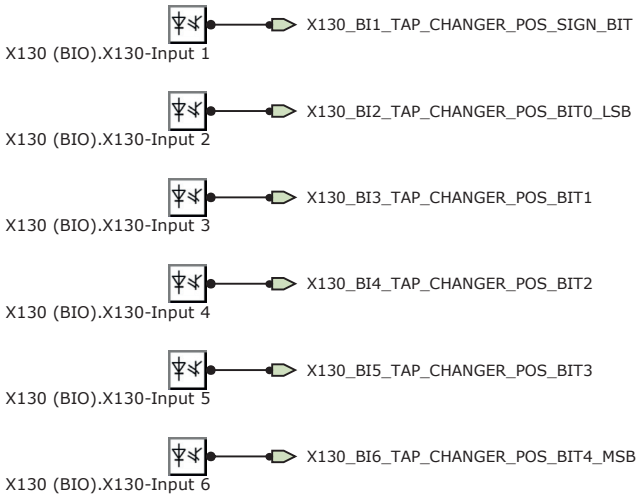


Figure 139: Binary inputs - X130 terminal block

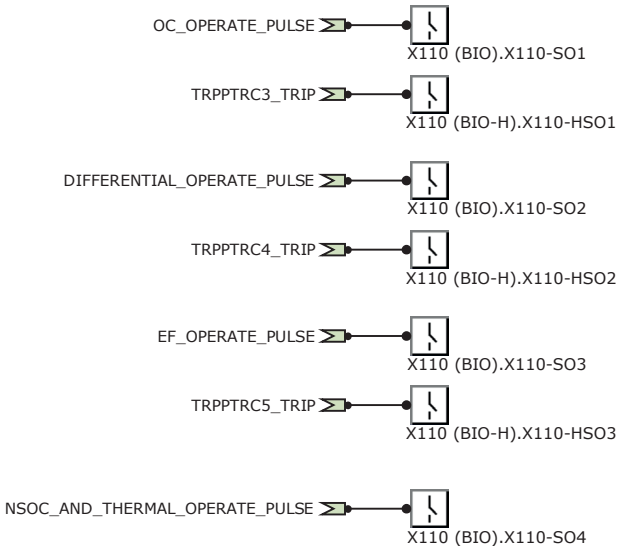


Figure 140: Binary outputs - X110 terminal block

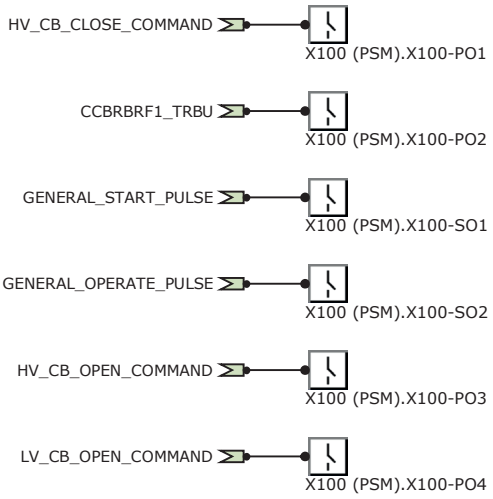


Figure 141: Binary outputs - X100 terminal block

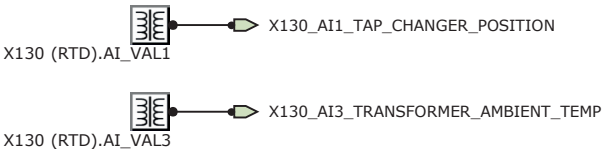


Figure 142: Default mA/RTD inputs X130

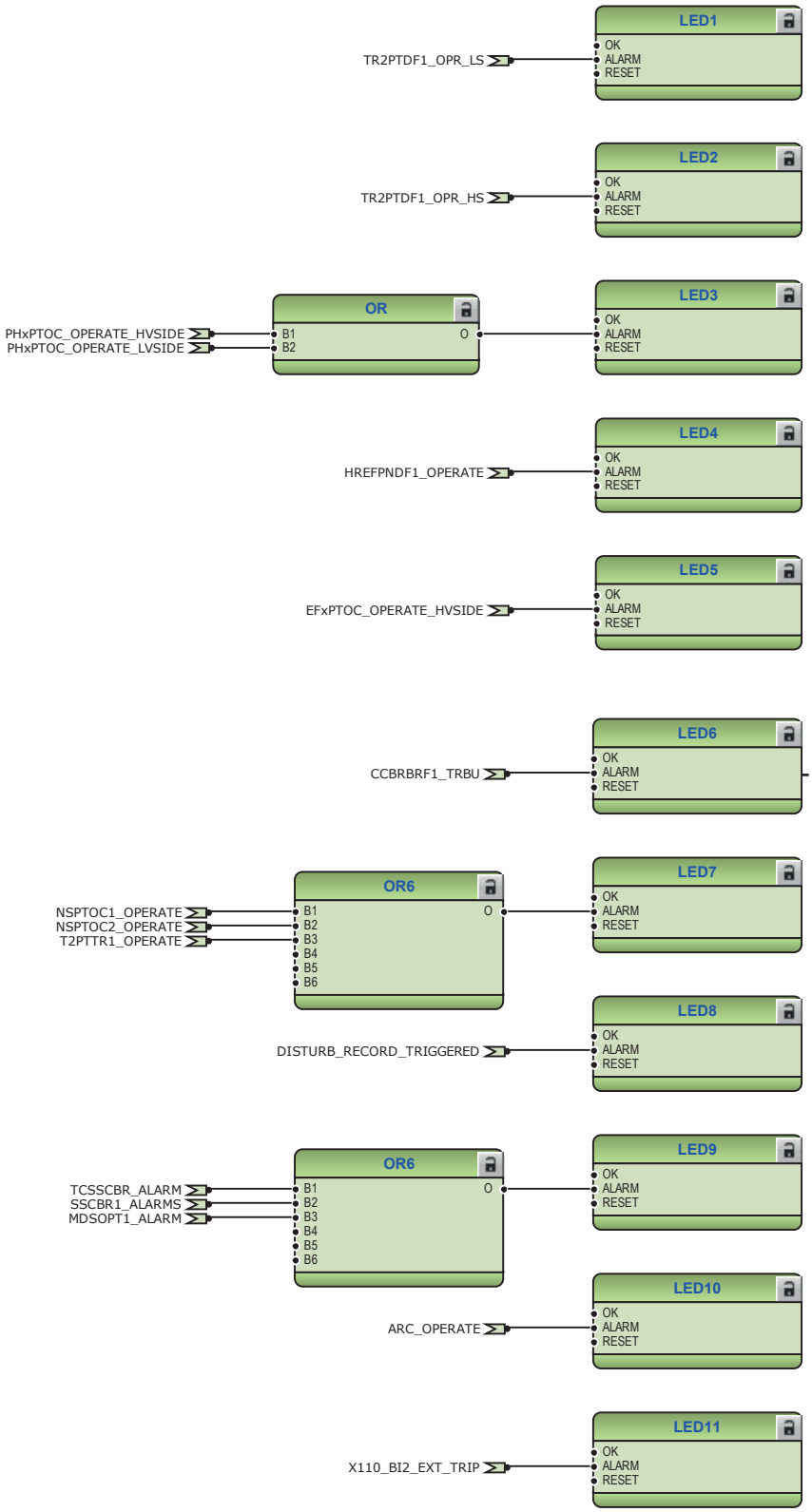


Figure 143: Default LED connection

3.5.3.7 Functional diagrams for other timer logics

In addition, configuration also includes overcurrent operate, differential operate, earth-fault operate and combined negative sequence and thermal overload operate logic. 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.

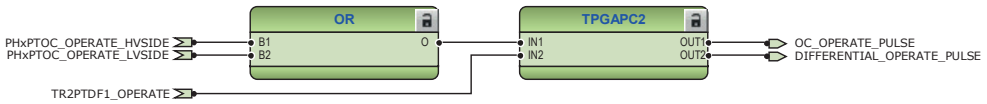


Figure 144: Timer logic for overcurrent and differential operate pulse

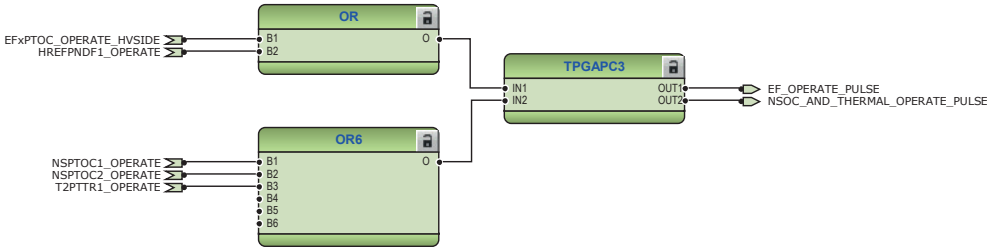


Figure 145: Timer logic for earth-fault and negative sequence and thermal overload operate pulse

3.5.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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.

3.6 Standard configuration D

3.6.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and high impedance based earth-fault protection for the low-voltage (LV) side. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.6.2 Functions

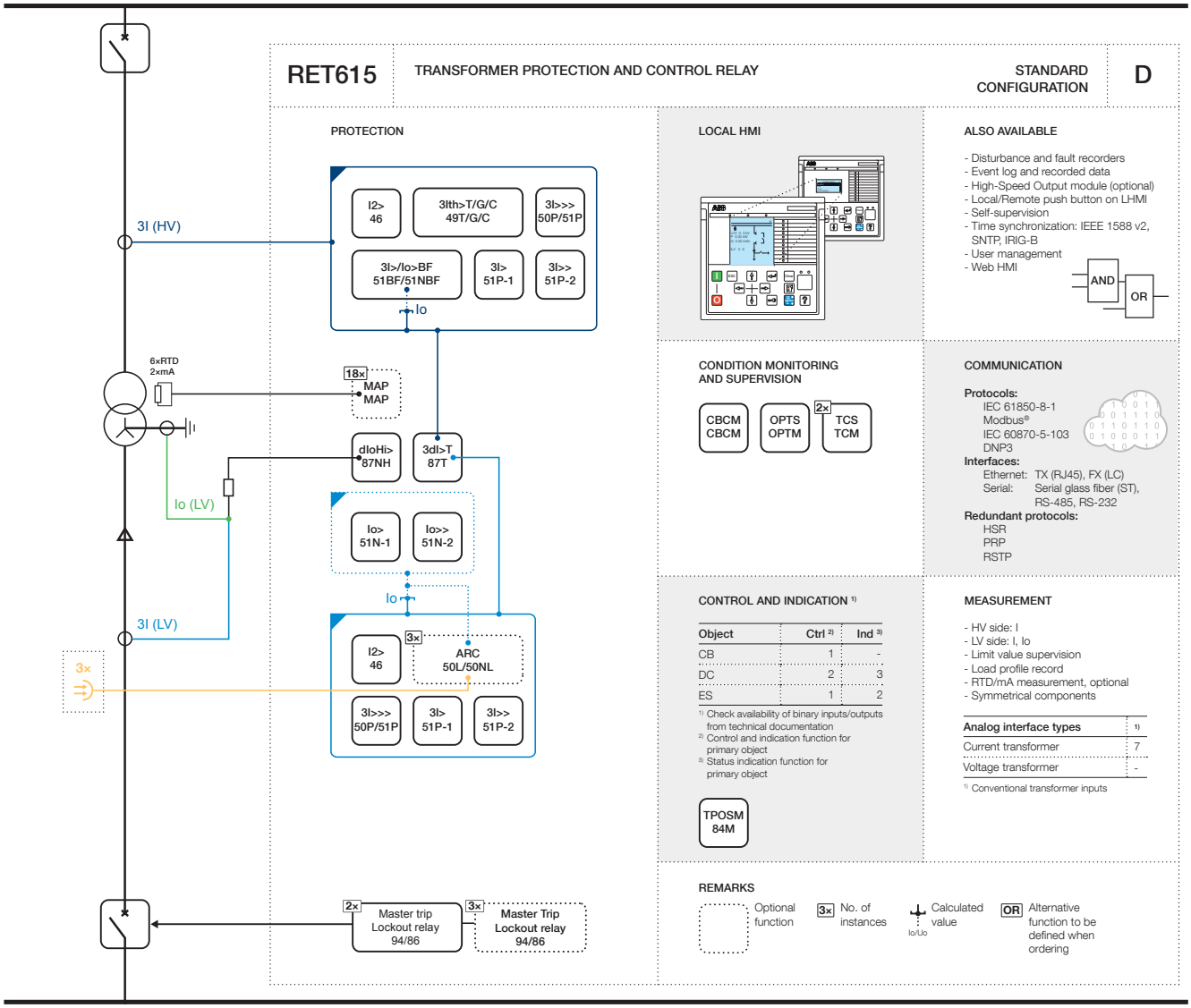


Figure 146: Functionality overview for standard configuration D

3.6.2.1 Default I/O connections

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

Table 29: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	BCD sign bit (tap changer position)
X130-BI2	BCD bit 0 (LSB)
X130-BI3	BCD bit 1
X130-BI4	BCD bit 2
X130-BI5	BCD bit 3
X130-BI6	BCD bit 4 (MSB)

Table 30: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 31: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
Table continues on next page	

Binary output	Description
X110-SO4	Thermal overload and negative phase-sequence 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

3.6.2.2 Default disturbance recorder settings

Table 32: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io B
8	-
9	-
10	-
11	-
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 33: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC2 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	HREFPDIF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	CCBRBRF1 - trret	Level trigger off
14	CCBRBRF1 - trbu	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
15	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
16	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
17	EFLPTOC2 - operate	Level trigger off
	EFHPTOC2 - operate	
18	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
19	TR2PTDF1 - operate	Positive or Rising
20	TR2PTDF1 - opr LS	Level trigger off
21	TR2PTDF1 - opr HS	Level trigger off
22	TR2PTDF1 - blkd2h	Level trigger off
23	TR2PTDF1 - blkd5h	Level trigger off
24	TR2PTDF1 - blkdwav	Level trigger off
25	HREFPDIF1 - operate	Level trigger off
26	T2PTTR1 - operate	Level trigger off
27	T2PTTR1 - alarm	Level trigger off
28	T2PTTR1 - blk close	Level trigger off
29	X110BI1 - ext OC blocking	Level trigger off
30	X110BI2 - ext trip	Positive or Rising
31	X110BI7 - HVCB closed	Level trigger off
32	X110BI8 - HVCB opened	Level trigger off
33	MDSOPT1 - alarm	Level trigger off
34	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
35	ARCSARC1 - operate	Positive or Rising
36	ARCSARC2 - operate	Positive or Rising
37	ARCSARC3 - operate	Positive or Rising

3.6.3 Functional diagrams

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

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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The protection relay offers six different setting groups which can be set based on 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.

3.6.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

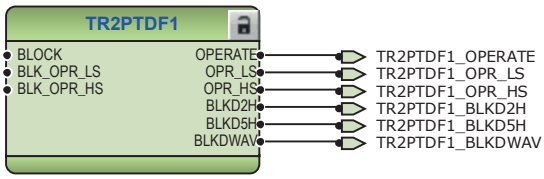


Figure 147: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110: BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

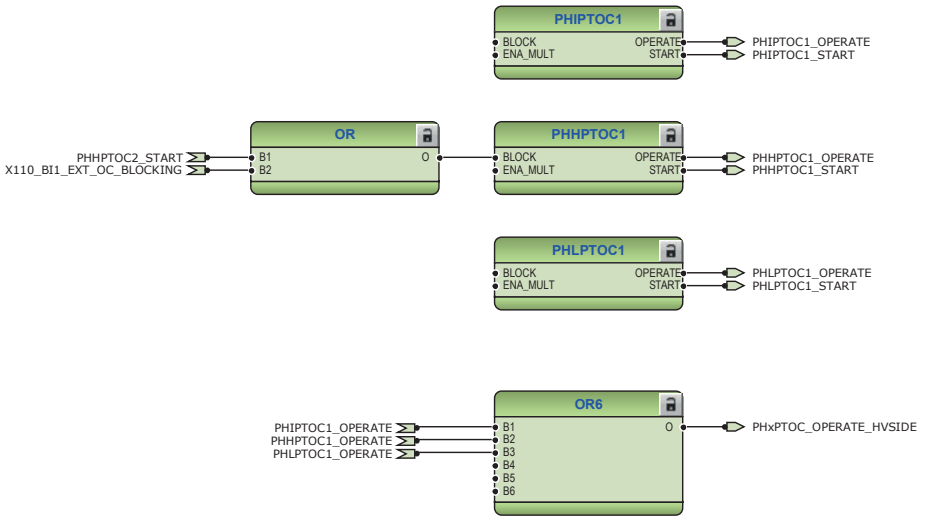


Figure 148: High-voltage side overcurrent protection function

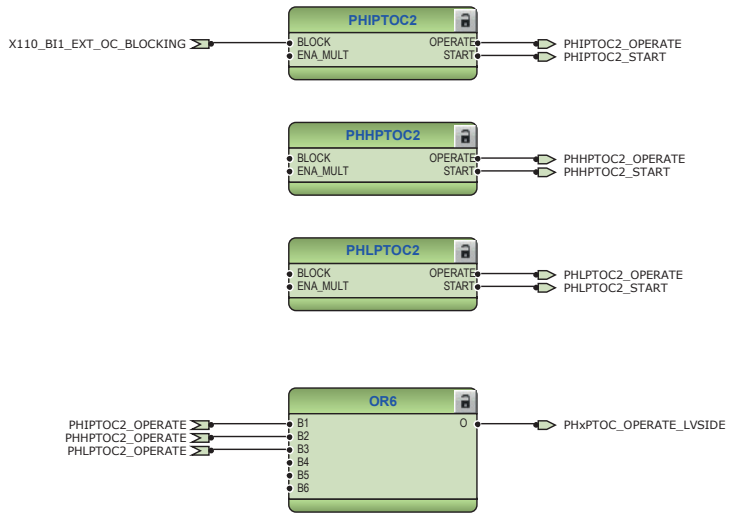


Figure 149: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from low-voltage side.

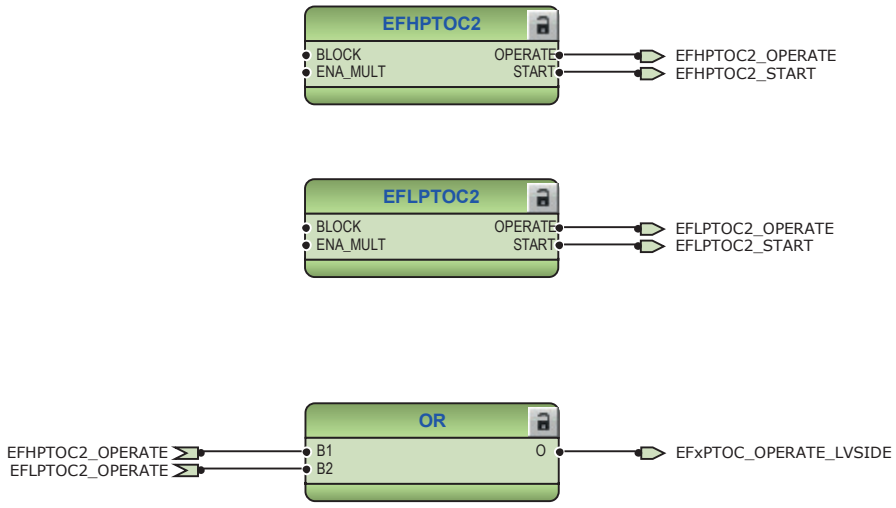


Figure 150: Low-voltage side earth-fault protection function

The configuration includes high-impedance based restricted earth-fault protection for low-voltage side of two-winding power transformers HREFPDIF1. The restricted earth-fault current stage operates exclusively on earth faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

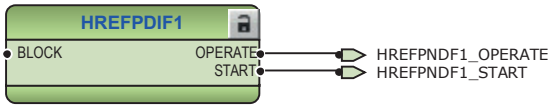


Figure 151: Restricted high-impedance earth-fault protection

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

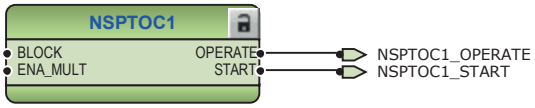


Figure 152: High-voltage side negative-sequence overprotection function

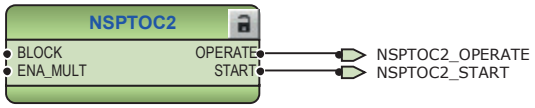


Figure 153: Low-voltage side negative-sequence overprotection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

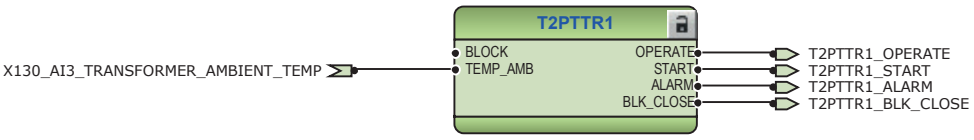


Figure 154: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase- and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

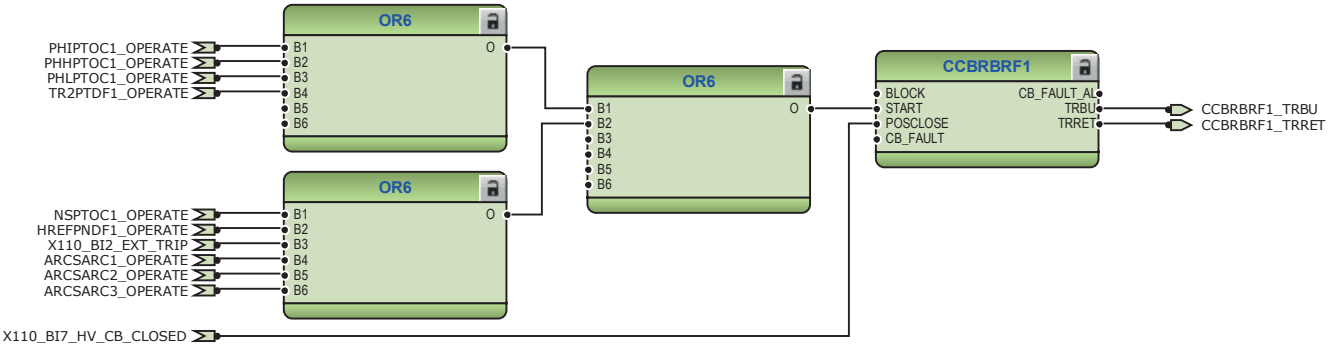


Figure 155: Circuit breaker failure protection function

Three arc protection ARCSARC1...3 stages 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 is ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

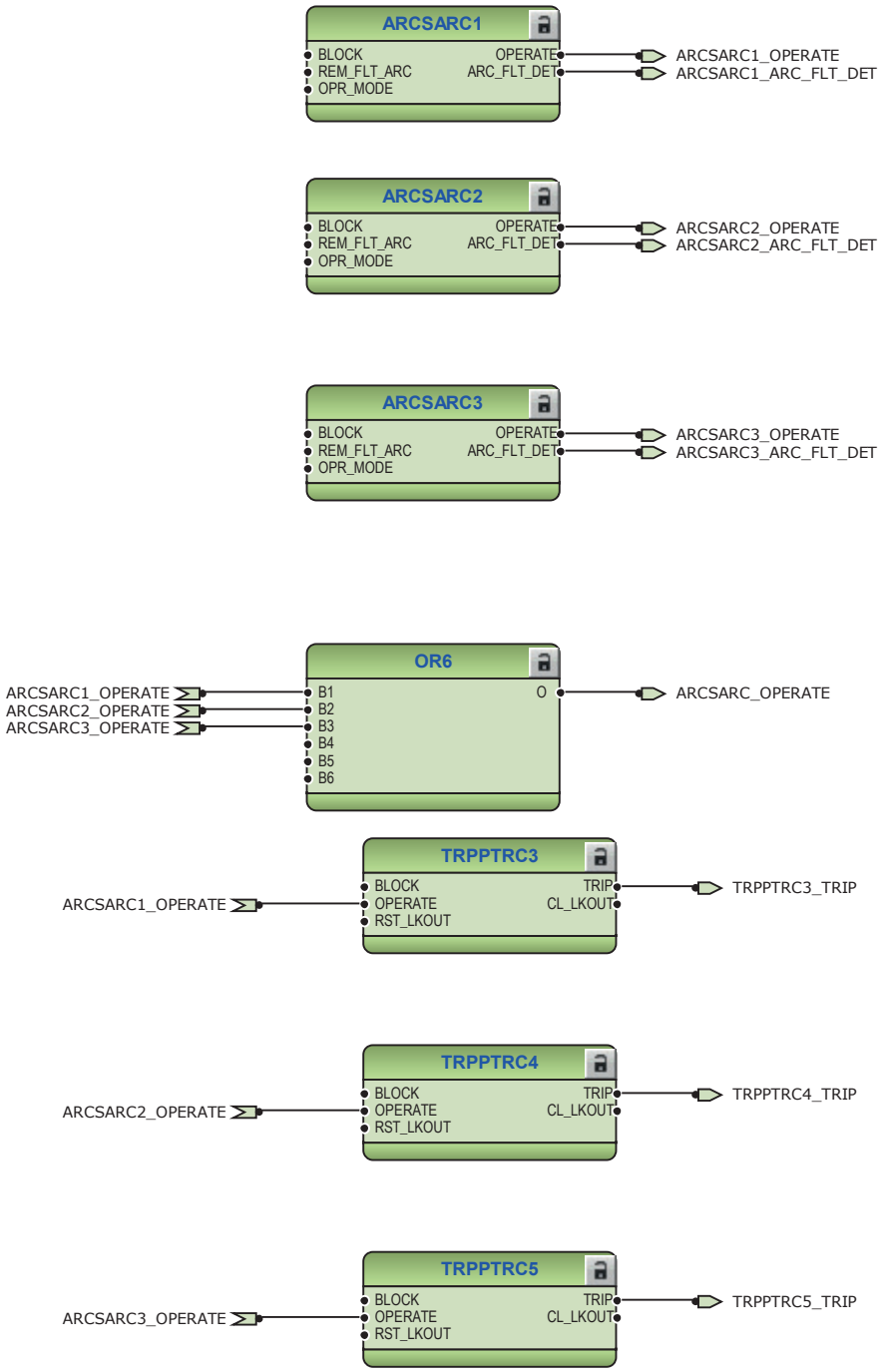


Figure 156: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

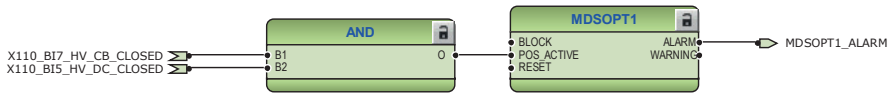


Figure 157: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs

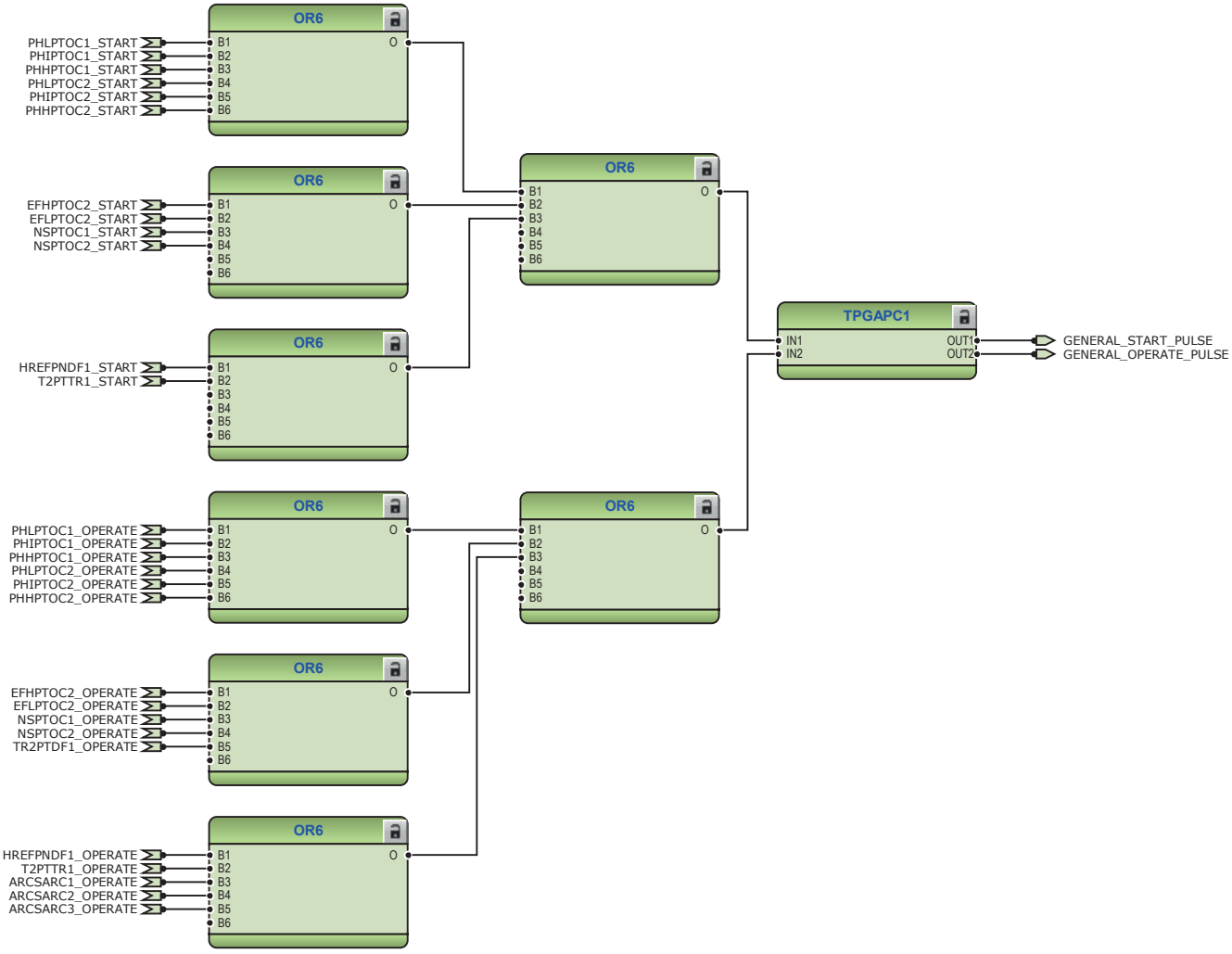


Figure 158: General start and operate signals

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is

selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

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

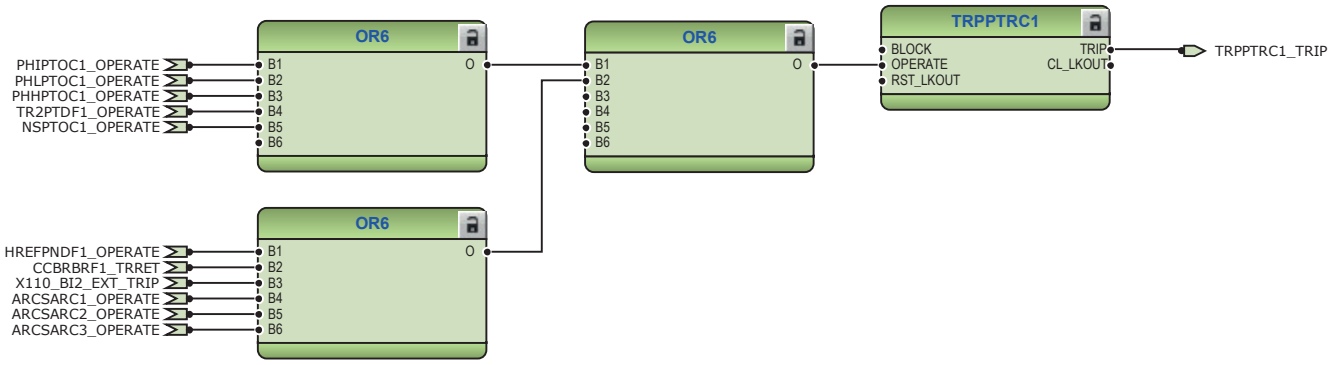


Figure 159: Trip logic TRPPTRC1

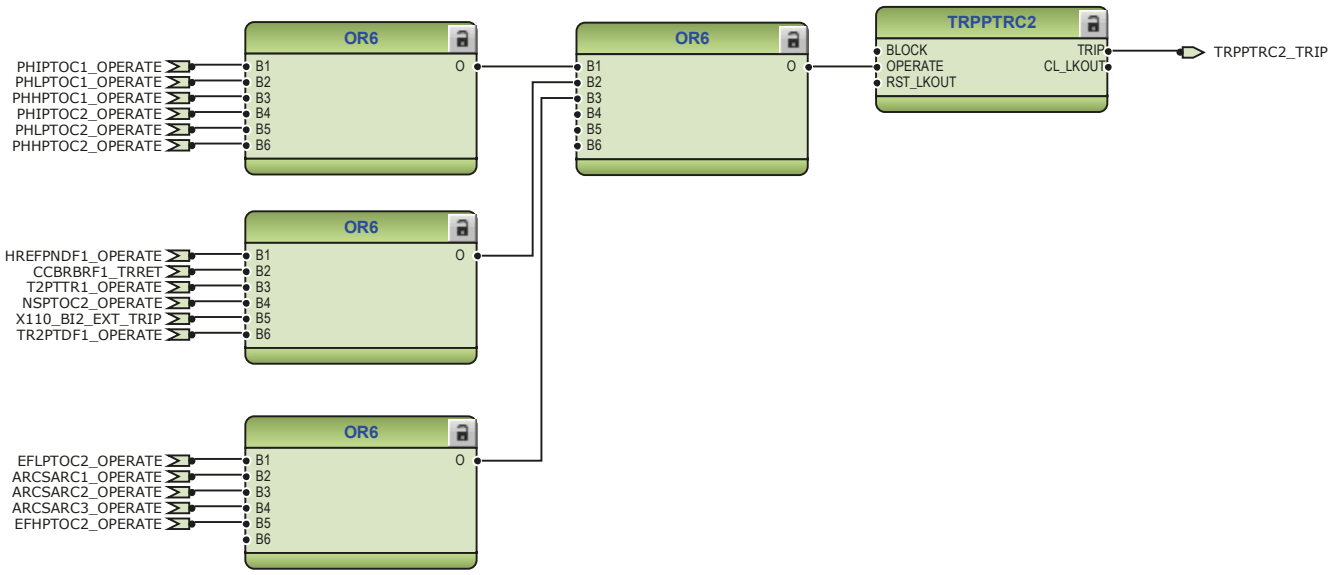


Figure 160: Trip logic TRPPTRC2

3.6.3.2 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.

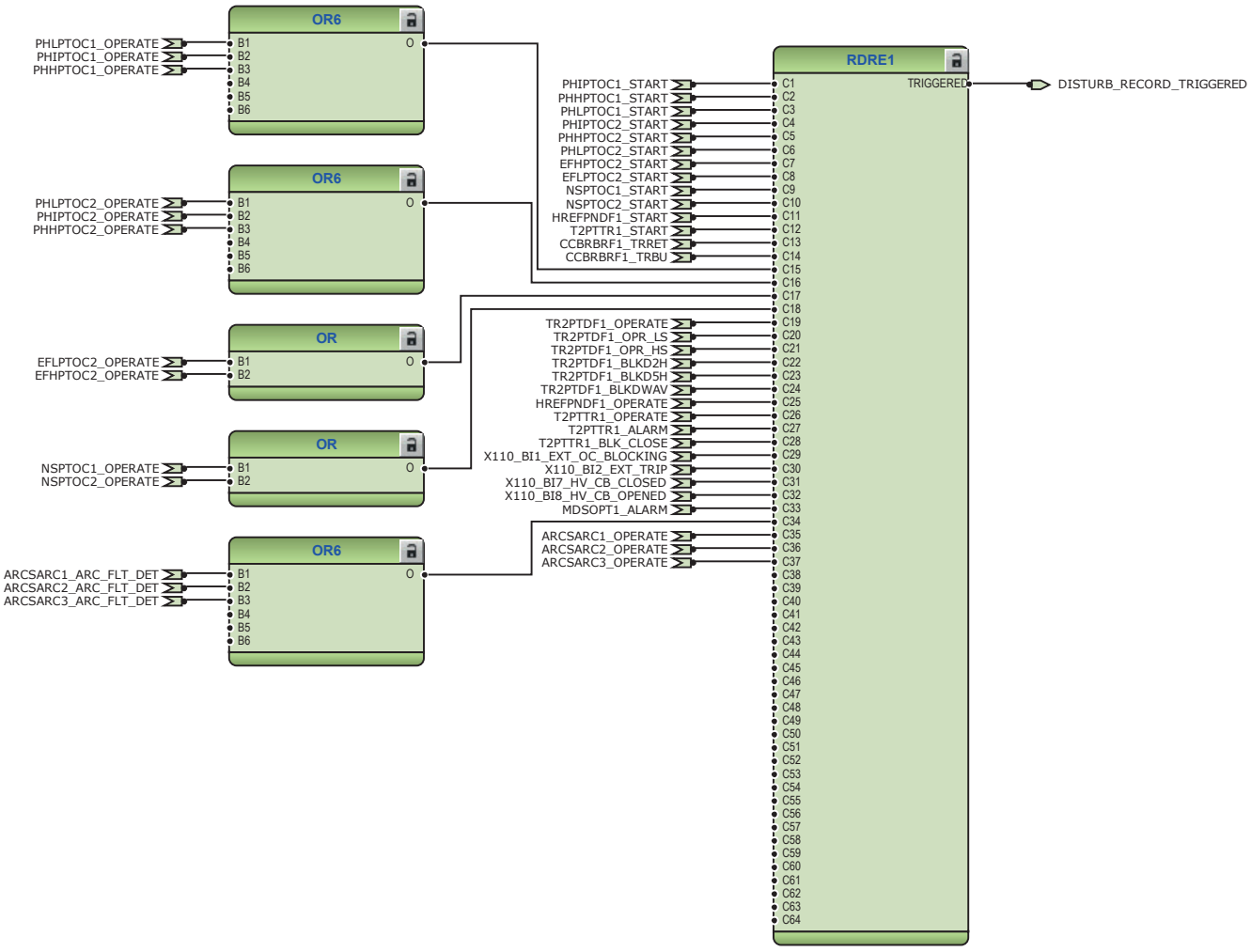


Figure 161: Disturbance recorder

3.6.3.3 Functional diagrams for condition monitoring

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

Set the parameters for SSCBR1 properly.

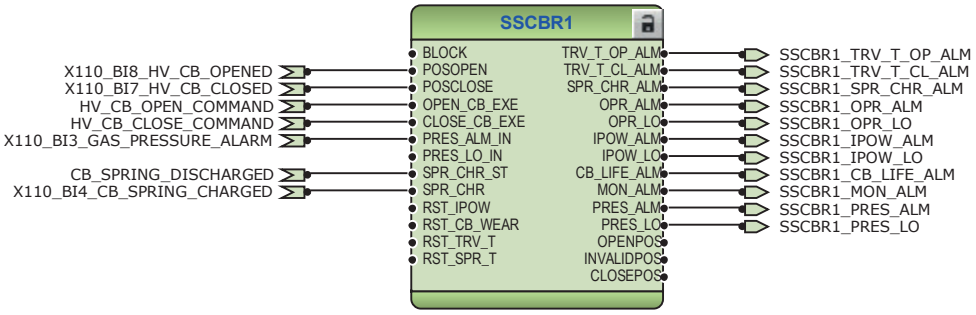


Figure 162: Circuit-breaker condition monitoring function

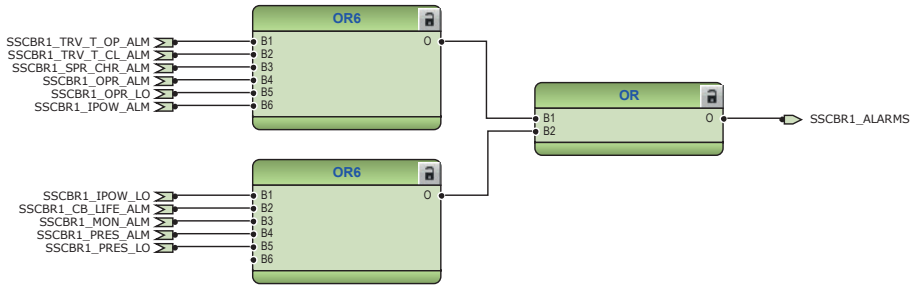


Figure 163: Logic for circuit-breaker monitoring alarm

Figure 164: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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

Set the parameters for TCSSCBR properly.

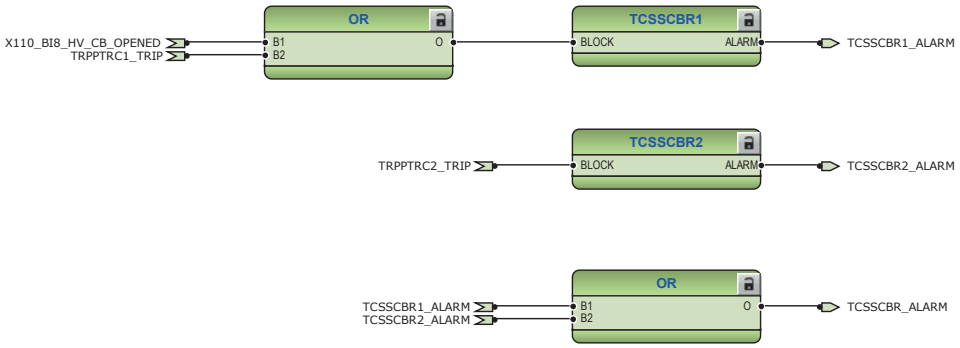


Figure 165: Trip circuit supervision function

3.6.3.4 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) status information is connected to DCSXSWI1.

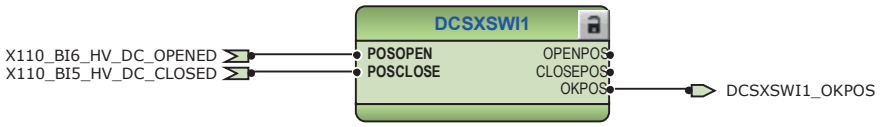


Figure 166: High-voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or closed (in service position). This, together with 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

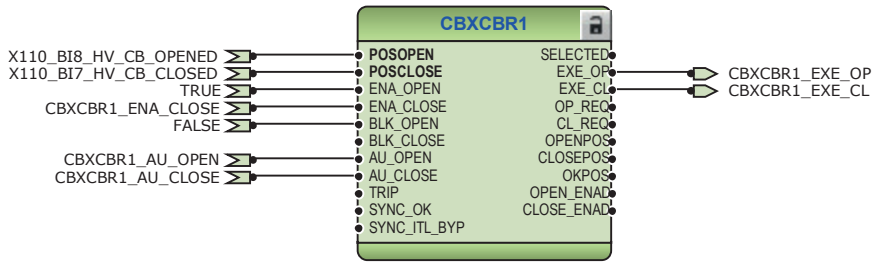


Figure 167: High-voltage side circuit breaker 1

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

Figure 168: Signals for closing coil of circuit breaker 1

Figure 169: Signals for opening coil of circuit breaker 1

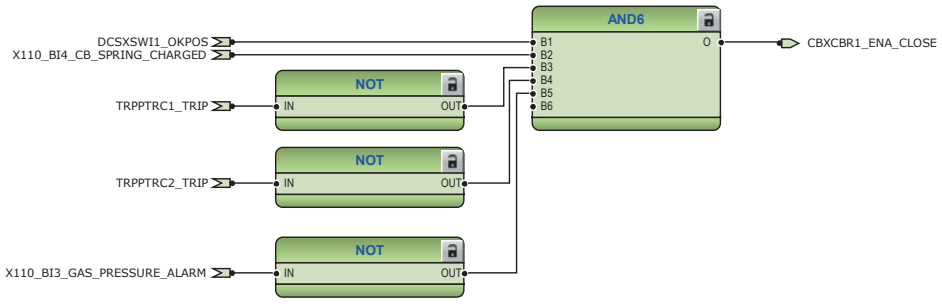


Figure 170: Circuit breaker 1 close enable logic

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

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

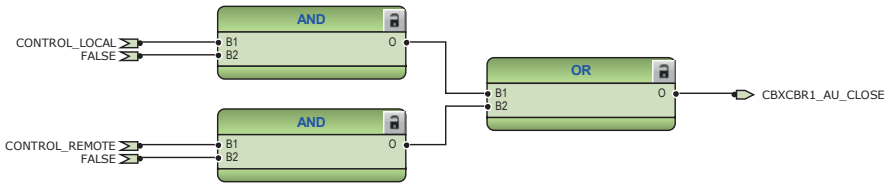


Figure 171: External closing command for circuit breaker 1

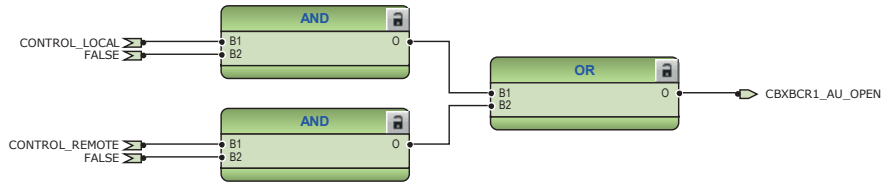


Figure 172: External opening command for circuit breaker 1

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. When binary signals are used TPOSYLTC1 is configured to use binary coded method to generate the integer value of the tap changer position.

Set the parameters for TPOSYLTC1 properly.

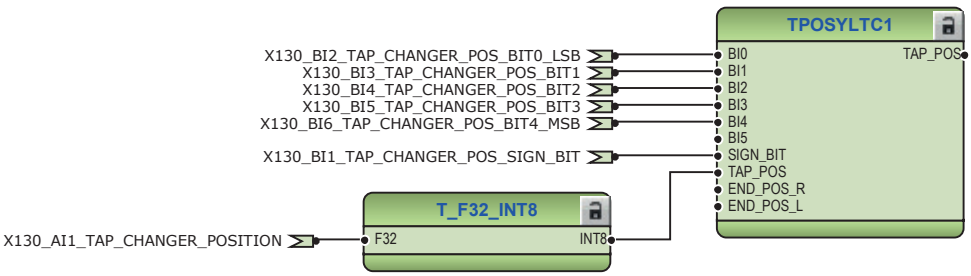


Figure 173: Tap changer position indicator

3.6.3.5 Functional diagrams for measurement functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current from high-voltage side and residual current measurement RESCMMXU2 measures the residual current from low-voltage side.

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.

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

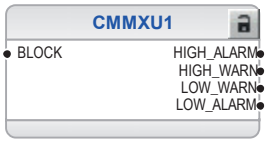


Figure 174: Current measurement: Three-phase current measurement (HV side)

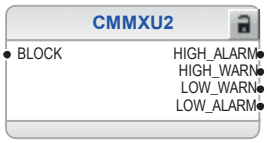


Figure 175: Current measurement: Three-phase current measurement (LV side)

Figure 176: Current measurement: Sequence current measurement (HV side)

Figure 177: Current measurement: Residual current measurement (LV side)

Figure 178: Other measurement: Data monitoring

Figure 179: Other measurement: Load profile record

3.6.3.6 Functional diagrams for I/O and alarms LEDs

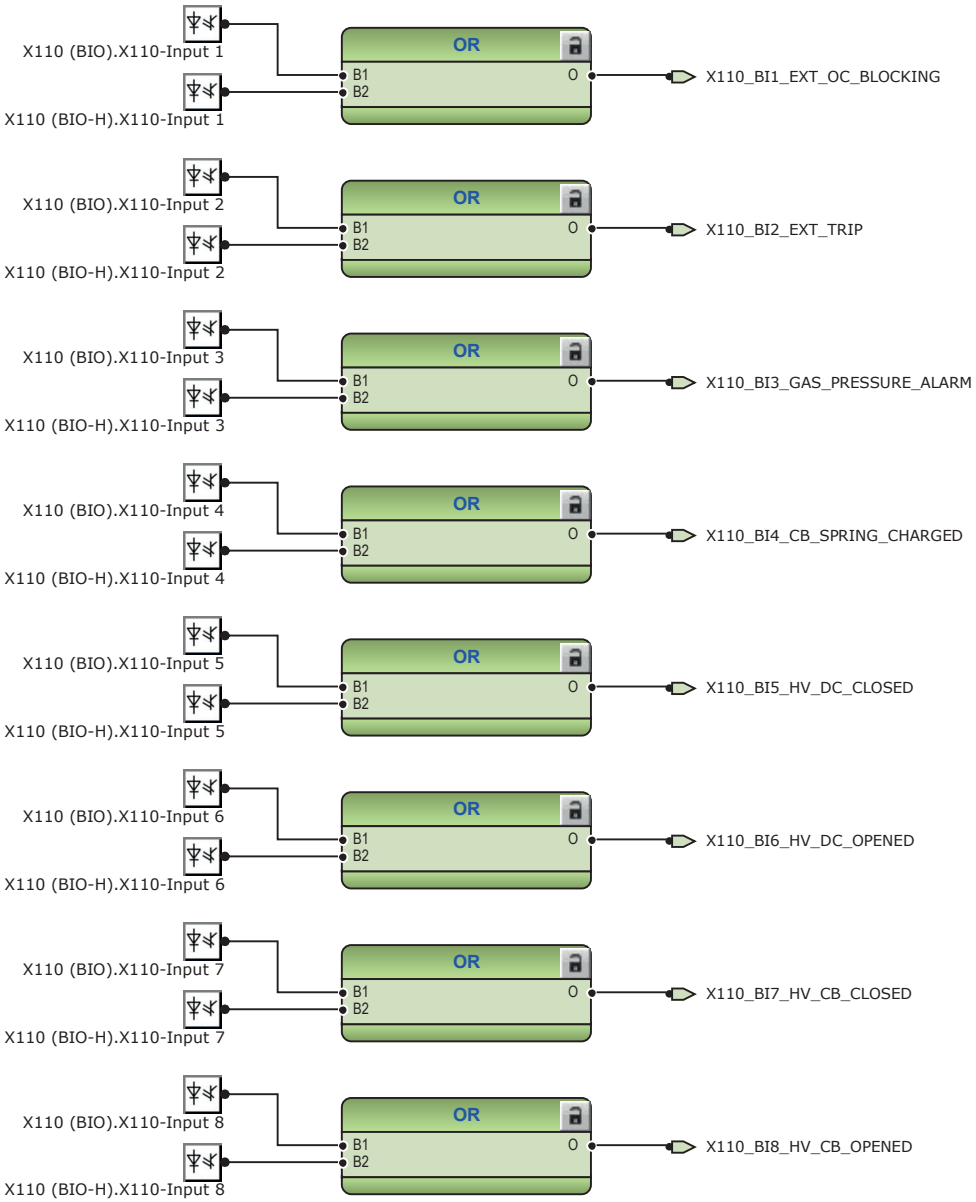


Figure 180: Binary inputs - X110 terminal block

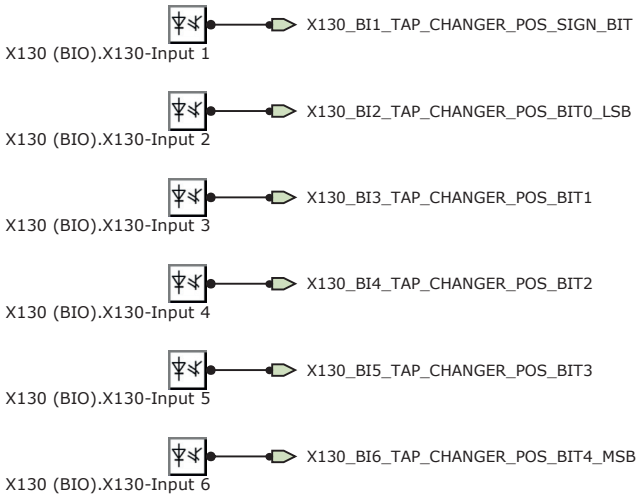


Figure 181: Binary inputs - X130 terminal block

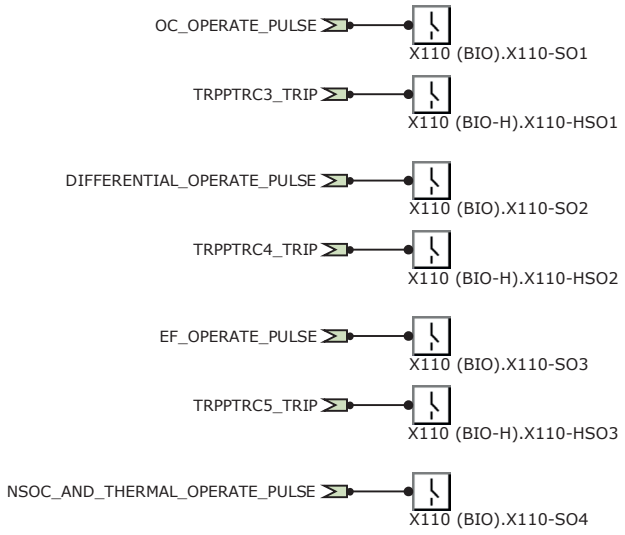


Figure 182: Binary outputs - X110 terminal block

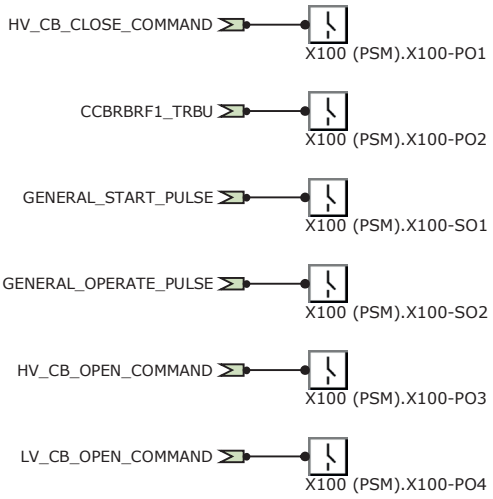


Figure 183: Binary outputs - X100 terminal block

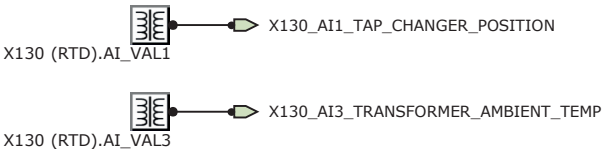


Figure 184: Default mA/RTD inputs X130

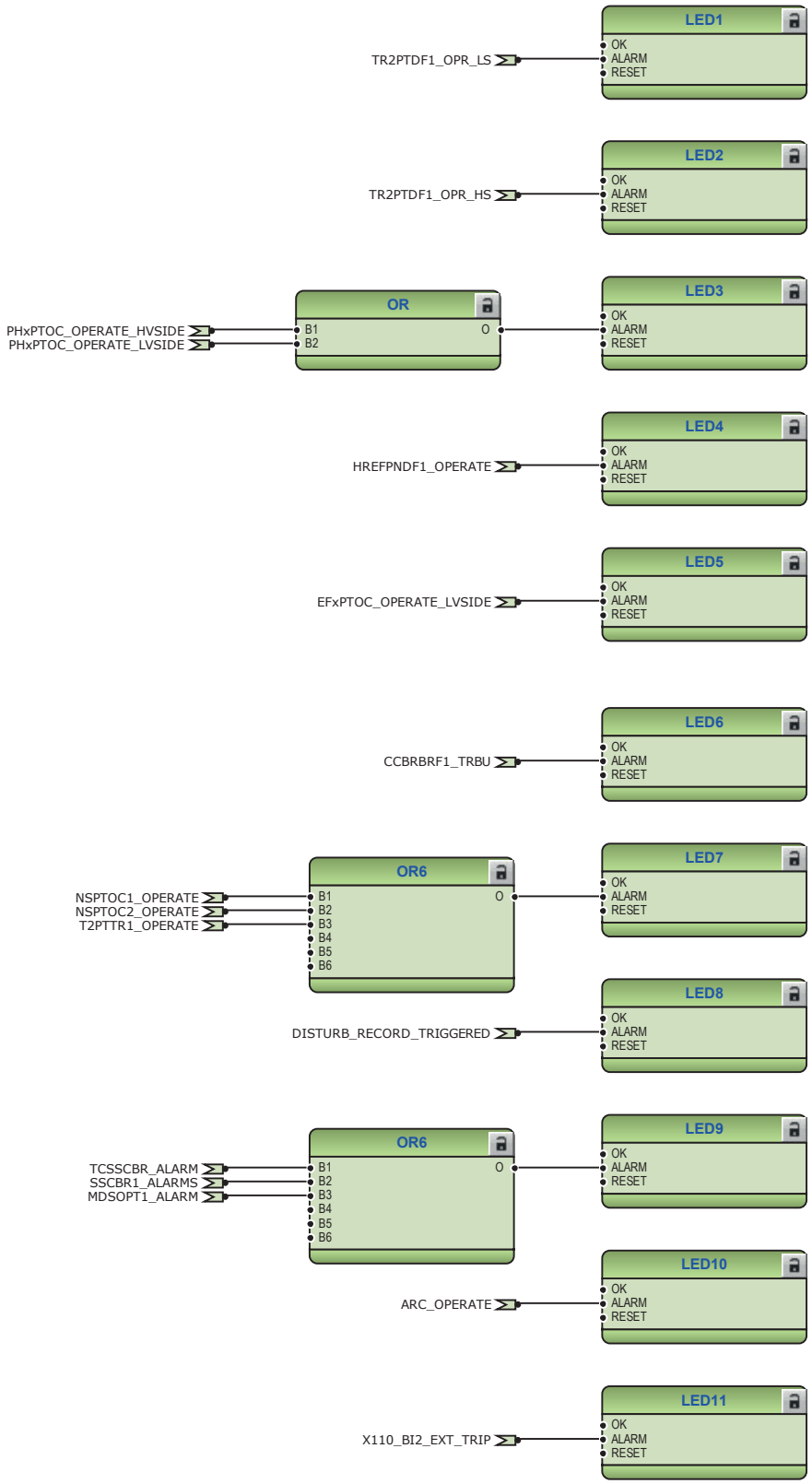


Figure 185: Default LED connection

3.6.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined negative sequence and thermal overload operate logic. 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.

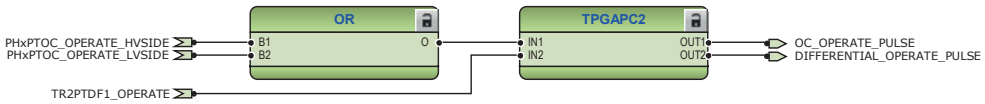


Figure 186: Timer logic for overcurrent and differential operate pulse

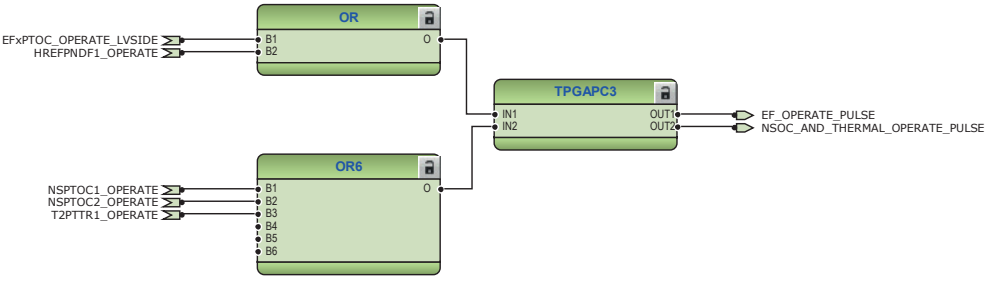


Figure 187: Timer logic for earth-fault and negative sequence and thermal overload operate pulse

3.6.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and few instances of 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.

3.7 Standard configuration E

3.7.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the high-voltage (HV) side, high voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.7.2 Functions

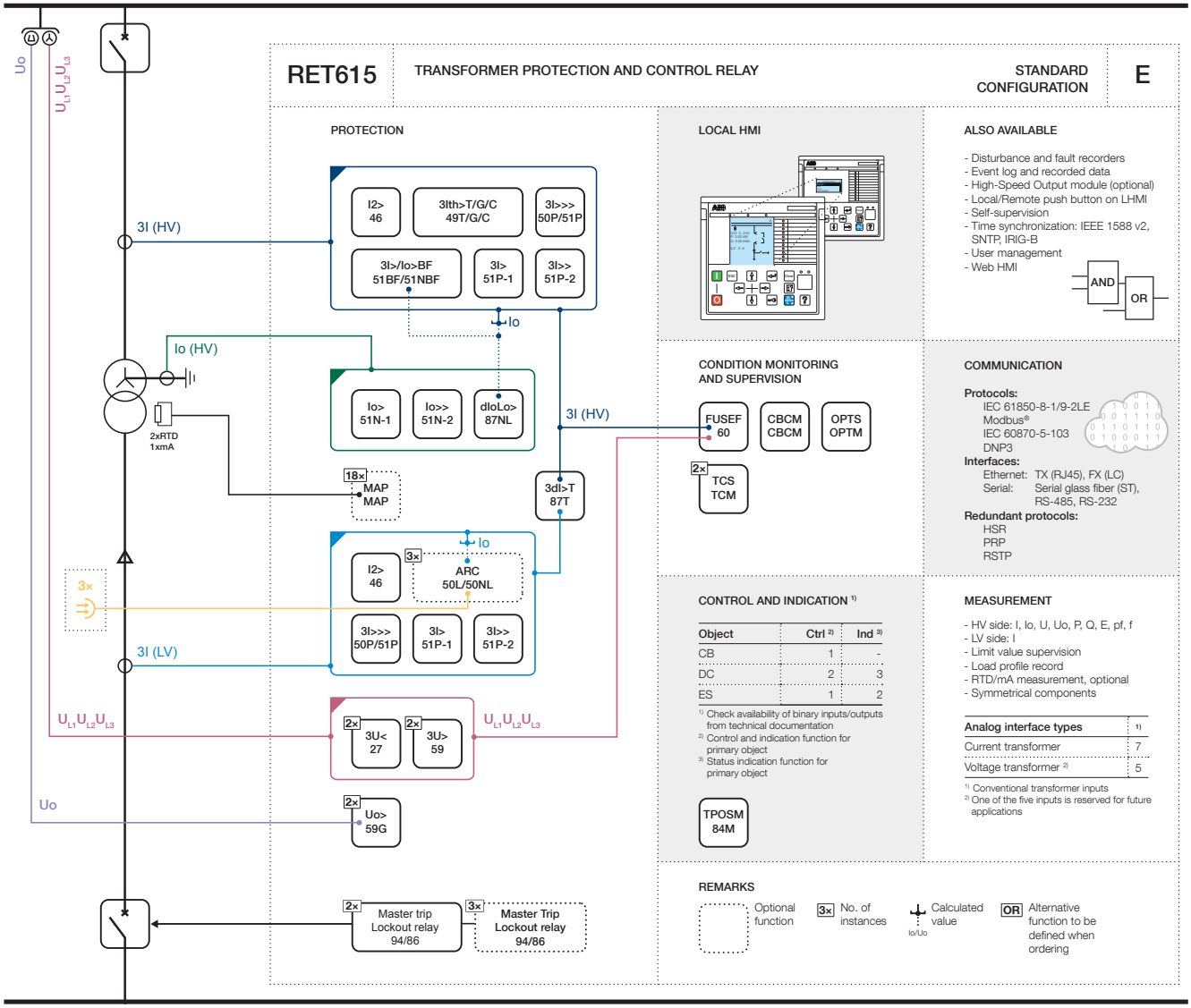


Figure 188: Functionality overview for standard configuration E

3.7.2.1 Default I/O connections

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

Table 34: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	Voltage transformer secondary MCB open
X130-BI2	-
X130-BI3	-
X130-BI4	-

Table 35: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 36: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
X110-SO4	Thermal overload and negative phase-sequence operate alarm
Table continues on next page	

Binary output	Description
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 37: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Overcurrent or earth-fault protection operate
4	Restricted earth-fault protection operate
5	Voltage protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.7.2.2 Default disturbance recorder settings

Table 38: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8Uo	Uo
9	U1
10	U2
11	U3
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 39: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC1 - start	Positive or Rising
8	EFLPTOC1 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	LREFPNDF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	ROVPTOV1 - start	Positive or Rising
14	ROVPTOV2 - start	Positive or Rising
15	PHPTOV1 - start	Positive or Rising
16	PHPTOV2 - start	Positive or Rising
17	PHPTUV1 - start	Positive or Rising
18	PHPTUV2 - start	Positive or Rising
19	CCBRBRF1 - trret	Level trigger off
20	CCBRBRF1 - trbu	Level trigger off
21	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
22	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
23	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
24	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
25	TR2PTDF1 - operate	Positive or Rising
26	TR2PTDF1 - opr LS	Level trigger off
27	TR2PTDF1 - opr HS	Level trigger off
28	TR2PTDF1 - blkd2h	Level trigger off
29	TR2PTDF1 - blkd5h	Level trigger off
30	TR2PTDF1 - blkdwav	Level trigger off
31	LREFPNDF1 - operate	Level trigger off
32	T2PTTR1 - operate	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	T2PTTR1 - alarm	Level trigger off
34	T2PTTR1 - blk close	Level trigger off
35	SEQSPVC1 - fusef3ph	Level trigger off
36	SEQSPVC1 - fusefu	Level trigger off
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
38	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
39	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
40	X110BI1 - ext OC blocking	Level trigger off
41	X110BI2 - ext trip	Positive or Rising
42	X110BI7 - HVCB closed	Level trigger off
43	X110BI8 - HVCB opened	Level trigger off
44	MDSOPT1 - alarm	Level trigger off
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

3.7.3 Functional diagrams

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

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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

The protection relay offers six different setting groups which can be set based on 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.

3.7.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to the master trips as well as to alarm LEDs

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

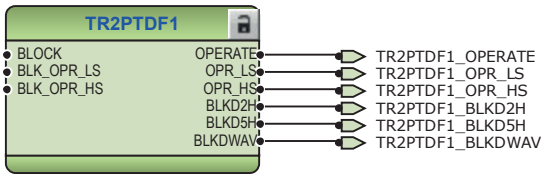


Figure 189: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

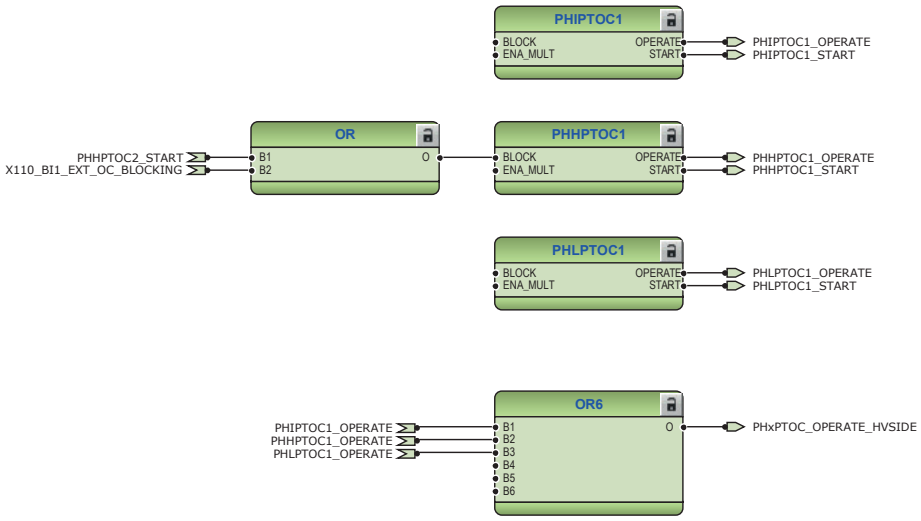


Figure 190: High-voltage side overcurrent protection function

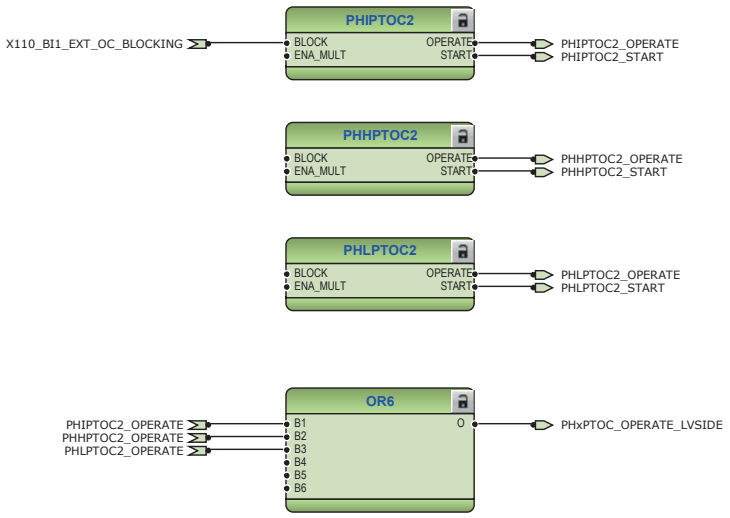


Figure 191: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from high-voltage side.

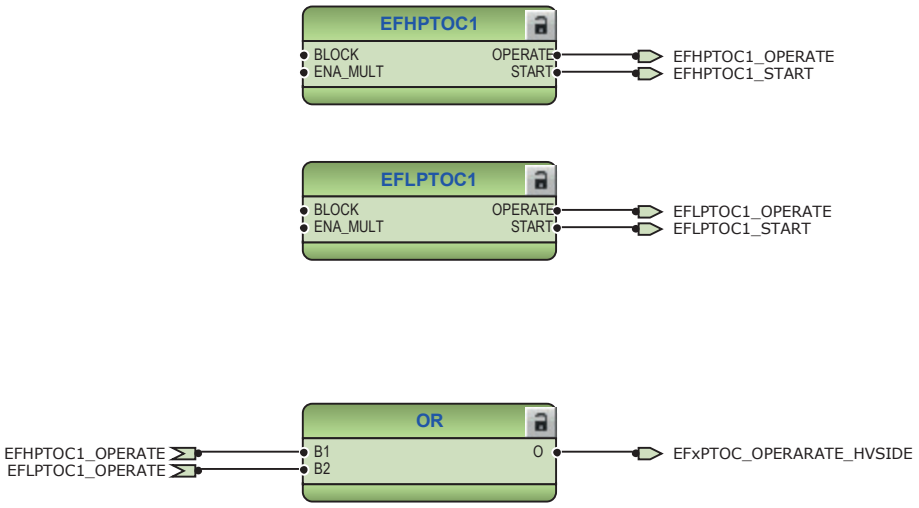


Figure 192: High-voltage side earth-fault protection function

Configuration also includes numerically stabilized low-impedance restricted earth-fault protection for high-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

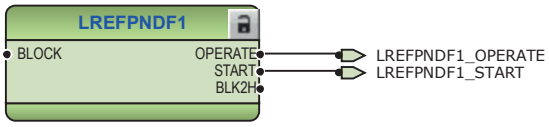


Figure 193: Restricted low-impedance earth-fault protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

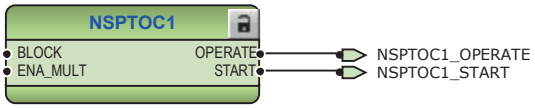


Figure 194: High-voltage side negative-sequence overcurrent protection function

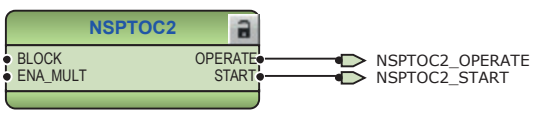


Figure 195: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

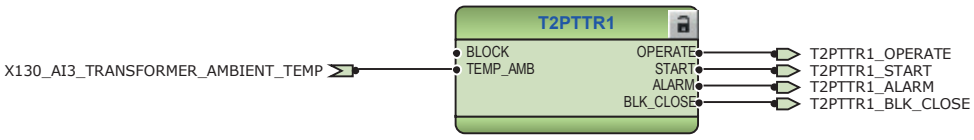


Figure 196: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. The TRBU output is used to give a back-up trip to the breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the binary output (X100:PO2).

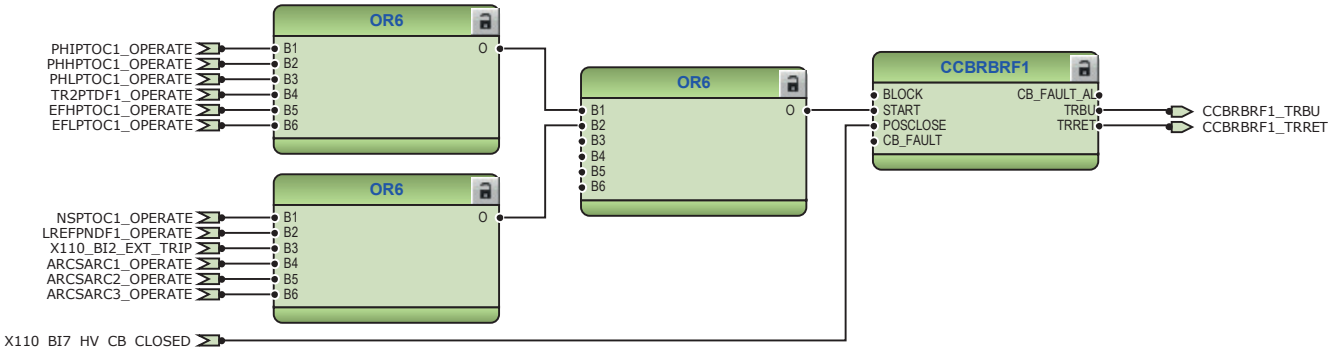


Figure 197: Circuit breaker failure protection function

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

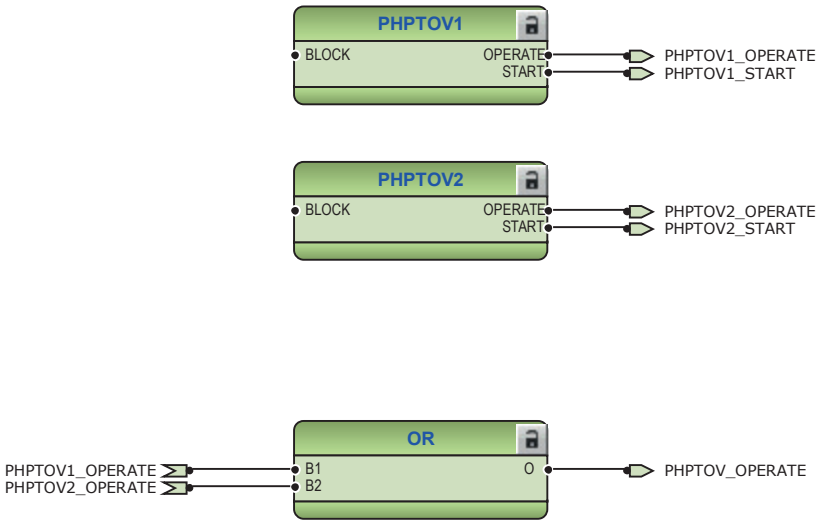


Figure 198: High-voltage side phase overvoltage protection function

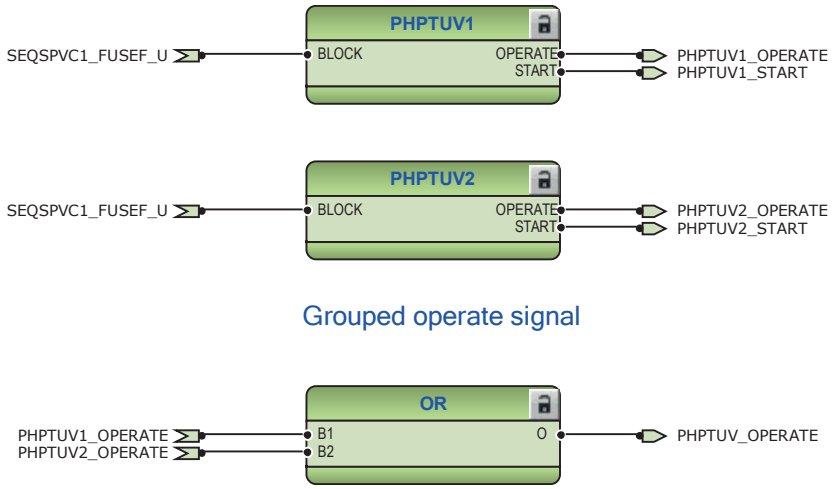


Figure 199: High-voltage side phase undervoltage protection function

High-voltage side phase undervoltage protection function

Residual overvoltage protection ROVPTOV provides earth-fault protection by detecting abnormal level of residual voltage.

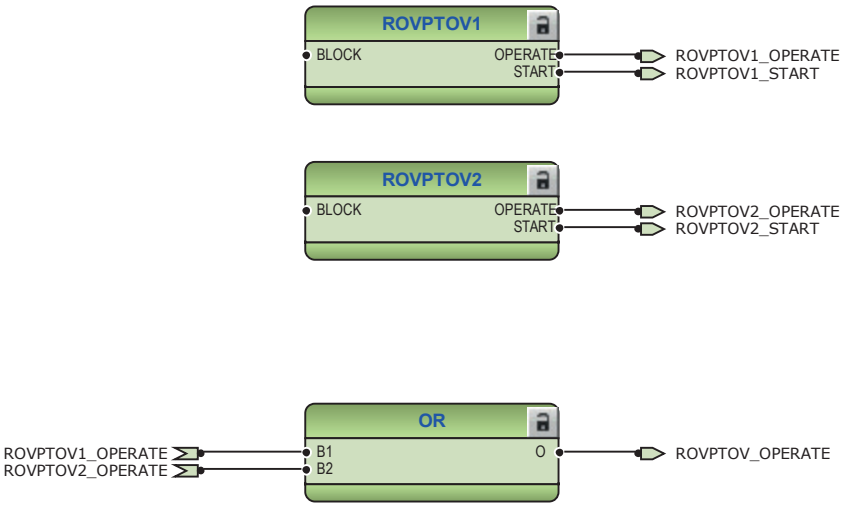


Figure 200: High-voltage side residual voltage protection function

Three arc protection ARCSARC1...3 stages 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 trip logic TRPPTRC1 and TRPPTRC2. If the IED has been ordered with high speed binary outputs, the individual operate signal from ARCSARC1...3 is connected to dedicated trip logic TRPPTRC3...5. The output of these TRPPTRC3...5 is available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

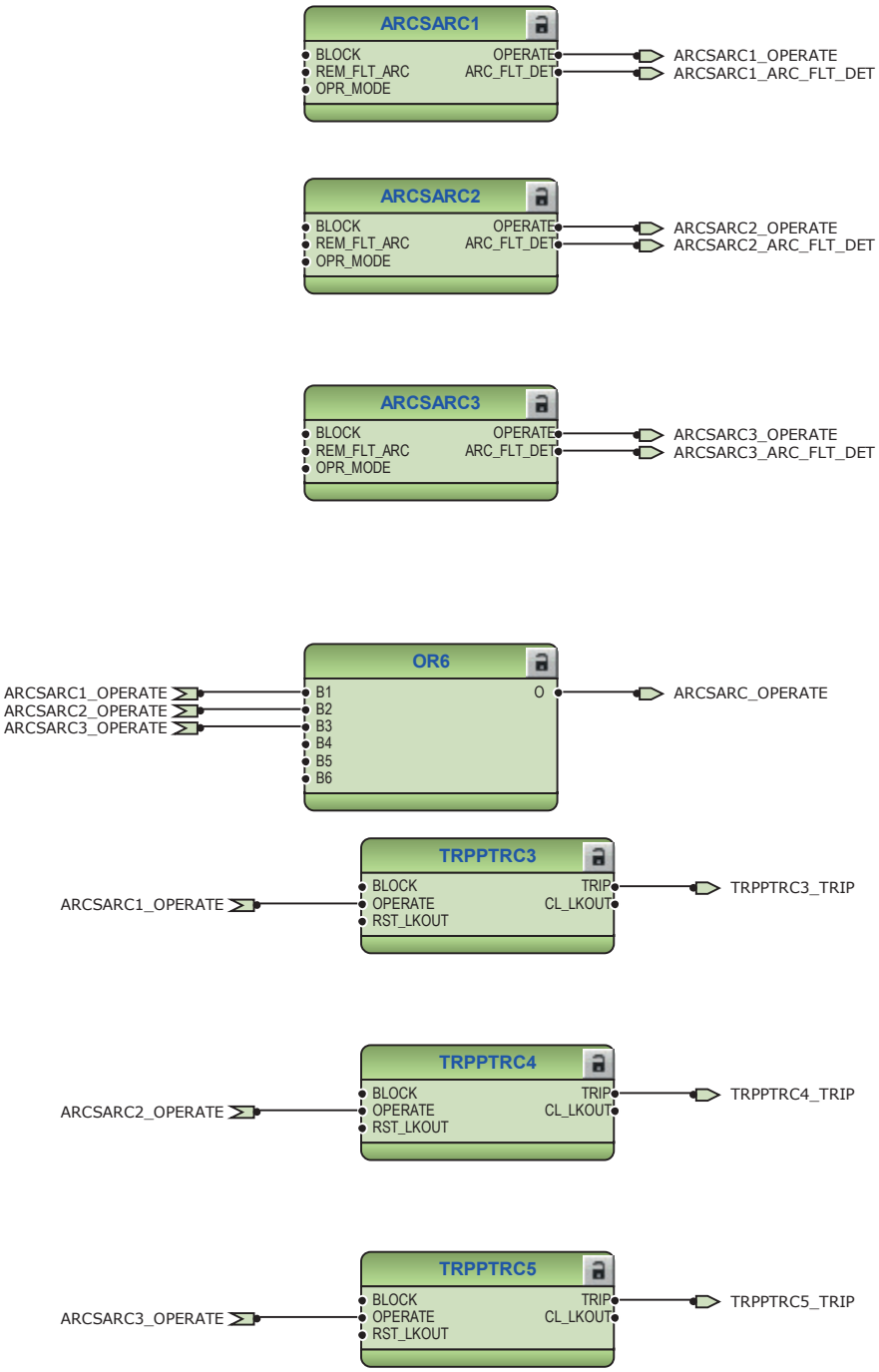


Figure 201: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

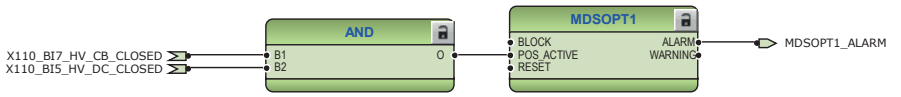


Figure 202: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

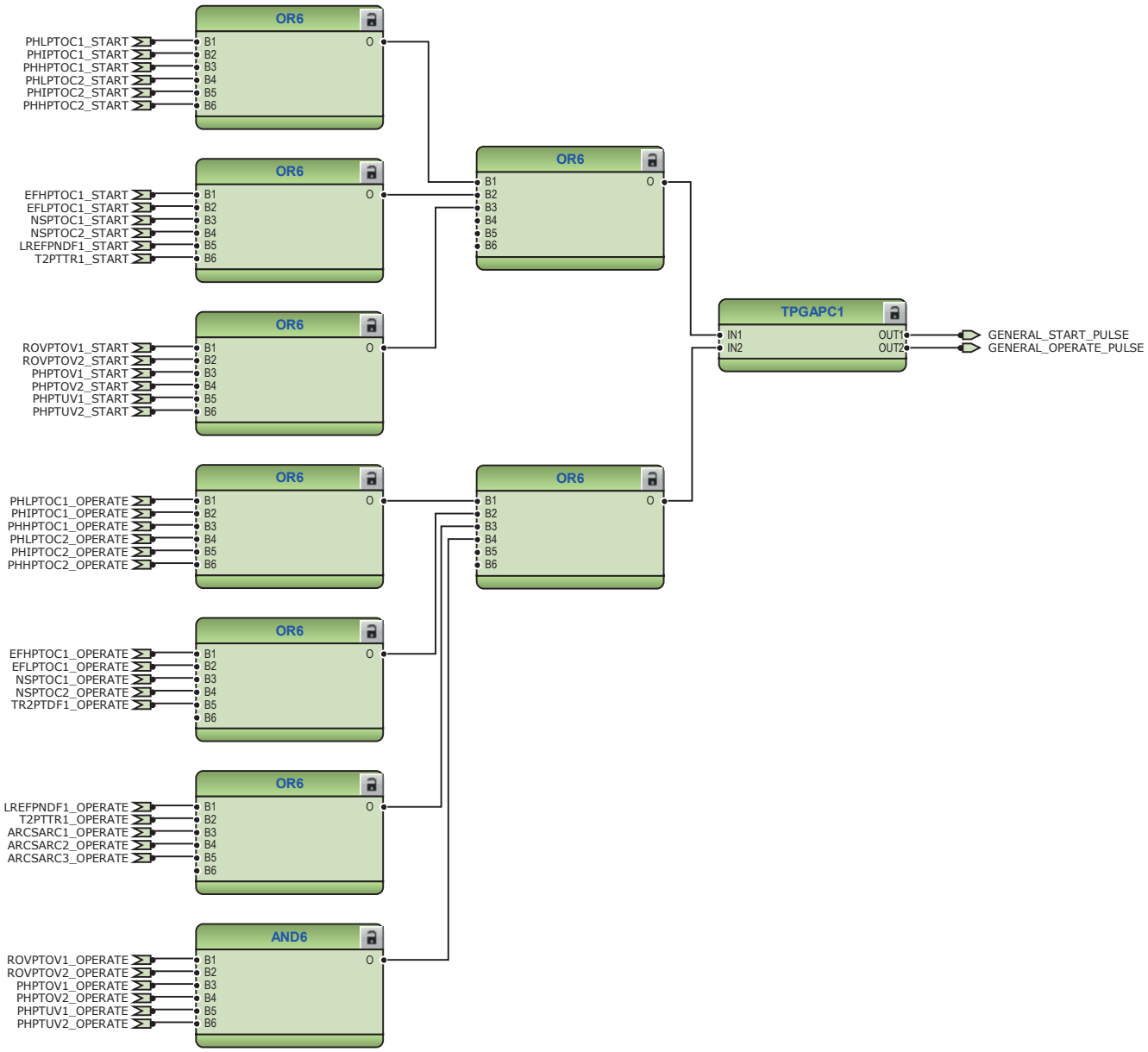


Figure 203: General start and operate signals

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at

binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of the trip logic to enable external reset with a push button.

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

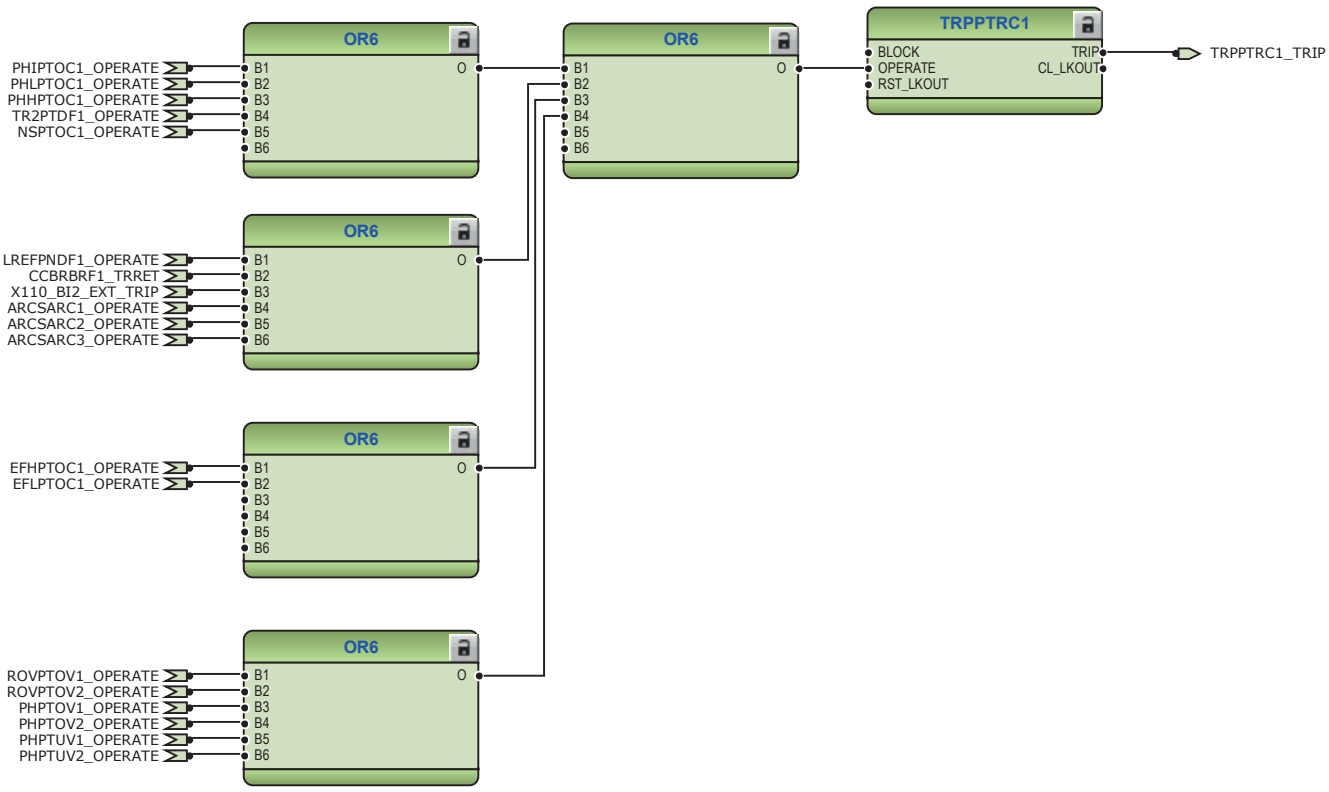


Figure 204: Trip logic TRPPTRC1

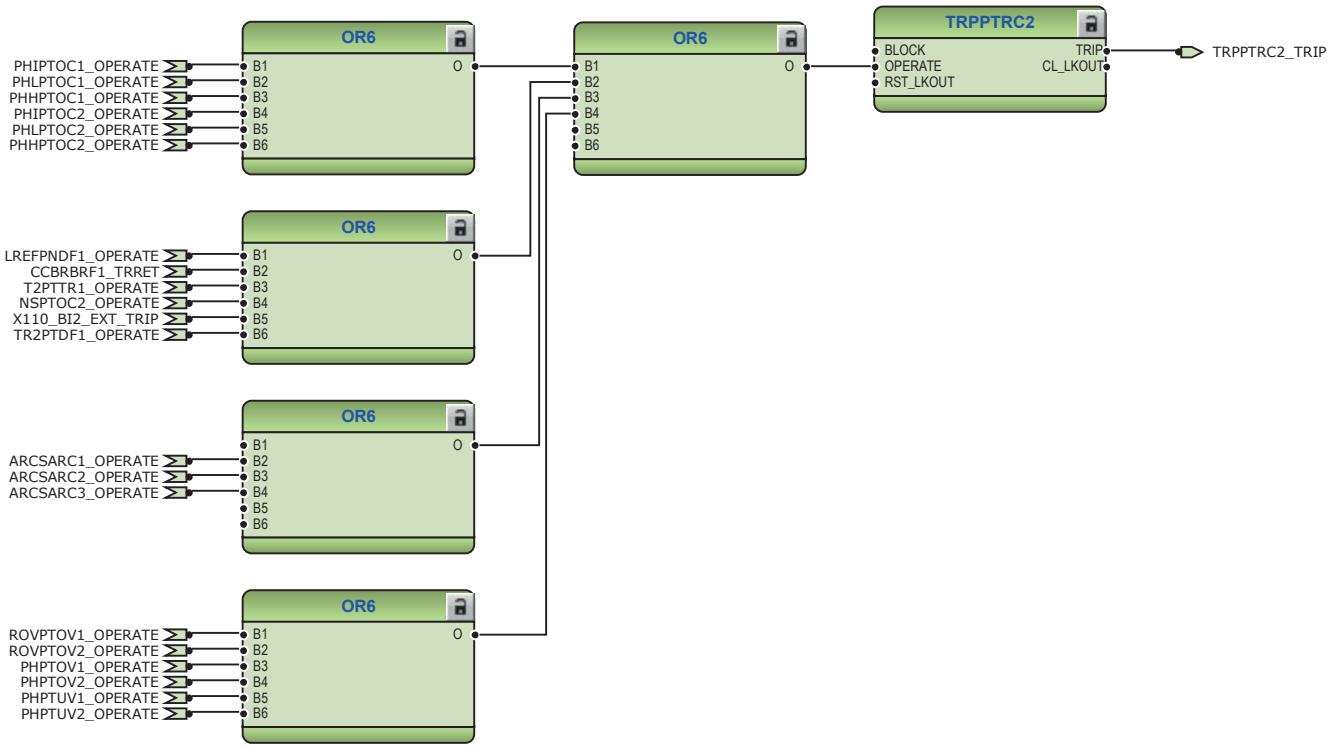


Figure 205: Trip logic TRPPTRC2

3.7.3.2 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.

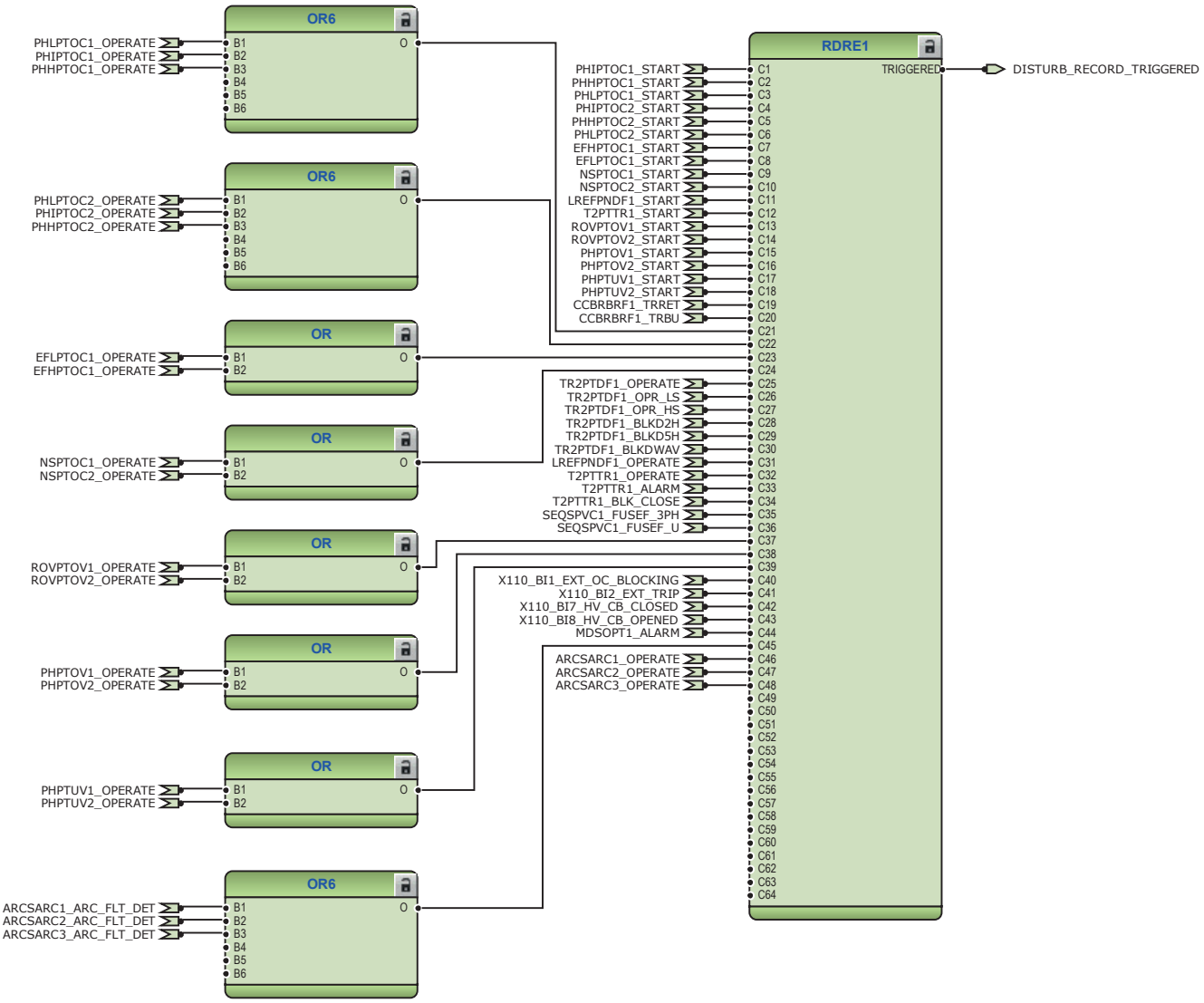


Figure 206: Disturbance recorder

3.7.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

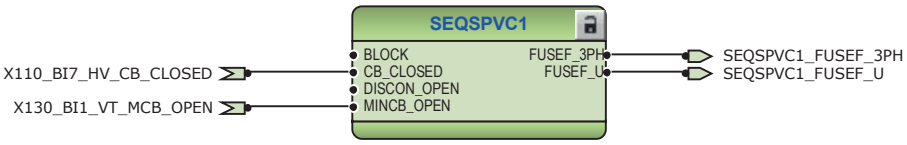


Figure 207: Fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

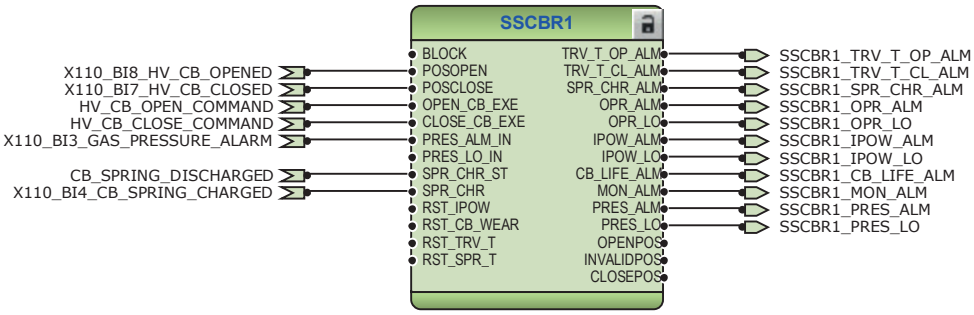


Figure 208: Circuit-breaker condition monitoring function

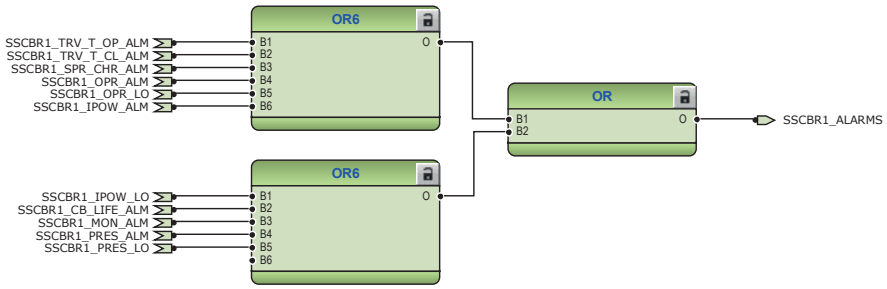


Figure 209: Logic for circuit-breaker monitoring alarm

Figure 210: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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.

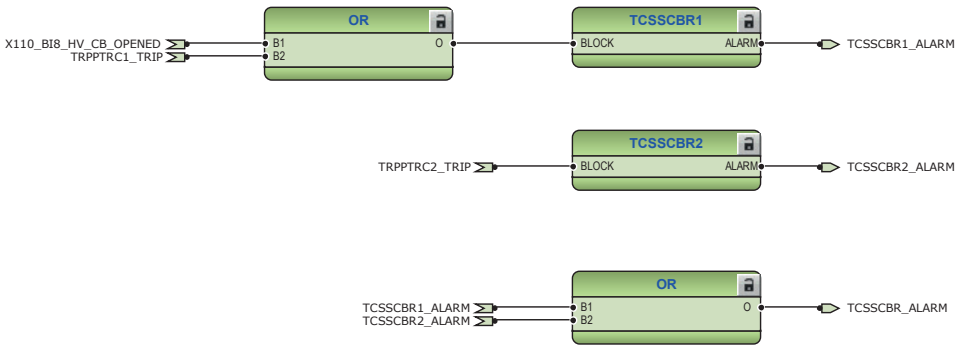


Figure 211: Trip circuit supervision function

3.7.3.4 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) status information is connected to DCSXSWI1.

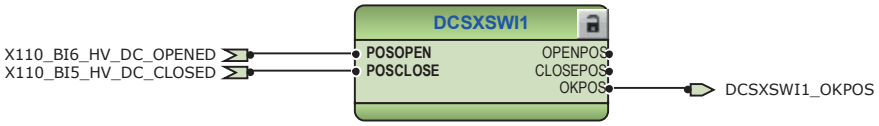


Figure 212: High voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or closed (in service position). This, together with 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

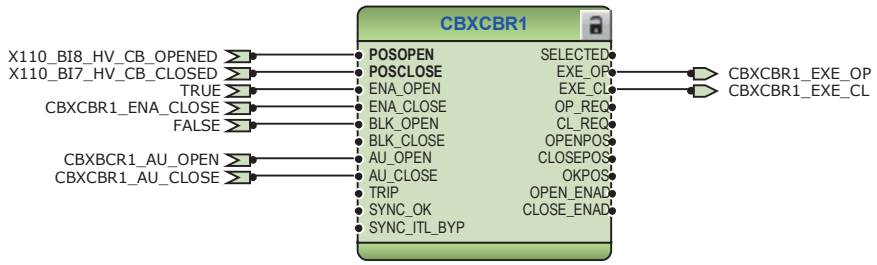


Figure 213: High-voltage side circuit breaker 1

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

Figure 214: Signals for closing coil of circuit breaker 1

Figure 215: Signals for opening coil of circuit breaker 1

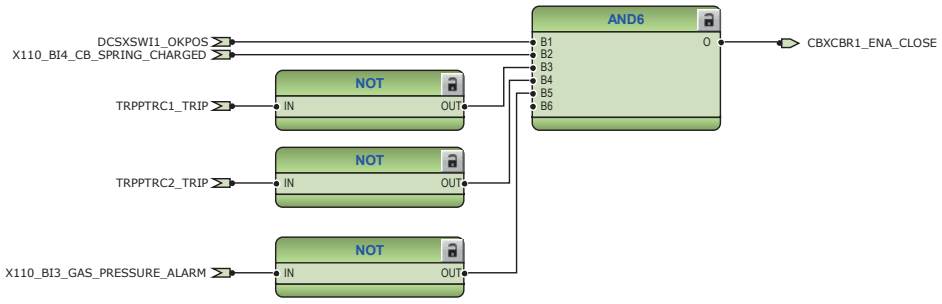


Figure 216: High-voltage side circuit breaker 1 close enable logic

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

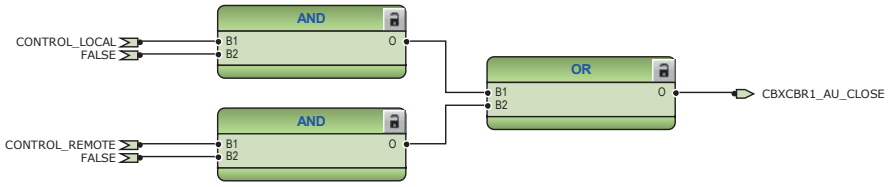


Figure 217: External closing command for circuit breaker 1

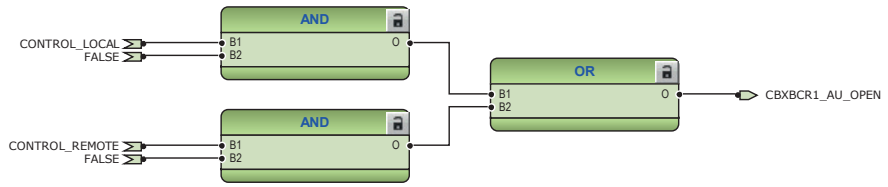


Figure 218: External opening command for circuit breaker 1

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters TPOSYLTC1 properly.

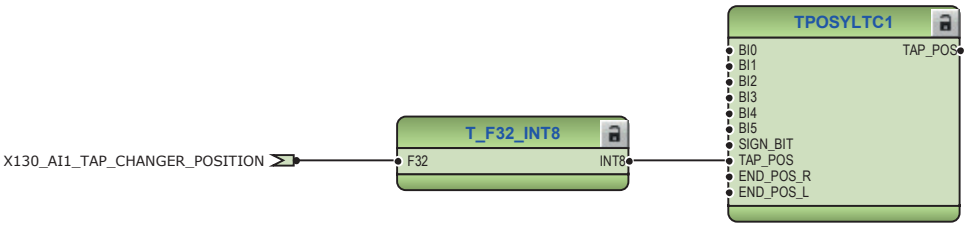


Figure 219: Tap changer position indicator

3.7.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current and residual current measurement RESCMMXU1 measures the residual current from high-voltage side.

The high-voltage side three 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. Sequence voltage measurement VSMSQI1 measures the sequence voltage and residual voltage measurement RESVMMXU1 measures the residual voltage from high-voltage side.

The measurements can be seen in the LHMI and they are available by using 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

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

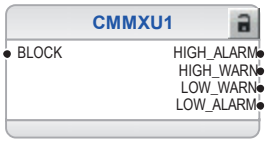


Figure 220: Current measurement: Three-phase current measurement (HV side)

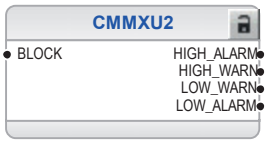


Figure 221: Current measurement: Three-phase current measurement (LV side)

Figure 222: Current measurement: Sequence current measurement (HV side)

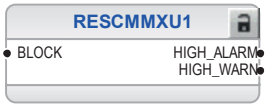


Figure 223: Current measurement: Residual current measurement (HV side)

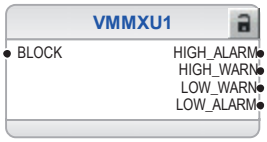


Figure 224: Voltage measurement: Three-phase voltage measurement (HV side)

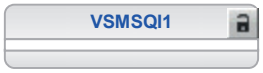


Figure 225: Voltage measurement: Sequence voltage measurement (HV side)

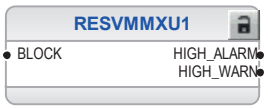


Figure 226: Voltage measurement: Residual voltage measurement (HV side)

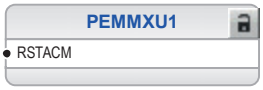


Figure 227: Other measurement: Three-phase power and energy measurement

Figure 228: Other measurement: Data monitoring

Figure 229: Other measurement: Load profile record

3.7.3.6 Functional diagrams for I/O and alarms LEDs

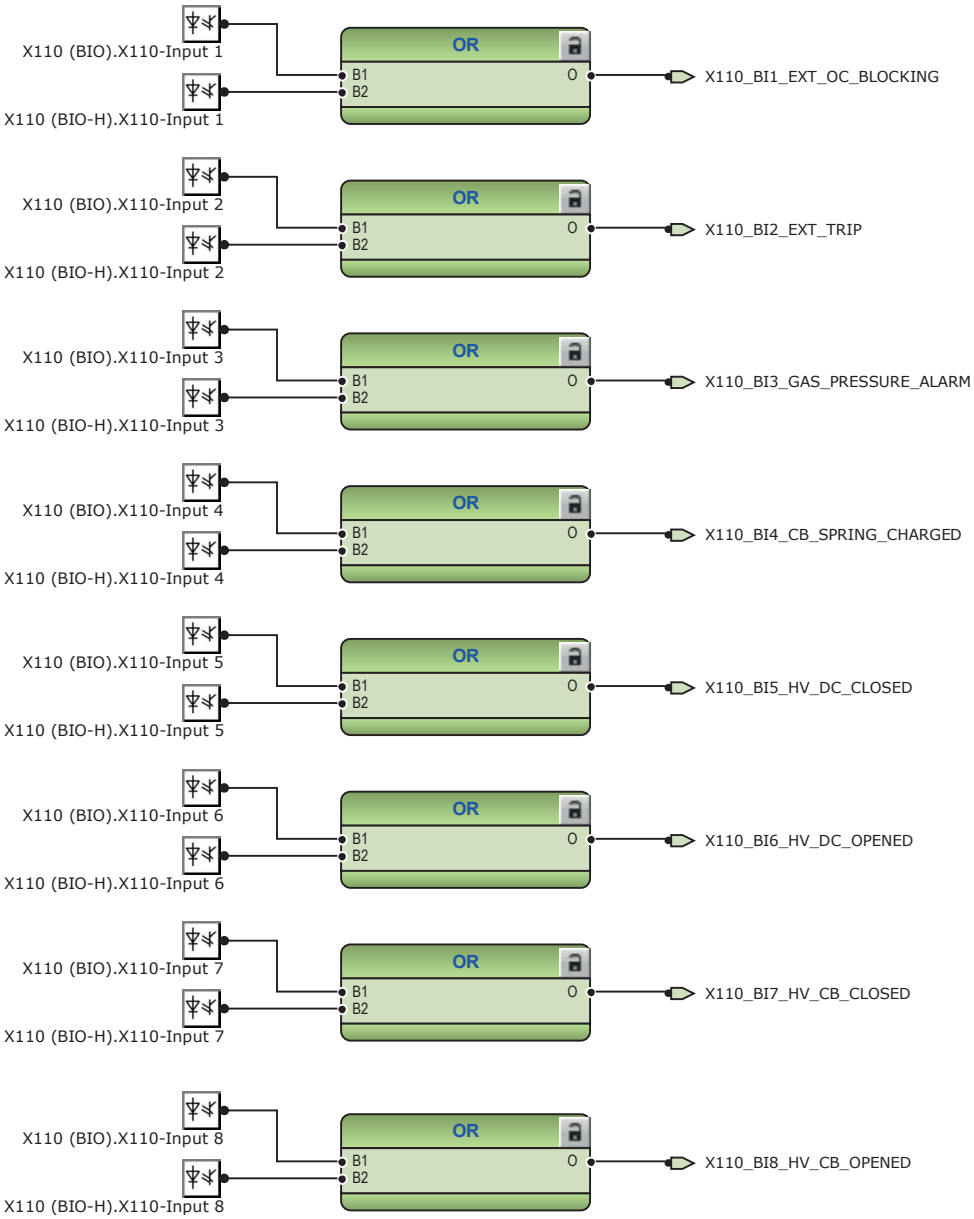


Figure 230: Binary inputs - X110 terminal block

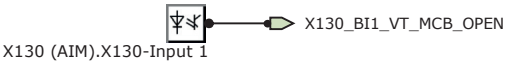


Figure 231: Binary inputs - X130 terminal block

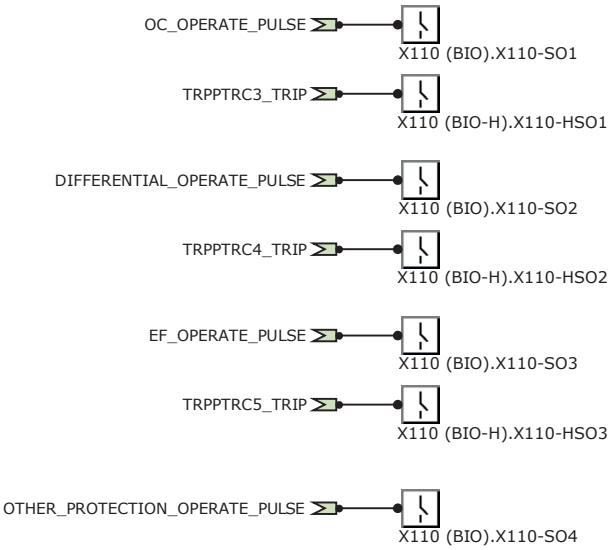


Figure 232: Binary outputs - X110 terminal block

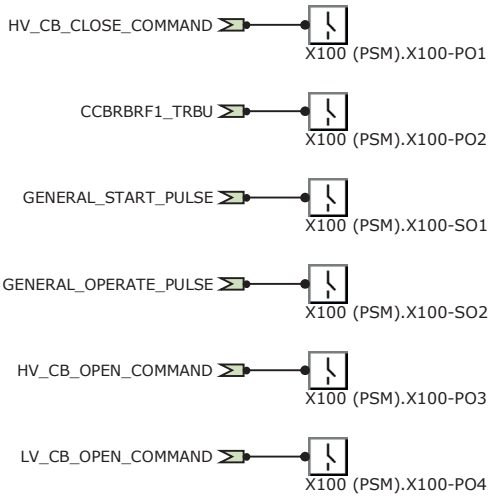


Figure 233: Binary outputs - X100 terminal block

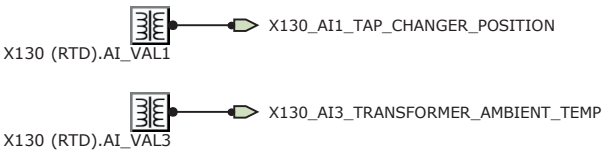


Figure 234: Default mA/RTD inputs X130

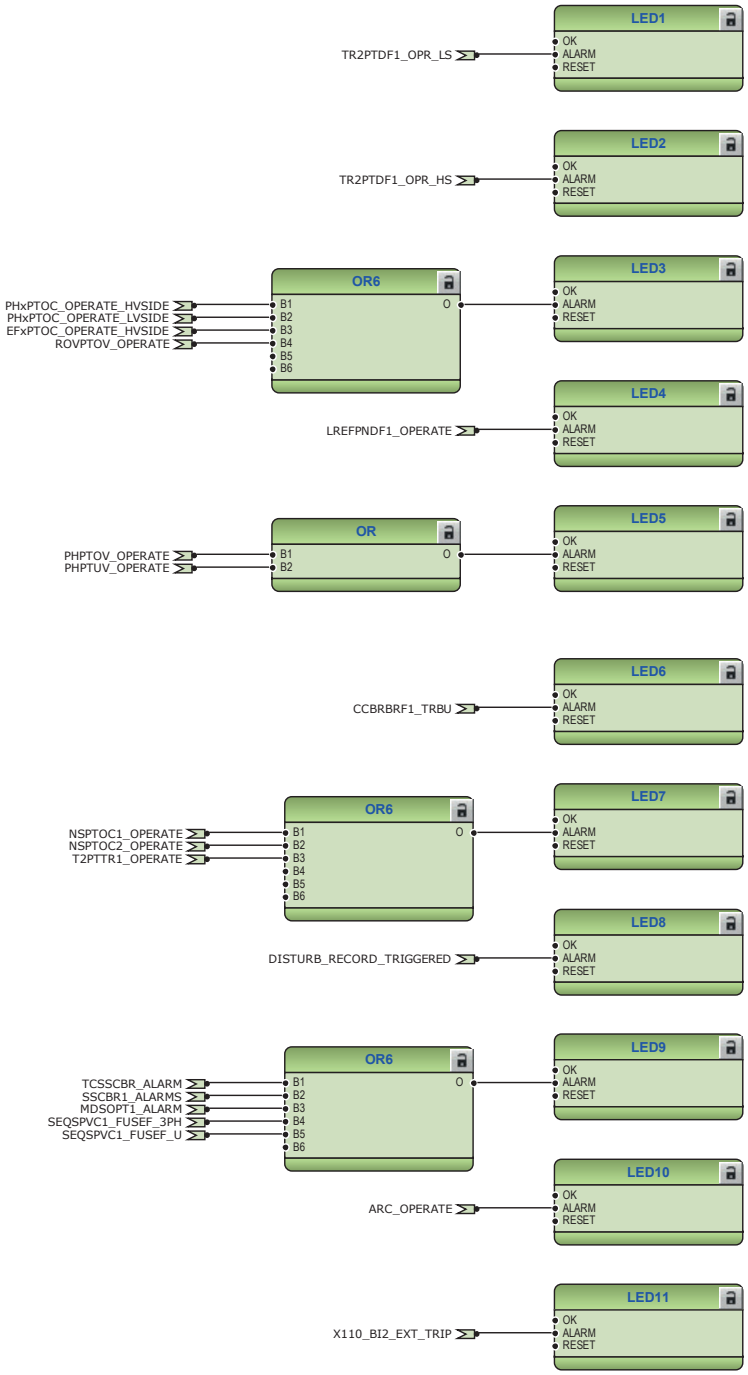


Figure 235: Default LED connection

3.7.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). 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.

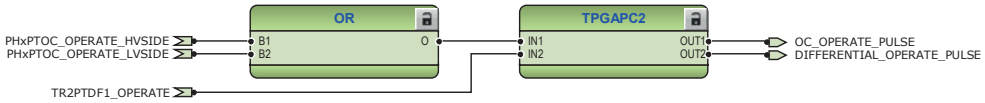


Figure 236: Timer logic for overcurrent and differential operate pulse

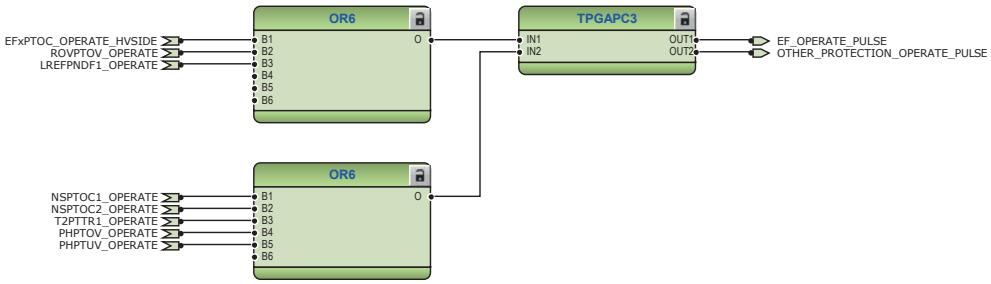


Figure 237: Timer logic for earth-fault and combined other operate pulse

3.7.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC and different types of timers and control functions. These functions are not included in application configuration but can be added based on the system requirements.

3.8 Standard configuration F

3.8.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the low-voltage (LV) side, high voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.8.2 Functions

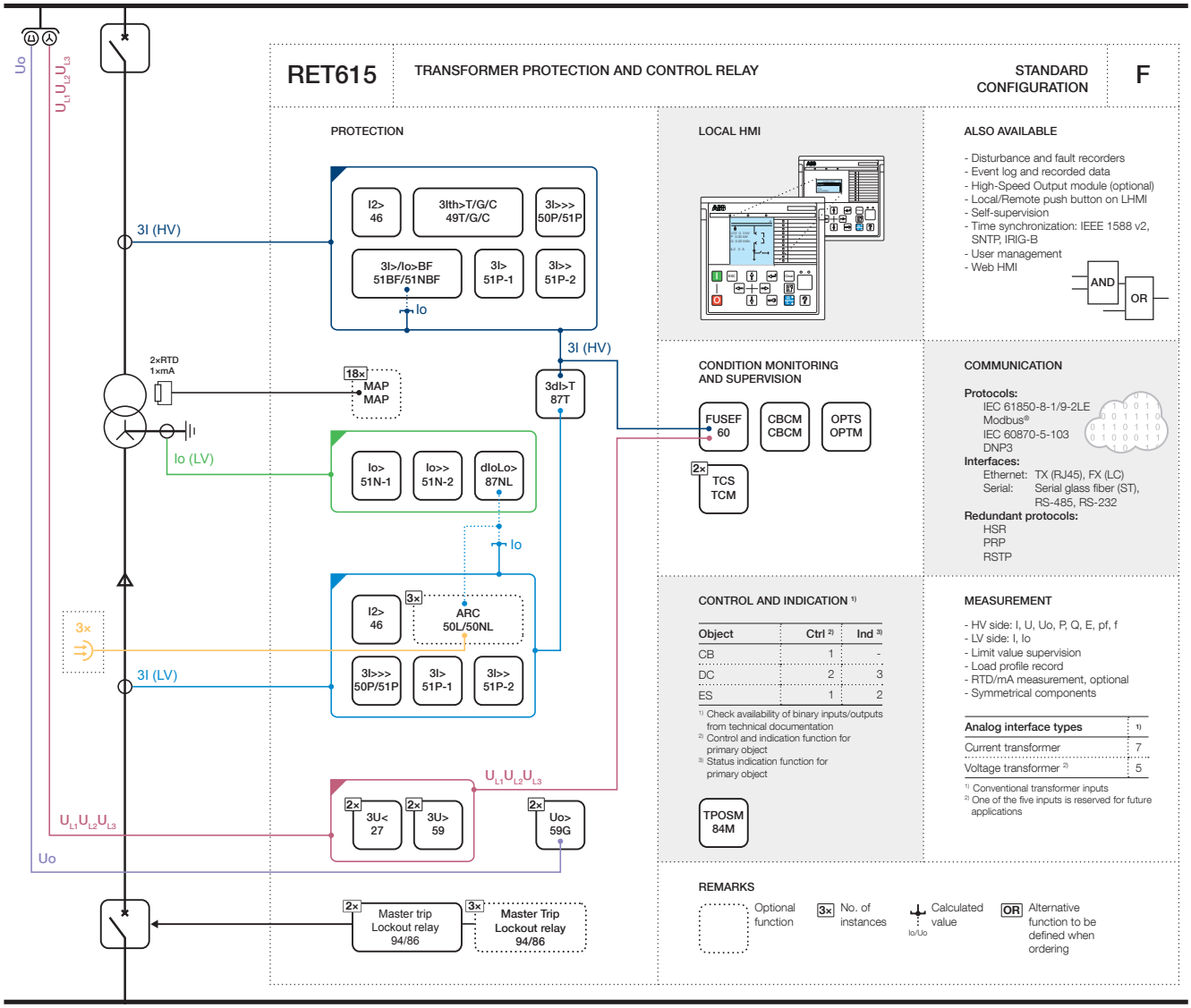


Figure 238: Functionality overview for standard configuration F

3.8.2.1 Default I/O connections

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

Table 40: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	Voltage transformer secondary MCB open
X130-BI2	-
X130-BI3	-
X130-BI4	-

Table 41: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 42: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
X110-SO4	Thermal overload and negative phase-sequence operate alarm
Table continues on next page	

Binary output	Description
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 43: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Overcurrent or earth-fault protection operate
4	Restricted earth-fault protection operate
5	Voltage protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.8.2.2 Default disturbance recorder settings

Table 44: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io B
8	Uo
9	U1
10	U2
11	U3
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 45: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC2 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	LREFPNDF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	ROVPTOV1 - start	Positive or Rising
14	ROVPTOV2 - start	Positive or Rising
15	PHPTOV1 - start	Positive or Rising
16	PHPTOV2 - start	Positive or Rising
17	PHPTUV1 - start	Positive or Rising
18	PHPTUV2 - start	Positive or Rising
19	CCBRBRF1 - trret	Level trigger off
20	CCBRBRF1 - trbu	Level trigger off
21	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
22	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
23	EFLPTOC2 - operate	Level trigger off
	EFHPTOC2 - operate	
24	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
25	TR2PTDF1 - operate	Positive or Rising
26	TR2PTDF1 - opr LS	Level trigger off
27	TR2PTDF1 - opr HS	Level trigger off
28	TR2PTDF1 - blkd2h	Level trigger off
29	TR2PTDF1 - blkd5h	Level trigger off
30	TR2PTDF1 - blkdwav	Level trigger off
31	LREFPNDF1 - operate	Level trigger off
32	T2PTTR1 - operate	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	T2PTTR1 - alarm	Level trigger off
34	T2PTTR1 - blk close	Level trigger off
35	SEQSPVC1 - fusef3ph	Level trigger off
36	SEQSPVC1 - fusefu	Level trigger off
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
38	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
39	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
40	X110BI1 - ext OC blocking	Level trigger off
41	X110BI2 - ext trip	Positive or Rising
42	X110BI7 - HVCB closed	Level trigger off
43	X110BI8 - HVCB opened	Level trigger off
44	MDSOPT1 - alarm	Level trigger off
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

3.8.3 Functional diagrams

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

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 high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

The high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The protection relay offers six different setting groups which can be set based on 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.

3.8.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

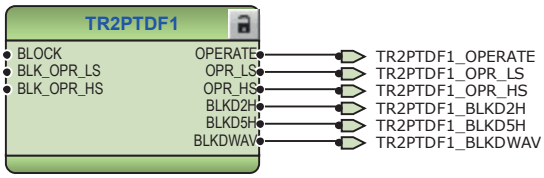


Figure 239: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110: BI1. In addition high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

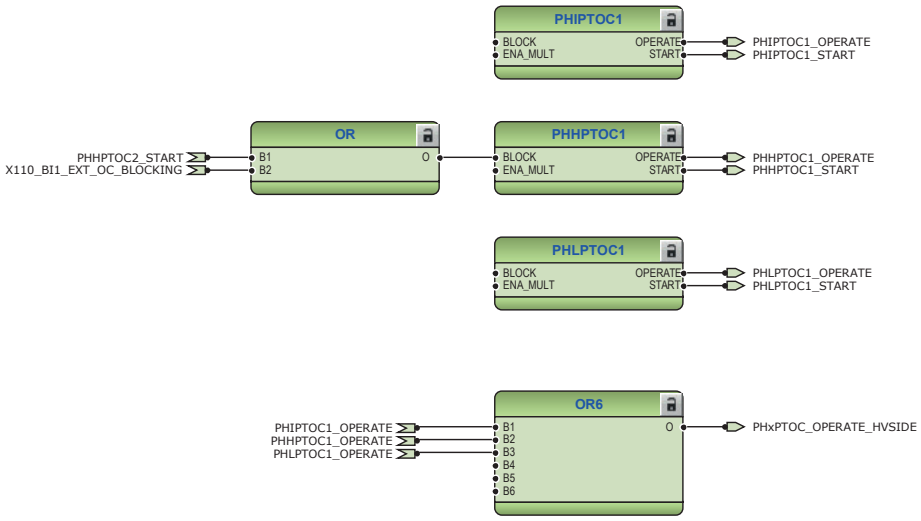


Figure 240: High-voltage side overcurrent protection function

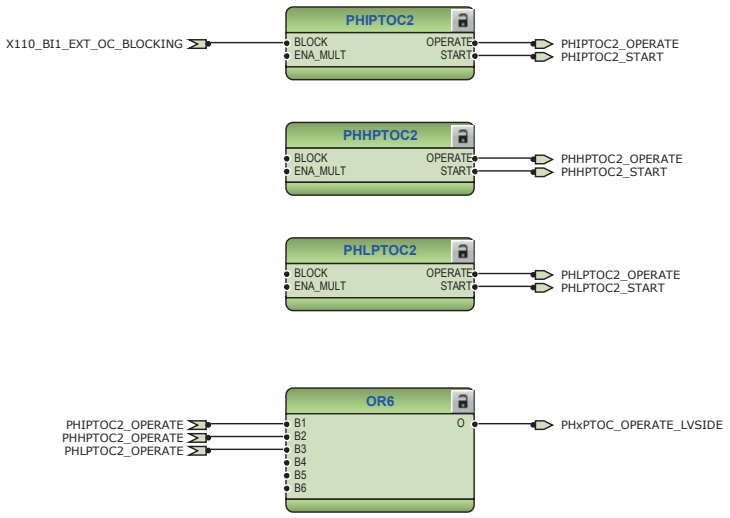


Figure 241: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from low-voltage side.

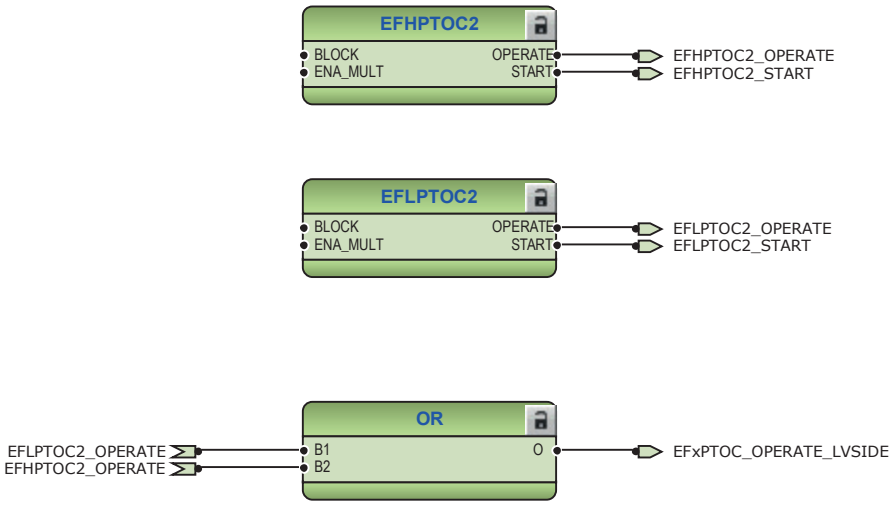


Figure 242: Low-voltage side earth-fault protection function

The configuration includes numerically stabilized low-impedance restricted earth-fault protection for low-voltage side of two-winding power transformers LREFPNDF1. The numerical differential current stage operates exclusively on earth faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

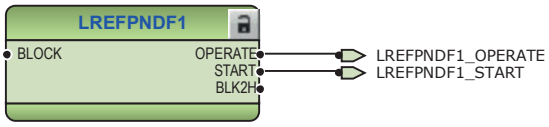


Figure 243: Restricted low-impedance earth-fault protection

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

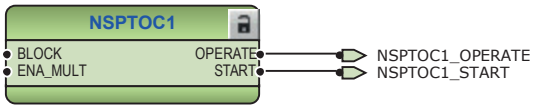


Figure 244: High-voltage side negative-sequence overcurrent protection function

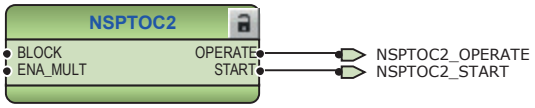


Figure 245: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

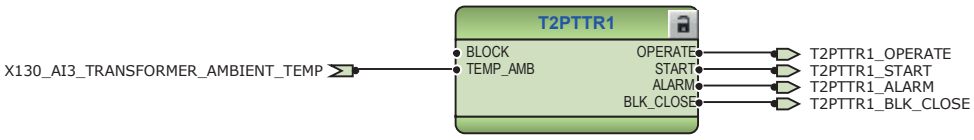


Figure 246: Transformer thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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

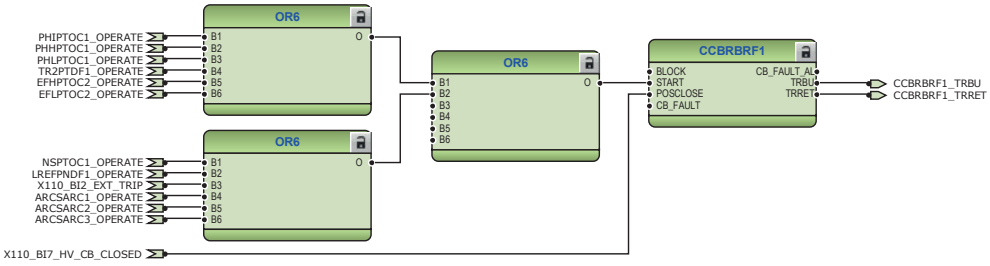


Figure 247: Circuit breaker failure protection function

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

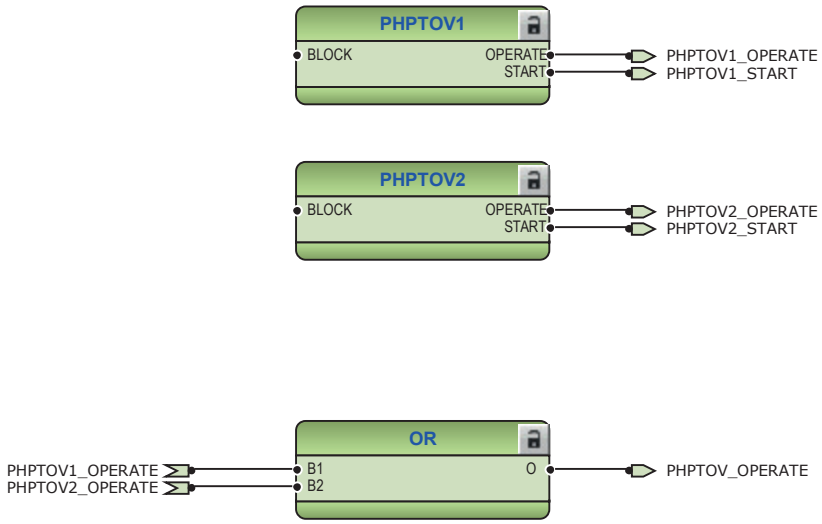


Figure 248: High-voltage side phase overvoltage protection function

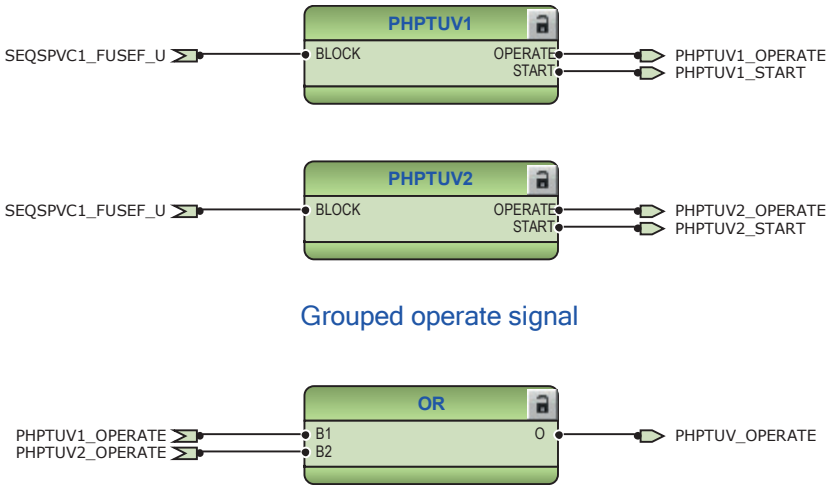


Figure 249: High-voltage side phase undervoltage protection function

Residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage.

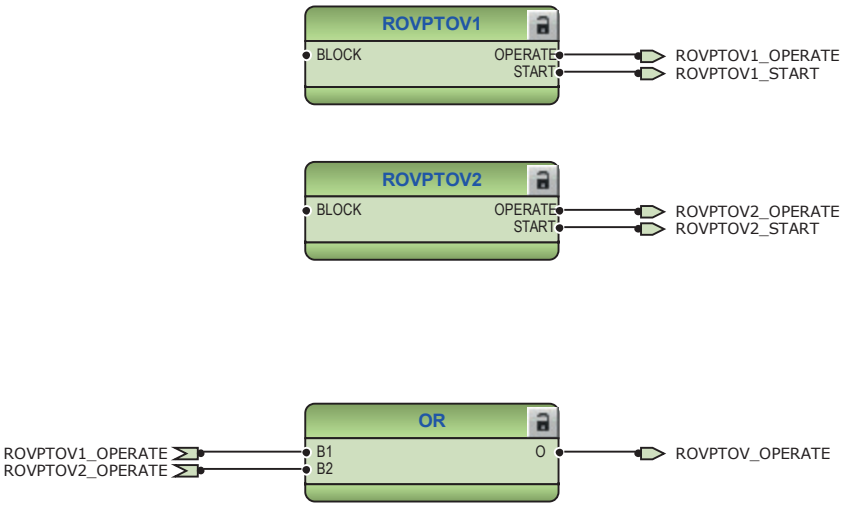


Figure 250: Residual voltage protection function

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

The operate signal 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 signal from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of these TRPPTRC3..5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

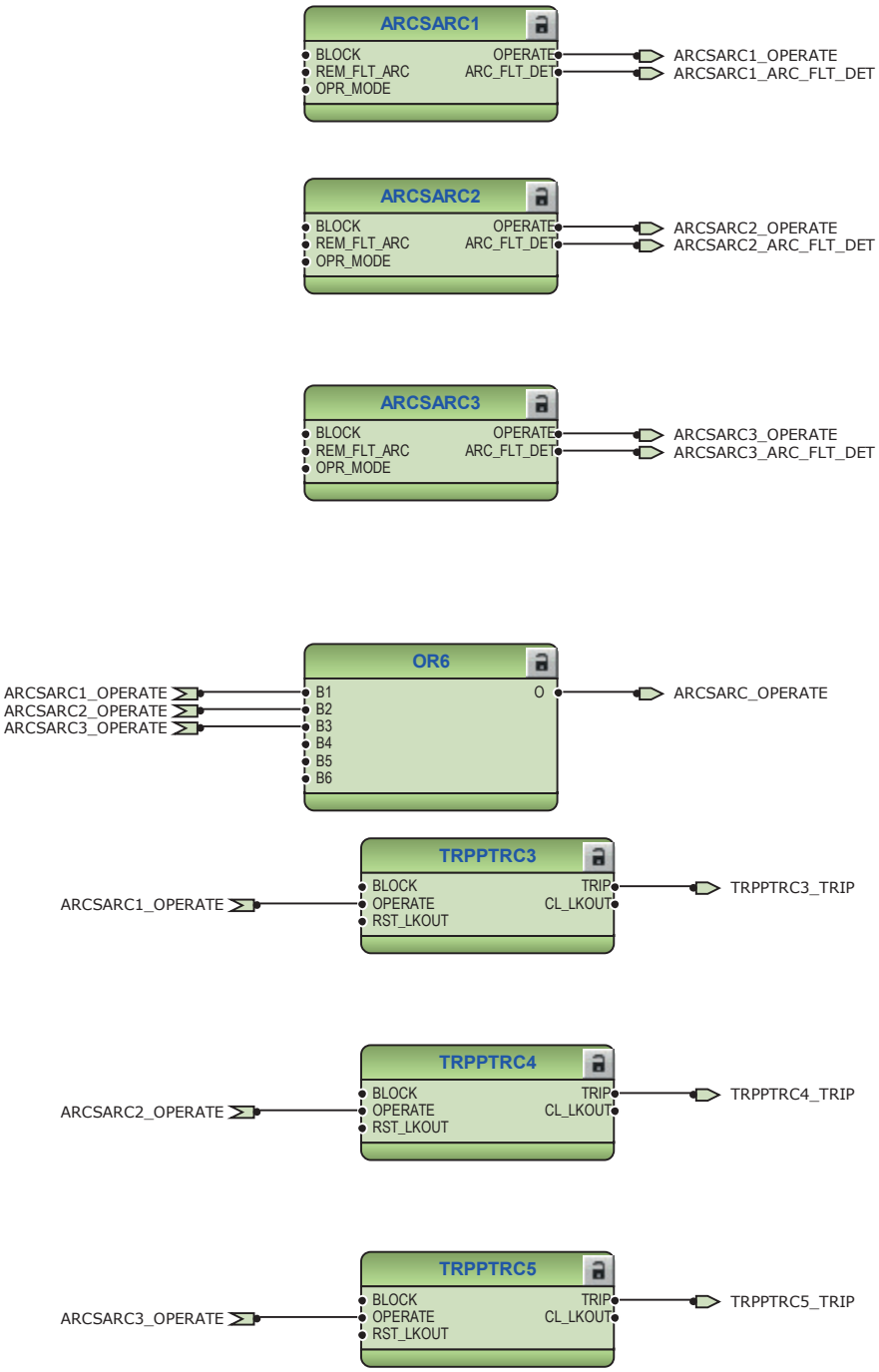


Figure 251: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

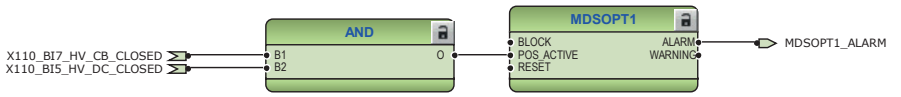


Figure 252: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

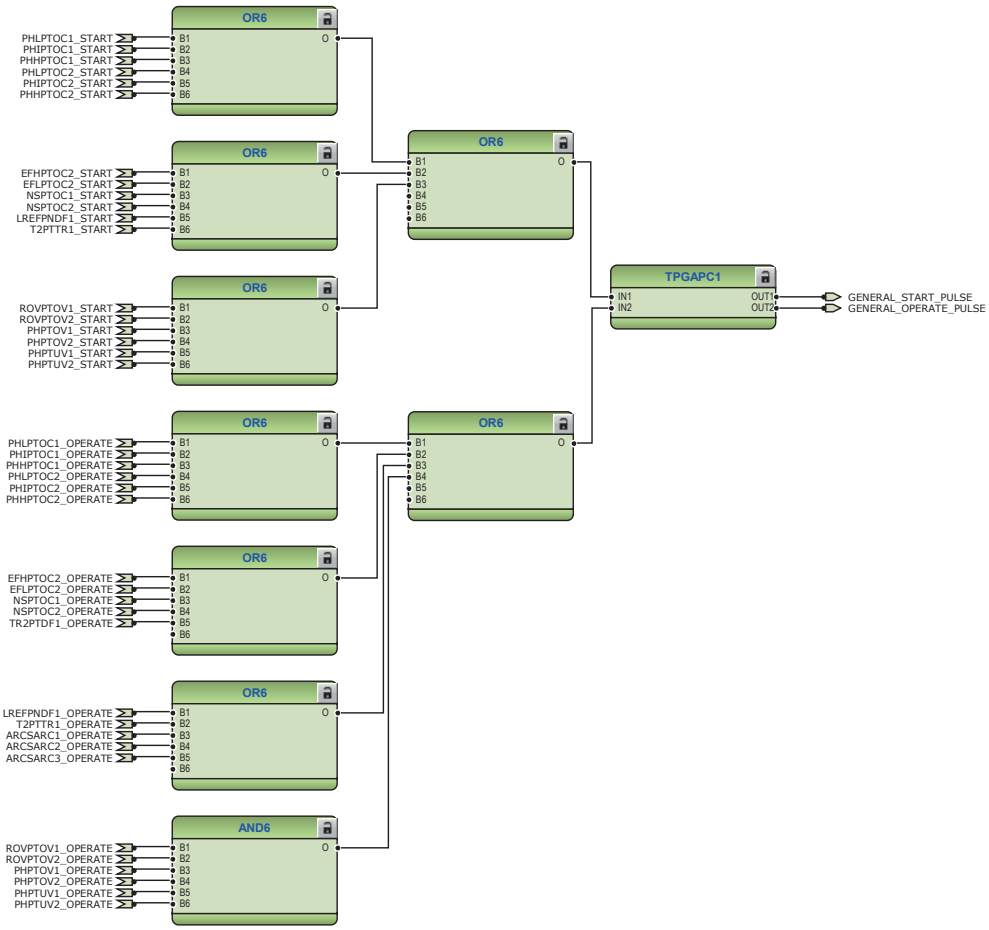


Figure 253: General start and operate signals

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

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

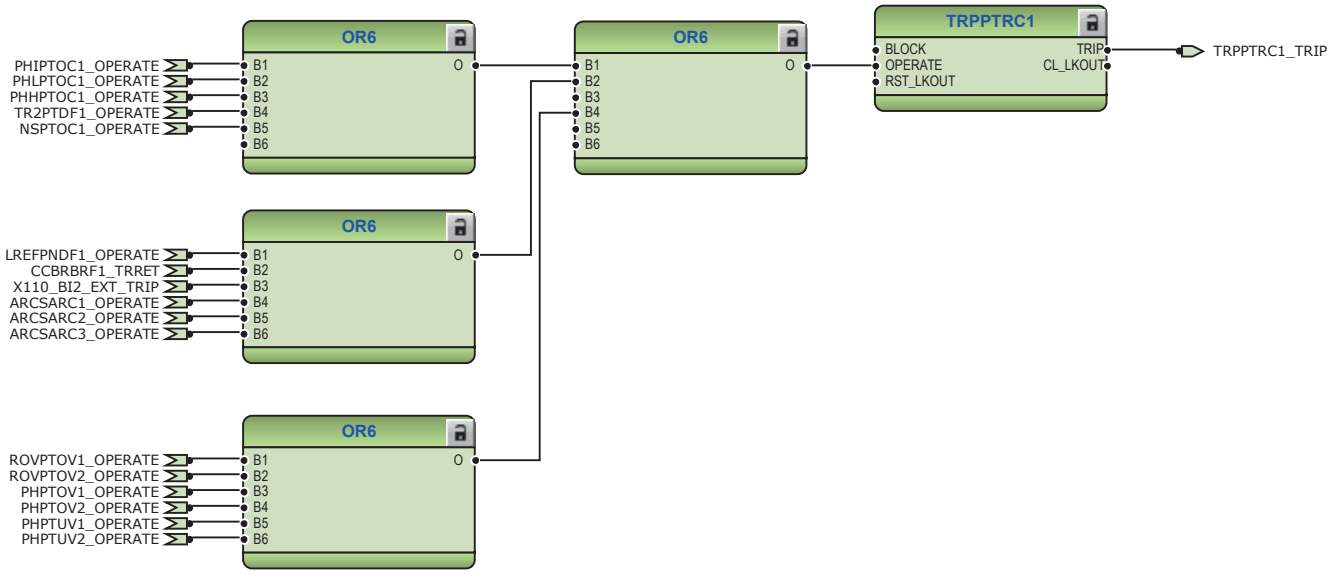


Figure 254: Trip logic TRPPTRC1

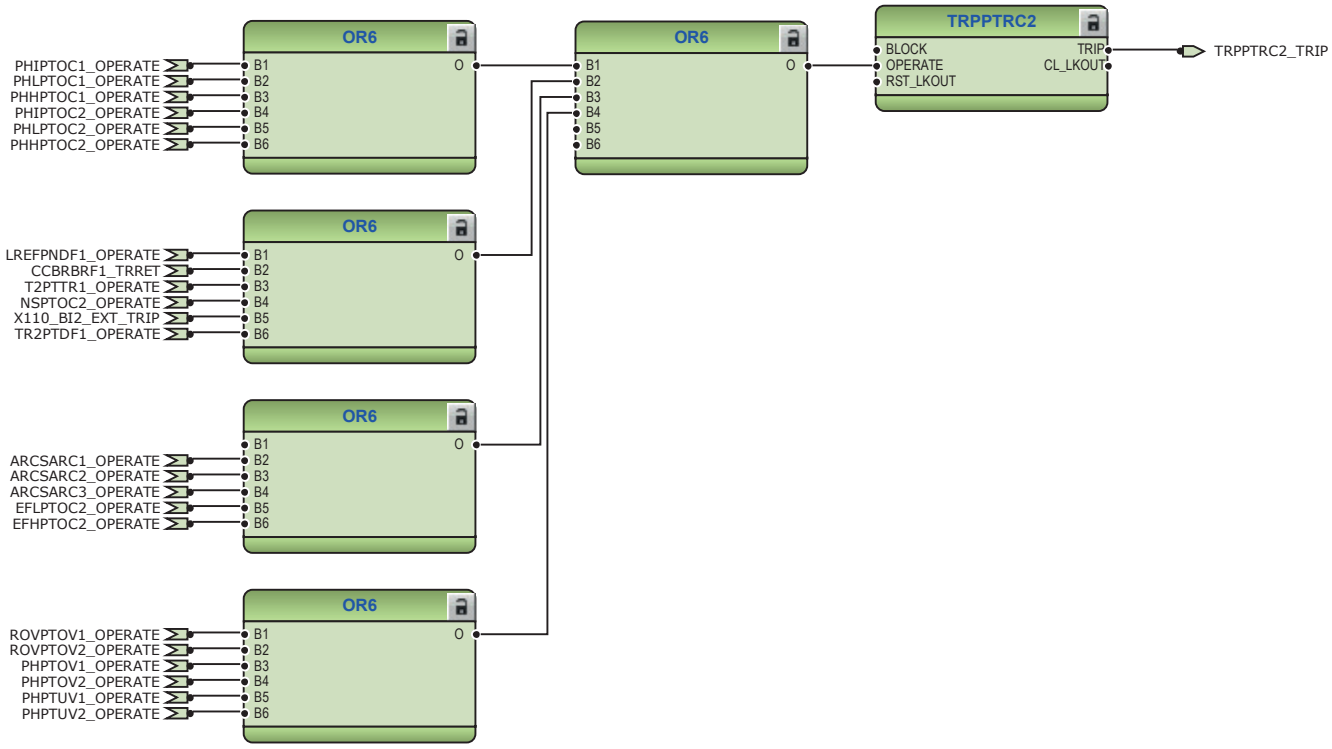


Figure 255: Trip logic TRPPTRC2

3.8.3.2 Functional diagrams for disturbance recorder

The START and 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.

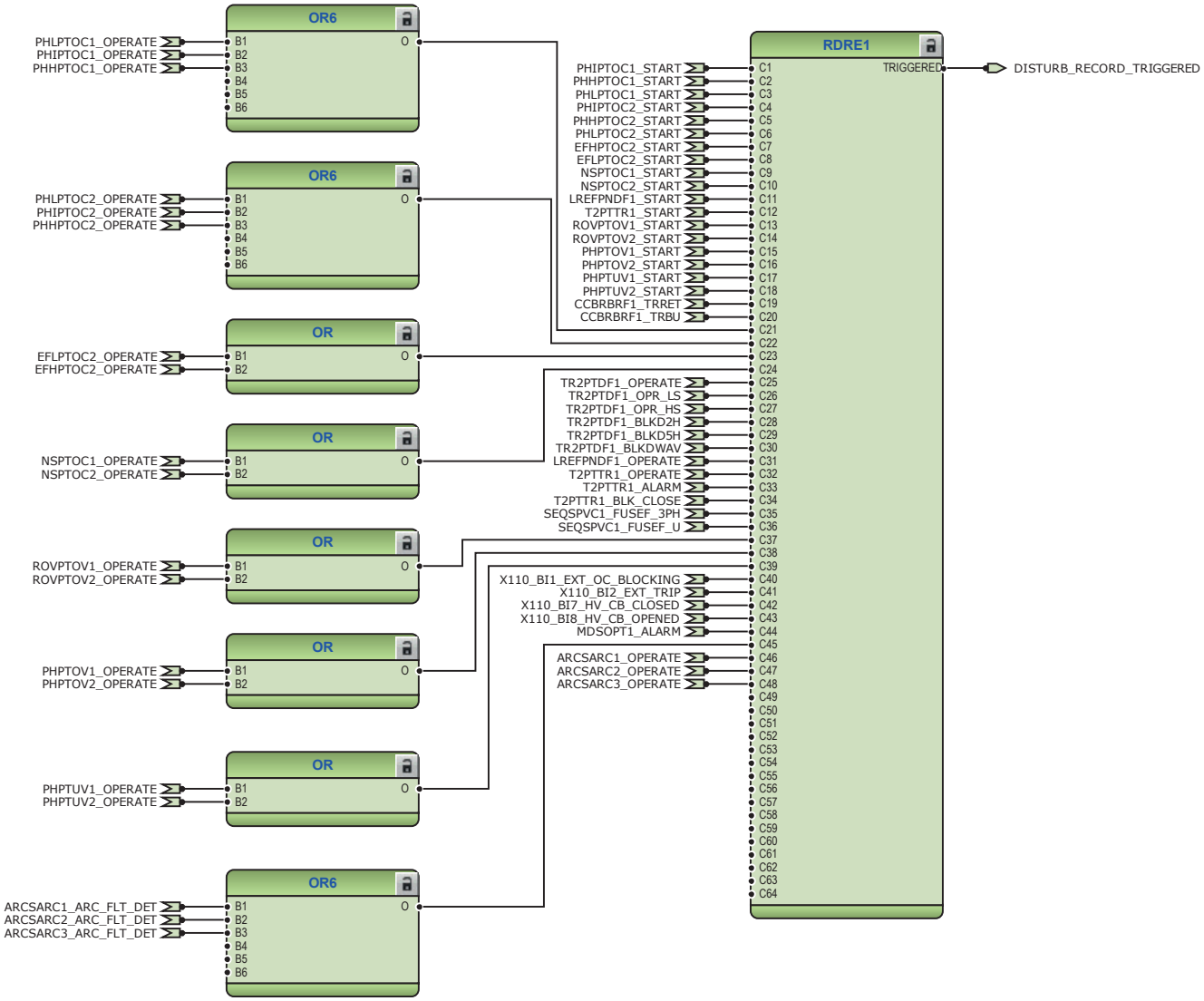


Figure 256: Disturbance recorder

3.8.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

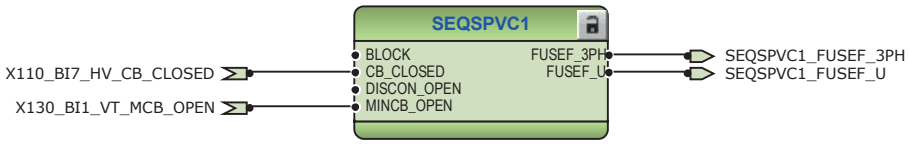


Figure 257: High-voltage fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

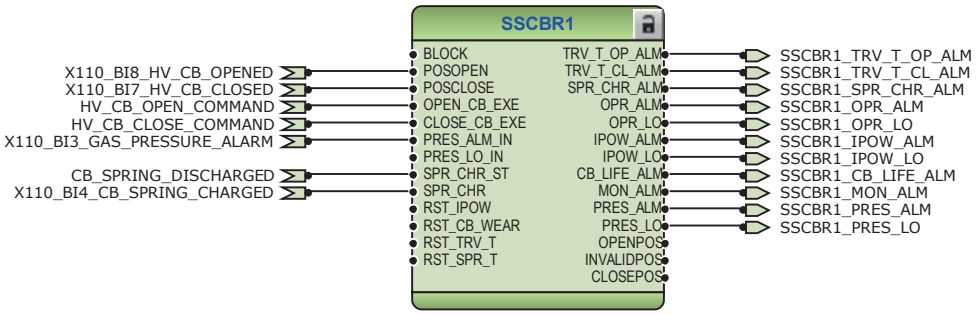


Figure 258: Circuit-breaker condition monitoring alarm

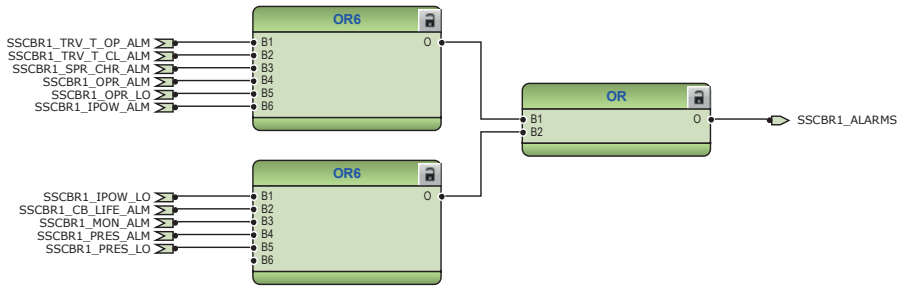


Figure 259: Logic for circuit-breaker monitoring alarm

Figure 260: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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.

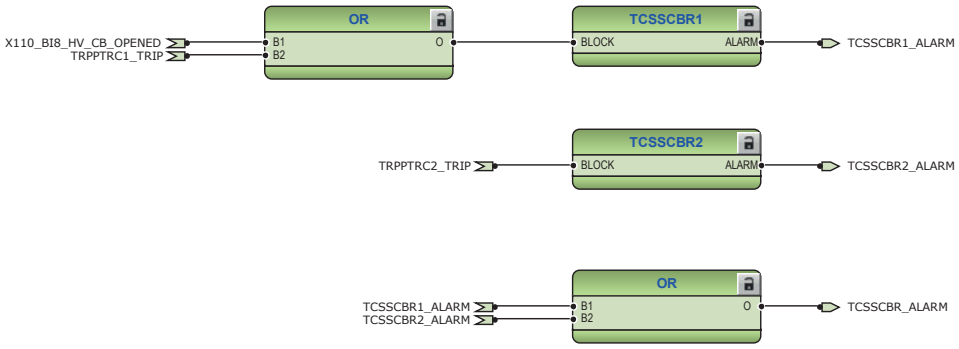


Figure 261: Trip circuit supervision function

3.8.3.4 Functional diagrams for control and interlocking

There are two types of disconnector and earthing switch function blocks are 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) status information is connected to DCSXSWI1.

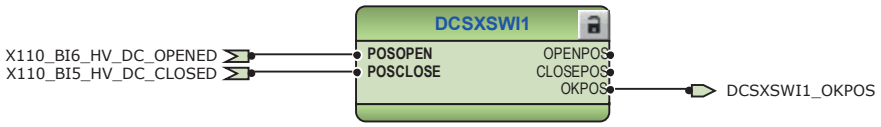


Figure 262: High-voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open (in test position) or close (in service position). This, together with 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

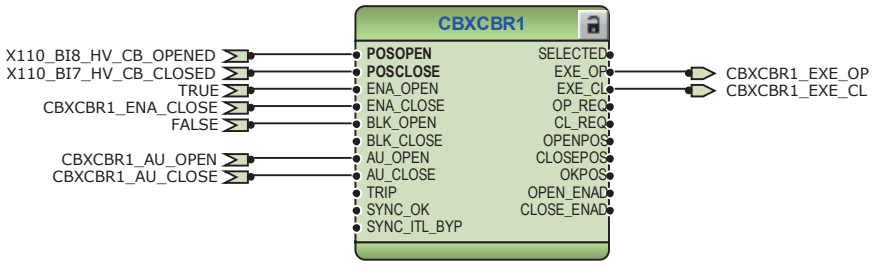


Figure 263: High-voltage side circuit breaker

Any additional signals required by the application can be connected for opening and closing of circuit breaker.

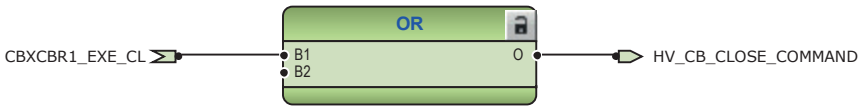


Figure 264: Signals for closing coil of circuit breaker 1

Figure 265: Signals for opening coil of circuit breaker 1

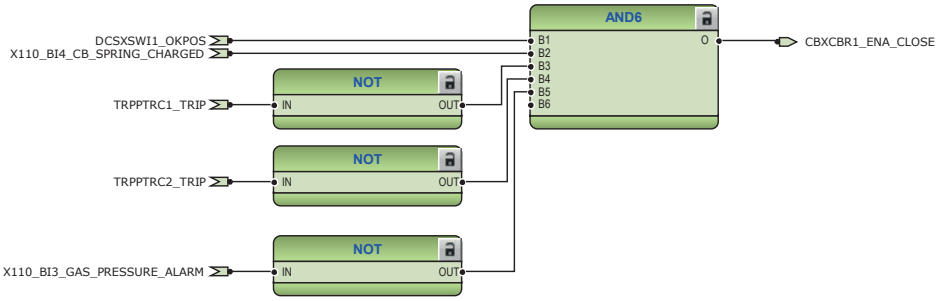


Figure 266: High-voltage side circuit breaker 1 close enable logic

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

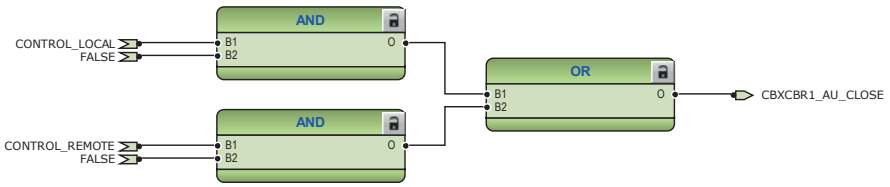


Figure 267: External closing command for circuit breaker 1

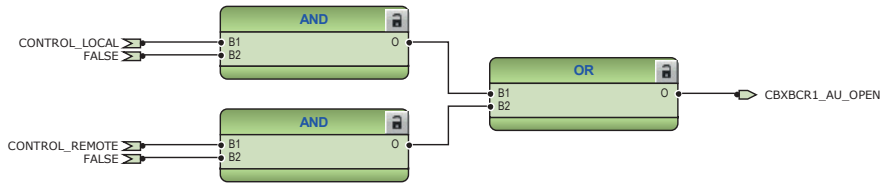


Figure 268: External opening command for circuit breaker 1

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters for TPOSYLTC1 properly.

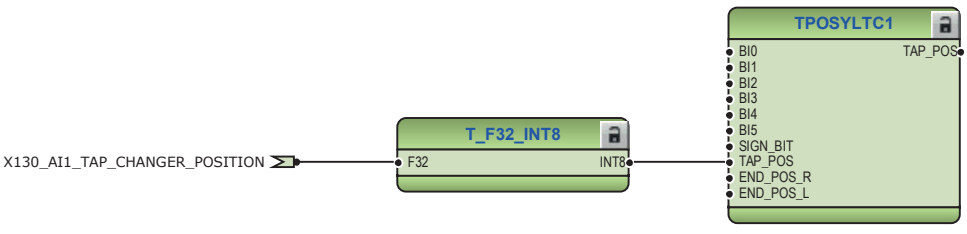


Figure 269: Tap changer position indicator

3.8.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement function CSMSQI1 measures the sequence current from high-voltage side and residual current measurement RESCMMXU2 measures the residual current and low-voltage side.

The high-voltage side three-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. Similarly, sequence voltage measurement VSMSQI1 measures the sequence voltage and residual voltage measurement RESVMMXU1 measures the residual voltage from high-voltage side.

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.

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

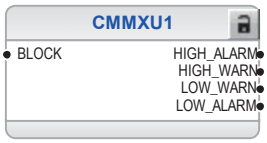


Figure 270: Current measurement: Three-phase current measurement (HV side)

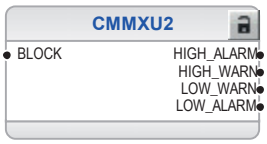


Figure 271: Current measurement: Three-phase current measurement (LV side)

Figure 272: Current measurement: Sequence current measurement (HV side)

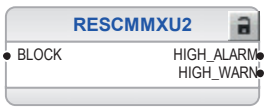


Figure 273: Current measurement: Residual current measurement (LV side)

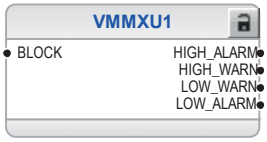


Figure 274: Voltage measurement: Three-phase voltage measurement (HV side)

Figure 275: Voltage measurement: Sequence voltage measurement (HV side)

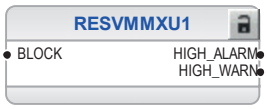


Figure 276: Voltage measurement: Residual voltage measurement (HV side)

Figure 277: Other measurement: Three-phase power and energy measuremen

Figure 278: Other measurement: Data monitoring

Figure 279: Other measurement: Load profile record

3.8.3.6 Functional diagrams for I/O and alarms LEDs

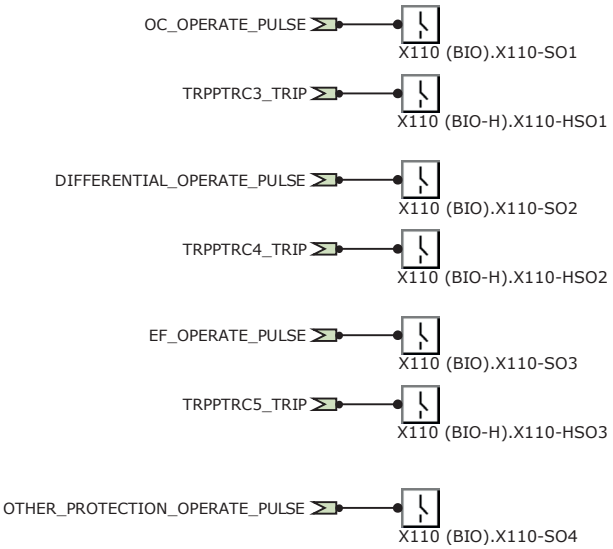


Figure 280: Binary inputs - X110 terminal block

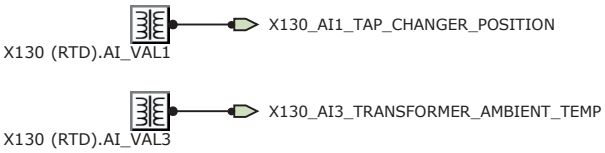


Figure 281: Binary inputs - X130 terminal block

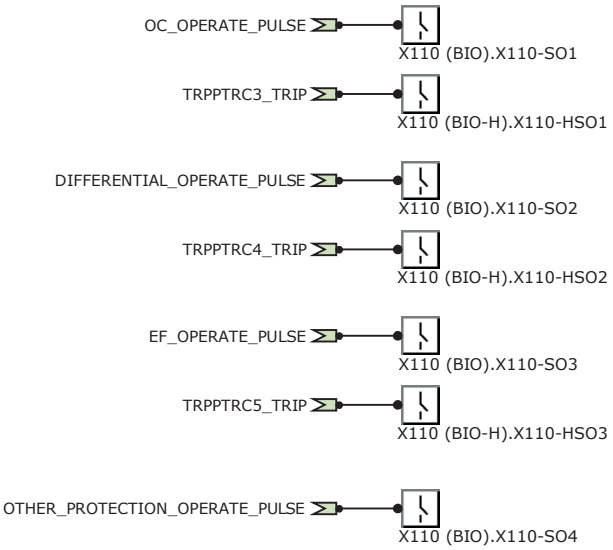


Figure 282: Binary outputs - X110 terminal block

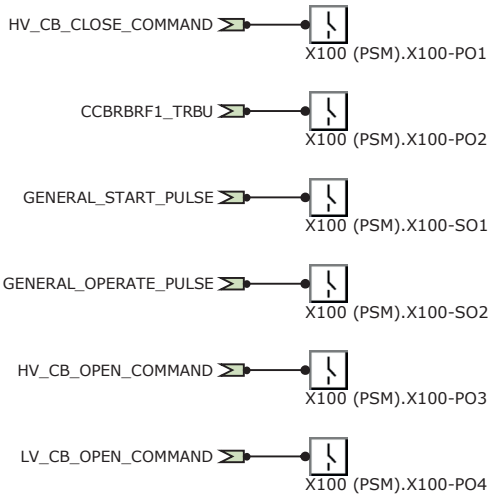


Figure 283: Binary outputs - X100 terminal block

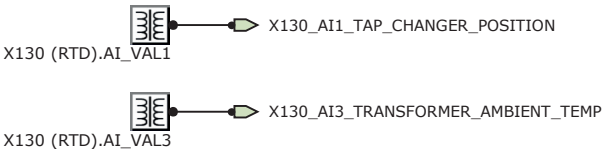


Figure 284: Default mA/RTD inputs X130

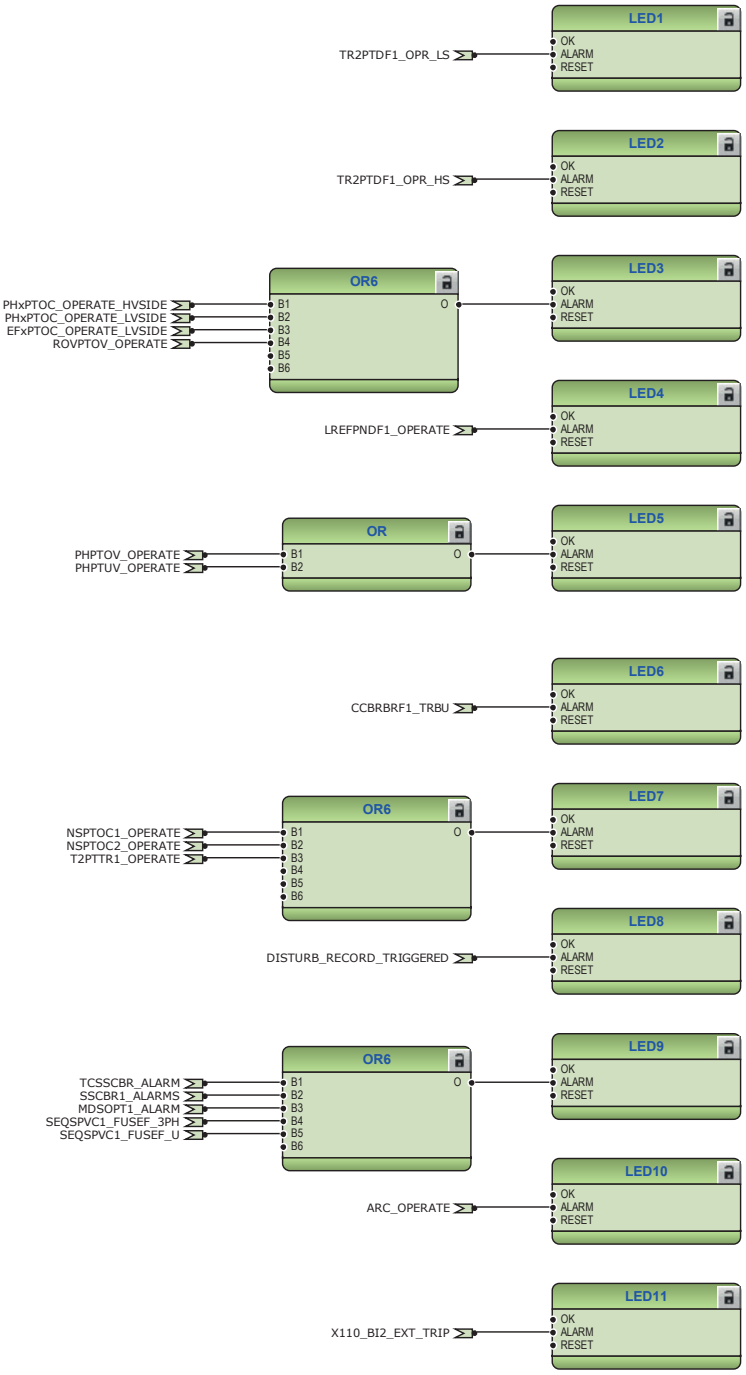


Figure 285: Default LED connection

3.8.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). 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.

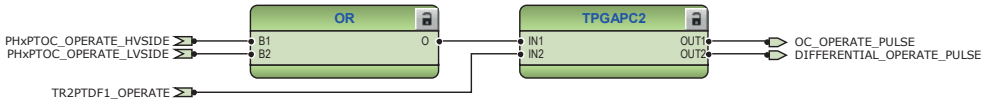


Figure 286: Timer logic for overcurrent and differential operate pulse

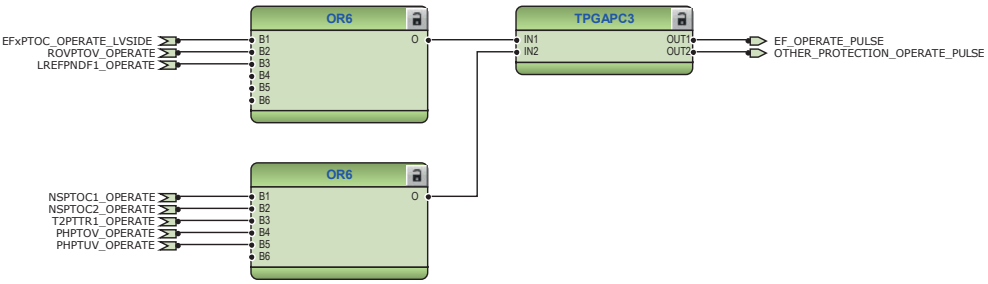


Figure 287: Timer logic for earth-fault and combined other operate pulse

3.8.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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.

3.9 Standard configuration G

3.9.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, high-impedance based restricted earth-fault protection for the high voltage (HV) side, high voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.9.2 Functions

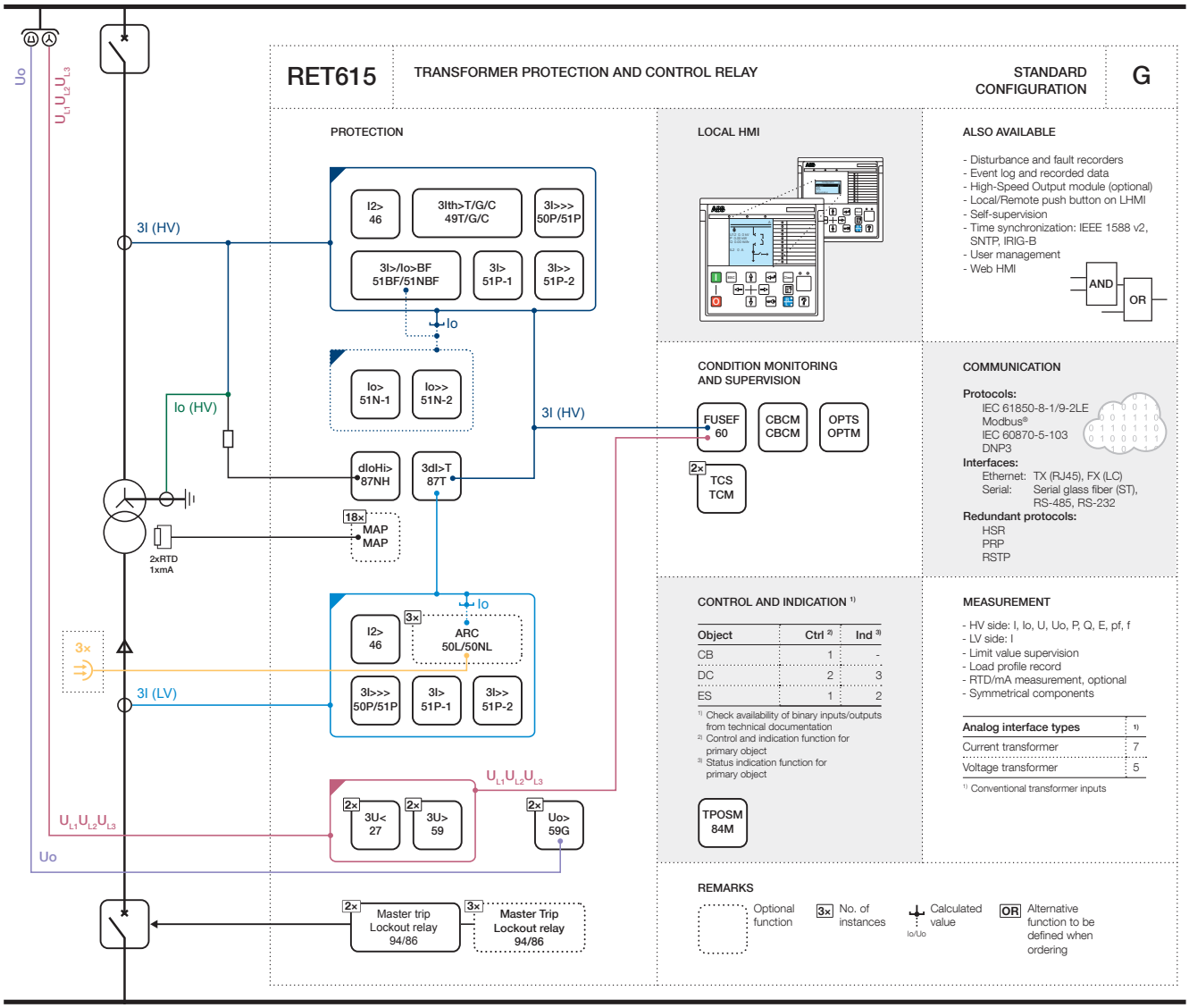


Figure 288: Functionality overview for standard configuration G

3.9.2.1 Default I/O connections

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

Table 46: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	Voltage transformer secondary MCB open
X130-BI2	-
X130-BI3	-
X130-BI4	-

Table 47: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 48: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
X110-SO4	Thermal overload and negative phase-sequence operate alarm
Table continues on next page	

Binary output	Description
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 49: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Overcurrent or earth-fault protection operate
4	Restricted earth-fault protection operate
5	Voltage protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.9.2.2 Default disturbance recorder settings

Table 50: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8	Uo
9	U1
10	U2
11	U3
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 51: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - tart	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC1 - start	Positive or Rising
8	EFLPTOC1 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	HREFPDIF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	ROVPTOV1 - start	Positive or Rising
14	ROVPTOV2 - start	Positive or Rising
15	PHPTOV1 - start	Positive or Rising
16	PHPTOV2 - start	Positive or Rising
17	PHPTUV1 - start	Positive or Rising
18	PHPTUV2 - start	Positive or Rising
19	CCBRBRF1 - trret	Level trigger off
20	CCBRBRF1 - trbu	Level trigger off
21	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
22	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
23	EFLPTOC1 - operate	Level trigger off
	EFHPTOC1 - operate	
24	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
25	TR2PTDF1 - operate	Positive or Rising
26	TR2PTDF1 - opr LS	Level trigger off
27	TR2PTDF1 - opr HS	Level trigger off
28	TR2PTDF1 - blkd2h	Level trigger off
29	TR2PTDF1 - blkd5h	Level trigger off
30	TR2PTDF1 - blkdwav	Level trigger off
31	HREFPDIF1 - operate	Level trigger off
32	T2PTTR1 - operate	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	T2PTTR1 - alarm	Level trigger off
34	T2PTTR1 - blk close	Level trigger off
35	SEQSPVC1 - fusef3ph	Level trigger off
36	SEQSPVC1 - fusefu	Level trigger off
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
38	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
39	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
40	X110BI1 - ext OC blocking	Level trigger off
41	X110BI2 - ext trip	Positive or Rising
42	X110BI7 - HVCB closed	Level trigger off
43	X110BI8 - HVCB opened	Level trigger off
44	MDSOPT1 - alarm	Level trigger off
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

3.9.3 Functional diagrams

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

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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

The protection relay offers six different setting groups which can be set based on 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.

3.9.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

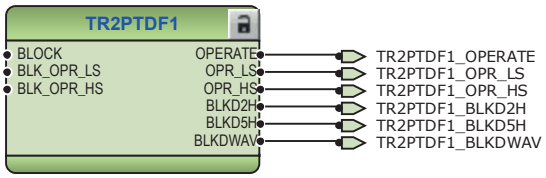


Figure 289: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110: BI1. In addition, high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This kind of blocking scheme enables coordinated overlapping of overcurrent protection zones.

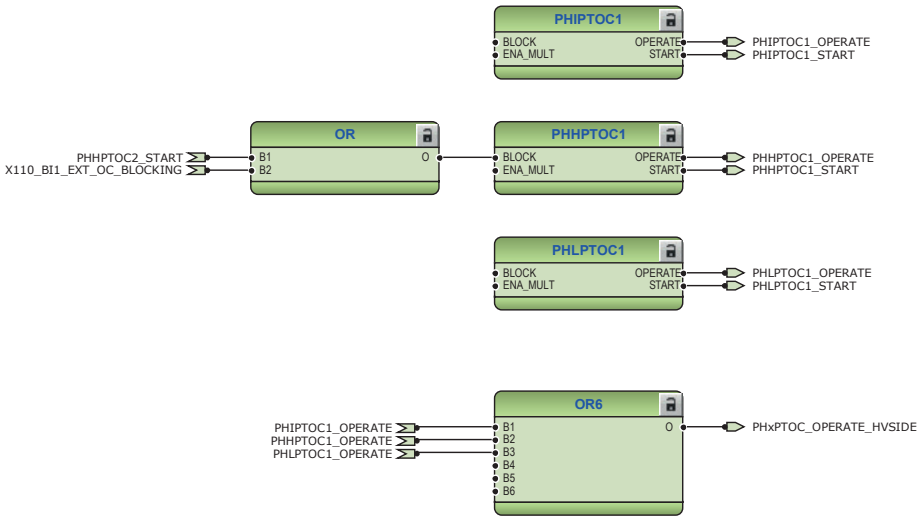


Figure 290: High-voltage side overcurrent protection function

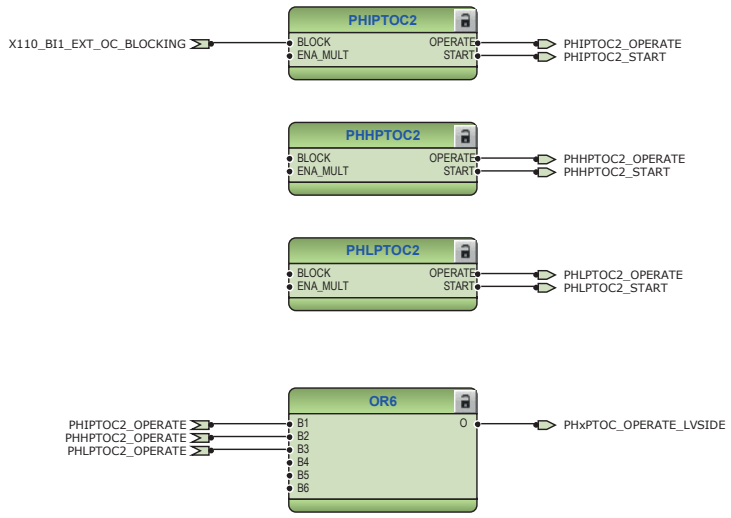


Figure 291: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from high-voltage side.

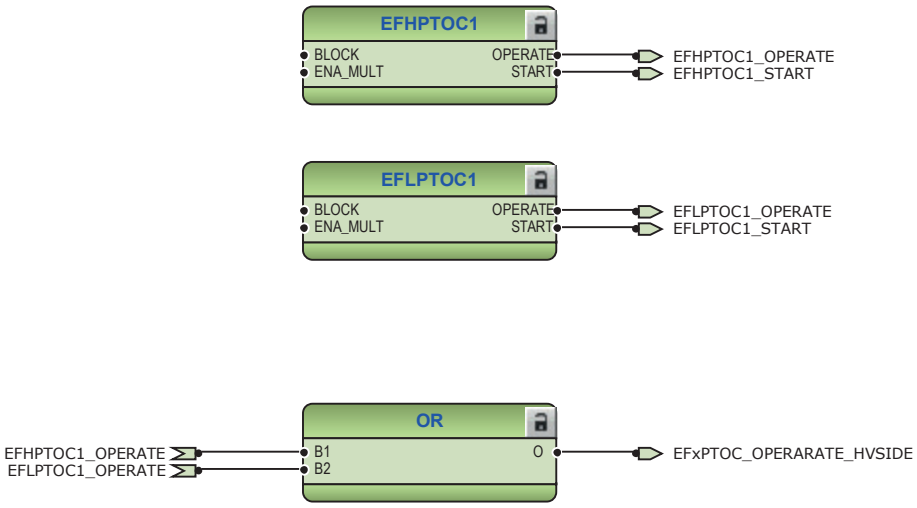


Figure 292: High-voltage side earth-fault protection

Configuration also includes high-impedance based restricted earth-fault protection for high-voltage side of two-winding power transformers HREFPDIF1. The restricted earth-fault current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

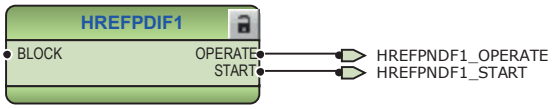


Figure 293: Restricted high-impedance earth-fault protection

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

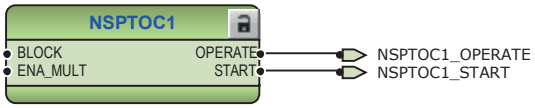


Figure 294: High-voltage side negative-sequence overcurrent protection function

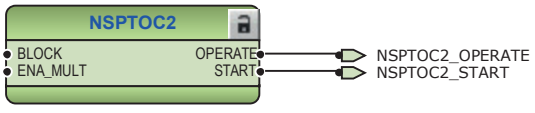


Figure 295: Low-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1 detects overload conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

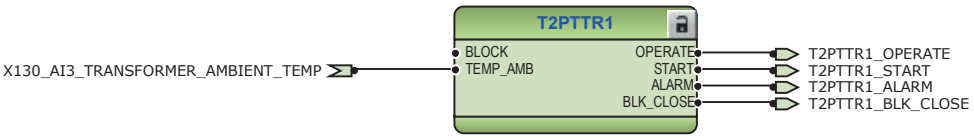


Figure 296: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

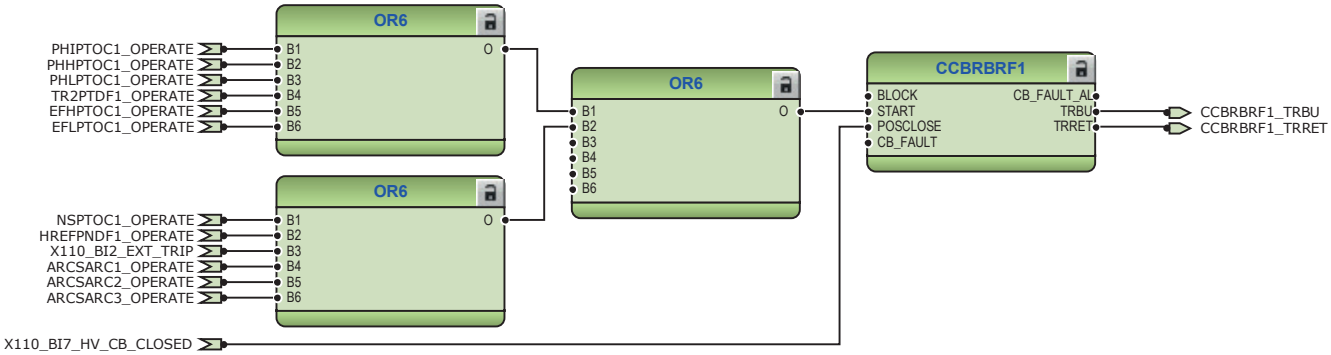


Figure 297: Circuit breaker failure protection function

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

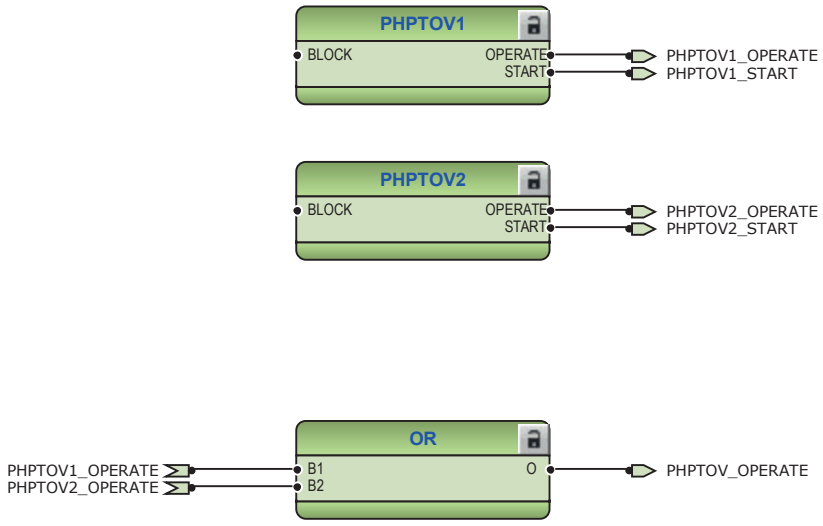


Figure 298: High-voltage phase overvoltage protection function

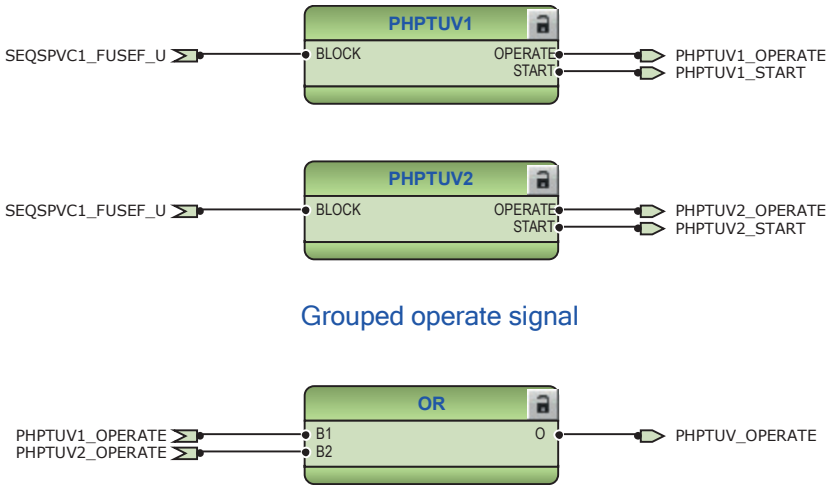


Figure 299: High-voltage phase undervoltage protection function

Residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting abnormal level of residual voltage.

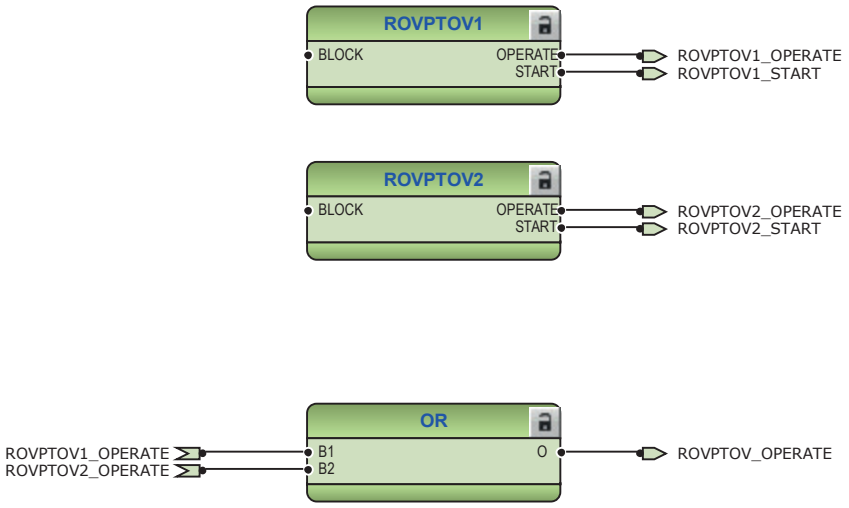


Figure 300: High-voltage side residual voltage protection function

Three arc protection ARCSARC1...3 stages 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 trip logic TRPPTRC1 and TRPPTRC2. If the IED is ordered with high speed binary outputs, the individual operate signals from ARCSARC1...3 are connected to dedicated trip logic TRPPTRC3...5. The output of these TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

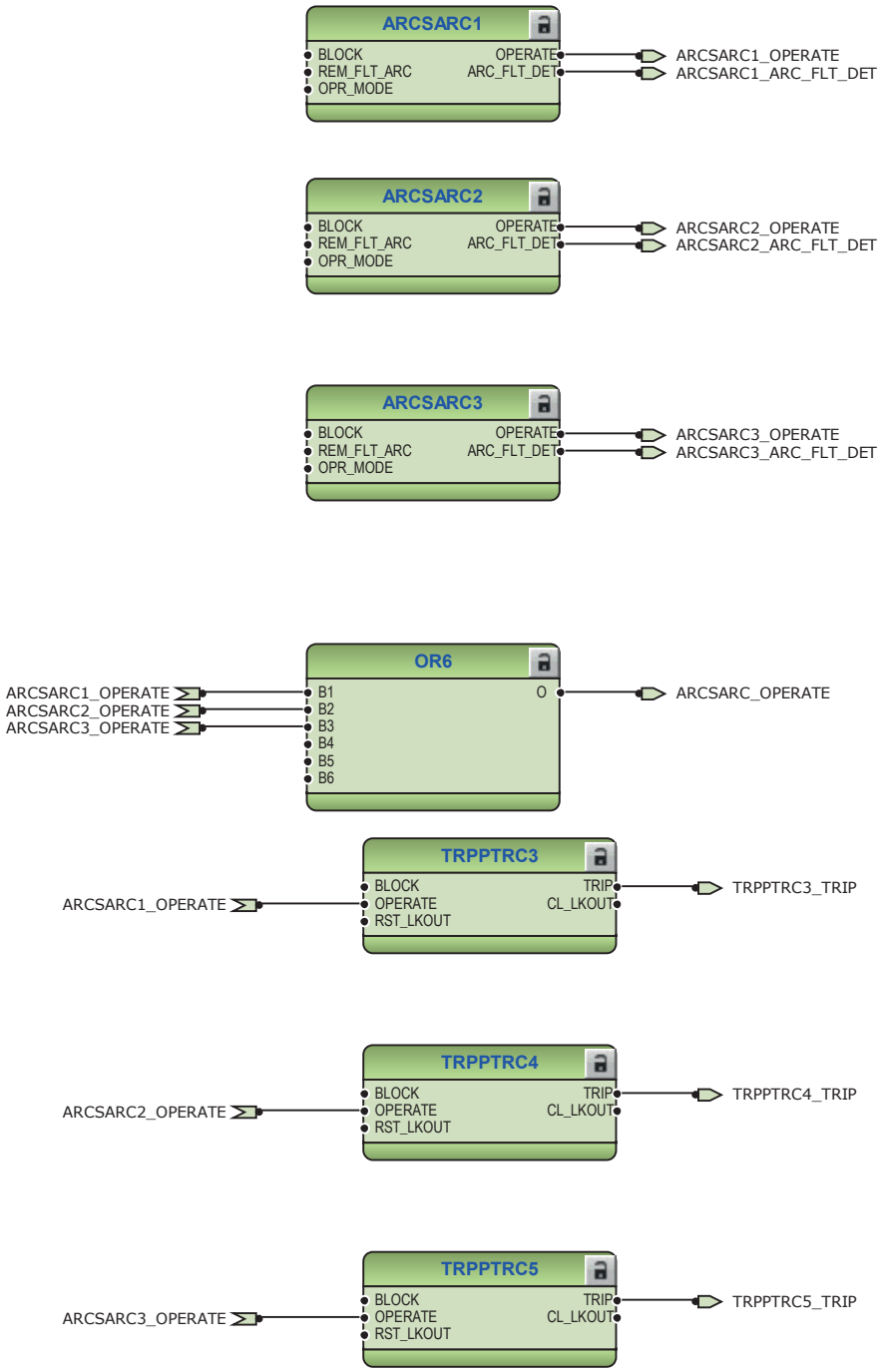


Figure 301: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

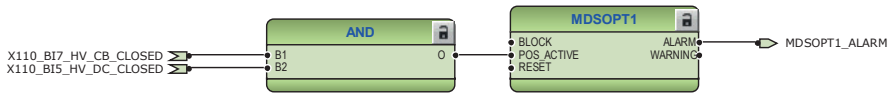


Figure 302: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

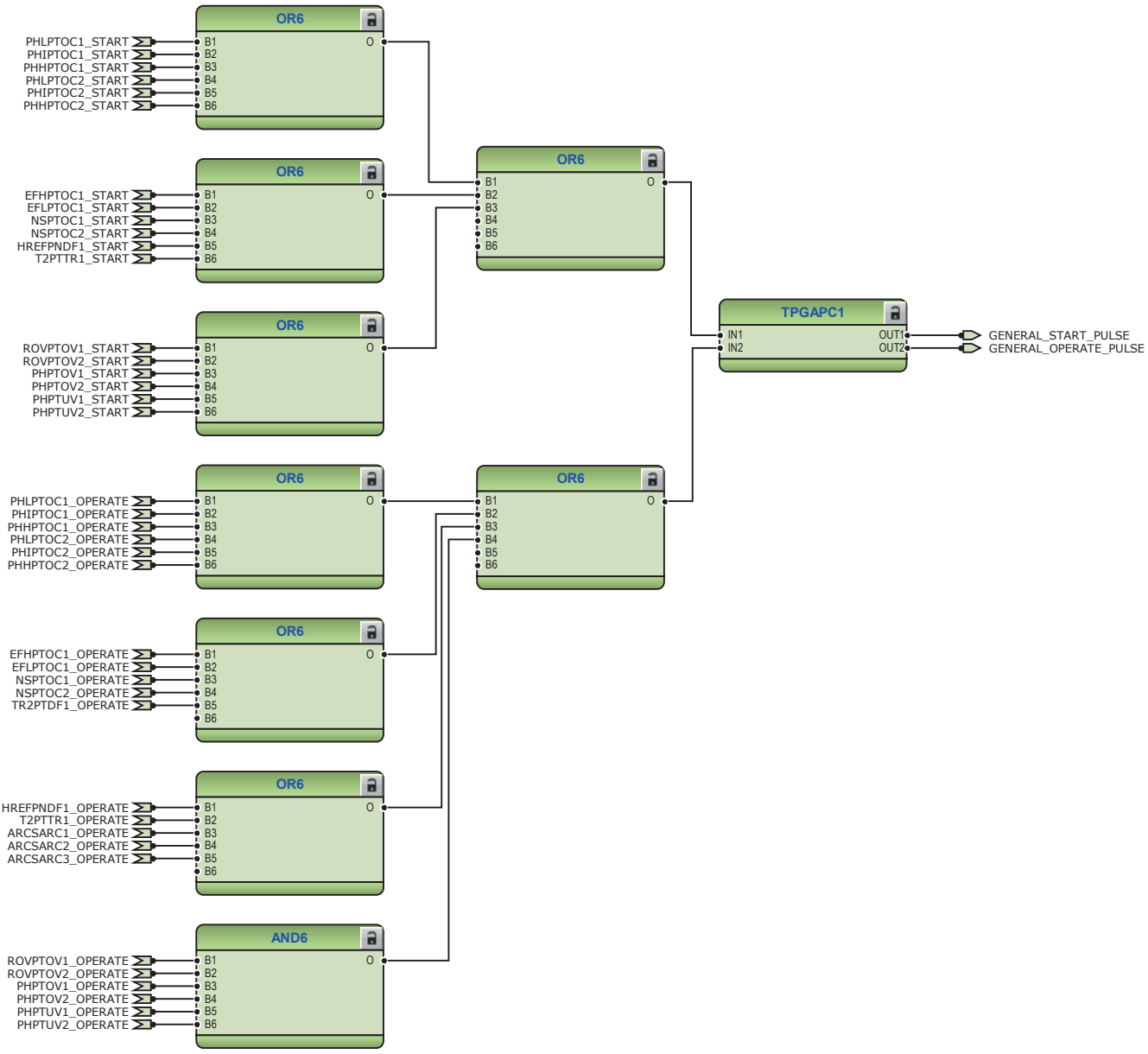


Figure 303: General start and operate signals

The operate signals from the protections are connected to the two trip logics: TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at

binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

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

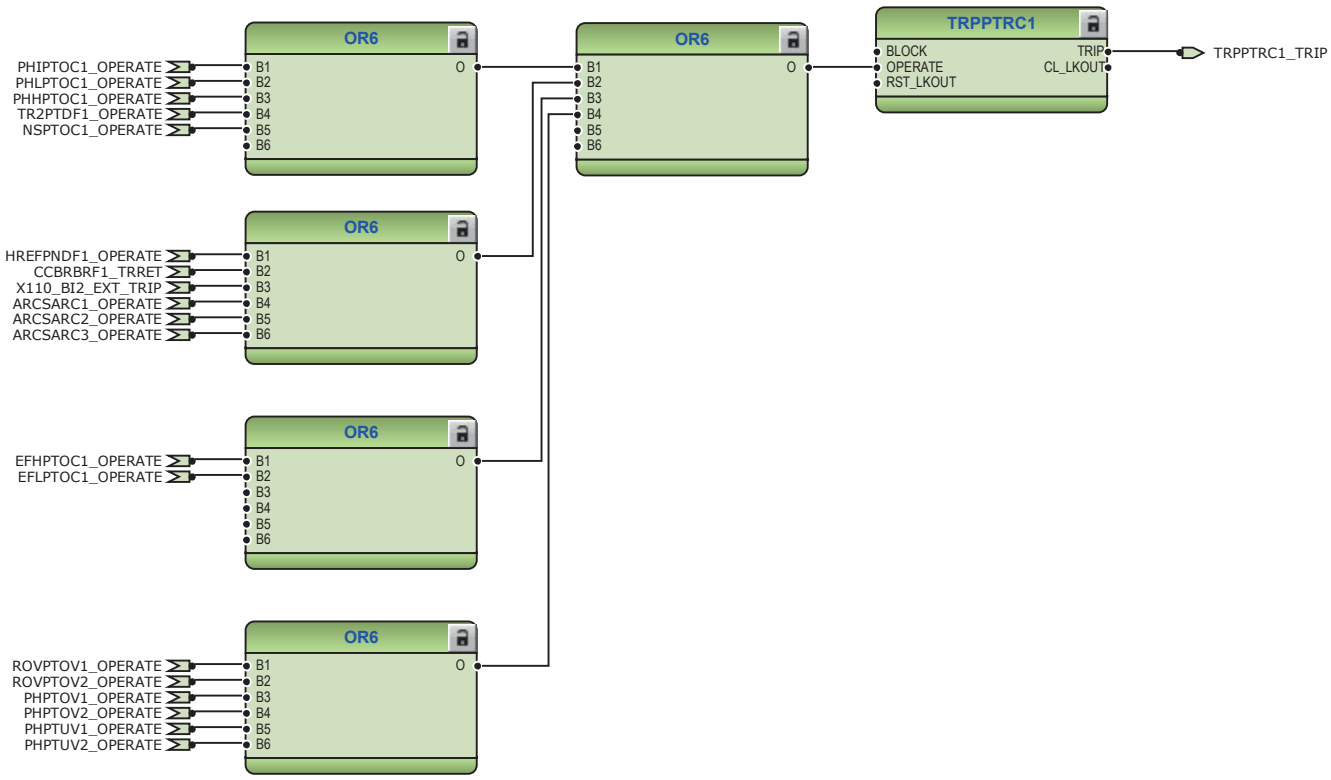


Figure 304: Trip logic TRPPTRC1

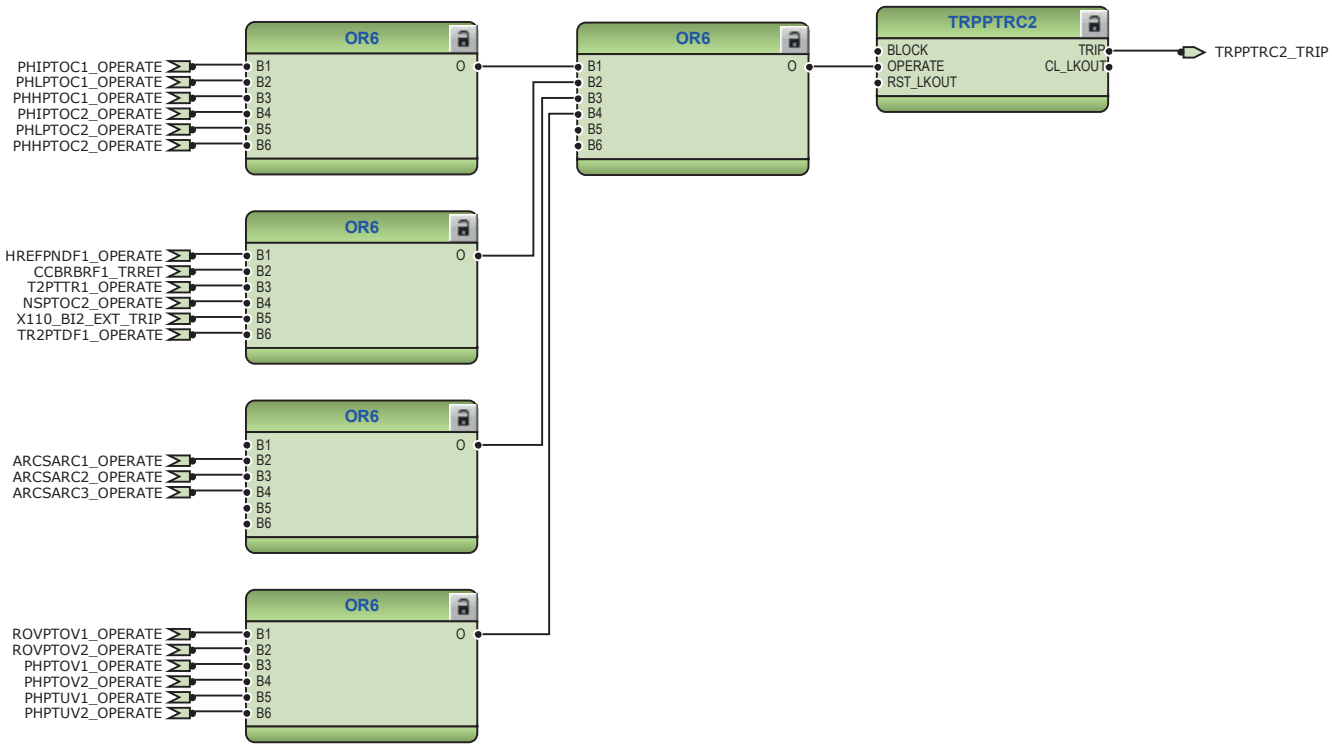


Figure 305: Trip logic TRPPTRC2

3.9.3.2 Functional diagrams for disturbance recorder

The START and 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.

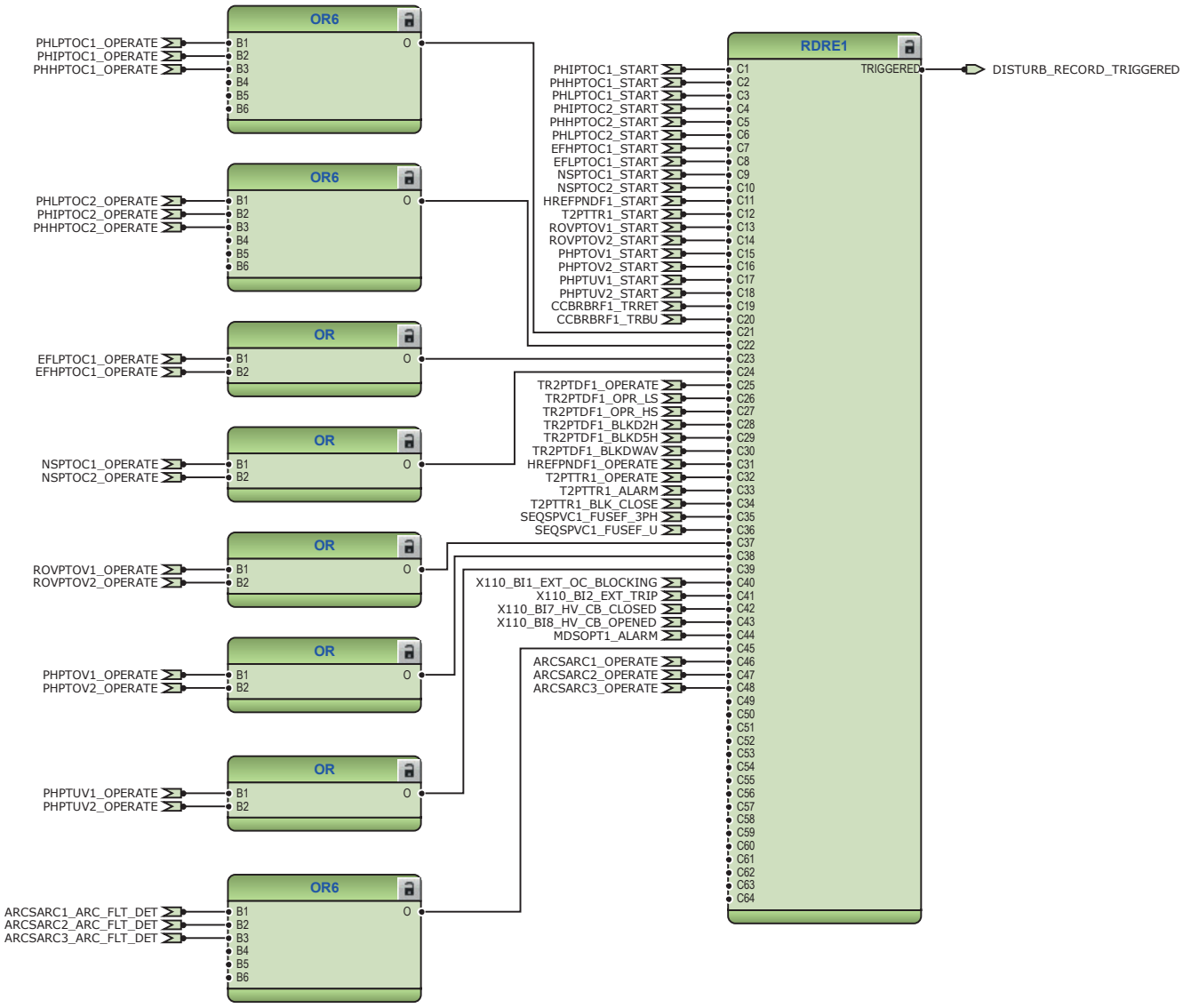


Figure 306: Disturbance recorder

3.9.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

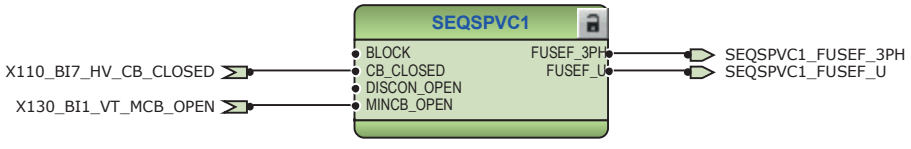


Figure 307: High-voltage side fuse failure supervision function

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

Set the parameters for SSCBR properly.

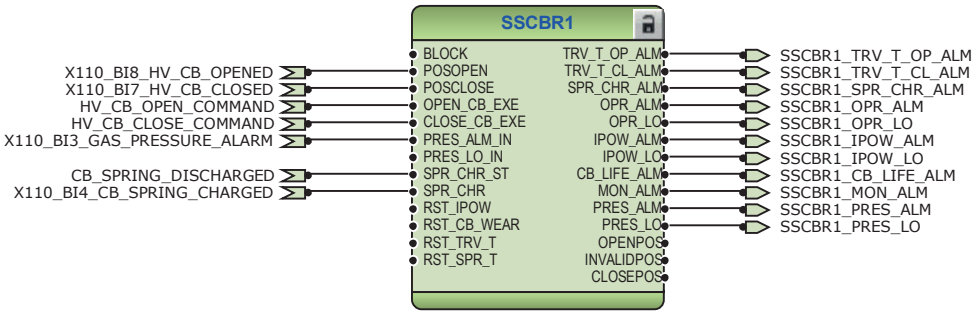


Figure 308: Condition monitoring function

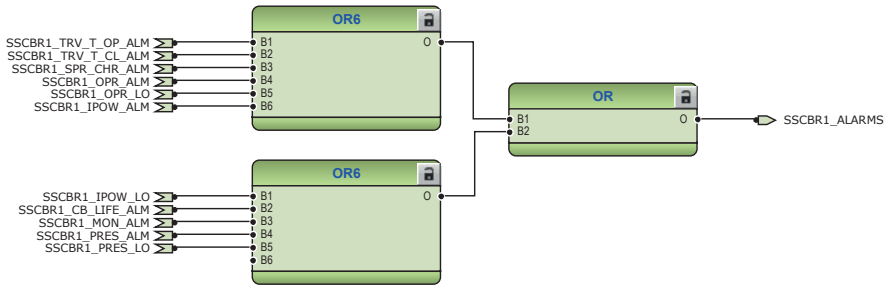


Figure 309: Logic for circuit-breaker monitoring alarm

Figure 310: 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. TCSSCBR1 is blocked by master trip TRPPTRC1 and TRPPTRC2 and the HV side 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.

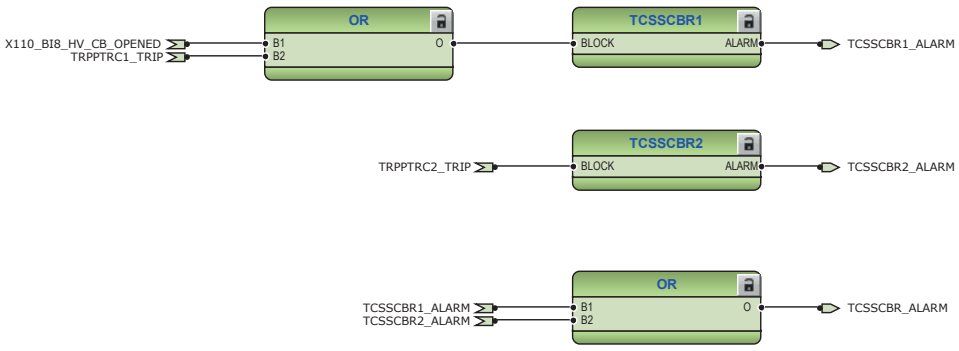


Figure 311: Trip circuit supervision function

3.9.3.4 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) status information is connected to DCSXSWI1.

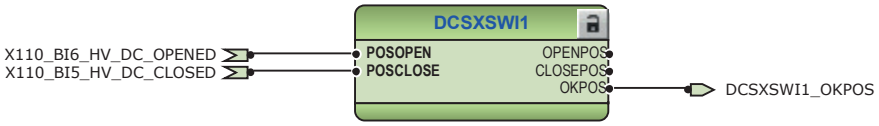


Figure 312: High-voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or closed (in service position). This, together with 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 of the interlocking conditions being active when the circuit-breaker truck is closed in service position.

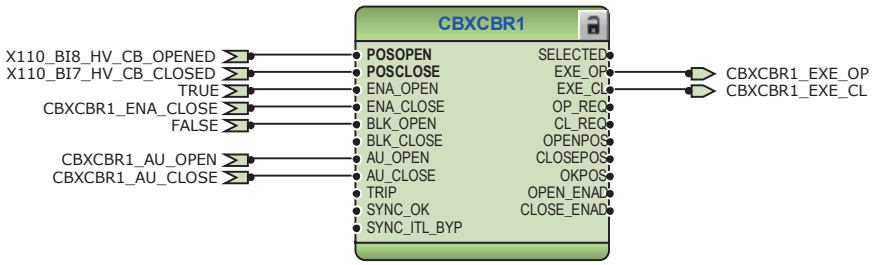


Figure 313: Circuit-breaker control logic: High-voltage side circuit breaker 1

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

Figure 314: Circuit-breaker control logic: Signals for closing coil of high-voltage side circuit breaker

Figure 315: Circuit-breaker control logic: Signals for closing coil of high-voltage side circuit breaker

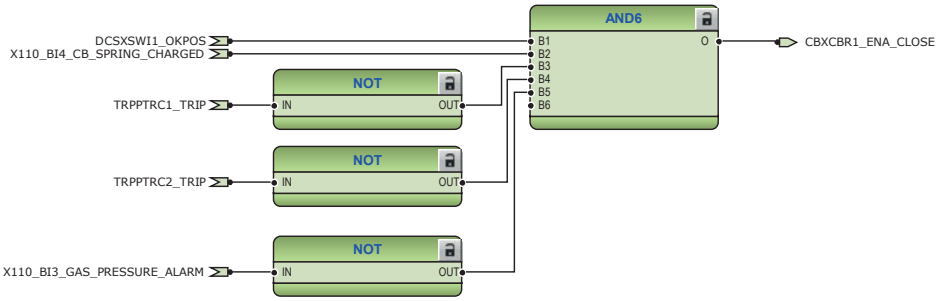


Figure 316: High-voltage side circuit-breaker close enable logic

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.

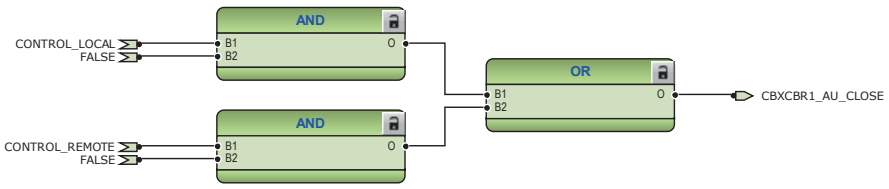


Figure 317: External closing command for circuit breaker

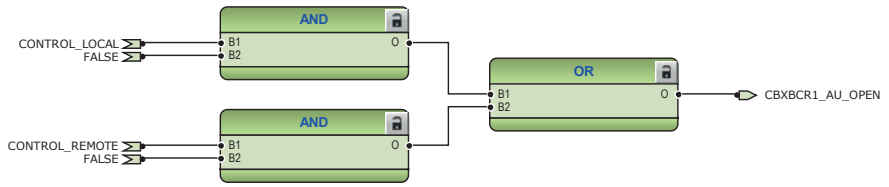


Figure 318: External opening command for circuit breaker

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters for TPOSYLTC1 properly.

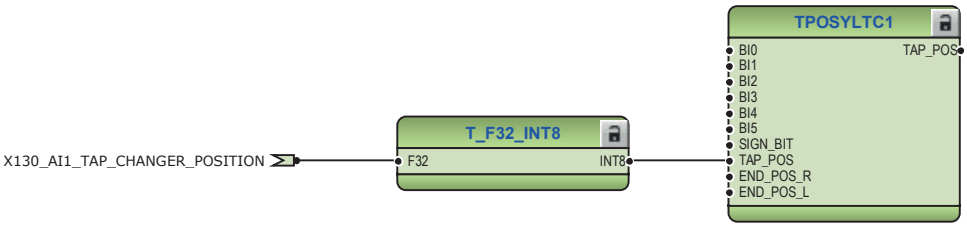


Figure 319: Tap changer position indicator

3.9.3.5 Functional diagrams for measurements functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current from high-voltage side.

The high-voltage side three-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. Sequence voltage measurement VSMSQI1 measures the sequence voltage and residual voltage measurement RESVMMXU1 measures the residual voltage from high-voltage side.

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.

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

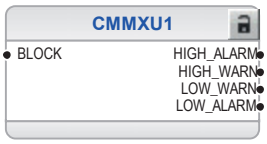


Figure 320: Current measurement: Three-phase current measurement (HV side)

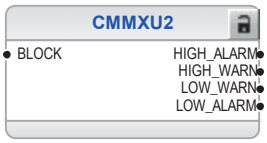


Figure 321: Current measurement: Three-phase current measurement (LV side)

Figure 322: Current measurement: Sequence current measurement (HV side)

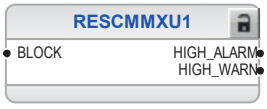


Figure 323: Current measurement: Residual current measurement (HV side)

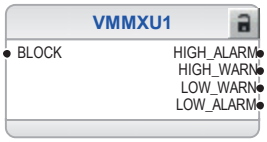


Figure 324: Voltage measurement: Three-phase voltage measurement (HV side)

Figure 325: Voltage measurement: Sequence voltage measurement (HV side)

Figure 326: Voltage measurement: Residual voltage measurement (HV side)

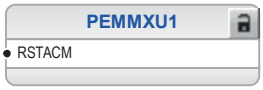


Figure 327: Other measurement: Three-phase power and energy measurement

Figure 328: Other measurement: Data monitoring

Figure 329: Other measurement: Load profile record

3.9.3.6 Functional diagrams for I/O and alarms LEDs

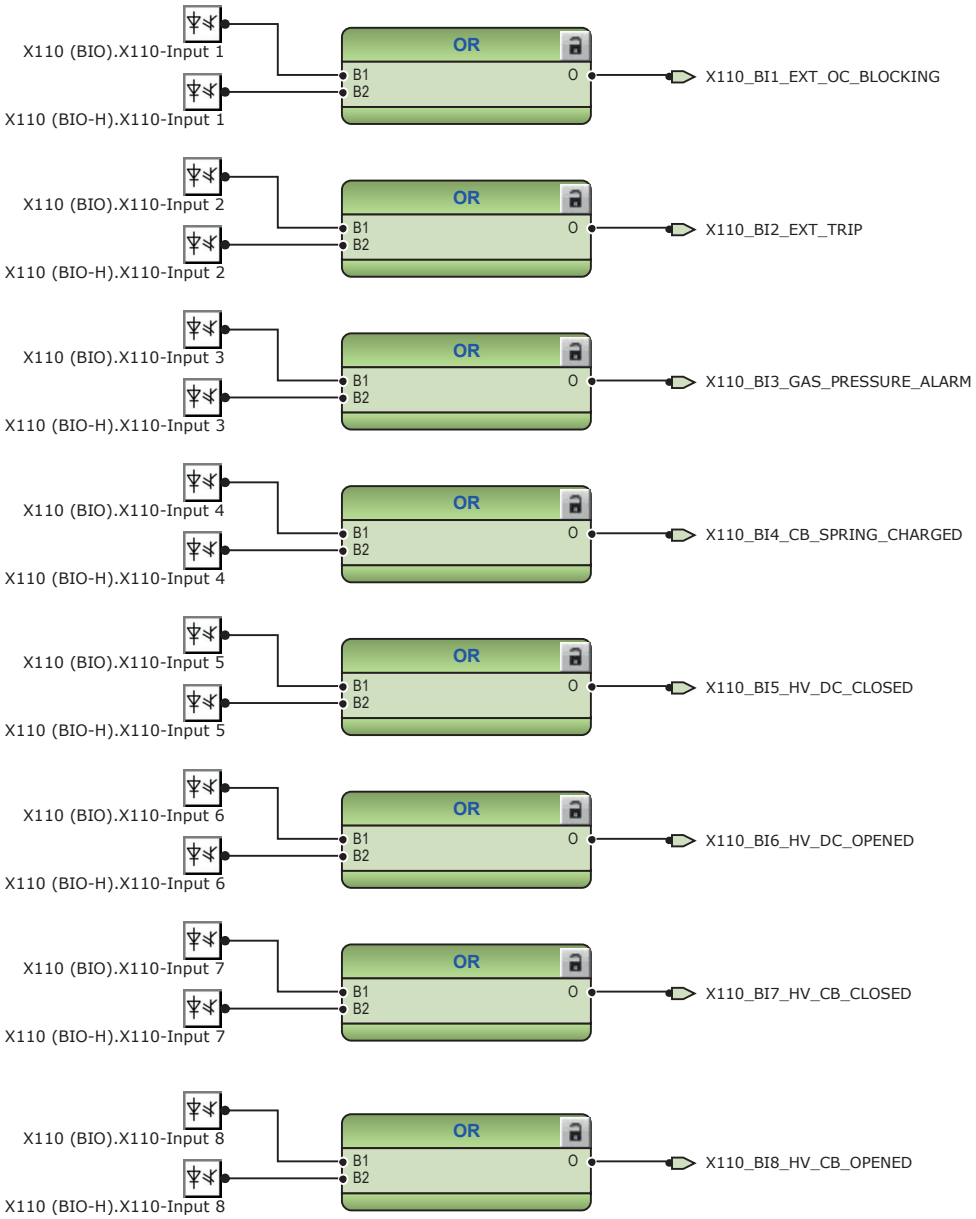


Figure 330: Binary inputs - X110 terminal block

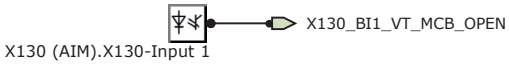


Figure 331: Binary inputs - X130 terminal block

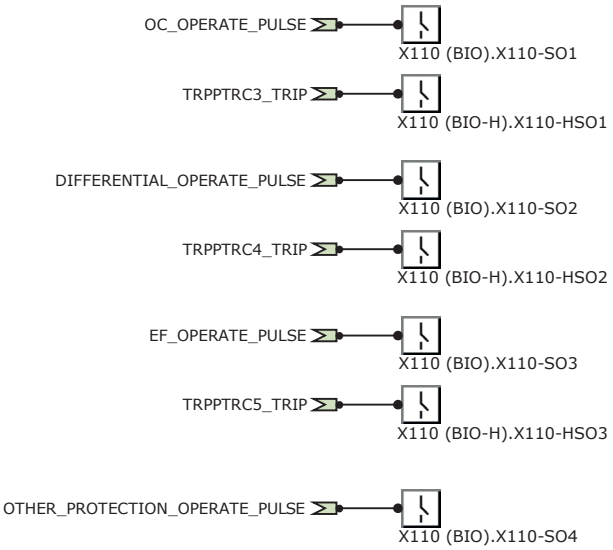


Figure 332: Binary outputs - X110 terminal block

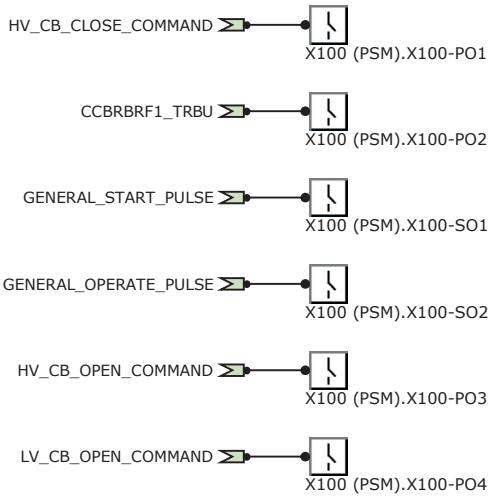


Figure 333: Binary outputs - X100 terminal block

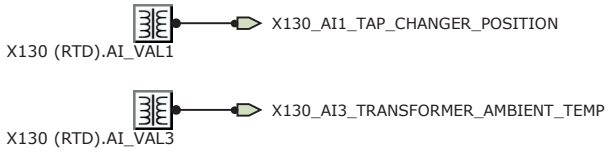


Figure 334: Default mA/RTD inputs X130

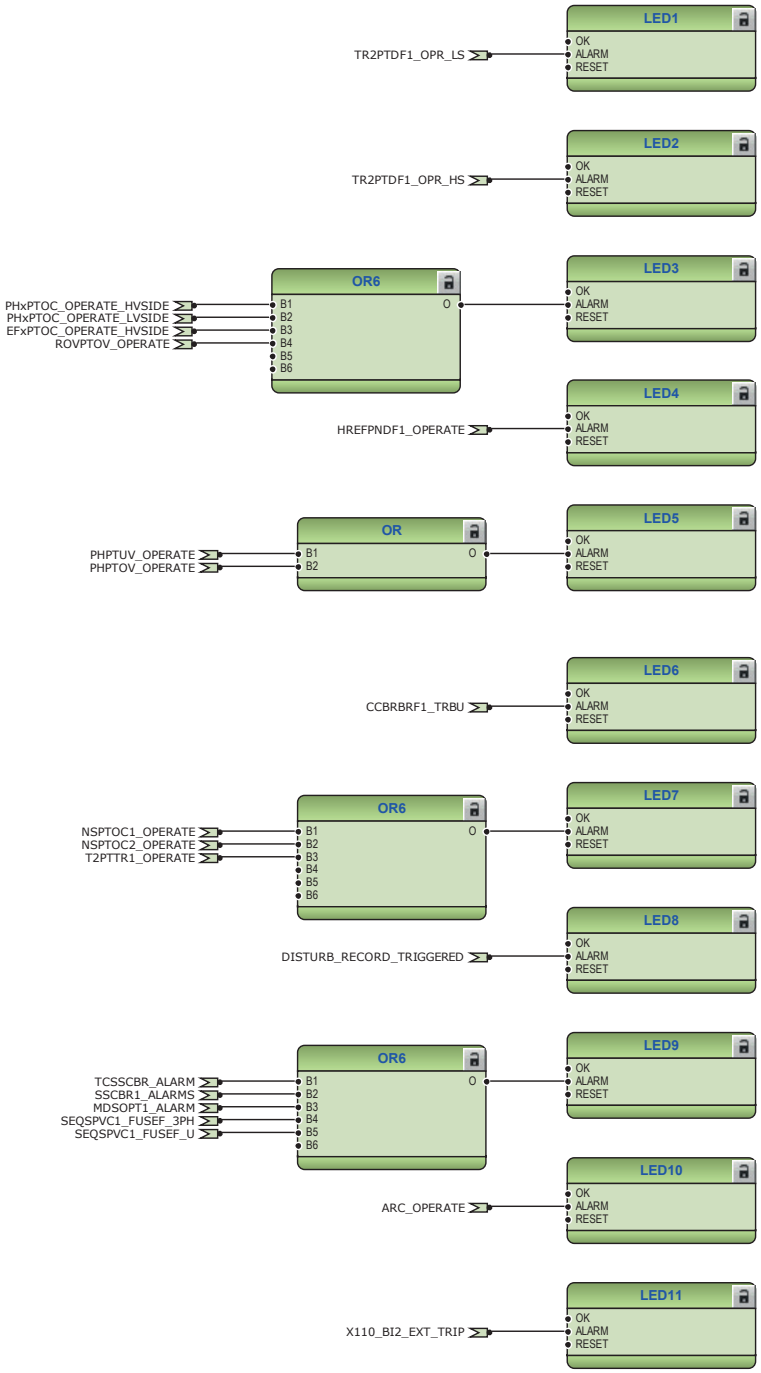


Figure 335: Default LED connection

3.9.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase overvoltage and undervoltage operate). 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.

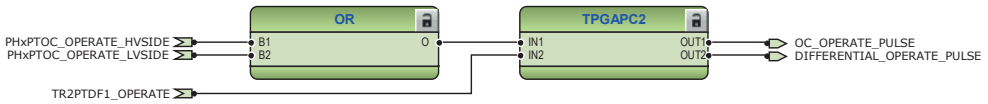


Figure 336: Timer logic for overcurrent and differential operate pulse

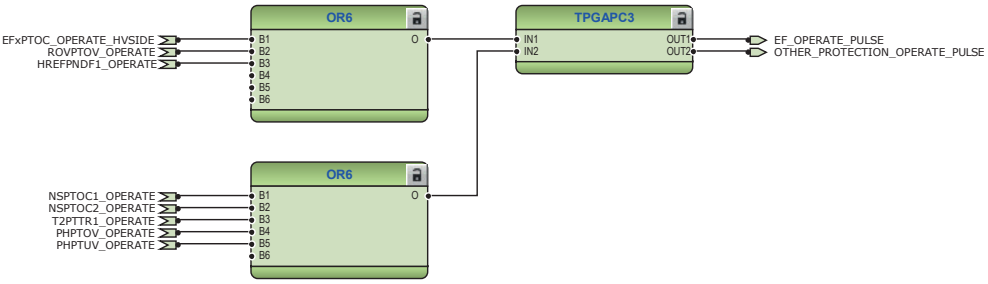


Figure 337: Timer logic for earth-fault and combined other operate pulse

3.9.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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.

3.10 Standard configuration H

3.10.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, high impedance based restricted earth-fault protection for the low-voltage (LV) side, high-voltage side phase voltage based protection and measurement function. The configuration is mainly intended for protection of the power transformer between current transformers.

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.

3.10.2 Functions

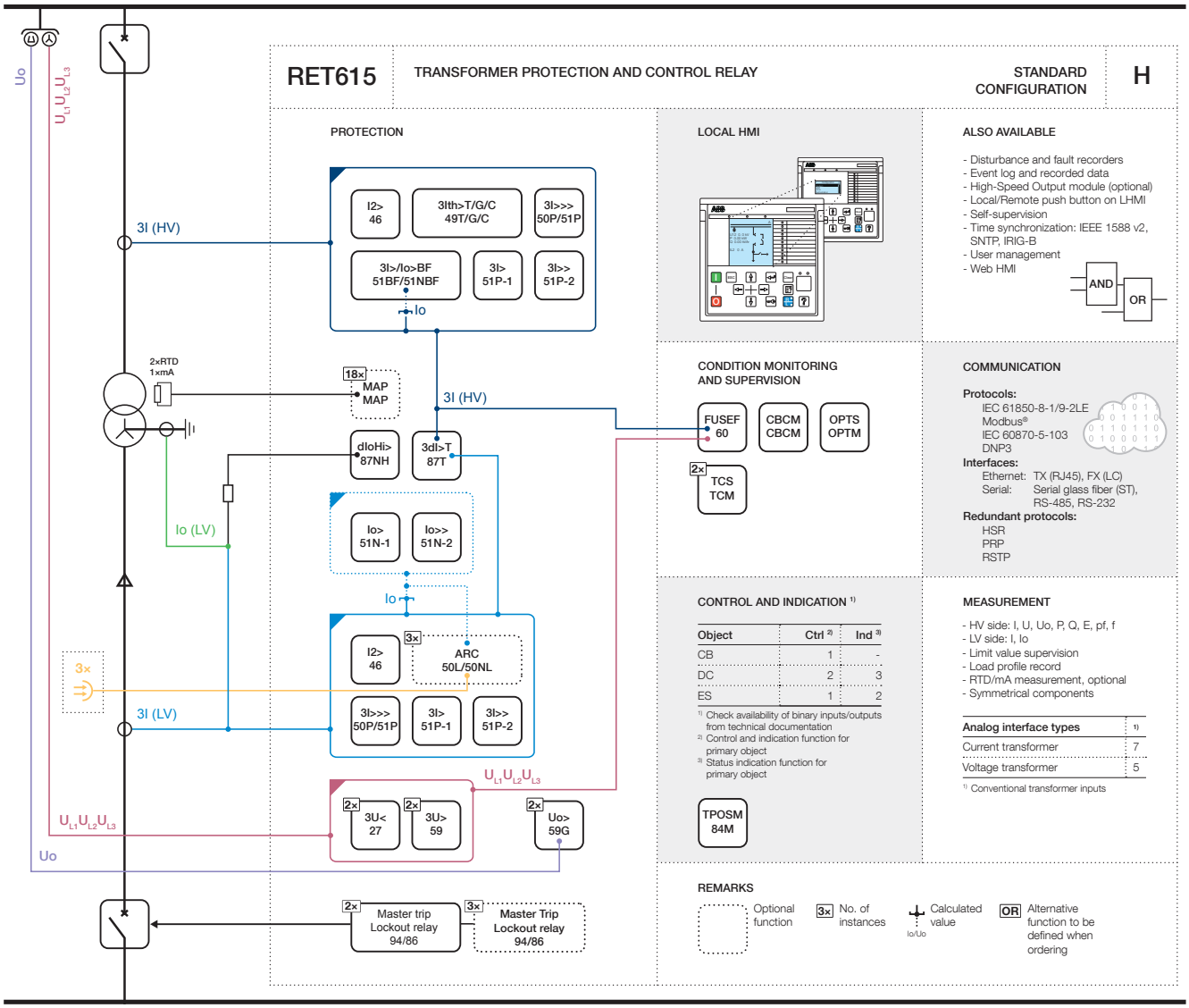


Figure 338: Functionality overview for standard configuration H

3.10.2.1 Default I/O connections

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

Table 52: Default connections for binary inputs

Binary input	Description
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (low voltage)
X110-BI2	External protection trip
X110-BI3	Circuit breaker low gas pressure indication
X110-BI4	Circuit breaker spring charged indication
X110-BI5	High-voltage side disconnector closed
X110-BI6	High-voltage side disconnector open
X110-BI7	High-voltage side circuit breaker closed
X110-BI8	High-voltage side circuit breaker open
X130-BI1	Voltage transformer secondary MCB open
X130-BI2	-
X130-BI3	-
X130-BI4	-

Table 53: Default connections for mA/RTD inputs

Analog input	Description
X130-AI1	Tap changer position
X130-AI2	-
X130-AI3	Ambient temperature
X130-AI4	-
X130-AI5	-
X130-AI6	-
X130-AI7	-
X130-AI8	-

Table 54: Default connections for binary outputs

Binary output	Description
X100-PO1	Close high-voltage 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 high-voltage
X100-PO4	Open circuit breaker/trip coil 2 low-voltage
X110-SO1	Overcurrent operate alarm
X110-SO2	Differential protection operate alarm
X110-SO3	Earth fault operate alarm
X110-SO4	Thermal overload and negative phase-sequence operate alarm
Table continues on next page	

Binary output	Description
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 55: Default connections for LEDs

LED	Description
1	Transformer differential protection biased stage operate
2	Transformer differential protection instantaneous stage operate
3	Overcurrent or earth-fault protection operate
4	Restricted earth-fault protection operate
5	Voltage protection operated
6	Circuit failure protection backup trip operated
7	NPS or thermal overload protection operated
8	Disturbance recorder triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision
10	Arc protection operate
11	Protection trip from external device

3.10.2.2 Default disturbance recorder settings

Table 56: Default disturbance recorder analog channels

Channel	Description[1)]
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	IoB
8	Uo
9	U1
10	U2
11	U3
12	-

1) Text with “B” refers to measurement on low-voltage side of the transformer

Table 57: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - start	Positive or Rising
2	PHHPTOC1 - start	Positive or Rising
3	PHLPTOC1 - start	Positive or Rising
4	PHIPTOC2 - start	Positive or Rising
5	PHHPTOC2 - start	Positive or Rising
6	PHLPTOC2 - start	Positive or Rising
7	EFHPTOC2 - start	Positive or Rising
8	EFLPTOC2 - start	Positive or Rising
9	NSPTOC1 - start	Positive or Rising
10	NSPTOC2 - start	Positive or Rising
11	HREFPDIF1 - start	Positive or Rising
12	T2PTTR1 - start	Positive or Rising
13	ROVPTOV1 - start	Positive or Rising
14	ROVPTOV2 - start	Positive or Rising
15	PHPTOV1 - start	Positive or Rising
16	PHPTOV2 - start	Positive or Rising
17	PHPTUV1 - start	Positive or Rising
18	PHPTUV2 - start	Positive or Rising
19	CCBRBRF1 - trret	Level trigger off
20	CCBRBRF1 - trbu	Level trigger off
21	PHIPTOC1 - operate	Level trigger off
	PHHPTOC1 - operate	
	PHLPTOC1 - operate	
22	PHIPTOC2 - operate	Level trigger off
	PHHPTOC2 - operate	
	PHLPTOC2 - operate	
23	EFLPTOC2 - operate	Level trigger off
	EFHPTOC2 - operate	
24	NSPTOC1 - operate	Level trigger off
	NSPTOC2 - operate	
25	TR2PTDF1 - operate	Positive or Rising
26	TR2PTDF1 - opr LS	Level trigger off
27	TR2PTDF1 - opr HS	Level trigger off
28	TR2PTDF1 - blkd2h	Level trigger off
29	TR2PTDF1 - blkd5h	Level trigger off
30	TR2PTDF1 - blkdwav	Level trigger off
31	HREFPDIF1 - operate	Level trigger off
32	T2PTTR1 - operate	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
33	T2PTTR1 - alarm	Level trigger off
34	T2PTTR1 - blk close	Level trigger off
35	SEQSPVC1 - fusef3ph	Level trigger off
36	SEQSPVC1 - fusefu	Level trigger off
37	ROVPTOV1 - operate	Level trigger off
	ROVPTOV2 - operate	
38	PHPTOV1 - operate	Level trigger off
	PHPTOV2 - operate	
39	PHPTUV1 - operate	Level trigger off
	PHPTUV2 - operate	
40	X110BI1 - ext OC blocking	Level trigger off
41	X110BI2 - ext trip	Positive or Rising
42	X110BI7 - HVCB closed	Level trigger off
43	X110BI8 - HVCB opened	Level trigger off
44	MDSOPT1 - alarm	Level trigger off
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

3.10.3 Functional diagrams

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

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 high-voltage and low-voltage side phase currents to the protection relay are fed from a current transformer. The neutral current to the protection relay is measured between the star point of the transformer and grounding.

The high-voltage side phase voltages to the protection relay are fed from a voltage transformer. The residual voltage to the protection relay represents the measured residual voltage via open-delta connected VTs on the high-voltage side.

The protection relay offers six different setting groups which can be set based on 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.

3.10.3.1 Functional diagrams for protection

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

Stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1 provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal. All operate signals from the functions are connected to both the master trips as well as to alarm LEDs.

For transformers having an online tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF1.

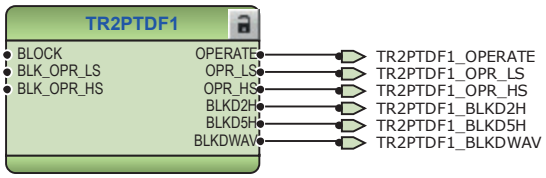


Figure 339: Transformer differential protection

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as low-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1 and instantaneous stage of low-voltage side PHIPTOC2 can be blocked by energizing the binary input X110:BI1. In addition high stage of high-voltage side PHHPTOC1 is blocked by start of high stage of low-voltage side PHHPTOC2.

A selective backup overcurrent protection can be achieved by using blockings between high-voltage side and low-voltage side overcurrent stages. This blocking scheme enables coordinated overlapping of overcurrent protection zones.

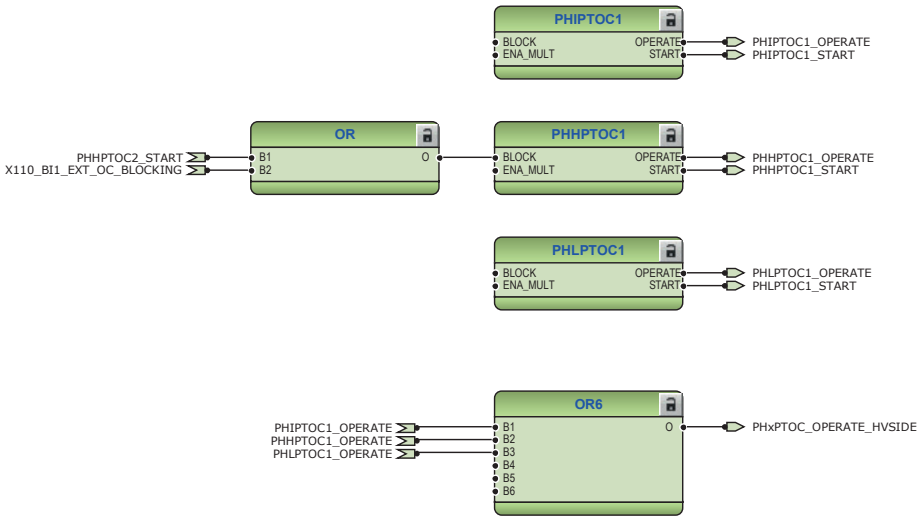


Figure 340: High-voltage side overcurrent protection function

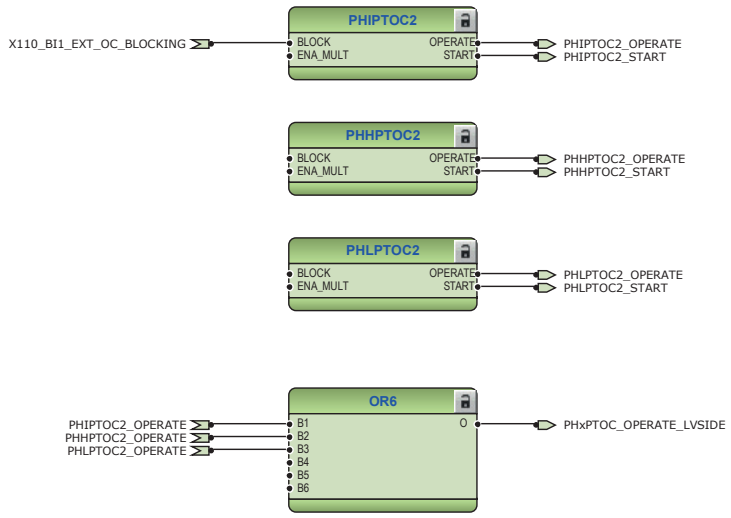


Figure 341: Low-voltage side overcurrent protection function

Two stages are offered for non-directional earth-fault protection. The earth-fault protection measures the neutral current from low-voltage side.

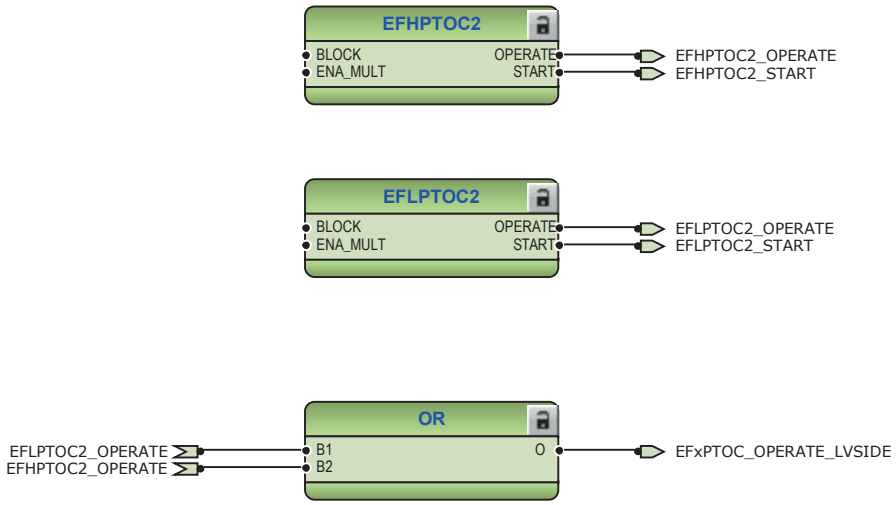


Figure 342: Low-voltage side earth-fault protection function

The configuration includes numerically stabilized low-impedance restricted earth-fault protection LREFPNDF1 for low-voltage side of two-winding power transformers. The numerical differential current stage operates exclusively on earth-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. An earth-fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and earth.

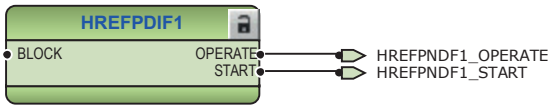
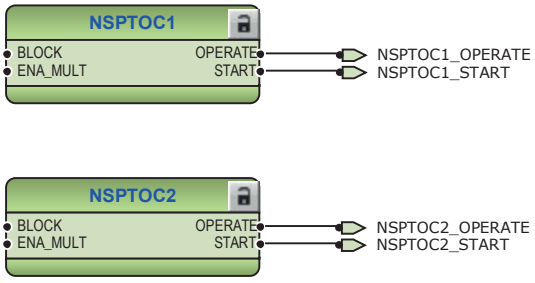


Figure 343: Low-voltage side restricted high-impedance earth-fault protection

Two negative-sequence overcurrent protection stages NSPTOC1 and NSPTOC2 are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1 measures negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.



Three-phase thermal overload protection, two time constants, T2PTTR1 detects overloads conditions. The BLK_CLOSE output of the function can be used to block the closing operation of circuit breaker. However, in the configuration it is connected

to disturbance recorder only. If the IED is ordered with an optional RTD/mA card, the information about the ambient temperature of the transformer is available to the function via RTD input X130:AI3.

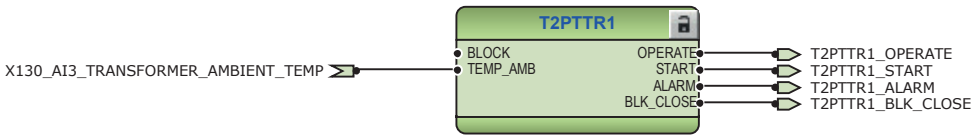


Figure 344: Thermal overcurrent protection function

Circuit breaker failure protection CCBRBRF1 is initiated via the START input by number of different protection functions available in the IED. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The function has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping both the high-voltage and low-voltage side circuit breaker through master trip 1 and master trip 2. 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.

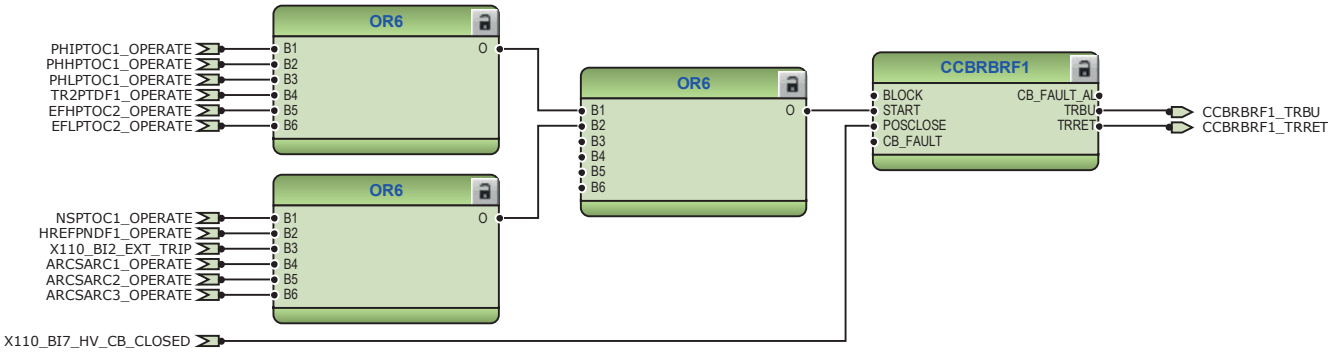


Figure 345: Circuit breaker protection function

Two overvoltage and undervoltage protection stages PHPTOV and PHPTUV offer protection against an abnormal phase voltage conditions. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to block undervoltage protection functions to avoid faulty tripping.

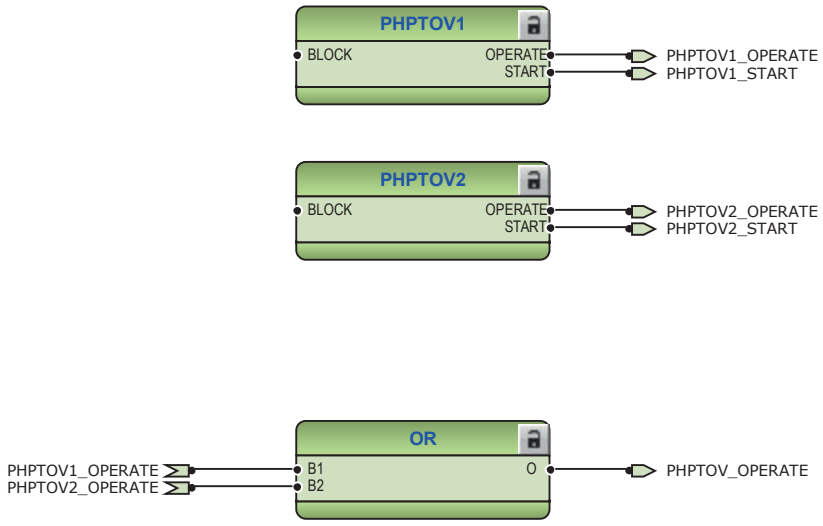


Figure 346: High-voltage side phase overvoltage protection function

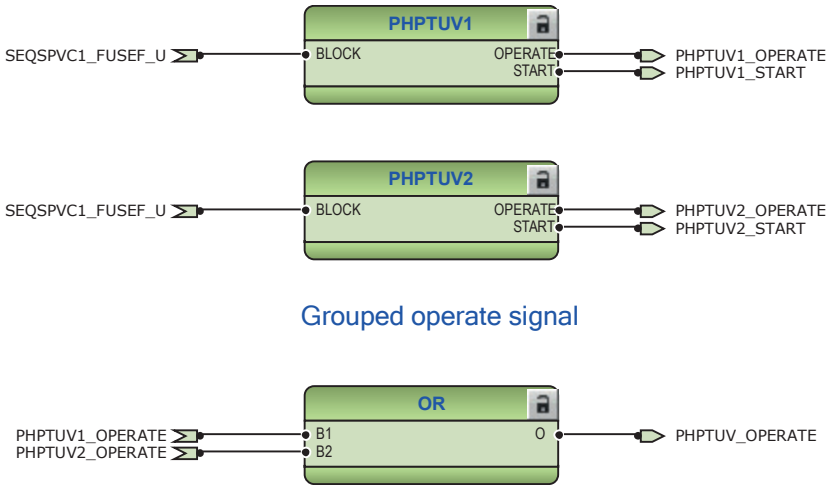


Figure 347: Low-voltage side phase overvoltage protection function

Residual overvoltage protection ROVPTOV1 provides earth-fault protection by detecting an abnormal level of residual voltage.

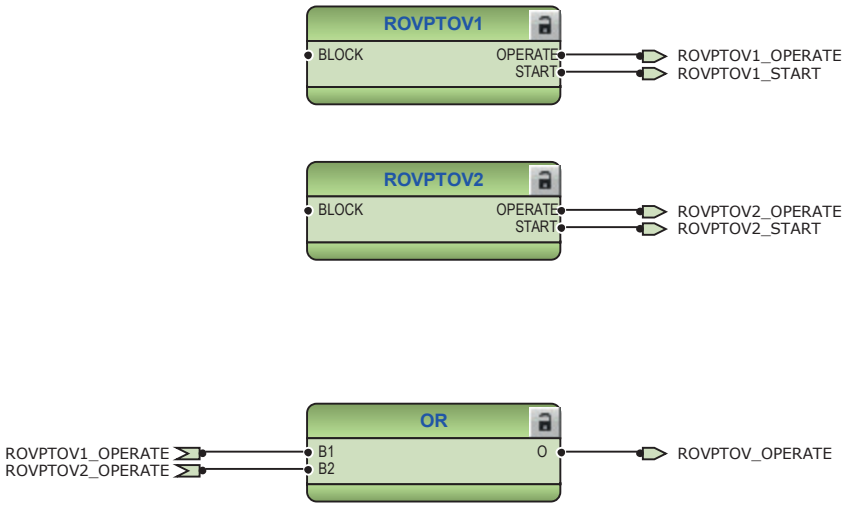


Figure 348: High-voltage side residual voltage protection function

Three arc protection ARCSARC1...3 stages 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 output of these TRPPTRC3...5 are available at high speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

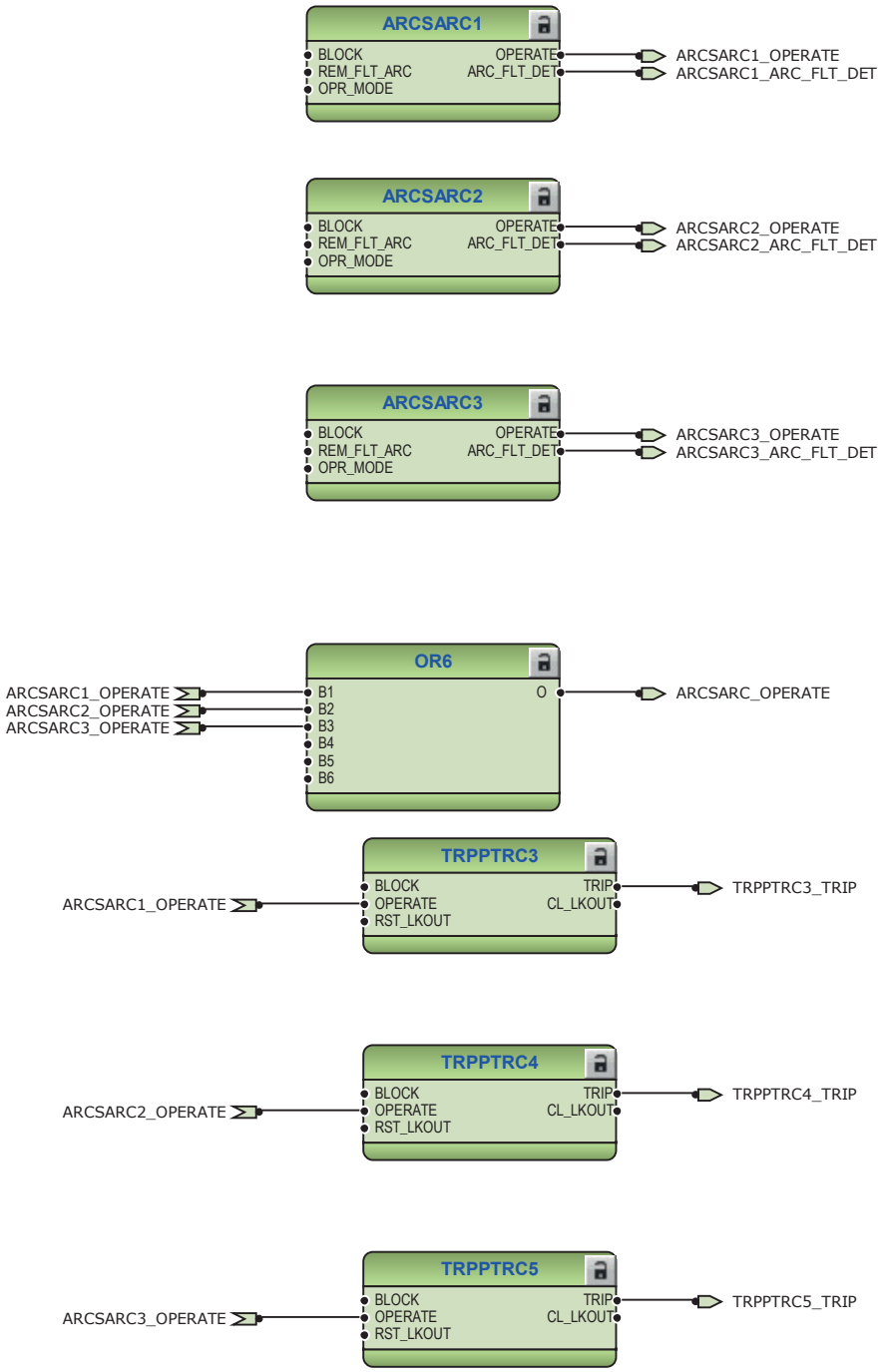


Figure 349: Arc protection with dedicated HSO

Runtime counter for machines and devices MDSOPT1 accumulates the operation time of the transformer.

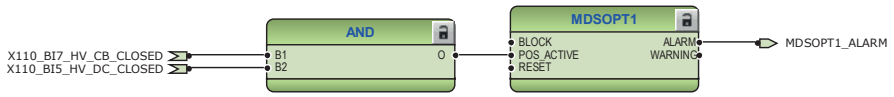


Figure 350: Transformer operation time counter

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 outputs from TPGAPC1 are connected to binary outputs.

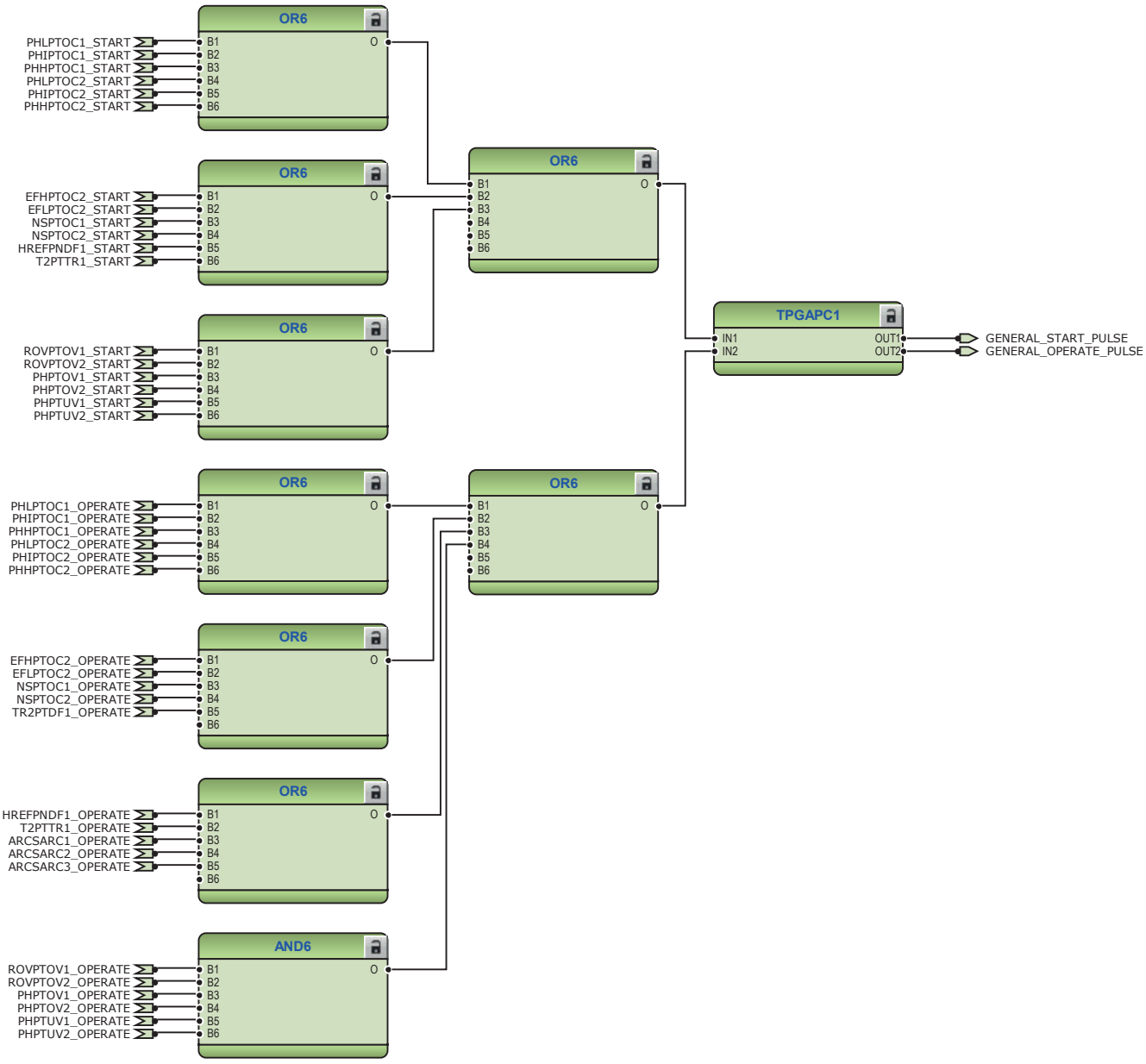


Figure 351: General start and operate signals

The operate signals from the protections are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output of these trip logic functions is available at

binary output X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and low voltage side.

The trip logic functions are provided with a lockout or latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input can be assigned to RST_LKOUT input of both the trip logic to enable external reset with a push button.

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

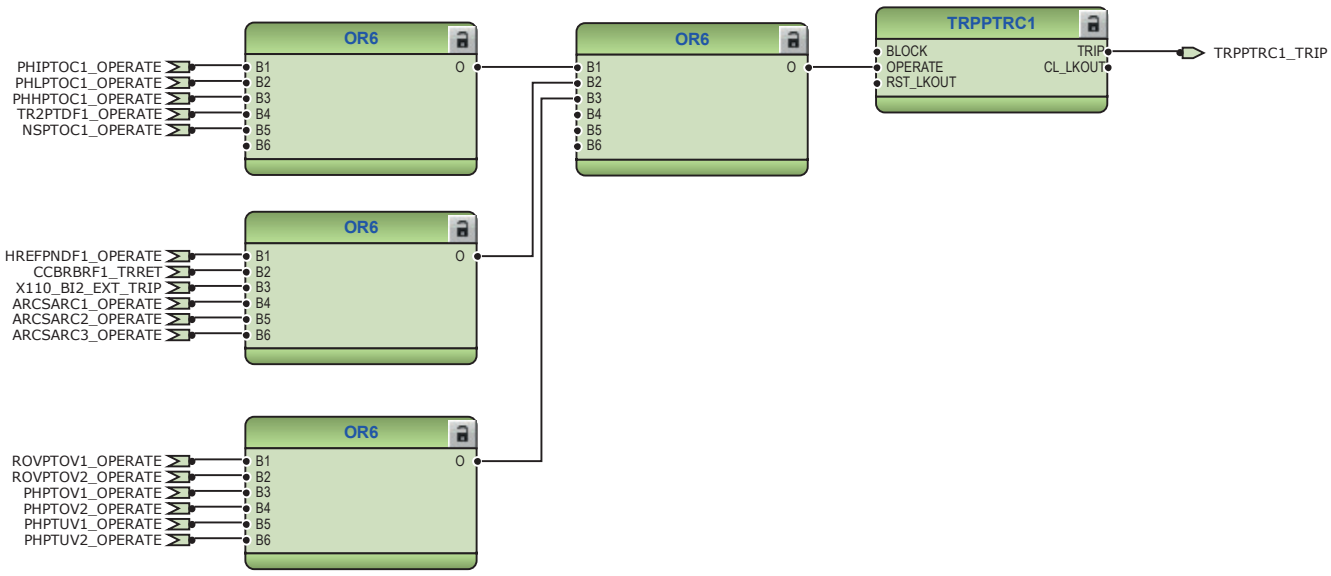


Figure 352: Trip logic TRPPTRC1

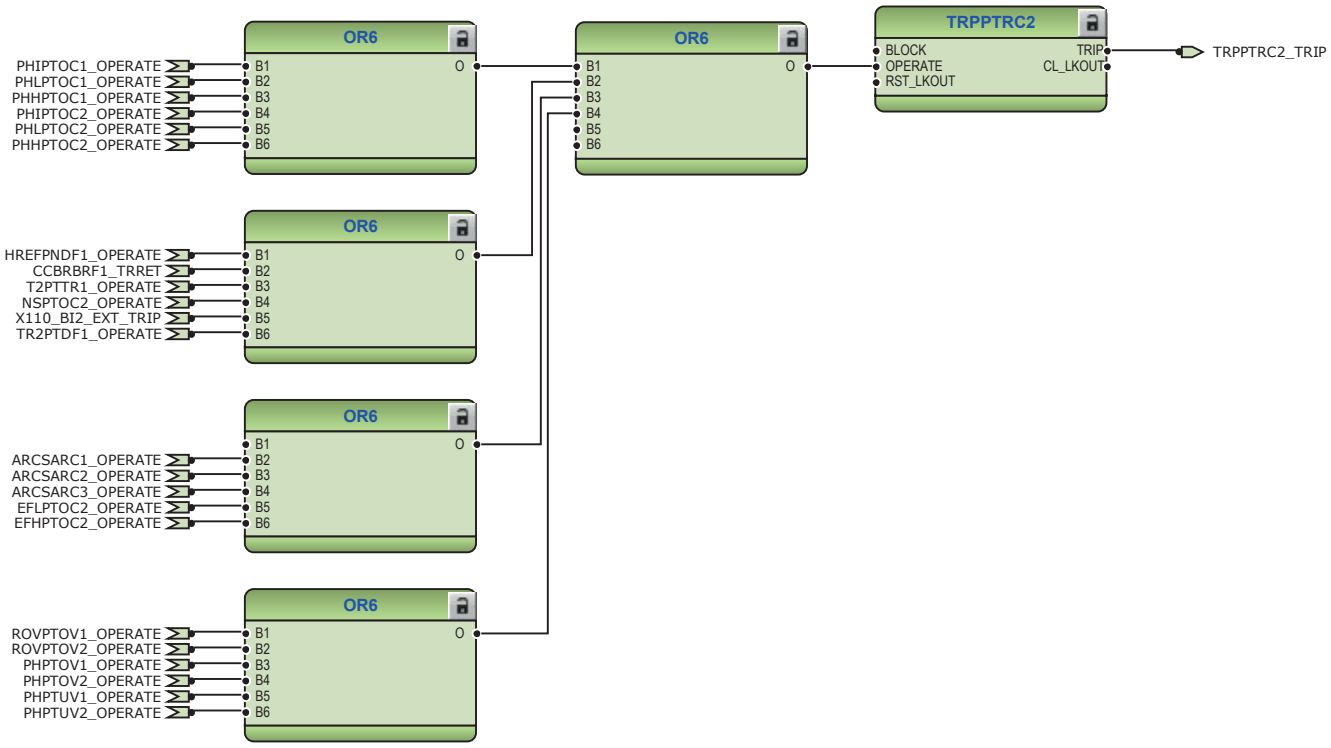


Figure 353: Trip logic TRPPTRC2

3.10.3.2 Functional diagrams for disturbance recorder

The START and 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.

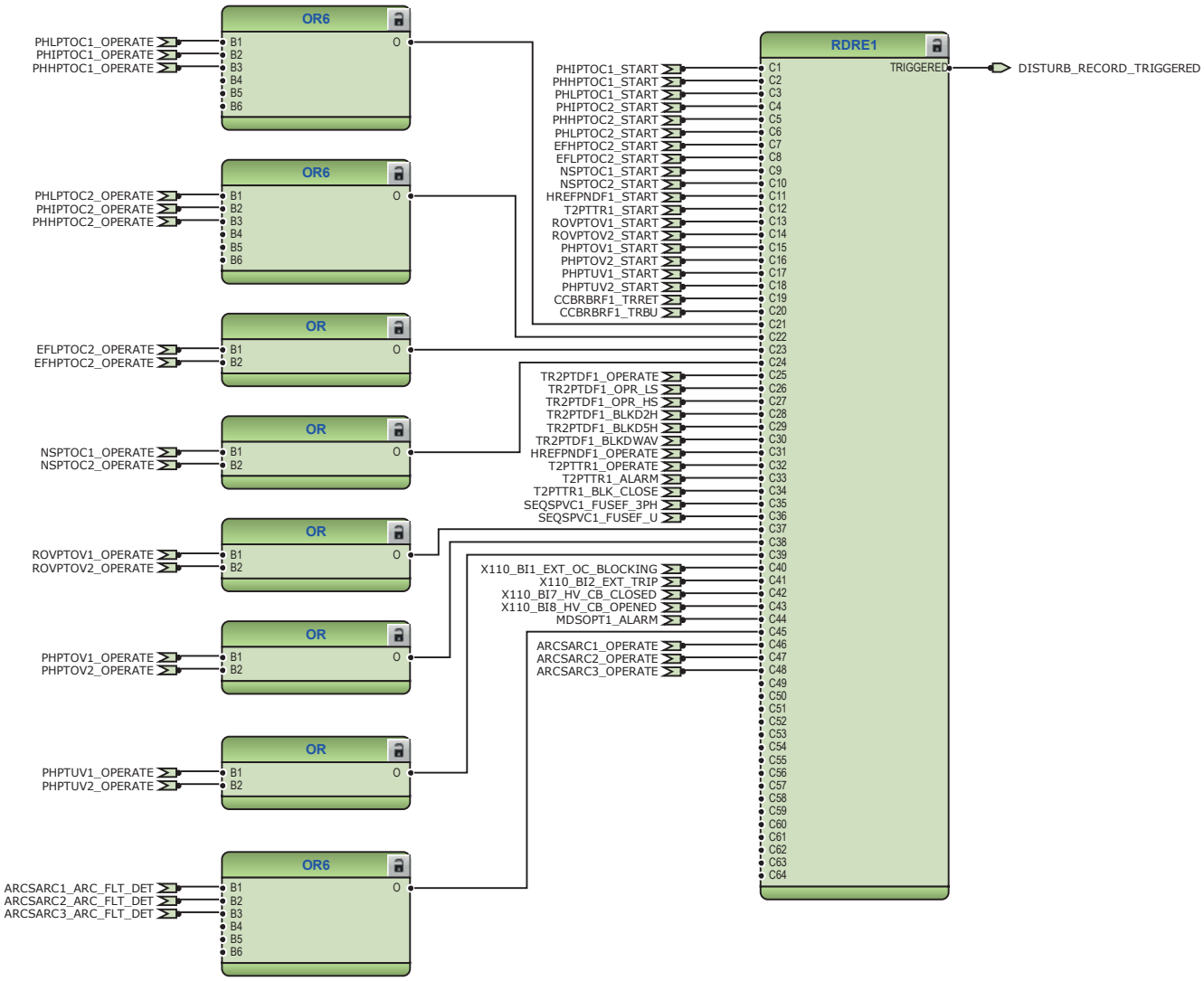


Figure 354: Disturbance recorder

3.10.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1 detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

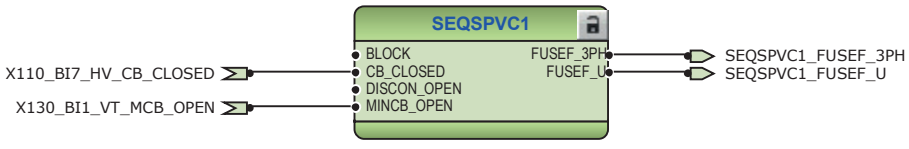


Figure 355: High-voltage side fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

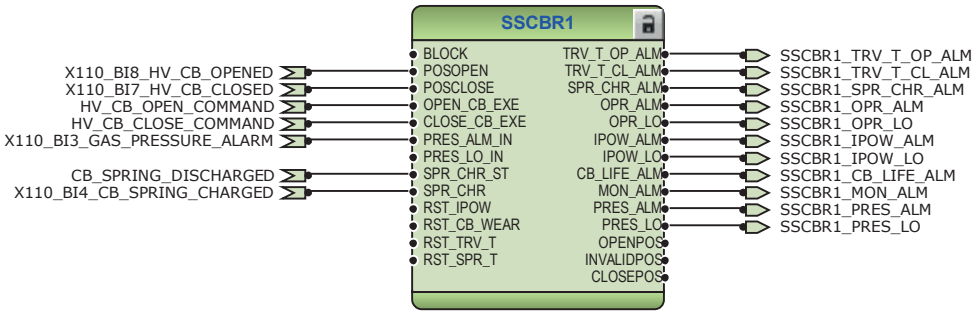


Figure 356: Condition monitoring function

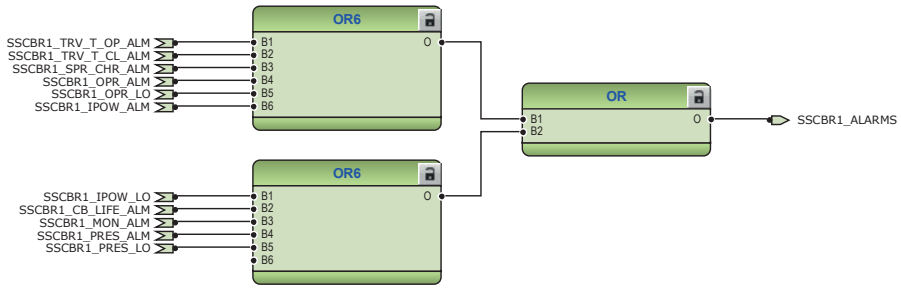


Figure 357: Logic for circuit-breaker monitoring alarm

Figure 358: 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. TCSSCBR1 is blocked by master trip 1 TRPPTRC1 and the HV side circuit breaker open signal. TCSSCBR2 is blocked by master trip 2 TRPPTRC2.

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.

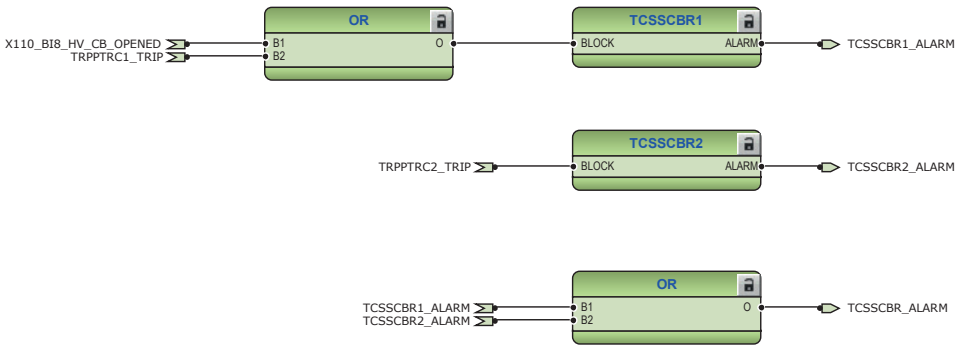


Figure 359: Trip circuit supervision function

3.10.3.4 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) status information is connected to DCSXSWI1.

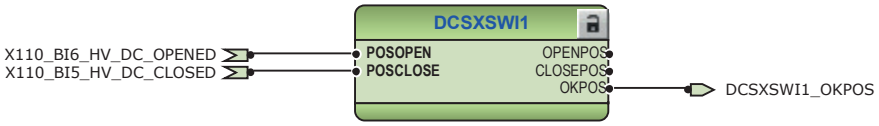


Figure 360: High-voltage side disconnector 1

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or closed (in service position). This output, together with 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 of the interlocking conditions being active when the circuit breaker truck is closed in service position.

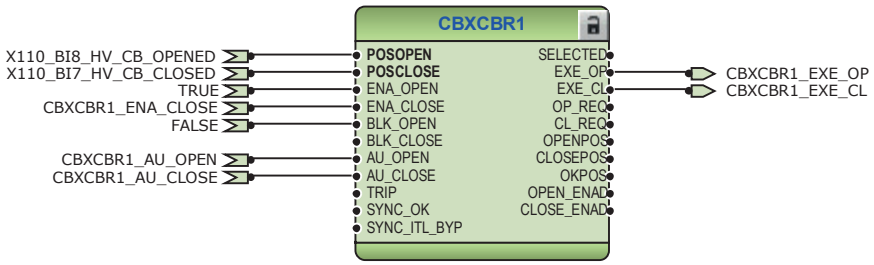


Figure 361: Circuit breaker control logic: High-voltage side circuit breaker 1

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

Figure 362: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker

Figure 363: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker

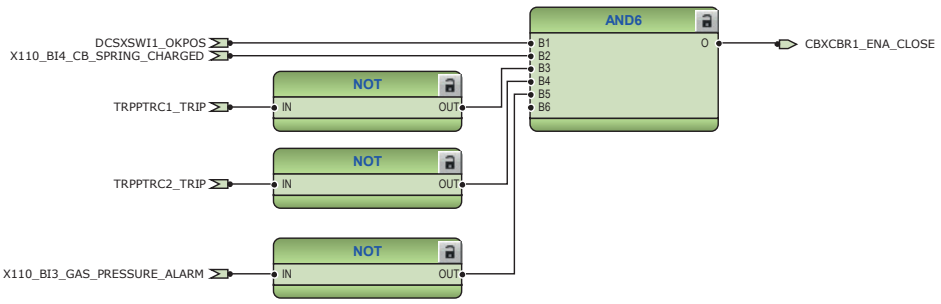


Figure 364: Circuit breaker close enable logic

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.

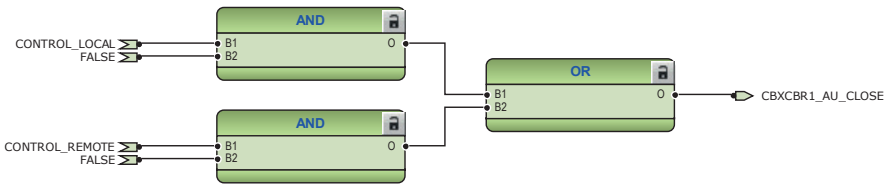


Figure 365: External closing command for circuit breaker

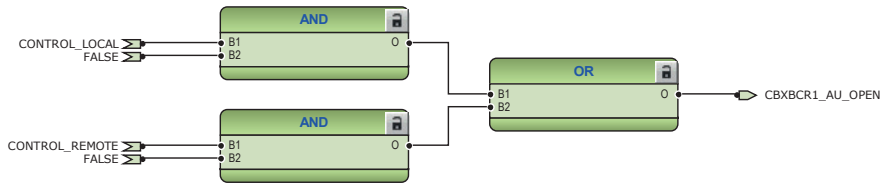


Figure 366: External opening command for circuit breaker

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IED via the tap changer position indication function TPOSYLTC1. Tap position information is available to TPOSYLTC1 by the binary inputs of the X130 card or alternatively by the mA input of the RTD card. In the configuration the information is available via mA input.

Set the parameters for TPOSYLTC1 properly.

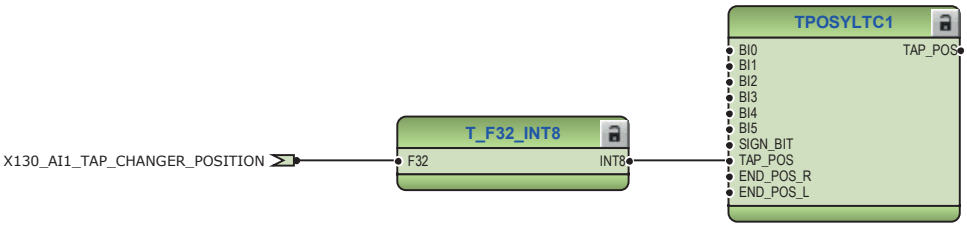


Figure 367: Tap changer position indicator

3.10.3.5 Functional diagrams for measurement functions

The high-voltage side and low-voltage side phase current inputs to the IED are measured by three-phase current measurement CMMXU1 and CMMXU2. The current input is connected to the X120 card in the back panel. Sequence current measurement CSMSQI1 measures the sequence current from high-voltage side and

residual current measurement RESCMMXU2 measures the residual current from low-voltage side.

The high-voltage side three-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. Sequence voltage measurement VSMSQI1 measures the sequence voltage and residual voltage measurement RESVMMXU1 measures the residual voltage from high-voltage side.

The measurements can be seen in the LHMI and they are available by using 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.

Three-phase power and energy measurement PEMMXU1 is also available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

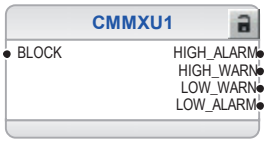


Figure 368: Current measurement: Three-phase current measurement (HV side)

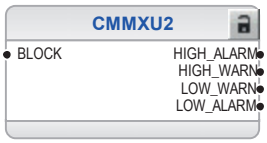


Figure 369: Current measurement: Three-phase current measurement (LV side)

Figure 370: Current measurement: Sequence current measurement (HV side)

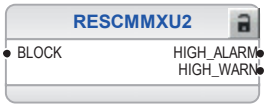


Figure 371: Current measurement: Residual current measurement (LV side)

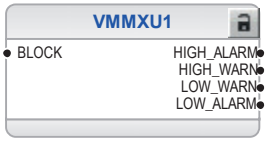


Figure 372: Voltage measurement: Three-phase voltage measurement (HV side)

Figure 373: Voltage measurement: Sequence voltage measurement (HV side)

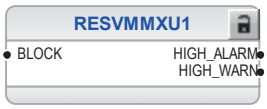


Figure 374: Voltage measurement: Residual voltage measurement (HV side)

Figure 375: Other measurement: Three-phase power and energy measurement

Figure 376: Other measurement: Data monitoring

Figure 377: Other measurement: Load profile record

3.10.3.6 Functional diagrams for I/O and alarms LEDs

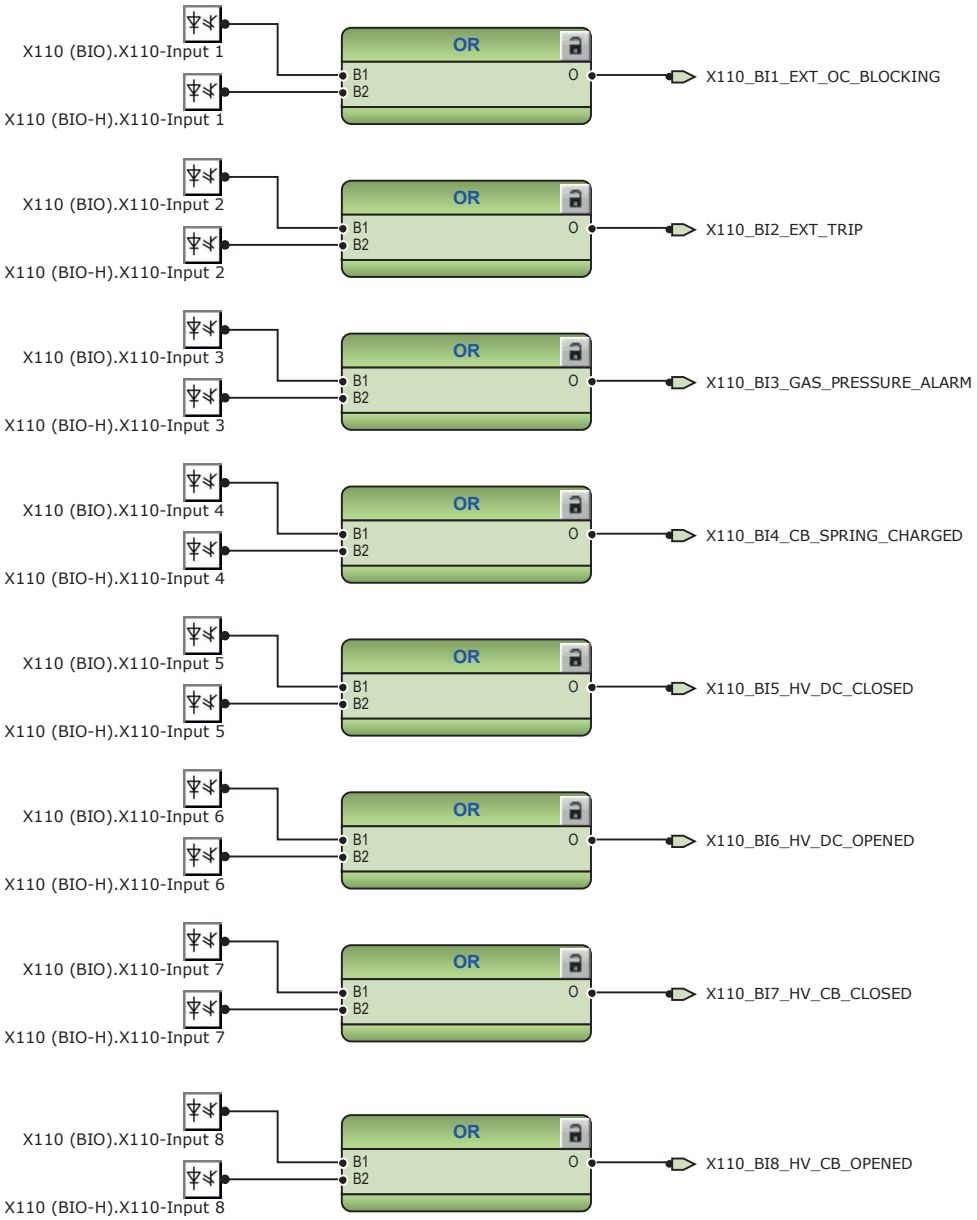


Figure 378: Binary inputs - X110 terminal block

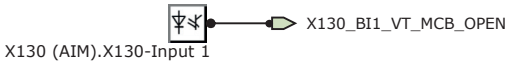


Figure 379: Binary inputs - X130 terminal block

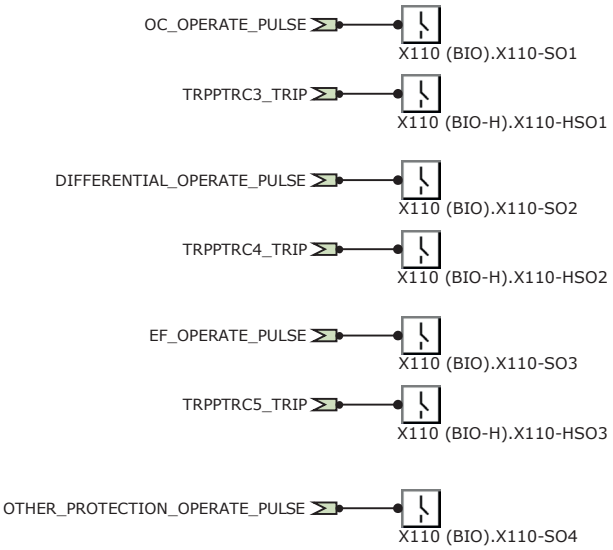


Figure 380: Binary outputs - X110 terminal block

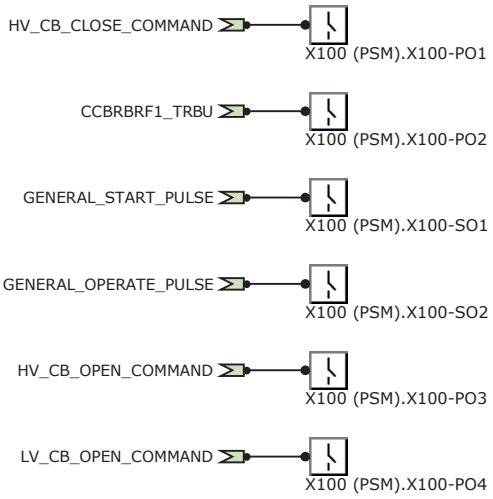


Figure 381: Binary outputs - X100 terminal block

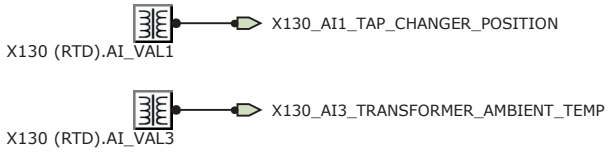


Figure 382: Default mA/RTD inputs X130

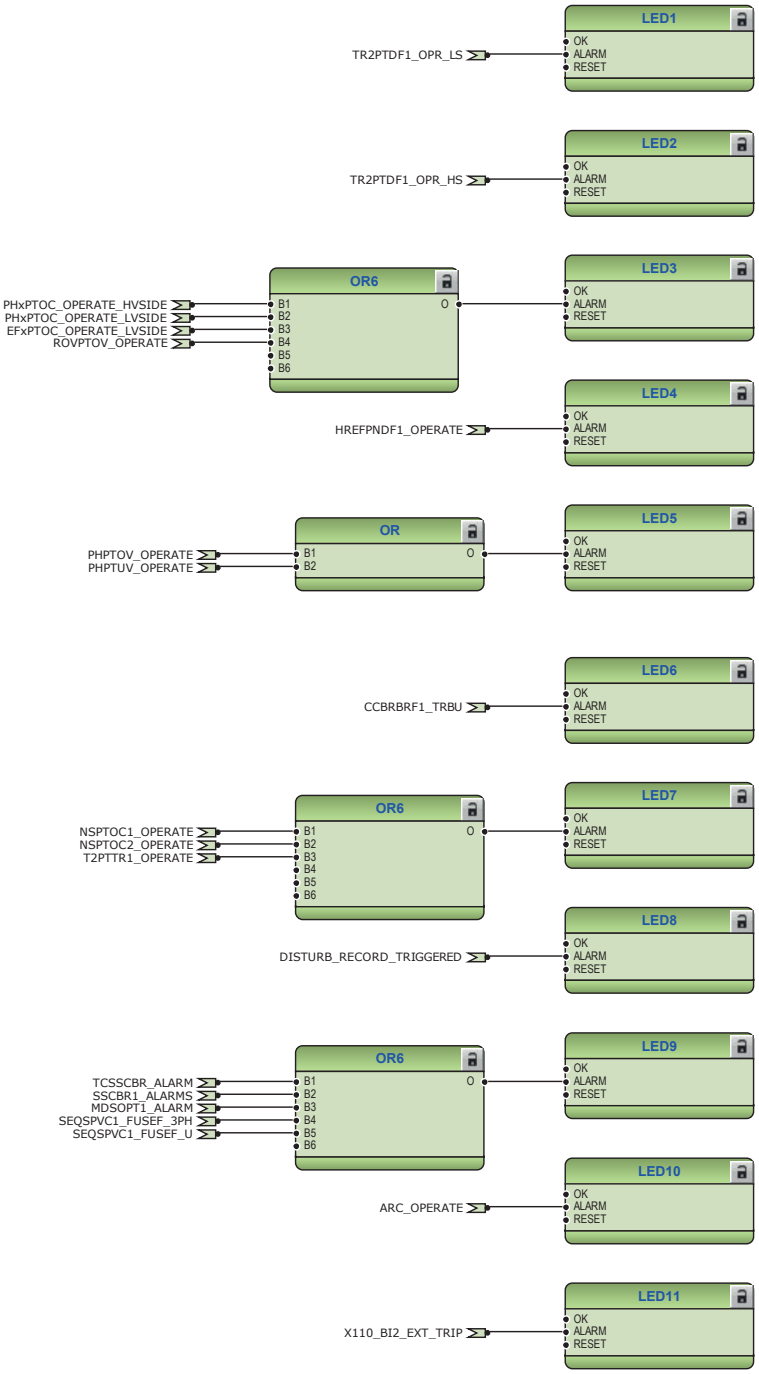


Figure 383: Default LED connection

3.10.3.7 Functional diagrams for other timer logics

The configuration includes overcurrent operate, differential operate, earth-fault operate and combined other protection operate logic (negative-sequence overcurrent, thermal overload operate, phase over and undervoltage operate). 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.

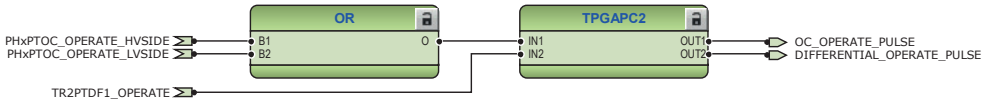


Figure 384: Timer logic for overcurrent and differential operate pulse

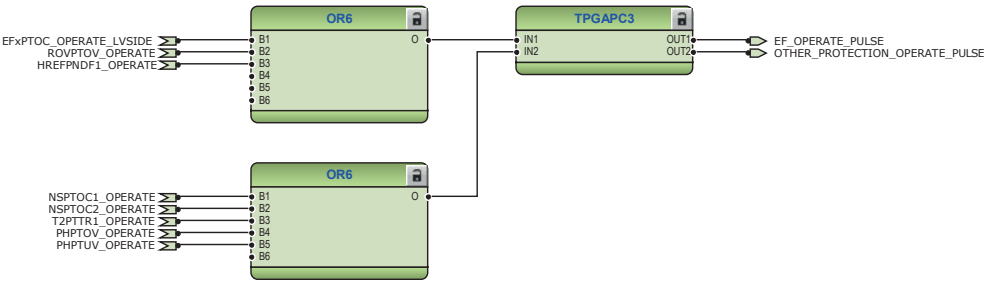


Figure 385: Timer logic for earth-fault and combined other operate pulse

3.10.3.8 Other functions

The configuration includes few instances of multipurpose protection MAPGAPC 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.

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 58: 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:

$F_a > 20 \times$ *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.

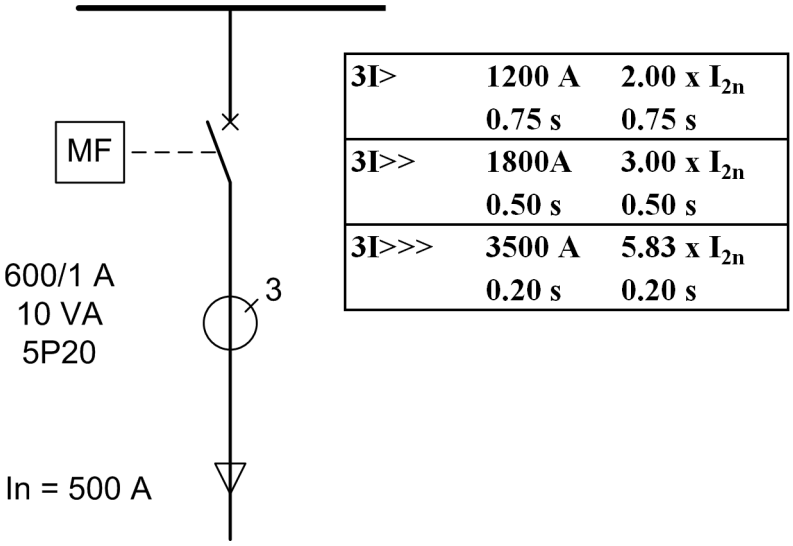


Figure 386: Example of three-stage overcurrent protection

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 386). 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 386.

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 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

Table 59: Phase current inputs

Terminal	Description
X120:1-2	IL1B
X120:3-4	IL2B
X120:5-6	IL3B
X120:7-8	IL1
X120:9-10	IL2
X120:11-12	IL3

5.1.1.2 Residual current

Table 60: Residual current input

Terminal	Description
X120:13-14	Io

5.1.1.3 Phase voltages

Table 61: Phase voltage inputs included in configurations E, F, G and H

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

5.1.1.4 Residual voltage

Table 62: Residual voltage input included in configurations E, F, G and H

Terminal	Description
X130:17-18	Uo

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 63: 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.

Table 64: Binary input terminals X110:1-13 with BIO0005 module

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

Table 65: Binary input terminals X110:1-10 with BIO0007 module

Terminal	Description
X110:1	BI1, +
X110:5	BI1, -
X110:2	BI2, +

Table continues on next page

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

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

Table 66: Binary input terminals X130:1-9

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

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

Table 67: 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, +

Table continues on next page

Terminal	Description
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 68: 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 an optional RTD0001 module in standard configurations A...D and with an AIM0003 module in standard configurations E...H.

Table 69: Optional RTD/mA inputs for standard configurations A, B, C and D

Terminal	Description
X130:1	mA1 (AI1), +
X130:2	mA1 (AI1), -
X130:3	mA2 (AI2), +
X130:4	mA2 (AI2), -
X130:5	RTD1 (AI3), +
X130:6	RTD1 (AI3), -
X130:7	RTD2 (AI4), +
X130:8	RTD2 (AI4), -
X130:9	RTD3 (AI5), +
X130:10	RTD3 (AI5), -

Table continues on next page

Terminal	Description
X130:11	Common[1)]
X130:12	Common[2)]
X130:13	RTD4 (AI6), +
X130:14	RTD4 (AI6), -
X130:15	RTD5 (AI7), +
X130:16	RTD5 (AI7), -
X130:17	RTD6 (AI8), +
X130:18	RTD6 (AI8), -

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

Table 70: Optional RTD/mA inputs for standard configurations E, F, G and H

Terminal	Description
X130:1	mA 1 (AI1), +
X130:2	mA 1 (AI1), -
X130:3	RTD1 (AI2), +
X130:4	RTD1 (AI2), -
X130:5	RTD1 (AI2), ground
X130:6	RTD2 (AI3), +
X130:7	RTD2 (AI3), -
X130:8	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. In the factory default configuration, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 71: 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

Table continues on next page

Terminal	Description
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. On delivery from the factory, the start and alarm signals from all the protection stages are routed to signalling outputs.

Table 72: 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 73: 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
X110:22	SO3, NC
X110:23	SO4, common
X110:24	SO4, NO

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

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

Table 74: 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 75: 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

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
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
HV	High voltage
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
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
LSB	Least significant bit
LV	Low voltage
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
MSB	Most significant bit
NC	Normally closed
NO	Normally open
NPS	Negative phase sequence
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
RET615	Transformer protection and control relay
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
WAN	Wide area network
WHMI	Web human-machine interface

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