RELION® 615 SERIES

Transformer Protection and Control
RET615 ANSI
Application Manual

Document ID: 1MAC206062-MB
Issued: 2019-06-07
Revision: D
Product version: 5.0 FP1

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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

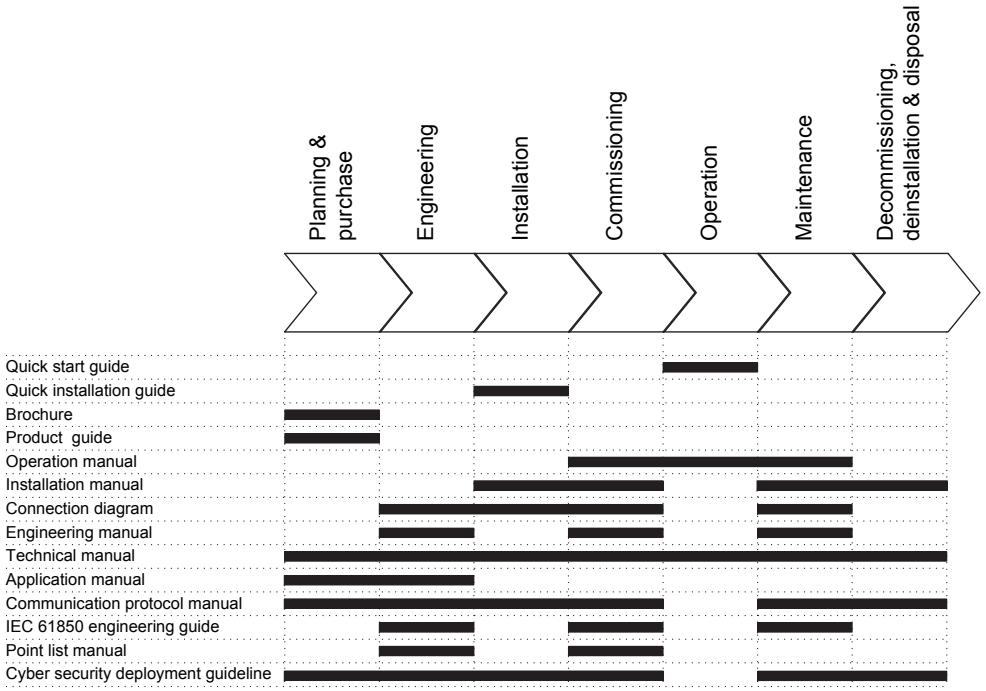

Figure 1: The intended use of documents during the product life cycle

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 series version	History
A/2018-02-26	5.0 FP1	First release
B/2018-09-11	5.0 FP1	Content updated
C/2019-05-08	5.0 FP1	Content updated
D/2019-06-07	5.0 FP1	Content updated

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MAC057386-MB
DNP3 Communication Protocol Manual	1MAC052479-MB
IEC 61850 Engineering Guide	1MAC053584-RG
Engineering Manual	1MAC108982-MB
Installation Manual	1MAC051065-MB
Operation Manual	1MAC054853-MB
Technical Manual	1MAC059074-MB
Cyber Security Deployment Guideline	1MAC052704-HT

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 "Enabled" and "Disabled".
- Input/output messages and monitored data names are shown in Courier font.
  When the function picks up, the `PICKUP` output is set to TRUE.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned, the dimension is in mm.
- 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	ANSI/C37.2-2008
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P (1)
	PHLPTOC2	3I> (2)	51P (2)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	50P-1 (1)
	PHHPTOC2	3I>> (2)	50P-1 (2)
Table continues on next page			

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P-3 (1)
	PHIPTOC2	3I>>> (2)	50P-3 (2)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67/51P-1(2)
	DPHLPDOC2	3I> -> (2)	67/51P-2(2)
Non-directional ground-fault protection, low stage	EFLPTOC2	Io> (2)	51N (2)
Non-directional ground-fault protection, high stage	EFHPTOC2	Io>> (2)	50G-2 (2)
Directional ground-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67/51N-1 (2)
	DEFLPDEF2	Io> -> (2)	67/51N-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)	59N (1)
	ROVPTOV3	Uo> (3)	59N (2)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27-1 (2)
	PHPTUV2	3U< (2)	27-2 (2)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59-1 (2)
	PHPTOV2	3U> (2)	59-2 (2)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81-1 (2)
	FRPFRQ2	f>/f<,df/dt (2)	81-2 (2)
Overexcitation protection	OEPVPH1	U/f> (1)	24-1 (2)
	OEPVPH2	U/f> (2)	24-2 (2)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T (1)
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF1	3dI>T (1)	87T
Numerically stabilized low-impedance restricted ground-fault protection	LREFPNDF1	dIoLo> (1)	87LOZREF (2)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	50BF (1)
	CCBRBRF2	3I>/Io>BF (2)	50BF (2)
Master trip	TRPPTRC1	Master Trip (1)	86/94-1
	TRPPTRC2	Master Trip (2)	86/94-2
	TRPPTRC3	Master Trip (3)	86/94-3
	TRPPTRC4	Master Trip (4)	86/94-4
	TRPPTRC5	Master Trip (5)	86/94-5

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Arc protection	ARCSARC1	ARC (1)	AFD-1 (2)
	ARCSARC2	ARC (2)	AFD-2 (2)
	ARCSARC3	ARC (3)	AFD-3 (2)
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)	52 (1)
	CBXCBR2	I <-> O CB (2)	52 (2)
Disconnector control	DCXSWI1	I <-> O DCC (1)	29DS-1
	DCXSWI2	I <-> O DCC (2)	29DS-2
Grounding switch control	ESXSWI1	I <-> O ESC (1)	29GS-1
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	52-TOC
	DCSXSWI2	I <-> O DC (2)	29DS-1
	DCSXSWI3	I <-> O DC (3)	29DS-2
Grounding switch indication	ESSXSWI1	I <-> O ES (1)	29GS-1
	ESSXSWI2	I <-> O ES (2)	29GS-2
Tap changer position indication	TPOSYLTC1	TPOSM (1)	84T
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (2)
Condition monitoring			

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	52CM (1)
	SSCBR2	CBCM (2)	52CM (2)
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			
Load profile record	LDPRLRC1	LOADPROF (1)	LoadProf
Three-phase current measurement	CMMXU1	3I (1)	IA, IB, IC (1)
	CMMXU2	3I (2)	IA, IB, IC (2)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU2	Io (2)	IG (2)
Three-phase voltage measurement	VMMXU1	3U (1)	VA, VB, VC (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	VG (2)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (2)
Single-phase power and energy measurement	SPEMMXU1	SP, SE	SP, SE (2)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (2)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRECEIVER	SMVRECEIVER	SMVRECEIVER
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	62TP-1
	TPGAPC2	TP (2)	62TP-2
	TPGAPC3	TP (3)	62TP-3
	TPGAPC4	TP (4)	62TP-4
Minimum pulse timer (second resolution)	TPSGAPC1	TPS (1)	62TPS-1
Minimum pulse timer (minute resolution)	TPMGAPC1	TPM (1)	62TPM-1
Pulse timer	PTGAPC1	PT (1)	62PT-1
	PTGAPC2	PT (2)	62PT-2
Time delay off	TOFGAPC1	TOF (1)	62TOF-1
	TOFGAPC2	TOF (2)	62TOF-2
	TOFGAPC3	TOF (3)	62TOF-3
	TOFGAPC4	TOF (4)	62TOF-4

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Time delay on	TONGAPC1	TON (1)	62TON-1
	TONGAPC2	TON (2)	62TON-2
	TONGAPC3	TON (3)	62TON-3
	TONGAPC4	TON (4)	62TON-4
Set-reset	SRGAPC1	SR (1)	SR-1
	SRGAPC2	SR (2)	SR-2
	SRGAPC3	SR (3)	SR-3
	SRGAPC4	SR (4)	SR-4
Move	MVGAPC1	MV (1)	MV-1
	MVGAPC2	MV (2)	MV-2
Generic control point	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
Generic up-down counters	UDFCNT1	UDCNT (1)	CTR-1
	UDFCNT2	UDCNT (2)	CTR-2
	UDFCNT3	UDCNT (3)	CTR-3
	UDFCNT4	UDCNT (4)	CTR-4

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, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
2.0	Product released
4.0	• User programming through Application Configuration • Frequency measurement protection • Load shedding and restoration • Single phase power and energy measurement • Load profile recorder
4.2	• New counters
5.0 FP1	• New layout in Application Configuration for all configurations • Support for IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • High-speed binary outputs • Optional RTD/mA inputs • Profibus adapter support • Support for multiple SLD pages • Import/export of settings via WHMI • Setting usability improvements • HMI event filtering tool • IEC 61850 Edition 2 • Currents sending support with IEC 61850-9-2 LE • Software closable Ethernet ports • 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 2.8 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 features

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- DNP3 TCP/IP or serial
- RTD/mA measurement 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	Details
Plug-in unit	-	HMI	Large (10 lines, 20 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	Optional BIO module	Only with configurations B and F: 8 binary inputs 4 SO contacts
			Only with configuration B and F: 8 binary inputs 3 high-speed SO contacts
	X120	AI/BI module	Only with configurations B and F: 6 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)]
Case	X130	Optional RTD/mA module	Optional for configuration B: 2 generic mA inputs 6 RTD sensor inputs
		Optional AI/BI module	Only with configuration F: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs Additionally with configuration F: 1 reference voltage input for SECRSYN1 (60...210 V)
		Optional AI/RTD/mA module	Only with configurations F and N: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA input 2 RTD sensor inputs Additionally with configuration F: 1 reference voltage input for SECRSYN1 (60...210 V)
		Optional BIO module	Optional for configuration B: 6 binary inputs 3 SO contacts
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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

The rated input levels are selected in the software of the protection relay for phase current and ground current. The binary input thresholds 18...176 V DC are selected by adjusting the protection relay's parameter settings.

The optional BIO module can be added in the protection relay to all standard configurations.

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
B	BA	BB	7	-	14	4 PO + 9 SO	-	-
		FF	7	-	14	4 PO + 5 SO + 3HSO	-	-
	BG	BA	7	-	8	4 PO + 6 SO	6	2
		FD	7	-	8	4 PO + 2 SO + 3 HSO	6	2
F	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.

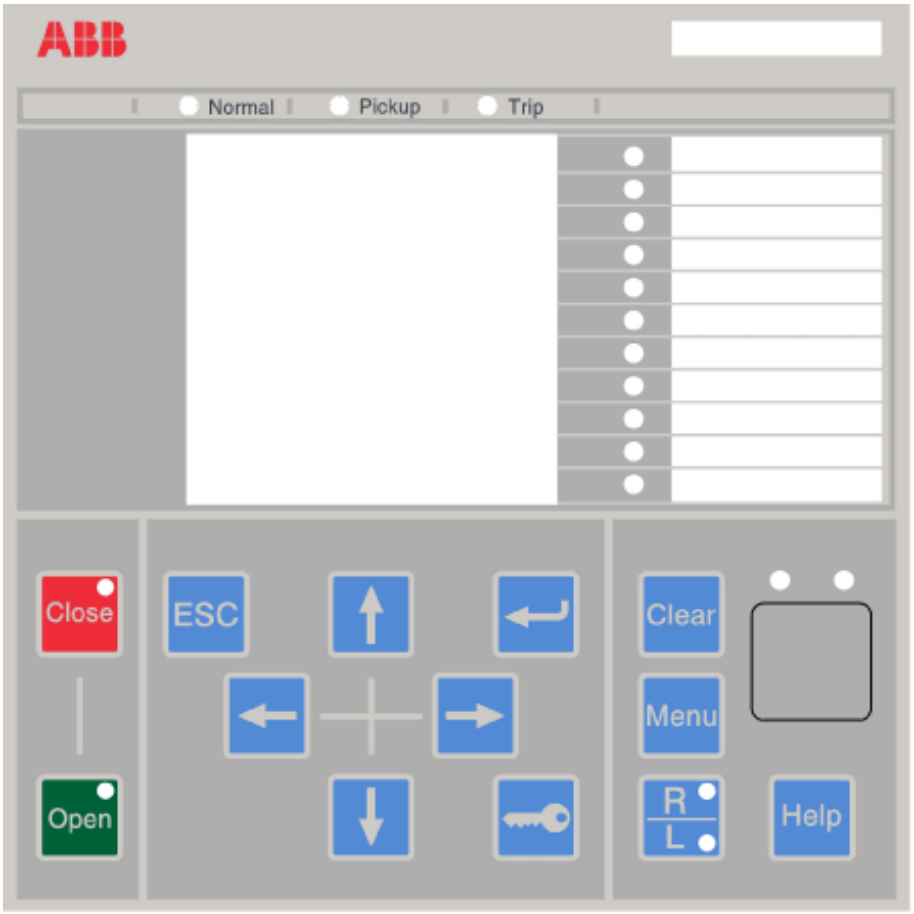

Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Large display

Character size[1)]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20

1) Depending on the selected language

The display view is divided into four basic areas.

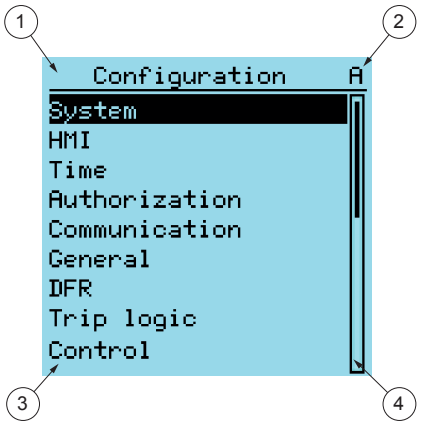

Figure 3: Display layout

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: Normal, Pickup 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.

There are two additional LEDs which are embedded into the control buttons 

and 

. They represent the status of breaker 1 (CBXCBR1).

2.4.3 Keypad

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

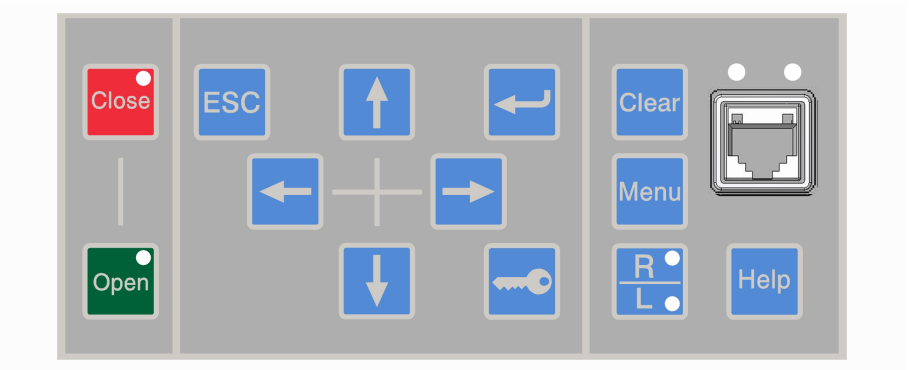

Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. The supported Web browser versions are Internet Explorer 9.0, 10.0 and 11.0. 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 11.0.

WHMI is disabled by default.WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- DFR 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.

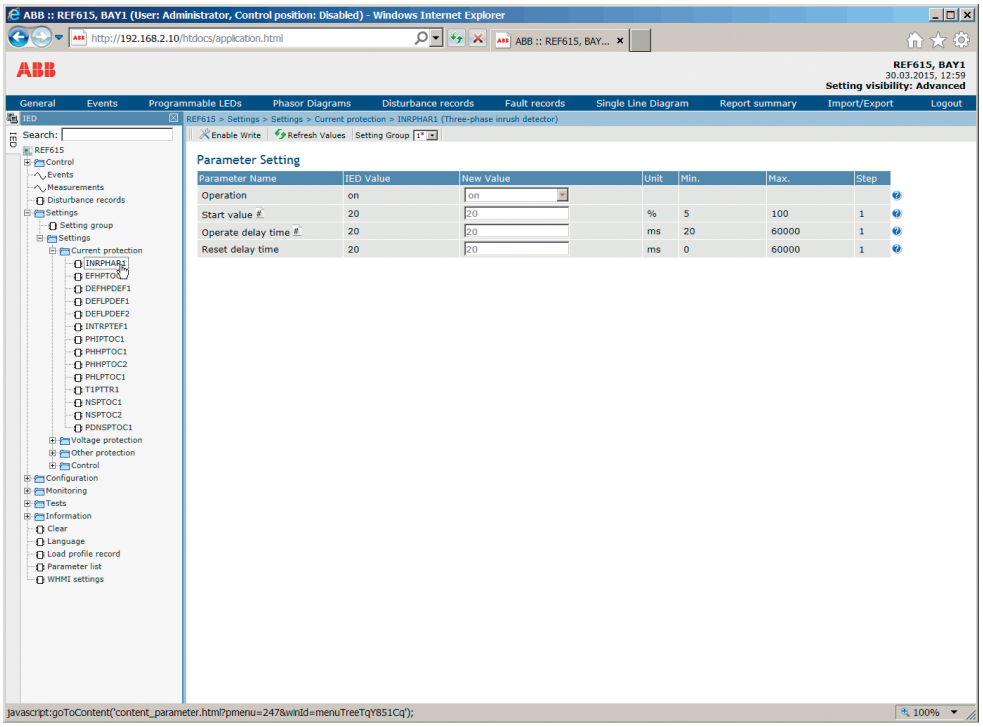

Figure 5: Example view of the WHMI

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 5: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with  (only locally) • Changing setting groups • Controlling • Clearing indications
ENGINEER	• Changing settings • Clearing event list • Clearing DFRs and load profile record • Changing system settings such as IP address, serial baud rate or DFR 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.

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850, IEC 61850-9-2 LE, Modbus® and DNP3. 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 protection relay utilizes Ethernet communication extensively for different purposes. The exact services depend on the ordered product variant and enabled functionality. HSR/PRP is available in 615 series Ver.5.0 FP1 ANSI.

HSR/PRP availability depends on the product ordering information. See the Rear communication modules chapter for information on HSR/PRP supported COM cards.

Table 6: TCP and UDP ports used for different services

Service	Port
File Transfer Protocol (FTP and FTPS)	20, 21
IEC 61850	102
Web Server HTTP	80
Web Server HTTPS	443
Simple Network Time Protocol (SNTP)	123
Modbus TCP	502
DNP TCP	20000

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and DFR records can be accessed using the IEC 61850 protocol. Oscillographic files are available to any Ethernet-based application in the standard COMTRADE 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 simultaneously report events to five different clients on the station bus.

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.

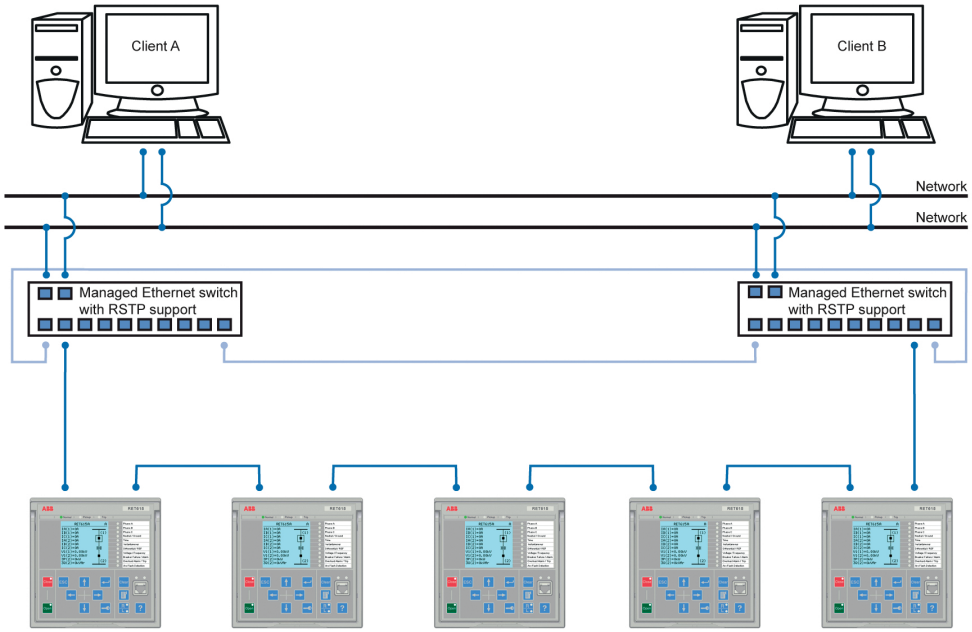

Figure 6: Self-healing Ethernet ring solution

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.

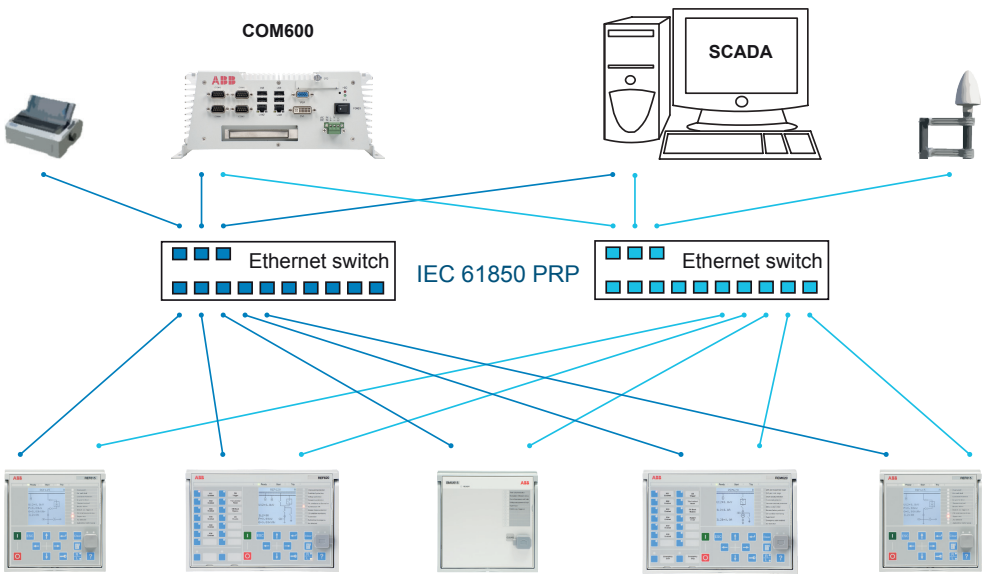

Figure 7: PRP solution

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.

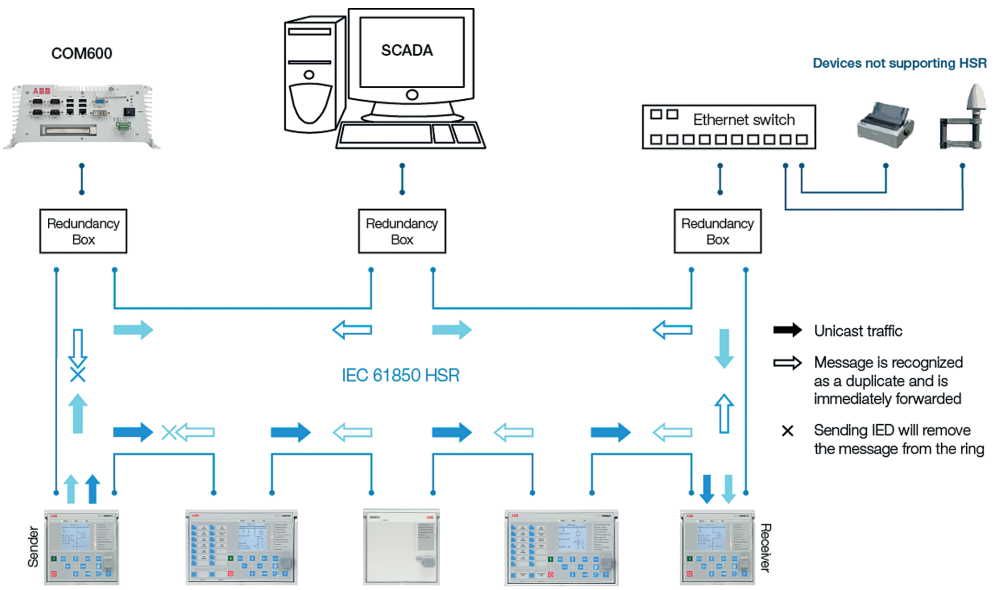

Figure 8: HSR solution

Section 3 RET615 standard configurations

3.1 Standard configurations

RET615 is available with two alternative standard configurations. The standard signal configuration can be altered by means of the signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions 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 7: Standard configurations

Description	Std. conf.
Transformer differential with low-impedance restricted ground-fault protection on the MV side	B
Transformer differential with voltage protection and measurements, and low-impedance restricted ground-fault protection on the MV side	F

Table 8: Supported functions

Function	IEC 61850	ANSI	B	F
Protection				
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	51P (1)	1^{HV}	1^{HV}
	PHLPTOC2	51P (2)	1^{MV}	1^{MV}
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	50P-1 (1)	1^{HV}	1^{HV}
	PHHPTOC2	50P-1 (2)	1^{MV}	1^{MV}
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	50P-3 (1)	1^{HV}	1^{HV}
	PHIPTOC2	50P-3 (2)	1^{MV}	1^{MV}
Table continues on next page				

Function	IEC 61850	ANSI	B	F
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P (2)		2[MV]
Non-directional ground-fault protection, low stage	EFLPTOC	51N (2)	1[MV]	1[MV]
Non-directional ground-fault protection, high stage	EFHPTOC	50G-2 (2)	1[MV]	1[MV]
Directional ground-fault protection, low stage	DEFLPDEF	67/51N (2)		2[MV]
Negative-sequence overcurrent protection	NSPTOC1	46 (1)	1[HV]	1[HV]
	NSPTOC2	46 (2)	1[MV]	1[MV]
Residual overvoltage protection	ROVPTOV1	59G (1)		1[MV]
	ROVPTOV2	59N (1)		1[MV]
Three-phase undervoltage protection	PHPTUV	27 (2)		2[MV]
Three-phase overvoltage protection	PHPTOV	59 (2)		2[MV]
Frequency protection	FRPFRQ	81 (2)		2[MV]
Overexcitation protection	OEPVPH	24 (2)		2[MV]
Three-phase thermal overload protection, two time constants	T2PTTR	49T (1)	1[HV]	1[HV]
Stabilized and instantaneous differential protection for two-winding transformers	TR2PTDF	87T	1	1
Numerically stabilized low-impedance restricted ground-fault protection	LREFPNDF	87LOZREF (2)	1[MV]	1[MV]
Circuit breaker failure protection	CCBRBRF1	50BF (1)	1[HV1)]	1[HV1)]
	CCBRBRF2	50BF (2)	1[MV]	1[MV]
Master trip	TRPPTRC	86/94	2 (3)[2)]	2 (3)[2)]
Arc protection	ARCSARC	AFD (2)	(3)[3)]	(3)[3)]
Multipurpose protection	MAPGAPC	MAP	18	18
Control				
Circuit-breaker control	CBXCBR1	52 (1)	1[HV]	1[HV]
	CBXCBR2	52 (2)	1[MV]	1[MV]
Disconnector control	DCXSWI	29DS	2	2
Grounding switch control	ESXSWI	29GS	1	1
Disconnector position indication	DCSXSWI	52-TOC	1	1
		29DS	2	2
Grounding switch indication	ESSXSWI	29GS	2	2
Tap changer position indication	TPOSYLTC	84T	1	1
Synchronism and energizing check	SECRSYN	25 (2)		1[MV]

Table continues on next page

Function	IEC 61850	ANSI	B	F
Condition monitoring				
Circuit-breaker condition monitoring	SSCBR1	52CM (1)	1^{HV}	1^{HV}
	SSCBR2	52CM (2)	1^{MV}	1^{MV}
Trip circuit supervision	TCSSCBR	TCM	2	2
Fuse failure supervision	SEQSPVC	60 (1)		1
Runtime counter for machines and devices	MDSOPT	OPTM	1	1
Measurement				
Load profile record	LDPRLRC	LoadProf	1	1
Three-phase current measurement	CMMXU	IA, IB, IC (1)	1^{HV}	1^{HV}
		IA, IB, IC (2)	1^{MV}	1^{MV}
Sequence current measurement	CSMSQI	I1, I2, I0 (1)	1^{HV}	1^{HV}
Residual current measurement	RESCMMXU	IG (2)	1^{MV}	1^{MV}
Three-phase voltage measurement	VMMXU	VA, VB, VC (2)		1^{MV}
Residual voltage measurement	RESVMMXU	VG (2)		1^{MV}
Sequence voltage measurement	VSMSQI	V1, V2, V0 (2)		1^{MV}
Single-phase power and energy measurement	SPEMMXU	SP, SE (2)		1^{MV}
Three-phase power and energy measurement	PEMMXU	P, E (2)		1^{MV}
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	(1)	(1)
Frequency measurement	FMMXU	f		1
IEC 61850-9-2 LE sampled value sending[4)]	SMVSENDER	SMVSENDER		(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRECEIVER	SMVRECEIVER		(1)
Other				
Minimum pulse timer (2 pcs)	TPGAPC	62TP	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1	1
Pulse timer (8 pcs)	PTGAPC	62PT	2	2
Time delay off (8 pcs)	TOFGAPC	62TOF	4	4
Time delay on (8 pcs)	TONGAPC	62TON	4	4
Set-reset (8 pcs)	SRGAPC	SR	4	4
Move (8 pcs)	MVGAPC	MV	2	2
Generic control point (16 pcs)	SPCGAPC	SPC	2	2

Table continues on next page

Function	IEC 61850	ANSI	B	F
Analog value scaling	SCA4GAPC	SCA4	4	4
Integer value move	MVI4GAPC	MVI4	1	1
Generic up-down counters	UDFCNT	CTR	4	4
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. MV = The function block is to be used on the medium-voltage side in the application.				

1) "Calculated I0" is always used
2) Master Trip included and connected to corresponding HSO in the configuration only when BIO0007 module is used. If additionally the ARC option is selected, then AFD is connected in the configuration to the corresponding Master Trip input.
3) IoB calculated and 3IB are always used
4) Only available 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

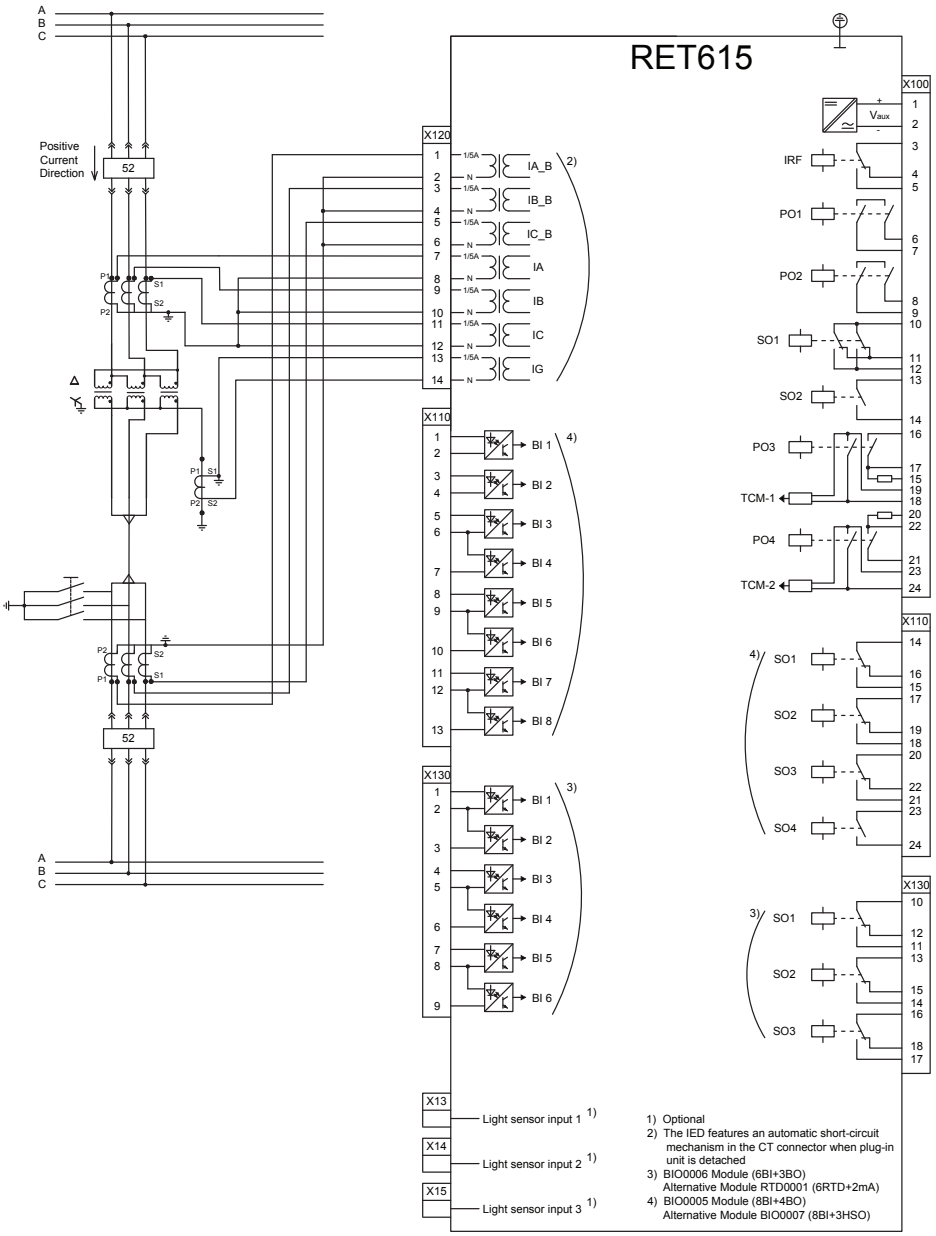

Figure 9: Connection diagram for the B configuration

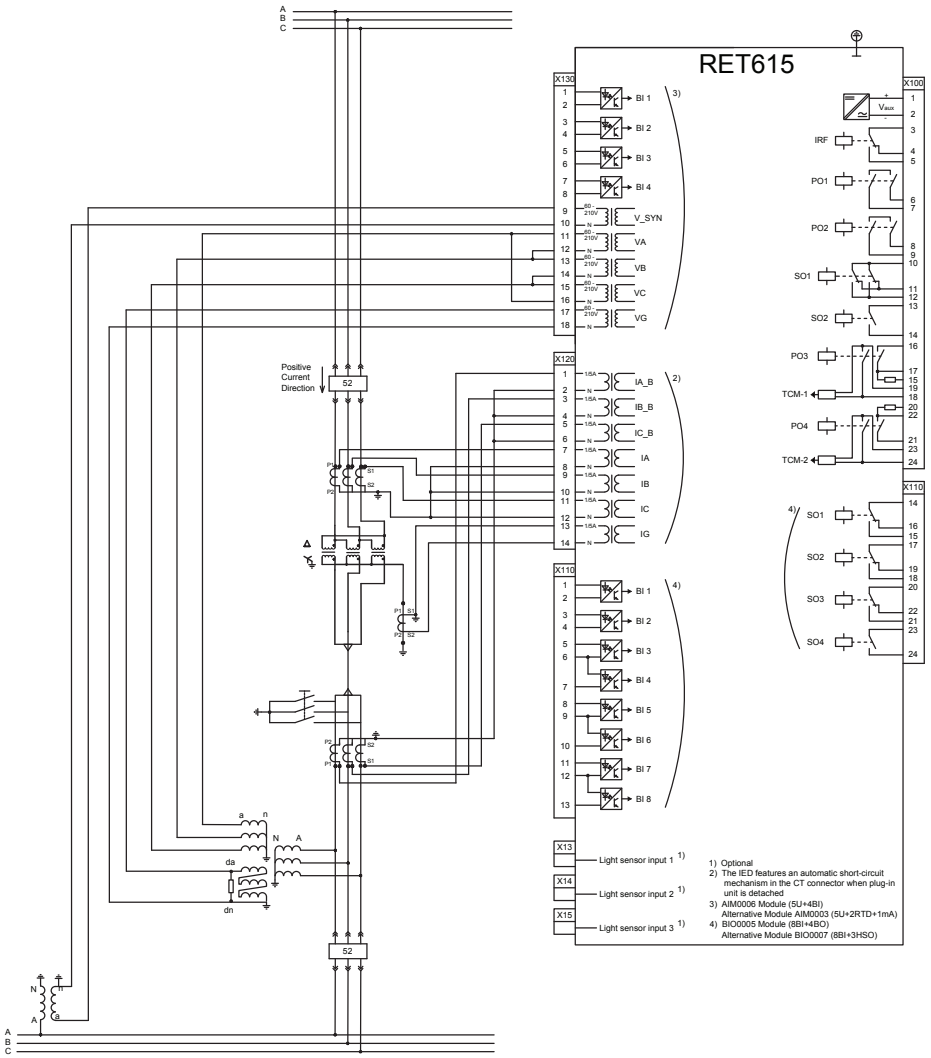

Figure 10: Connection diagram for the F configuration

3.3 Standard configuration B

3.3.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers and numerical restricted ground-fault protection for the medium-voltage (MV) 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

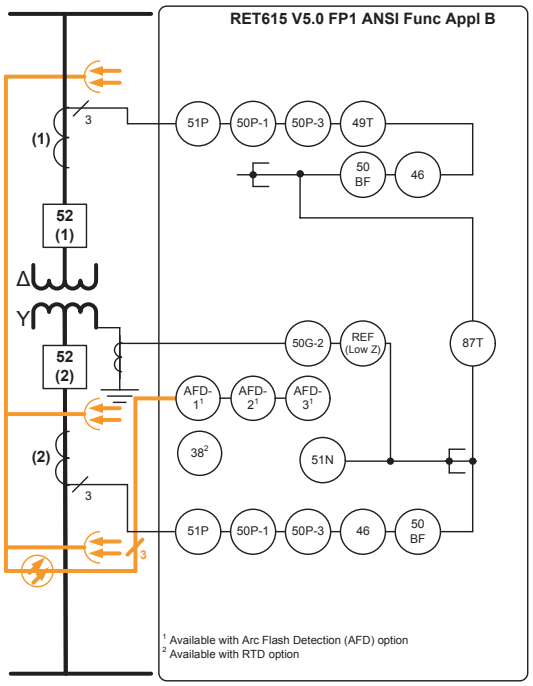

Figure 11: Functionality overview for standard configuration B

3.3.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Description	Connector pins
IA_B	Phase A current, MV side	X120:1-2
IB_B	Phase B current, MV side	X120:3-4
IC_B	Phase C current, MV side	X120:5-6
IA	Phase A current, HV side	X120:7-8
IB	Phase B current, HV side	X120:9-10
IC	Phase C current, HV side	X120:11-12
Table continues on next page		

Analog input	Description	Connector pins
IG	Residual current IG	X120:13-14
AI1	Tap changer position	X130:1-2
AI2	-	X130:3-4
AI3	Ambient temperature	X130:5-6
AI4	-	X130:7-8
AI5	-	X130:9-10
AI6	-	X130:13-14
AI7	-	X130:15-16
AI8	-	X130:17-18

Table 10: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (medium voltage)	X110:1-2	X110:1,5
X110-BI2	External protection trip	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	Medium-voltage side circuit breaker closed indication	X110:8-9	X110:6,10
X110-BI6	Medium-voltage side circuit breaker open indication	X110:10-9	X110:7,10
X110-BI7	High-voltage side circuit breaker closed indication	X110:11-12	X110:8,10
X110-BI8	High-voltage side circuit breaker open indication	X110:13-12	X110:9-10
X130-BI1	BCD sign bit (tap changer position)	X130:1-2	
X130-BI2	BCD bit 0 (LSB)	X130:3-2	
X130-BI3	BCD bit 1	X130:4-5	
X130-BI4	BCD bit 2	X130:6-5	
X130-BI5	BCD bit 3	X130:7-8	
X130-BI6	BCD Bit 4 (MSB)	X130:9-8	

Table 11: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100:6-7
X100-PO2	Close medium-voltage circuit breaker	X100:8-9
X100-SO1	Breaker failure backup trip to upstream breaker (Breaker 1 and 2)	X100:10-11,(12)
X100-SO2	-	X100:13-14

Table continues on next page

Binary output	Description	Connector pins
X100-PO3	Open circuit breaker/trip coil 1 high-voltage	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2 medium-voltage	X100:20-24
X110-SO1	Overcurrent trip alarm	X110:14-16
X110-SO2	Differential protection trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	Thermal overload and negative phase-sequence trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 12: Default connections for LEDs

LED	Default usage	ID	Label description
1	Transformer differential protection biased stage trip	LED_DiffProtBiasedLowStage_1	Diff. prot. biased low stage
2	Transformer differential protection instantaneous stage trip	LED_DiffProtHighStage_1	Diff. prot. high stage
3	Non-directional overcurrent protection trip	LED_Overcurrent_1	Overcurrent
4	Restricted ground-fault protection trip	LED_RestrictedEarthFault_1	Restricted ground-fault
5	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
6	Circuit failure protection backup trip	LED_BreakerFailure_1	Breaker failure
7	Negative sequence overcurrent or thermal overload protection trip	LED_NPSOrThermalOverload_1	Neg. Seq./Thermal Ovld.
8	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Protection trip from external device	LED_ExternalTrip_1	External trip

3.3.2.2 Default disturbance recorder settings

Table 13: Default disturbance recorder analog channels

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

Table 14: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHLPTOC1 - pickup	Positive or Rising
4	PHIPTOC2 - pickup	Positive or Rising
5	PHHPTOC2 - pickup	Positive or Rising
6	PHLPTOC2 - pickup	Positive or Rising
7	EFHPTOC2 - pickup	Positive or Rising
8	EFLPTOC2 - pickup	Positive or Rising
9	NSPTOC1 - pickup	Positive or Rising
10	NSPTOC2 - pickup	Positive or Rising
11	LREFPNDF1 - pickup	Positive or Rising
12	T2PTTR1 - pickup	Positive or Rising
13	CCBRBRF1 - trret	Level trigger off
14	CCBRBRF1 - trbu	Level trigger off
15	PHxPTOC1 - trip	Level trigger off
16	PHxPTOC2 - trip	Level trigger off
17	EFxPTOC2 - trip	Level trigger off
18	NSPTOC - trip	Level trigger off
Table continues on next page		

Channel	ID text	Level trigger mode
19	TR2PTDF1 - trip	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 - trip	Level trigger off
26	T2PTTR1 - trip	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 open	Level trigger off
33	MDSOPT1 - alarm	Level trigger off
34	ARCSARC - ARC flt det	Level trigger off
35	ARCSARC1 - trip	Positive or Rising
36	ARCSARC2 - trip	Positive or Rising
37	ARCSARC3 - trip	Positive or Rising
38	CCBRBRF2- trret	Level trigger off
39	CCBRBRF2 - trbu	Level trigger off
40	X110BI5 - MVCB closed	Level trigger off
41	X110BI6 - MVCB open	Level trigger off
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-

Table continues on next page

Channel	ID text	Level trigger mode
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

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 medium-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 relay's protection functionality in detail and according to the factory set default connections.

The stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1_87T provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The relay 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 a trip signal. All trip 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_87T.

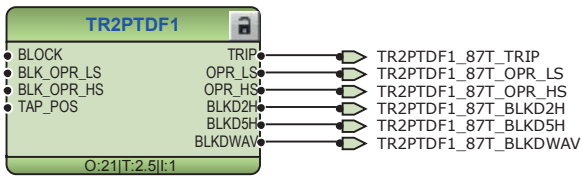

Figure 12: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as medium-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1_50P-1(1) and instantaneous stage of medium-voltage side PHIPTOC2_50P-3(2) can be blocked by energizing the binary input X110:BI1. In addition, high stage of high-voltage side PHHPTOC1_50P-1(1) is blocked by pickup of high stage of medium-voltage side PHHPTOC2_50P-1(2).

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

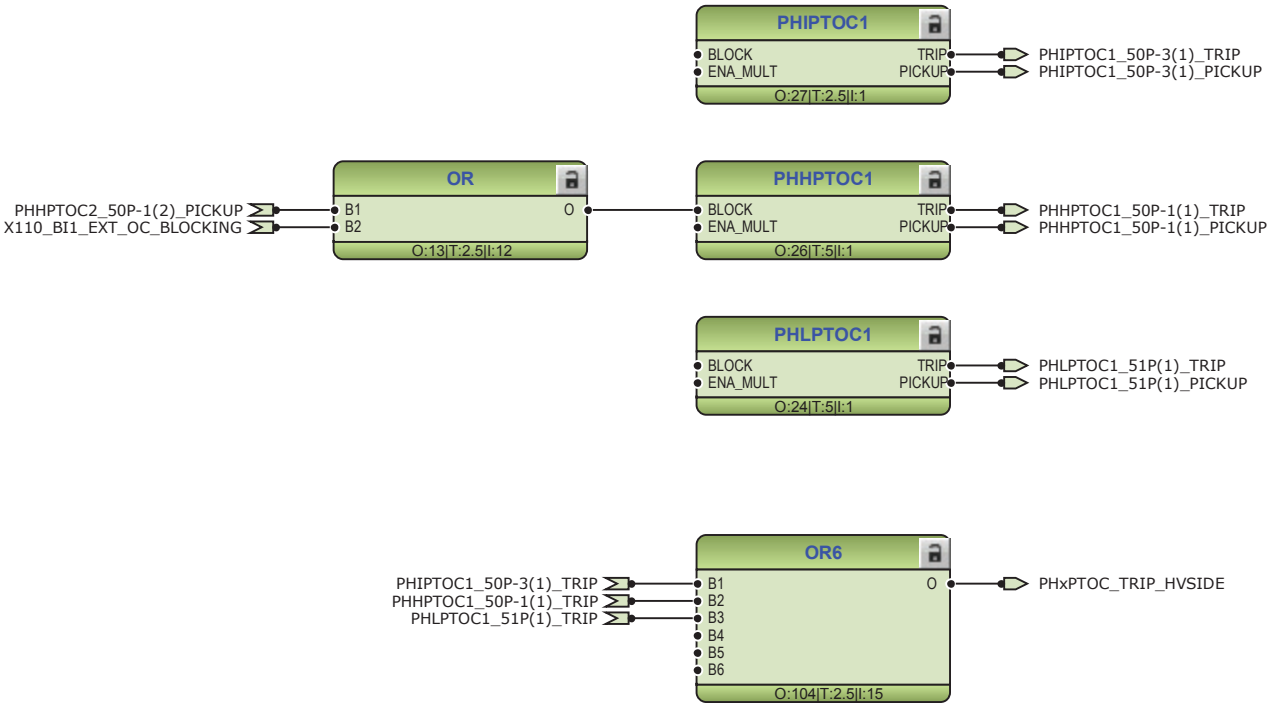

Figure 13: High-voltage side overcurrent protection function

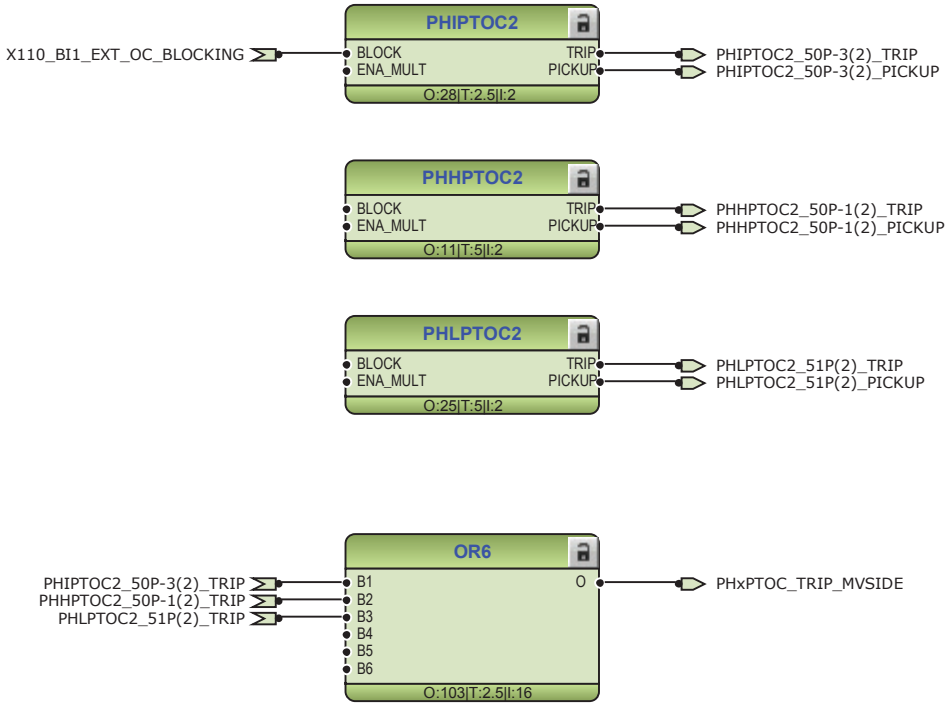

Figure 14: Medium-voltage side overcurrent protection function

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

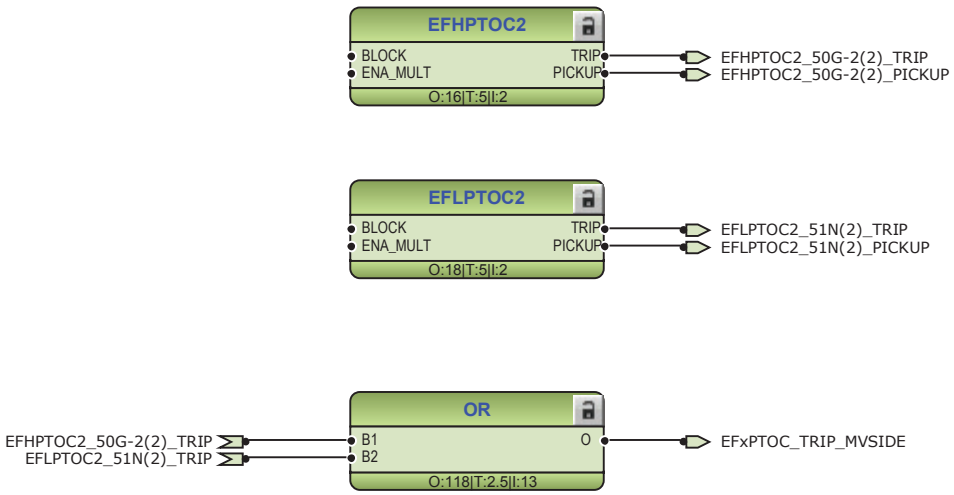

Figure 15: Medium-voltage side ground-fault protection function

The configuration includes numerically stabilized low-impedance restricted ground-fault protection function for medium-voltage side of two-winding power transformers LREFPNDF1_87LOZREF(2). The numerical differential current stage trips exclusively on ground-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. A ground 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 ground.

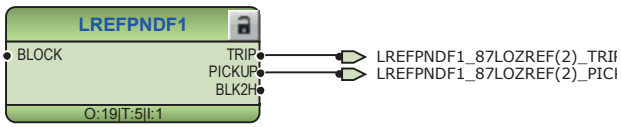

Figure 16: Restricted low-impedance ground-fault protection

Two negative-sequence overcurrent stages NSPTOC1_46(1) and NSPTOC2_46(2) are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1_46(1) measures negative-sequence current from the high-voltage side and NSPTOC2_46(2) from the medium-voltage side.

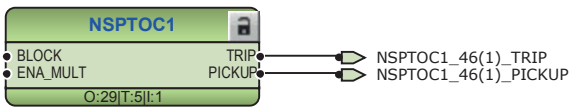

Figure 17: High-voltage side negative-sequence overcurrent protection function

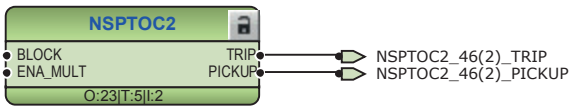

Figure 18: Medium-voltage side negative-sequence overcurrent protection function

Three-phase thermal overload protection, two time constants, T2PTTR1_49T(1) 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 relay 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.

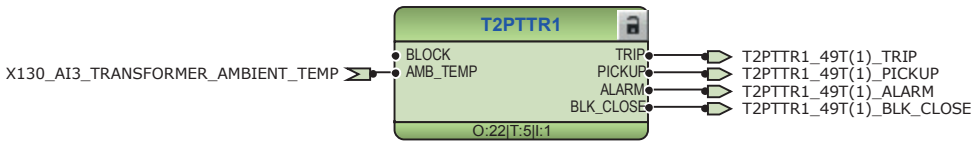

Figure 19: Thermal overload protection function

Circuit breaker failure protection CCBRBRF1_50BF(1) is initiated via the PICKUP input by number of different protection functions available in the relay. 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 trip output is used for retripping the high-voltage and medium-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 trip output signal is connected to the binary output X100:PO2.

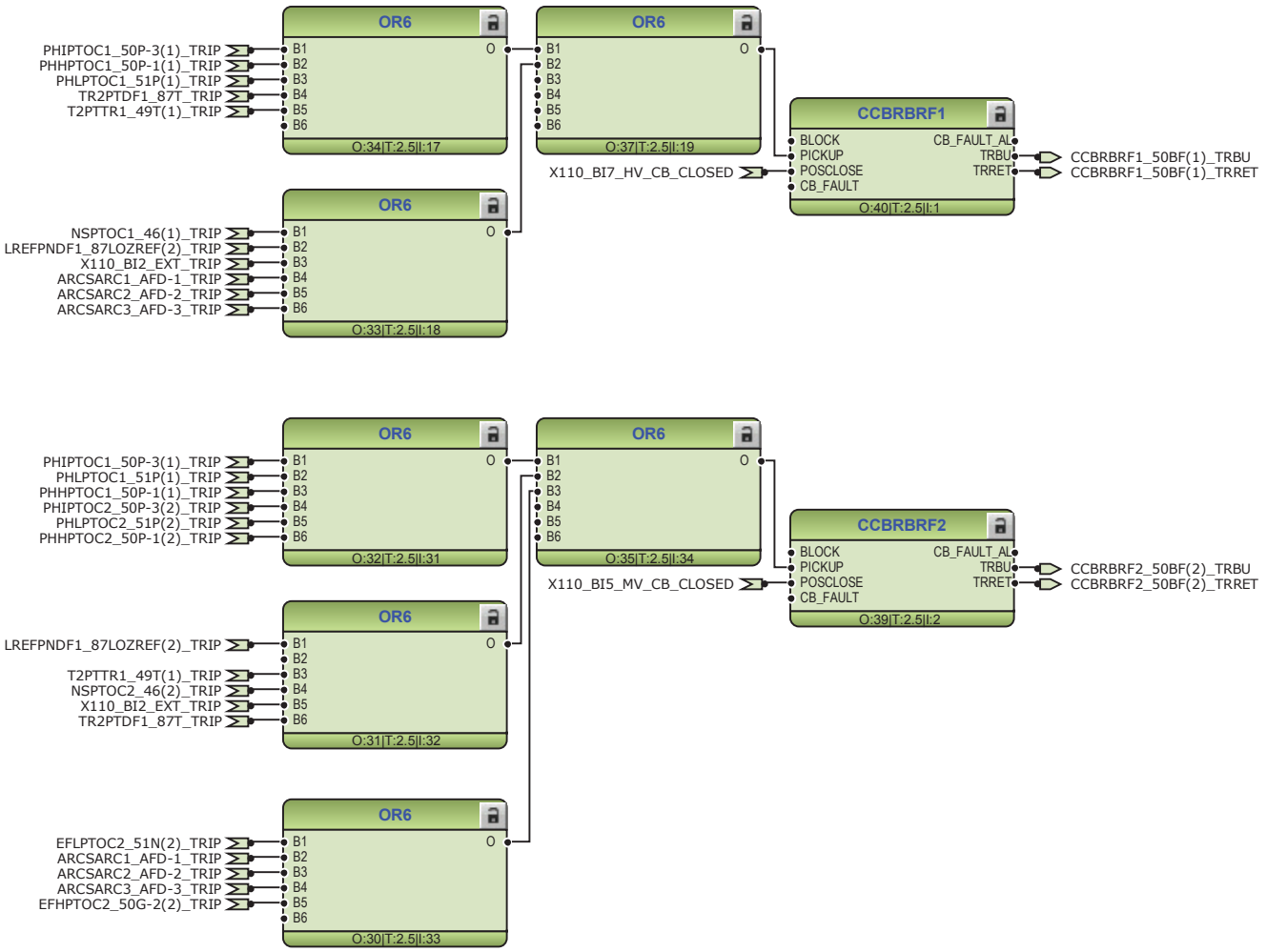

Figure 20: Circuit breaker failure protection function

Three arc protection stages ARCSARC1...3_AFD-1…3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. If the relay is ordered with high-speed binary outputs, the individual trip signals from ARCSARC1...3_AFD-1…3 are connected to dedicated trip logic TRPPTRC3...5_86/94-3…5. The output of TRPPTRC3...5_86/94-3…5 is available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

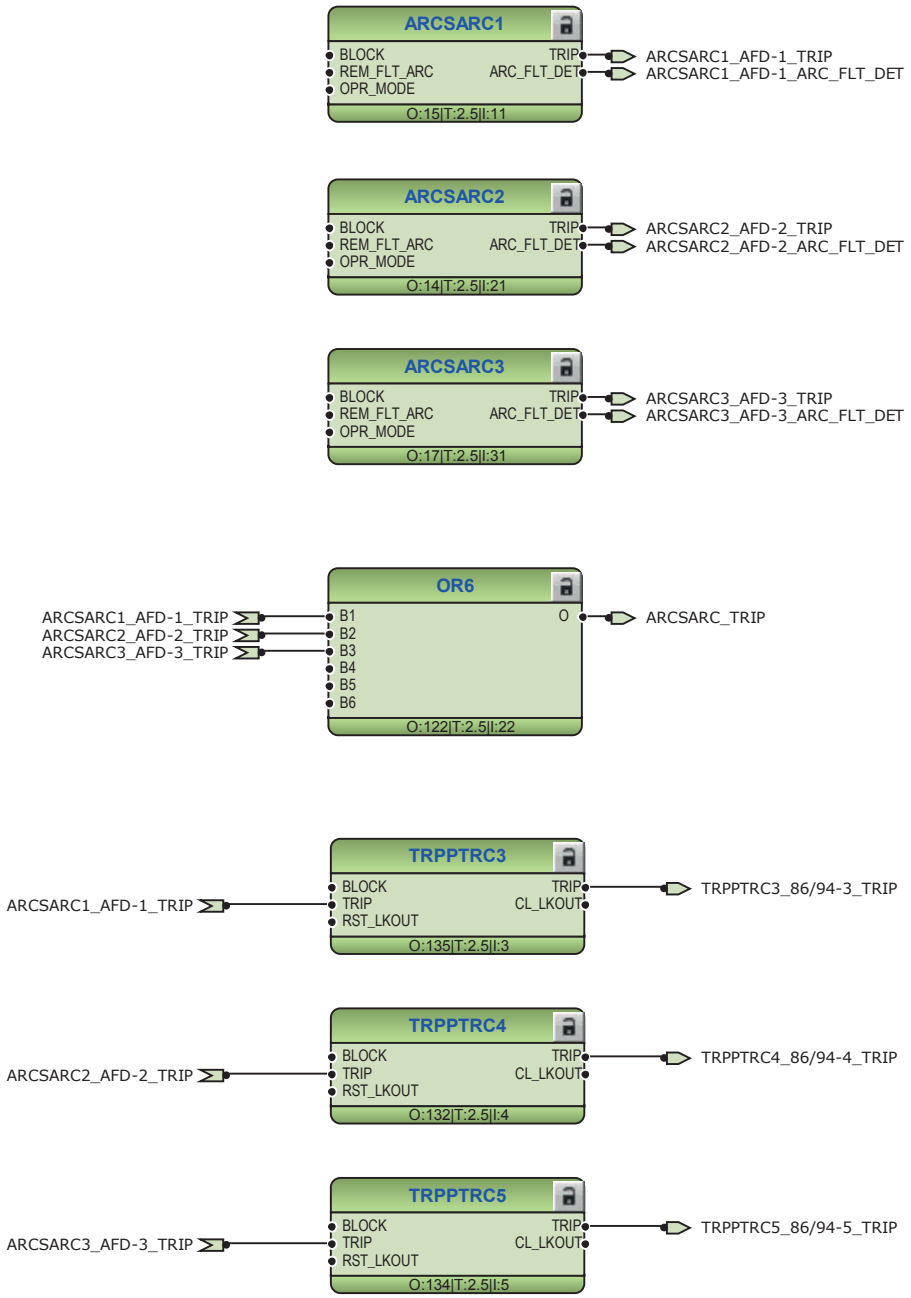

Figure 21: Arc protection with dedicated high-speed output

Runtime counter for machines and devices MDSOPT1_OPTM-1 accumulates the operation time of the transformer.

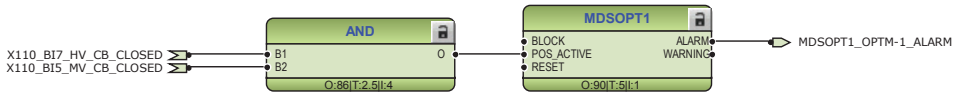

Figure 22: Transformer operation time counter

General pickup and trip 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.

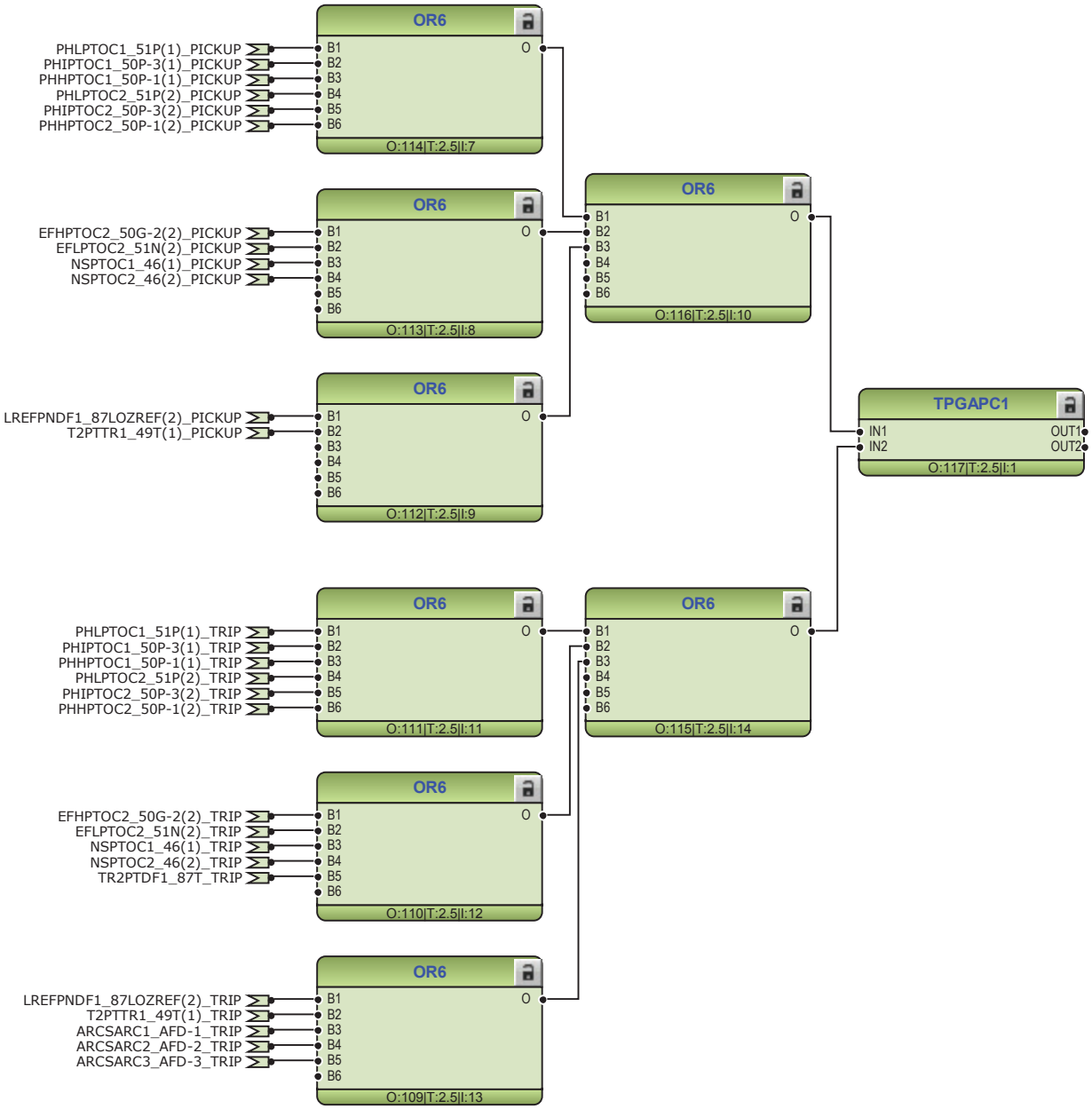

Figure 23: General pickup and trip signals

The trip signals from the protection are connected to the two trip logics: TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO4 which are further intended to open circuit breaker on high voltage and medium 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_86/94-3…5 are also available if the relay is ordered with high-speed binary outputs options.

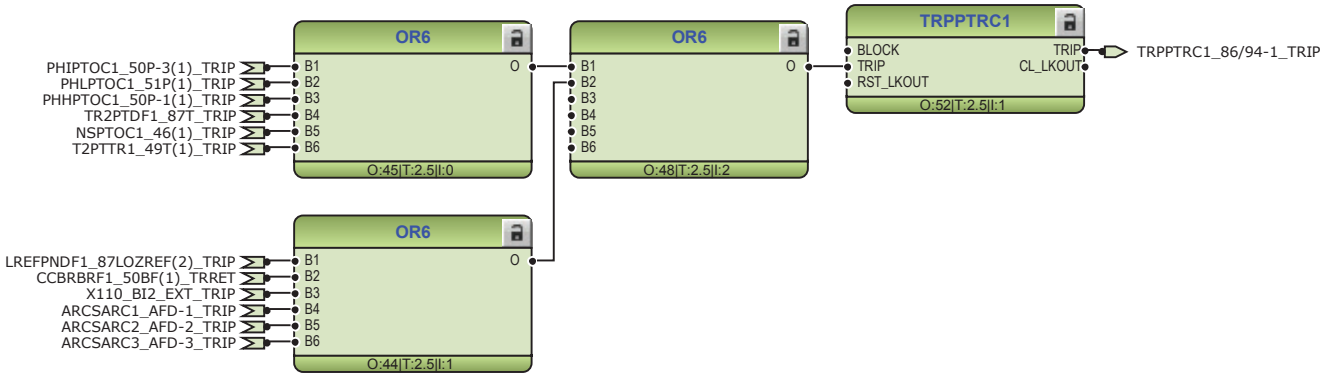

Figure 24: Trip logic TRPPTRC1

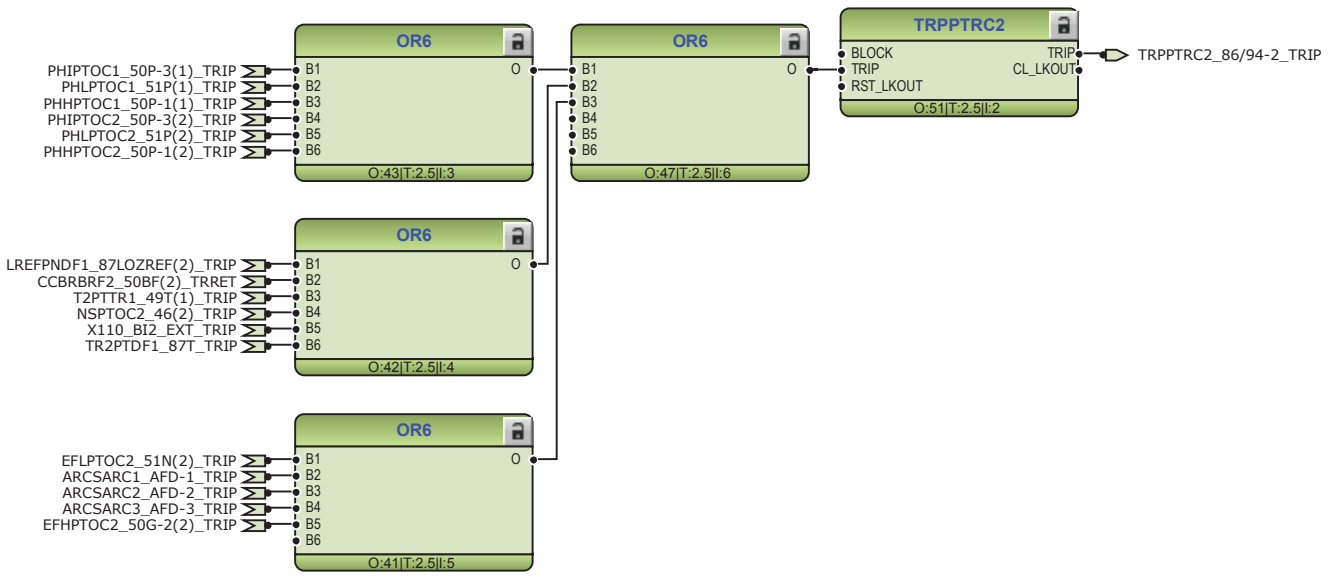

Figure 25: Trip logic TRPPTRC2

3.3.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs from the protection stages are routed to trigger the disturbance recorder or, alternatively, only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected signals from different functions and the few binary inputs are also connected to the disturbance recorder.

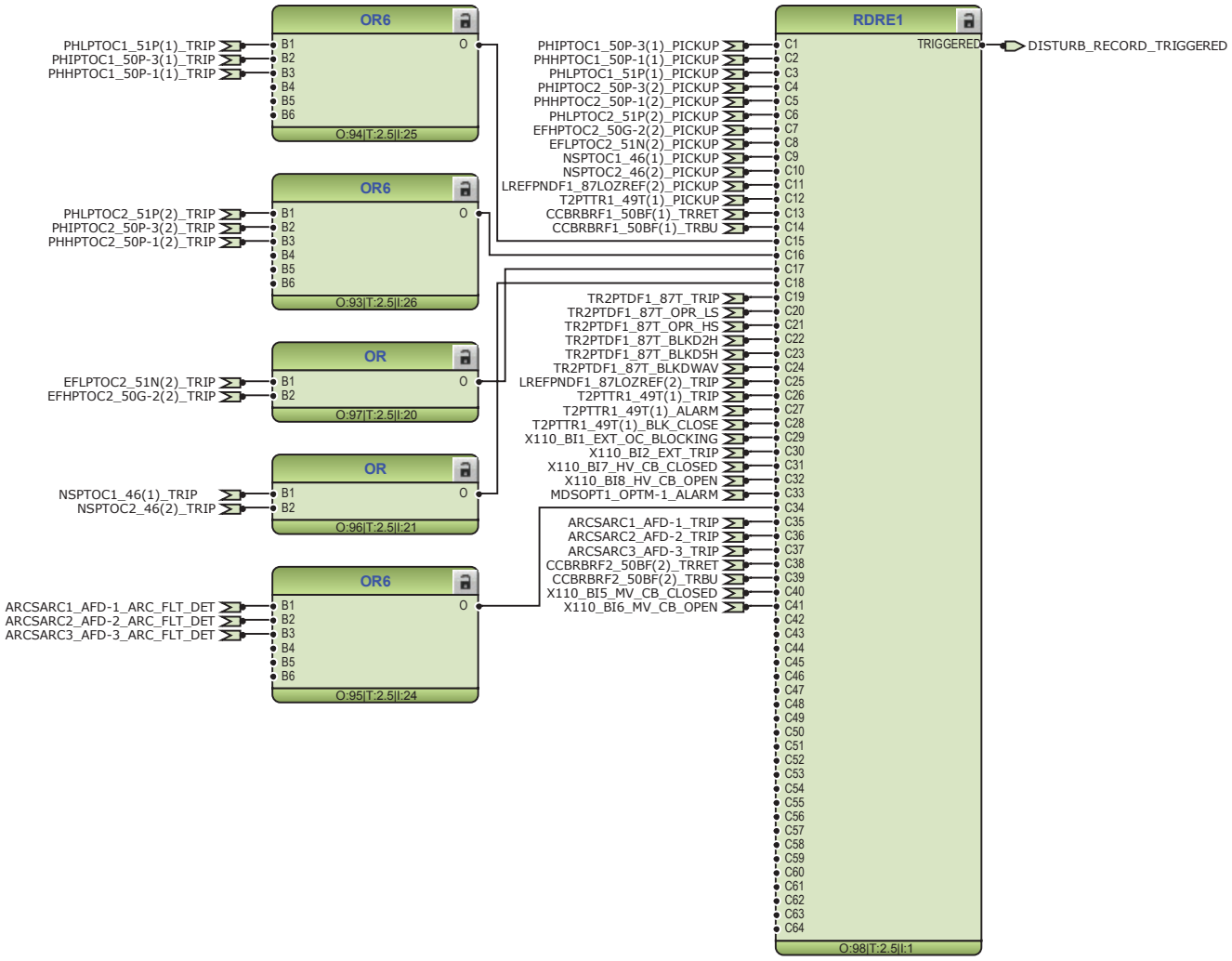

Figure 26: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

Circuit-breaker condition monitoring SSCBR1_52CM(1) and SSCBR1_52CM(2) supervises the switch status based on the connected binary input information and the

measured current levels. SSCBR1_52CM(1) and SSCBR1_52CM(2) introduce various supervision methods.

Set the parameters for SSCBR_52CM properly.

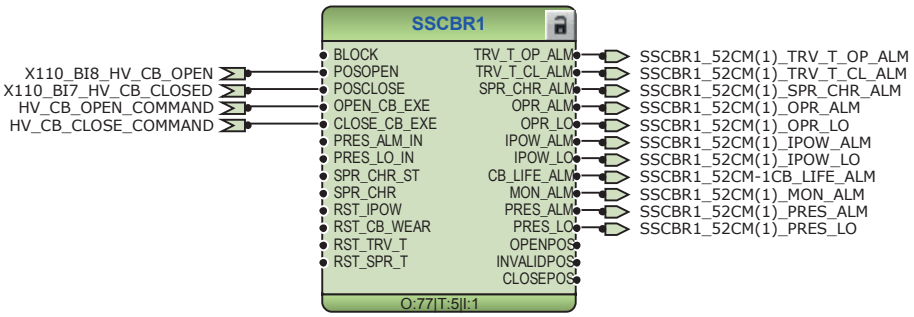

Figure 27: Circuit-breaker 1 condition monitoring function

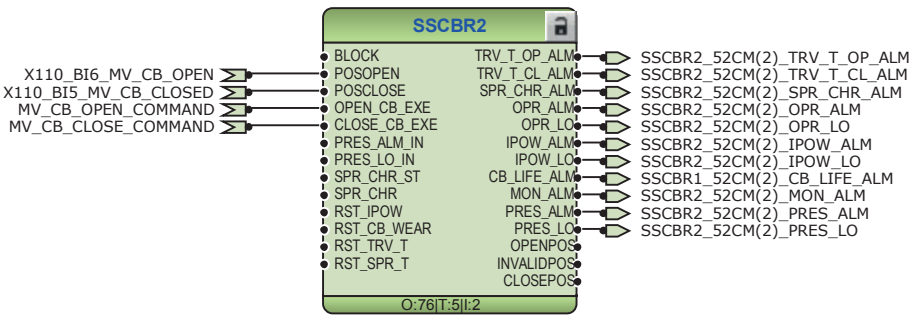

Figure 28: Circuit-breaker 2 condition monitoring function

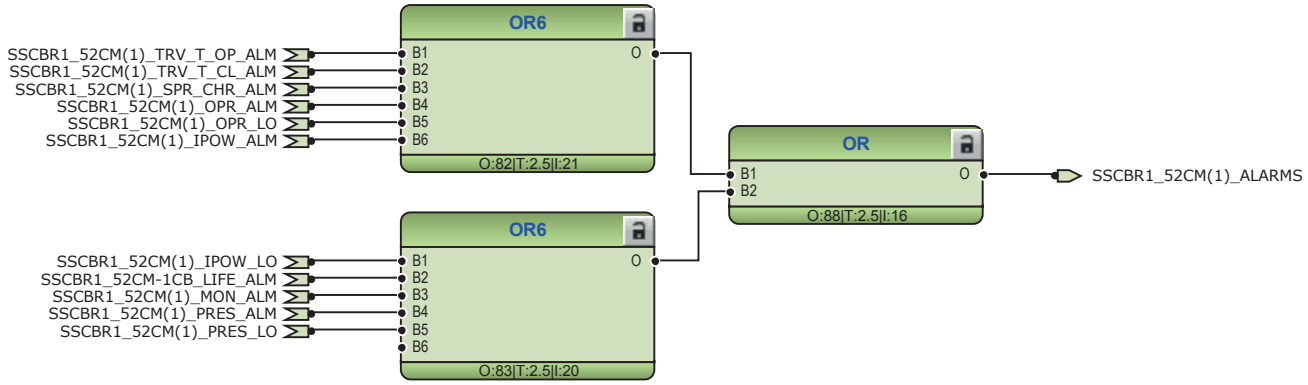

Figure 29: Logic for circuit breaker 1 monitoring alarm

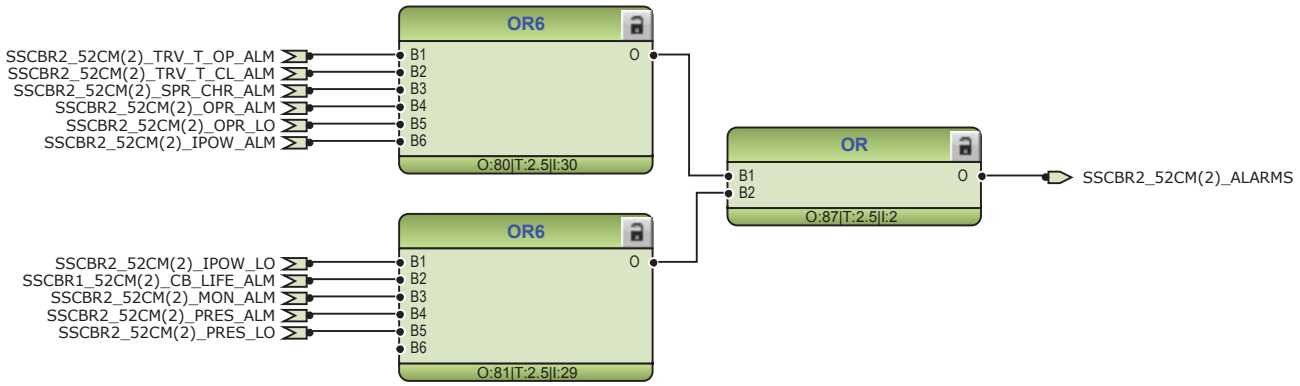

Figure 30: Logic for circuit breaker 2 monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. TCSSCBR1_TCM-1 function is blocked by the master trips TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 and the generator circuit breaker open signal, whereas TCSSCBR2-TCM-2 function is blocked by the master trip TRPPTRC6_86/94-6 and the field excitation 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 TCSSCBR_TCM properly.

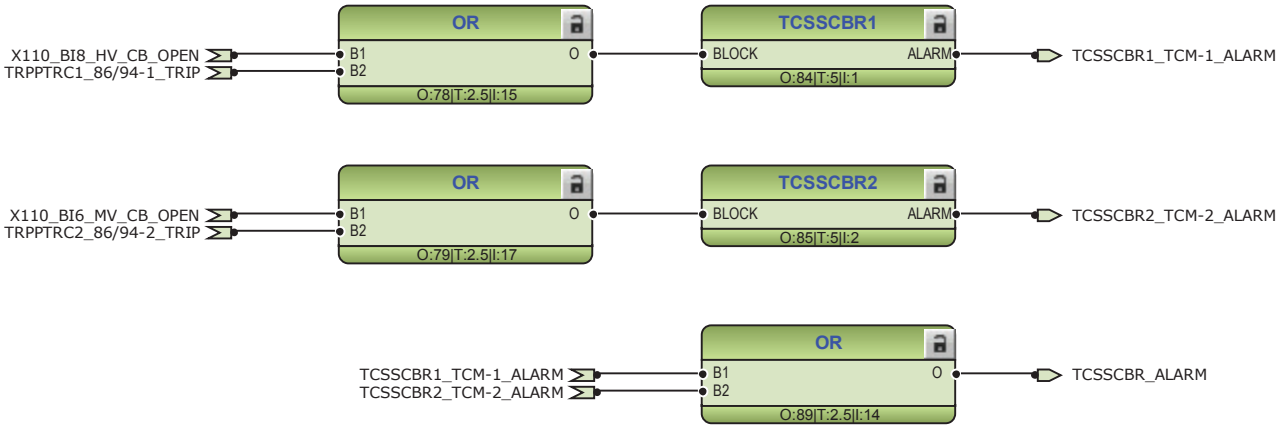

Figure 31: Trip circuit supervision function

3.3.3.4 Functional diagrams for control and interlocking

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.

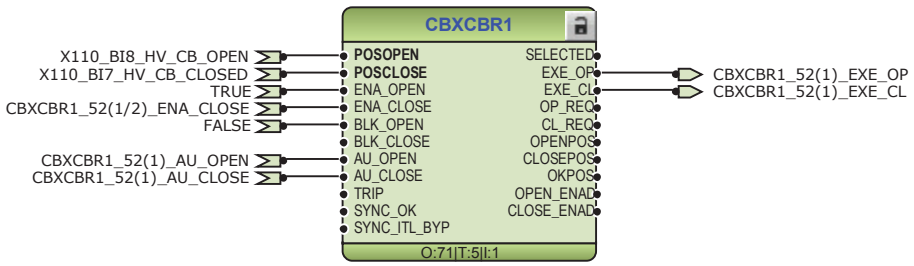

Figure 32: Circuit breaker 1 control logic

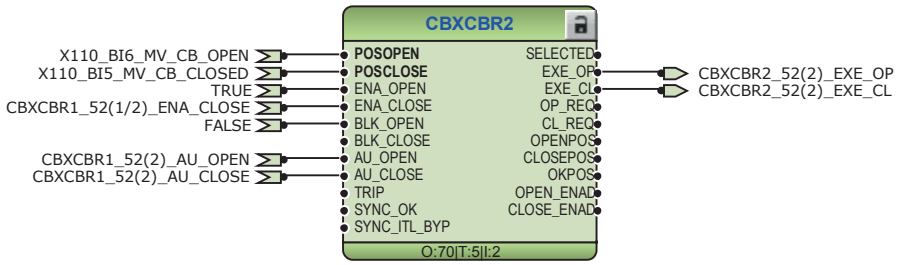

Figure 33: Circuit breaker 2 control logic

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

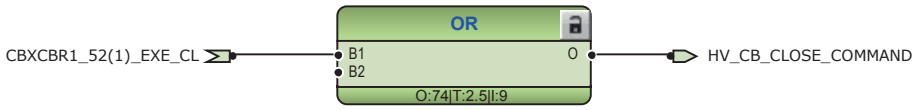

Figure 34: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker 1

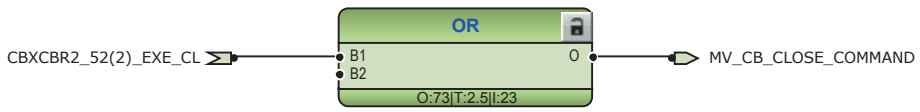

Figure 35: Circuit breaker control logic: Signals for closing coil of medium-voltage side circuit breaker 2

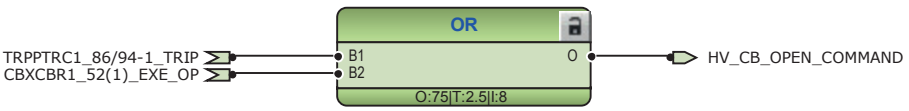

Figure 36: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker 1

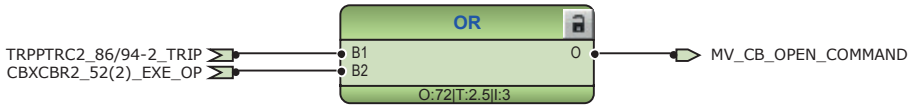

Figure 37: Circuit breaker control logic: Signals for opening coil of medium-voltage side circuit breaker 2

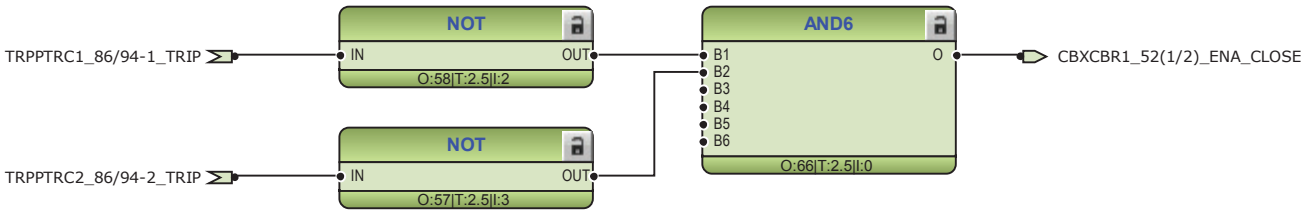

Figure 38: Circuit breaker close enable logic

The configuration includes the logic for generating circuit breaker external opening command with the relay 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 of circuit breaker in local or remote mode, if applicable for the configuration.

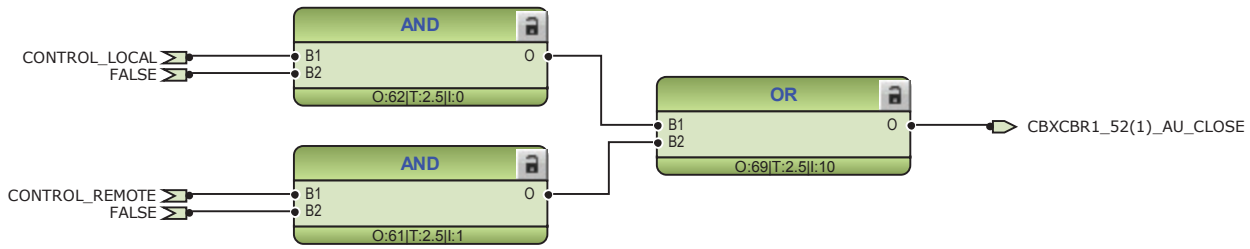

Figure 39: External closing command for circuit breaker 1

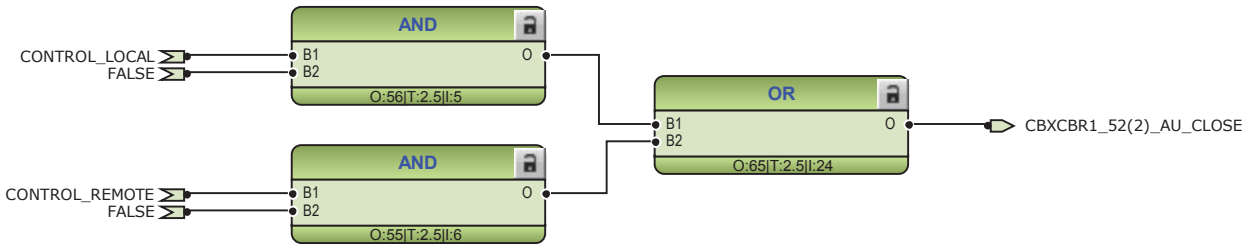

Figure 40: External closing command for circuit breaker 2

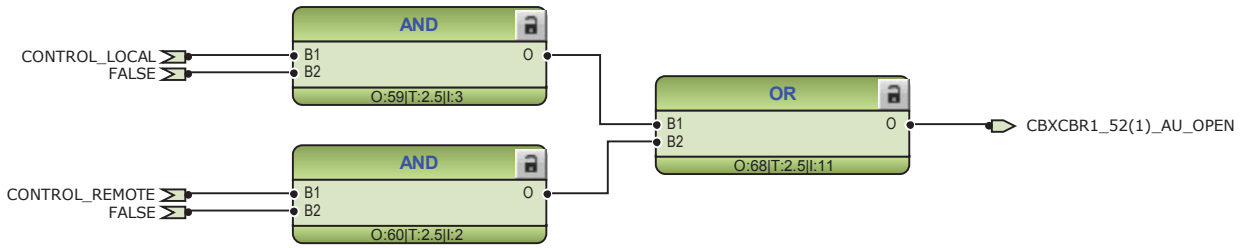

Figure 41: External opening command for circuit breaker 1

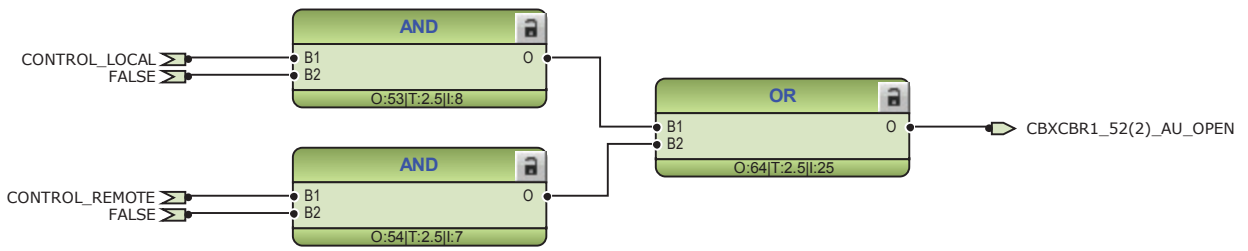

Figure 42: External opening command for circuit breaker 2

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the relay 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.

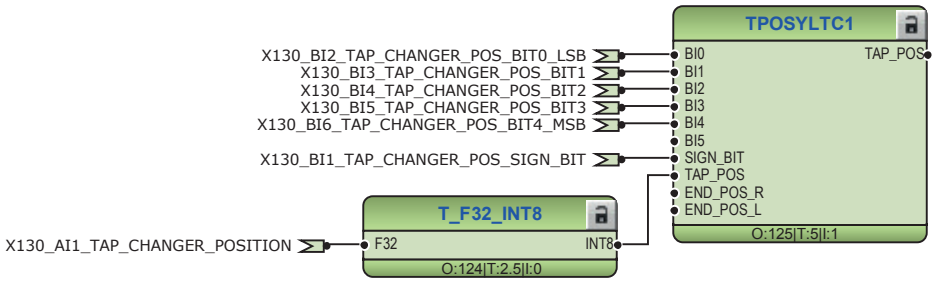

Figure 43: Tap changer position indicator

3.3.3.5 Functional diagrams for measurement functions

The high-voltage side and medium-voltage side phase current inputs to the relay 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 medium-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.

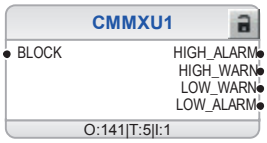

Figure 44: Three-phase current measurement (HV side)

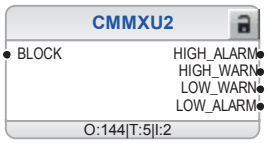

Figure 45: Current measurement: Three-phase current measurement (MV side)

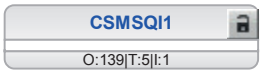

Figure 46: Sequence current measurement (HV side)

Figure 47: Ground current measurement (MV side)

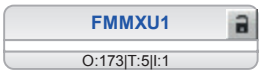

Figure 48: Frequency measurement

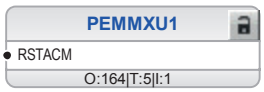

Figure 49: Three-phase power and energy measurement

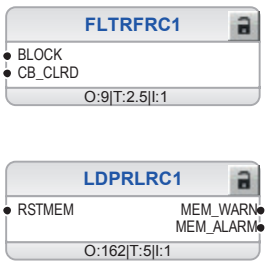

Figure 50: Data monitoring and load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

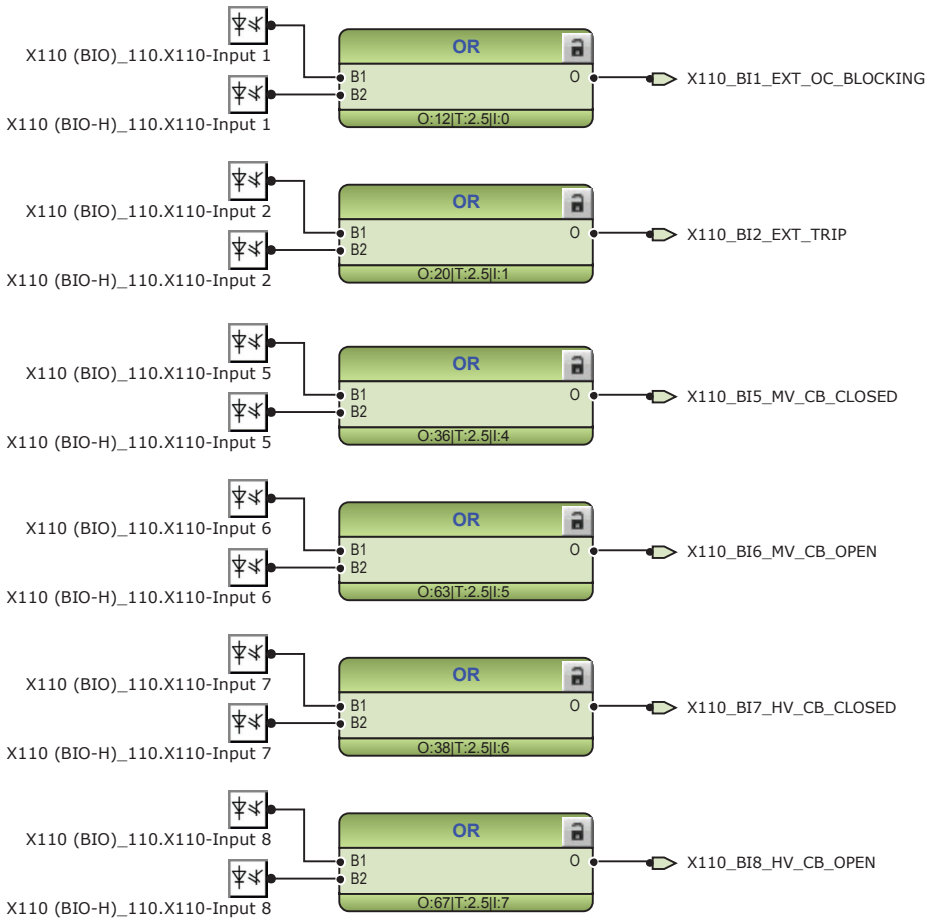

Figure 51: Default binary inputs - X110

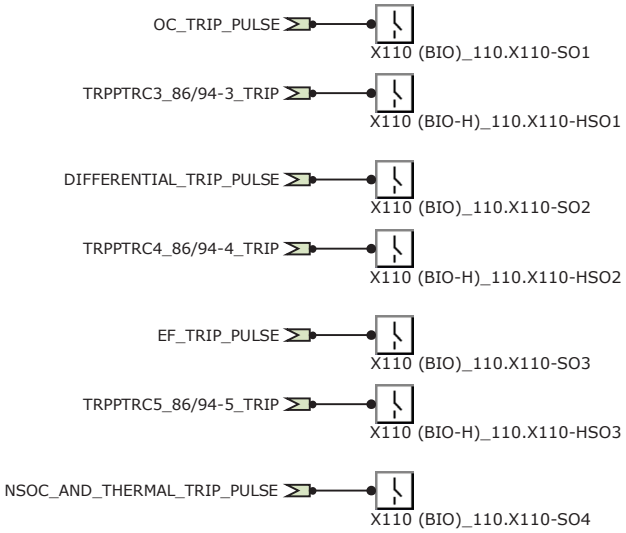

Figure 52: Default binary outputs - X110

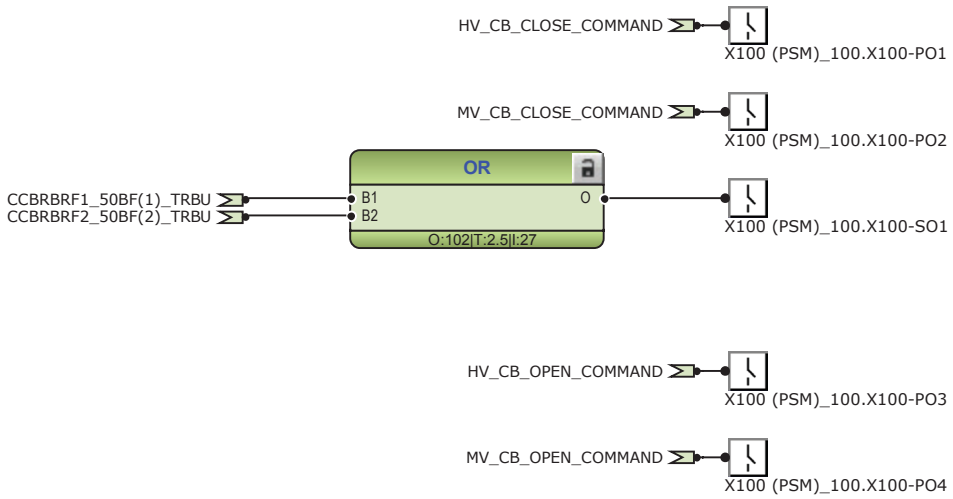

Figure 53: Default binary outputs - X100

Figure 54: Default binary input - X130

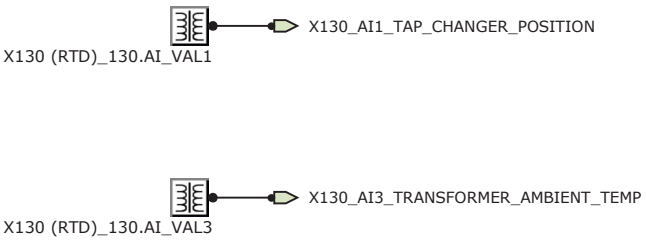

Figure 55: mA/TRD input - X130

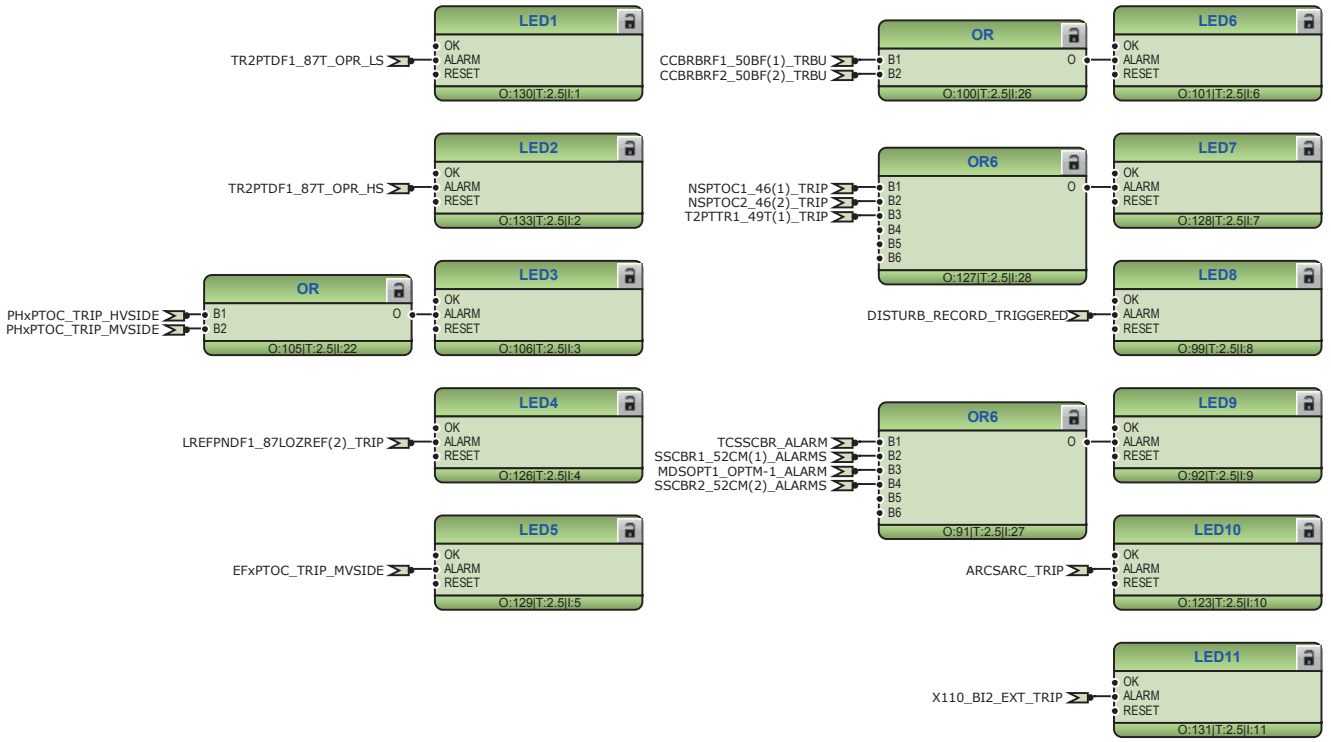

Figure 56: Default LED connection

3.3.3.7 Functional diagrams for other functions

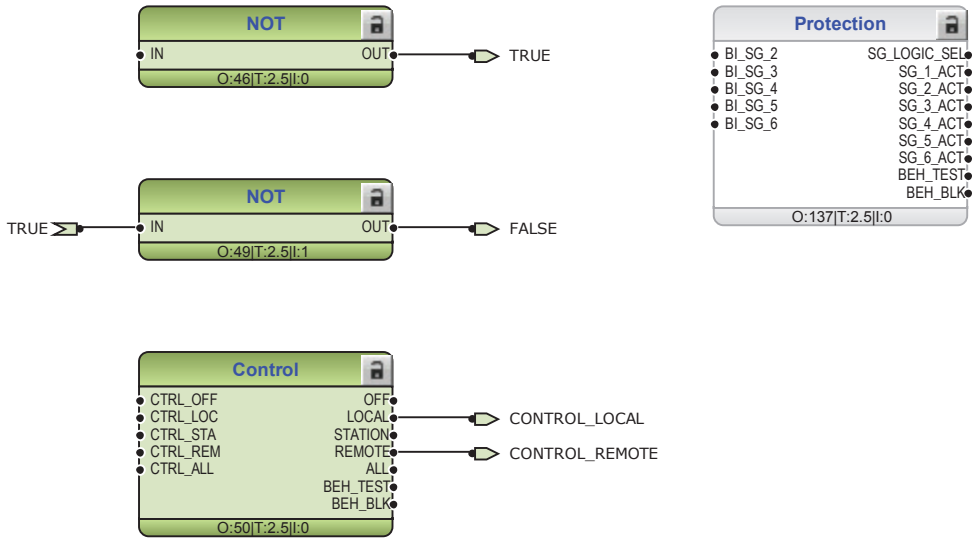

Figure 57: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.3.3.8 Functional diagrams for other timer logics

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

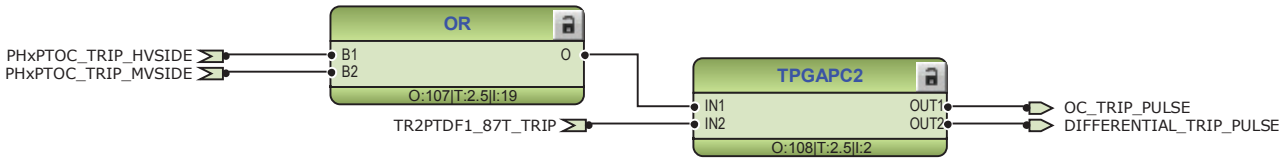

Figure 58: Timer logic for overcurrent and differential trip pulse

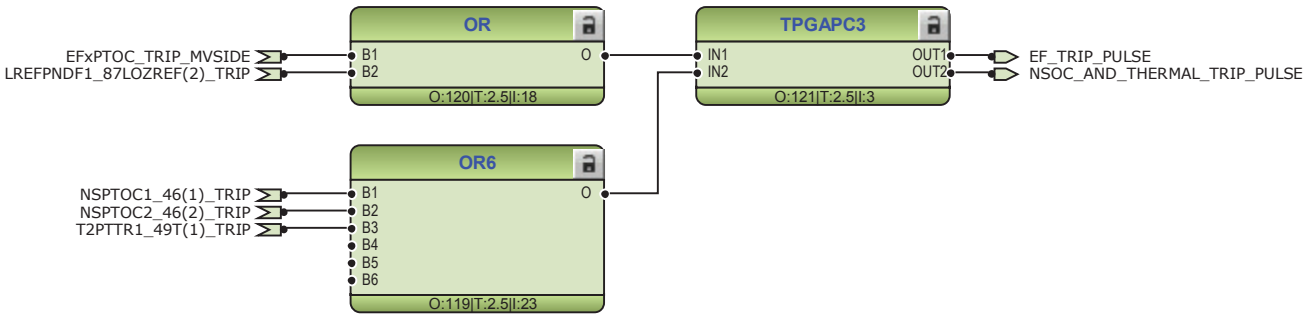

Figure 59: Timer logic for ground-fault and negative sequence with thermal overload protection trip alarm

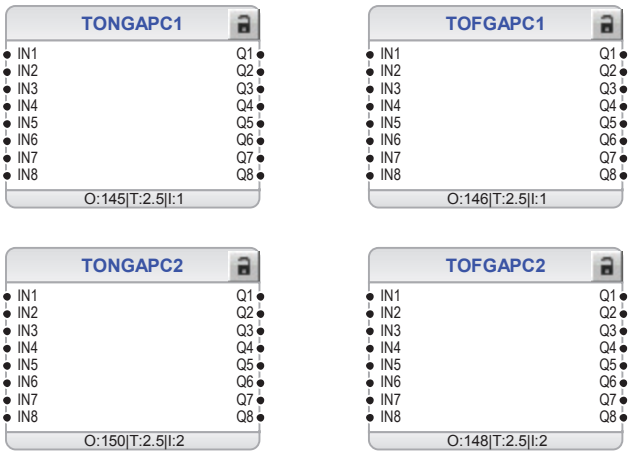

Figure 60: Programmable timers

3.3.3.9 Functional diagrams for communication

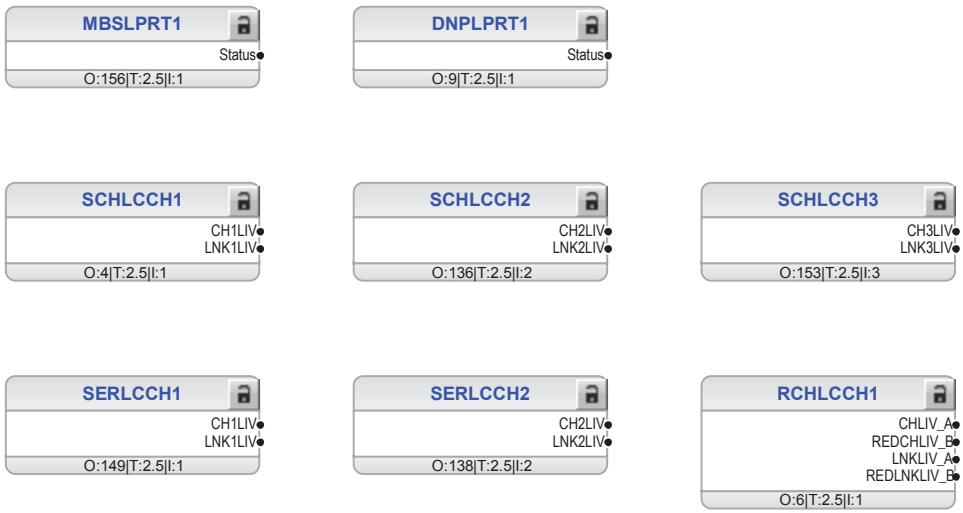

Figure 61: Default communication function connection

3.4 Standard configuration F

3.4.1 Applications

The standard configuration includes three-phase transformer differential protection for two-winding transformers, numerical restricted ground-fault protection for the medium-voltage (MV) 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.

3.4.2 Functions

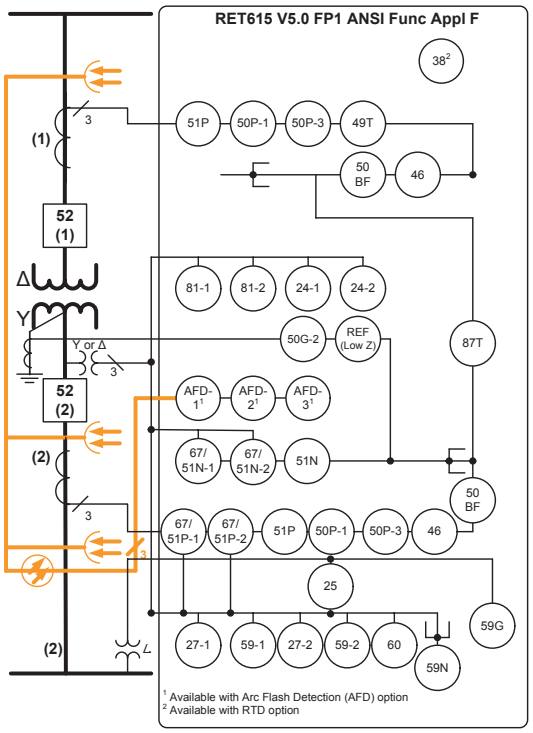

Figure 62: Functionality overview for standard configuration F

3.4.2.1 Default I/O connections

Table 15: Default connections for analog inputs

Analog input	Description	Connector pins
IA_B	Phase A current, MV side	X120:1-2
IB_B	Phase B current, MV side	X120:3-4
IC_B	Phase C current, MV side	X120:5-6
IA	Phase A current, HV side	X120:7-8
IB	Phase B current, HV side	X120:9-10
IC	Phase C current, HV side	X120:11-12
IG	Residual current IG	X120:13-14
VA	Phase voltage VA	X130:11-12
VB	Phase voltage VB	X130:13-14
VC	Phase voltage VC	X130:15-16
VG	Residual voltage VG	X130:17-18

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	Blocking of O/C high state (high voltage) and instantaneous stage (medium voltage)	X110:1-2	X110:1,5
X110-BI2	External protection trip	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	Medium-voltage side circuit breaker closed indication	X110:8-9	X110:6,10
X110-BI6	Medium-voltage side circuit breaker open indication	X110:10-9	X110:7,10
X110-BI7	High-voltage side circuit breaker closed indication	X110:11-12	X110:8,10
X110-BI8	High-voltage side circuit breaker open indication	X110:13-12	X110:9-10
X130-BI1	Voltage transformer secondary MCB open	X130:1-2	
X130-BI2	-	X130:3-4	
X130-BI3	-	X130:5-6	
X130-BI4	-	X130:7-8	

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100:6-7
X100-PO2	Close medium-voltage circuit breaker	X100:8-9
X100-SO1	Breaker failure backup trip to upstream breaker (Breaker 1 and 2)	X100:10-11,(12)
X100-SO2	-	X100:13-14
X100-PO3	Open circuit breaker/trip coil 1 high-voltage	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2 medium-voltage	X100:20-24
X110-SO1	Overcurrent trip alarm	X110:14-16
X110-SO2	Differential protection trip alarm	X110:17-19
X110-SO3	Ground-fault trip alarm	X110:20-22
X110-SO4	Thermal overload and negative phase-sequence trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 18: Default connections for LEDs

LED	Default usage	ID	Label description
1	Transformer differential protection biased stage trip	LED_DiffProtBiasedLowStage_1	Diff. prot. biased low stage
2	Transformer differential protection instantaneous stage trip	LED_DiffProtHighStage_1	Diff. prot. high stage
3	Overcurrent or ground-fault protection trip	LED_OC_or_EF	Overcurrent or Ground-fault
4	Restricted earth-fault protection trip	LED_RestrictedEarthFault_1	Restricted ground-fault
5	Voltage protection trip	LED_VoltageProt	Voltage protection
6	Circuit failure protection backup trip	LED_BreakerFailure_1	Breaker failure
7	Negative sequence overcurrent or thermal overload protection trip	LED_NPSOrThermalOverload_1	Neg. Seq./Thermal Ovld.
8	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
9	TCS, fuse failure, measuring circuit fault or circuit breaker supervision	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Protection trip from external device	LED_ExternalTrip_1	External trip

3.4.2.2 Default disturbance recorder settings

Table 19: Default disturbance recorder analog channels

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

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHIPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHLPTOC1 - pickup	Positive or Rising
4	PHIPTOC2 - pickup	Positive or Rising
5	PHHPTOC2 - pickup	Positive or Rising
6	PHLPTOC2 - pickup	Positive or Rising
7	EFHPTOC2 - pickup	Positive or Rising
8	EFLPTOC2 - pickup	Positive or Rising
9	NSPTOC1 - pickup	Positive or Rising
10	NSPTOC2 - pickup	Positive or Rising
11	LREFPNDF1 - pickup	Positive or Rising
12	T2PTTR1 - pickup	Positive or Rising
13	ROVPTOV1 - pickup	Positive or Rising
14	ROVPTOV2 - pickup	Positive or Rising
15	PHPTOV1 - pickup	Positive or Rising
16	PHPTOV2 - pickup	Positive or Rising
17	PHPTUV1 - pickup	Positive or Rising
18	PHPTUV2 - pickup	Positive or Rising
19	CCBRBRF1 - trret	Level trigger off
20	CCBRBRF1 - trbu	Level trigger off
21	PHxPTOC1 - trip	Level trigger off
22	PHxPTOC2 - trip	Level trigger off
23	EFxPTOC2 - trip	Level trigger off
24	NSPTOC - trip	Level trigger off
25	TR2PTDF1 - trip	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 - trip	Level trigger off
32	T2PTTR1 - trip	Level trigger off
33	T2PTTR1 - alarm	Level trigger off
34	T2PTTR1 - blk close	Level trigger off
35	SEQSPVC1 - fusef3ph	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
36	SEQSPVC1 - fusefu	Level trigger off
37	ROVPTOV - trip	Level trigger off
38	PHPTOV - trip	Level trigger off
39	PHPTUV - trip	Level trigger off
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	ARCSARC - ARC flt det	Level trigger off
46	ARCSARC1 - trip	Positive or Rising
47	ARCSARC2 - trip	Positive or Rising
48	ARCSARC3 - trip	Positive or Rising
49	DPHLPDOC1 - pickup	Positive or Rising
50	DPHLPDOC2 - pickup	Positive or Rising
51	DPHLPDOC -trip	Level trigger off
52	OEOVPH1 - pickup	Positive or Rising
53	OEOVPH2 - pickup	Positive or Rising
54	OEOVPH - trip	Level trigger off
55	CCBRBRF2- trret	Level trigger off
56	CCBRBRF2 - trbu	Level trigger off
57	X110BI5 - MVCB closed	Level trigger off
58	X110BI6 - MVCB open	Level trigger off
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

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 medium-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 relay's protection functionality in detail and according to the factory set default connections.

The stabilized and instantaneous differential protection for two-winding transformers TR2PTDF1_87T provides protection of power transformer unit including, for example, winding short-circuit and inter-turn faults. The relay 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 a trip signal. All trip 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_87T.

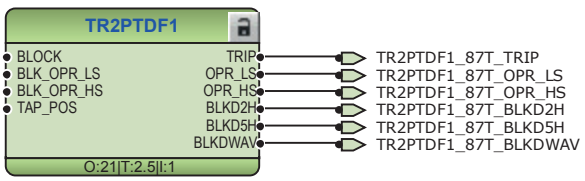

Figure 63: Transformer differential protection function

Three non-directional overcurrent stages each are offered for overcurrent and short-circuit protection for high-voltage as well as medium-voltage side of the transformer. The high stage of high-voltage side PHHPTOC1_50P-1(1) and instantaneous stage of medium-voltage side PHIPTOC2_50P-3(2) can be blocked by energizing the binary input

X110:BI1. In addition, high stage of high-voltage side PHHPTOC1_50P-1(1) is blocked by pickup of high stage of medium-voltage side PHHPTOC2_50P-1(2).

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

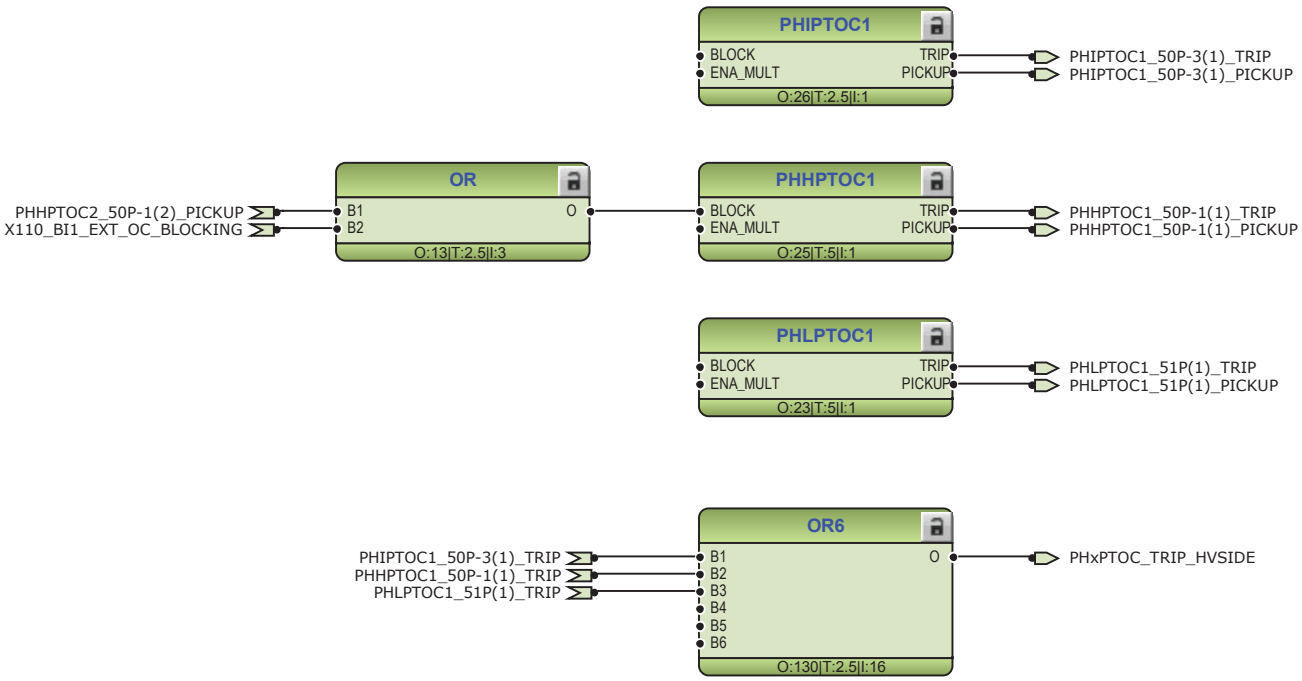

Figure 64: High-voltage side overcurrent protection function

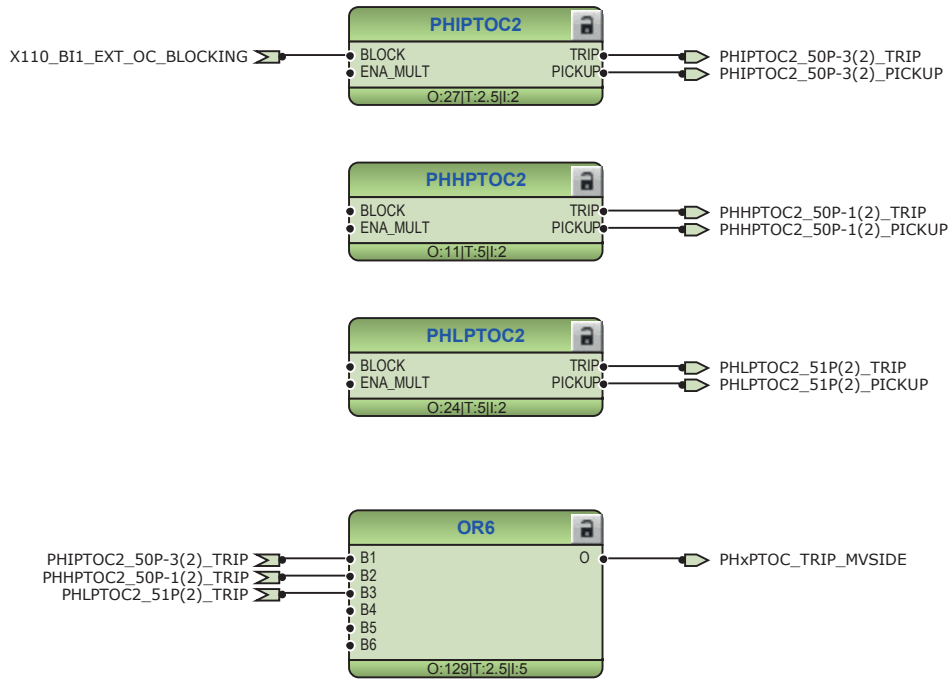

Figure 65: Medium-voltage side overcurrent protection function

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

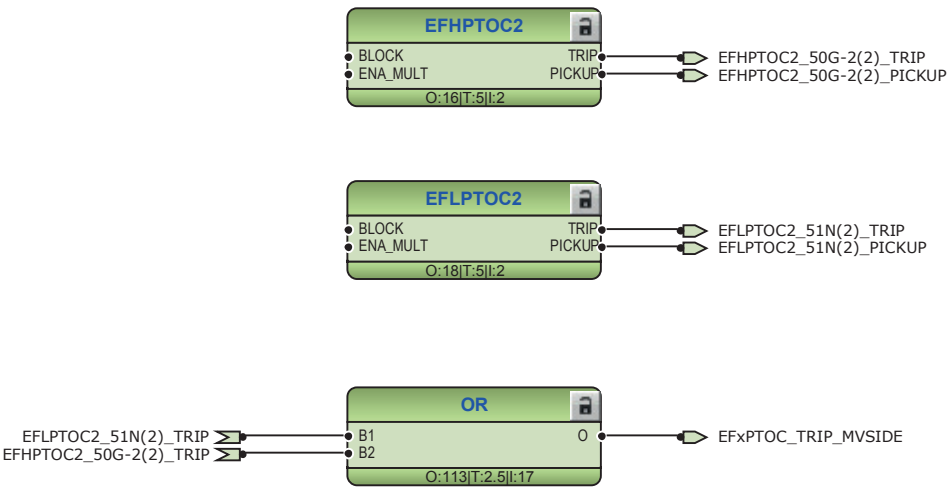

Figure 66: Medium-voltage side ground-fault protection function

The configuration includes numerically stabilized low-impedance restricted ground-fault protection function for medium-voltage side of two-winding power transformers

LREFPNDF1_87LOZREF(2). The numerical differential current stage trips exclusively on ground-faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. A ground 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 ground.

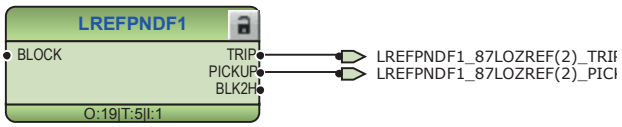

Figure 67: Restricted low-impedance ground-fault protection

Two negative-sequence overcurrent stages NSPTOC1_46(1) and NSPTOC2_46(2) are provided for phase unbalance protection. These functions are used to protect the transformer against thermal stress and damage. NSPTOC1_46(1) measures negative-sequence current from the high-voltage side and NSPTOC2_46(2) from the medium-voltage side.

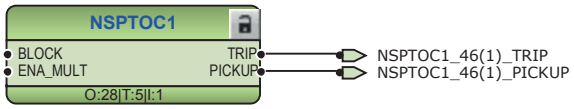

Figure 68: High-voltage side negative-sequence overcurrent protection function

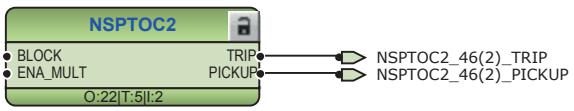

Figure 69: Medium-voltage side negative-sequence overcurrent protection function

Circuit breaker failure protection CCBRBRF1_50BF(1) is initiated via the `PICKUP` input by number of different protection functions available in the relay. 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` trip output is used for retripping the high-voltage and medium-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` trip output signal is connected to the binary output X100:PO2.

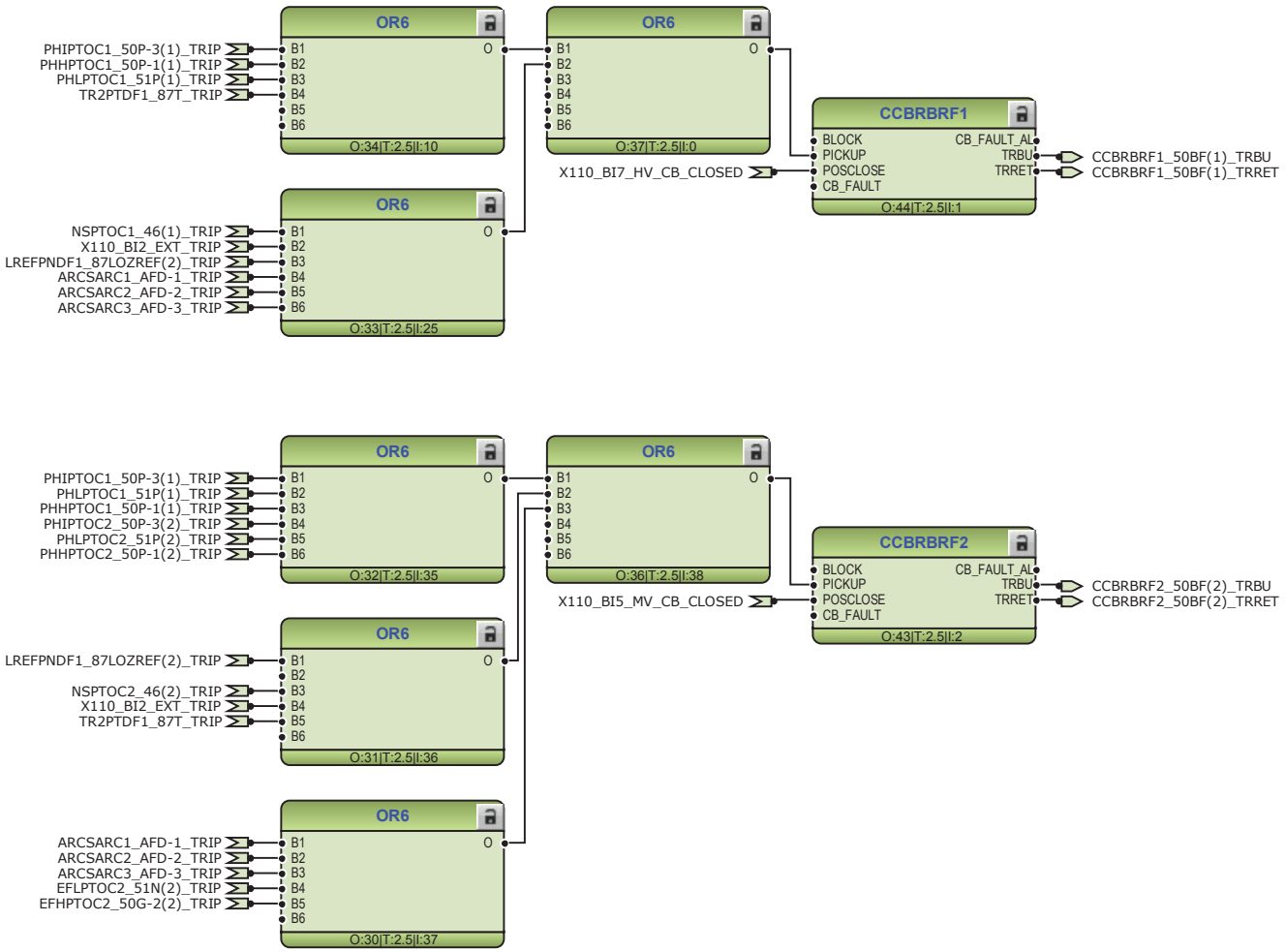

Figure 70: Circuit breaker failure protection function

Two overvoltage and undervoltage protection stages PHPTOV_59 and PHPTUV_27 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.

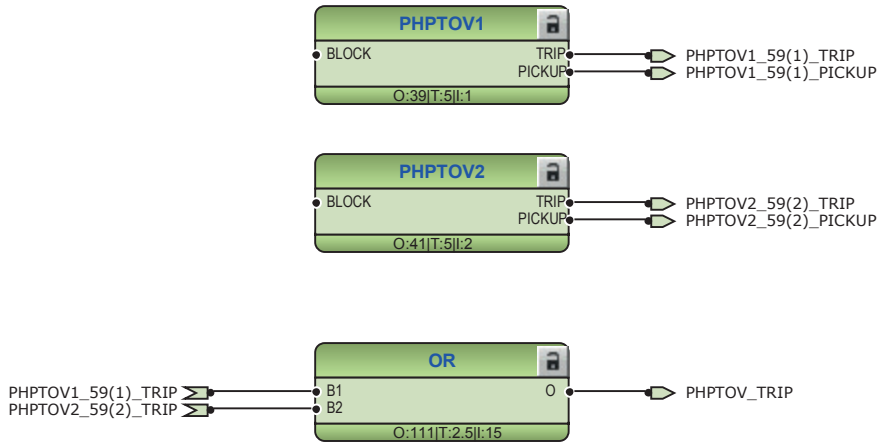

Figure 71: High-voltage side phase overvoltage protection function

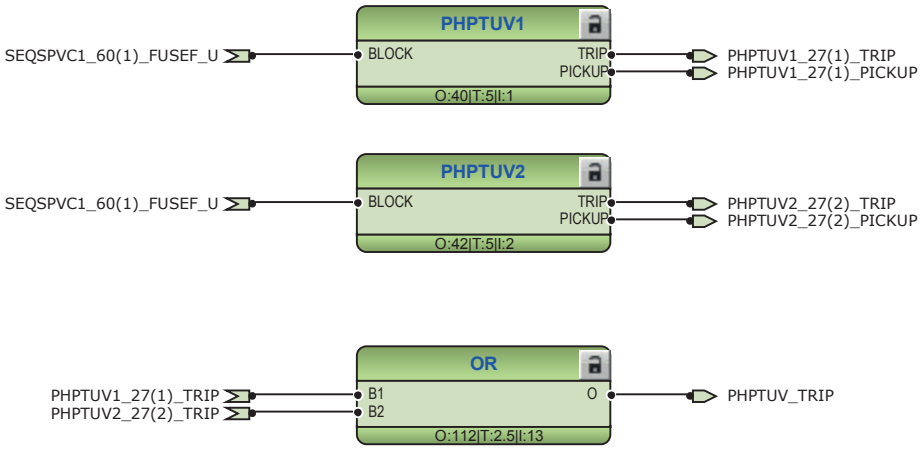

Figure 72: High-voltage side phase undervoltage protection function

Three arc protection stages ARCSARC1...3_AFD-1…3 are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. If the relay is ordered with high-speed binary outputs, the individual trip signals from ARCSARC1...3_AFD-1…3 are connected to dedicated trip logic TRPPTRC3...5_86/94-3…5. The output of TRPPTRC3...5_86/94-3…5 is available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

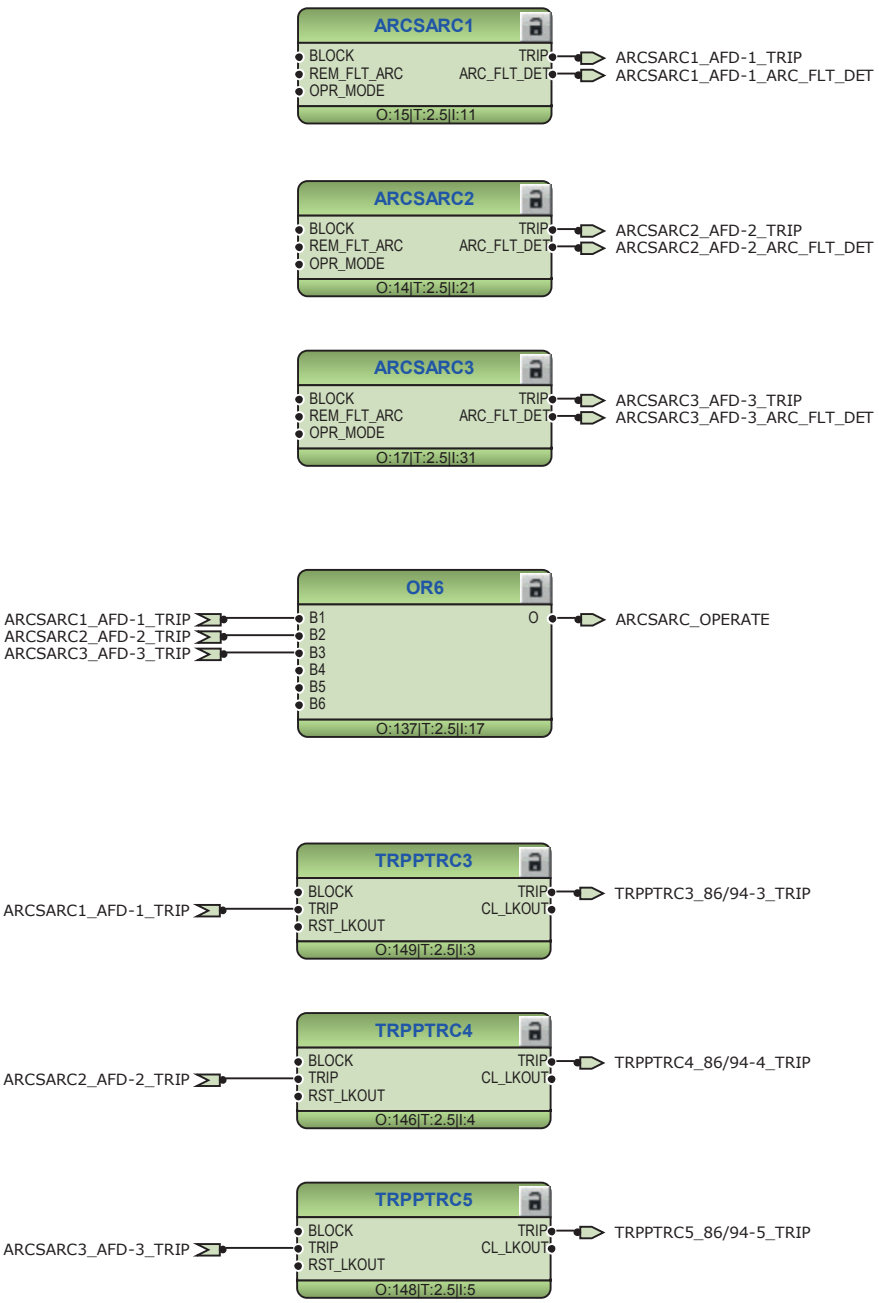

Figure 73: Arc protection with dedicated high-speed output

Runtime counter for machines and devices MDSOPT1_OPTM-1 accumulates the operation time of the transformer.

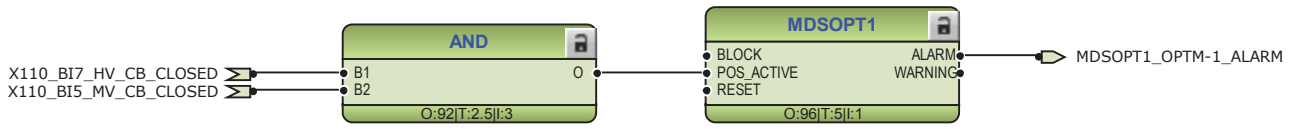

Figure 74: Transformer operation time counter

General pickup and trip 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.

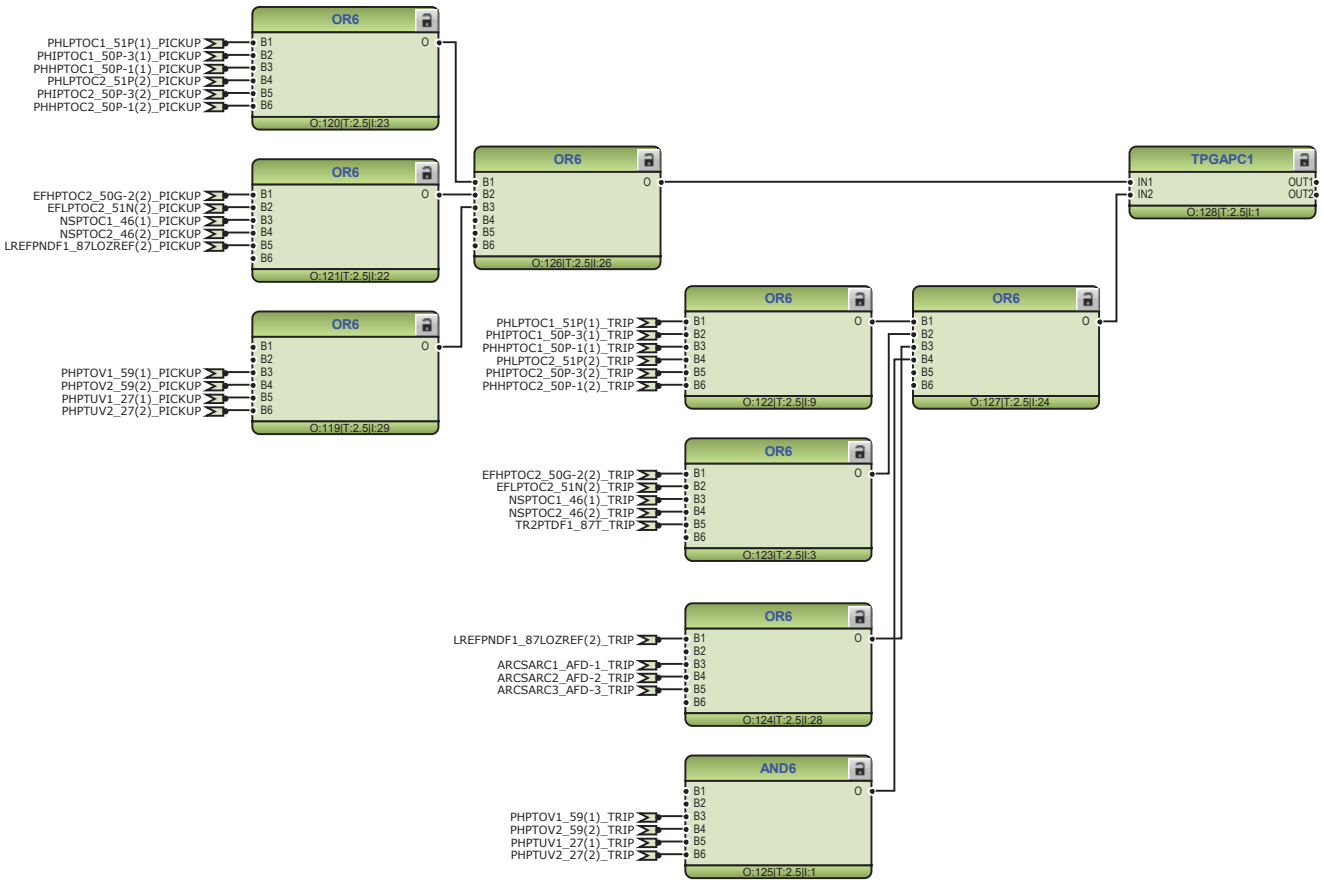

Figure 75: General pickup and trip signals

The trip signals from the protection are connected to the two trip logics: TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2. 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 medium 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_86/94-3…5 are also available if the relay is ordered with high-speed binary outputs options.

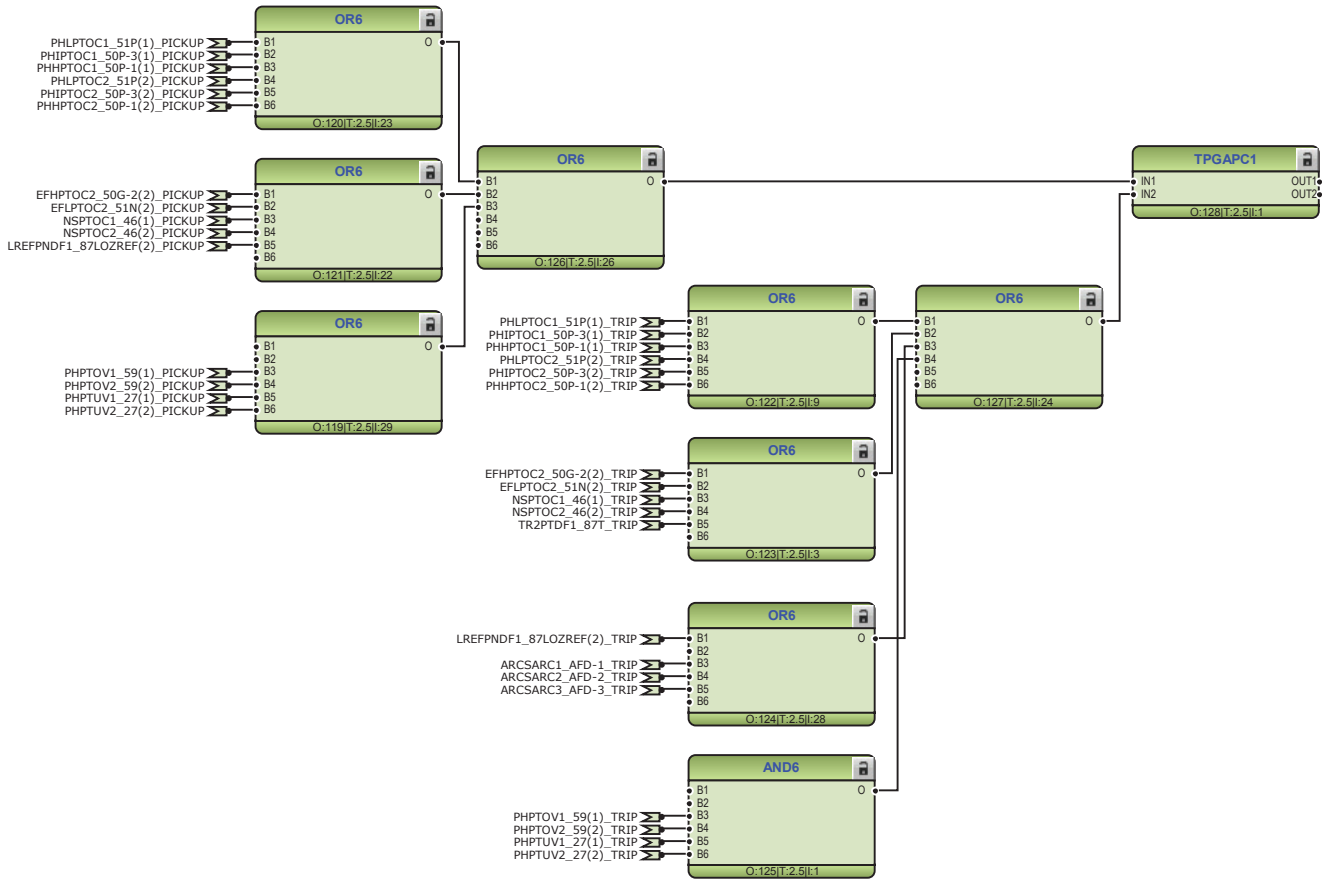

Figure 76: Trip logic TRPPTRC1

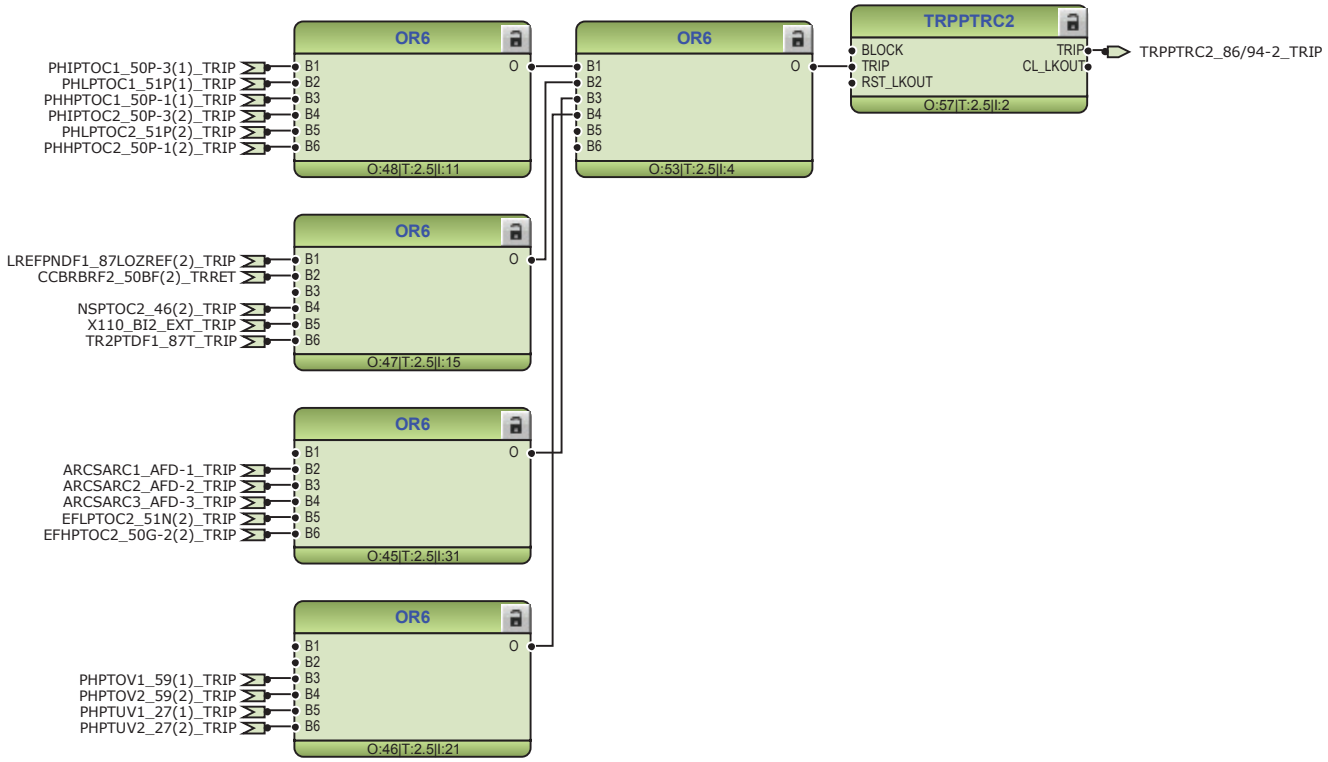

Figure 77: Trip logic TRPPTRC2

3.4.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP 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.

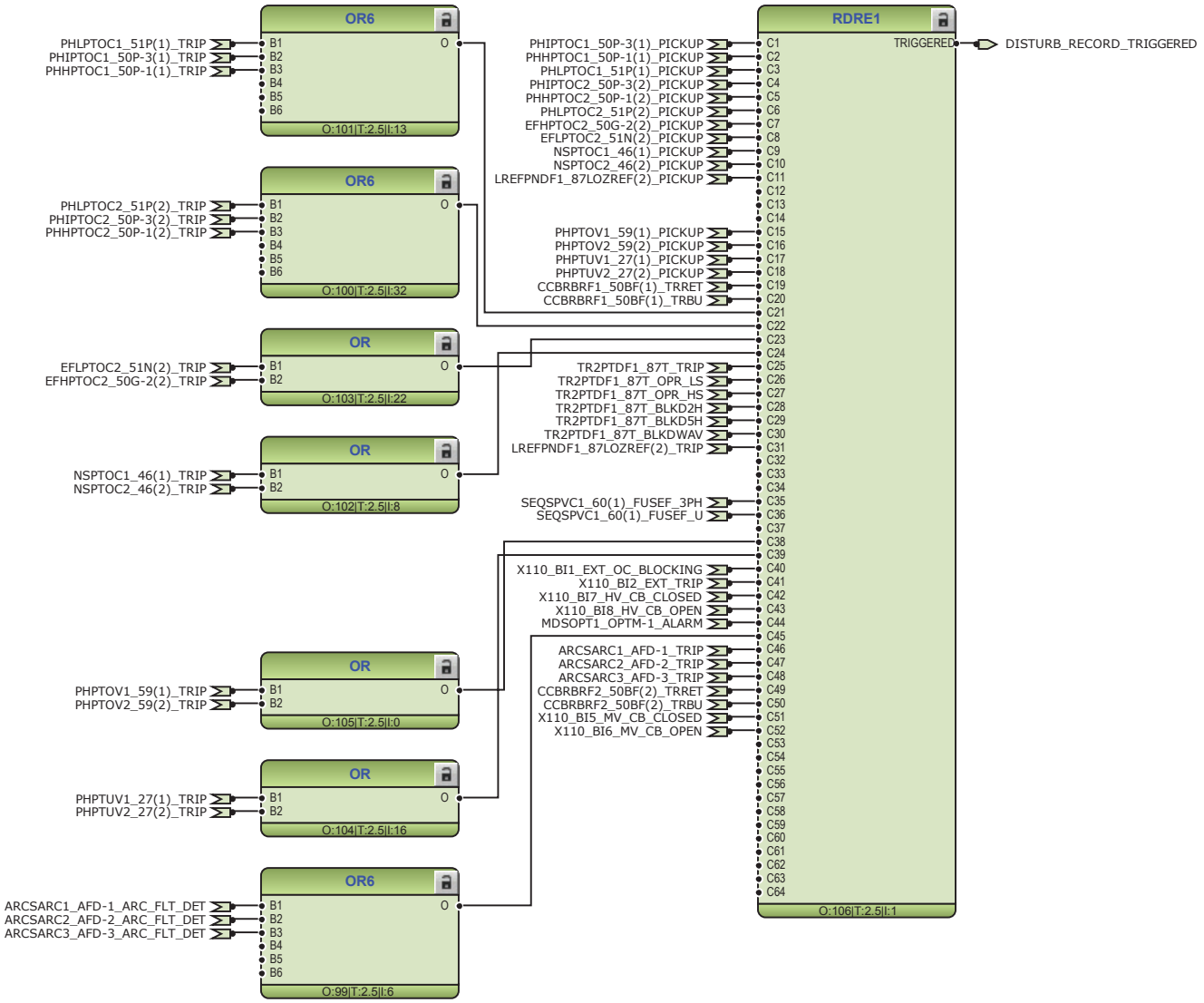

Figure 78: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

Fuse failure supervision SEQSPVC1_60(1) detects failures in the high-voltage side voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

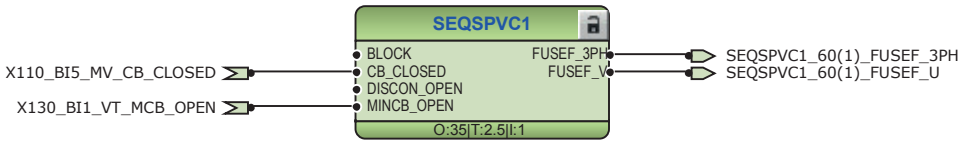

Figure 79: High-voltage fuse failure supervision function

Circuit-breaker condition monitoring SSCBR1_52CM(1) and SSCBR1_52CM(2) supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM(1) and SSCBR1_52CM(2) introduce various supervision methods.

Set the parameters for SSCBR_52CM properly.

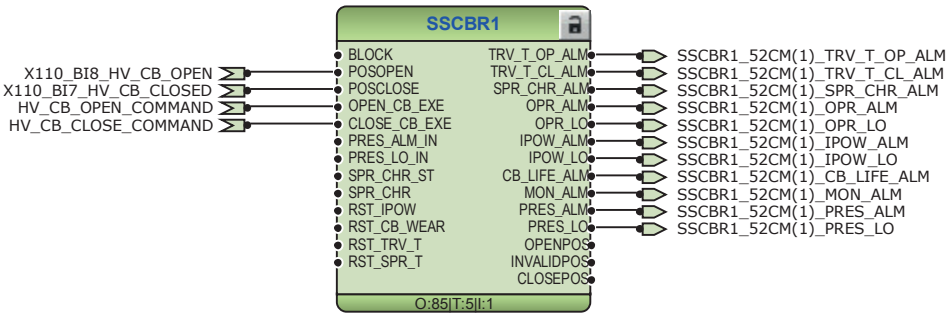

Figure 80: Circuit-breaker 1 condition monitoring function

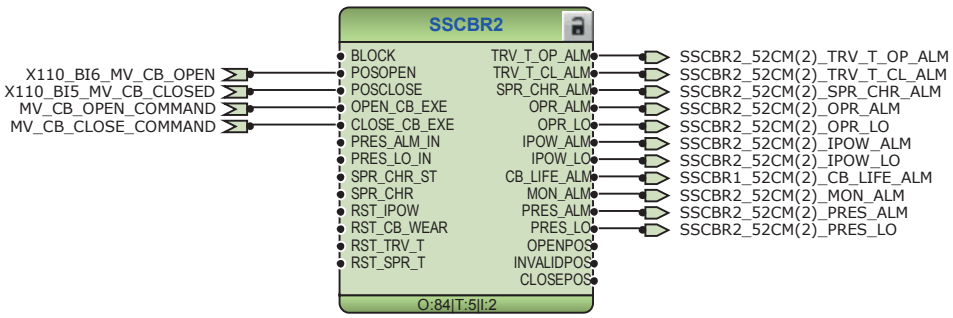

Figure 81: Circuit-breaker 2 condition monitoring function

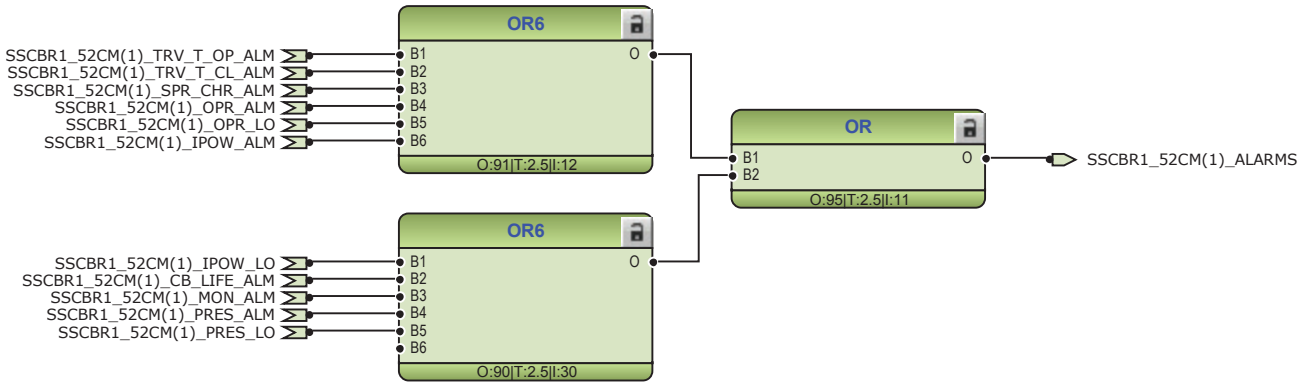

Figure 82: Logic for circuit breaker 1 monitoring alarm

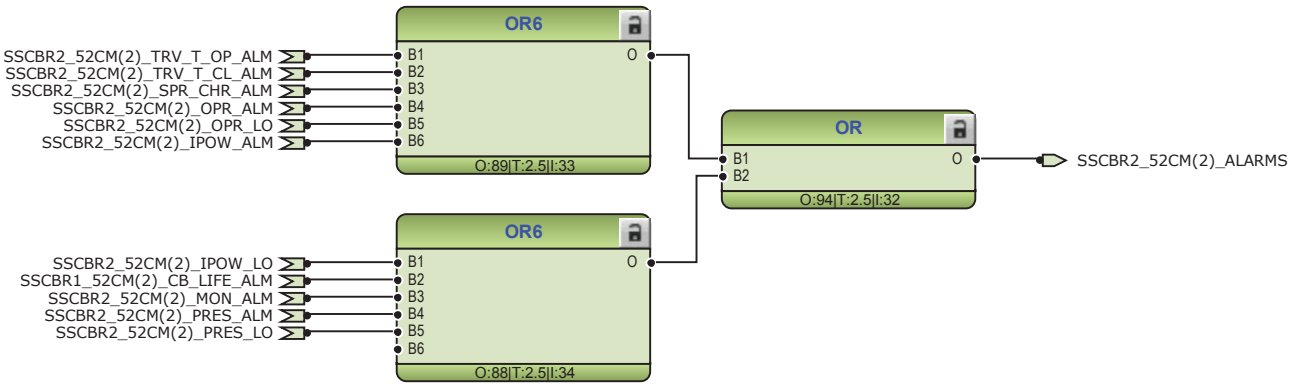

Figure 83: Logic for circuit 2 breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. TCSSCBR1_TCM-1 function is blocked by the master trips TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 and the generator circuit breaker open signal, whereas TCSSCBR2-TCM-2 function is blocked by the master trip TRPPTRC6_86/94-6 and the field excitation 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 TCSSCBR_TCM properly.

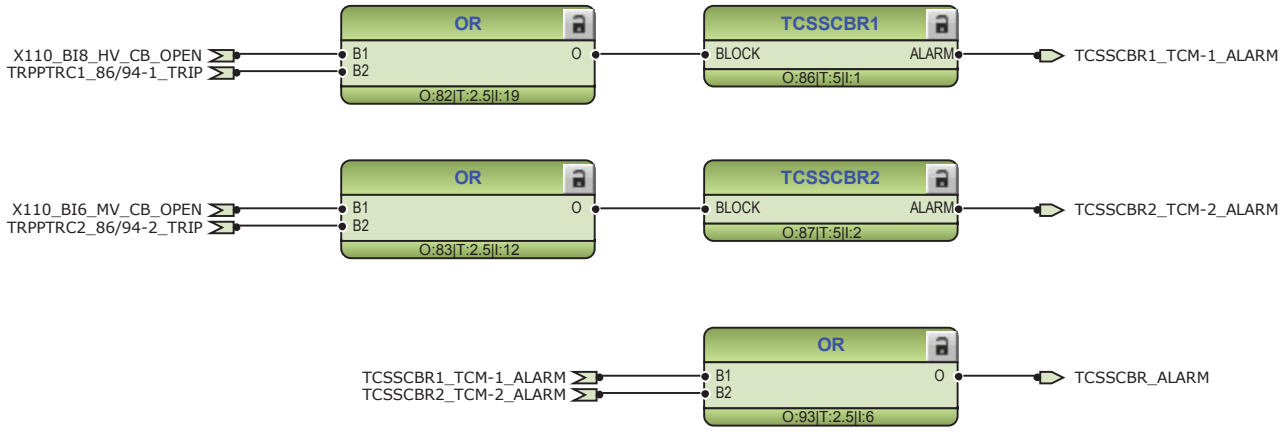

Figure 84: Trip circuit supervision function

3.4.3.4 Functional diagrams for control and interlocking

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

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

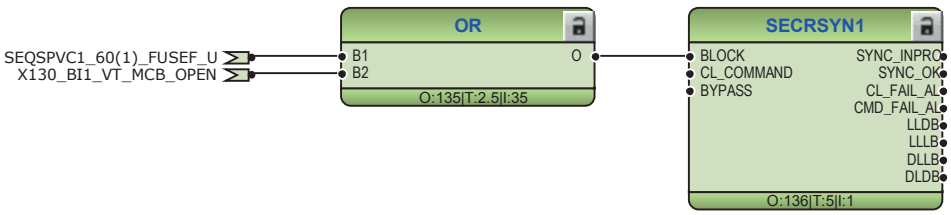

Figure 85: Synchrocheck function

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.

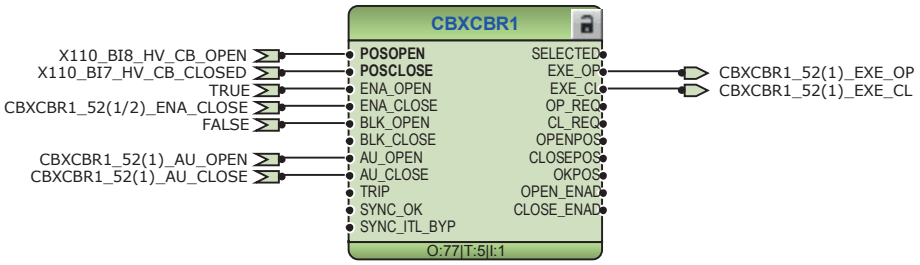

Figure 86: Circuit breaker 1 control logic

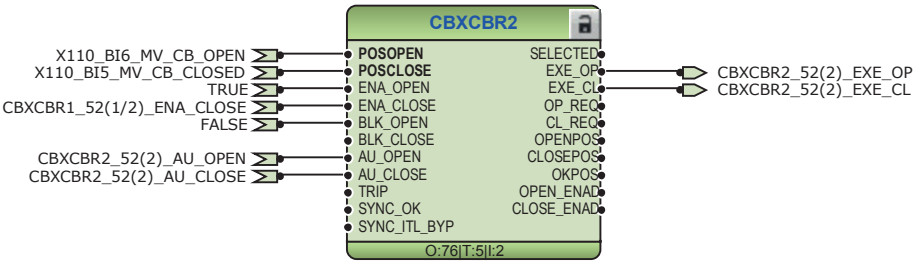

Figure 87: Circuit breaker 2 control logic

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

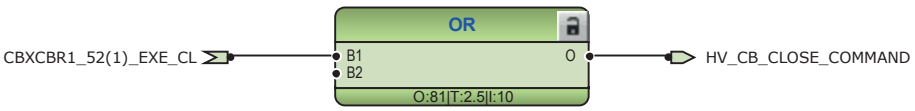

Figure 88: Circuit breaker control logic: Signals for closing coil of high-voltage side circuit breaker 1

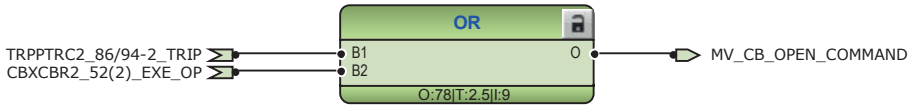

Figure 89: Circuit breaker control logic: Signals for closing coil of medium-voltage side circuit breaker 2

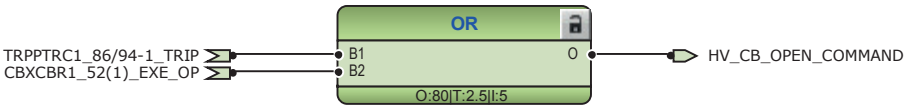

Figure 90: Circuit breaker control logic: Signals for opening coil of high-voltage side circuit breaker 1

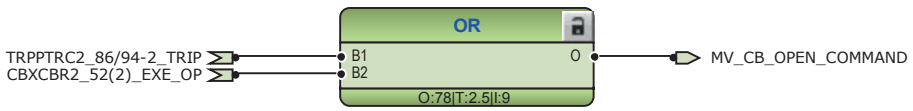

Figure 91: Circuit breaker control logic: Signals for opening coil of medium-voltage side circuit breaker 2

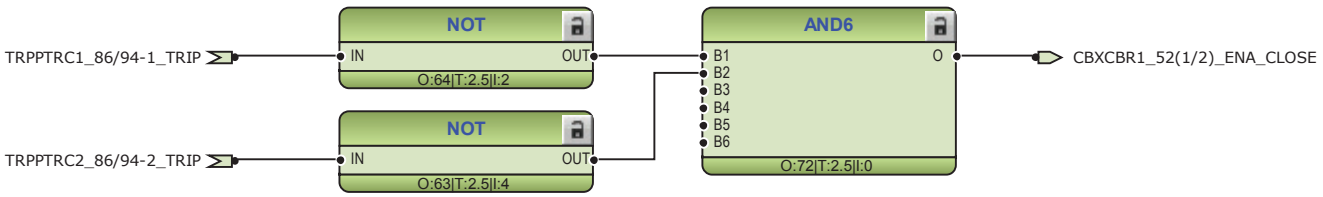

Figure 92: Circuit breaker close enable logic

The configuration includes the logic for generating circuit breaker external opening command with the relay 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 of circuit breaker in local or remote mode, if applicable for the configuration.

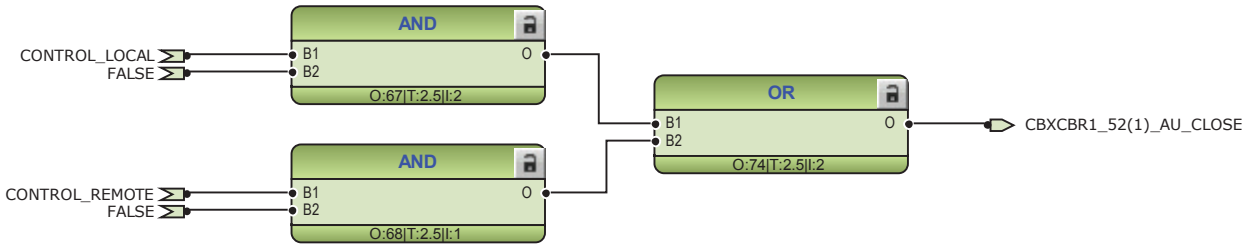

Figure 93: External closing command for circuit breaker 1

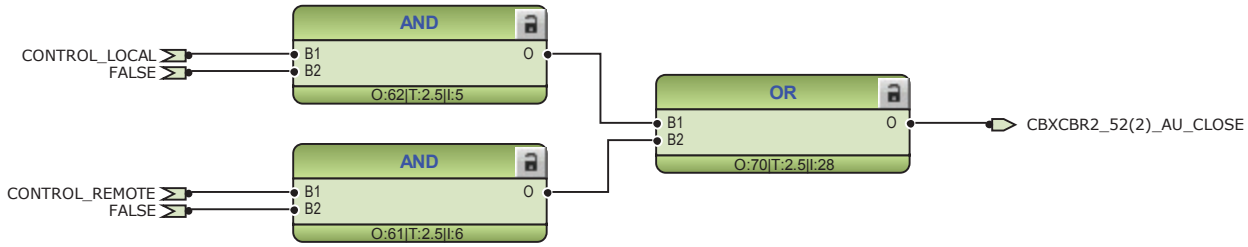

Figure 94: External closing command for circuit breaker 2

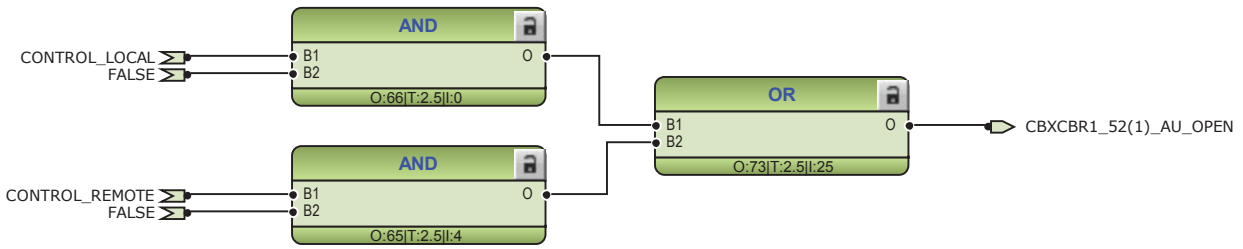

Figure 95: External opening command for circuit breaker 1

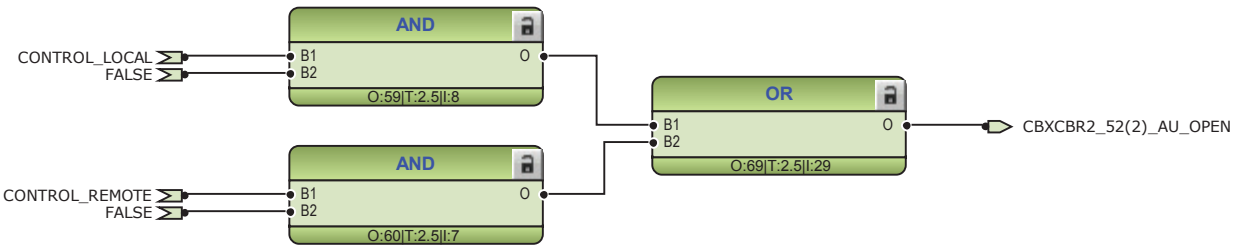

Figure 96: External opening command for circuit breaker 2

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the relay 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.

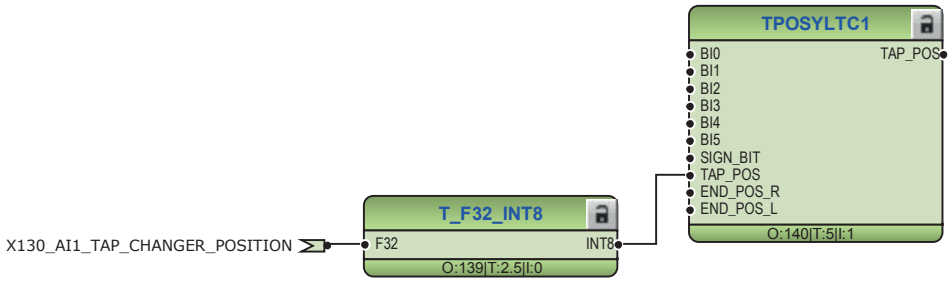

Figure 97: Tap changer position indicator

3.4.3.5 Functional diagrams for measurement functions

The high-voltage side and medium-voltage side phase current inputs to the relay 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 medium-voltage side.

The high-voltage side three-phase voltage inputs to the relay 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 Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

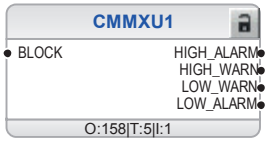

Figure 98: Three-phase current measurement (HV side)

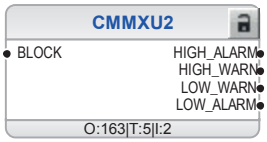

Figure 99: Three-phase current measurement (MV side)

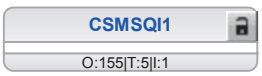

Figure 100: Sequence current measurement (HV side)

Figure 101: Ground current measurement (MV side)

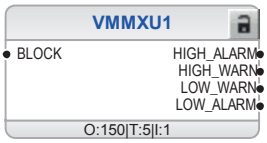

Figure 102: Three-phase voltage measurement (HV side)

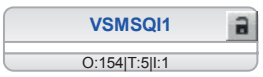

Figure 103: Sequence voltage measurements (HV side)

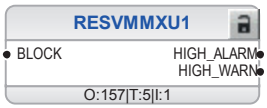

Figure 104: Ground voltage measurements (HV side)

Figure 105: Frequency measurement

Figure 106: Three-phase power and energy measurement

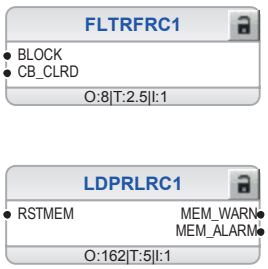

Figure 107: Data monitoring and load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

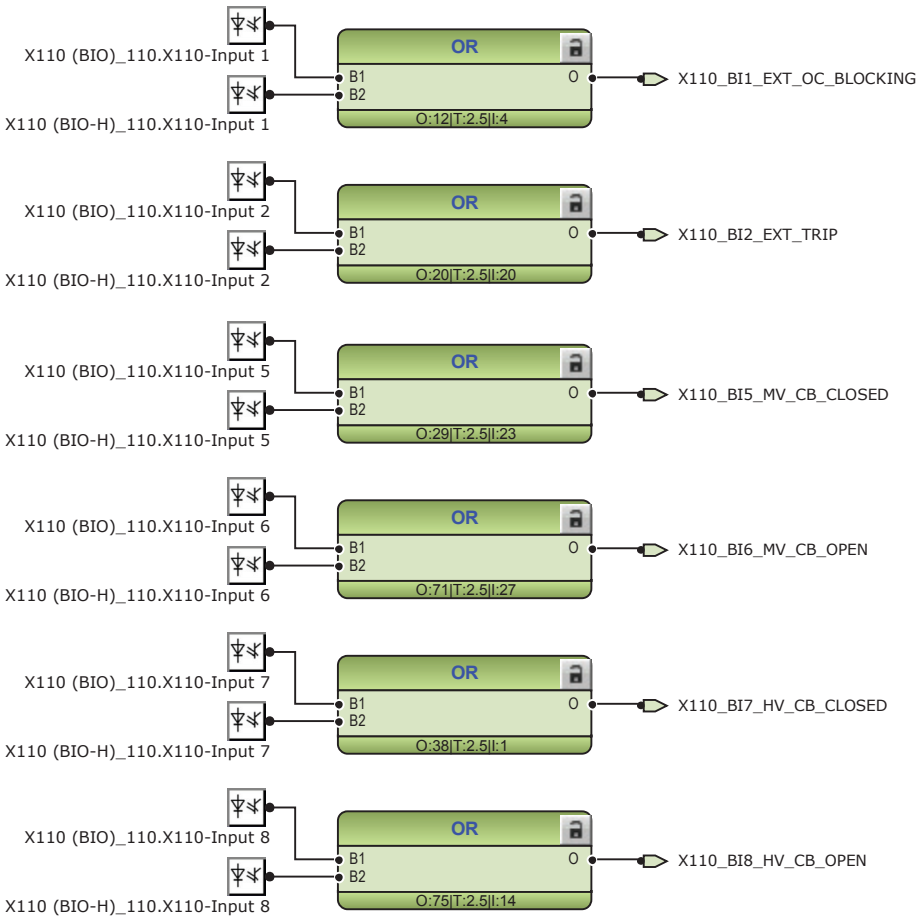

Figure 108: Default binary inputs - X110

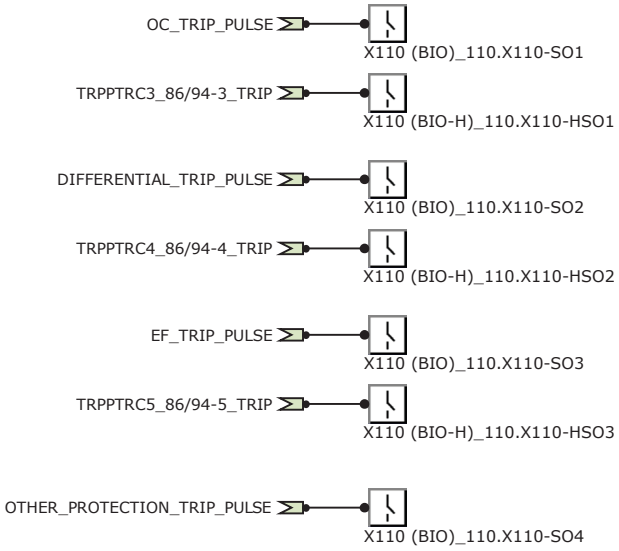

Figure 109: Default binary outputs - X110

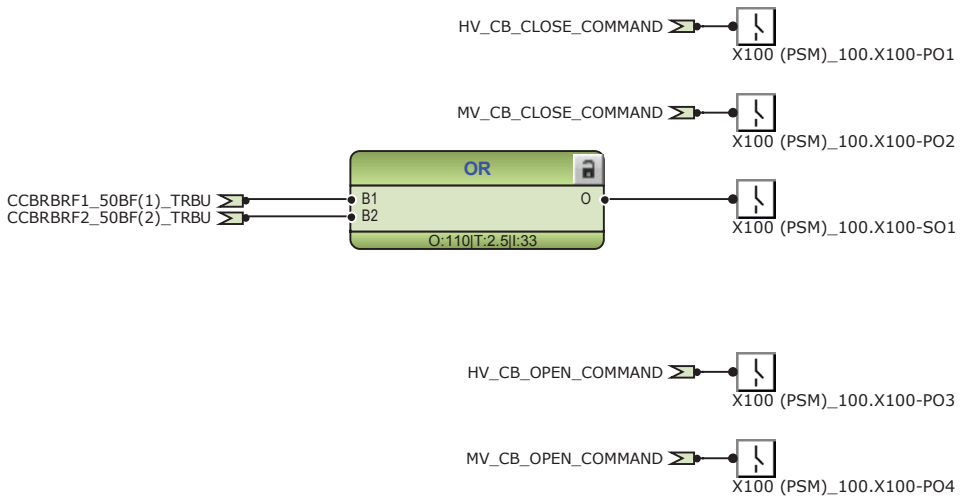

Figure 110: Default binary outputs - X100

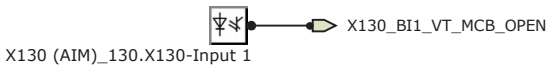

Figure 111: Default binary input - X130

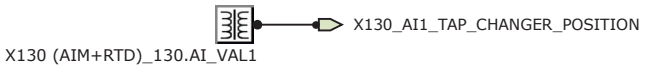

Figure 112: mA/TRD input - X130

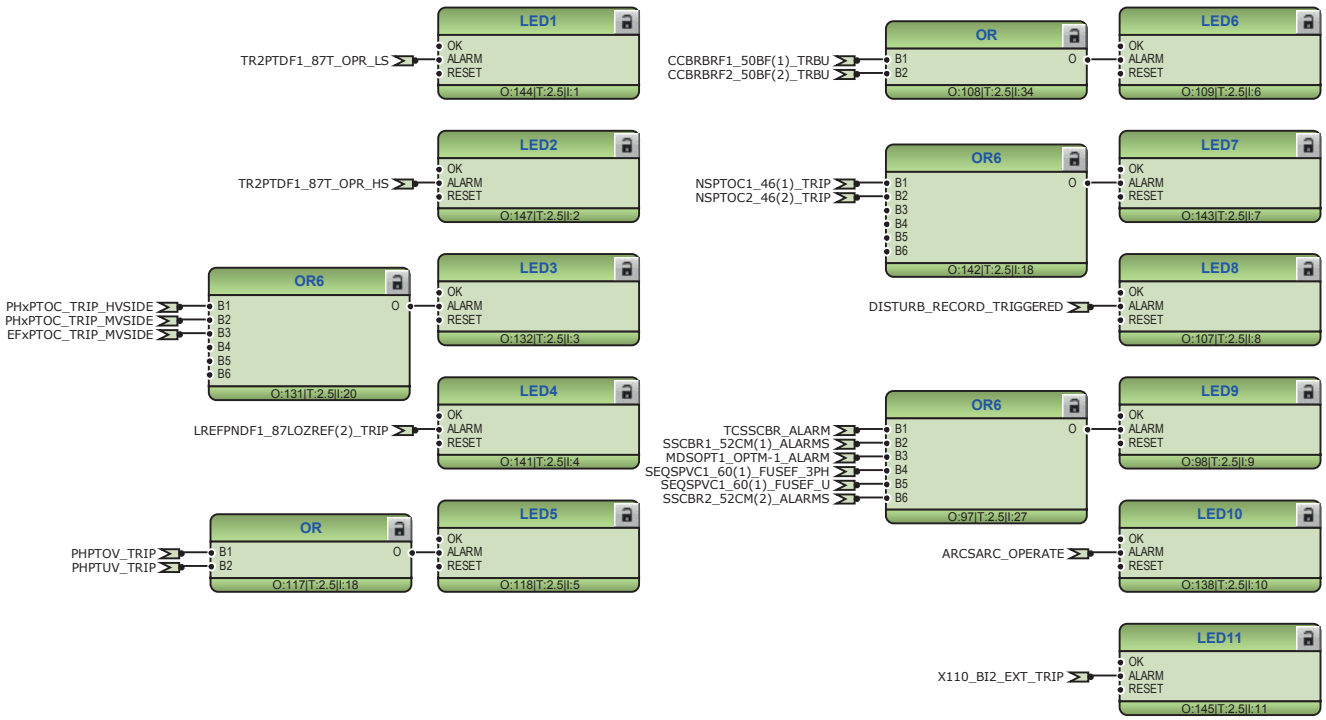

Figure 113: Default LED connection

3.4.3.7 Functional diagrams for other functions

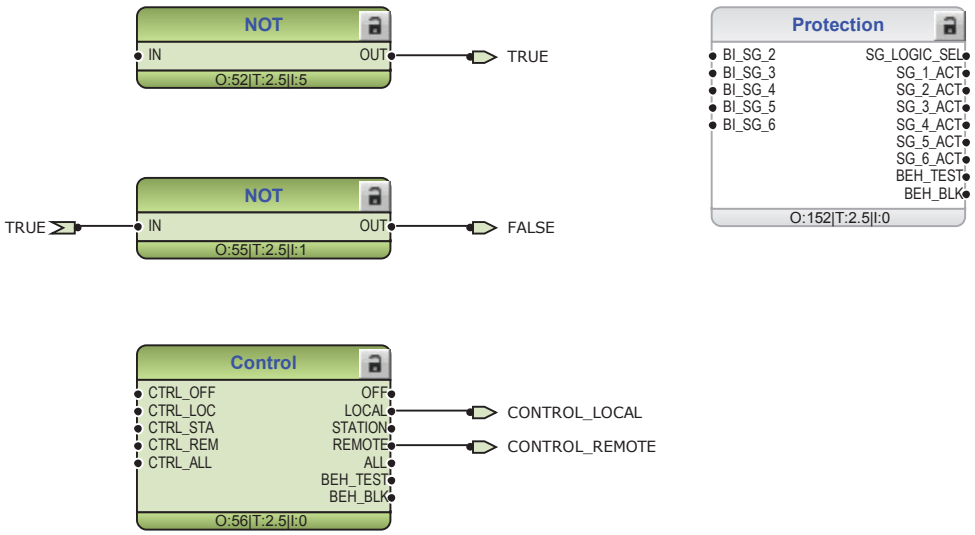

Figure 114: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.4.3.8 Functional diagrams for other timer logics

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

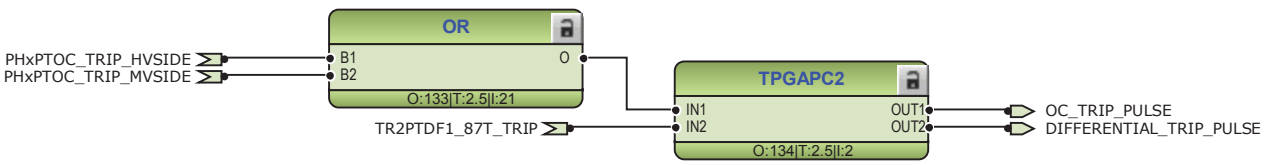

Figure 115: Timer logic for overcurrent and differential trip pulse

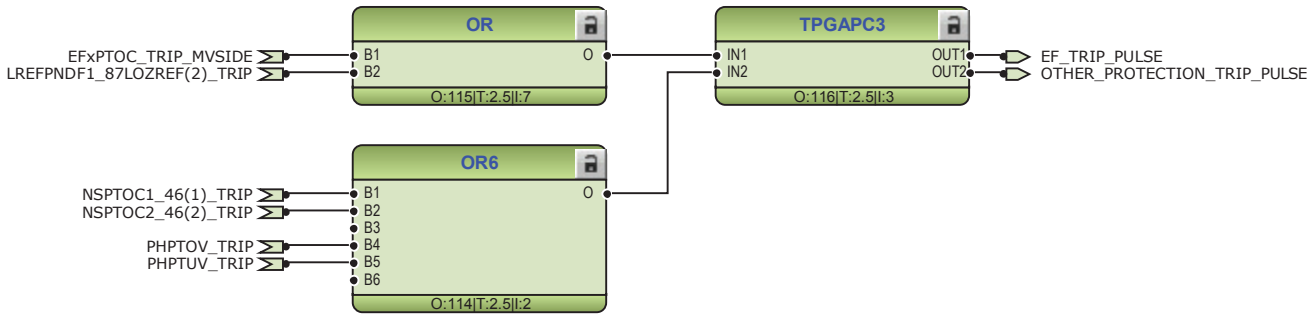

Figure 116: Timer logic for ground-fault and negative sequence with thermal overload protection trip alarm

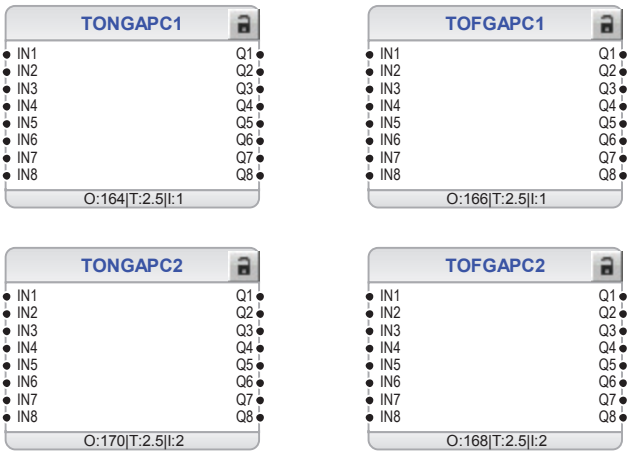

Figure 117: Programmable timers

3.4.3.9 Functional diagrams for communication

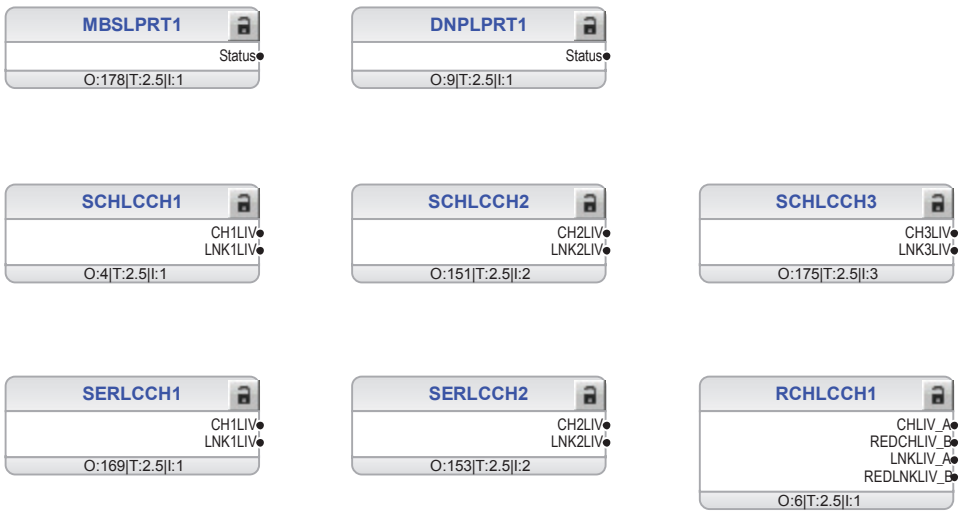

Figure 118: Default communication function connection

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for overcurrent protection

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

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

4.1.1.1 Current transformer accuracy class and accuracy limit factor

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

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

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

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

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

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

The actual accuracy limit factor is calculated using the formula:

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

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

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

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

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

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

I_{kmax} is the highest fault current.

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

Recommended pickup current settings

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

Current pickup 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 trip 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 pickup 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 trip 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 pickup current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the trip 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 pickup 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 pickup value* / I_{1n}

The *Current pickup value* is the primary pickup 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.

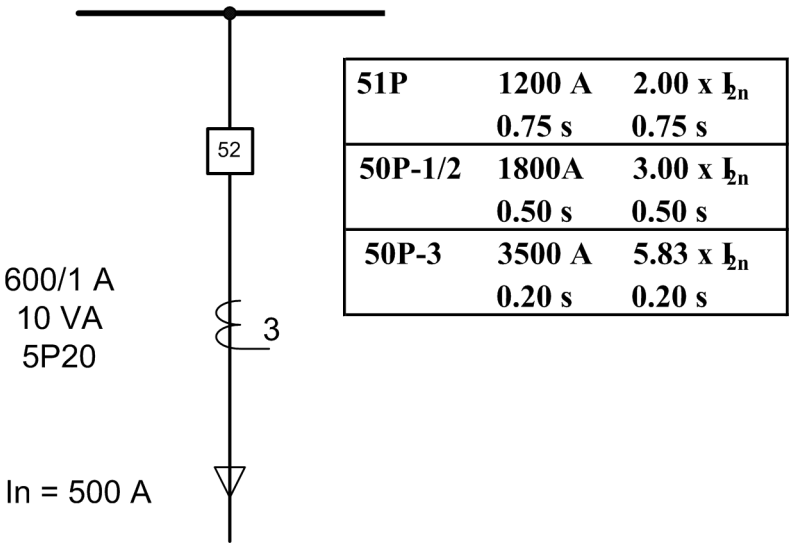

Figure 119: Example of three-stage overcurrent protection

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 pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next protection relay (not visible in Figure 119). 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 pickup current settings have to be defined so that the protection relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in Figure 119.

For the application point of view, the suitable setting for instantaneous stage (50P-3) in this example is 3 500 A ($5.83 \times I_{2n}$). 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

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

Table 22: Phase current inputs

Terminal	Description
X120:1-2	IA2
X120:3-4	IB2
X120:5-6	IC2
X120:7-8	IA
X120:9-10	IB
X120:11-12	IC

5.1.1.2 Ground current

Table 23: Ground current input

Terminal	Description
X120:13-14	IG

5.1.1.3 Phase voltages

Table 24: Phase voltage inputs included in configuration F

Terminal	Description
X130:11-12	VA
X130:13-14	VB
X130:15-16	VC

5.1.1.4 Ground voltage

Table 25: Additional residual voltage input included in configuration F

Terminal	Description
X130:17-18	

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 is marked on the LHMI of the protection relay on the top of the HMI of the plug-in unit.

Table 26: Auxiliary voltage supply

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

5.1.3 Binary inputs

The binary inputs can be used, for example, to generate a blocking signal, to unlatch output contacts, to trigger the digital fault recorder or for remote control of protection relay's settings.

Binary inputs of slot X110 are available with configurations B and F.

Table 27: 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, -

Table continues on next page

Terminal	Description
X110:10	BI6, +
X110:11	BI7, +
X110:12	BI7, -
X110:12	BI8, -
X110:13	BI8, +

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

Terminal	Description
X110:1	BI1, +
X110:5	BI1, -
X110:2	BI2, +
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 is optional for configuration B.

Table 29: 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, -

Table continues on next page

Terminal	Description
X130:6	BI4, +
X130:7	BI5, +
X130:8	BI5, -
X130:8	BI6, -
X130:9	BI6, +

Binary inputs of slot X130 are optional for configuration F.

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

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

5.1.4 Optional light sensor inputs

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

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 flash detector option is selected when ordering a protection relay, the light sensor inputs are included in the communication module.

Table 31: Light sensor input connectors

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

5.1.5 RTD/mA inputs

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

Table 32: Optional RTD/mA inputs with RTD0001 module

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), -
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 33: Optional RTD/mA inputs with AIM0003 module

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 34: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCM resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCM1 input), NO
X100:19	PO3 (TCM1 input), NO
X100:20	PO4, NO (TCM resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCM2 input), NO
X100:24	PO4 (TCM2 input), NO

5.2.2 Outputs for signalling

SO output contacts can be used for signalling on pickup and tripping of the protection relay. On delivery from the factory, the pickup and alarm signals from all the protection stages are routed to signalling outputs.

Table 35: Output contacts X100:10-14

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

Output contacts of slot X110 are available with configurations B and F.

Output contacts of slot X110 are optional.

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

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

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

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

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

Output contacts of slot X130 are optional for configuration B.

Table 38: Output contacts X130:10-18

Terminal	Description
X130:10	SO1, common
X130:11	SO1, NO
X130:12	SO1, NC
X130:13	SO2, common
X130:14	SO2, NO

Table continues on next page

Terminal	Description
X130:15	SO2, NC
X130:16	SO3, common
X130:17	SO3, NO
X130:18	SO3, NC

5.2.3 IRF

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

Table 39: IRF contact

Terminal	Description
X100:3	IRF, common
X100:4	Closed; IRF, or V_{aux} disconnected
X100:5	Closed; no IRF, and V_{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
AI	Analog input
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DFR	Digital fault recorder
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.
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
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 61850	International standard for substation communication and modeling
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IP	Internet protocol
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.
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy 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
SNTP	Simple Network Time Protocol
SO	Signal output
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
UDP	User datagram protocol
UL	Underwriters Laboratories
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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