RELION® 615 SERIES

Motor Protection and Control REM615 ANSI

Application Manual

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Table of contents

Section 1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

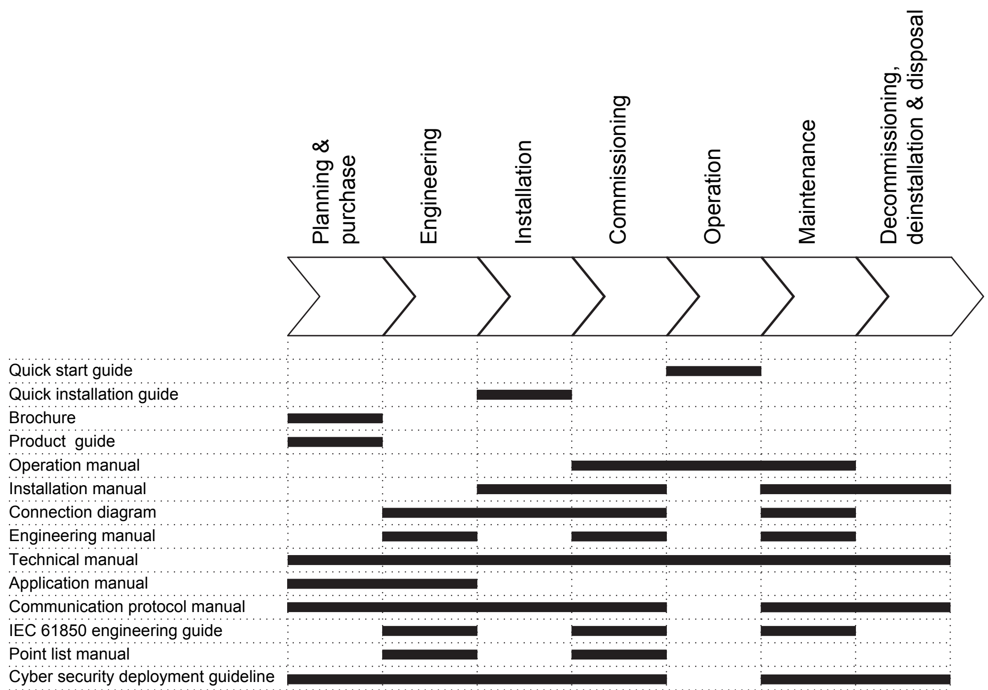


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2018-02-26	5.0 FP1	First release
B/2019-05-08	5.0 FP1	Content updated
C/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
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	50P-1
	PHHPTOC2	3I>> (2)	50P-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
Non-directional ground-fault protection, low stage	EFLPTOC1	Io> (1)	51G
Non-directional ground-fault protection, high stage	EFHPTOC1	Io>> (1)	50G-1
	EFHPTOC2	Io>> (2)	50G-2
Directional ground-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67/51N
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G-1
	ROVPTOV2	Uo> (2)	59N-1
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27-1
	PHPTUV2	3U< (2)	27-2
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59-1
	PHPTOV2	3U> (2)	59-2
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	27PS
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47-1
	NSPTOV2	U2> (2)	47-2
Three-phase remnant undervoltage protection	MSVPR1	3U< (1)	27R
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81-1
	FRPFRQ2	f>/f<,df/dt (2)	81-2
Overexcitation protection	OEPVPH1	U/f> (1)	24-1
	OEPVPH2	U/f> (2)	24-2
Negative-sequence overcurrent protection for machines	MNSPTOC1	I2>M (1)	46M-1
	MNSPTOC2	I2>M (2)	46M-2
Loss of load supervision	LOFLPTUC1	3I< (1)	37M-1
	LOFLPTUC2	3I< (2)	37M-2
Motor load jam protection	JAMPTOC1	Ist> (1)	51LR-1
	JAMPTOC2	Ist> (2)	51LR-2
Motor start-up supervision	STTPMSU1	Is2t n< (1)	66/51LRS
Phase reversal protection	PREVPTOC1	I2>> (1)	46R
Thermal overload protection for motors	MPTTR1	3Ith>M (1)	49M
Motor differential protection	MPDIF1	3dI>M	87M
High-impedance differential protection for phase A	HIAPDIF1	dHi_A>(1)	87A
High-impedance differential protection for phase B	HIBPDIF1	dHi_B>(1)	87B
High-impedance differential protection for phase C	HICPDIF1	dHi_C>(1)	87C

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	50BF
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
Arc protection	ARCSARC1	ARC (1)	AFD-1
	ARCSARC2	ARC (2)	AFD-2
	ARCSARC3	ARC (3)	AFD-3
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
Underpower protection	DUPPDPR1	P< (1)	32U-1
	DUPPDPR2	P< (2)	32U-2
Reverse power/directional overpower protection	DOPPDPR1	P>/Q> (1)	32O-1
	DOPPDPR2	P>/Q> (2)	32O-2
	DOPPDPR3	P>/Q> (3)	32O-3
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	52
Disconnector control	DCXSWI1	I <-> O DCC (1)	29DS-1
	DCXSWI2	I <-> O DCC (2)	29DS-2

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
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
Emergency startup	ESMGAPC1	ESTART (1)	62EST
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	52CM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM-1
	TCSSCBR2	TCS (2)	TCM-2
Current circuit supervision	CCSPVC1	MCS 3I (1)	CCM
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60
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
	CMMXU2	3I (2)	IA, IB, IC (2)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0
Residual current measurement	RESCMMXU1	Io (1)	IG
Three-phase voltage measurement	VMMXU1	3U (1)	VA, VB, VC
Residual voltage measurement	RESVMMXU1	Uo (1)	VG
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0
Single-phase power and energy measurement	SPEMMXU1	SP, SE	SP, SE-1
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E-1
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f
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	TPGAPC1	TP (1)	62TP-1
	TPGAPC2	TP (2)	62TP-2
	TPGAPC3	TP (3)	62TP-3
	TPGAPC4	TP (4)	62TP-4

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
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
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 REM615 overview

2.1 Overview

REM615 is a dedicated motor protection and control relay designed for the protection, control, measurement and supervision of induction motors in manufacturing and process industry. REM615 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 • Single phase power and energy measurement • Load profile recorder
4.2	• New configurations to tailor for core balance current differential and RTD through RIO600 application • Core balance current differential functions • Generic up-down counters • Remnant voltage protection function • Over/under directional real/reactive power protection functions • Support for HSR/PRP protocol support for a limited configurations
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 • 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

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.8 or later
- REM615 Connectivity Package Ver.5.1 or later
  - Parameter Setting
  - Signal Monitoring
  - Event Viewer
  - Disturbance Handling
  - Application Configuration
  - Signal Matrix
  - Graphical Display Editor
  - Communication Management
  - IED User Management
  - IED Compare
  - Firmware Update
  - Fault Record tool
  - Load Record Profile

- Lifecycle Traceability
- Configuration Wizard
- AR Sequence Visualizer
- Label Printing
- IEC 61850 Configuration
- IED Configuration Migration

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

2.2 Operation functionality

2.2.1 Optional features

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- DNP3 TCP/IP or serial
- RTD/mA measurements and multipurpose protection (configurations A and B only)
- IEC 61850-9-2 LE (configurations B, D only)
- 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 A, B, D and E: 8 binary inputs 4 SO contacts
			Only with configurations A, B, D and E: 8 binary inputs 3 high-speed SO contacts
	X120	AI/BI module	Only with configuration A: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A) 3 binary inputs
			Only with configuration A: 3 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)] 3 binary inputs
			Only with configuration B: 3 phase voltage inputs (60...210 V) 3 phase current inputs (1/5 A) 1 residual current input (1/5 A)
			Only with configuration E: 6 phase current inputs (1/5 A) 1 residual current input (1/5 A)
			Only with configurations B: 3 phase voltage inputs (60...210 V) 3 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)]
Case	X130	Optional RTD/mA module	Optional for configurations A and B: 2 generic mA inputs 6 RTD sensor inputs
		AI/BI module	Only with configuration E: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
		Optional BIO module	Optional for configuration B: 6 binary inputs 3 SO contacts
		Sensor input module	Only with configuration D: 3 combi sensor inputs (three-phase current and voltage) 1 residual current input (0.2/1 A)[1)]
	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	Combi sensor	BI	BO	RTD	mA
A	AC/AD	AB	4	-	-	4	4 PO + 2 SO	-	-
		AD	4	-	-	12	4 PO + 6 SO	-	-
		FE	4	-	-	12	4 PO + 6 SO	-	-
	AG/AH	AB	4	-	-	4	4 PO + 2 SO + 3 HSO	6	2
B	CA/CB	AH	4	3	-	8	4 PO + 6 SO	-	-
		AJ	4	3	-	14	4 PO + 9 SO	-	-
		FD	4	3	-	8	4 PO + 2 SO + 3 HSO	-	-
		FF	4	3	-	14	4PO +5SO +3HSO	-	-
	CC/CD	AH	4	3	-	8	4 PO + 6 SO	6	2
		FD	4	3	-	8	4 PO + 2 SO + 3 HSO	6	2

Table continues on next page

Std. conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
D	DA	AH	1	-	3	8	4 PO + 6 SO	-	-
		FD	1	-	3	8	4 PO + 2 SO + 3 HSO	-	-
E	BC	AD	7	5	-	12	4 PO + 6 SO	-	-
		FE	7	5	-	12	4 PO + 2 SO + 3 HSO	-	-

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.

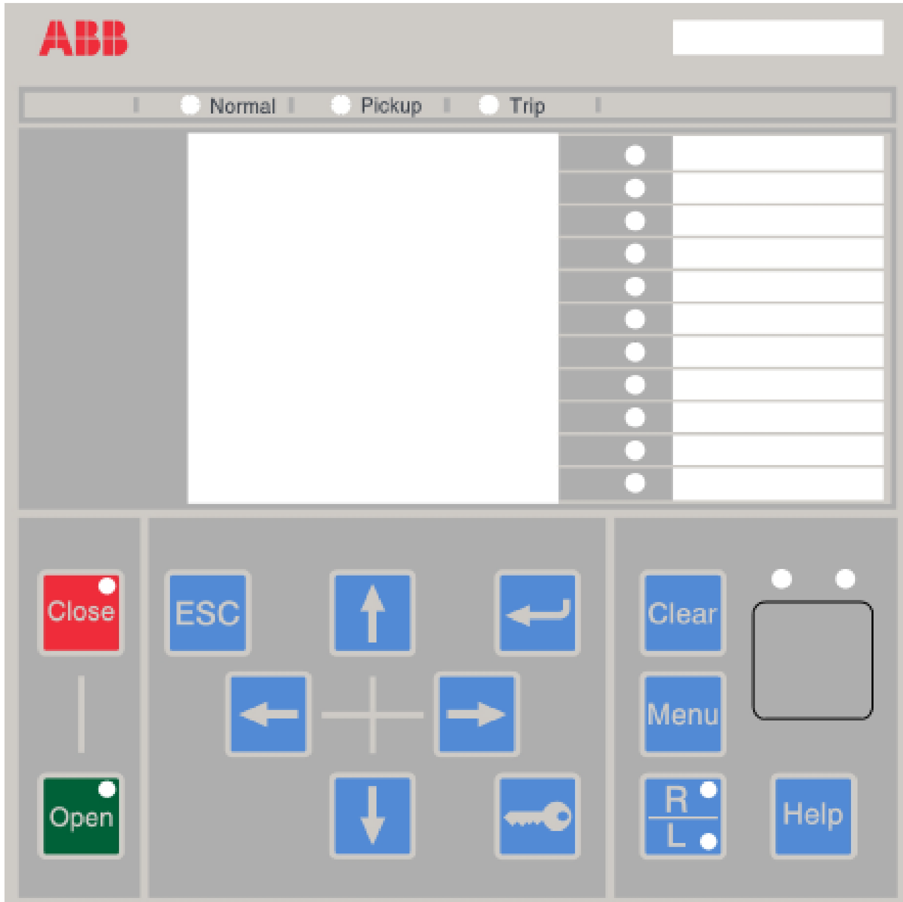


Figure 2: Example of the LHMI

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.

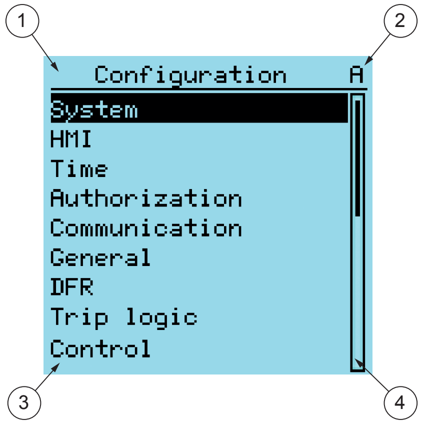


Figure 3: Display layout

1 Header

2 Icon

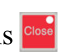
3 Content

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.

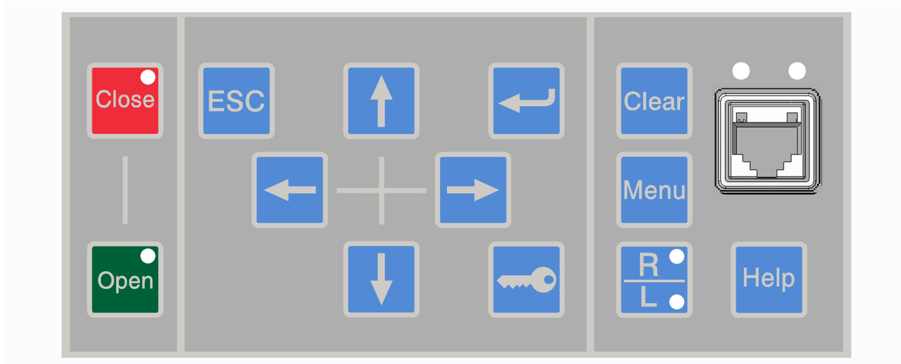


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

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.

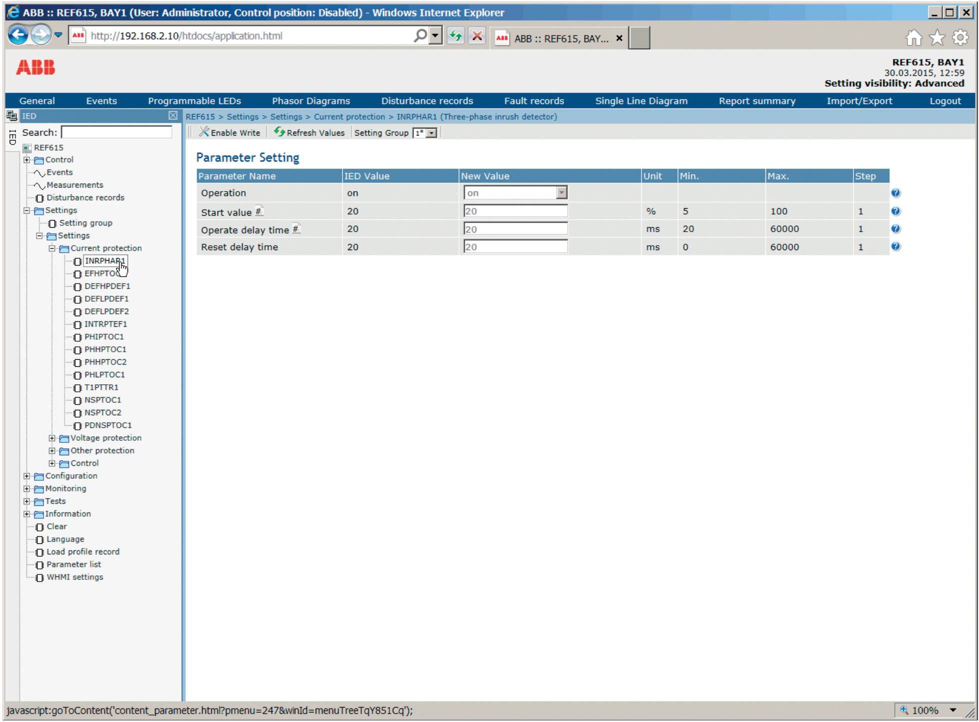


Figure 5: Example view of the WHMI

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 R/L (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.

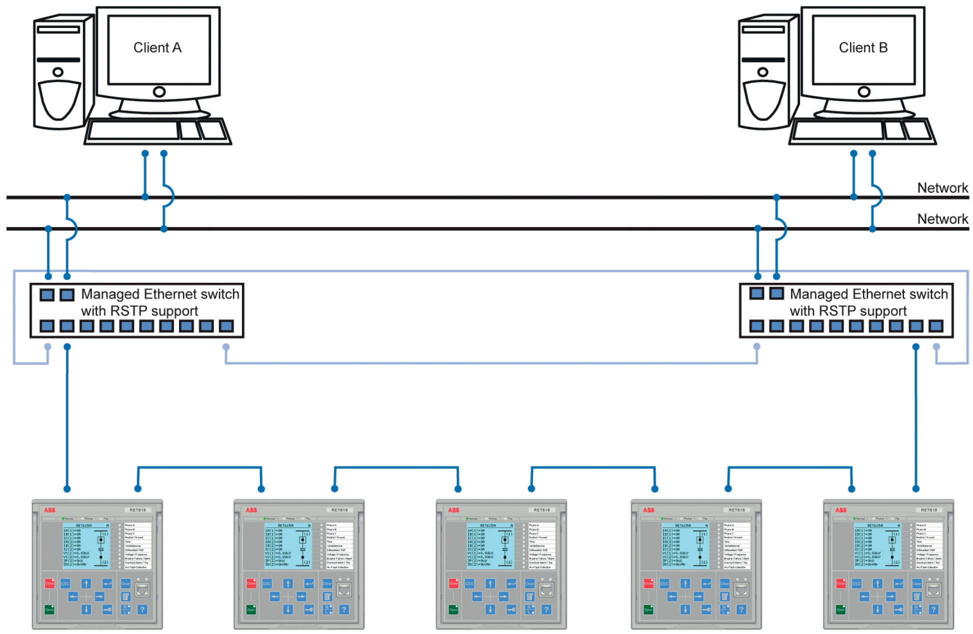


Figure 6: Self-healing Ethernet ring solution

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.

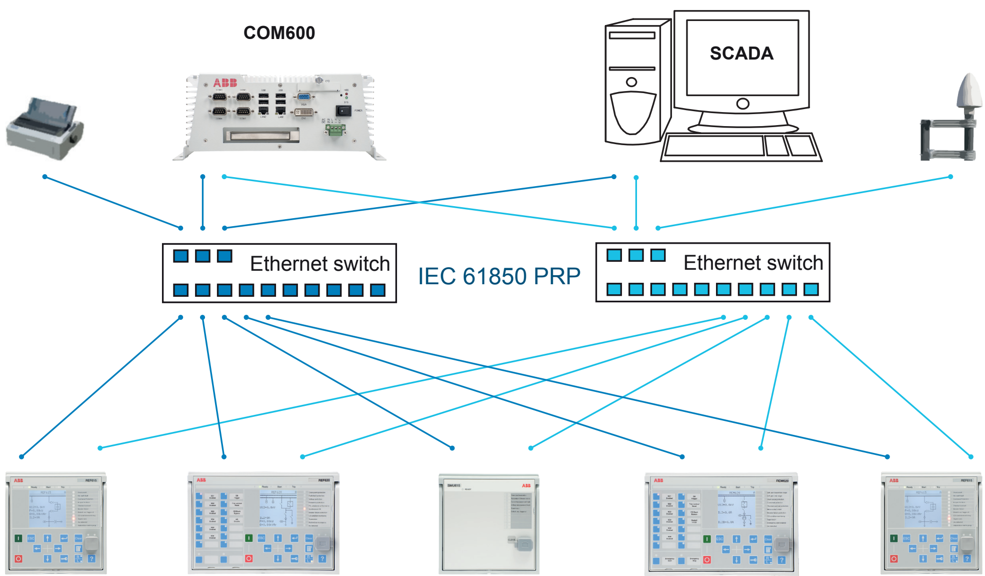


Figure 7: PRP solution

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.

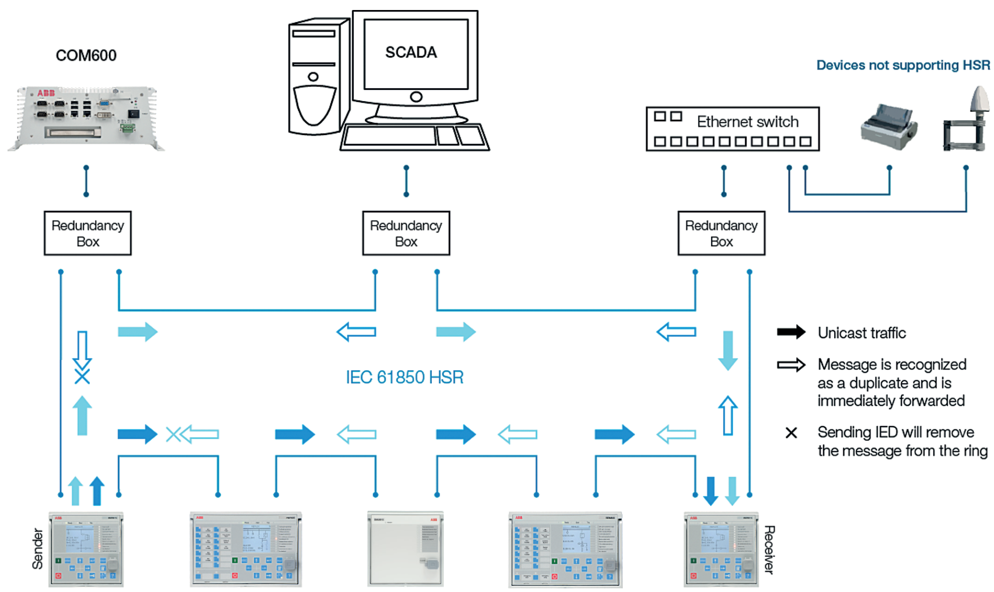


Figure 8: HSR solution

Section 3 REM615 standard configurations

3.1 Standard configurations

REM615 is available with four alternative standard configurations. The standard signal configuration can be altered by means of the graphical signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of the relay supports the creation of multi-layer logic functions using various logical elements including timers and flip-flops. By combining protection functions with logic function blocks, the relay configuration can be adapted to user-specific application requirements.

The relay is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. Some of the supported functions in REM615 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.
Basic motor protection (RTD option)	A
Motor protection with voltage and frequency based protection and measurements (RTD option)	B
Motor protection with voltage and frequency based protection and measurements (sensor inputs)	D
Differential (core balance and true), overcurrent, load loss, phase and neutral voltage, frequency and RTD protection, power protection and power system metering for medium to large motors	E

Table 8: Supported functions

Function	IEC 61850	ANSI	A	B	D	E
Protection						
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	51P	1	1	1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	50P	1	1	1	2
Table continues on next page						

Function	IEC 61850	ANSI	A	B	D	E
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1	1	1
Non-directional ground-fault protection, low stage	EFLPTOC	51G	1			1
Non-directional ground-fault protection, high stage	EFHPTOC	50G	1	1	1	2
Directional ground-fault protection, low stage	DEFLPDEF	67/51N		1	1	1
Residual overvoltage protection	ROVPTOV	59G				1
		59N				1
Three-phase undervoltage protection	PHPTUV	27		1	1	2
Three-phase overvoltage protection	PHPTOV	59				2
Positive-sequence undervoltage protection	PSPTUV	27PS		1	1	1
Negative-sequence overvoltage protection	NSPTOV	47		1	1	2
Three-phase remnant undervoltage protection (source 1)	MSVPR	27R		1	1	1
Frequency protection	FRPFRQ	81		2	2	2
Overexcitation protection	OEPVPH	24				2
Negative-sequence overcurrent protection for machines	MNSPTOC	46M	2	2	2	2
Loss of load supervision	LOFLPTUC	37M	1	1	1	2
Motor load jam protection	JAMPTOC	51LR	1	1	1	2
Motor start-up supervision	STTPMSU	66/51LRS	1	1	1	1
Phase reversal protection	PREVPTOC	46R	1	1	1	1
Thermal overload protection for motors	MPTTR	49M	1	1	1	1
Motor differential protection	MPDIF	87M				1
High-impedance differential protection for phase A	HIAPDIF	87A				1
High-impedance differential protection for phase B	HIBPDIF	87B				1
High-impedance differential protection for phase C	HICPDIF	87C				1
Circuit breaker failure protection	CCBRBRF	50BF	1	1	1	1
Master trip	TRPPTRC	86/94	2 (3)[1)]	2 (3)[1)]	2 (3)[1)]	2 (3)[1)]

Table continues on next page

Function	IEC 61850	ANSI	A	B	D	E
Arc protection	ARCSARC	AFD	(3)	(3)	(3)	(3)
Multipurpose protection	MAPGAPC	MAP	18	18	18	18
Underpower protection	DUPPDPR	32U				2
Reverse power/directional overpower protection	DOPPDPR	32O				3
Control						
Circuit-breaker control	CBXCBR	52	1	1	1	1
Disconnector control	DCXSWI	29DS	2	2	2	2
Grounding switch control	ESXSWI	29GS	1	1	1	1
Disconnector position indication	DCSXSWI	52-TOC	1	1	1	1
		29DS	2	2	2	2
Grounding switch indication	ESSXSWI	29GS	2	2	2	2
Emergency start-up	ESMGAPC	62EST	1	1	1	1
Condition monitoring						
Circuit-breaker condition monitoring	SSCBR	52CM	1	1	1	1
Trip circuit supervision	TCSSCBR	TCM	2	2	2	2
Current circuit supervision	CCSPVC	CCM	1	1	1	1
Fuse failure supervision	SEQSPVC	60		1	1	1
Runtime counter for machines and devices	MDSOPT	OPTM	1	1	1	1
Measurement						
Load profile record	LDPRLRC	LoadProf	1	1	1	1
Three-phase current measurement	CMMXU	IA, IB, IC	1	1	1	2
Sequence current measurement	CSMSQI	I1, I2, I0	1	1	1	1
Residual current measurement	RESCMMXU	IG	1	1	1	1
Three-phase voltage measurement	VMMXU	VA, VB, VC		1	1	1
Residual voltage measurement	RESVMMXU	VG				1
Sequence voltage measurement	VSMSQI	V1, V2, V0		1	1	1
Single-phase power and energy measurement	SPEMMXU	SP, SE		1	1	1
Three-phase power and energy measurement	PEMMXU	P, E		1	1	1
RTD/mA measurement	XRGGIO130	X130 (RTD)	(1)	(1)		

Table continues on next page

Function	IEC 61850	ANSI	A	B	D	E
Frequency measurement	FMMXU	f		1	1	1
IEC 61850-9-2 LE sampled value sending[2)]	SMVSENDER	SMVSENDER		(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing)[2)]	SMVRECEIVE R	SMVRECEIVE R		(1)	(1)	(1)
Other						
Minimum pulse timer (2 pcs)	TPGAPC	62TP	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	62PT	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	62TOF	4	4	4	4
Time delay on (8 pcs)	TONGAPC	62TON	4	4	4	4
Set-reset (8 pcs)	SRGAPC	SR	4	4	4	4
Move (8 pcs)	MVGAPC	MV	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	SPC	2	2	2	2
Analog value scaling	SCA4GAPC	SCA4	4	4	4	4
Integer value move	MVI4GAPC	MVI4	1	1	1	1
Generic up-down counters	UDFCNT	CTR	4	4	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						

1) 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.
2) 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

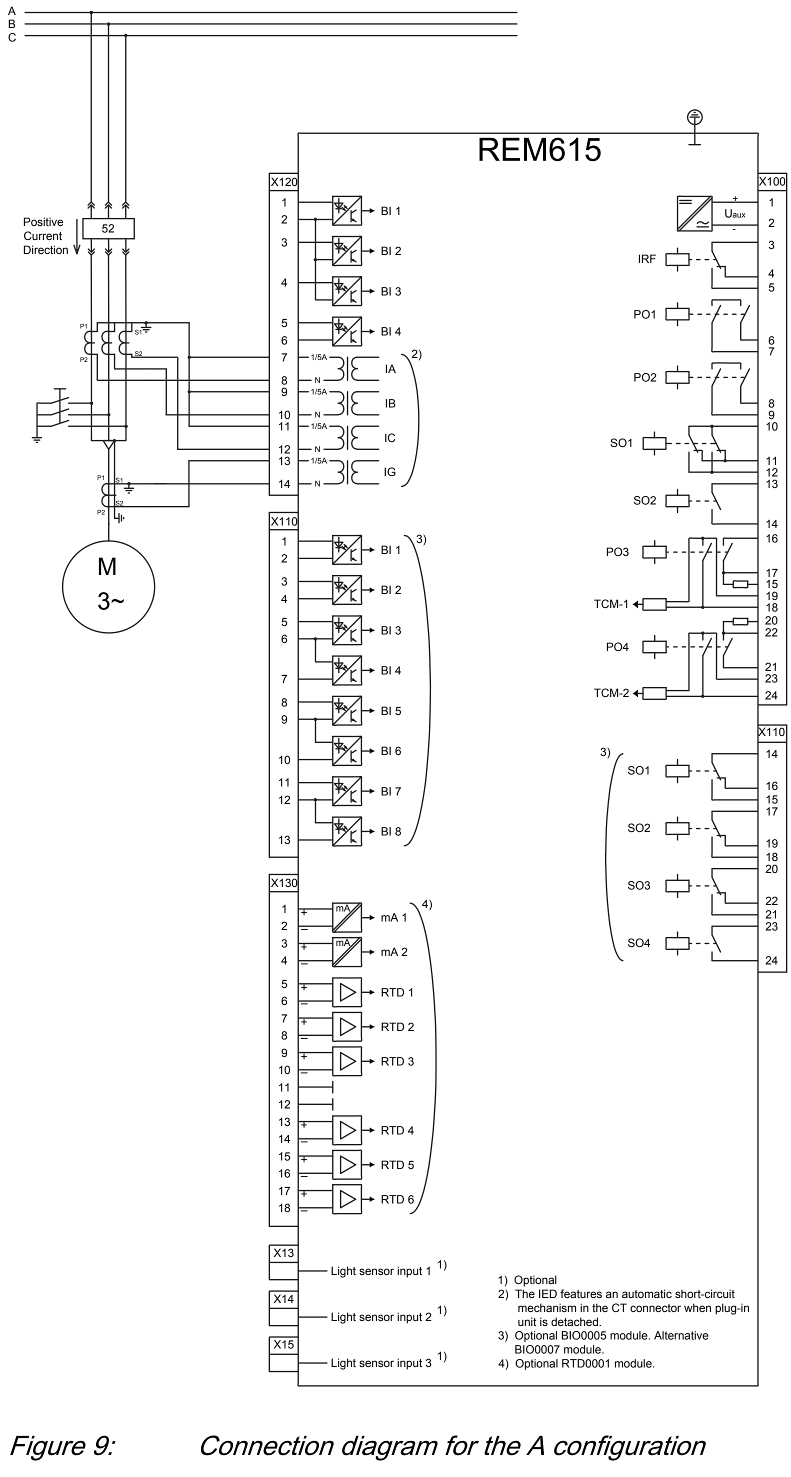


Figure 9: Connection diagram for the A configuration

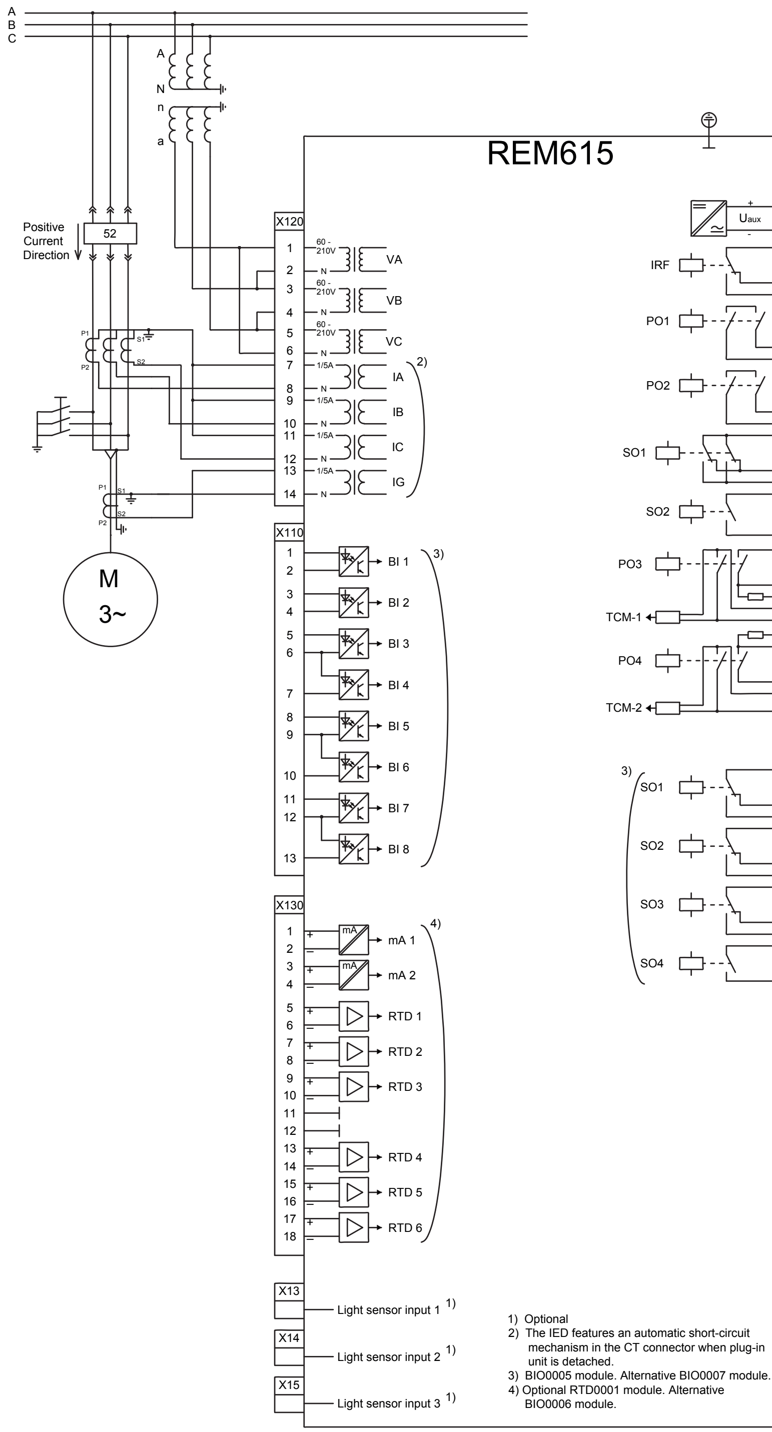


Figure 10: Connection diagram for the B configuration

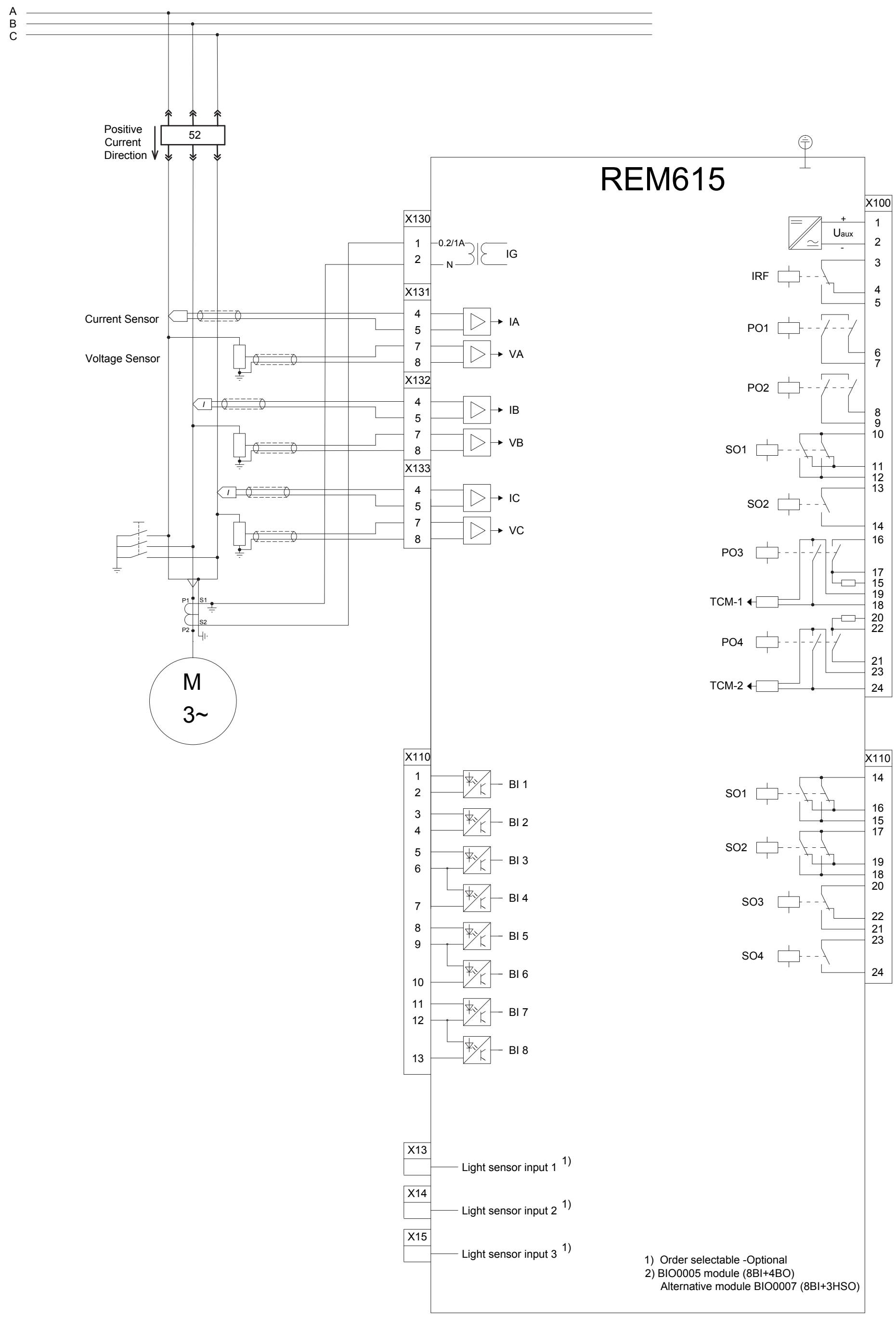


Figure 11: Connection diagram for the D configuration

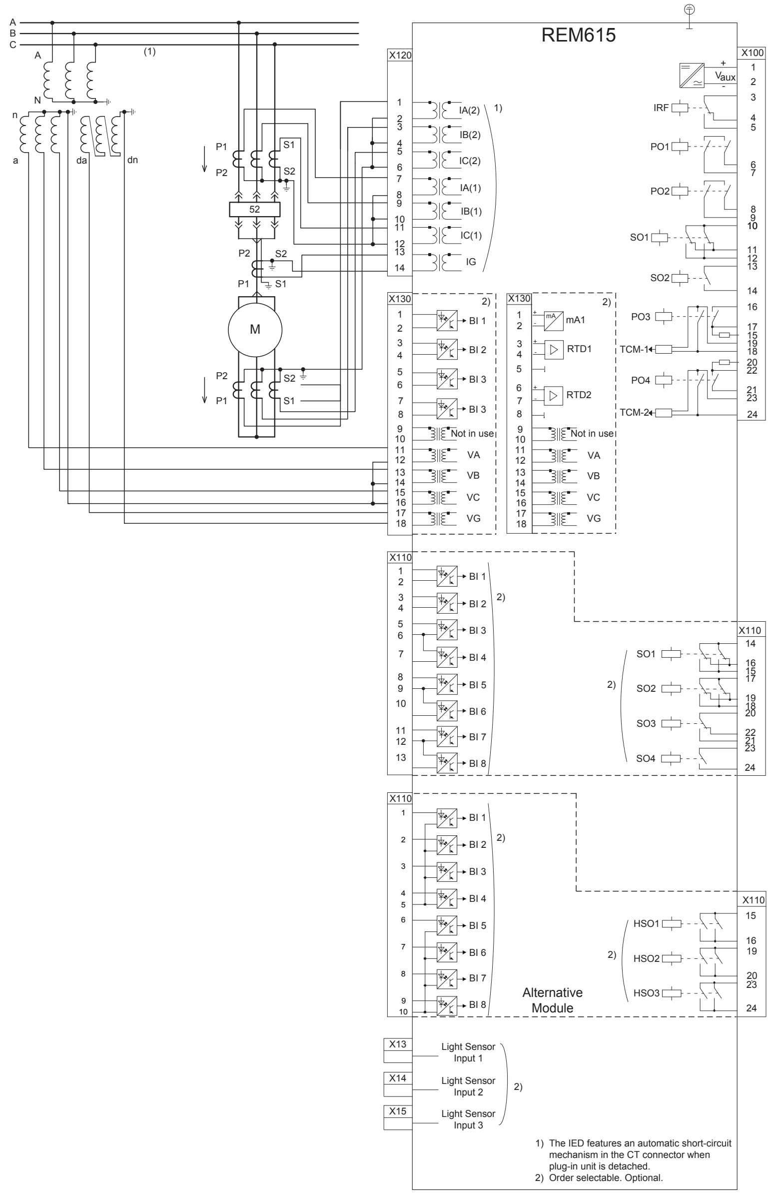


Figure 12: Connection diagram for the E configuration with wye VT and true differential protection based connection

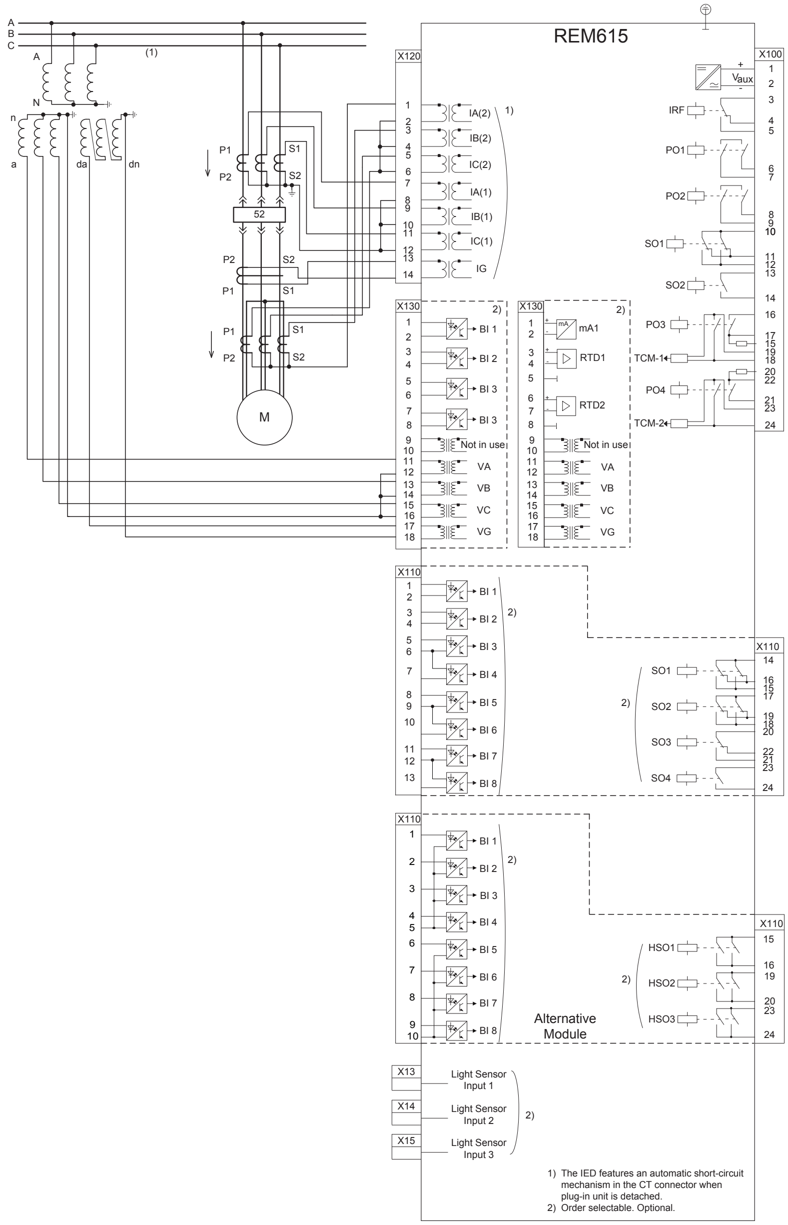


Figure 13: Connection diagram for the E configuration with wye VT and core-balance based differential protection connection

3.3 Standard configuration A

3.3.1 Applications

The standard configuration is intended for comprehensive protection and control functionality of circuit breaker controlled asynchronous motors. With minor modifications, the standard configuration can also be applied for contactor controlled motors. There is also an option for mA/RTD measurement and protection.

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

3.3.2 Functions

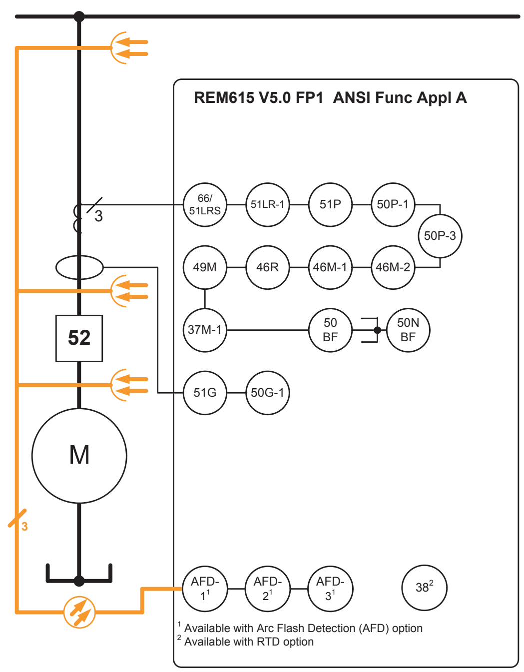


Figure 14: Functionality overview for standard configuration A

3.3.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
mA1	mA1	X130:1-2
mA2	mA2	X130:3-4
RTD1	Motor winding U temperature	X130:5-6
RTD2	Motor winding V temperature	X130:7-8
RTD3	Motor winding W temperature	X130:9-10
RTD4	Motor cooling air temperature	X130:13-14
RTD5	Motor bearing temperature	X130:15-16
RTD6	Motor ambient temperature	X130:17-18

Table 10: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	-	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10
X120-BI1	Emergency start	X120:1-2	
X120-BI2	Circuit breaker closed position indication	X120:3-2	
X120-BI3	Circuit breaker open position indication	X120:4-2	
X120-BI4	External restart inhibit	X120:5-6	

Table 11: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Restart enable	X100:6-7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8-9
X100-SO1	Open command (for contractor application)	X100:10-11,(12)
X100-SO2	Pickup indication	X100:13-14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X110-SO1	-	X110:14-16
X110-SO2	-	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	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	Short-circuit protection trip	LED_ShortCircuit_1	Short circuit
2	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
3	Thermal overload protection trip	LED_ThermalOverload_1	Thermal overload
4	Combined operate indication of the other protection functions	LED_CombinedProtection_1	Combined Protection
5	Motor restart inhibit	LED_MotorRestartInhibit_1	Motor restart inhibit
6	Breaker failure protection trip	LED_BreakerFailure_1	Breaker failure
7	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
8	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
9	TCS, motor runtime counter or measuring circuit fault alarm	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Emergency start enabled	LED_EmergencyStartEnabled	Emergency start enabled

3.3.2.2 Default disturbance recorder settings

Table 13: Default disturbance recorder analog channels

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

Table 14: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHIPTOC1 - pickup	Positive or Rising
3	EFLPTOC1 - pickup	Positive or Rising
4	EFHPTOC1 - pickup	Positive or Rising
5	MPTTR1 - alarm	Level trigger off
6	MPTTR1 - blk restart	Level trigger off
7	ESMGAPC1 - st emerg ena	Level trigger off
8	STTPMSU1 - mot startup	Positive or Rising
9	STTPMSU1 - lock start	Level trigger off
10	MNSPTOC1 - pickup	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - pickup	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - pickup	Positive or Rising
15	MAPGAPC1 - pickup	Positive or Rising
16	MAPGAPC2 - pickup	Positive or Rising
17	MAPGAPC3 - pickup	Positive or Rising
18	CCBRBRF1 - trret	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
19	CCBRBRF1 - trbu	Level trigger off
20	PHLPTOC1 - trip	Level trigger off
21	PHIPTOC1 - trip	Level trigger off
22	JAMPTOC1 - trip	Level trigger off
23	EFxPTOC1 - trip	Level trigger off
24	MNSPTOC - trip	Level trigger off
25	PREVPTOC1 - trip	Level trigger off
26	LOFLPTUC1 - trip	Level trigger off
27	MPTTR1 - trip	Level trigger off
28	MAPGAPC1 - trip	Level trigger off
29	MAPGAPC2 - trip	Level trigger off
30	MAPGAPC3 - trip	Level trigger off
31	X120BI1 - Emerg start ena	Level trigger off
32	X120BI2 - CB closed	Level trigger off
33	X120BI3 - CB open	Level trigger off
34	X120BI4 - Ext restart inhibit	Level trigger off
35	STTPMSU1 - opr iit	Positive or Rising
36	CCSPVC1 - fail	Level trigger off
37	ARCSARC - ARC flt det	Level trigger off
38	ARCSARC1 - trip	Positive or Rising
39	ARCSARC2 - trip	Positive or Rising
40	ARCSARC3 - trip	Positive or Rising
41	-	-
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 phase currents to the protection relay are fed from a current transformer. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages. The signal VG represents the measured ground voltage.

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

Two overcurrent stages are offered for overcurrent and short-circuit protection. The nondirectional low stage PHLPTOC1_51P can be used for overcurrent protection whereas the instantaneous stage PHIPTOC1_50P-3 can be used for short-circuit protection. The operation of PHIPTOC1_50P-3 is not blocked as default by any functionality and it should be set over the motor pickup current level to avoid unnecessary operation.

The Motor load jam protection function JAMPTOC1_51LR-1 is blocked by the motor start-up protection function.

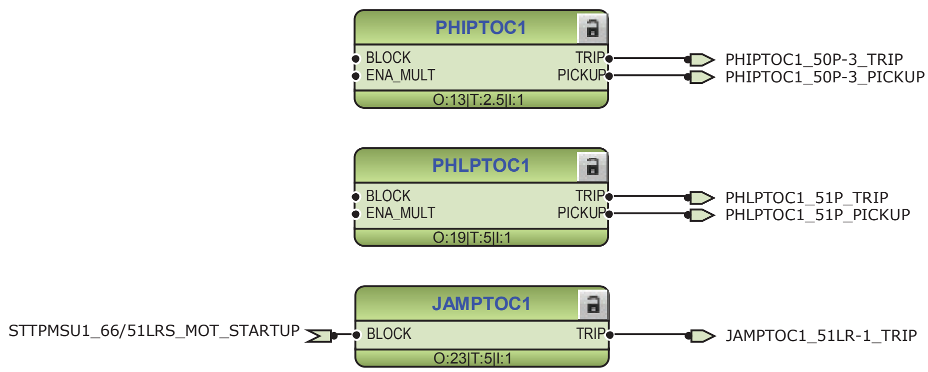


Figure 15: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect the motor against phase unbalance. Unbalance in the network feeder of the motor causes overheating of the motor.

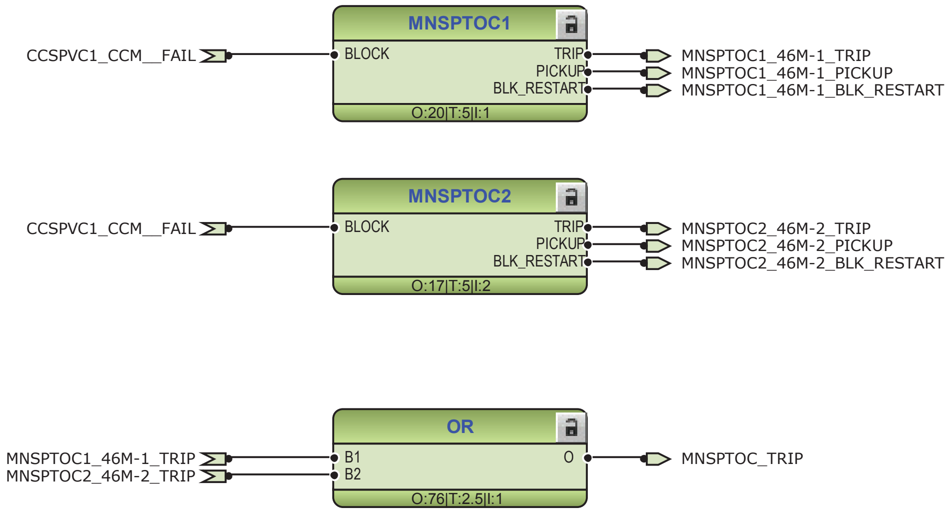


Figure 16: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1_46R is based on the calculated negative phase sequence current. It detects high negative-sequence current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

The negative-sequence and phase reversal protection are blocked if the current circuit supervision detects failure in the current measurement circuit.

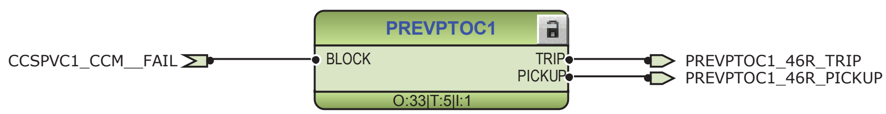


Figure 17: Phase reversal protection function

Two stages are provided for non-directional ground-fault protection to detect phase-to-ground faults that may be the result of, for example, insulation ageing.

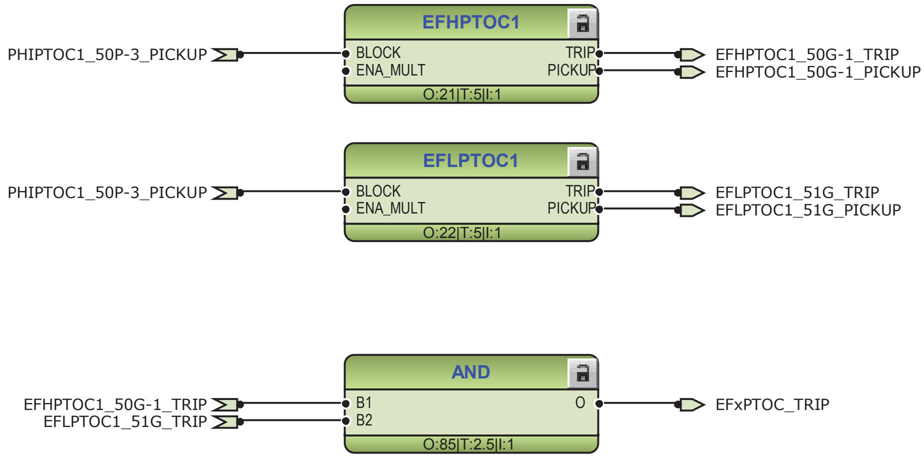


Figure 18: Ground-fault protection functions

The emergency start function ESMGAPC1_62EST allows motor start-ups although the calculated thermal level or cumulative start-up time counter is blocking the restart. The emergency start is enabled for ten minutes after the selected binary input X120:BI1 is energized.

On the rising edge of the emergency pickup signal, various events occur.

- The calculated thermal level in MPTTR1_49M is set slightly below the restart inhibit level to allow at least one motor start-up.
- The value of the cumulative start-up time counter STTPMSU1_66/51LRS is set slightly below the set restart inhibit value to allow at least one motor start-up.
- The set pickup value of the MAPGAPC1_MAP-1 function is increased (or decreased) depending on the *Pickup value Add* setting (only if the optional RTD/mA module is included).
- Alarm LED 11 is activated.

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time has expired.

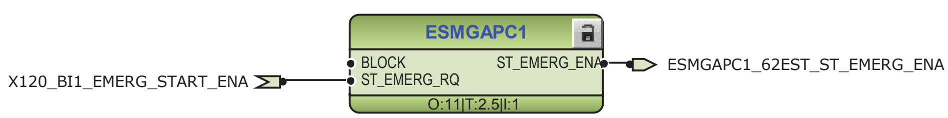


Figure 19: Motor emergency start-up function

The thermal overload protection for motors MPTTR1_49M detects short and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. Restart blocking, issued by the thermal overload function, prevents the closing of the breaker in machine overload situation. The emergency start request removes the blocking and enables the restarting of the motor.

If the relay is ordered with a RTD/mA card, the motor ambient temperature can be measured with input RTD X130:AI8 and it is connected to the thermal overload protection function MPTTR1_49M.

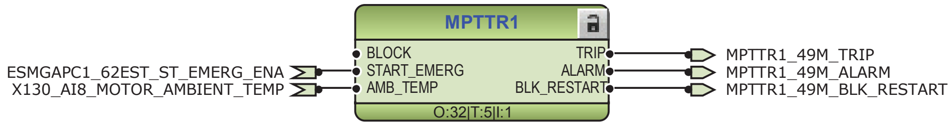


Figure 20: Motor thermal overload protection

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection where the motor has damping remanence voltage after the circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

The restart inhibit is also activated under various conditions.

- A trip command becomes active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- An external restart inhibit is activated by a binary input X120:BI4.

With the motor start-up supervision function STTPMSU1_66/51LRS, the starting of the motor is supervised by monitoring the three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1_62EST and STTPMSU1_66/51LRS is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

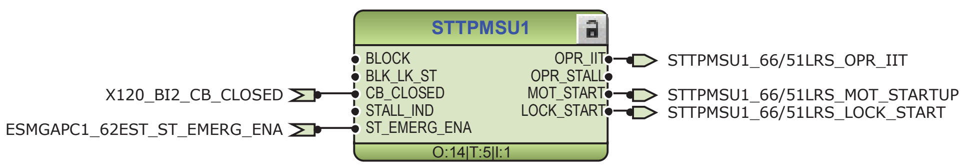


Figure 21: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1_OPTM-1 provides history data since the last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed.

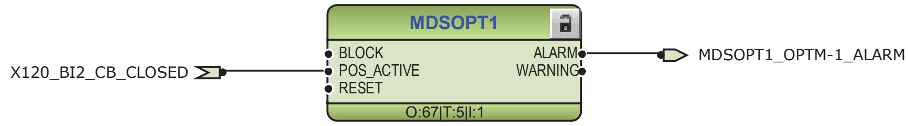


Figure 22: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1_37M-1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

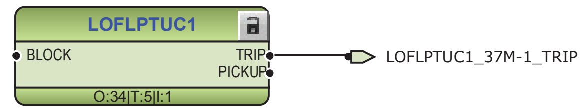


Figure 23: Loss of load protection function

The RTD/mA monitoring (optional) functionality provides several temperature measurements for motor protection. Temperature of the motor windings U, V and W is measured with inputs RTD X130:AI3, RTD X130:AI4, and RTD X130:AI5. The measured values are connected from function X130 (RTD) to function MAX3. The maximum temperature value is connected to the analog multipurpose protection MAPGAPC1_MAP-1.

The motor cooling air temperature and motor bearing temperature can be measured with inputs RTD X130:AI6 and RTD X130:AI7. The protection functionality from these temperatures is provided by MAPGAPC2_MAP-2 and MAPGAPC3_MAP-3 functions.

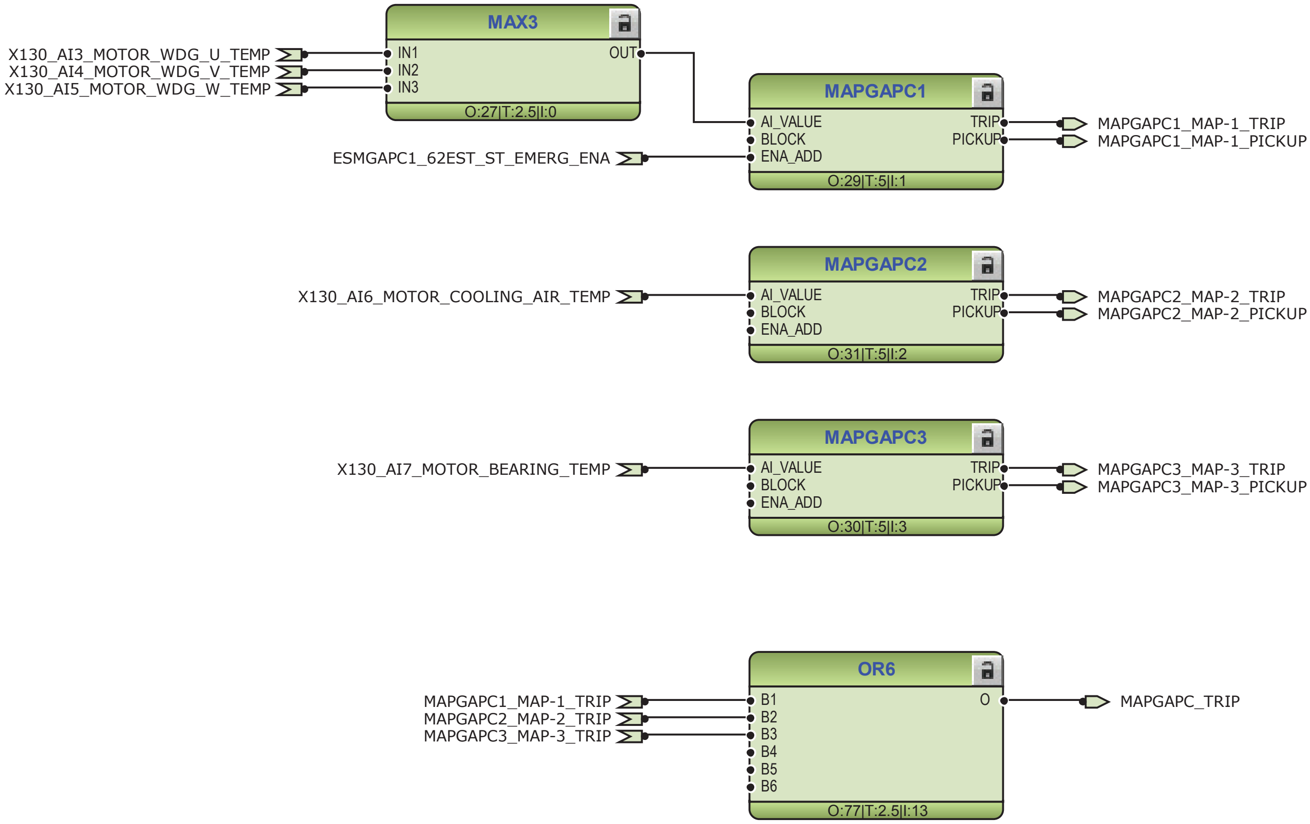


Figure 24: Multipurpose mA/RTD monitoring

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

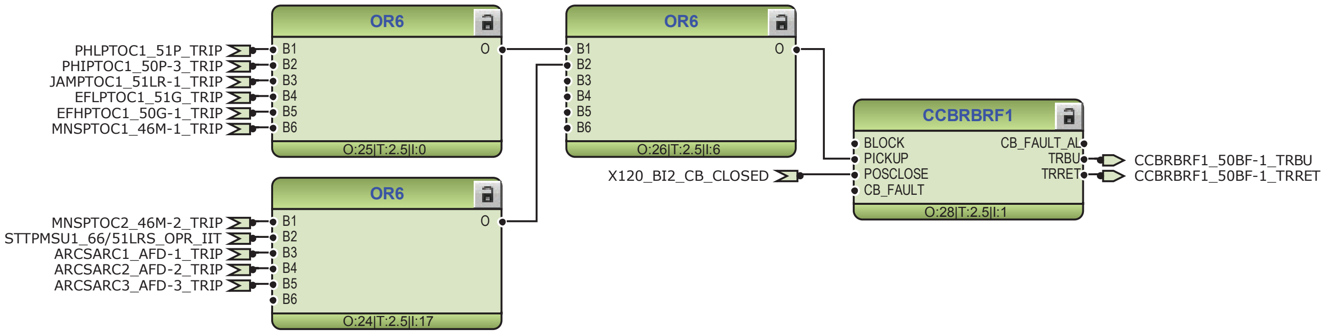


Figure 25: Circuit breaker failure protection function

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, that is, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to both trip logic 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 outputs of TRPPTRC3...5__86/94-3…5 are available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

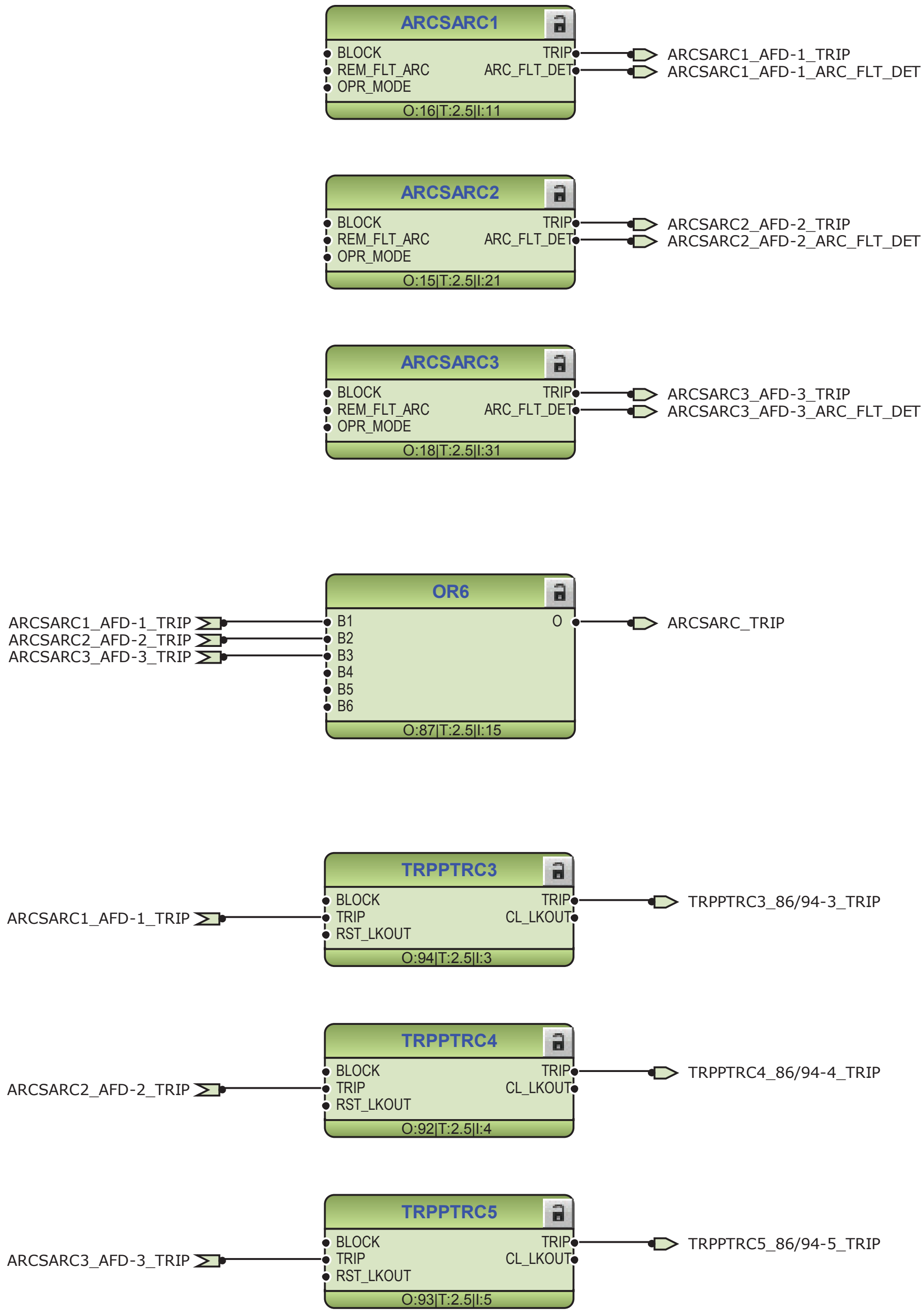


Figure 26: Arc protection with dedicated high-speed output

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

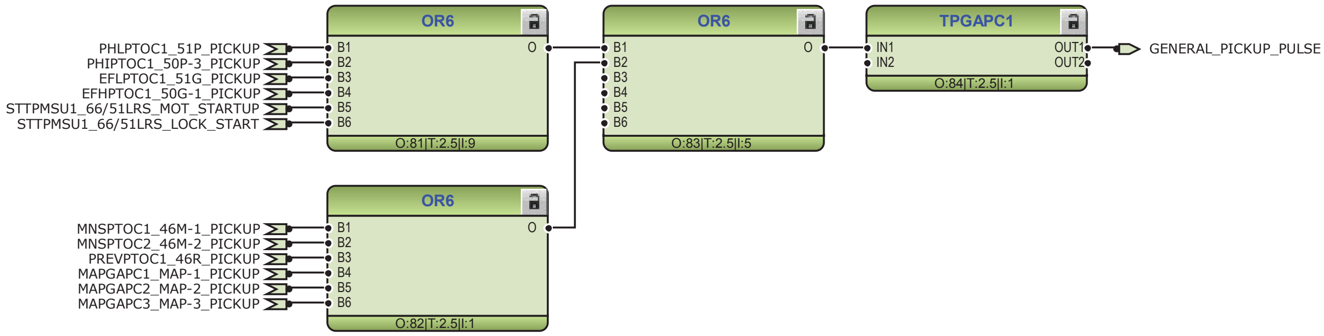


Figure 27: General pickup and trip signals

The trip signals from the protection functions are connected to trip logics TRPPTRC1_86/94-1. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:SO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, the binary input can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5_86/94-3…5 are also available if the relay is ordered with high-speed binary outputs options.

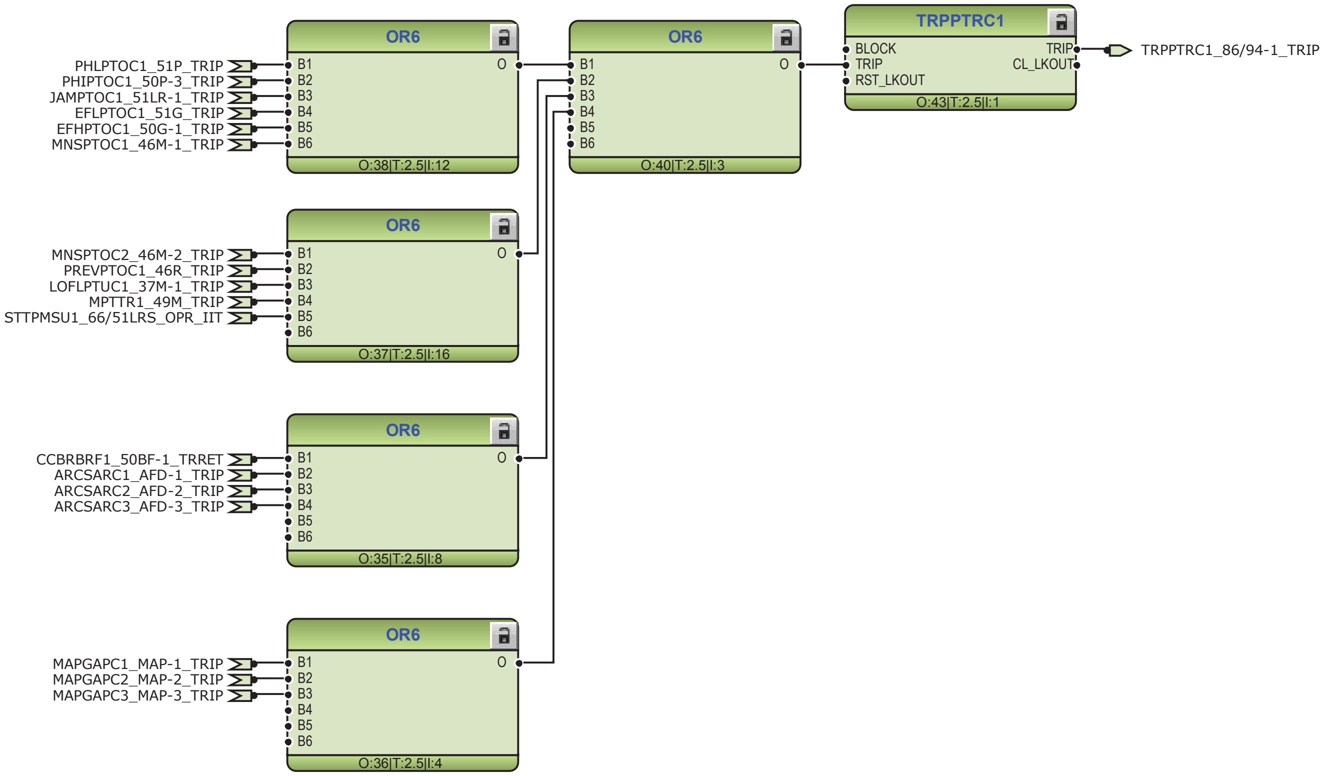


Figure 28: Trip logic TRPPTRC1

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.

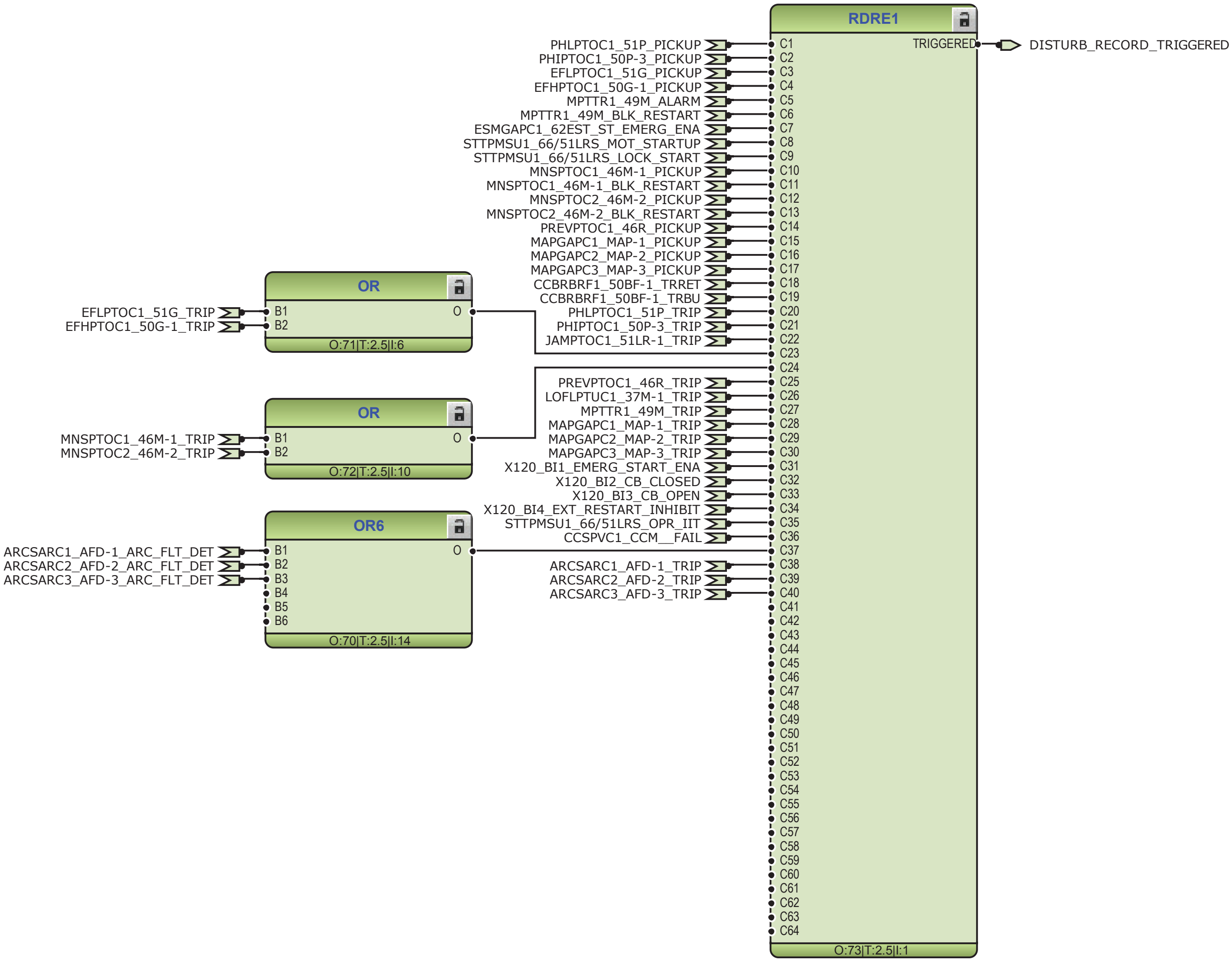


Figure 29: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

CCSPVC1_CCM detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measure the calculated sequence component currents to avoid unnecessary operation. However, the `BLOCK` input signal is not connected in the configuration.

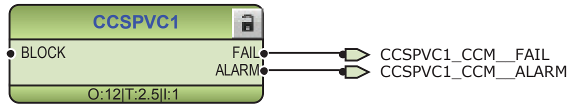


Figure 30: Current circuit supervision function

The circuit-breaker condition monitoring function SSCBR1_52CM supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM introduces various supervision methods.

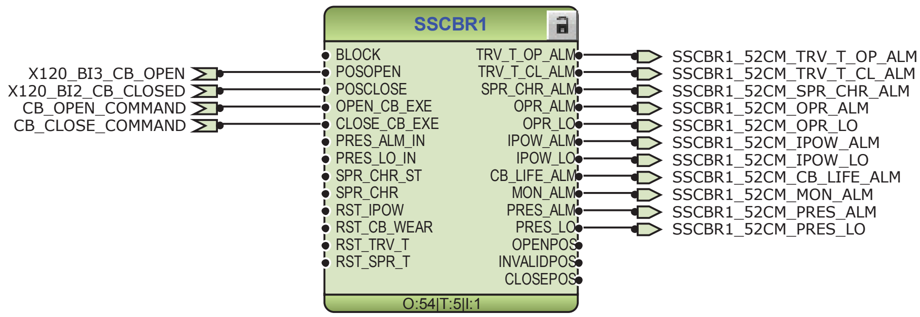


Figure 31: Circuit-breaker condition monitoring function

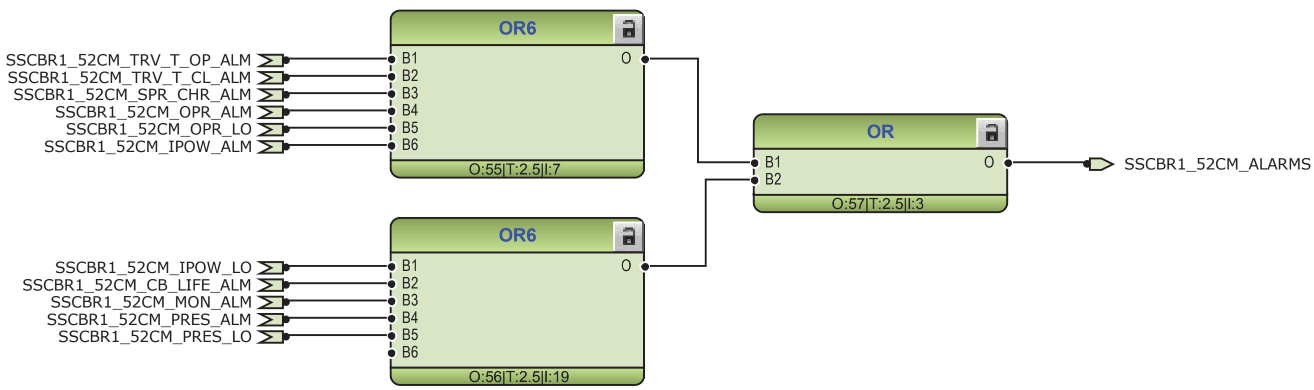


Figure 32: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 for master trip and TCSSCBR2_TCM-2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1_TCM-1 is blocked by the master trip TRPPTRC1_86/94-1 and the circuit breaker open signal. The trip circuit supervision function TCSSCBR2_86/94-2 is blocked by the circuit breaker close signal.

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

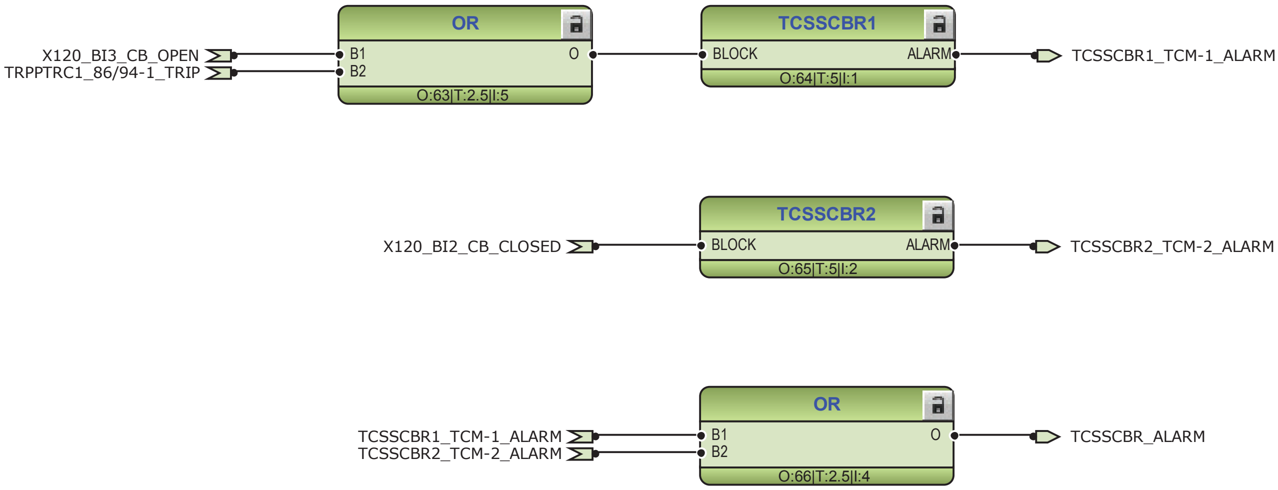


Figure 33: Trip circuit supervision function

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 and ground switch position status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status. In the configuration, only trip logic activates the close-enable signal to the circuit-breaker control function block. The open operation for circuit breaker is always enabled.

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

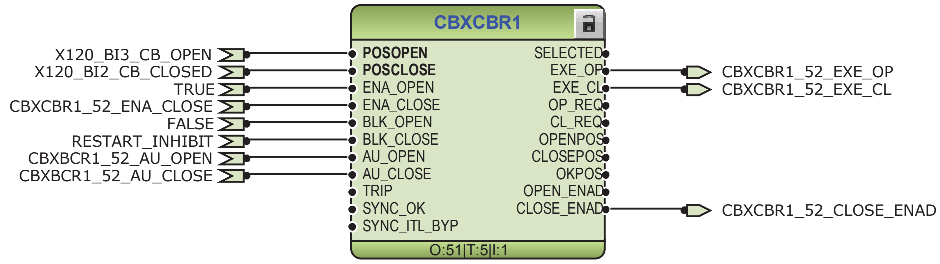


Figure 34: Circuit breaker 1 control logic

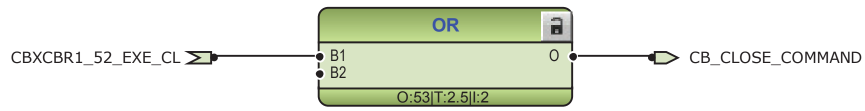


Figure 35: Signals for closing coil of circuit breaker 1

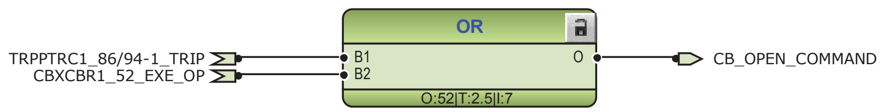


Figure 36: Signals for opening coil of circuit breaker 1

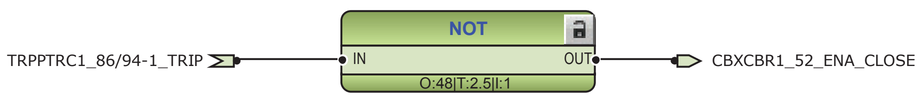


Figure 37: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the closing of circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

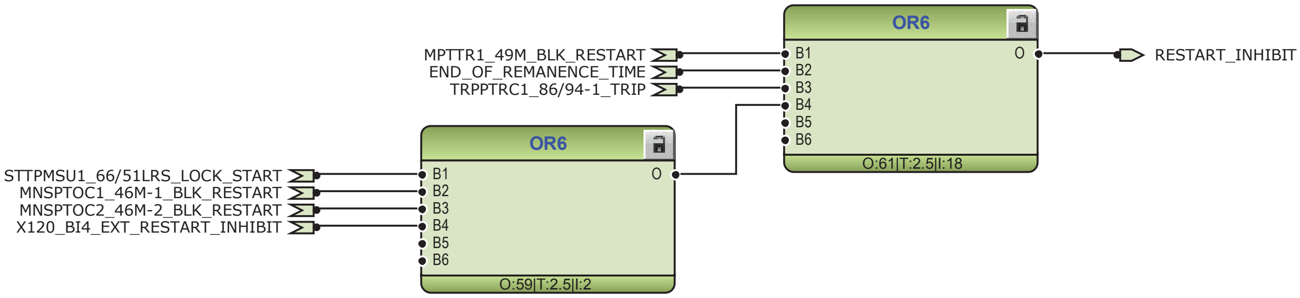


Figure 38: Circuit breaker 1 close blocking logic

When the motor restart is inhibited, the BLK_CLOSE input is activated and the circuit breaker is not closed. When all conditions of the circuit breaker closing are met, the CLOSE_ENAD output of the CBXCBR1_52 is activated and the X100:PO1 output is closed.

The configuration also includes restart inhibit. Restart inhibit is activated under various conditions.

- A trip command is active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- Thermal protection has issued blocked restart.
- An external restart inhibit is activated by a binary input X120:BI4.
- Time during which remanence voltage is present.

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

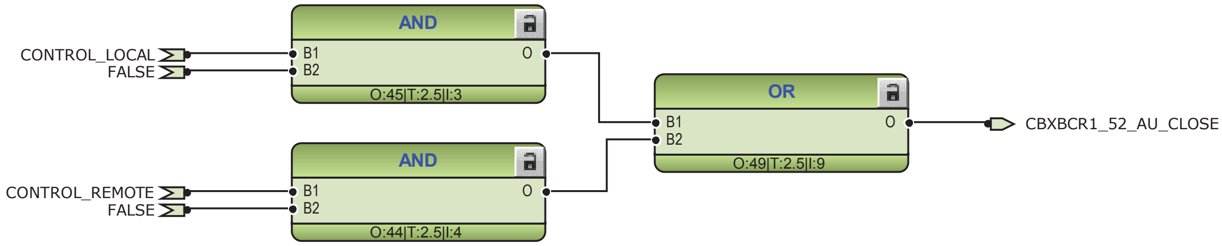


Figure 39: External closing command for circuit breaker 1

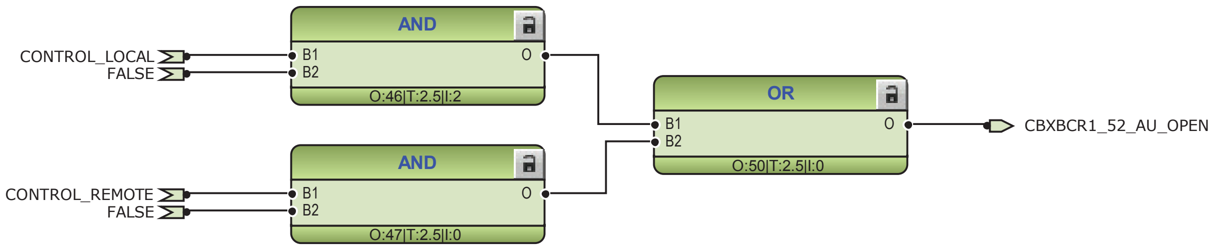


Figure 40: External opening command for circuit breaker 1

3.3.3.5 Functional diagrams for measurement functions

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

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

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

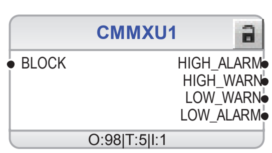


Figure 41: Three-phase current measurement

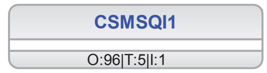


Figure 42: Sequence current measurement

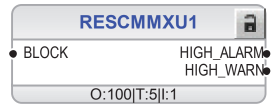


Figure 43: Residual current measurement

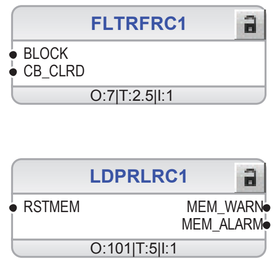


Figure 44: Data monitoring and load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

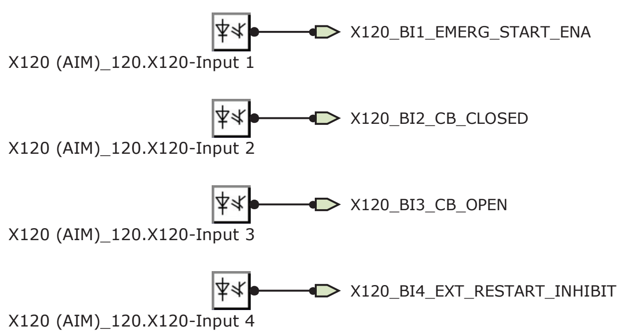


Figure 45: Default binary inputs - X120

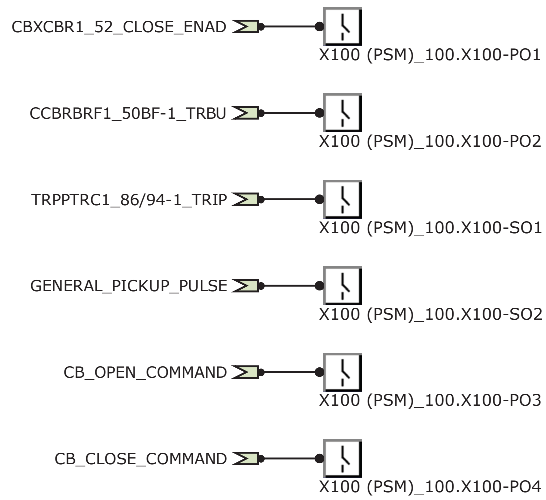


Figure 46: Default binary outputs - X100

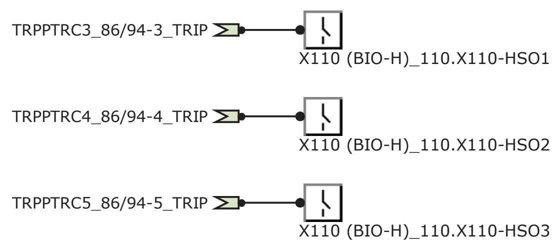


Figure 47: Default binary outputs - X110

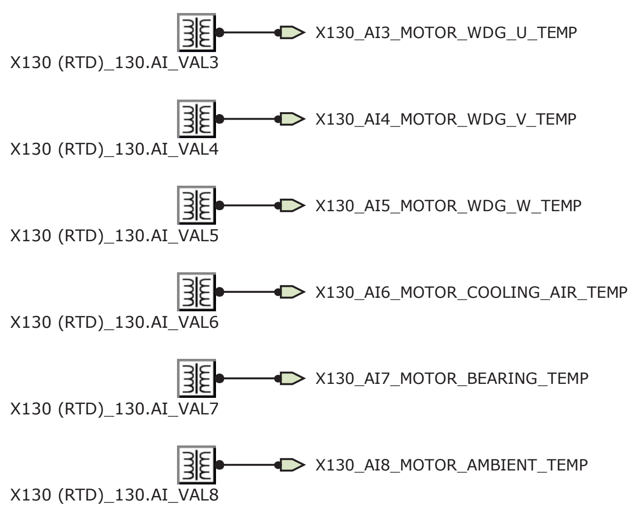


Figure 48: Default mA/RTD inputs - X130

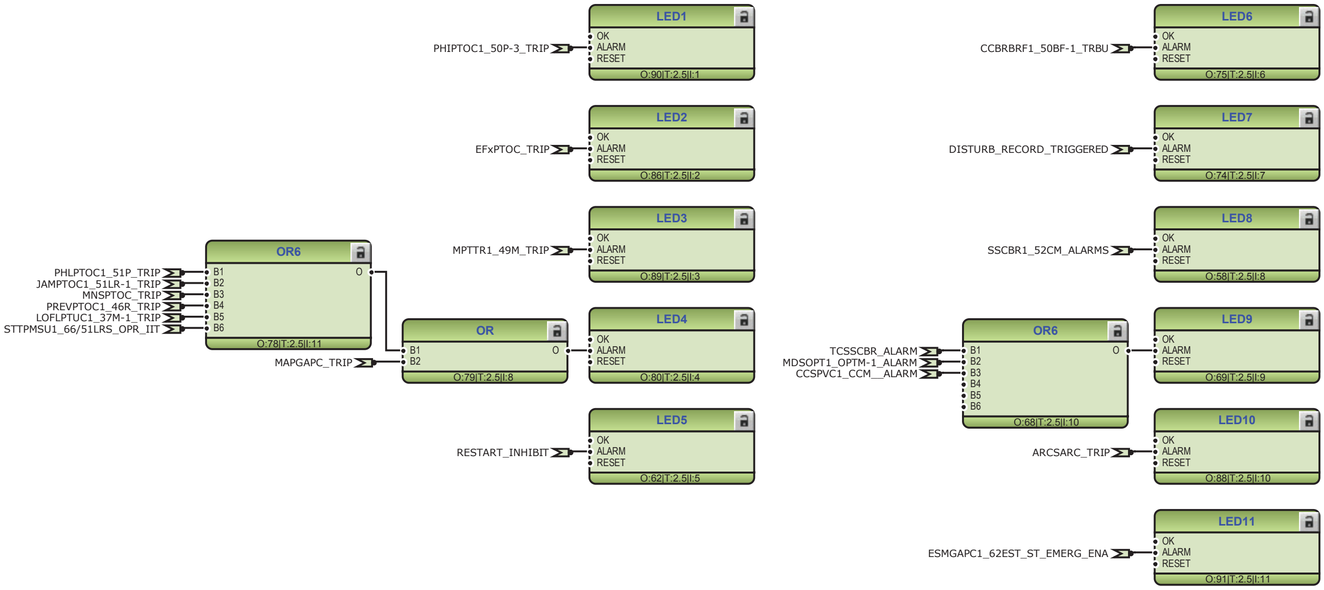


Figure 49: Default LED connections

3.3.3.7 Functional diagrams for other timer logics

The configuration also includes logic for remanence voltage. The restart inhibit is activated for a set period when a circuit breaker is in open state. This is called remanence voltage protection where the motor has damping remanence voltage after the opening of a circuit breaker. Reclosing after a short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

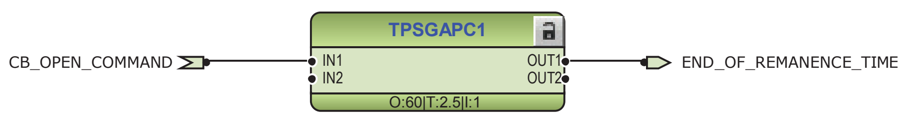


Figure 50: Timer logic for remanence voltage to disappear

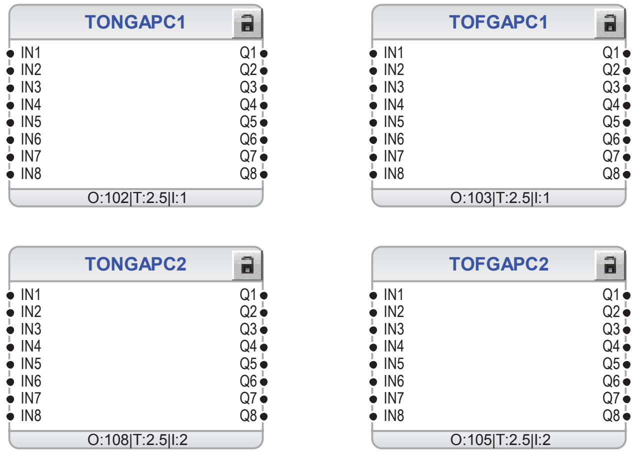


Figure 51: Programmable timers

3.3.3.8 Functional diagrams for other functions

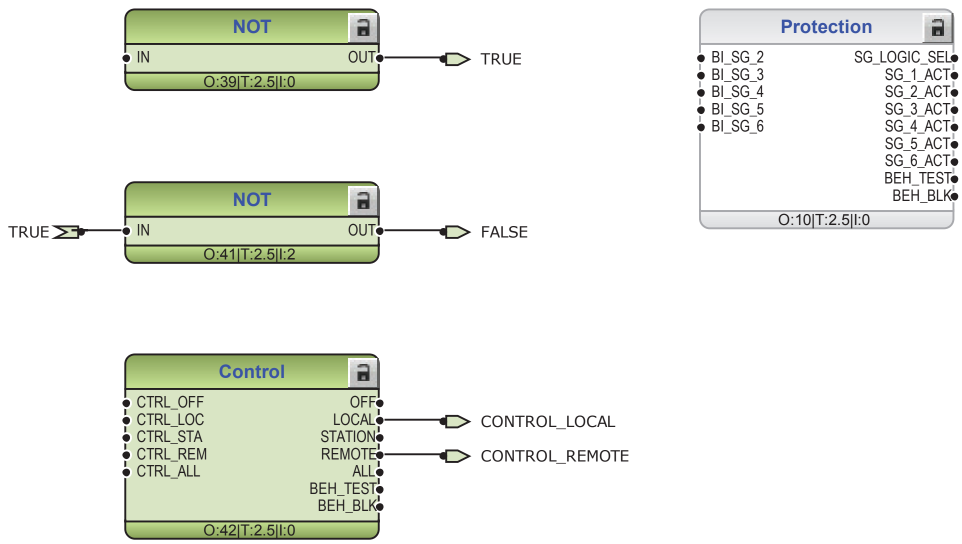


Figure 52: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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.

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

3.3.3.9 Functional diagrams for communication

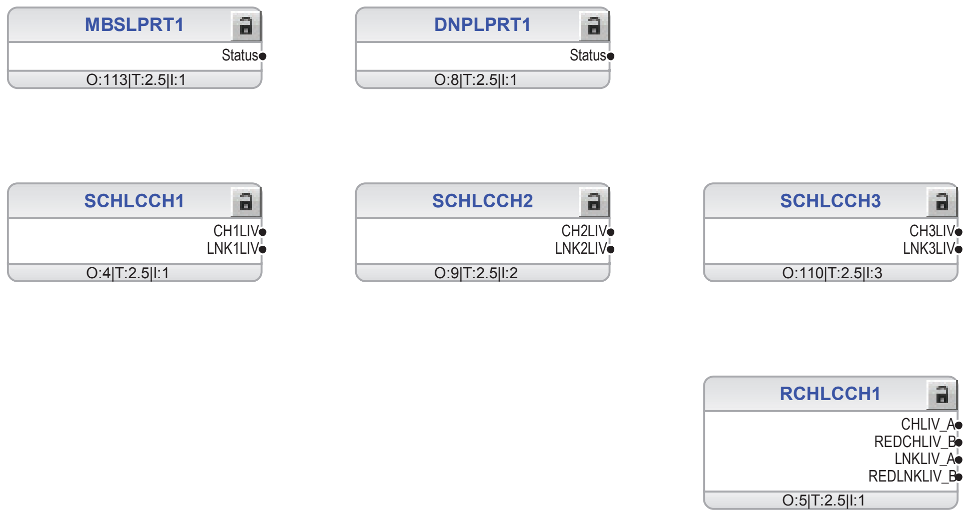


Figure 53: Default communication function connection

3.4 Standard configuration B

3.4.1 Applications

The standard configuration is intended for comprehensive protection and control functionality of the circuit breaker controlled asynchronous motors. With minor modifications, the standard configuration can also be applied for contactor controlled motors. There is also an option for mA/RTD measurement and protection.

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

3.4.2 Functions

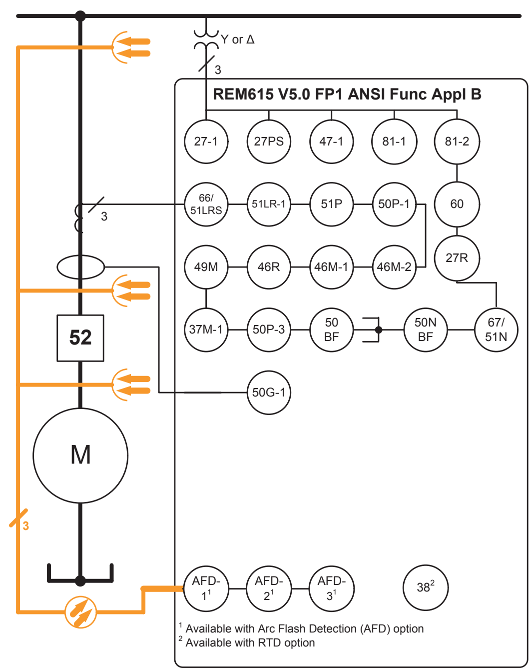


Figure 54: Functionality overview for standard configuration B

3.4.2.1 Default I/O connections

Table 15: Default connections for analog inputs

Analog input	Description	Connector pins
VA	Phase voltage VA	X120:1-2
VB	Phase voltage VB	X120:3-4
VC	Phase voltage VC	X120:5-6
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
mA1	mA1	X130:1-2
mA2	mA2	X130:3-4
RTD1	Motor winding U temperature	X130:5-6
RTD2	Motor winding V temperature	X130:7-8
RTD3	Motor winding W temperature	X130:9-10

Table continues on next page

Analog input	Description	Connector pins
RTD4	Motor cooling air temperature	X130:13-14
RTD5	Motor bearing temperature	X130:15-16
RTD6	Motor ambient temperature	X130:17-18

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	Emergency restart inhibit	X110:1-2	X110:1,5
X110-BI2	External trip	X110:3-4	X110:2,5
X110-BI3	Circuit breaker closed position indication	X110:5-6	X110:3,5
X110-BI4	Circuit breaker open position indication	X110:7-6	X110:4-5
X110-BI5	Voltage transformer secondary MCB open	X110:8-9	X110:6,10
X110-BI6	Emergency start	X110:10-9	X110:7,10
X110-BI7	Lockout reset	X110:11-12	X110:8,10
X110-BI8	Setting group change	X110:13-12	X110:9-10

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Restart enable	X100:6-7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8-9
X100-SO1	Open command (for contractor application)	X100:10-11,(12)
X100-SO2	Pickupt indication	X100:13-14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X110-SO1	Motor startup indication	X110:14-16
X110-SO2	Thermal overload alarm	X110:17-19
X110-SO3	Voltage protection alarm	X110:20-22
X110-SO4	Trip indication	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	Short-circuit protection trip	LED_ShortCircuit_1	Short circuit
2	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
3	Thermal overload protection trip	LED_ThermalOverload_1	Thermal overload
4	Combined operate indication of the other protection functions	LED_CombinedProtection_1	Combined Protection
5	Motor restart inhibit	LED_MotorRestartInhibit_1	Motor restart inhibit
6	Breaker failure protection trip	LED_BreakerFailure_1	Breaker failure
7	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
8	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
9	TCS, motor runtime counter or measuring circuit fault alarm	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Emergency start enabled	LED_EmergencyStartEnabled	Emergency start enabled

3.4.2.2 Default disturbance recorder settings

Table 19: Default disturbance recorder analog channels

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

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHIPTOC1 - pickup	Positive or Rising
3	DEFLPDEF1 - pickup	Positive or Rising
4	EFHPTOC1 - pickup	Positive or Rising
5	MPTTR1 - alarm	Level trigger off
6	MPTTR1 - blk restart	Level trigger off
7	ESMGAPC1 - st emerg ena	Level trigger off
8	STTPMSU1 - mot startup	Positive or Rising
9	STTPMSU1 - lock start	Level trigger off
10	MNSPTOC1 - pickup	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - pickup	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - pickup	Positive or Rising
15	PHPTUV1 - pickup	Positive or Rising
16	PSPTUV1 - pickup	Positive or Rising
17	NSPTOV1 - pickup	Positive or Rising
18	FRPFRQ1 - pickup	Positive or Rising
19	FRPFRQ2 - pickup	Positive or Rising
20	MAPGAPC1 - pickup	Positive or Rising
21	MAPGAPC2 - pickup	Positive or Rising
22	MAPGAPC3 - pickup	Positive or Rising
23	CCBRBRF1 - trret	Level trigger off
24	CCBRBRF1 - trbu	Level trigger off
25	PHLPTOC1 - trip	Level trigger off
26	PHIPTOC1 - trip	Level trigger off
27	JAMPTOC1 - trip	Level trigger off
28	DEFLPDEF1/EFHPTOC1 - trip	Level trigger off
29	MNSPTOC - trip	Level trigger off
30	PREVPTOC1 - trip	Level trigger off
31	LOFLPTUC1 - trip	Level trigger off
32	MPTTR1 - trip	Level trigger off
33	PHPTUV1 - trip	Level trigger off
34	PSPTUV1 - trip	Level trigger off
35	NSPTOV1 - trip	Level trigger off
Table continues on next page		

Channel	ID text	Level trigger mode
36	FRPFRQ1 - trip	Level trigger off
37	FRPFRQ2 - trip	Level trigger off
38	MAPGAPC1 - trip	Level trigger off
39	MAPGAPC2 - trip	Level trigger off
40	MAPGAPC3 - trip	Level trigger off
41	X110BI1 - Ext restart inhibit	Positive or Rising
42	X110BI2 - Ext trip	Level trigger off
43	X110BI6 - Emerg start ena	Level trigger off
44	X110BI3 - CB closed	Level trigger off
45	X110BI4 - CB open	Level trigger off
46	X110BI7 - rst lockout	Level trigger off
47	X110BI5 - MCB opened	Level trigger off
48	X110BI8 - SG changed	Level trigger off
49	STTPMSU1 - opr iit	Positive or Rising
50	SEQSPVC1 - fusef 3ph	Level trigger off
51	SEQSPVC1 - fusef u	Level trigger off
52	CCSPVC1 - fail	Level trigger off
53	ARCSARC - ARC flt det	Level trigger off
54	ARCSARC1 - trip	Positive or Rising
55	ARCSARC2 - trip	Positive or Rising
56	ARCSARC3 - trip	Positive or Rising
57	MSVPR1 - U_LO	Level trigger off
58	-	-
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 phase currents to the protection relay are fed from a current transformer. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The phase voltages to the protection relay are fed from a voltage transformer.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages.

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

Two overcurrent stages are offered for overcurrent and short-circuit protection. The nondirectional low stage PHLPTOC1_51P can be used for overcurrent protection whereas the instantaneous stage PHIPTOC1_50P-3 can be used for short-circuit protection. The operation of PHIPTOC1_50P-3 is not blocked as default by any functionality and it should be set over the motor pickup current level to avoid unnecessary operation.

The Motor load jam protection function JAMPTOC1_51LR-1 is blocked by the motor start-up protection function.

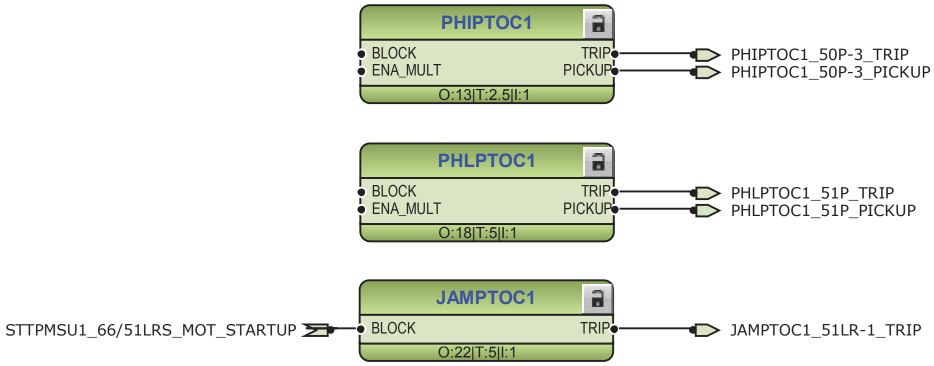


Figure 55: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect the motor against phase unbalance. Unbalance in the network feeder of the motor causes overheating of the motor.

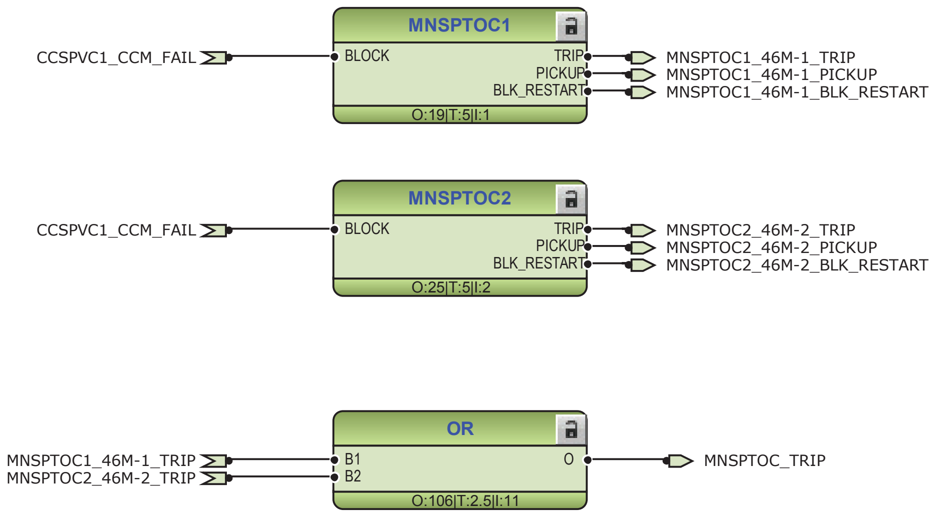


Figure 56: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1_46R is based on the calculated negative phase sequence current. It detects high negative-sequence current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

The negative-sequence and phase reversal protection are blocked if the current circuit supervision detects failure in the current measurement circuit.

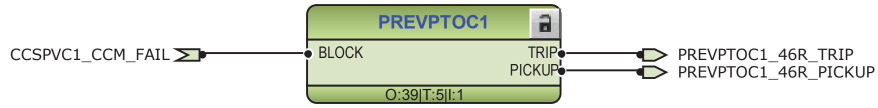


Figure 57: Phase reversal protection function

One stage is provided for non-directional ground-fault protection EFHPTOC1_50G-1 to detect phase-to-ground faults that may be result of, for example, insulation ageing. In addition, there is a directional protection stage DEFLPDEF1_67/51N-1 which can also be used as a low stage non-directional ground-fault protection without residual voltage requirement. However, the residual voltage can help to detect ground faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor start-up.

Both the directional and non-directional ground-fault protection are blocked by the activation of instantaneous stage of overcurrent protection

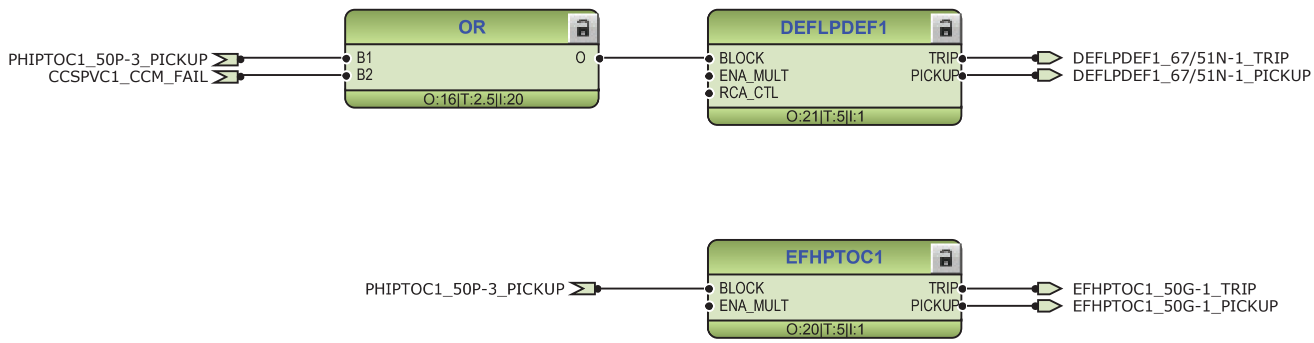


Figure 58: Ground-fault protection functions

The emergency start function ESMGAPC1_62EST allows motor start-ups although the calculated thermal level or cumulative start-up time counter is blocking the restart. The emergency start is enabled for ten minutes after the selected binary input X110:BI6 is energized.

On the rising edge of the emergency pickup signal, various events occur.

- The calculated thermal level in MPTTR1_49M is set slightly below the restart inhibit level to allow at least one motor start-up.
- The value of the cumulative start-up time counter STTPMSU1_66/51LRS is set slightly below the set restart inhibit value to allow at least one motor start-up.
- The set pickup value of the MAPGAPC1_MAP-1 function is increased (or decreased) depending on the *Pickup value Add* setting (only if the optional RTD/mA module is included).
- Alarm LED 11 is activated.

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time has expired.

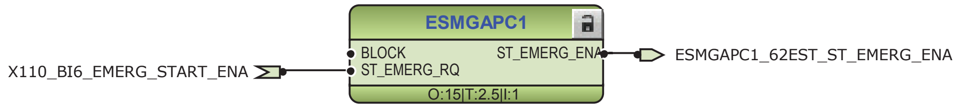


Figure 59: Motor emergency start-up function

The thermal overload protection for motors MPTTR1_49M detects short and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. Restart blocking, issued by the thermal overload function, prevents the closing of the breaker in machine overload situation. The emergency start request removes the blocking and enables the restarting of the motor.

If the relay is ordered with a RTD/mA card, the motor ambient temperature can be measured with input RTD X130:AI8 and it is connected to the thermal overload protection function MPTTR1_49M.

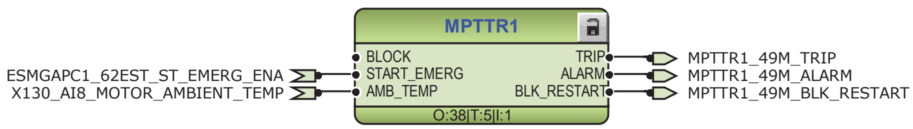


Figure 60: Motor thermal overload protection

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection where the motor has damping remanence voltage after the circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

The restart inhibit is also activated under various conditions.

- A trip command becomes active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- An external restart inhibit is activated by a binary input X120:BI4.

With the motor start-up supervision function STTPMSU1_66/51LRS, the starting of the motor is supervised by monitoring the three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1_62EST and STTPMSU1_66/51LRS is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

The upstream blocking from the motor start-up is connected to the binary output X110:SO1. The output is used for sending a blocking signal to the relevant overcurrent protection stage of the relay at the infeeding bay.

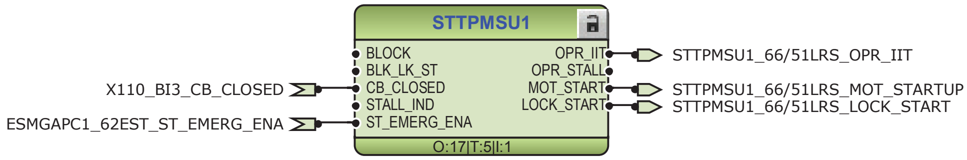


Figure 61: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1_OPTM-1 provides history data since the last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed.

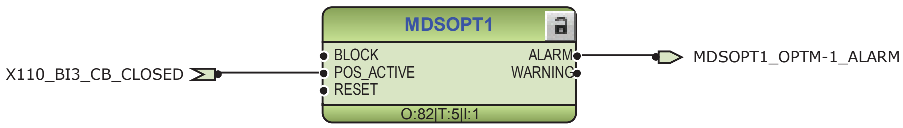


Figure 62: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1_37M-1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

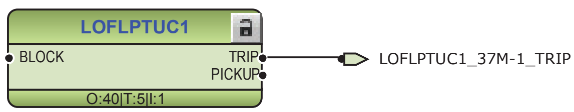


Figure 63: Loss of load protection function

The RTD/mA monitoring (optional) functionality provides several temperature measurements for motor protection. Temperature of the motor windings U, V and W is measured with inputs RTD X130:AI3, RTD X130:AI4, and RTD X130:AI5. The measured values are connected from function X130 (RTD) to function MAX3. The maximum temperature value is connected to the analog multipurpose protection MAPGAPC1_MAP-1.

The motor cooling air temperature and motor bearing temperature can be measured with inputs RTD X130:AI6 and RTD X130:AI7. The protection functionality from these temperatures is provided by MAPGAPC2_MAP-2 and MAPGAPC3_MAP-3 functions.

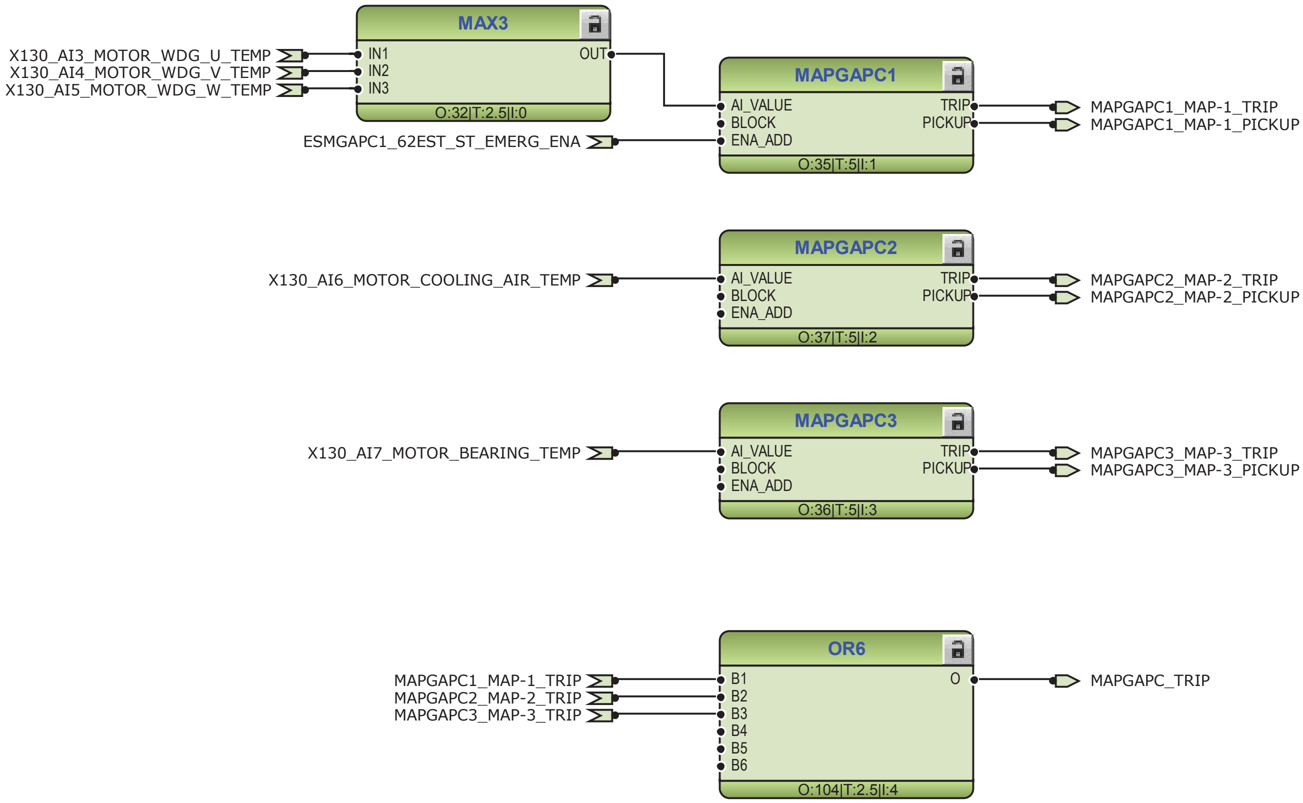


Figure 64: Multipurpose mA/RTD monitoring

The three-phase undervoltage protection PHPTUV1_27-1 offers protection against abnormal phase voltage conditions. The positive-sequence undervoltage protection PSPTUV1_27PS and negative-sequence overvoltage protection NSPTOV1_47-1 functions are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order.

A failure in the voltage measuring circuit is detected by the fuse failure function. The activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping. The three-phase undervoltage protection PHPTUV1_27-1 in addition is also blocked during motor start-up to prevent unwanted operation in case of a short voltage drop.

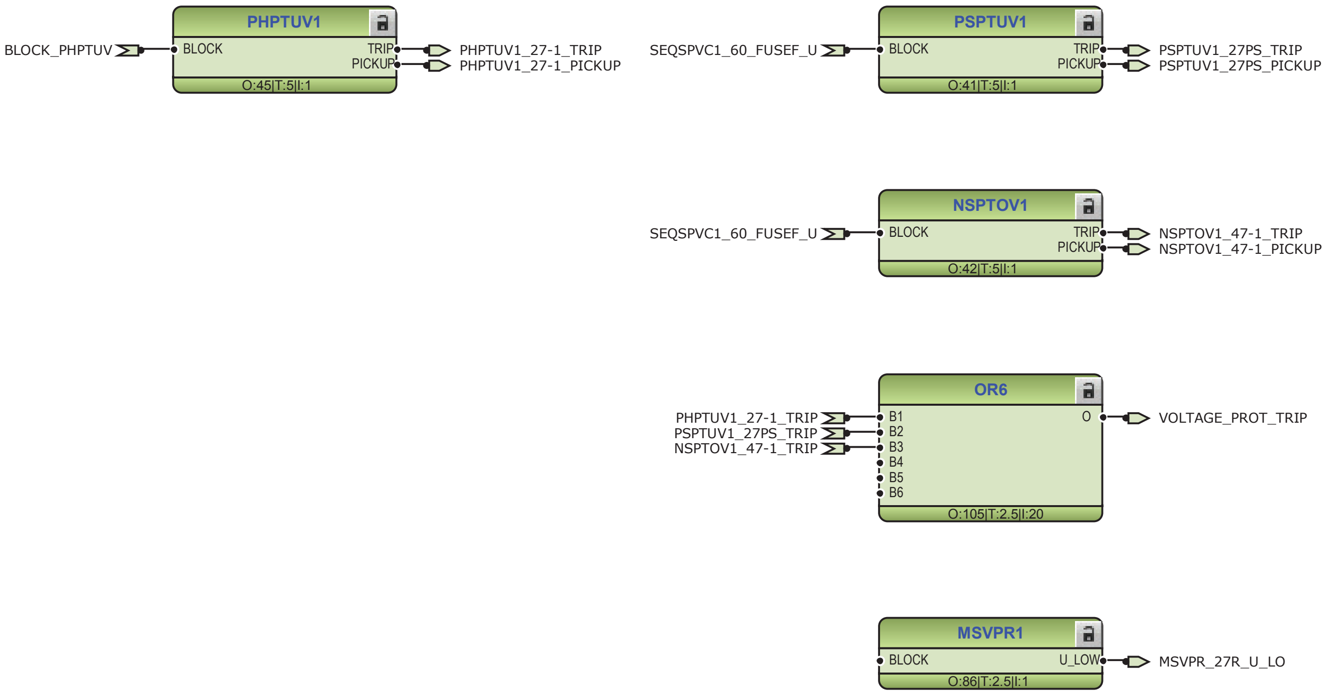


Figure 65: Voltage protection function

Two frequency protection stages FRPFRQ1_81-1 and FRPFRQ2_81-2 are offered. These functions are used to protect the motor against abnormal power system frequency.

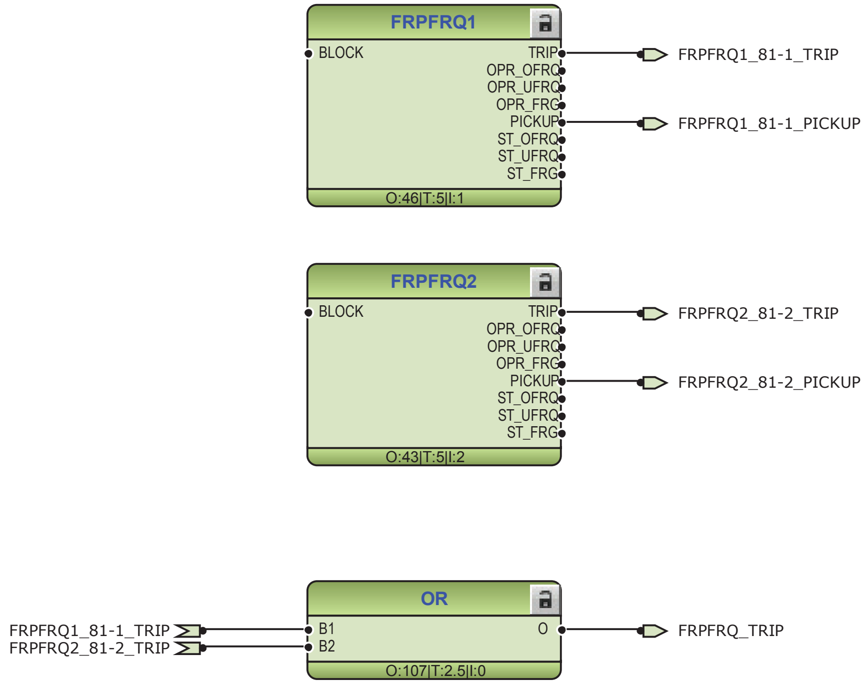


Figure 66: Frequency protection function

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

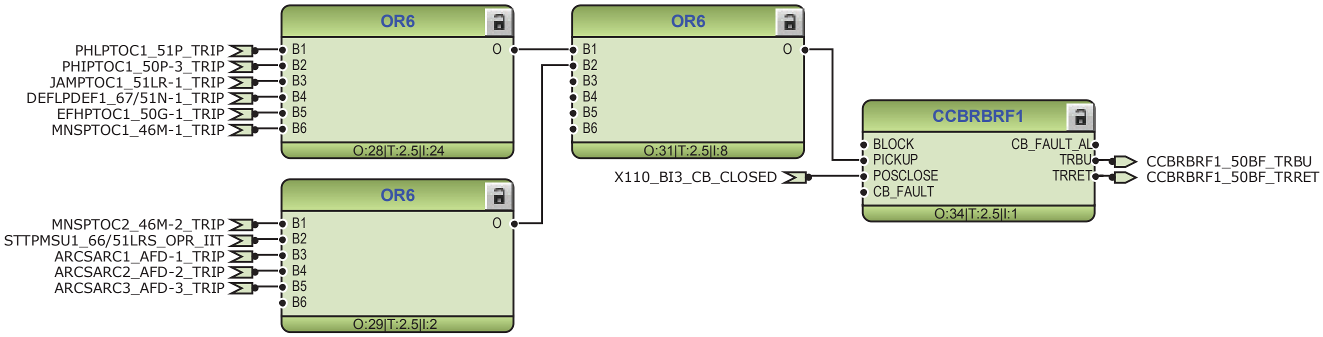


Figure 67: Circuit breaker failure protection function

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, that is, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to both trip logic 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 outputs of TRPPTRC3...5__86/94-3…5 are available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

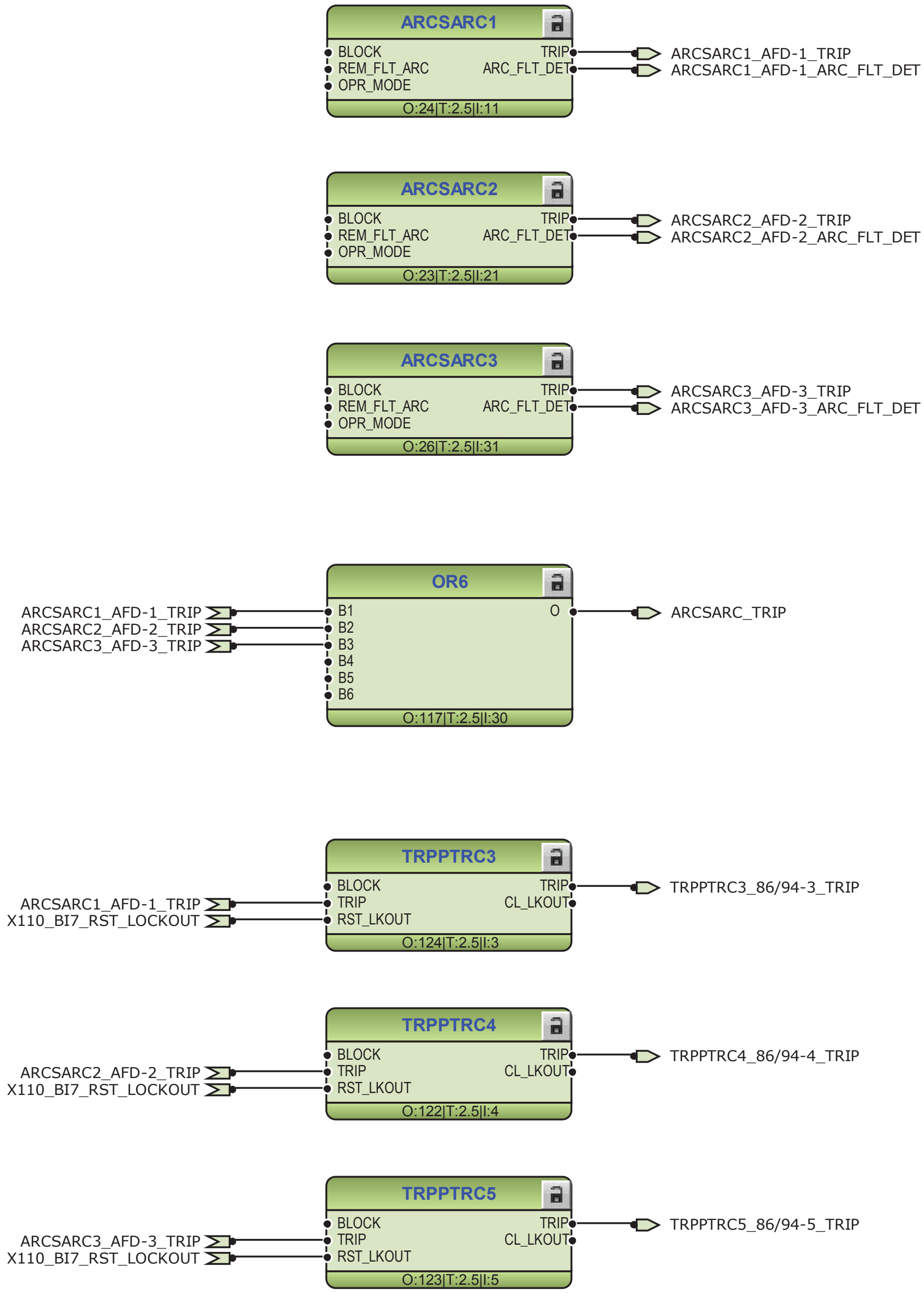


Figure 68: Arc protection with dedicated high-speed output

General pickup and trip from all the functions are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

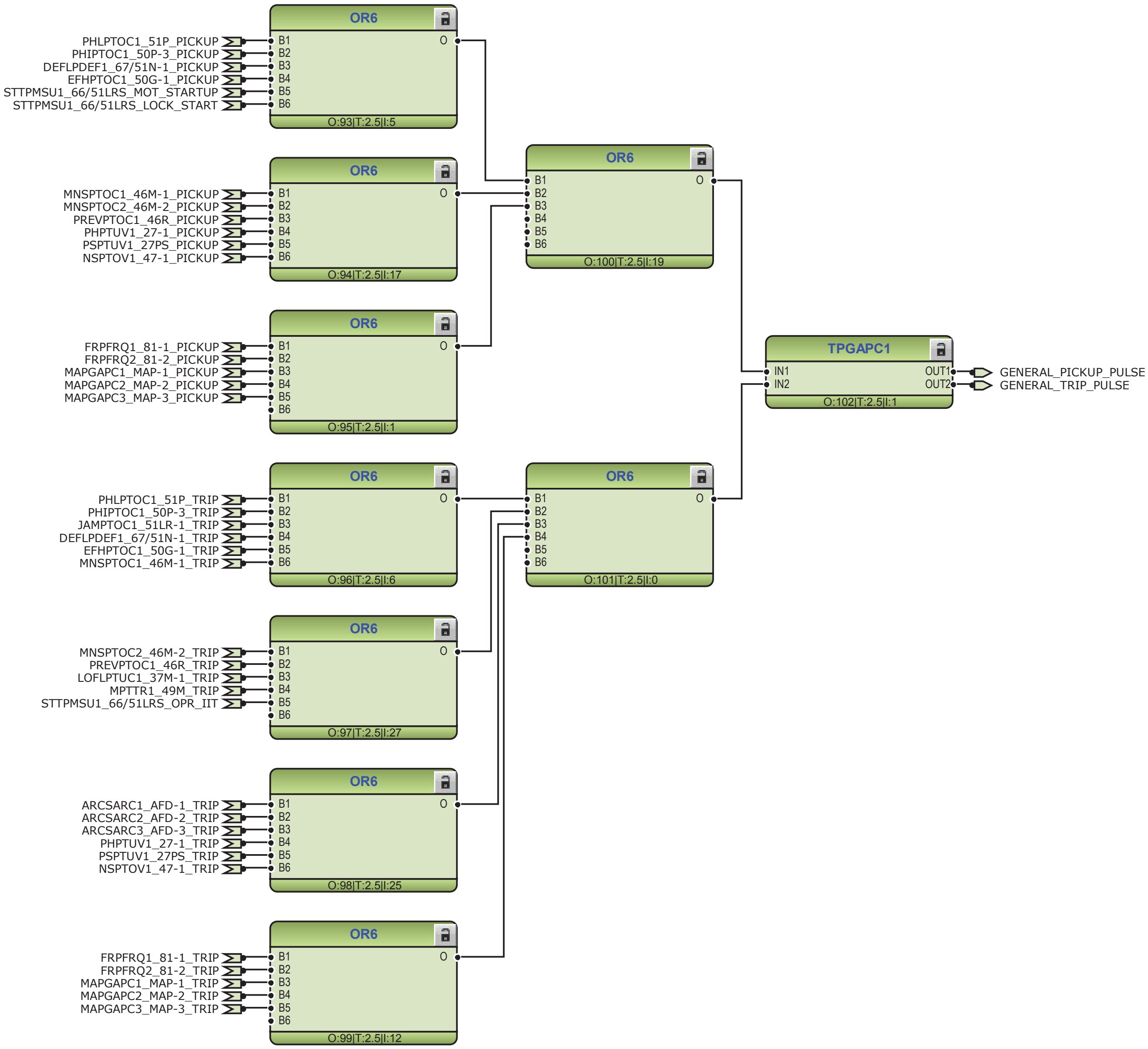


Figure 69: General pickup and trip signals

The trip signals from the protection functions are connected to trip logics TRPPTRC1_86/94-1. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:SO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, the binary input can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5_86/94-3…5 are also available if the relay is ordered with high-speed binary outputs options.

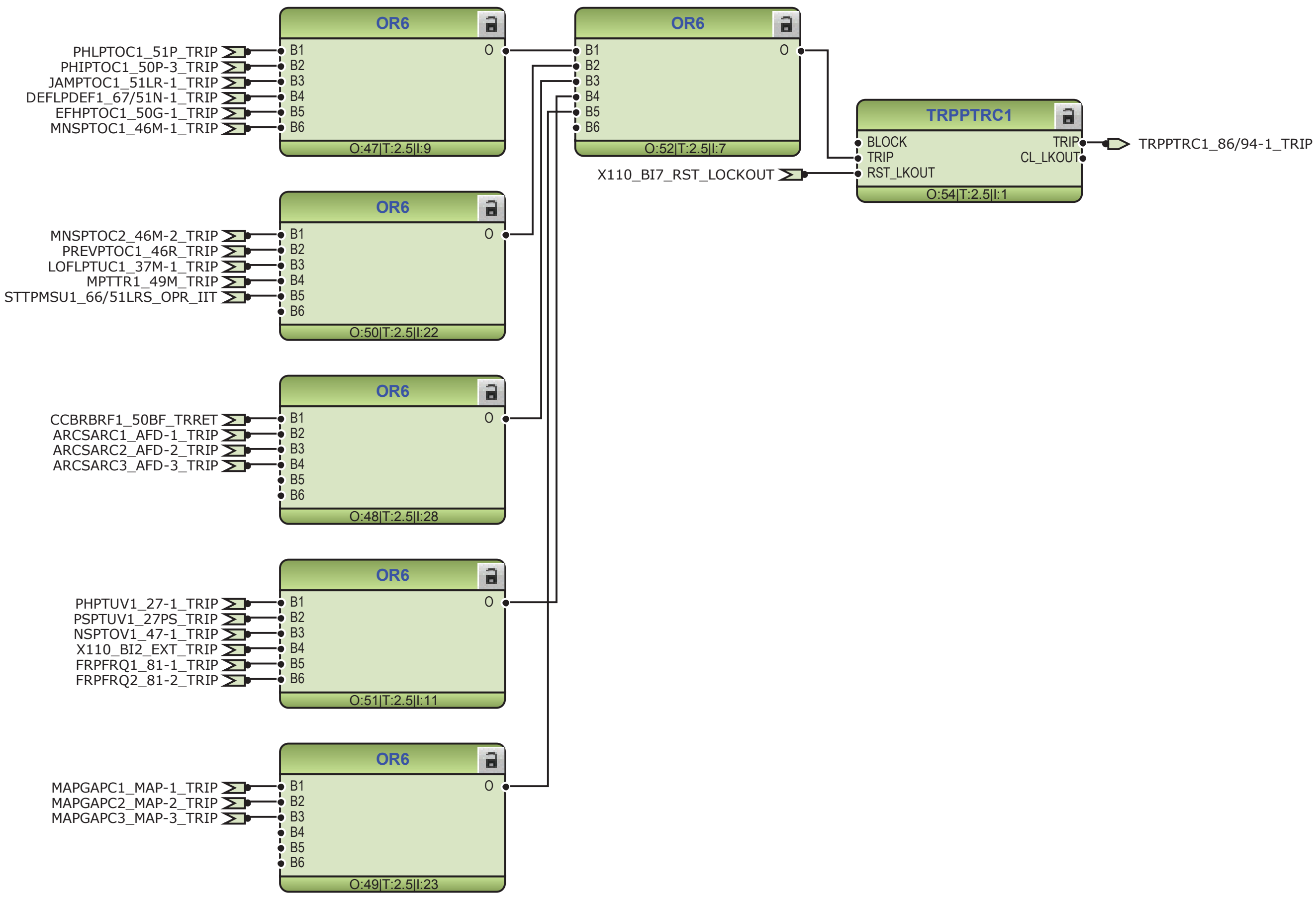


Figure 70: Trip logic TRPPTRC1

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.

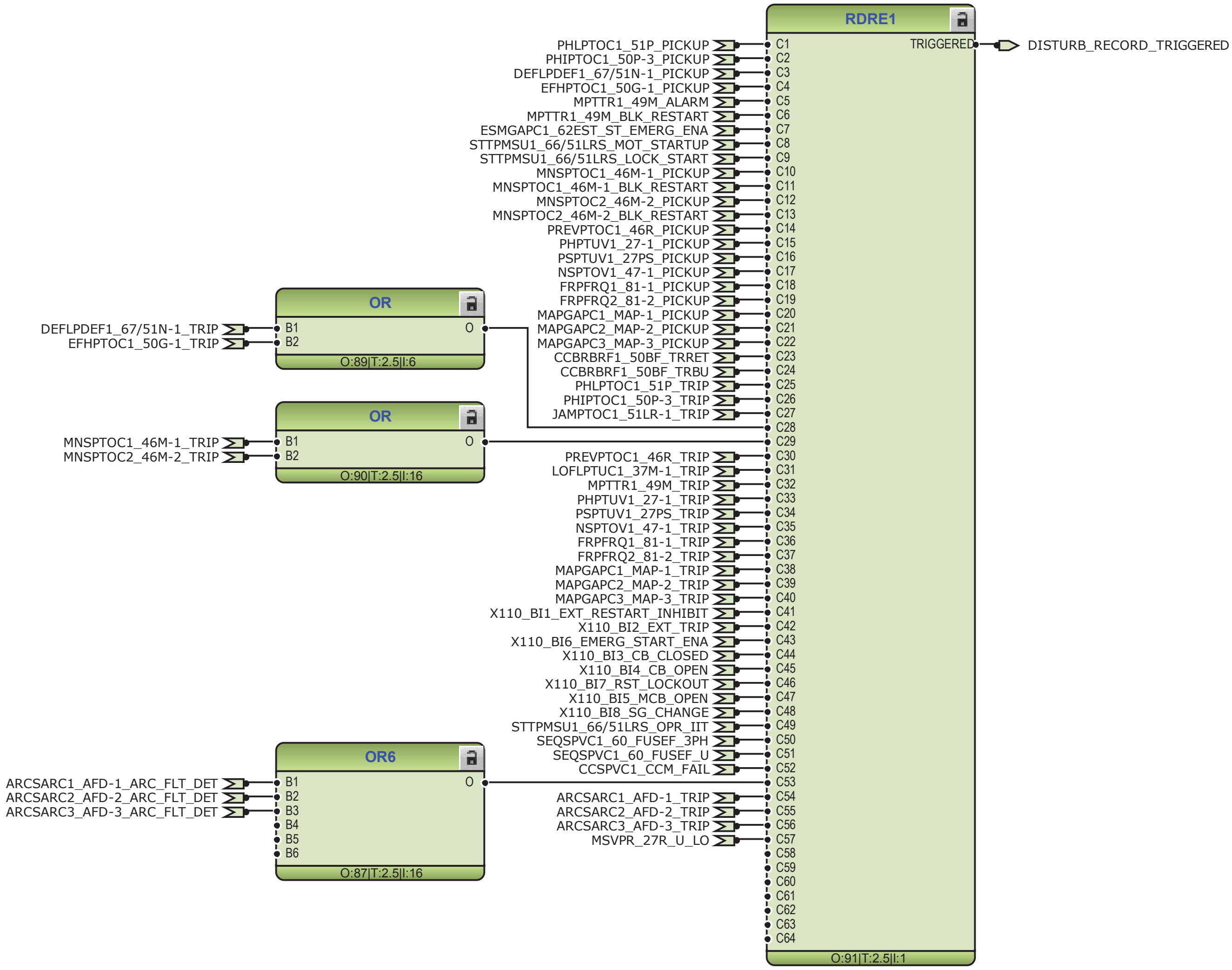


Figure 71: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

CCSPVC1_CCM detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measure the calculated sequence component currents to avoid unnecessary operation. However, the `BLOCK` input signal is not connected in the configuration.

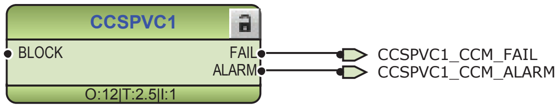


Figure 72: Current circuit supervision function

The fuse failure supervision SEQSPVC1_60 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

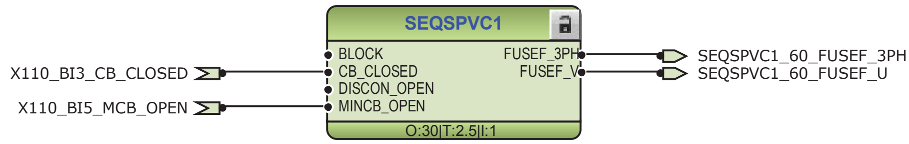


Figure 73: Fuse failure supervision function

The circuit-breaker condition monitoring function SSCBR1_52CM supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM introduces various supervision methods.

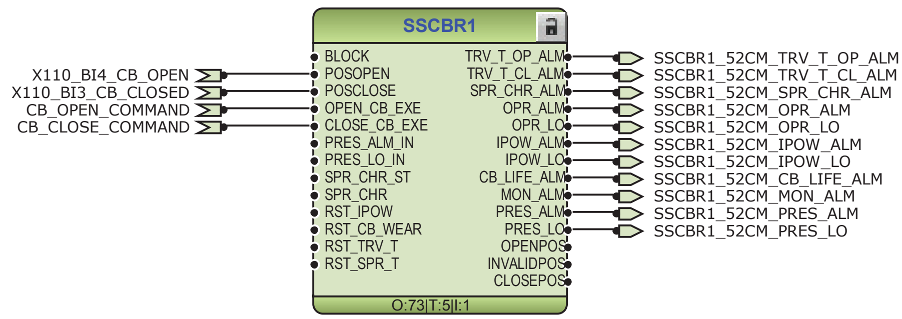


Figure 74: Circuit-breaker condition monitoring function

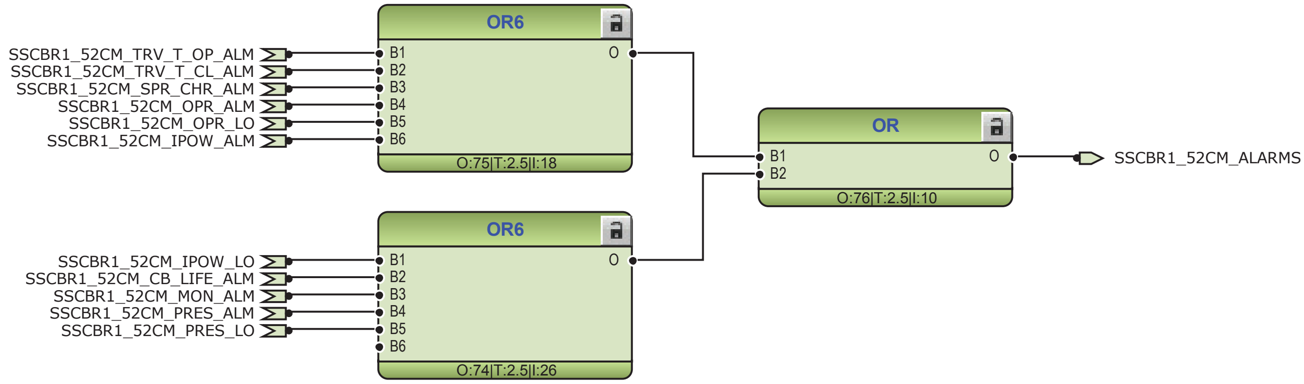


Figure 75: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 for master trip and TCSSCBR2_TCM-2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1_TCM-1 is blocked by the master trip TRPPTRC1_86/94-1 and the circuit breaker open signal. The trip circuit supervision function TCSSCBR2_86/94-2 is blocked by the circuit breaker close signal.

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

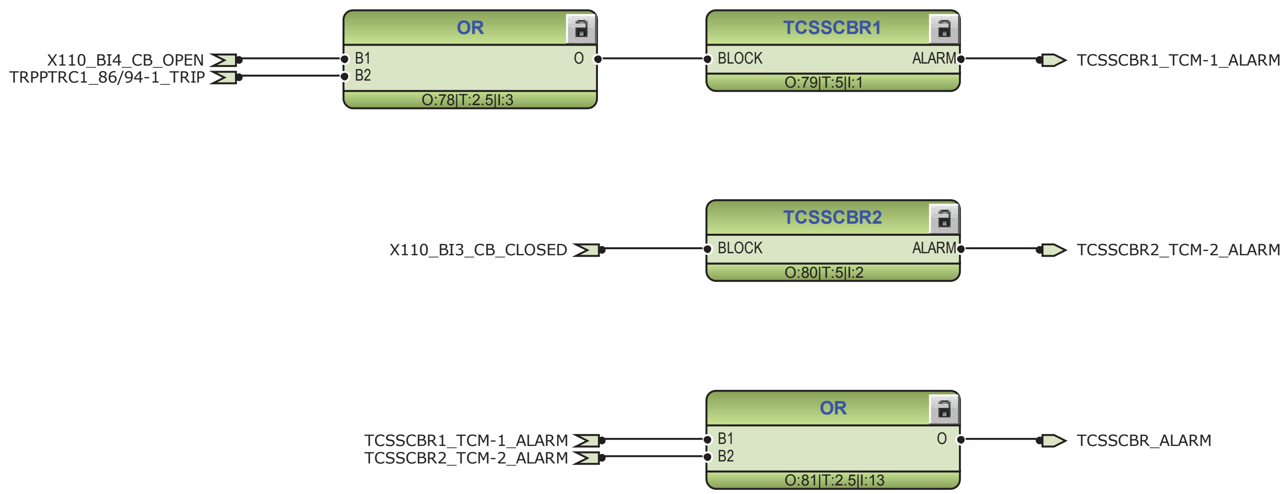


Figure 76: Trip circuit supervision function

3.4.3.4 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 and ground switch position status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status. In the configuration, only trip logic activates the close-enable signal to the circuit-breaker control function block. The open operation for circuit breaker is always enabled.

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

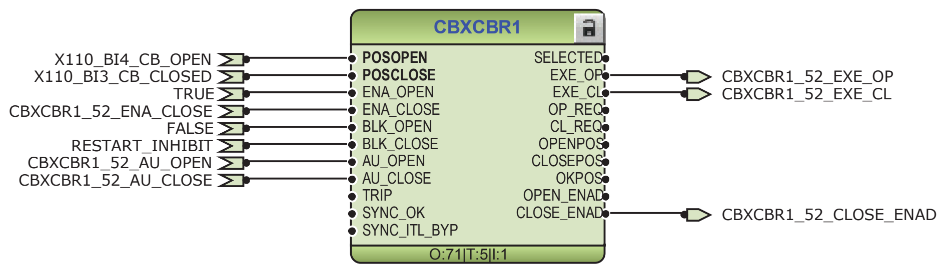


Figure 77: Circuit breaker 1 control logic

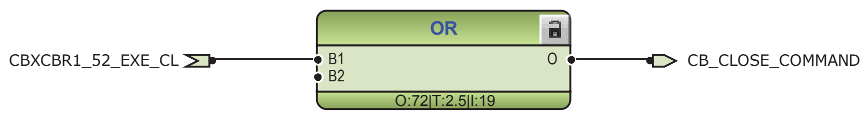


Figure 78: Signals for closing coil of circuit breaker 1

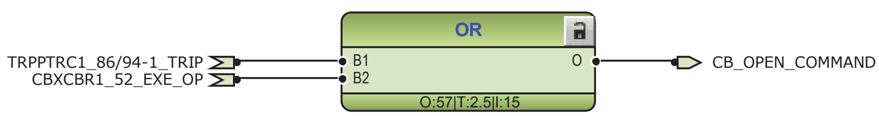


Figure 79: Signals for opening coil of circuit breaker 1

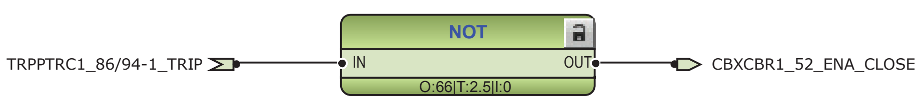


Figure 80: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the closing of circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

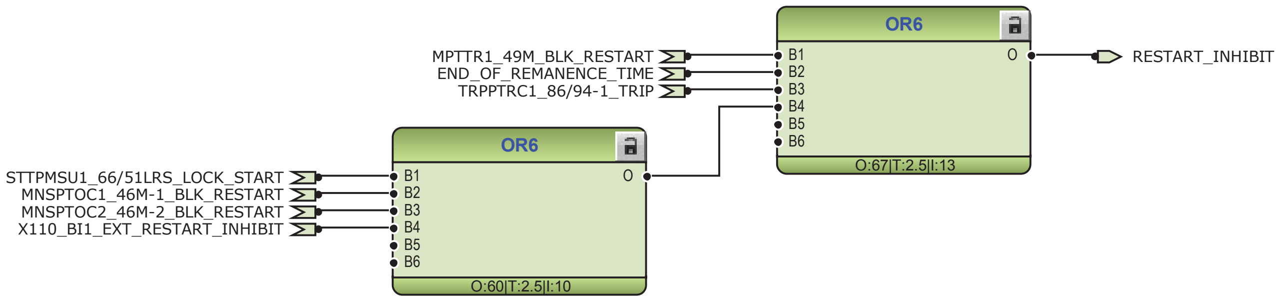


Figure 81: Circuit breaker 1 close blocking logic

When the motor restart is inhibited, the BLK_CLOSE input is activated and the circuit breaker is not closed. When all conditions of the circuit breaker closing are met, the CLOSE_ENAD output of the CBXCBR1_52 is activated and the X100:PO1 output is closed.

The configuration also includes restart inhibit. Restart inhibit is activated under various conditions.

- A trip command is active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- Thermal protection has issued blocked restart.
- An external restart inhibit is activated by a binary input X120:BI4.
- Time during which remanence voltage is present.

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

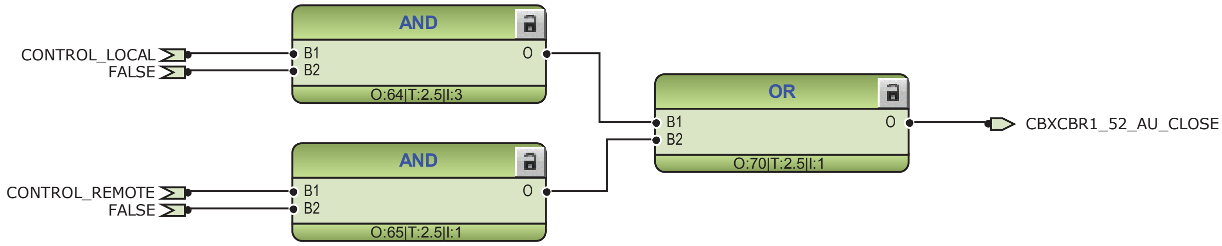


Figure 82: External closing command for circuit breaker 1

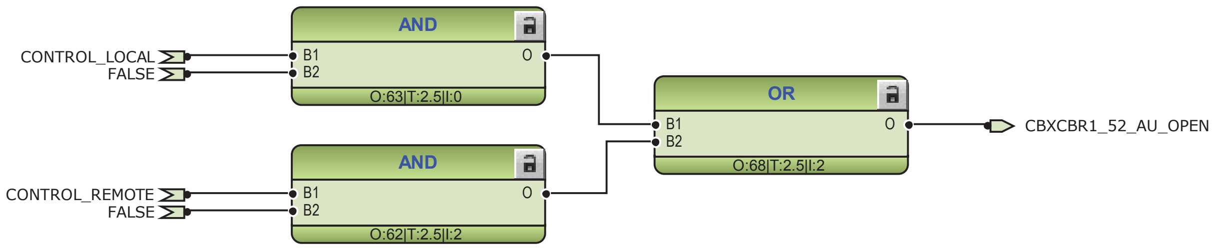


Figure 83: External opening command for circuit breaker 1

3.4.3.5 Functional diagrams for measurement functions

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

The three-phase voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1 respectively. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

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

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

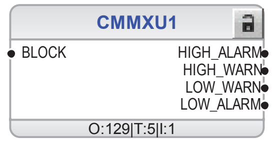


Figure 84: Three-phase current measurement

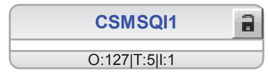


Figure 85: Sequence current measurement

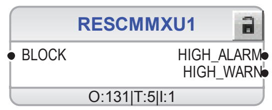


Figure 86: Residual current measurement

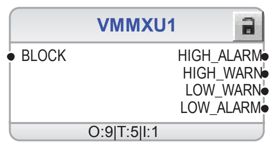


Figure 87: Three-phase voltage measurement

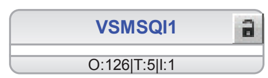


Figure 88: Sequence voltage measurement

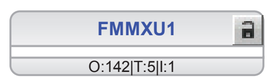


Figure 89: Frequency measurement

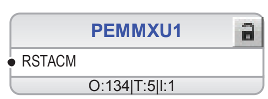


Figure 90: Three-phase power and energy measurement

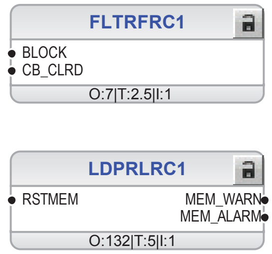


Figure 91: Data monitoring and load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

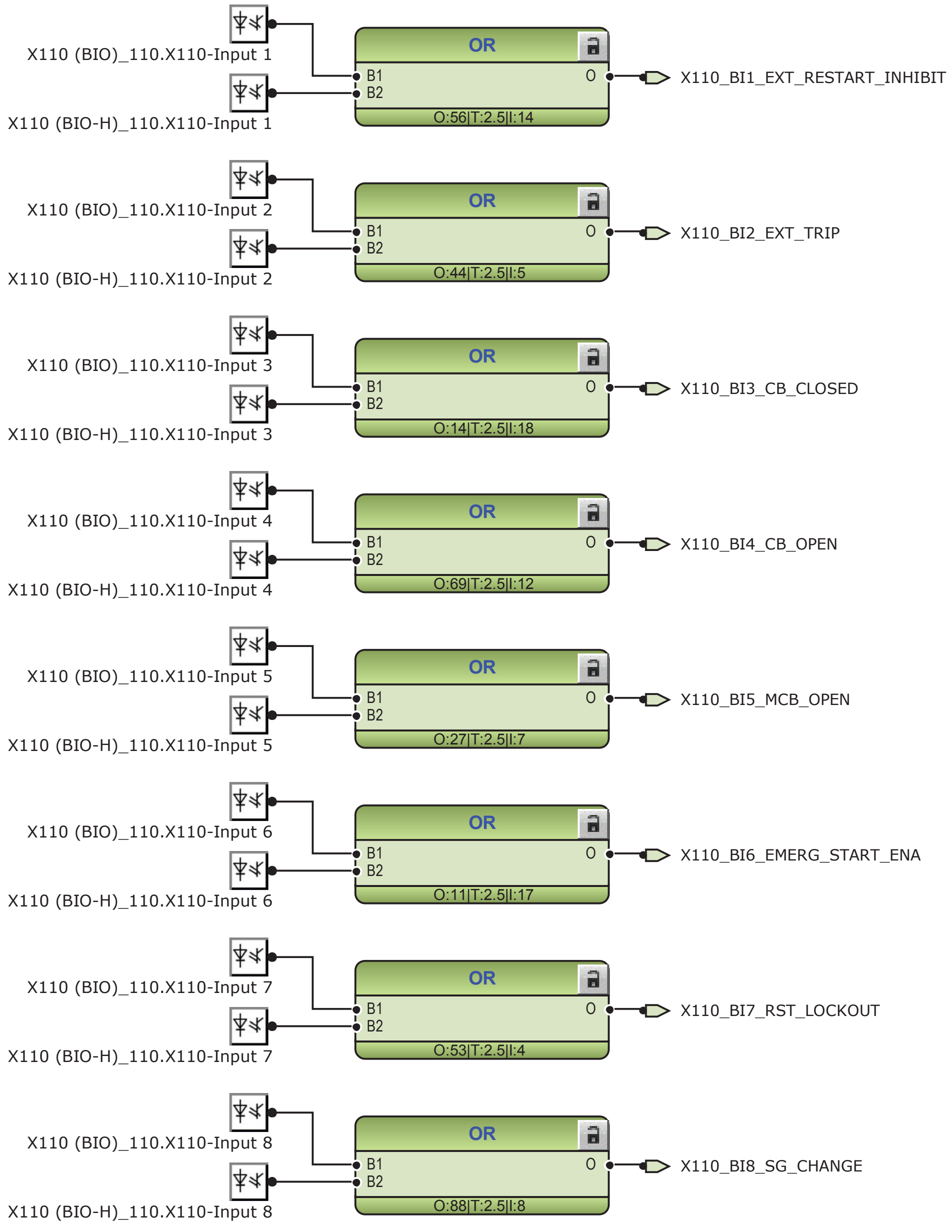


Figure 92: Default binary inputs - X110

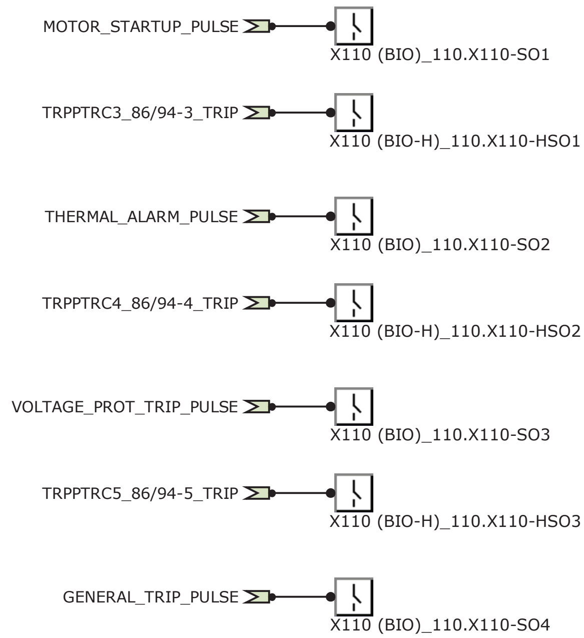


Figure 93: Default binary outputs - X110

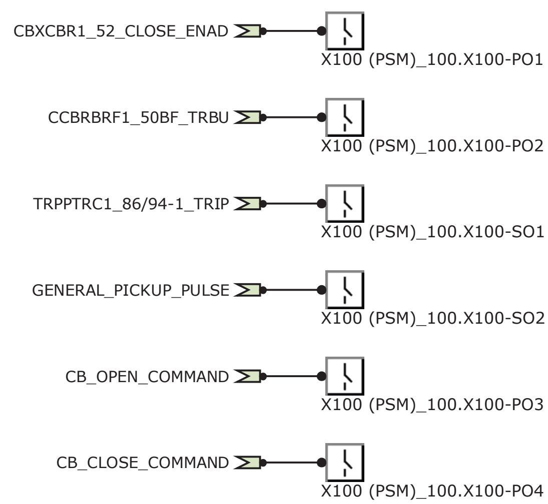


Figure 94: Default binary outputs - X100

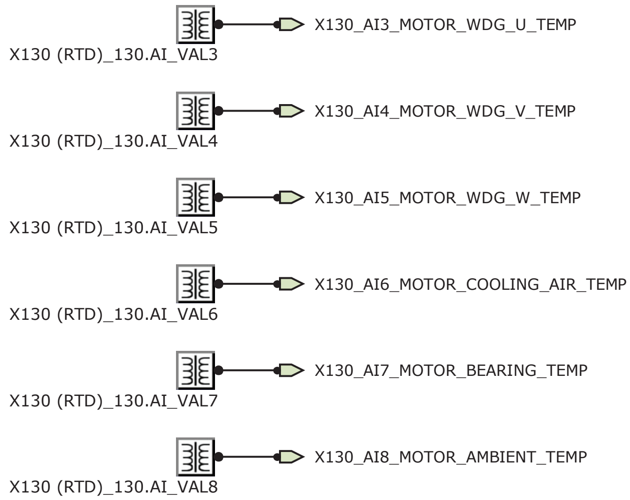


Figure 95: Default mA/RTD inputs X130

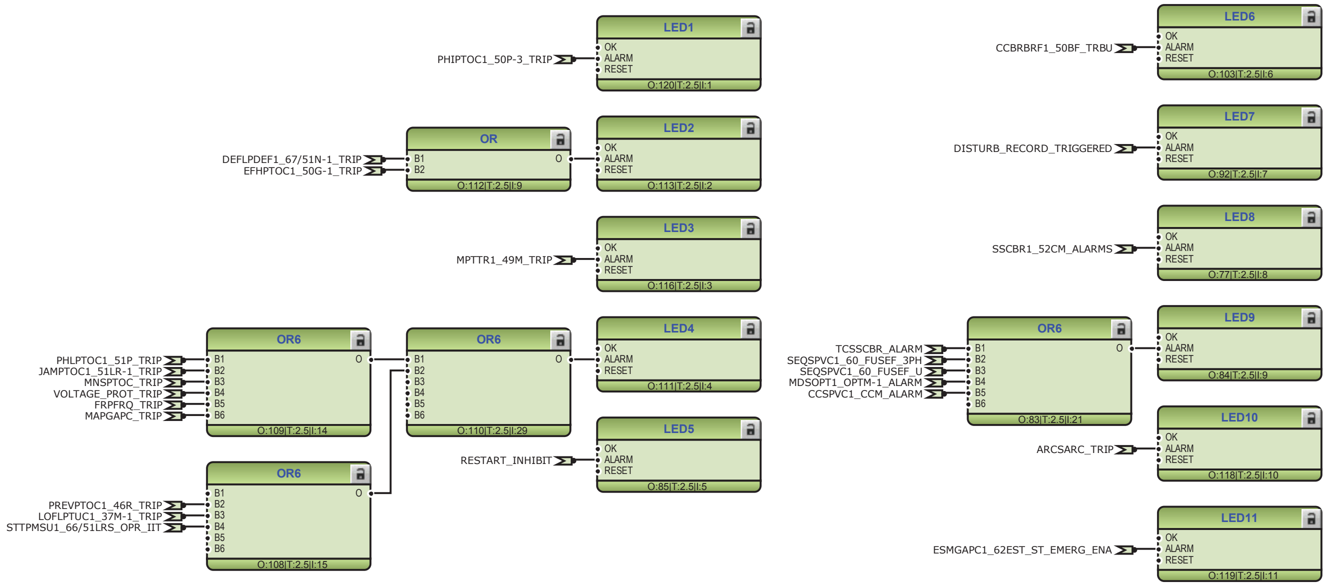


Figure 96: Default LED connections

3.4.3.7 Functional diagrams for other timer logics

The configuration also includes logic for remanence voltage. The restart inhibit is activated for a set period when a circuit breaker is in open state. This is called remanence voltage protection where the motor has damping remanence voltage after the opening of a circuit breaker. Reclosing after a short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

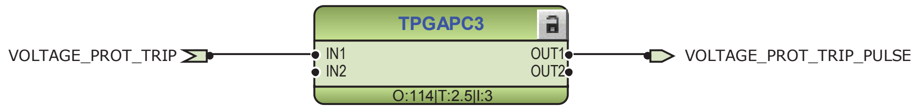


Figure 97: Timer logic for voltage protection trip alarm

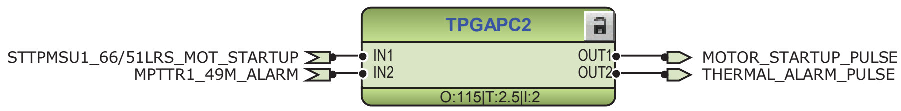


Figure 98: Timer logic for motor start-up and thermal alarm

Add signals for blocking phase undervoltage protection.

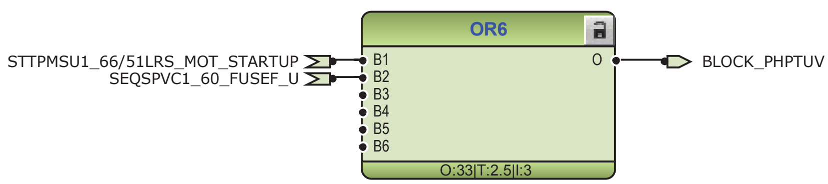


Figure 99: Blocking logic for phase undervoltage protection

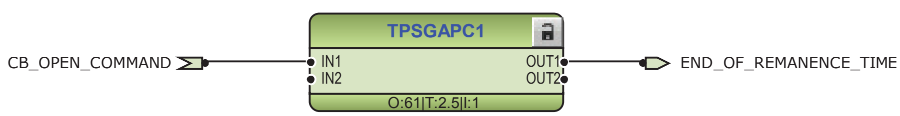


Figure 100: Timer logic for remanence voltage to disappear

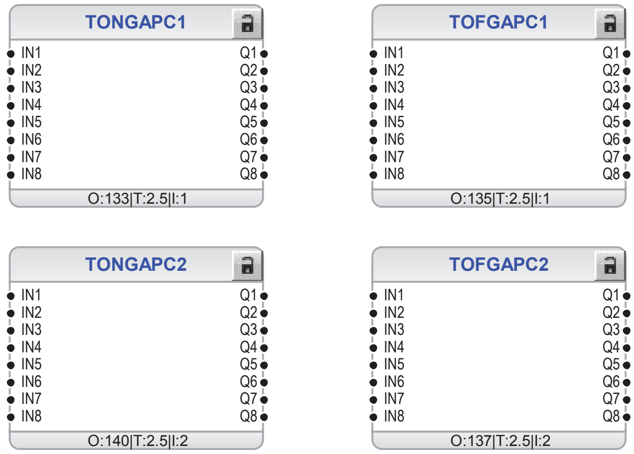


Figure 101: Programmable timers

3.4.3.8 Functional diagrams for other functions

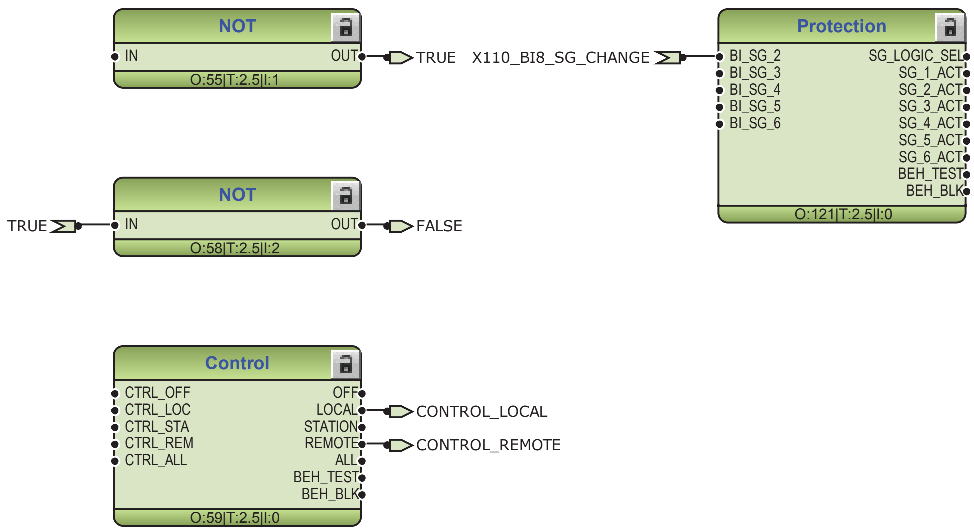


Figure 102: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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.

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

3.4.3.9 Functional diagrams for communication

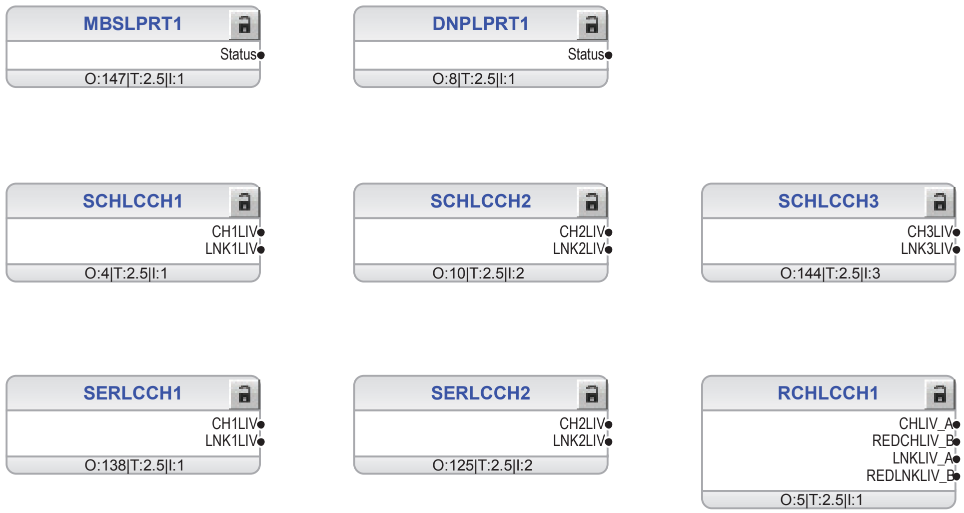


Figure 103: Default communication function connection

3.5 Standard configuration D

3.5.1 Applications

The standard configuration for motor protection with current and voltage based protection and measurements functions is mainly intended for comprehensive protection and control functionality of circuit breaker controlled asynchronous motors. With minor modifications this standard configuration can be applied also for contactor controlled motors.

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

3.5.2 Functions

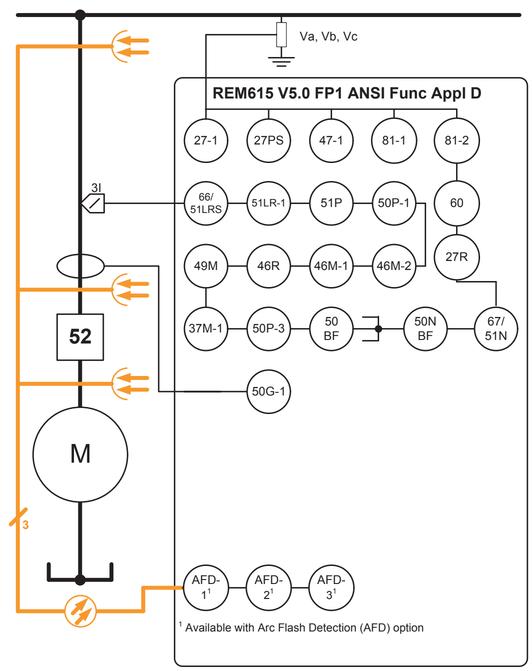


Figure 104: Functionality overview for standard configuration D

3.5.2.1 Default I/O connections

Table 21: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X131:4-5
IB	Phase B current	X132:4-5
IC	Phase C current	X133:4-5
IG	Residual current IG	X130:1-2
VA	Phase voltage VA	X131:7-8
VB	Phase voltage VB	X132:7-8
VC	Phase voltage VC	X133:7-8

Table 22: *Default connections for binary inputs*

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	-	X110:3-4	X110:2,5
X110-BI3	Circuit breaker in opened position	X110:5-6	X110:3,5
X110-BI4	Circuit breaker in closed position	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	-	X110:11-12	X110:8,10
X110-BI8	-	X110:13-12	X110:9-10

Table 23: *Default connections for binary outputs*

Binary output	Description	Connector pins
X100-PO1	Release for circuit breaker closing	X100:6-7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8-9
X100-SO1	-	X100:10-11,(12)
X100-SO2	-	X100:13-14
X100-PO3	Open circuit breaker/trip	X100:15-19
X100-PO4	Close circuit breaker	X100:20-24
X110-SO1	-	X110:14-16
X110-SO2	-	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	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 24: *Default connections for LEDs*

LED	Default usage	ID	Label description
1	Circuit breaker close enabled	LED_CBcloseenabled_1	CB close enabled
2	Overcurrent protection trip	LED_ShortCircuit_1	Overcurrent
3	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
4	Loss of load protection trip	LED_LossOfLoad_1	Loss of load
5	Other protection function trip	LED_CombinedProtection_1	Combined Protection
6	-	-	-

Table continues on next page

LED	Default usage	ID	Label description
7	Thermal overload protection trip	LED_ThermalOverload_1	Thermal overload
8	Undervoltage or frequency protection trip	LED_UVorFrequency_1	UV / Frequency
9	Supervision alarm	LED_Supervision_1	Supervision
10	Circuit breaker condition monitoring alarm	LED_CBConditionMonitoring_1	CB condition monitoring
11	-	-	-

3.5.2.2 Default disturbance recorder settings

Table 25: Default disturbance recorder analog channels

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

Table 26: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHIPTOC1 - pickup	Positive or Rising
3	DEFLPDEF1 - pickup	Positive or Rising
4	EFHPTOC1 - pickup	Positive or Rising
5	MPTTR1 - alarm	Level trigger off
6	MPTTR1 - blk restart	Level trigger off
7	ESMGAPC1 - st emerg ena	Level trigger off
8	STTPMSU1 - mot startup	Positive or Rising
9	STTPMSU1 - lock start	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
10	MNSPTOC1 - pickup	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - pickup	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - pickup	Positive or Rising
15	PHPTUV1 - pickup	Positive or Rising
16	PSPTUV1 - pickup	Positive or Rising
17	NSPTOV1 - pickup	Positive or Rising
18	FRPFRQ1 - pickup	Positive or Rising
19	FRPFRQ2 - pickup	Positive or Rising
20	CCBRBRF1 - trret	Level trigger off
21	CCBRBRF1 - trbu	Level trigger off
22	PHLPTOC1 - trip	Level trigger off
23	PHIPTOC1 - trip	Level trigger off
24	JAMPTOC1 - trip	Level trigger off
25	DEFLPDEF1/EFHPTOC1 - trip	Level trigger off
26	MNSPTOC - trip	Level trigger off
27	PREVPTOC1 - trip	Level trigger off
28	LOFLPTUC1 - trip	Level trigger off
29	MPTTR1 - trip	Level trigger off
30	PHPTUV1 - trip	Level trigger off
31	PSPTUV1 - trip	Level trigger off
32	NSPTOV1 - trip	Level trigger off
33	FRPFRQ1 - trip	Level trigger off
34	FRPFRQ2 - trip	Level trigger off
35	-	-
36	-	-
37	X110BI4 - CB closed	Level trigger off
38	X110BI3 - CB open	Level trigger off
39	STTPMSU1 - opr iit	Positive or Rising
40	STTPMSU1 - opr stall	Positive or Rising
41	CCSPVC1 - fail	Level trigger off
42	ARCSARC - ARC flt det	Level trigger off
43	ARCSARC1 - trip	Positive or Rising
44	ARCSARC2 - trip	Positive or Rising
45	ARCSARC3 - trip	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
46	MSVPR1 - U_LO	Level trigger off
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

3.5.3 Functional diagrams

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

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 phase voltages to the protection relay are fed from Combi sensors. The residual voltage is calculated internally

The phase currents to the protection relay are fed from Rogowski or Combi sensors. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages.

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

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

3.5.3.1 Functional diagrams for protection

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

Two overcurrent stages are offered for overcurrent and short-circuit protection. The nondirectional low stage PHLPTOC1_51P can be used for overcurrent protection whereas the instantaneous stage PHIPTOC1_50P-3 can be used for short-circuit protection. The operation of PHIPTOC1_50P-3 is not blocked as default by any functionality and it should be set over the motor pickup current level to avoid unnecessary operation.

The Motor load jam protection function JAMPTOC1_51LR-1 is blocked by the motor start-up protection function.

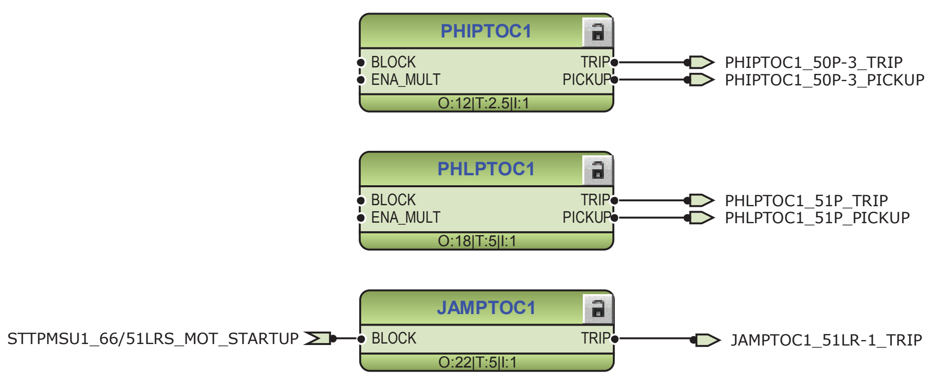


Figure 105: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect the motor against phase unbalance. Unbalance in the network feeder of the motor causes overheating of the motor.

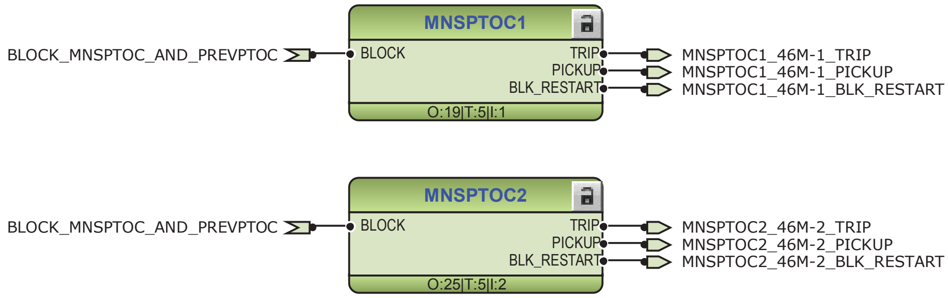


Figure 106: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1_46R is based on the calculated negative phase sequence current. It detects high negative-sequence current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

The negative-sequence and phase reversal protection are blocked if the current circuit supervision detects failure in the current measurement circuit.

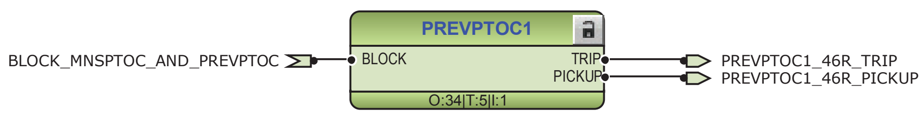


Figure 107: Phase reversal protection function

One stage is provided for non-directional ground-fault protection EFHPTOC1_50G-1 to detect phase-to-ground faults that may be result of, for example, insulation ageing. In addition, there is a directional protection stage DEFLPDEF1_67/51N which can also be used as a low stage non-directional ground-fault protection without residual voltage requirement. However, the residual voltage can help to detect ground faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor start-up.

Both the directional and non-directional ground-fault protection are blocked by the activation of instantaneous stage of overcurrent protection

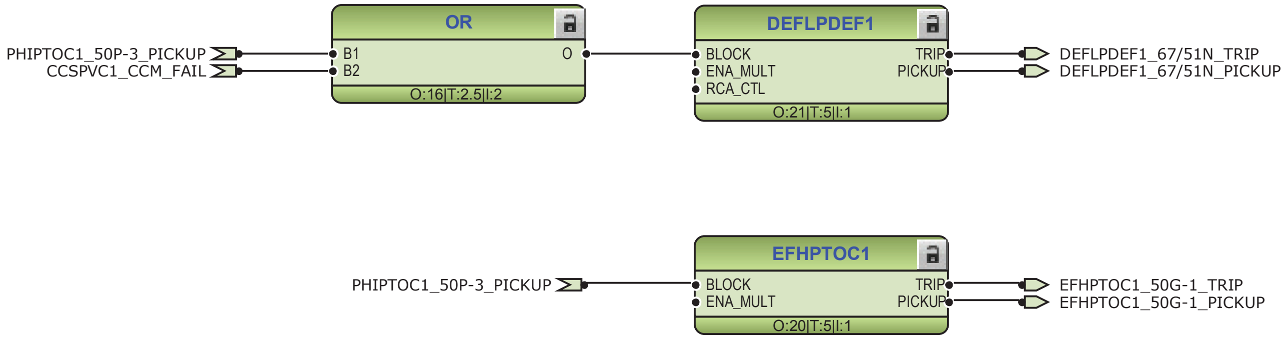


Figure 108: Ground-fault protection functions

The emergency start function ESMGAPC1_62EST allows motor start-ups although the calculated thermal level or cumulative start-up time counter is blocking the restart. The emergency start is enabled for ten minutes after the selected binary input X110:BI6 is energized.

On the rising edge of the emergency pickup signal, various events occur.

- The calculated thermal level in MPTTR1_49M is set slightly below the restart inhibit level to allow at least one motor start-up.
- The value of the cumulative start-up time counter STTPMSU1_66/51LRS is set slightly below the set restart inhibit value to allow at least one motor start-up.
- The set pickup value of the MAPGAPC1_MAP-1 function is increased (or decreased) depending on the *Pickup value Add* setting (only if the optional RTD/mA module is included).
- Alarm LED 11 is activated.

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time has expired.

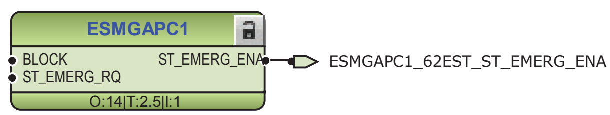


Figure 109: Motor emergency start-up function

The thermal overload protection for motors MPTTR1_49M detects short and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. Restart blocking, issued by the thermal overload function, prevents the closing of the breaker in machine overload situation. The emergency start request removes the blocking and enables the restarting of the motor.

If the relay is ordered with a RTD/mA card, the motor ambient temperature can be measured with input RTD X130:AI8 and it is connected to the thermal overload protection function MPTTR1_49M.

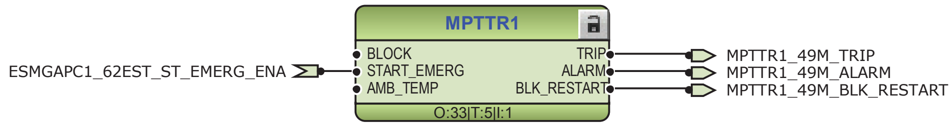


Figure 110: Motor thermal overload protection

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection where the motor has damping remanence voltage after the circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

The restart inhibit is also activated under various conditions.

- A trip command becomes active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- An external restart inhibit is activated by a binary input X120:BI4.

With the motor start-up supervision function STTPMSU1_66/51LRS, the starting of the motor is supervised by monitoring the three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1_62EST and STTPMSU1_66/51LRS is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

The upstream blocking from the motor start-up is connected to the binary output X110:SO1. The output is used for sending a blocking signal to the relevant overcurrent protection stage of the relay at the infeeding bay.

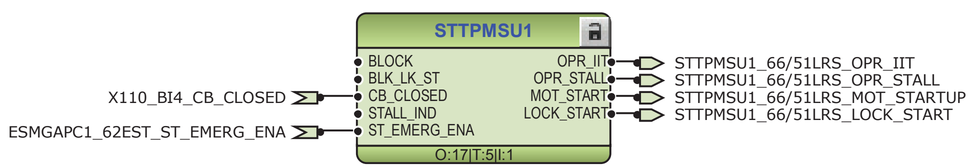


Figure 111: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1_OPTM-1 provides history data since the last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed.

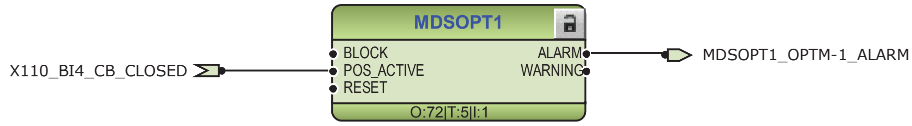


Figure 112: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1_37M-1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

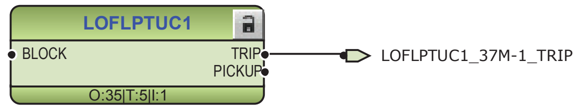


Figure 113: Loss of load protection function

The three-phase undervoltage protection PHPTUV1_27-1 offers protection against abnormal phase voltage conditions. The positive-sequence undervoltage protection PSPTUV1_27PS and negative-sequence overvoltage protection NSPTOV1_47-1 functions are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order.

A failure in the voltage measuring circuit is detected by the fuse failure function. The activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping. The three-phase undervoltage protection PHPTUV1_27-1 in addition is also blocked during motor start-up to prevent unwanted operation in case of a short voltage drop.

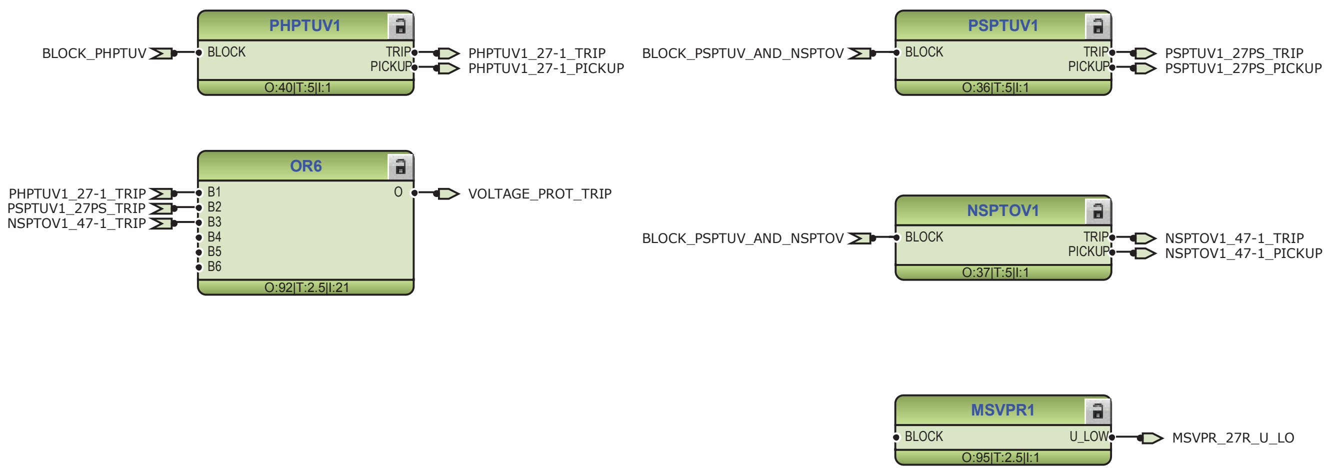


Figure 114: Voltage protection function

Two frequency protection stages FRPFRQ1_81-1 and FRPFRQ2_81-2 are offered. These functions are used to protect the motor against abnormal power system frequency.

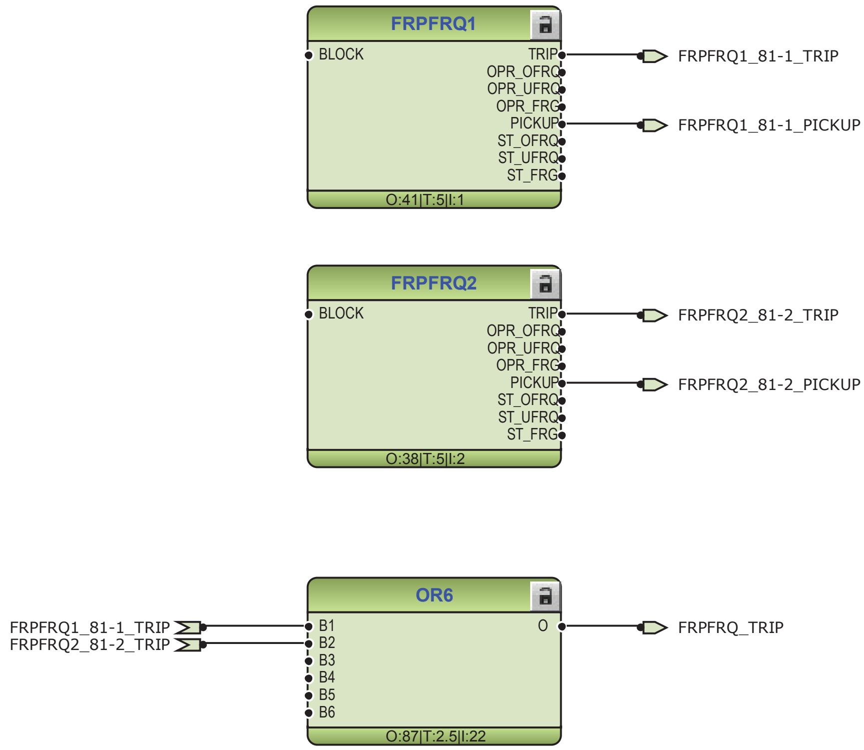


Figure 115: Frequency protection function

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

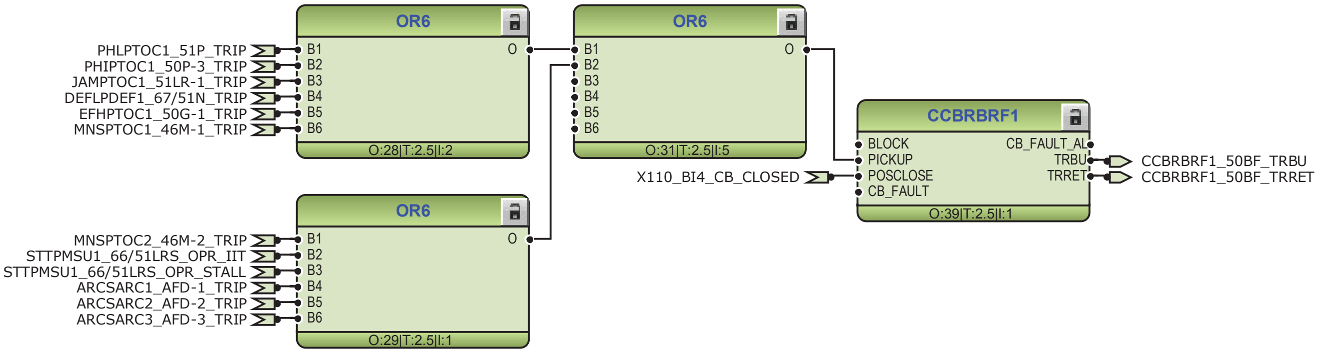


Figure 116: Circuit breaker failure protection function

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, that is, with or without the phase and residual current check.

The trip signals from ARCSARC1...3_AFD-1…3 are connected to both trip logic 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 outputs of TRPPTRC3...5__86/94-3…5 are available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

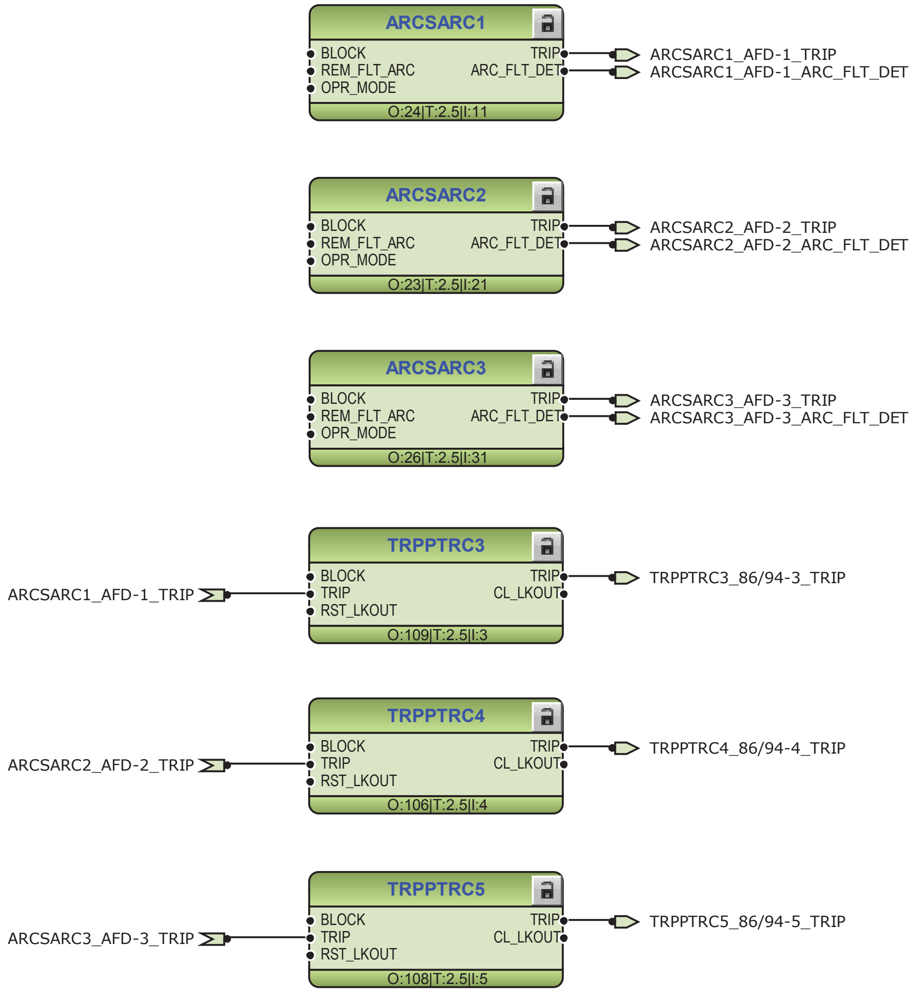


Figure 117: Arc protection with dedicated high-speed output

General pickup and trip from all the functions are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs. The output from TPGAPC is connected to binary outputs.

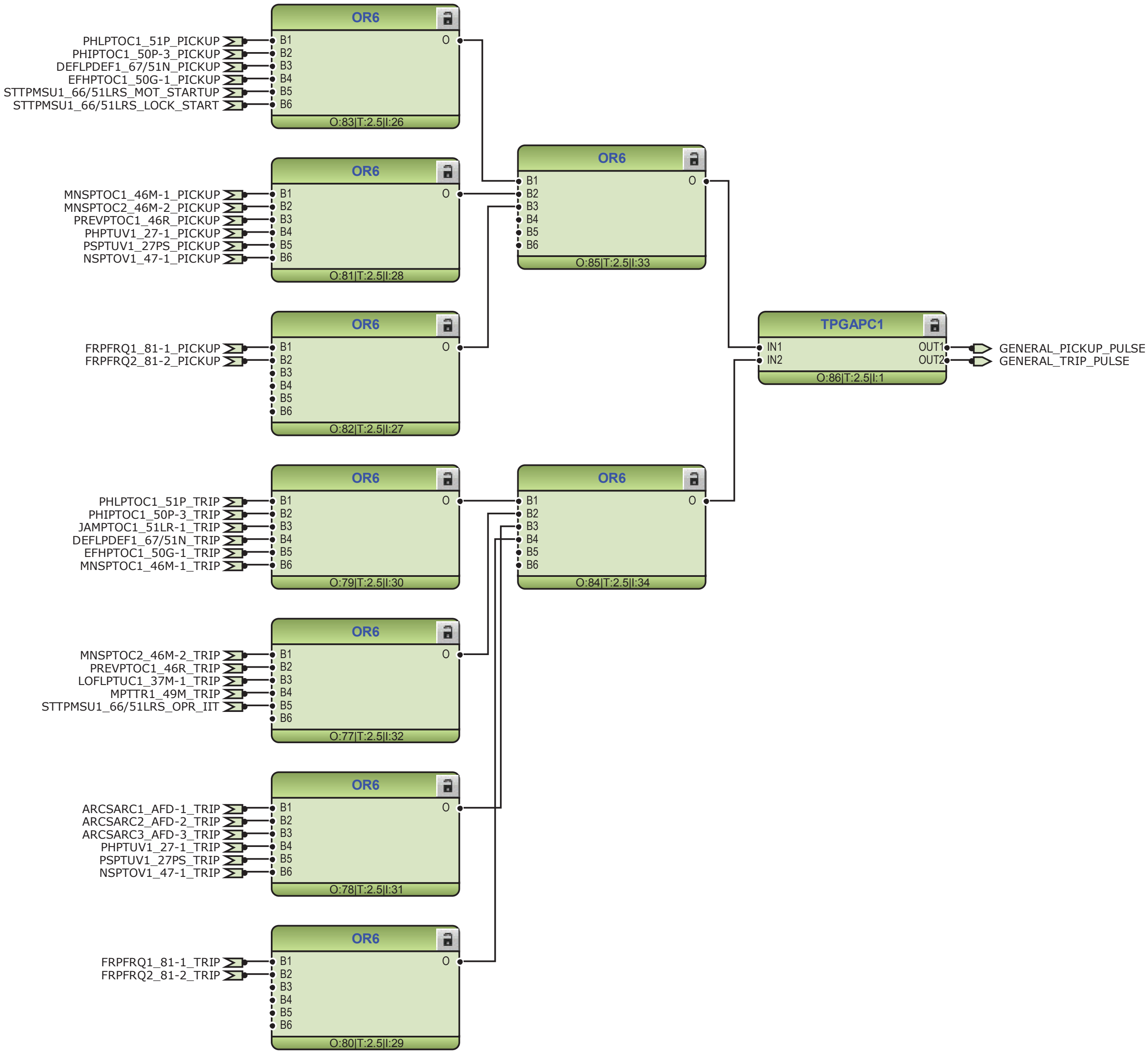


Figure 118: General pickup and trip signals

The trip signals from the protection functions are connected to trip logics TRPPTRC1_86/94-1. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:SO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, the binary input can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...5_86/94-3…5 are also available if the relay is ordered with high-speed binary outputs options.

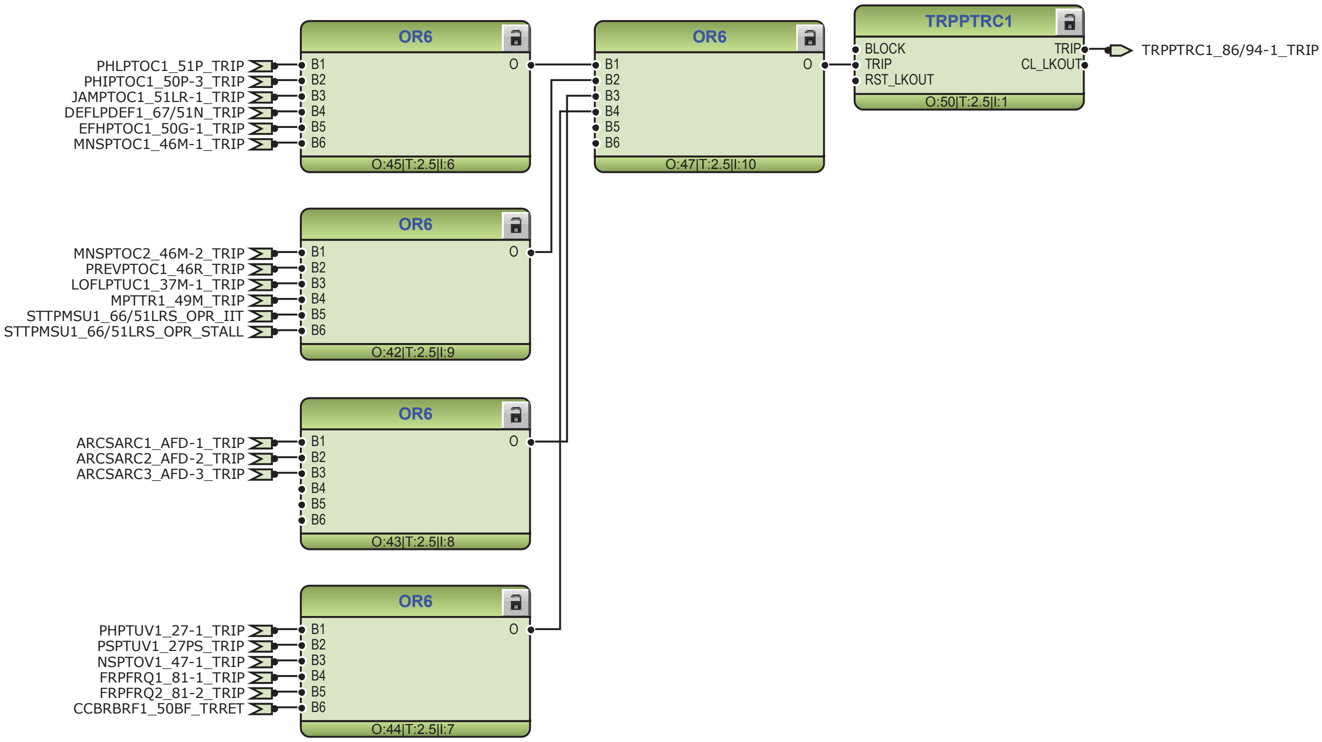


Figure 119: Trip logic TRPPTRC1

3.5.3.2 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.

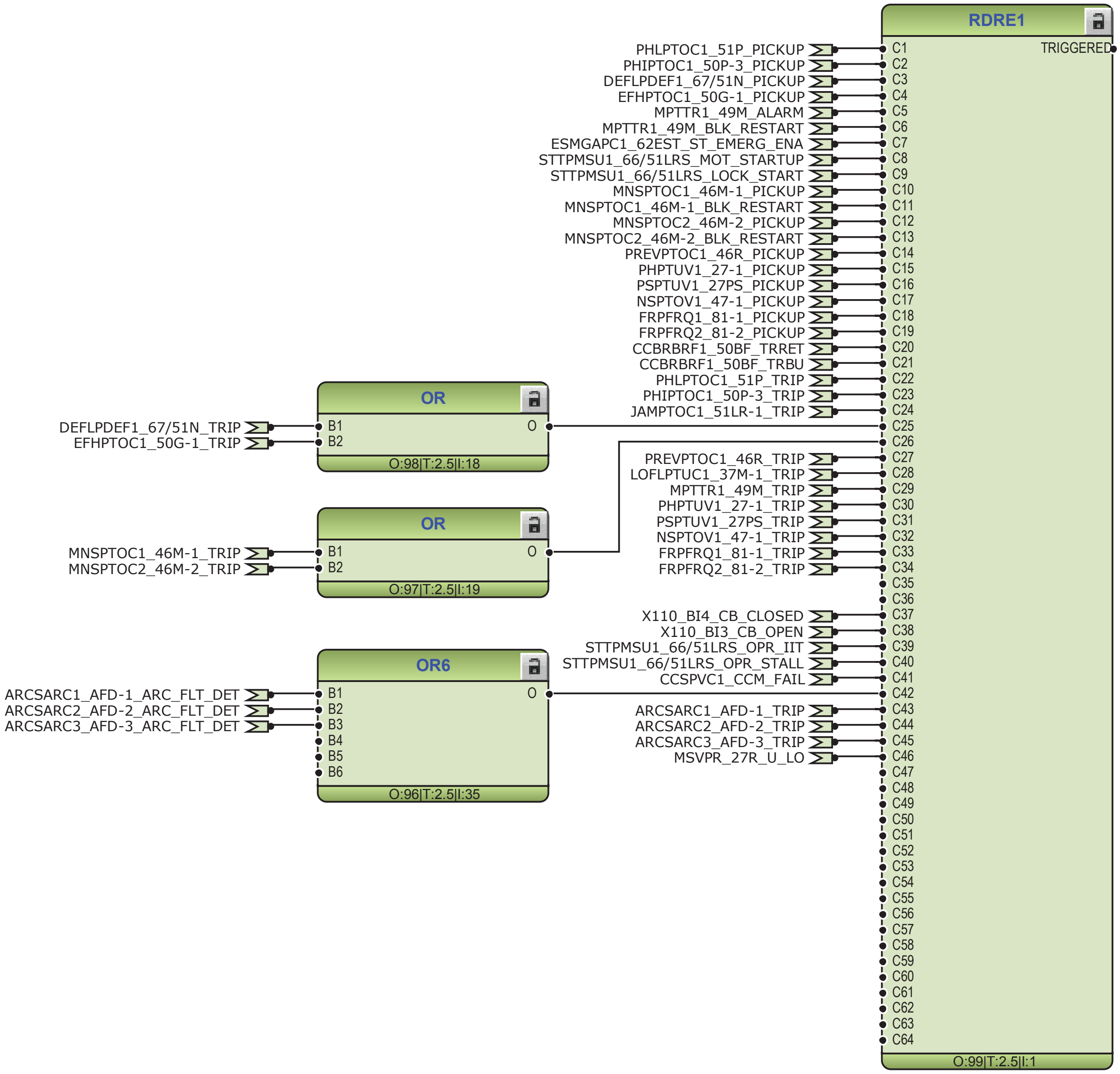


Figure 120: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

CCSPVC1_CCM detects failures in the current measuring circuits. When a failure is detected, it can be used to block the current protection functions that measure the calculated sequence component currents to avoid unnecessary operation. However, the BLOCK input signal is not connected in the configuration.

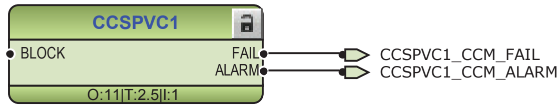


Figure 121: Current circuit supervision function

The fuse failure supervision SEQSPVC1_60 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

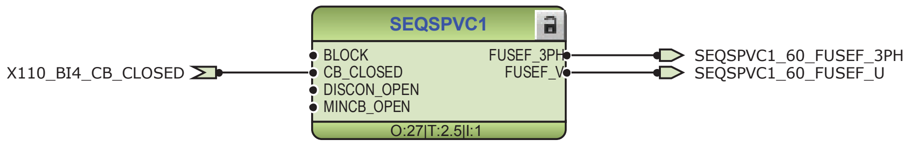


Figure 122: Fuse failure supervision function

The circuit-breaker condition monitoring function SSCBR1_52CM supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM introduces various supervision methods.

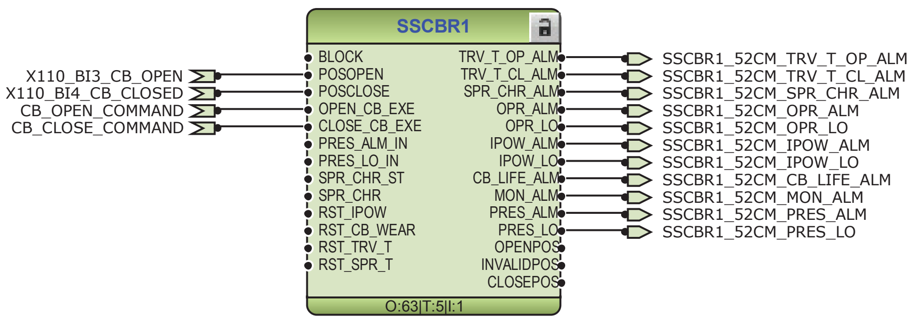


Figure 123: Circuit-breaker condition monitoring function

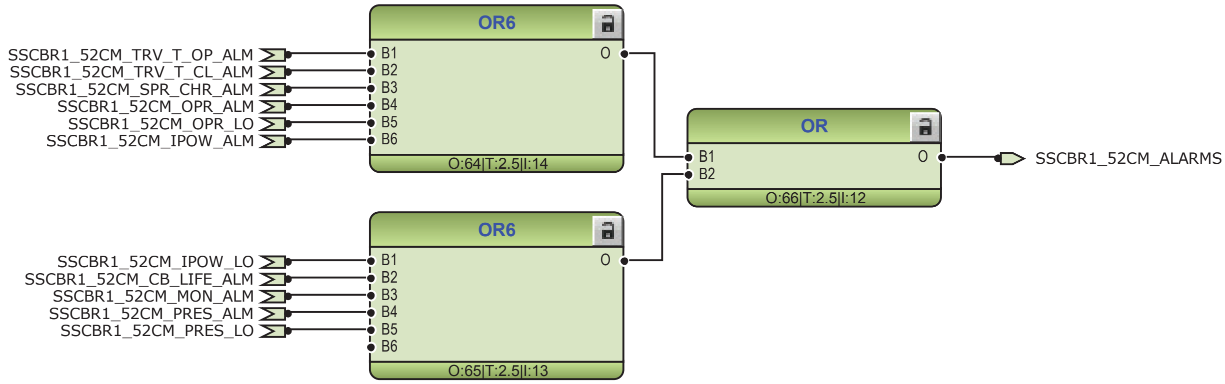


Figure 124: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 for master trip and TCSSCBR2_TCM-2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1_TCM-1 is blocked by the master trip TRPPTRC1_86/94-1 and the circuit breaker open signal. The trip circuit supervision function TCSSCBR2_86/94-2 is blocked by the circuit breaker close signal.

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

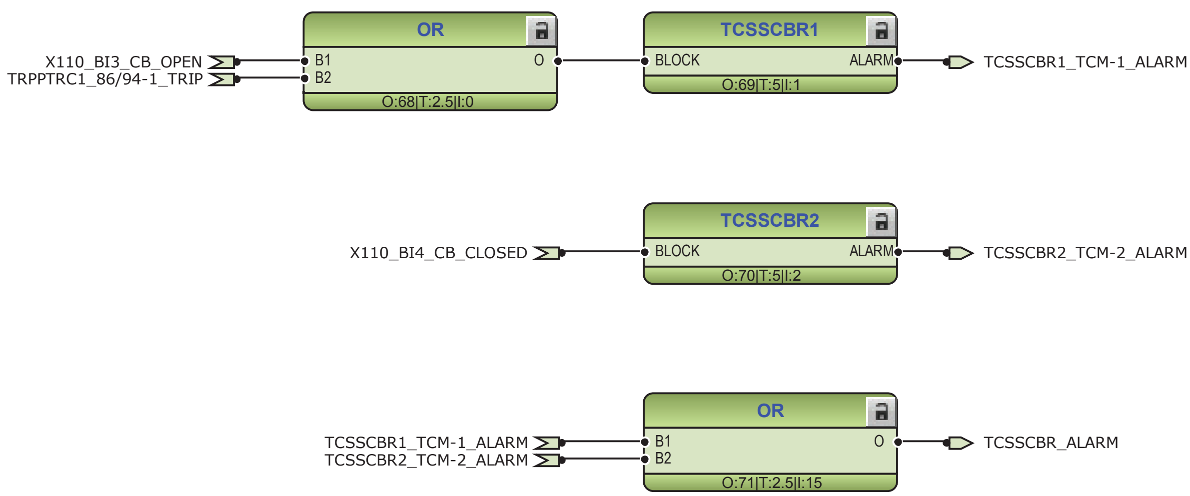


Figure 125: Trip circuit supervision function

3.5.3.4 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 and ground switch position status, status of the trip logics, gas pressure alarm and circuit breaker spring charging status. In the configuration, only trip logic activates the close-enable signal to the circuit-breaker control function block. The open operation for circuit breaker is always enabled.

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

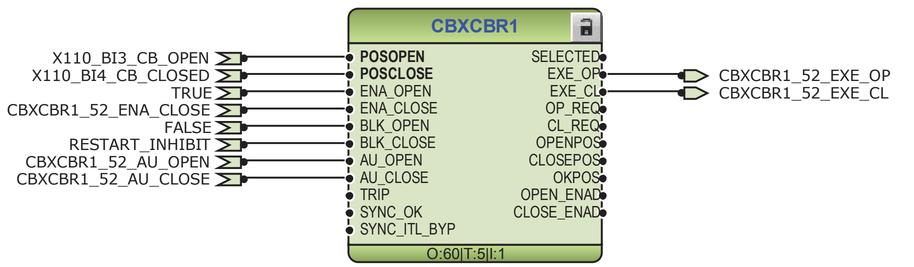


Figure 126: Circuit breaker 1 control logic

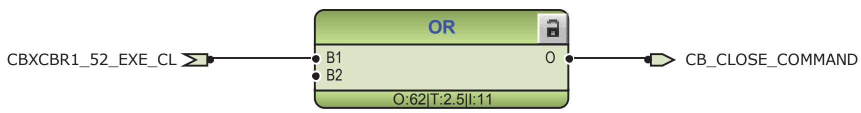


Figure 127: Signals for closing coil of circuit breaker 1

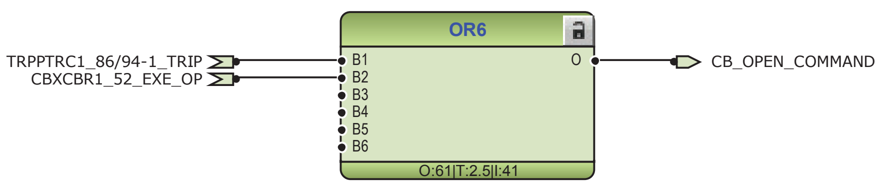


Figure 128: Signals for opening coil of circuit breaker 1

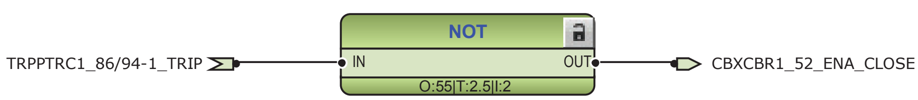


Figure 129: Circuit breaker 1 close enable logic

Connect higher-priority conditions before enabling the closing of circuit breaker. These conditions cannot be bypassed with bypass feature of the function.

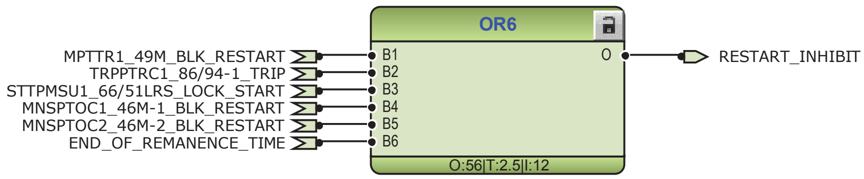


Figure 130: Circuit breaker 1 close blocking logic

When the motor restart is inhibited, the `BLK_CLOSE` input is activated and the circuit breaker is not closed. When all conditions of the circuit breaker closing are met, the `CLOSE_ENAD` output of the CBXCBR1_52 is activated and the X100:PO1 output is closed.

The configuration also includes restart inhibit. Restart inhibit is activated under various conditions.

- A trip command is active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- Thermal protection has issued blocked restart.
- An external restart inhibit is activated by a binary input X120:BI4.
- Time during which remanence voltage is present.

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

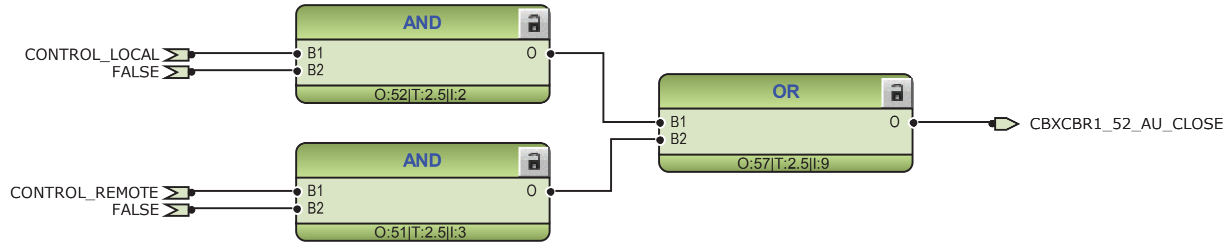


Figure 131: External closing command for circuit breaker 1

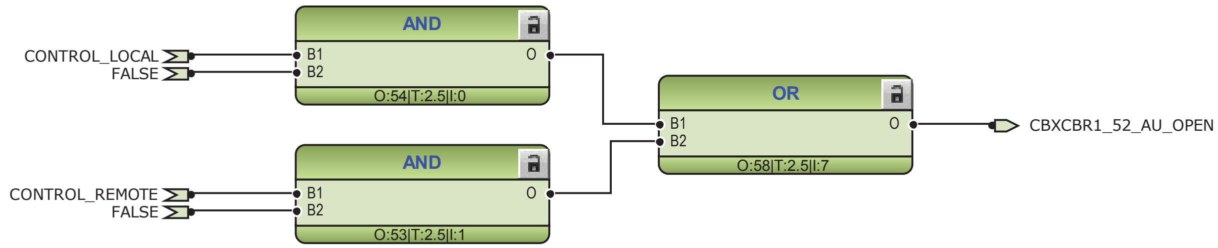


Figure 132: External opening command for circuit breaker 1

3.5.3.5 Functional diagrams for measurement functions

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

The three-phase voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1 respectively. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

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

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

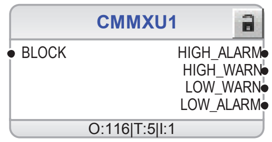


Figure 133: *Three-phase current measurement*

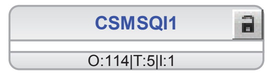


Figure 134: *Sequence current measurement*

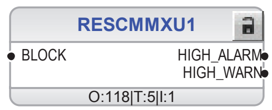


Figure 135: *Residual current measurement*

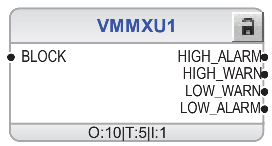


Figure 136: *Three-phase voltage measurement*

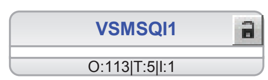


Figure 137: *Sequence voltage measurement*

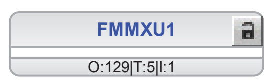


Figure 138: *Frequency measurement*

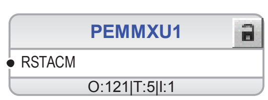


Figure 139: *Three-phase power and energy measurement*

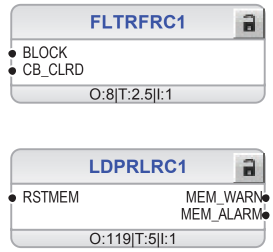


Figure 140: Data monitoring and load profile record

3.5.3.6 Functional diagrams for I/O and alarm LEDs

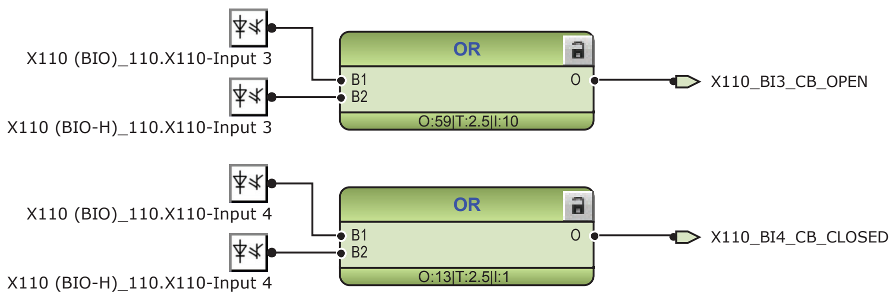


Figure 141: Default binary inputs - X110

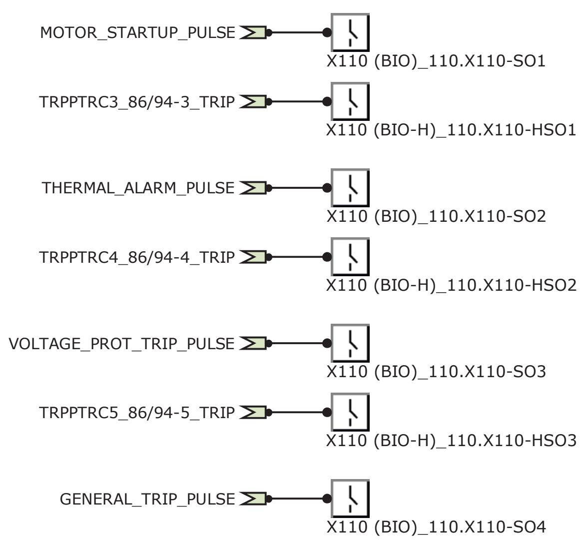


Figure 142: Default binary outputs - X110

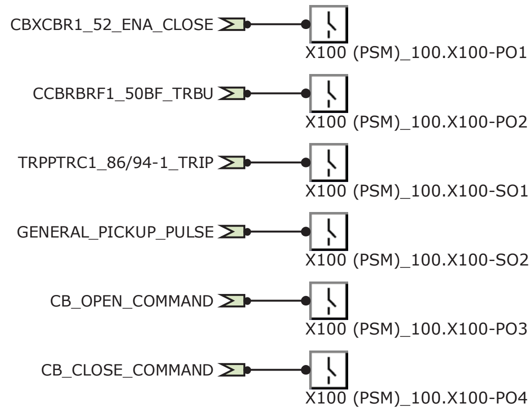


Figure 143: Default binary outputs - X100

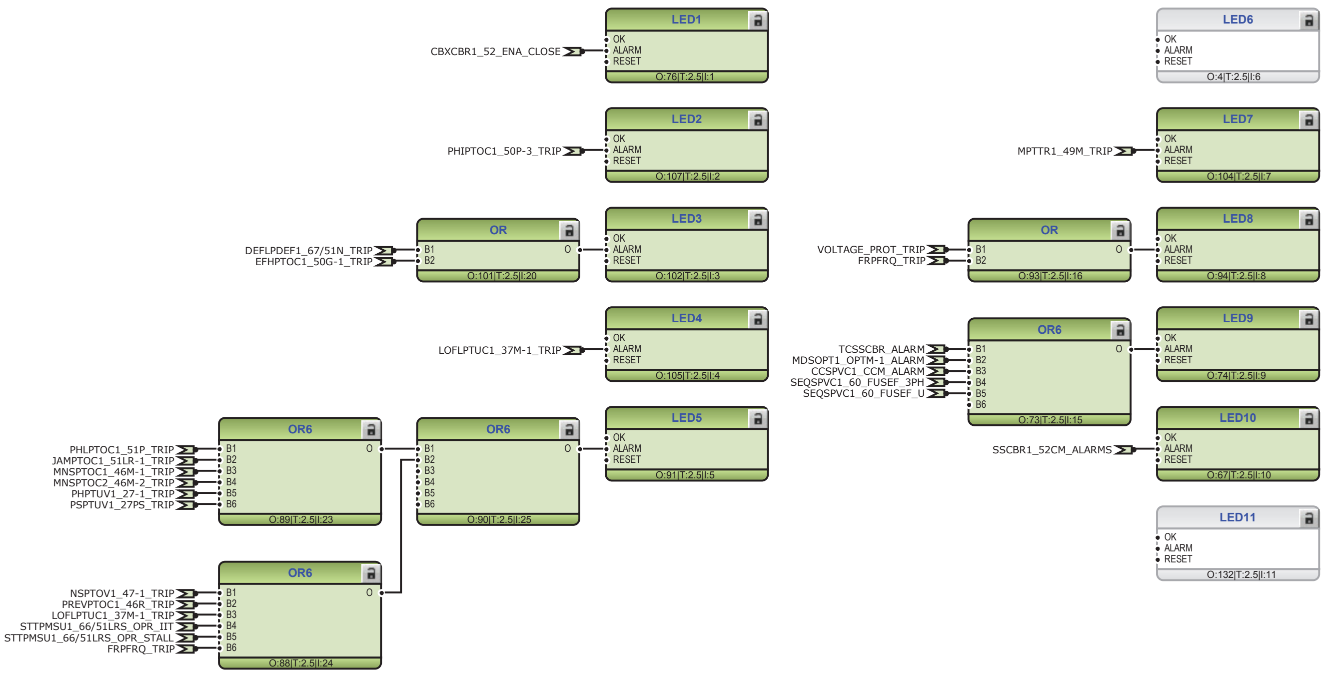


Figure 144: Default LED connections

3.5.3.7 Functional diagrams for other timer logics

The configuration also includes logic for remanence voltage. The restart inhibit is activated for a set period when a circuit breaker is in open state. This is called remanence voltage protection where the motor has damping remanence voltage after the opening of a circuit breaker. Reclosing after a short period of time can lead to stress for the machine and other apparatus. The remanence voltage protection waiting time can be set by a timer function TPSGAPC1.

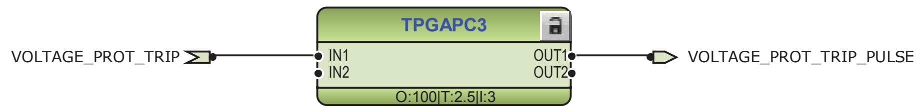


Figure 145: Timer logic for voltage protection trip alarm

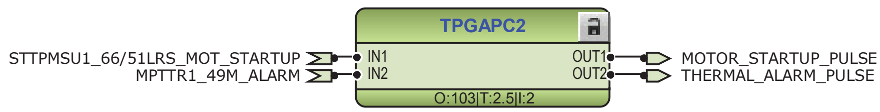


Figure 146: Timer logic for motor start-up and thermal alarm

Add signals for blocking phase undervoltage protection.

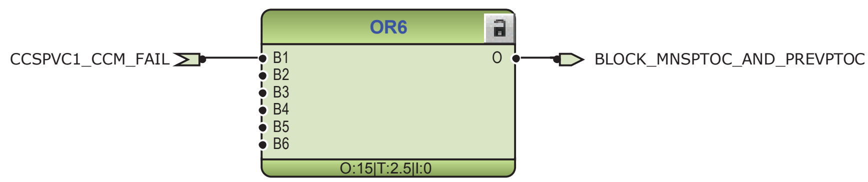


Figure 147: Blocking logic for phase reversal and negative-sequence overcurrent protection

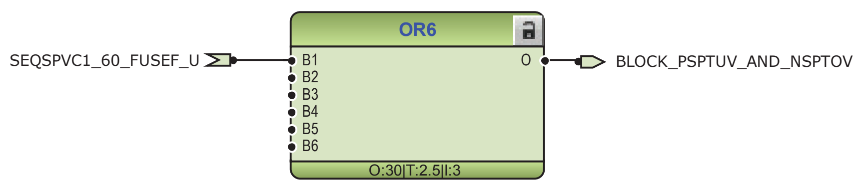


Figure 148: Blocking logic for positive-sequence undervoltage and negative-sequence overvoltage protection

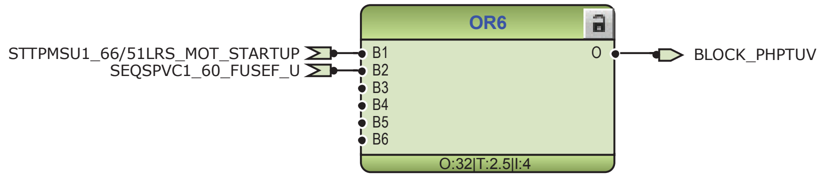


Figure 149: Blocking logic for phase undervoltage protection

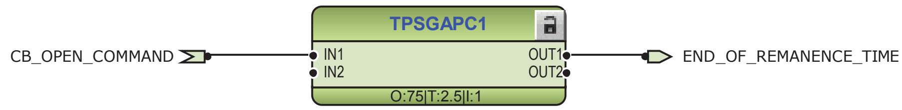


Figure 150: Timer logic for remanence voltage to disappear

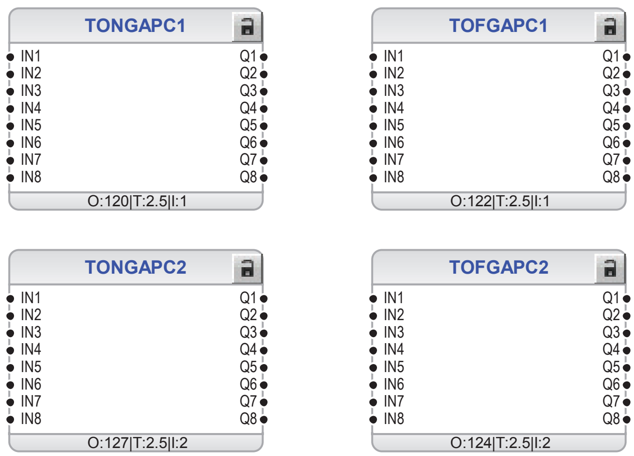


Figure 151: Programmable timers

3.5.3.8 Functional diagrams for other functions

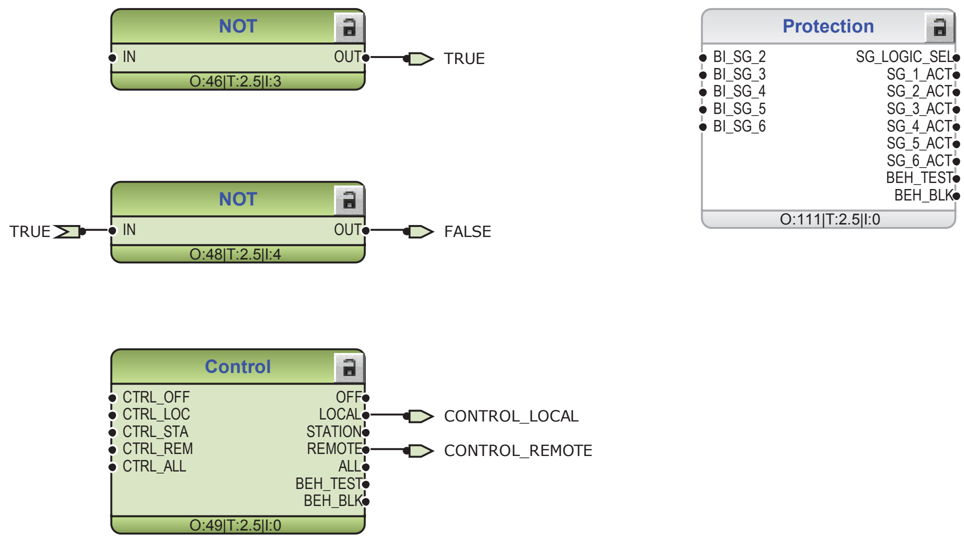


Figure 152: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

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.

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

3.5.3.9 Functional diagrams for communication

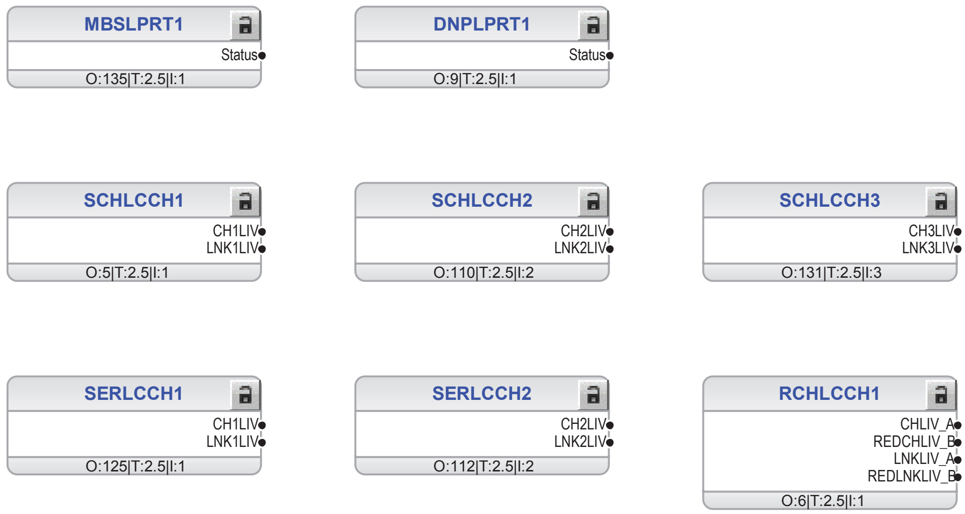


Figure 153: Default communication function connection

3.6 Standard configuration E

3.6.1 Applications

The standard configuration for order code functional applications can be used for medium to large circuit breaker controlled induction motors with true and core balance differential, current, voltage, frequency, power, over-excitation and thermal protections. This configuration does not have the internal RTD module in the relay and its thermal protections are realized through use of the remote RTD devices (ABB RIO600) with GOOSE communication. This configuration can also be applied for contactor controlled motors.

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

3.6.2 Functions

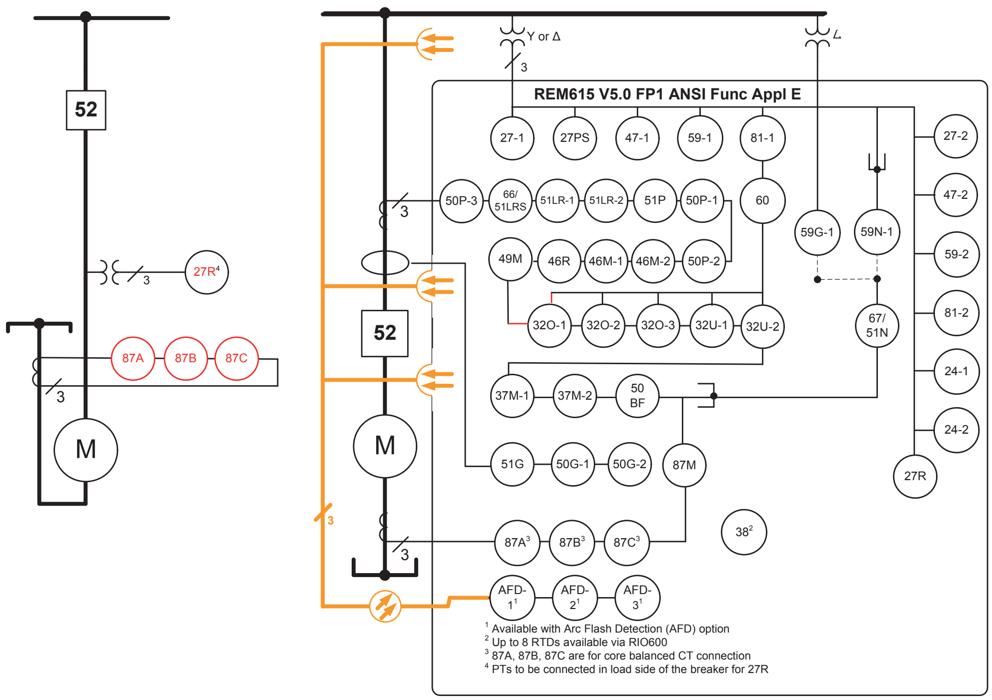


Figure 154: Functionality overview for standard configuration E

3.6.2.1 Default I/O connections

Table 27: Default connections for analog inputs

Analog input	Description	Connector pins
IA(2)	Phase A current, neutral side	X120:1-2
IB(2)	Phase B current, neutral side	X120:3-4
IC(2)	Phase C current, neutral side	X120:5-6
IA(1)	Phase A current, line side	X120:7-8
IB(1)	Phase B current, line side	X120:9-10
IC(1)	Phase C current, line 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 28: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	-	X110:1-2	X110:1,5
X110-BI2	-	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	Emergency start enable	X110:10-9	X110:7,10
X110-BI7	Circuit breaker closed position indication	X110:11-12	X110:8,10
X110-BI8	Circuit breaker open position indication	X110:13-12	X110:9-10

Table 29: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	-	X100:10-11,(12)
X100-SO2	-	X100:13-14
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open circuit breaker/trip coil 2	X100:20-24
X110-SO1	Stator Alarm RTD	X110:14-16
X110-SO2	Bearing Alarm RTD	X110:17-19
X110-SO3	-	X110:20-22
X110-SO4	-	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO2	Arc protection instance 2 trip activated	X110:19-20
X110-HSO3	Arc protection instance 3 trip activated	X110:23-24

Table 30: Default connections for LEDs

LED	Default usage	ID	Label description
1	Phase A	LED_Phase_A	Phase A overcurrent
2	Phase B	LED_Phase_B	Phase B overcurrent
3	Phase C	LED_Phase_C	Phase C overcurrent
4	Neutral / Ground	LED_Neutral	Ground-fault
5	Overcurrent	LED_Overcurrent_1	Overcur./Diff.
6	Undercurrent Protection	LED_Undercurrent	Undercurrent

Table continues on next page

LED	Default usage	ID	Label description
7	Locked Rotor/Load Jam	LED_Locked_Rotor_Jam	Locked Rotor/Jam
8	Combined Protection	LED_CombinedProtection_1	Combined Protection
9	Phase Rev. / Neg. Seq.	LED_Phase_Rev_Neg_Seq	Phase Rev. / Neg. Seq.
10	Overload Alarm/Trip	LED_Overload_Alarm_Trip	Overload Alarm/Trip
11	Arc flash detection	LED_ArcDetected_1	Arc detected

3.6.2.2 Default disturbance recorder settings

Table 31: Default disturbance recorder analog channels

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

Table 32: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	TRPPTRC1_86/94-1_TRIP	Positive or Rising
2	TRPPTRC2_86/94-2_TRIP	Positive or Rising
3	CBXCBR1_52-1_EXE_OP	Positive or Rising
4	CBXCBR1_52-1_EXE_CL	Positive or Rising
5	CCBRBRF1_50BF_TRBU	Positive or Rising
6	-	-
7	-	-
8	-	-
9	CCSPVC1_CCM_FAIL	Positive or Rising
10	LOFLPTUC1_37M-1_PICKUP	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
11	LOFLPTUC2_37M-2_PICKUP	Positive or Rising
12	OC_PICKUP_ALARM	Positive or Rising
13	OEPVPH1_24-1_TRIP	Positive or Rising
14	OEPVPH2_24-2_TRIP	Positive or Rising
15	MSVPR1 - U_LO	Positive or Rising
16	-	-
17	-	-
18	-	-
19	-	-
20	-	-
21	-	-
22	-	-
23	-	-
24	-	-
25	-	-
26	-	-
27	-	-
28	-	-
29	-	
30	-	-
31	-	-
32	-	-
33	-	-
34	-	-
35	-	-
36	-	-
37	-	-
38	-	-
39	-	-
40	-	-
41	-	-
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-

Table continues on next page

Channel	ID text	Level trigger mode
47	-	-
48	-	-
49	-	-
50	-	-
51	-	-
52	-	-
53	-	-
54	-	-
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

3.6.3 Functional diagrams

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

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

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

The phase voltages to the protection relay are fed from a voltage transformer.

The common signal marked with IA, IB and IC represents the three phase currents on line side, whereas the signal marked with IA2, IB2 and IC2 represents the three phase current on neutral side or the three phase core-balance current dependent on the application.

The signal marked with VA, VB and VC represents the three phase voltages.

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

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

3.6.3.1 Functional diagrams for protection

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

Two types of current differential protections are provided in this configuration: percentage restrained current differential MPDIF1_87M using two sets of CTs from line and neutral side respectively and the phase segregated core-balanced current differentials HIAPDIF1_87A, HIBPDIF1_87B, HICPDIF1_87C using the second set of CTs that sense the phase core-balanced current. These two types of differential functions must match the primary CT arrangement. When the CT arrangement is suitable for MPDIF1_87M, the core-balanced differential functions HIAPDIF1_87A, HIBPDIF1_87B, HICPDIF1_87C must be disabled. Similarly, when the CT arrangement is suitable for the core-balanced differentials, 87M must be disabled.

If only four CTs are available with three on the line side and one on the neutral side, a ground current differential scheme can be formed with HIAPDIF1_87A being enabled and the other differential functions being disabled. In this case, the ground current measured through a residual connection of three phase CTs and the ground current through the neutral CT should be differentially connected, then the resulting differential ground current is fed to IA2 current terminals in the relay.

If the high-impedance current differential protection is desirable, the core-balanced differential protection functions can be used to form the scheme. The external high-impedance module, which may comprise a stabilizing resistor and a voltage dependent resistor that limits the secondary voltage developed due to a fault to a safe level, must be provided. See the technical manual for details.

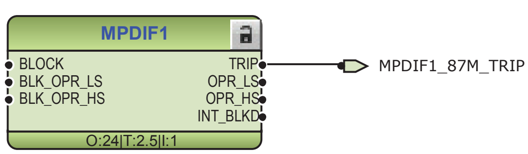


Figure 155: Motor percentage restrained current differential protection

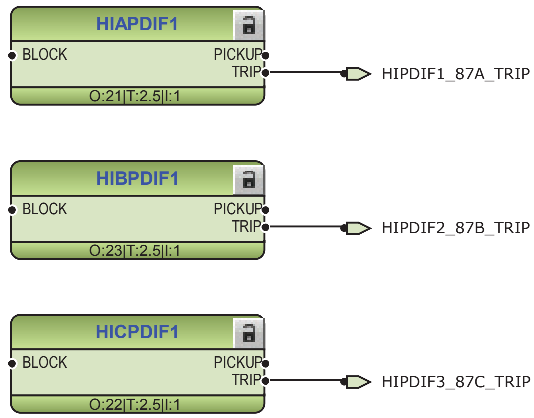


Figure 156: Motor core-balanced current differential protection

Three three-phase overcurrent protection stages PHLPTOC1_51P, PHHPTOC1_50P-1 and PHHPTOC2_50P- 2 are provided for the overcurrent and short-circuit protection of a motor. PHLPTOC1_51P can be used for the overcurrent protection and PHHPTOC1_50P-1 and PHHPTOC2_50P-2 for the short-circuit protection.

The operation of PHLPTOC1_51P, PHHPTOC1/2_50P-1/2 is not blocked as default by any functionality and the settings should be set such as to avoid unnecessary false trip or alarm. The operation of PHLPTOC1_51P, PHHPTOC1/2_50P-1/2 is connected to alarm LED 5. These functions can be blocked by the motor starting output if the desired settings (pickup threshold and its trip delay) could cause these functions to trip during motor normal starting.

The motor load jam protection function JAMPTOC1/2_51LR-1/2 is blocked by the motor start-up protection function.

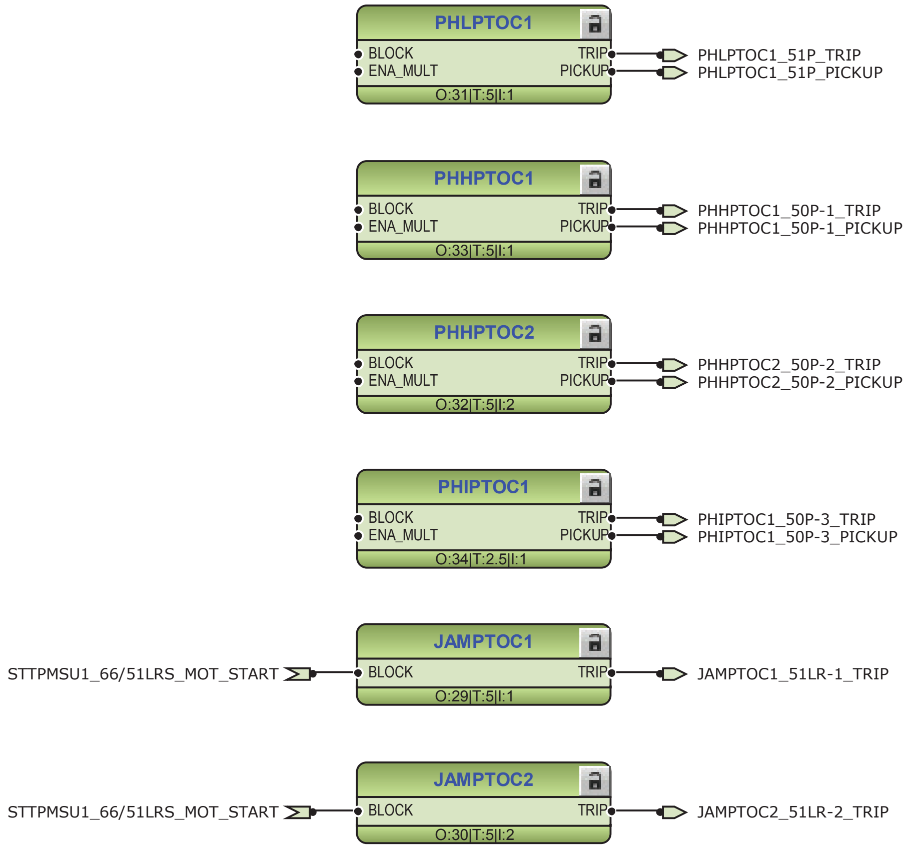


Figure 157: Non-directional phase overcurrent protections

Alarm LEDs 1, 2 and 3 are configured so as to indicate which phase has resulted into tripping of PHLPTOC1_51P, PHHPTOC1/2_50P-1/2. Overcurrent faults in Phase A, B and C are mapped to Alarm LEDs 1, 2 and 3 respectively.

Three non-directional ground-fault protection EFLPTOC1_51G,EFHPTOC1_50G-1 and EFHPTOC2_50G-2 stages are provided to detect phase-to-ground faults that may be a result of, for example, insulation ageing or sudden failure of insulation. The operation of EFLPTOC1_51G,EFHPTOC1/2_50G-1/2 is not blocked as default by any functionality. The operation of ground-fault protection functions is connected to alarm LED 4.

In addition, there is a directional ground-fault protection stage DEFLPDEF1_67/51N which can be used as a low stage non-directional ground-fault protection without voltage requirement. However, the residual voltage can help to detect ground faults at a low fault current level selectively and to discriminate the apparent residual current caused, for example, by partial current transformer saturation at motor start-up.

DEFLPDEF1_67/51N is blocked by Current circuit supervision CCSPVC1_CCM function, to avoid maloperation in case of failure in current measuring circuits. The operation of ground-fault protection functions is connected to alarm LED 4.

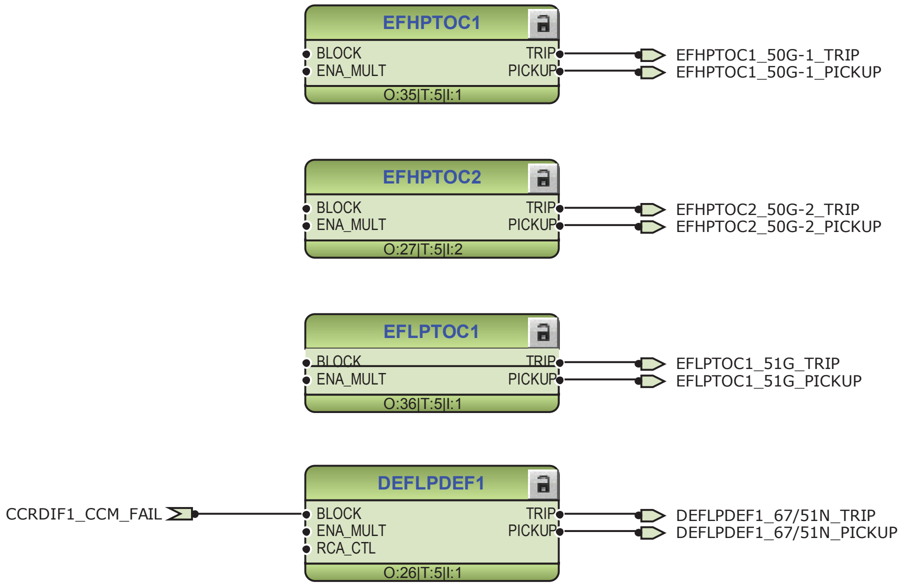


Figure 158: Ground-fault protections

The configuration also includes a pickup alarm. The pickup outputs from PHLPTOC1_51P, PHHPTOC1/2_50P-1/2, EFLPTOC1_51G, EFHPTOC1/2_50G-1/2 and DEFLPDEF1_67/51N are connected together to have a combined overcurrent pickup alarm which is connected to the disturbance recorder as default.

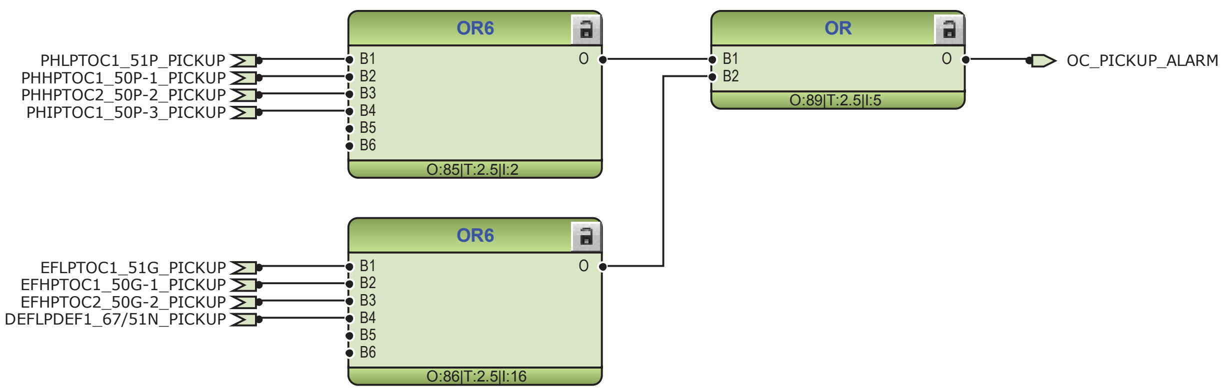


Figure 159: Current pickup alarm

For voltage protection, two instances of three-phase undervoltage PHPTUV1_27-1 and PHPTUV2_27-2, three-phase overvoltage PHPTOV1_59-1 and PHPTOV2_59-2, and negative-sequence overvoltage NSPTOV1_47-1 and NSPTOV2_47-2, as well as one instance of positive-sequence undervoltage PSPTUV1_27PS and residual overvoltage ROVPTOV1_59G-1 and ROVPTOV2_59N-1 protection functions are offered. The PHPTUV_27, PSPTUV_27PS, NSPTOV_47 and ROVPTOV_59G/N protection functions are blocked if the fuse failure is detected.

The positive-sequence undervoltage and negative-sequence overvoltage protections are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order.

In addition, one remnant undervoltage MSVPR1_27R protection function is provided to monitor the voltage of the motor terminal or a bus to which the motor is connected. When a motor is de-energized, its terminal voltage gradually decreases both in magnitude and frequency. Re-energizing the motor with the remnant voltage would be detrimental to the motor. This function can accurately measure the remnant voltage level with a wide range frequency of 10...70 Hz. This function can be used in the automatic bus transfer schemes to prevent the rotating machines from damage.

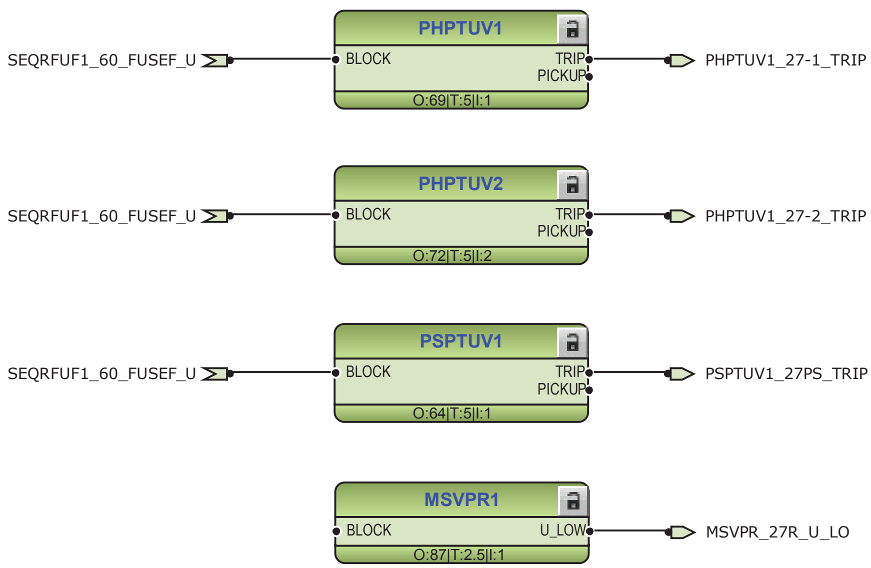


Figure 160: Undervoltage protections

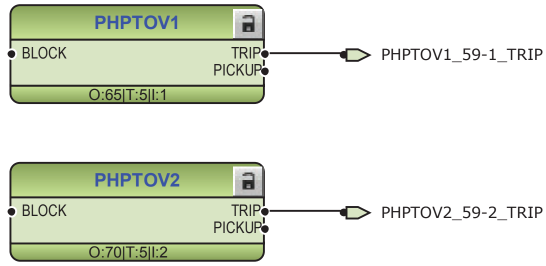


Figure 161: Overvoltage functions

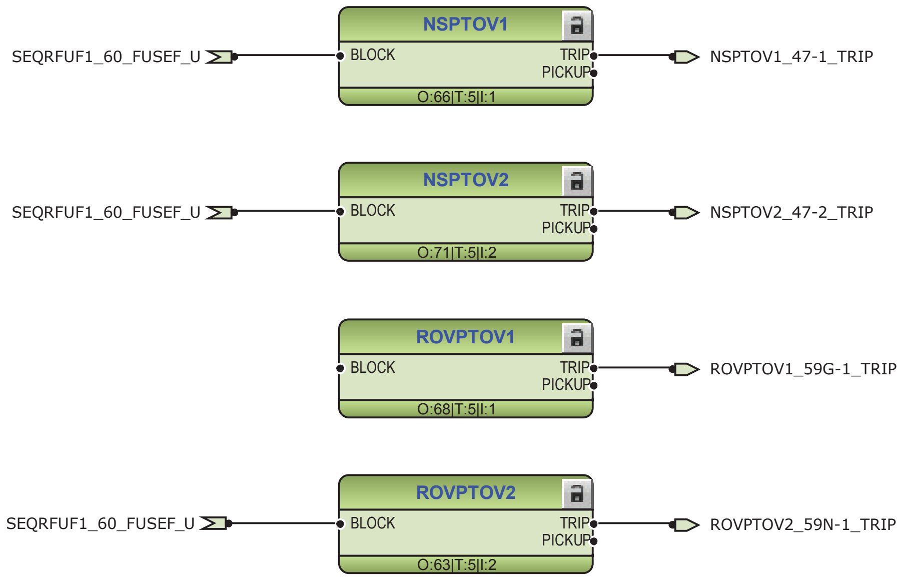


Figure 162: Negative-sequence and residual overvoltage functions

Three directional overpower functions DOPPDPR1_32O-1, DOPPDPR2_32O-2, and DOPPDPR3_32O-3 are provided to act on forward or reverse, real or reactive over power protection or alarm. By default, the DOPPDPR1_32O-1 and DOPPDPR2_32O-2 trip outputs are connected to master trip 1, and all three trip outputs go to the alarm LED. Also, DOPPDPR3_32O- 3 trip output is designated as the alarm function but not connected to anywhere; similarly all the pickup outputs are ORed to generate a collective DOPPDPR_32O_PICKUP for some application convenience.

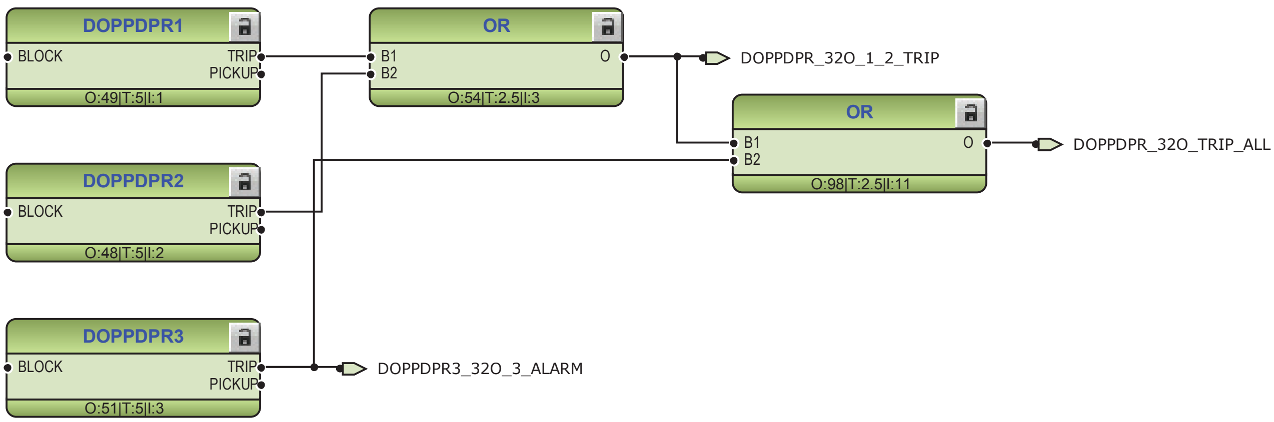


Figure 163: Directional overpower protections

Two directional under power functions DUPPDPR1_32U-1 and DUPPDPR2_32U-2 are provided to act on forward or reverse, real under power protection or alarm. By default, these underpower function outputs are not connected to anywhere. The under power functions are blocked by the fuse failure.

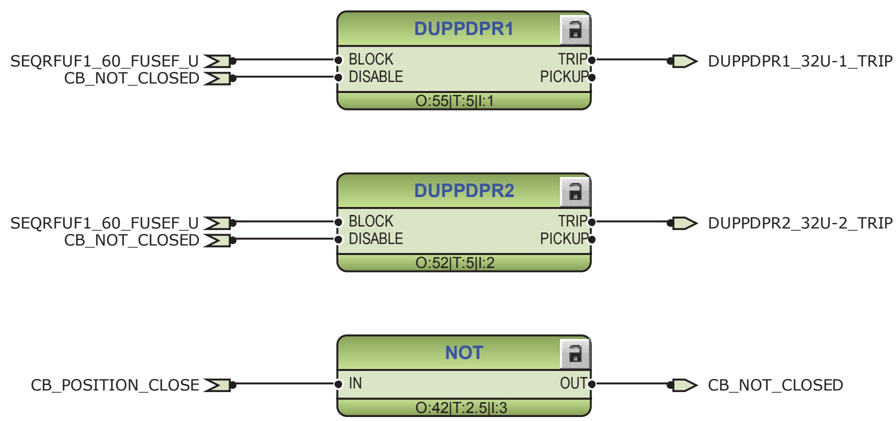
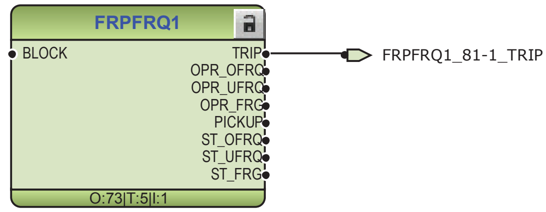


Figure 164: Directional underpower protections

Two stages of frequency protection functions FRPFRQ1_81-1 and FRPFRQ2_81-2 are also available in the configuration. FRPFRQ_81 can be set to trip as under frequency or over frequency or as rate of change of frequency protection. The operation of voltage and frequency protection functions is connected to alarm LED 8.



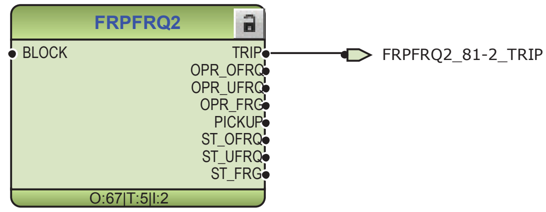
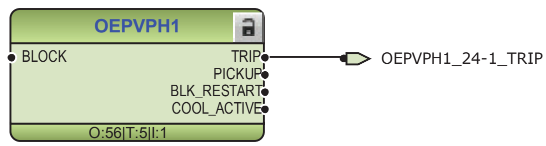


Figure 165: Frequency protection

Two overexcitation protection stages OEPVPH1_24-1 and OEPVPH2_24-2 are provided for motor overexcitation protection. By default, outputs of these functions are connected to alarm LED.



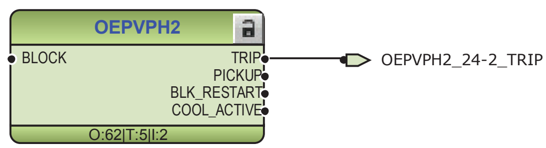


Figure 166: Overexcitation protection

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Excessive negative sequence current results into overheating of the motor eventually resulting into insulation damage.

This configuration also includes phase reversal protection PREVPTOC1_46R, based on the calculated negative phase-sequence current. It detects too high negative phase sequence current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the reverse direction.

The operation of MNSPTOC1_46M-1 , MNSPTOC2_46M-2 and PREVPTOC1_46R is not blocked as default by any functionality.

The operation of these protection functions is connected to alarm LED 9.

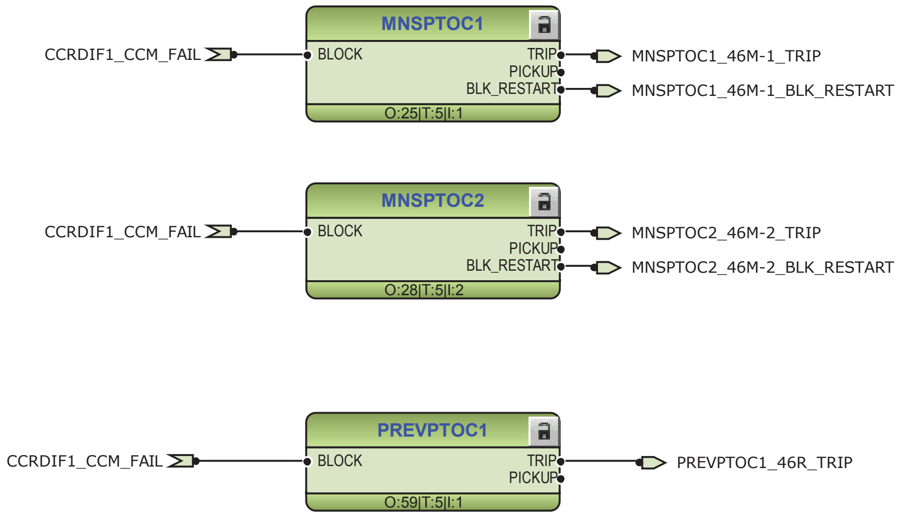


Figure 167: Negative-sequence and phase reversal protection

The thermal overload protection function MPTTR1_49M detects short and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker during machine overload condition, the emergency start request removes this blocking and enables the user to start the motor again.

The alarm and operation of thermal overload protection functions is connected to alarm LED 10.

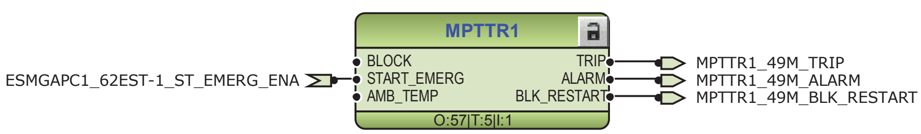


Figure 168: Motor thermal overload protection

With the motor start-up supervision function STTPMSU1_66/51LRS the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor. It is also possible to connect the speed switch to determine the locked rotor situation.

The operation of STTPMSU1_66/51LRS (along with motor jam protection) is connected to alarm LED 7.

When the emergency start request is activated by ESMGAPC1_62EST-1 and if STTPMSU1_66/51LRS is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

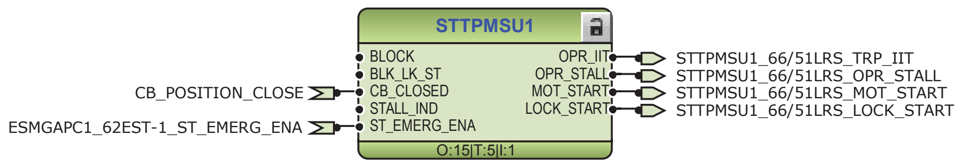


Figure 169: Motor start-up supervision

Two motor jam protections JAMPTOC1_51LR-1 and JAMPTOC2_51LR-2 are also available for protecting the motor under locked rotor or mechanical jam situations during running conditions. JAMPTOC1/2_51LR-1/2 are blocked by the motor start-up protection STTPMSU1_66/51LRS to avoid operation of JAMPTOC1/2_51LR-1/2 during motor starting condition. The operation of JAMPTOC1/2_51LR-1/2 along with motor start-up protection is connected to alarm LED 7.

Two loss of load protection stages LOFLPTUC1_37M-1 and LOFLPTUC2_37M-2 are provided for detecting a sudden loss of load on the motor. The loss of load situation can happen, for example, if there is damaged pump or due to sudden breakdown in conveyor belt.

The operation of LOFLPTUC1_37M-1 and LOFLPTUC2_37M-2 is not blocked as default by any functionality. The operation of these protection functions is connected to alarm LED 6.

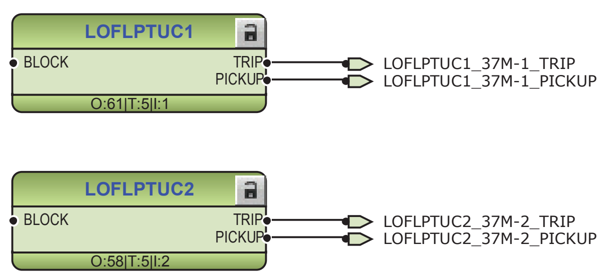


Figure 170: Loss of load protection

The circuit-breaker failure protection CCBRBRF1_50BF is initiated via the pickup input by a number of different protection functions in the relay. CCBRBRF1_50BF offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1_50BF has two operating outputs: TRRET and TRBU. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU trip output signal is connected to the output PO2 (X100: 8-9).

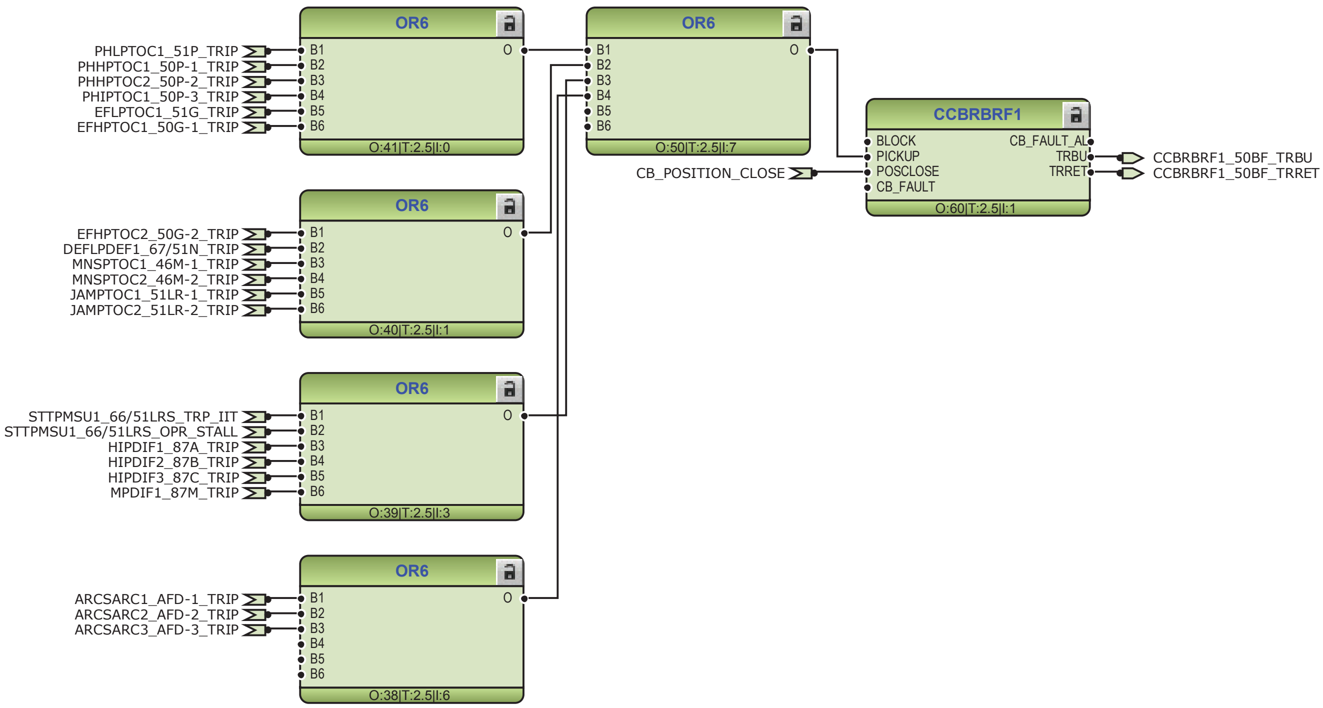


Figure 171: Circuit-breaker failure protection and associated binary output

The TRRET trip output can be used for retripping its own circuit breaker through the Master Trip again.

In this configuration, eight multipurpose analog protection functions MAPGAPC1…8_MAP-1…8 are included which can be used as an underprotection or overprotection. In this configuration these functions are by default used to provide thermal protection with remote RTD/mA sensors (RIO600) through GOOSE communication. By default, the GOOSE communication configurations are not provided. It is the user's responsibility to enable this application based on their communication infrastructure. See the ABB RIO600 manuals for details.

The default logic below can be used with eight RTD measurements, with six RTDs on the windings, one on motor bearing and other on load bearing. Without modification of the default logic, it can also be used with twelve RTD measurements, six on windings, two on motor bearings, two on load bearings and others on case or ambient. If needed, the default logic can always be modified to meet the application need.

Take six winding temperature measurement as an example. Three MAX-3 functions are used to obtain the maximum temperature among the six winding temperatures, and the maximum temperature value is then connected to the multipurpose analog protection block MAPGAPC1_MAP-1.

It is mandatory to connect IN1 input of MAX-3 function. Leaving IN1 input disconnected results in wrong maximum output at OUT.

The MAX-3 function always selects the maximum quantity from the connected inputs. It must be verified that input connections start from input1. Otherwise the function generates error code.

In the default, MAP-2 is designated for the motor winding temperature alarm, MAPGAPC3_MAP- 3 and MAPGAPC4_MAP-4 are for motor bearing temperature trip and alarm, MAPGAPC5_MAP-5 and MAPGAPC6_MAP-6 are for load bearing temperature trip and alarm, and MAPGAPC7_MAP-7 and MAPGAPC8_MAP-8 are for other purpose such as case or ambient temperature.

If the motor ambient temperature is measured, it can be connected to MPTTR1_49M.

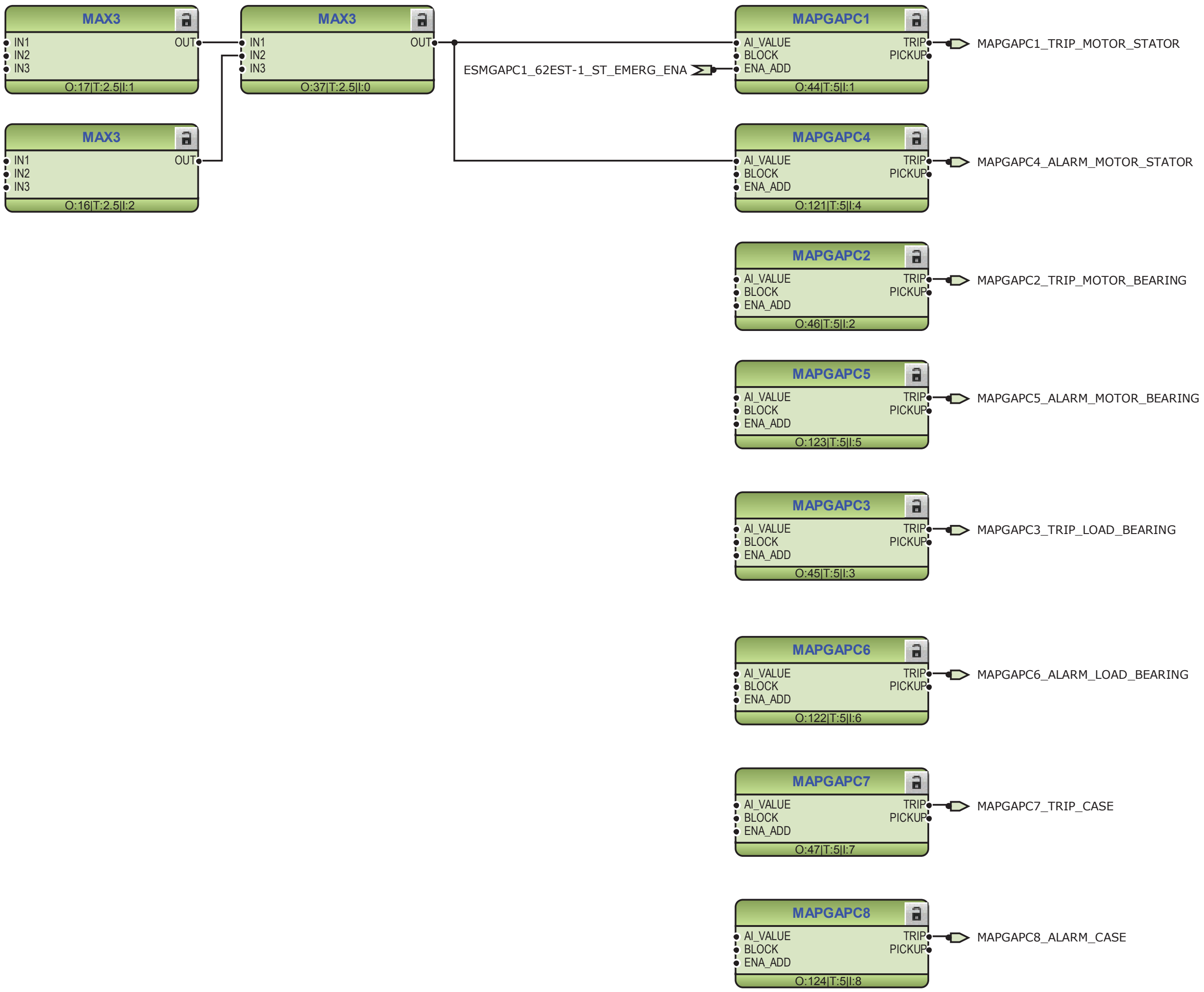


Figure 172: General purpose protection function

The trip and alarm levels for each RTD group can be set independently. By default, the collective RTD trip signal from four trip signals are connected to mast trip and the collective RTD alarm signal is generated but not connected to anywhere. All the trip and alarm outputs are connected to alarm LED.

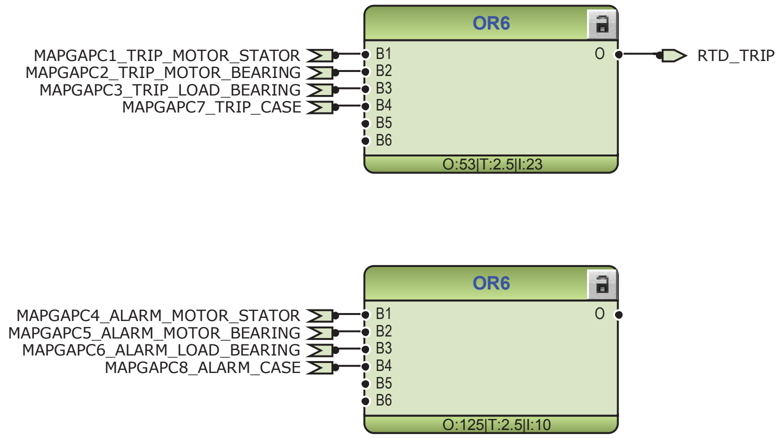


Figure 173: RTD trip and alarm

Three arc protection functions ARCSARC1_AFD-1, ARCSARC2_AFD-2 and ARCSARC3_AFD-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.

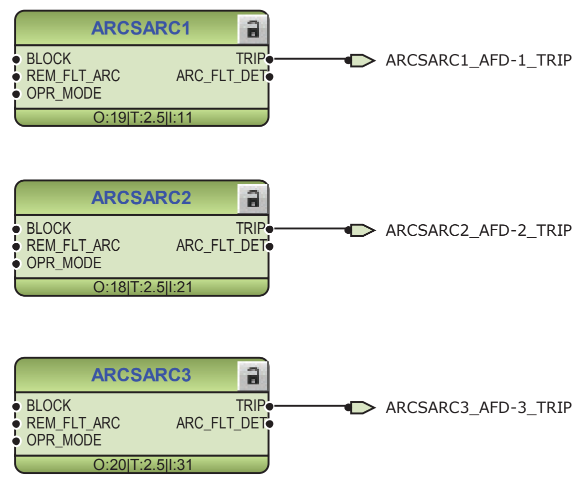


Figure 174: Arc protection

Trip signal from ARCSARC1_AFD-1 is connected to Master trip 1, available at PO3 (X100: 15-19), whereas the trip signal from ARCSARC2_AFD-2 and ARCSARC3_AFD-3 is by default not connected to anywhere.

If the relay has been ordered with high-speed binary outputs, it is recommended the arc protection trips be connected to the high-speed trip outputs.

Two master trip logics TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2 are provided as a trip command collector. The trip signals from the protection functions are connected to trip logics and the output of these trip logic functions is available at binary output X100:PO3 (X100:16-19) and also to high-speed output HSO1 (X110:15-16) for the relays ordered with high-speed binary output cards.

Open control commands to the circuit breaker from the local or remote are also connected directly to the output PO3 (X100:16-19) from circuit breaker control CBXCBR_52 function block. TRPPTRC2_86/94-2 is not used by the default in this configuration.

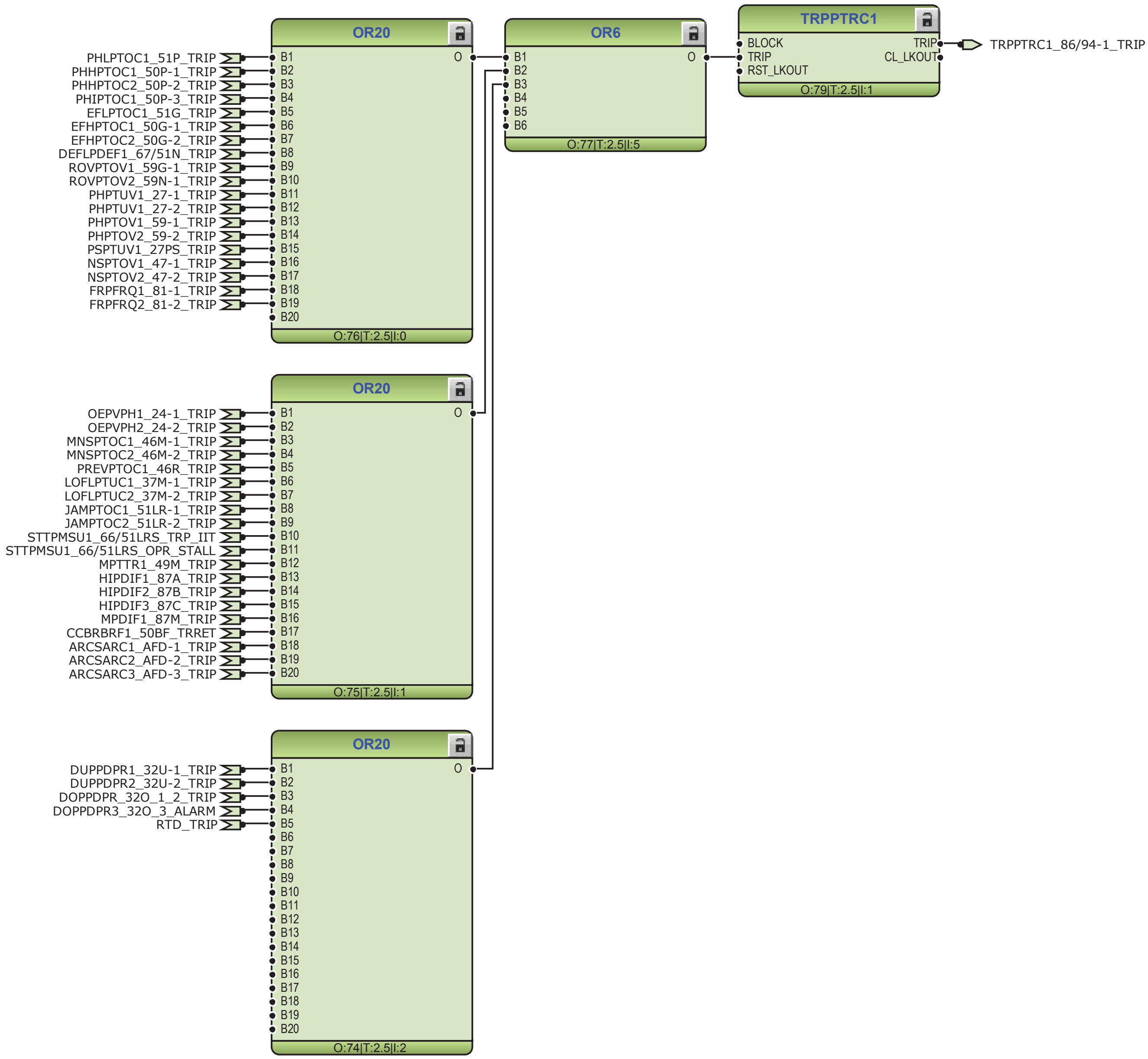


Figure 175: Master trip logic 1

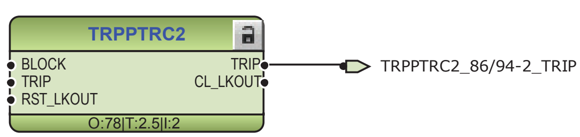


Figure 176: Master trip logic 2

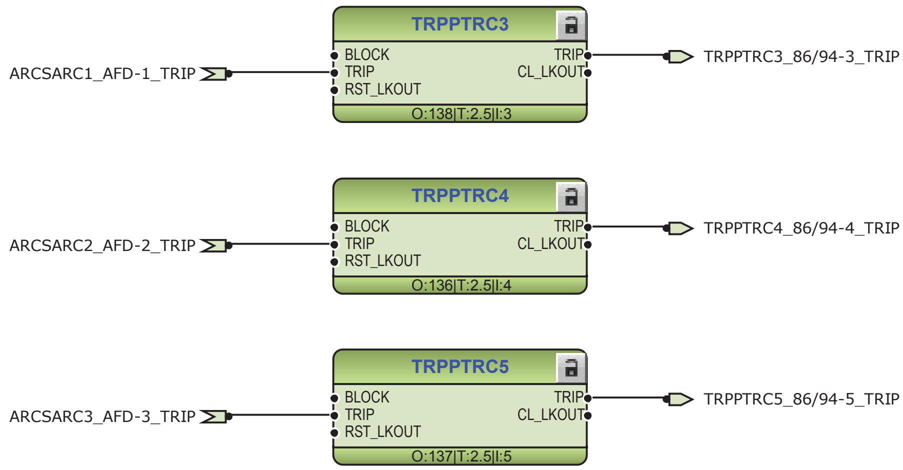


Figure 177: Master trip logic 3/4/5

3.6.3.2 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.

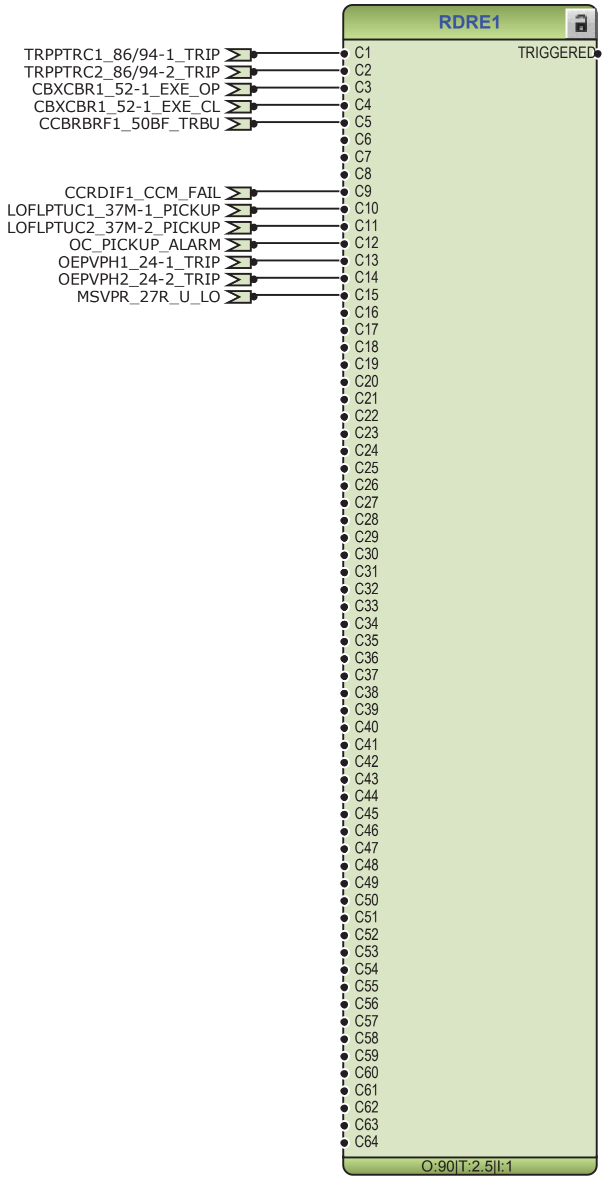


Figure 178: 64 channel disturbance and fault recorder

3.6.3.3 Functional diagrams for condition monitoring

Two trip circuit monitoring stages TCSSCBR1_TCM-1 and TCSSCBR2_TCM-2 are provided to supervise the trip circuit of the circuit breaker connected at PO3 (X100:15-19) and PO4 (X100:20- 24).

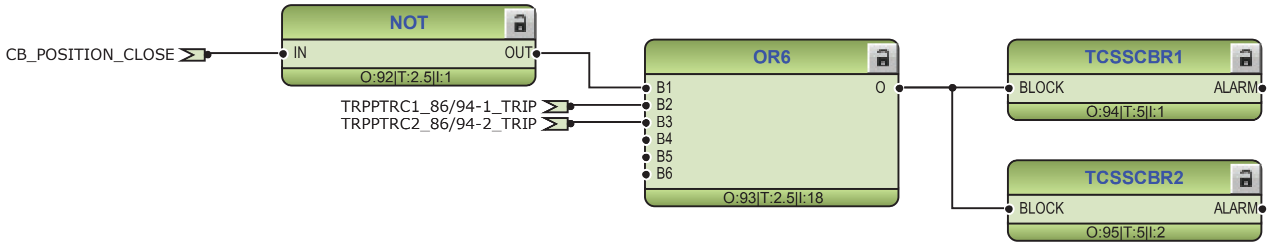


Figure 179: Trip circuit monitoring

The TCSSCBR1_TCM-1 and TCSSCBR2_TCM-2 functions are blocked by TRPPTRC1_86/94-1, TRPPTRC2_86/94-2 and the circuit-breaker open position signal.

By default TCSSCBR1_TCM-1 and TCSSCBR2_TCM-2 are not configured in the configuration. By default it is expected that there is no external resistor in the circuit breaker tripping/closing coil circuit connected parallel with circuit breaker normally open/closed auxiliary contact.

A failure in current measuring circuits is detected by current circuit supervision function CCSPVC1_CCM. When a failure is detected, the function activates and can be used to block protection functions which trip using calculated sequence component currents, for example MNSPTOC_46M, thus avoiding maloperation

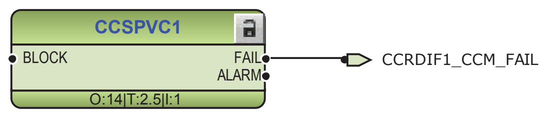


Figure 180: Current circuit supervision

By default the `FAIL` output from CCSPVC1_CCM function is only connected to the disturbance recorder.

Similar to CCSPVC1_CCM function, a failure in voltage measurement circuit is detected by fuse failure supervision function SEQSPVC1_60. The function is used to block the voltage protection and directional protection functions at failures in the secondary circuits between the voltage transformer and protection relay to avoid maloperation.

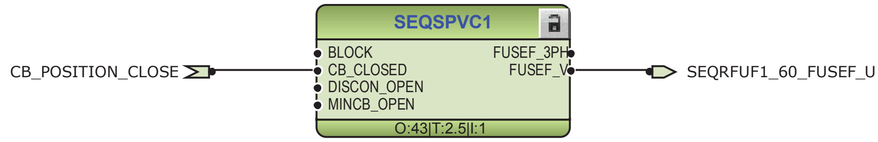


Figure 181: Fuse failure supervision

Two motor run time counter stages OPTM-1 and OPTM-2 are provided to calculate and present the total number of motor running hours; these running hours are incremented when the energizing circuit breaker is in closed position.

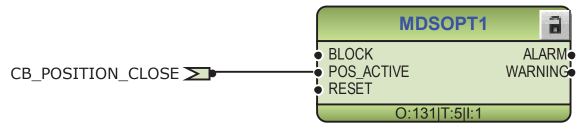


Figure 182: Runtime counter

By default MDSOPT1_OPTM-1 is not configured in the configuration.

The circuit breaker condition monitoring function SSCBR1_52CM supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision alarms.

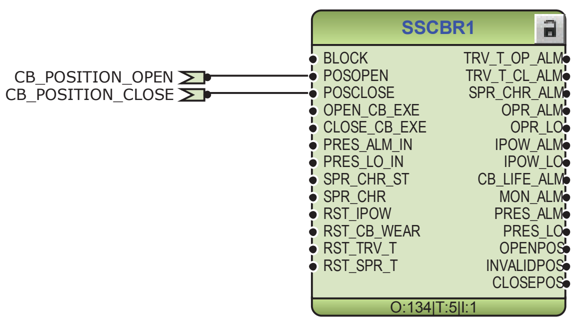


Figure 183: Circuit breaker condition monitoring

Outputs from the SSCBR1_52CM function are not configured in the configuration.

3.6.3.4 Functional diagrams for control

The emergency start function ESMGAPC1_62EST allows motor start-ups although the restart inhibit is activated. The emergency start is enabled for ten minutes after the selected binary input BI1 (X120:1:2) is energized. On the rising edge of the emergency start signal:

- Calculated thermal level is set slightly below the restart inhibit level to allow at least one motor start-up.
- Value of the cumulative start-up time counter STTPMSU1_66/51LRS is set slightly below the set restart inhibit value to allow at least one motor start-up.
- Trip value of the MAPGAPC1_MAP-1 function is increased by set value.

A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time of 10 minutes has expired.

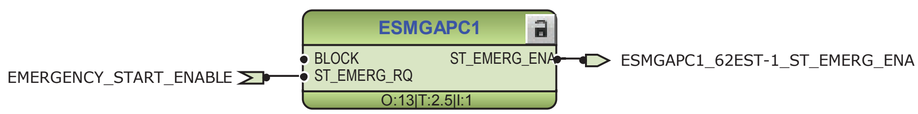


Figure 184: Emergency start

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and ground switch position status and the status of the Master Trip logics and gas pressure alarm and circuit-breaker spring charging. The OK_POS output of the CBXCBR1_52 can also be connected to the interlocking logic enabling the breaker closing, thus breaker closing in intermediate state can be prevented. With the present configuration, the activation of ENA_CLOSE input is configured using only Master Trip logic TRPPTRC1_86/94-1 and TRPPTRC2_86/94-2, that is, the circuit breaker cannot be closed in case master trip is active.

Configuration also includes motor restart inhibit logic. When the motor restart is inhibited, the BLK_CLOSE input is activated and closing of the breaker is not possible.

When all conditions of the circuit breaker closing are fulfilled, the EXE_CL output of the CBXCBR_52 is activated and output PO1 (X100:6-7) is closed, if a closing command is given.

The motor restart inhibit is activated when one of the following is true.

- A trip command is active.
- Motor start-up supervision has issued lockout.
- Motor unbalance function has issued restart blocking.
- Motor thermal overload function has issued restart blocking.

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

When a motor is de-energized, the motor terminal voltage gradually decreases at a speed that depends on load inertia. In case of pumping load, it could reverse its rotating direction before it stops. Re-energizing a motor in rotating could be detrimental to the motor. A simple logic shown below can ensure a safe motor starting. When the breaker opens, a long pulse timer of a few seconds to a few minutes (anti-backspin timer) is initiated to block the breaker from closing. Another approach is to measure the motor terminal remnant voltage MSVPR1_27R so that the motor is allowed to close only if MSVPR1_27R trips, in other words, the motor terminal voltage is low enough. Both the blocking close logic outputs are by default not connected to BLK_CLOSE, it is the user's responsibility to enable this feature. Note that when the MSVPR1_27R function based logic is selected, the MSVPR1_27R function itself must be enabled. These two logic outputs can both be connected to BLK_CLOSE.

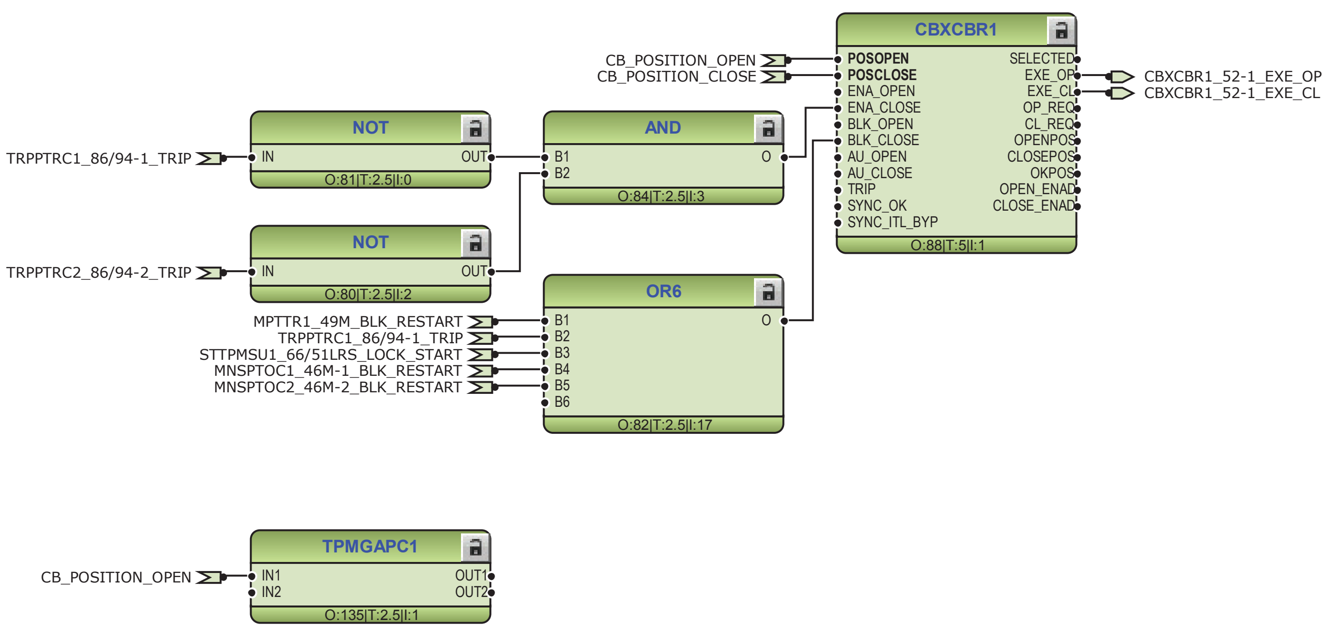


Figure 185: Circuit breaker control

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR1_52 with PCM600, the function assumes that the breaker close commands are allowed continuously.

3.6.3.5 Functional diagrams for measurement functions

The phase current on line side inputs to the relay are measured by the three-phase current measurement function CMMXU1. The phase current on neutral side inputs to the relay are measured by the three-phase current measurement function CMMXU2. The current input is connected to the X120 card in the back panel. Similarly, the sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1 respectively. The voltage input is connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage and the residual voltage measurement RESVMMXU1 measures the residual voltage.

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

The frequency measurement FMMXU1 of the power system and the three-phase power and energy measurement PEMMXU1 and single-phase power and energy measurement SPEMMXU1 are available. The load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

Figure 186: Three-phase current measurement

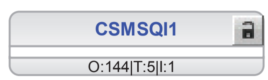


Figure 187: Sequence current measurement

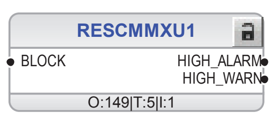


Figure 188: Residual current measurement

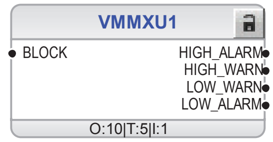


Figure 189: Three-phase voltage measurement

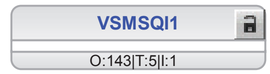


Figure 190: Sequence voltage measurement

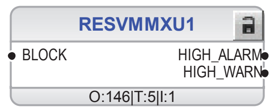


Figure 191: Residual voltage measurement

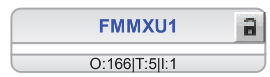


Figure 192: Frequency measurement

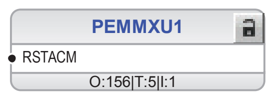


Figure 193: Three-phase power and energy measurement

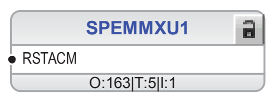


Figure 194: Single-phase power and energy measurement

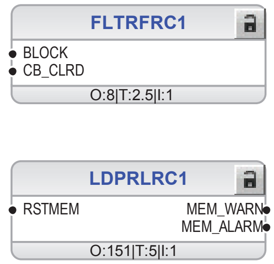


Figure 195: Data monitoring and load profile record

3.6.3.6 Functional diagrams for I/O and alarm LEDs

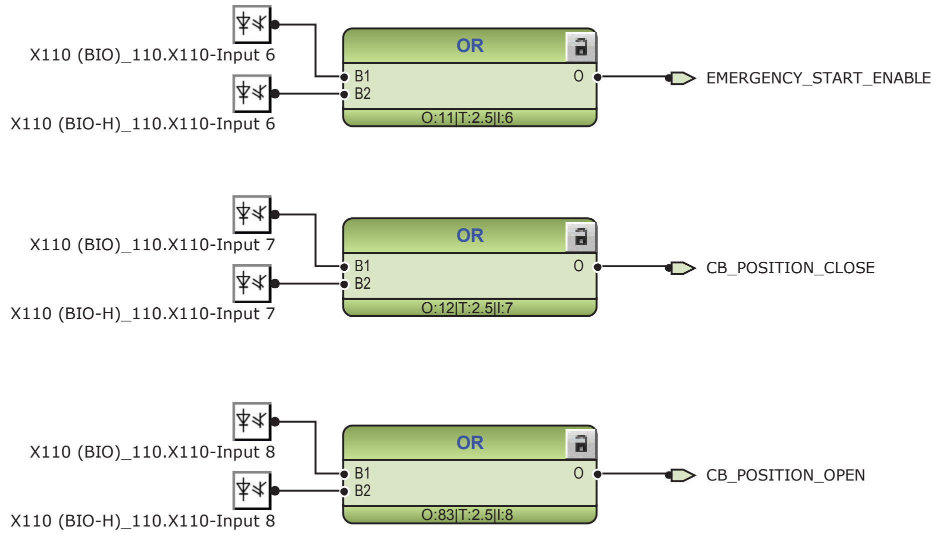


Figure 196: Default binary inputs - X110

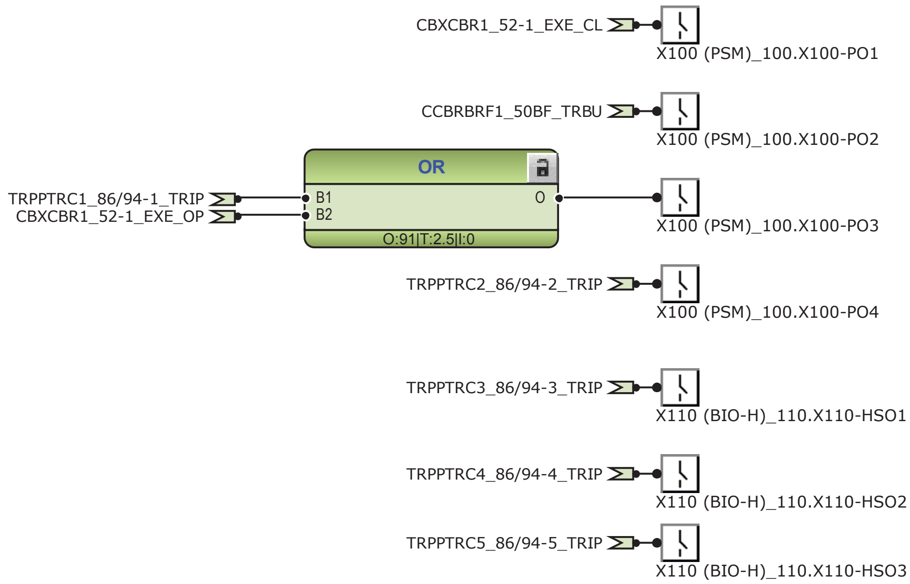


Figure 197: Default binary outputs - X100

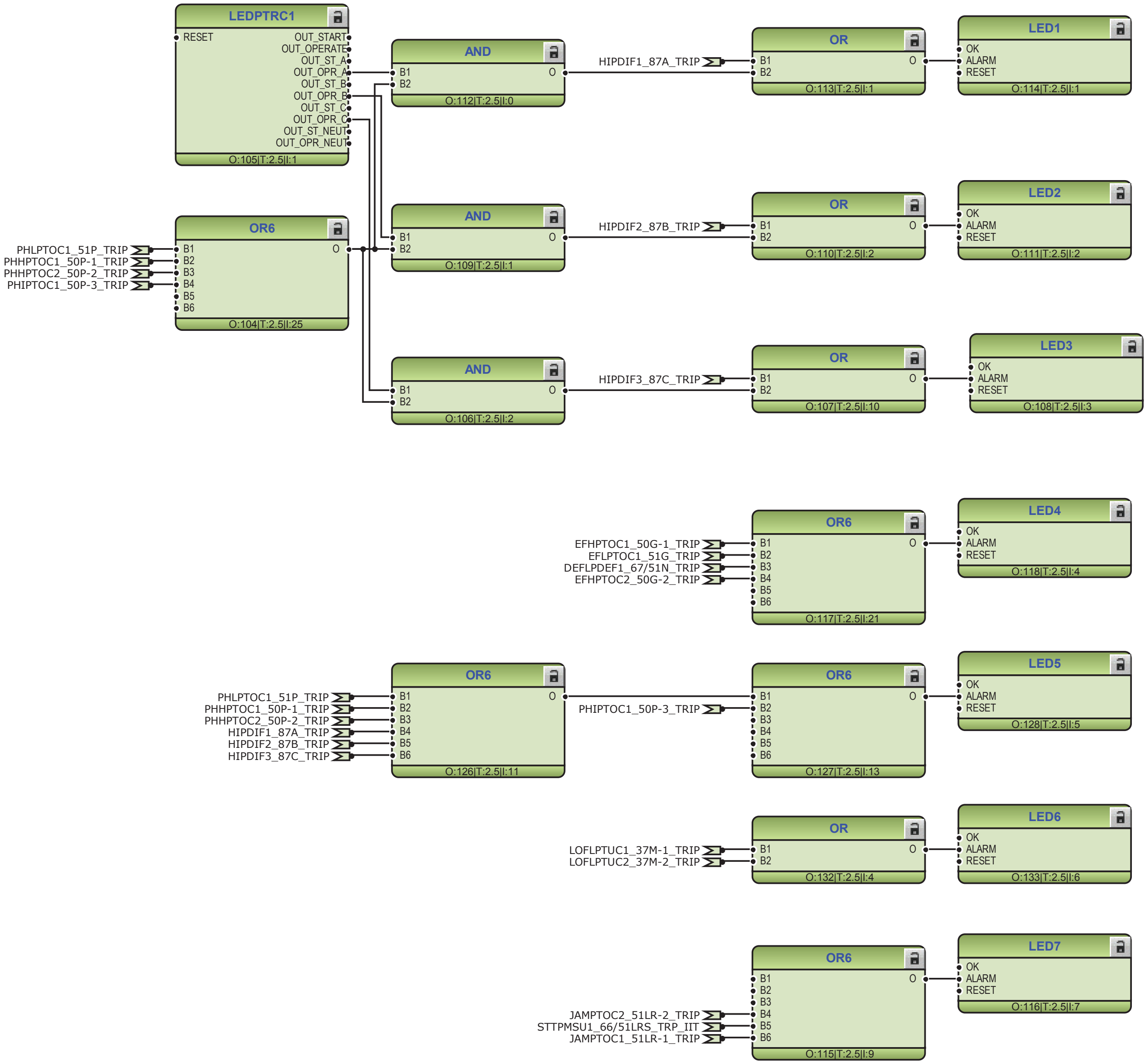


Figure 198: Default LED connections

3.6.3.7 Functional diagrams for other timer logics

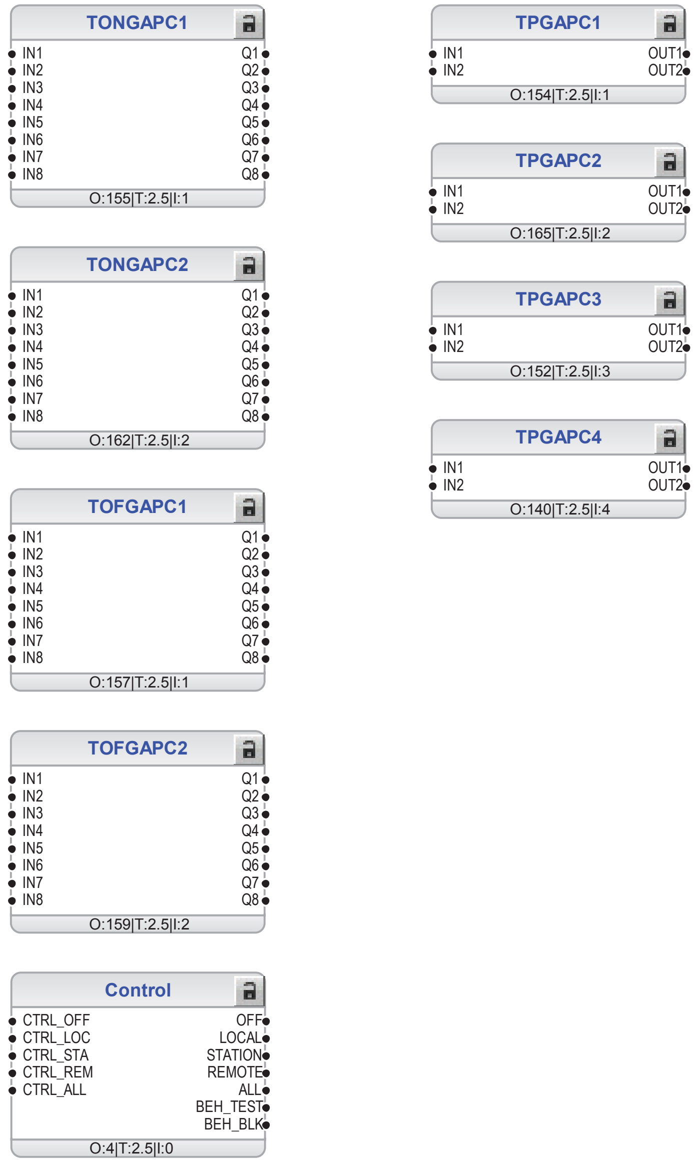


Figure 199: Functional diagrams for other timer logics

3.6.3.8 Functional diagrams for communication

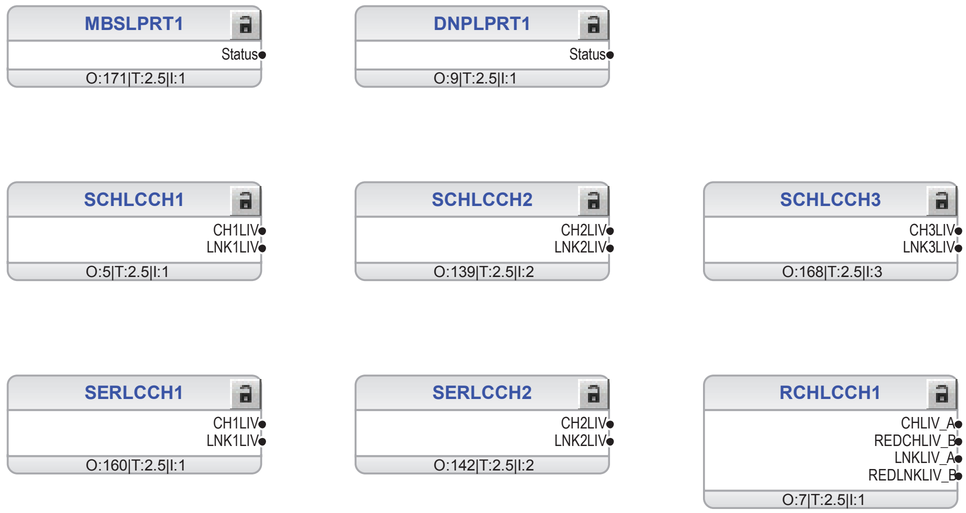


Figure 200: Default communication function connection

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 33: 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 × (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.

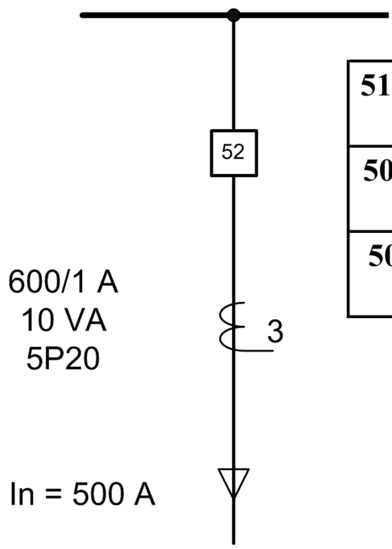
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the pickup current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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.



51P	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
50P-1/2	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
50P-3	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 201: 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 201). 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 201.

For the application point of view, the suitable setting for instantaneous stage (50P-3) in this example is 3 500 A (5.83 × I_{2n}). I_{2n} is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

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 34: Phase current inputs included in configurations A and B

Terminal	Description
X120:7-8	IA
X120:9-10	IB
X120:11-12	IC

Table 35: Phase current inputs included in configuration E

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

5.1.1.2 Ground current

Table 36: Ground current input included in configurations A, B and E

Terminal	Description
X120:13-14	IG

Table 37: Ground current input included in configuration D

Terminal	Description
X130:1-2	IG

5.1.1.3 Phase voltages

Table 38: Phase voltage inputs included in configuration B

Terminal	Description
X120:1-2	V1
X120:3-4	V2
X120:5-6	V3

Table 39: Phase voltage inputs included in configuration E

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

5.1.1.4 Ground voltage

Table 40: Additional residual voltage input included in configuration E

Terminal	Description
X130:17-18	VG

5.1.1.5 Sensor inputs

Table 41: Combi sensor inputs included in configuration D

Terminal	Description
X131	IA VA
X132	IB VB
X133	IC VC

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 42: 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 A, B, D and E.

Table 43: Binary input terminals X110:1-13 with BIO0005 module

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

Table 44: Binary input terminals X110:1-10 with BIO0007 module

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

Binary inputs of slot X120 are available with configuration A.

Table 45: Binary input terminals X120-1...6

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

Binary inputs of slot X130 is optional for configuration B.

Table 46: Binary input terminals X130:1-9

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

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 47: 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 configurations A and B.

Table 48: 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

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 49: 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)

Table continues on next page

Terminal	Description
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 50: 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 A, B, D and E.

Output contacts of slot X110 are optional.

Table 51: Output contacts X110:14-24 with BIO0005

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

Table continues on next page

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

Table 52: 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 53: Output contacts X130:10-18

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

5.2.3 IRF

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

Table 54: 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
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.
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
REM615	Motor 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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