RELION® 615 SERIES

Motor Protection and Control REM615

Application Manual

Document ID: 1MRS756885
Issued: 2021-11-11
Revision: N
Product version: 5.0 FP1

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Conformity

This product complies with following directive and regulations.

Directives of the European parliament and of the council:

- Electromagnetic compatibility (EMC) Directive 2014/30/EU
- Low-voltage Directive 2014/35/EU
- RoHS Directive 2011/65/EU

UK legislations:

- Electromagnetic Compatibility Regulations 2016
- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

These conformities are the result of tests conducted by the third-party testing in accordance with the product standard EN / BS EN 60255-26 for the EMC directive / regulation, and with the product standards EN / BS EN 60255-1 and EN / BS EN 60255-27 for the low voltage directive / safety regulation.

The product is designed in accordance with the international standards of the IEC 60255 series.

Contents

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

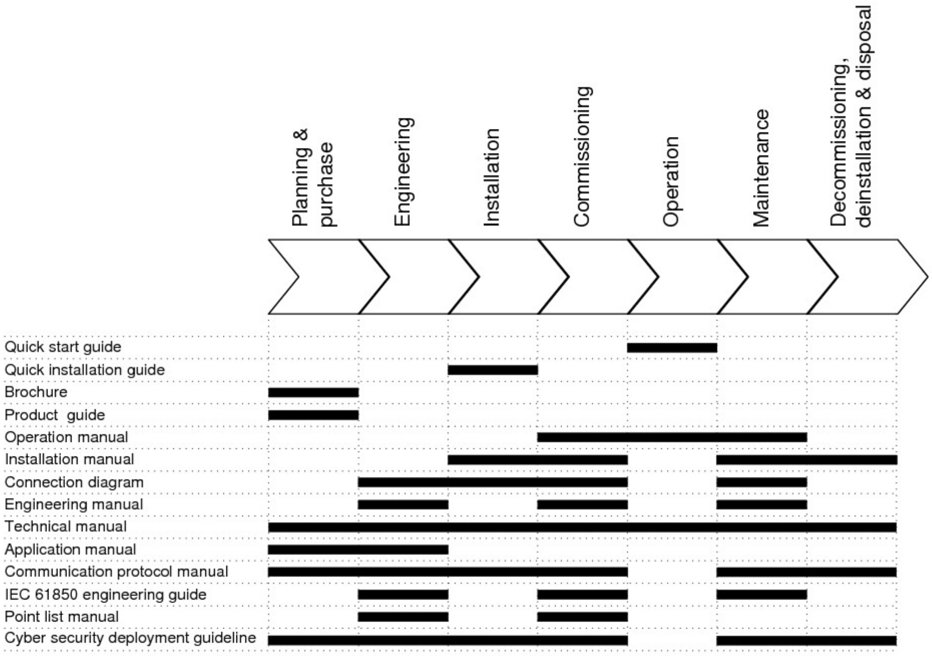


Figure 1: The intended use of documents during the product life cycle

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

1.3.2 Document revision history

Document revision/date	Product version	History
A/2009-07-03	2.0	First release
B/2010-06-11	3.0	Content updated to correspond to the product version
C/2010-06-29	3.0	Terminology updated
D/2010-09-24	3.0	Content updated
E/2012-05-11	4.0	Content updated to correspond to the product version
F/2013-02-21	4.0 FP1	Content updated to correspond to the product version
G/2013-12-20	5.0	Content updated to correspond to the product version
H/2014-01-24	5.0	Content updated
K/2015-10-30	5.0 FP1	Content updated to correspond to the product version
L/2016-05-20	5.0 FP1	Content updated
M/2018-12-20	5.0 FP1	Content updated
N/2021-11-11	5.0 FP1	Content updated

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS756468
DNP3 Communication Protocol Manual	1MRS756709
IEC 60870-5-103 Communication Protocol Manual	1MRS756710
IEC 61850 Engineering Guide	1MRS756475
Engineering Manual	1MRS757121
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887
Cyber Security Deployment Guideline	1MRS758280

1.4 Symbols and conventions

1.4.1 Symbols

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

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

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

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

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

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

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push-button navigation in the LHMI menu structure is presented by using the push-button icons.

  To navigate between the options, use and .
- Menu paths are presented in bold.

  Select **Main menu** > **Settings**.
- LHMI messages are shown in Courier font.

  To save the changes in nonvolatile memory, select `Yes` and press .
- Parameter names are shown in italics.

  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.

  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.

When the function starts, the START output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
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)	37 (1)
Motor load jam protection	JAMPTOC1	Ist> (1)	51LR (1)
Motor start-up supervision	STTPMSU1	Is2t n< (1)	49,66,48,51LR (1)
Phase reversal protection	PREVPTOC1	I2>> (1)	46R (1)
Thermal overload protection for motors	MPTTR1	3Ith>M (1)	49M (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
	TRPPTRC3	Master Trip (3)	94/86 (3)
	TRPPTRC4	Master Trip (4)	94/86 (4)
	TRPPTRC5	Master Trip (5)	94/86 (5)
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
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)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
	MAPGAPC16	MAP (16)	MAP (16)
	MAPGAPC17	MAP (17)	MAP (17)
	MAPGAPC18	MAP (18)	MAP (18)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC (1)	I <-> O ESC (1)
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Emergency start-up	ESMGAPC1	ESTART (1)	ESTART (1)
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60 (1)
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM (1)
Measurement			
Disturbance recorder	RDRE1	DR (1)	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (1)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f (1)
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV	SMVRCV
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)

Table continues on the next page

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

2 REM615 overview

2.1 Description

REM615 is a dedicated motor protection and control relay designed for the protection, control, measurement and supervision of asynchronous 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, IEC 60870-5-103, Modbus ® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302.

2.1.1 Product version history

Product version	Product history
2.0	Product released
3.0	• New configurations A and B • Additions to configuration C • Application configurability support • Analog GOOSE support • Large display with single line diagram • Enhanced mechanical design • Increased maximum amount of events and fault records • Frequency measurement and protection • RTD/mA measurement and protection • Multi-port Ethernet option
4.0	• Additions/changes for configurations A-C • Dual fiber optic Ethernet communication option (COM0032) • Generic control point (SPCGGIO) function blocks • Additional logic blocks • Button object for SLD • Controllable disconnector and earth switch objects for SLD • Additional multi-purpose protection instances • Increased maximum amount of events and fault records

Table continues on the next page

Product version	Product history
4.0 FP1	• High-availability seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • Parallel use of IEC 61850 and DNP3 protocols • Parallel use of IEC 61850 and IEC 60870-5-103 protocols • Two selectable indication colors for LEDs (red or green) • Online binary signal monitoring with PCM600
5.0	• New configuration D • New layout in Application Configuration tool for all configurations • Support for IEC 61850-9-2 LE • IEEE 1588 v2 time synchronization • Load profile recorder • High-speed binary outputs • Profibus adapter support • Support for multiple SLD pages • Import/export of settings via WHMI • Setting usability improvements • HMI event filtering tool
5.0 FP1	• IEC 61850 Edition 2 • Currents sending support with IEC 61850-9-2 LE • Support for configuration migration (starting from Ver.3.0 to Ver.5.0 FP1) • Software closable Ethernet ports • Chinese language support • Report summary via WHMI • Additional timer, set-reset and analog value scaling functions

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.6 (Rollup 20150626) 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 *www.abb.com/substationautomation* or directly with Update Manager in PCM600.

2.2 Operation functionality

2.2.1 Optional functions

- Arc protection
- Modbus TCP/IP or RTU/ ASCII
- IEC 60870-5-103
- DNP3 TCP/IP or serial
- RTD/mA measurements and multipurpose protection (configurations A and B only)
- IEC 61850-9-2 LE (configurations B, C and 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 options	
Plug-in unit	-	HMI	Small (5 lines, 20 characters) Large (10 lines, 20 characters) with SLD
			Small Chinese (3 lines, 8 or more characters) Large Chinese (7 lines, 8 or more characters) with SLD
	X100	Auxiliary power/BO module	48...250 V DC/100...240 V AC; or 24...60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact

Table continues on the next page

Main unit	Slot ID	Content options	
	X110[1]	BIO module	8 binary inputs 4 signal output contacts
		BIO module	8 binary inputs 3 HSO contacts
	X120	AI/BI module	Only with configurations A and C: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[2] 4 binary inputs
		AI/BI module	Only with configuration B: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[2] 3 phase voltage inputs (60...210 V)
Case	X130	AI/BI module	Only with configuration C: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
		Optional RTD/mA module	Optional for configurations A and B: 2 generic mA inputs 2 generic mA inputs 6 RTD sensor inputs
		Optional BIO module	Optional for configuration B: 6 binary inputs 3 signal output contacts
		Sensor input module	Only with standard 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.

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

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

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

1 BIO module (X110) is optional for configuration A.
2 The 0.2/1 A input is normally used in applications requiring sensitive earth-fault protection and featuring core-balance current transformers.

Table 3: Input/output overview

Std. conf.	Ordercode 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 + 2 SO + 3 HSO	–	–
	AG / AH	AB	4	–	–	4	4 PO + 2 SO	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	4 PO + 5 SO + 3 HSO	–	–
	CC / DD	AH	4	3	–	8	4 PO + 6 SO	6	2
		FD	4	3	–	8	4 PO + 2 SO + 3 HSO	6	2
C	AE / AF	AG	4	5	–	16	4 PO + 6 SO	–	–
		FC	4	5	–	16	4 PO + 2 SO + 3 HSO	–	–
D	DA / DB	AH	1	–	3	8	4 PO + 6 SO	–	–
		FD	1	–	3	8	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.

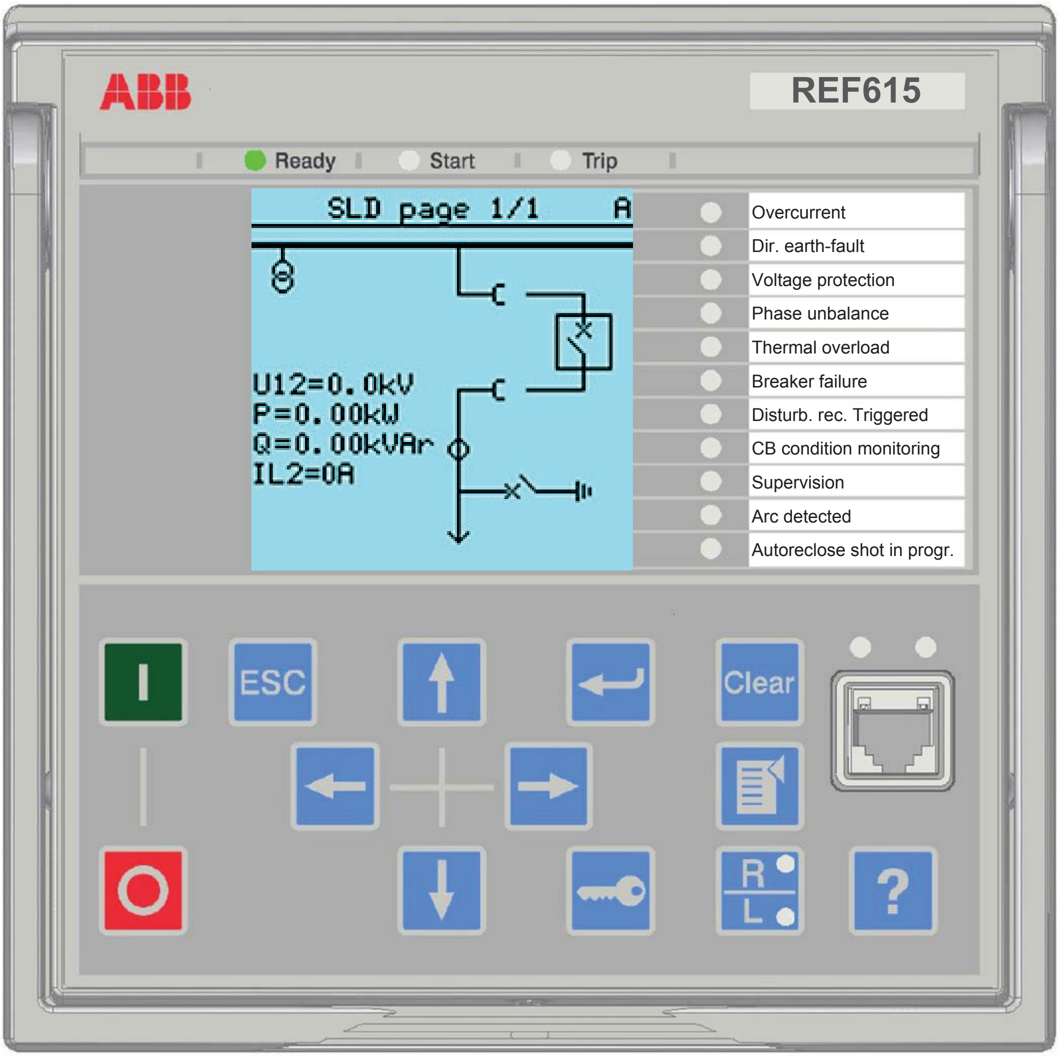


Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Small display

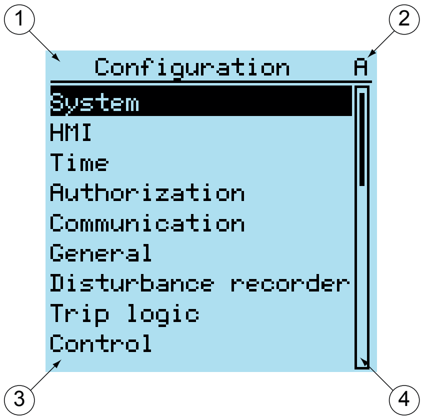
Character size[1]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

1 Depending on the selected language

Table 5: Large display

Character size[1]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20
Large, variable width (13 × 14 pixels)	7	8 or more

The display view is divided into four basic areas.



1 Header
2 Icon
3 Content
4 Scroll bar (displayed when needed)

Figure 3: Display layout

2.4.2 LEDs

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

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

2.4.3 Keypad

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

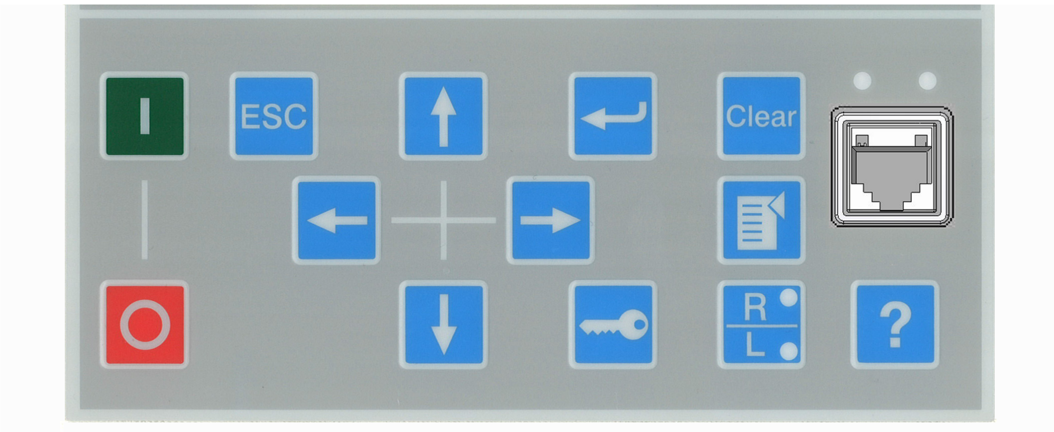


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

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

WHMI is disabled by default.

WHMI offers several functions.

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

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

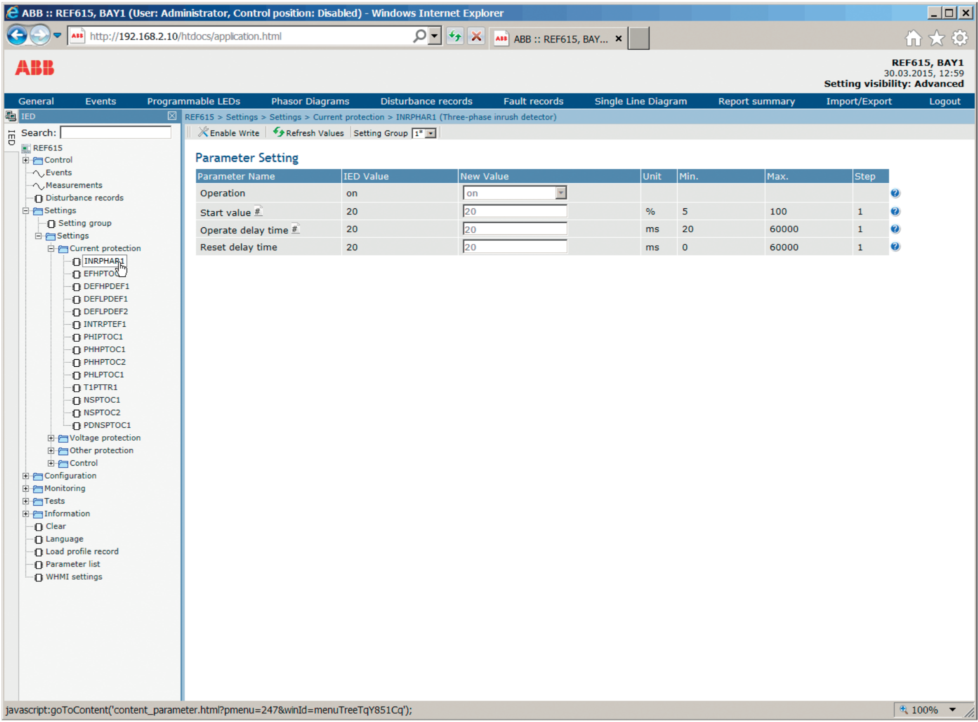


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

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

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

Table 6: Predefined user categories

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

For user authorization for PCM600, see PCM600 documentation.

2.6.1 Audit trail

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

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

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

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

Table 7: Audit trail events

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

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

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

Table 8: Comparison of authority logging levels

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

2.7 Communication

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

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

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

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber-optic LC connector (100Base-FX).

2.7.1 Self-healing Ethernet ring

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

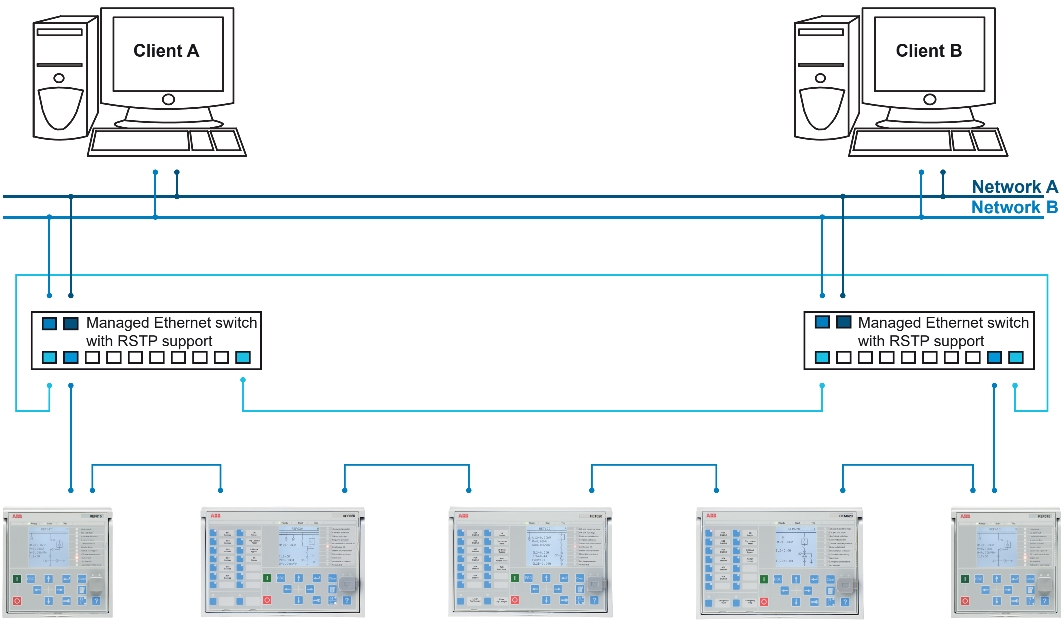


Figure 6: Self-healing Ethernet ring solution

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

2.7.2 Ethernet redundancy

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

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

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

PRP

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

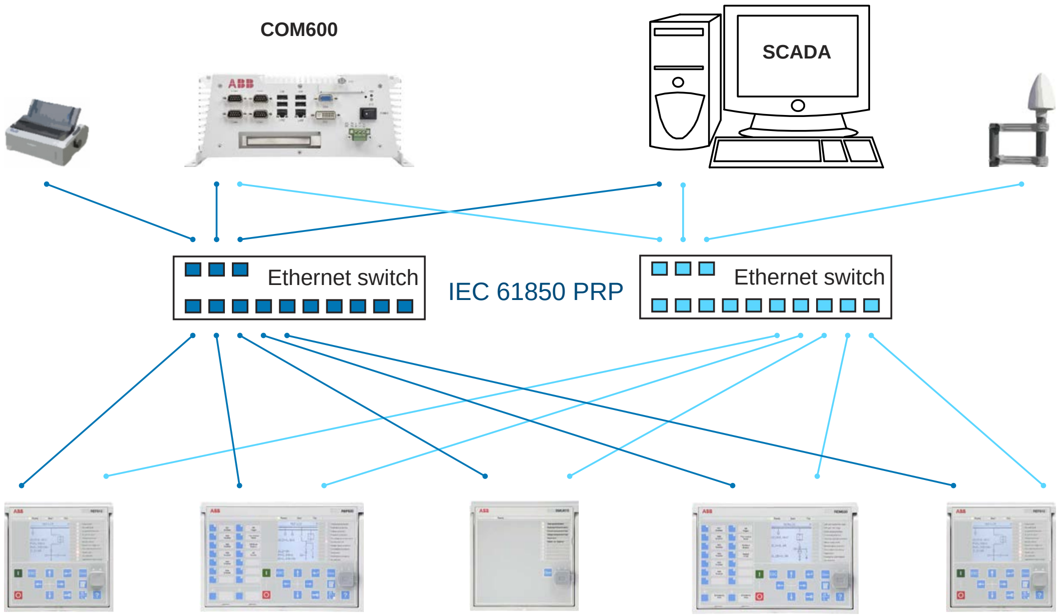


Figure 7: PRP solution

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

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

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

HSR

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

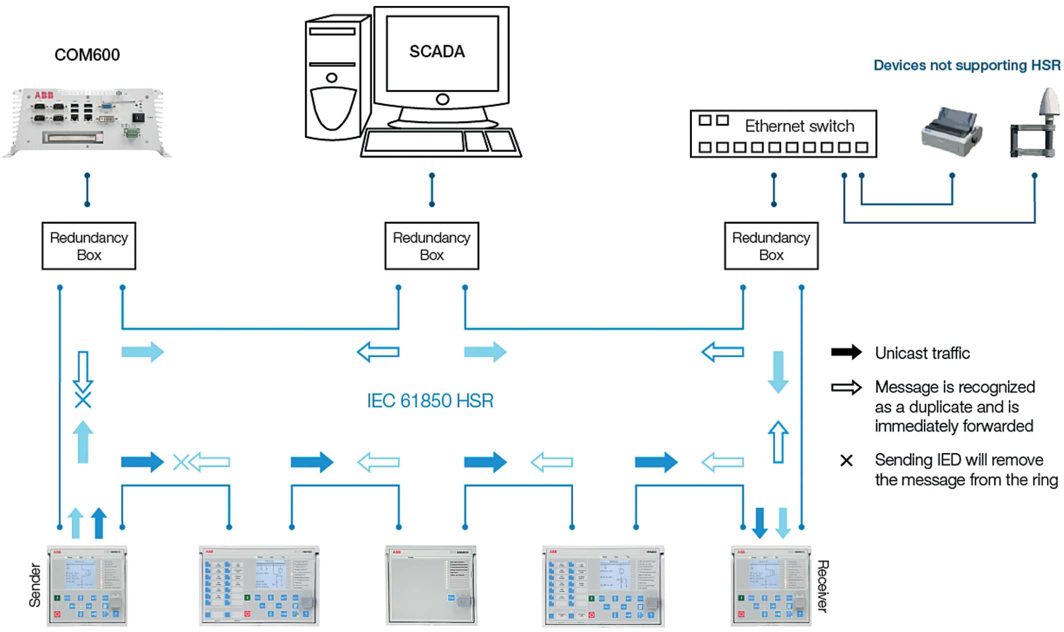


Figure 8: HSR solution

2.7.3 Process bus

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

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

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

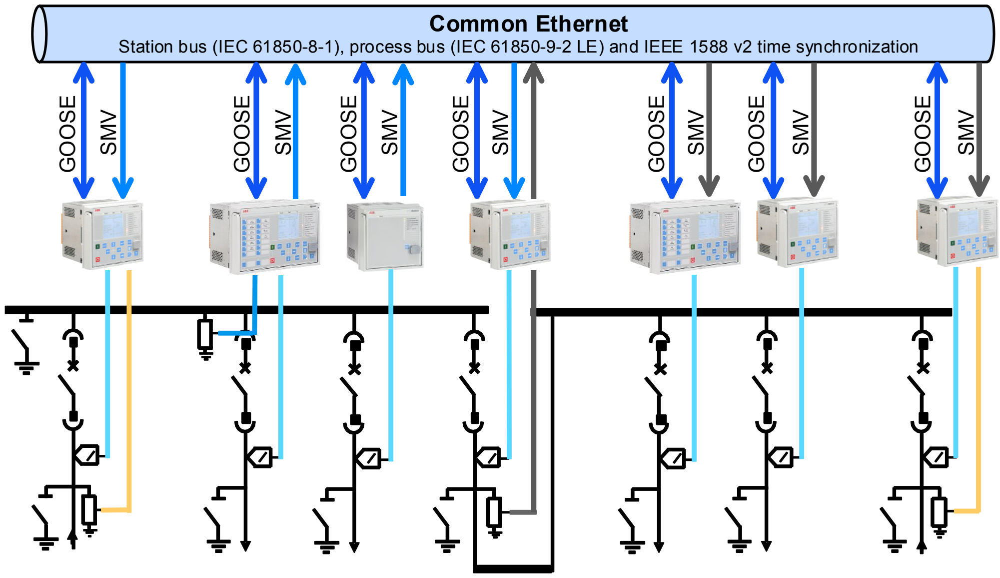


Figure 9: Process bus application of voltage sharing and synchrocheck

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

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

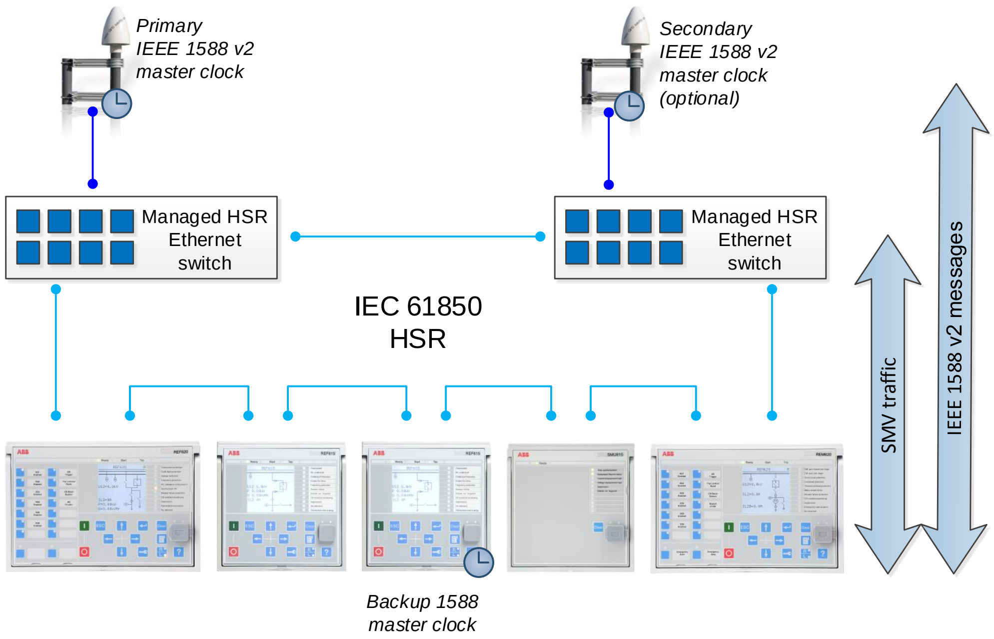


Figure 10: Example network topology with process bus, redundancy and IEEE 1588 v2 time synchronization

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

2.7.4 Secure communication

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

3 REM615 standard configurations

3.1 Standard configuration

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 9: 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	C
Motor protection with voltage and frequency based protection and measurements (sensor inputs)	D

3.1.1 Supported functions in REM615

Table 10: Supported functions

Function	IEC 61850	A	B	C	D
		ME01	ME02	ME03	ME04
Protection					
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1	1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	1	1	1	1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1	1
Non-directional earth-fault protection, low stage	EFLPTOC	1			

Table continues on the next page

Function	IEC 61850	A	B	C	D
		ME01	ME02	ME03	ME04
Non-directional earth-fault protection, high stage	EFHPTOC	1	1	1	1
Directional earth-fault protection, low stage	DEFLPDEF		1	1	1 [4]
Three-phase undervoltage protection	PHPTUV		1	1	1
Positive-sequence undervoltage protection	PSPTUV		1	1	1
Negative-sequence overvoltage protection	NSPTOV		1	1	1
Frequency protection	FRPFRQ		2	2	2
Negative-sequence overcurrent protection for machines	MNSPTOC	2	2	2	2
Loss of load supervision	LOFLPTUC	1	1	1	1
Motor load jam protection	JAMPTOC	1	1	1	1
Motor start-up supervision	STTPMSU	1	1	1	1
Phase reversal protection	PREVPTOC	1	1	1	1
Thermal overload protection for motors	MPTTR	1	1	1	1
Circuit breaker failure protection	CCBRBRF	1	1	1	1
Master trip	TRPPTRC	2 (3)	2 (3) [5]	2 (3) [5]	2 (3) [5]
Arc protection	ARCSARC	(3)	(3)	(3)	(3)
Multipurpose protection	MAPGAPC	18	18	18	18
Control					
Circuit-breaker control	CBXCBR	1	1	1	1
Disconnector control	DCXSWI	2	2	2	2
Earthing switch control	ESXSWI	1	1	1	1
Disconnector position indication	DCSXSWI	3	3	3	3
Earthing switch indication	ESSXSWI	2	2	2	2
Emergency start-up	ESMGAPC	1	1	1	1
Condition monitoring and supervision					
Circuit-breaker condition monitoring	SSCBR	1	1	1	1
Trip circuit supervision	TCSSCBR	2	2	2	2
Current circuit supervision	CCSPVC	1	1	1	1
Fuse failure supervision	SEQSPVC		1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1	1
Measurement					
Disturbance recorder	RDRE	1	1	1	1
Load profile record	LDPRLRC	1	1	1	1
Fault record	FLTRFRC	1	1	1	1
Three-phase current measurement	CMMXU	1	1	1	1
Sequence current measurement	CSMSQI	1	1	1	1
Residual current measurement	RESCMMXU	1	1	1	1
Three-phase voltage measurement	VMMXU		1	1	1
Residual voltage measurement	RESVMMXU			1	
Sequence voltage measurement	VSMSQI		1	1	1
Three-phase power and energy measurement	PEMMXU		1	1	1
RTD/mA measurement	XRGGIO130	(1)	(1)		
Frequency measurement	FMMXU1		1	1	1

Table continues on the next page

[4] "Uo calculated" is always used.

[5] Master trip is included and connected to the corresponding HSO in the configuration only when the BIO0007 module is used. If additionally the ARC option is selected, ARCSARC is connected in the configuration to the corresponding master trip input.

Function	IEC 61850	A	B	C	D
		ME01	ME02	ME03	ME04
IEC 61850-9-2 LE sampled value sending	SMVSENDER		(1)	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) [6][7]	SMVRCV		(1)	(1)	(1)
Other					
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4	4
Move (8 pcs)	MVGAPC	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1	1	1
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = optional					

3.1.2 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.

[6] Available only with IEC 61850-9-2
[7] Available only with COM0031-0037

3.2 Connection diagrams

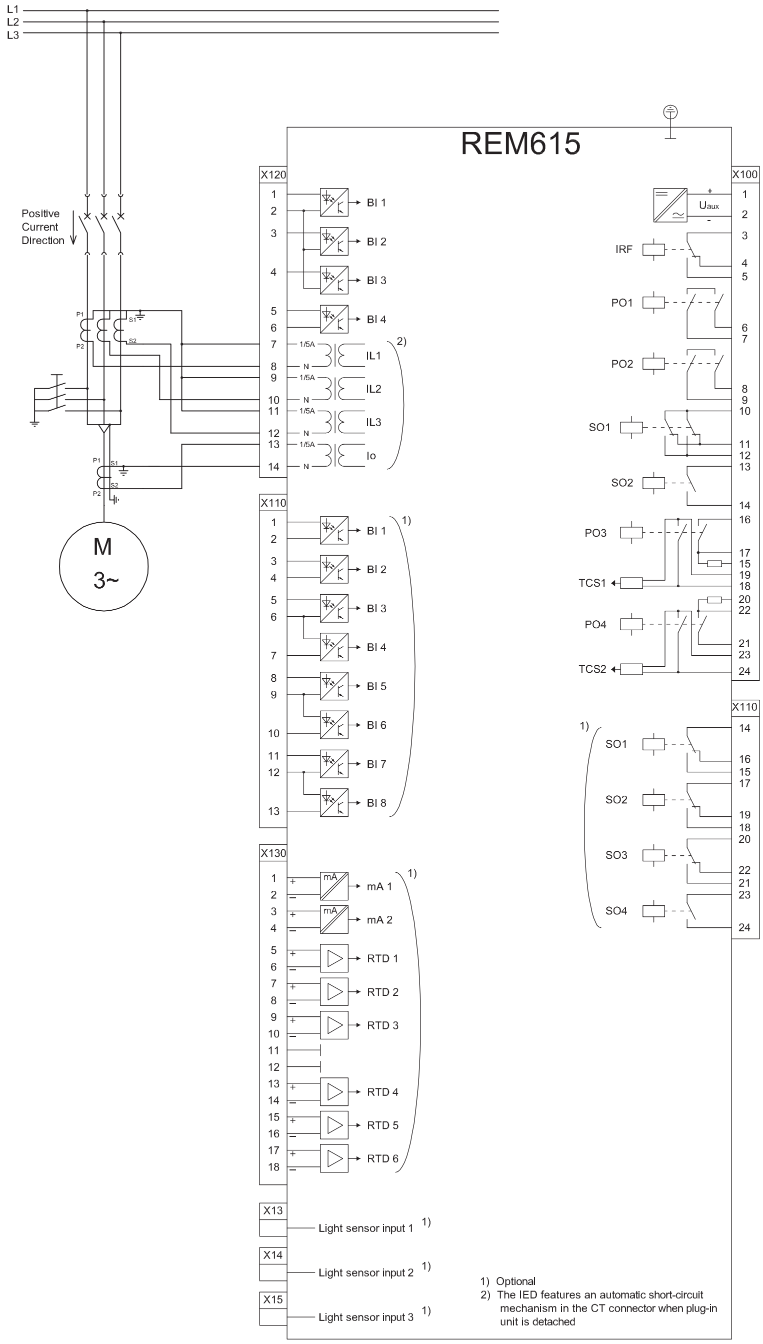


Figure 11: Connection diagram for the A configuration

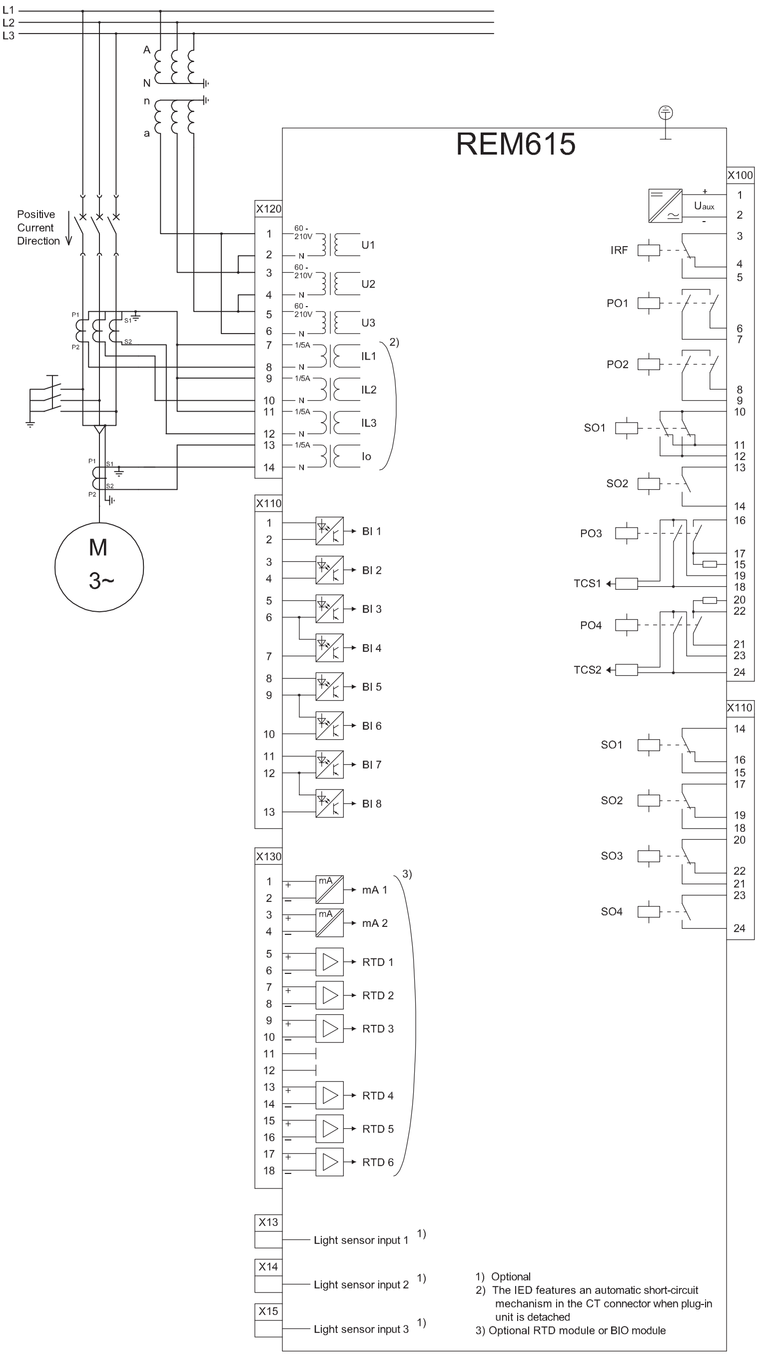


Figure 12: Connection diagram for the B configuration

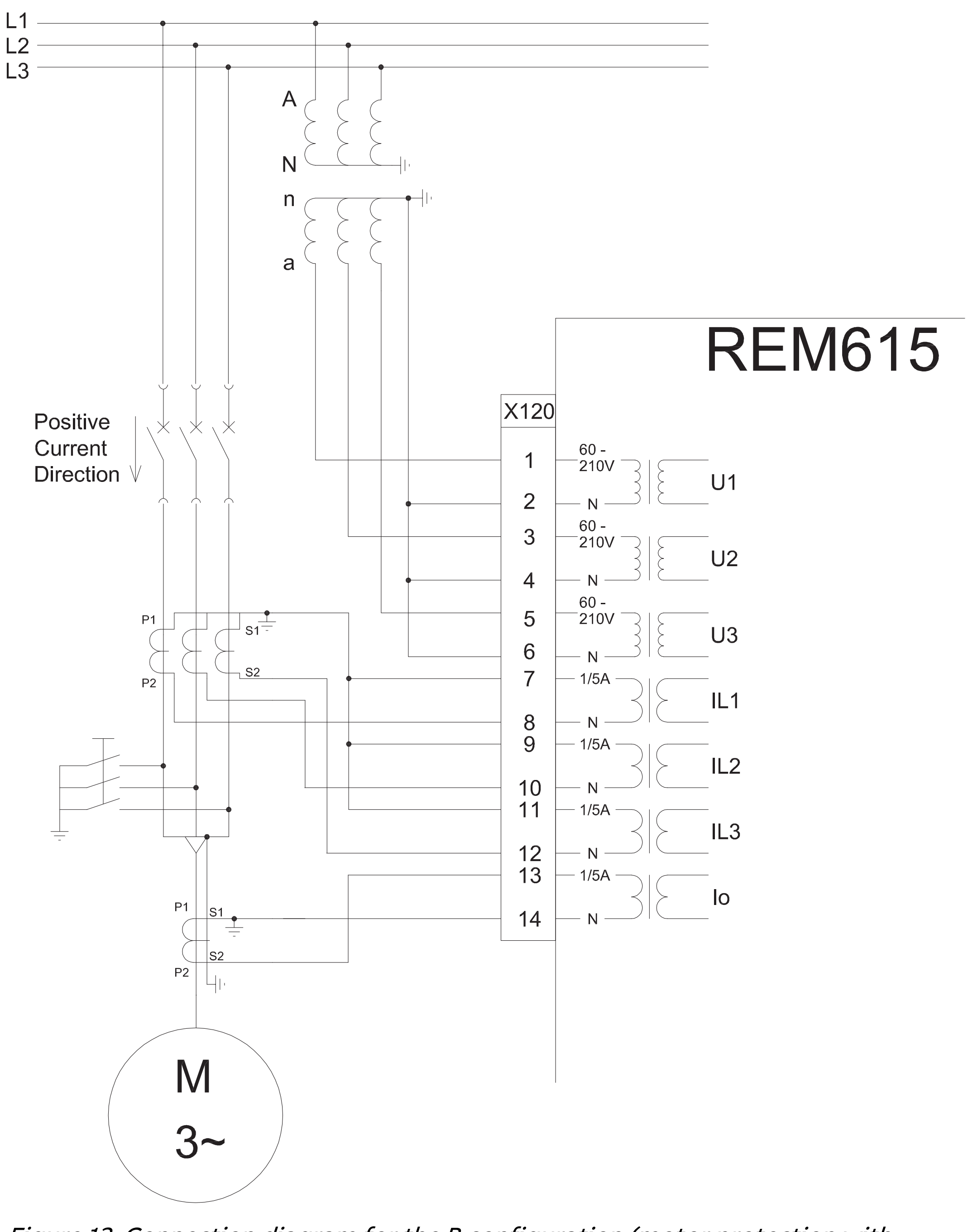


Figure 13: Connection diagram for the B configuration (motor protection with phase-to-earth voltage measurement)

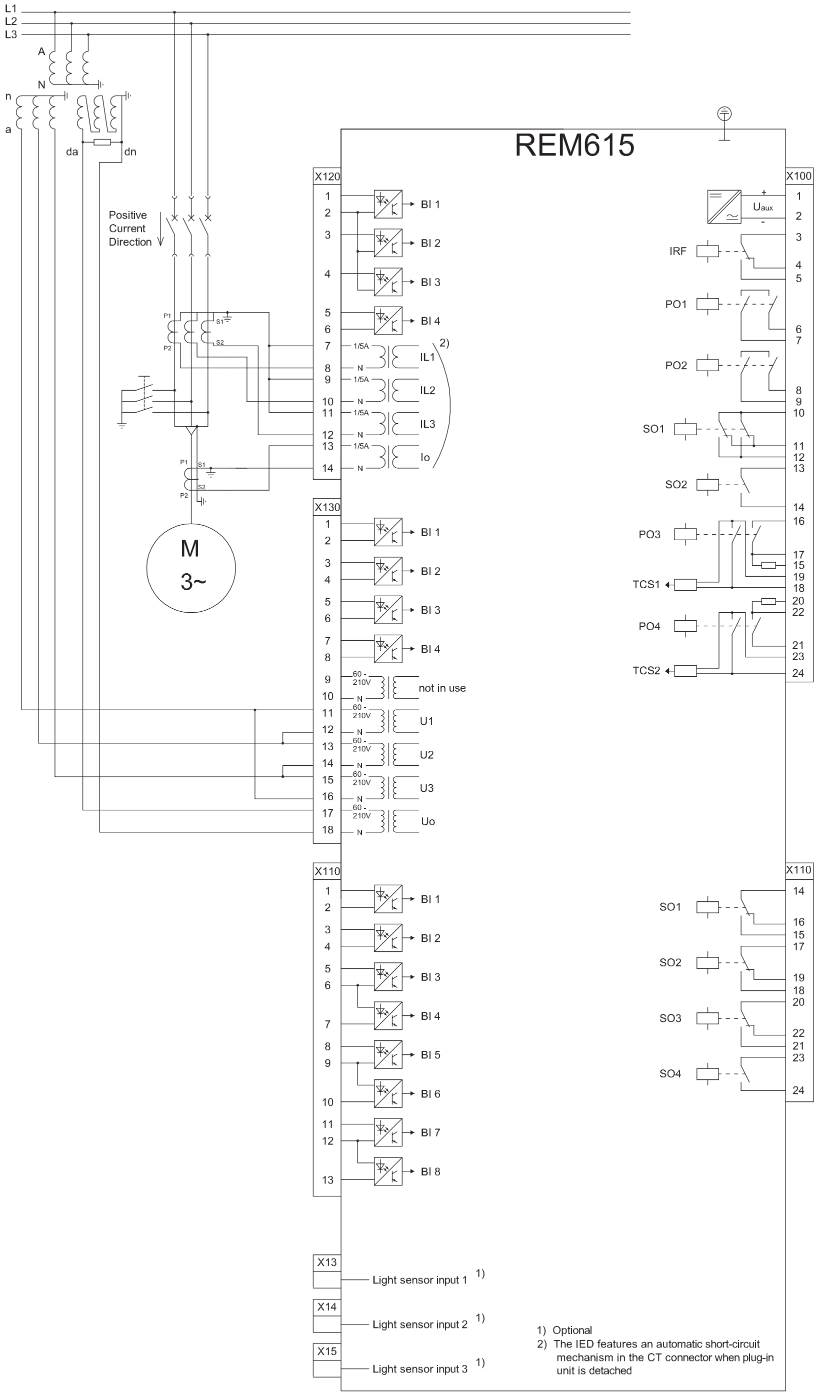


Figure 14: Connection diagram for the C configuration

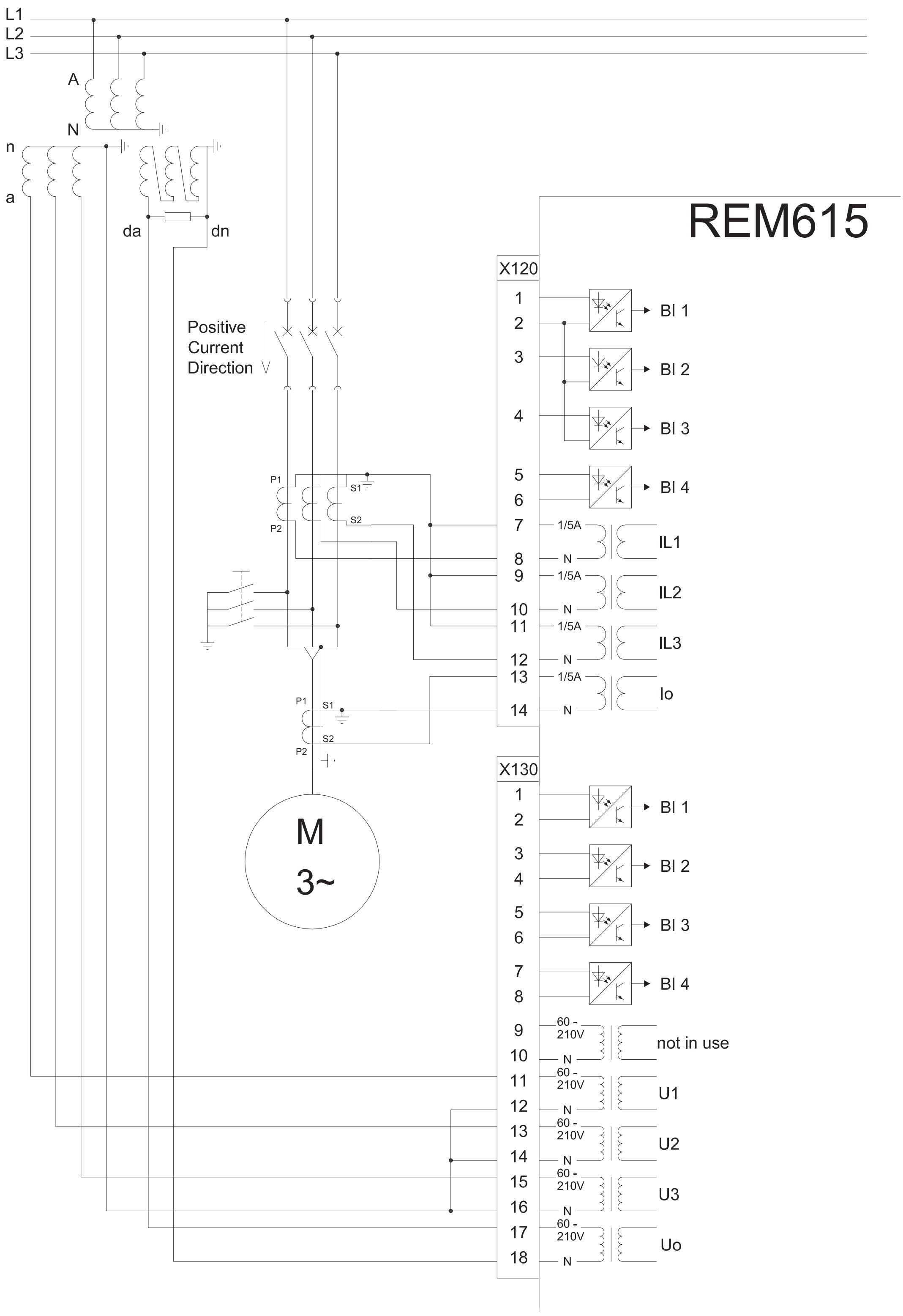


Figure 15: Connection diagram for the C configuration (motor protection with phase-to-earth voltage measurement)

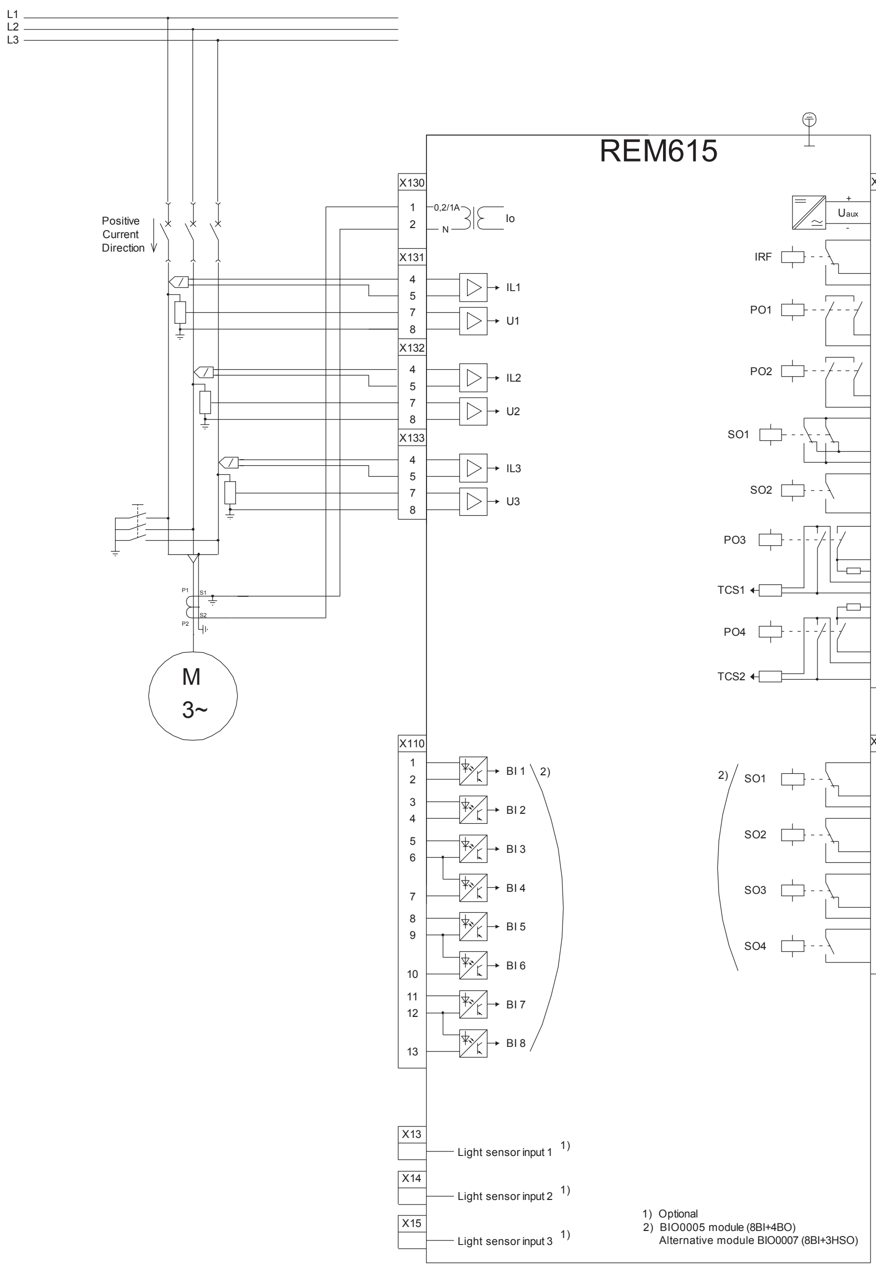


Figure 16: Connection diagram for the D configuration with SIM0002 module

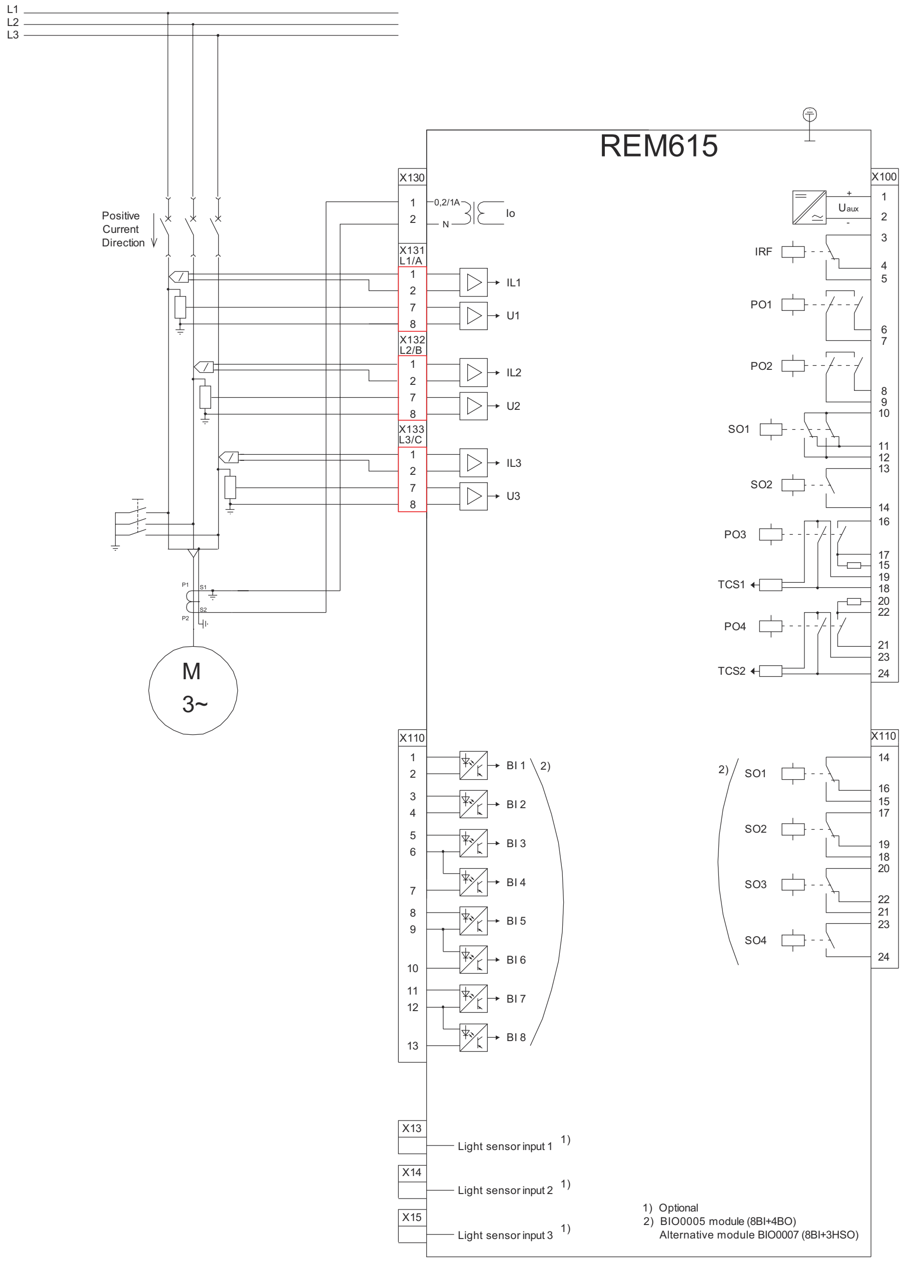


Figure 17: Connection diagram for the D configuration with SIM0005 module

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

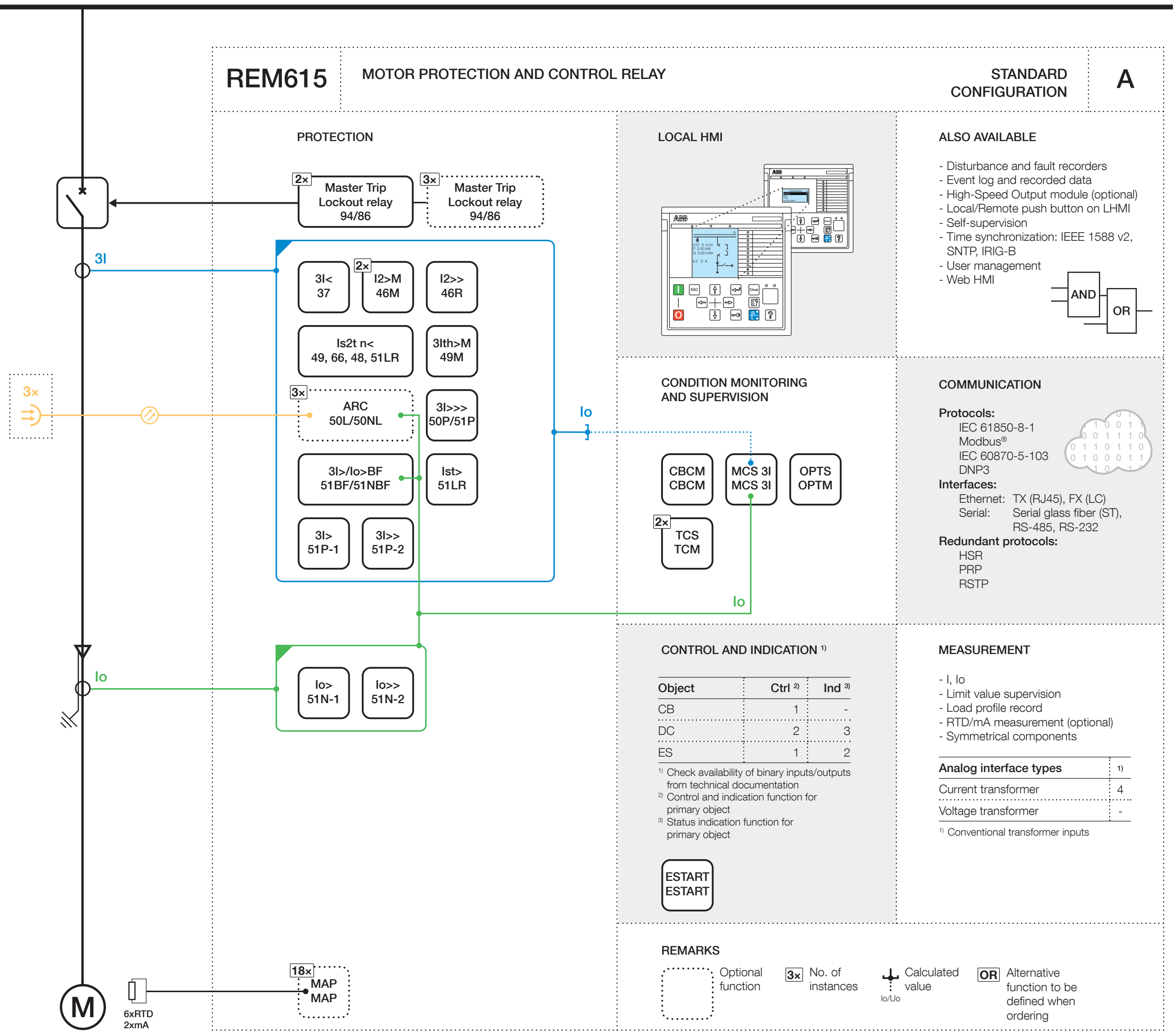


Figure 18: Functionality overview for standard configuration A

3.3.2.1 Default I/O connections

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

Table 11: Default connections for binary inputs

Binary input	Description
X120-BI1	Emergency start
X120-BI2	Circuit breaker closed
X120-BI3	Circuit breaker open
X120-BI4	External restart inhibit

Table 12: Default connections for mA/RTD inputs

RTD/mA input	Description
X130-AI1	–
X130-AI2	–
X130-AI3	Motor winding U temperature
X130-AI4	Motor winding V temperature
X130-AI5	Motor winding W temperature
X130-AI6	Motor cooling air temperature
X130-AI7	Motor bearing temperature
X130-AI8	Motor ambient temperature

Table 13: Default connections for binary outputs

Binary output	Description
X100-PO1	Restart enable
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Open command (for contractor application)
X100-SO2	Start indication
X100-PO3	Open circuit breaker/trip
X100-PO4	Close circuit breaker
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 14: Default connections for LEDs

LED	Description
1	Short-circuit protection operate
2	Earth-fault protection operate
3	Thermal overload protection operate
4	Combined operate indication of the other protection functions
5	Motor restart inhibit

Table continues on the next page

LED	Description
6	Breaker failure protection operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	TCS, motor runtime counter or measuring circuit fault alarm
10	Arc protection operate
11	Emergency start enabled

3.3.2.2 Default disturbance recorder settings

Table 15: Default disturbance recorder analog channels

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

Table 16: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHIPTOC2 - start	Positive or Rising
3	EFLPTOC1 - start	Positive or Rising
4	EFHPTOC1 - start	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 - start	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - start	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - start	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
15	MAPGAPC1 - start	Positive or Rising
16	MAPGAPC2 - start	Positive or Rising
17	MAPGAPC3 - start	Positive or Rising
18	CCBRBRF1 - trret	Level trigger off
19	CCBRBRF1 - trbu	Level trigger off
20	PHLPTOC1 - operate	Level trigger off
21	PHIPTOC2 - operate	Level trigger off
22	JAMPTOC1 - operate	Level trigger off
23	EFLPTOC1 - operate	Level trigger off
	EFHPTOC2 - operate	
24	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
25	PREVPTOC1 - operate	Level trigger off
26	LOFLPTUC1 - operate	Level trigger off
27	MPTTR1 - operate	Level trigger off
28	MAPGAPC1 - operate	Level trigger off
29	MAPGAPC2 - operate	Level trigger off
30	MAPGAPC3 - operate	Level trigger off
31	X120BI1 - Emerg start ena	Level trigger off
32	X120BI2 - CB closed	Level trigger off
33	X120BI3 - CB opened	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	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
38	ARCSARC1 - operate	Positive or Rising
39	ARCSARC2 - operate	Positive or Rising
40	ARCSARC3 - operate	Positive or Rising

3.3.3 Functional diagrams

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

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

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

Two overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional low stage PHLPTOC1 can be used for overcurrent protection whereas instantaneous stage PHIPTOC1 can be used for short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation. The Motor load jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

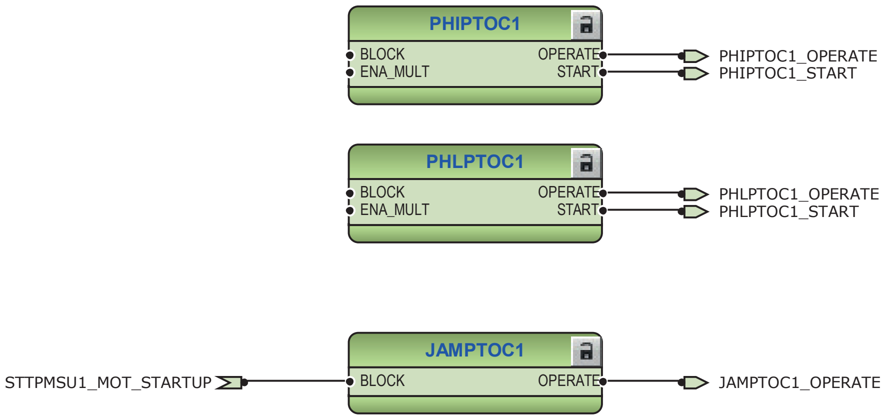


Figure 19: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 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.

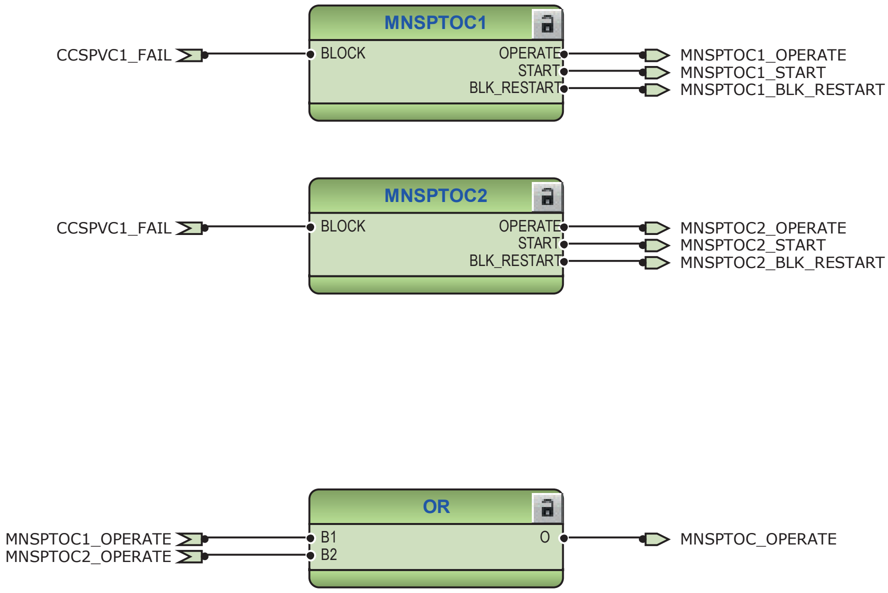


Figure 20: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1 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.

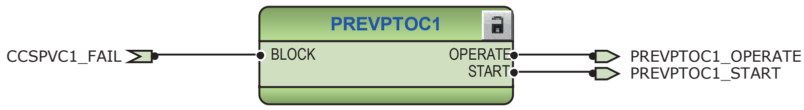


Figure 21: Phase reversal protection function

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

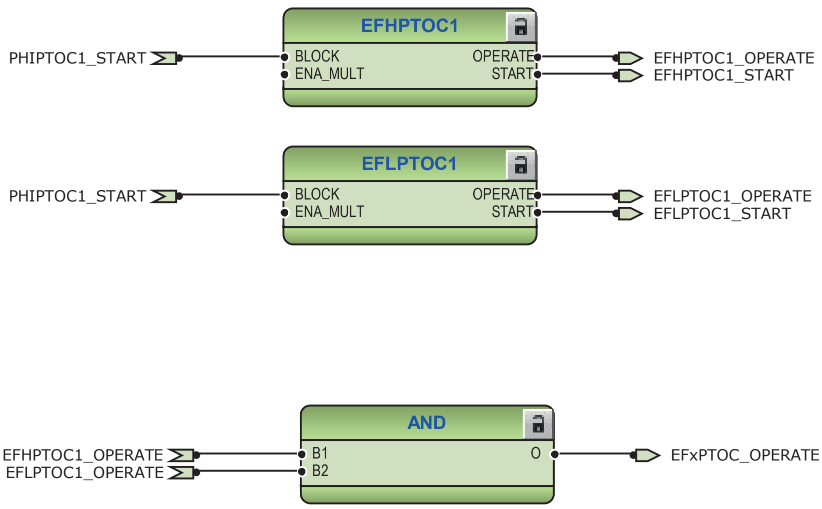


Figure 22: Earth-fault protection functions

The emergency start function ESMGAPC1 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 start signal, various events occur.

- The calculated thermal level in MPTTR1 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 is set slightly below the set restart inhibit value to allow at least one motor start-up.
- The set start value of the MAPGAPC1 function is increased (or decreased) depending on the *Start 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.

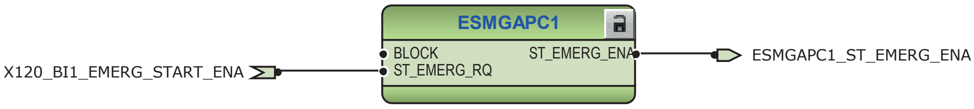


Figure 23: Motor emergency start-up function

The thermal overload protection for motors MPTTR1 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 IED is ordered with 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.

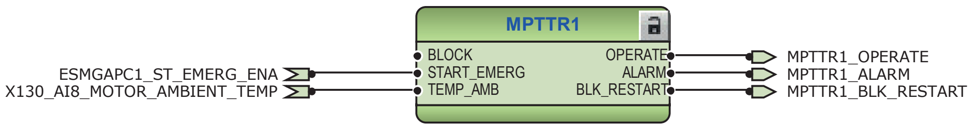


Figure 24: Thermal overcurrent protection function

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. Re-closing 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.

- An active trip command
- 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, the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1 and STTPMSU1 is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

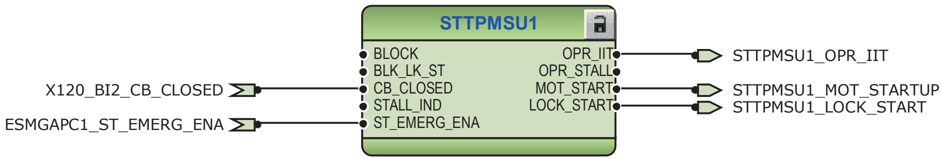


Figure 25: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1 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.

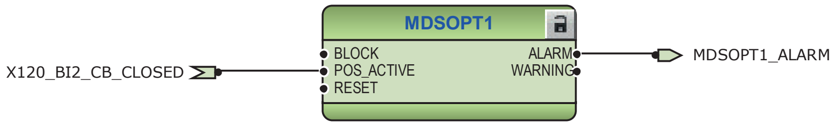


Figure 26: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

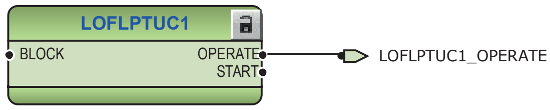


Figure 27: Loss of load protection function

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 multipurpose analog protection block MAPGAPC1.

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 and MAPGAPC3 functions.

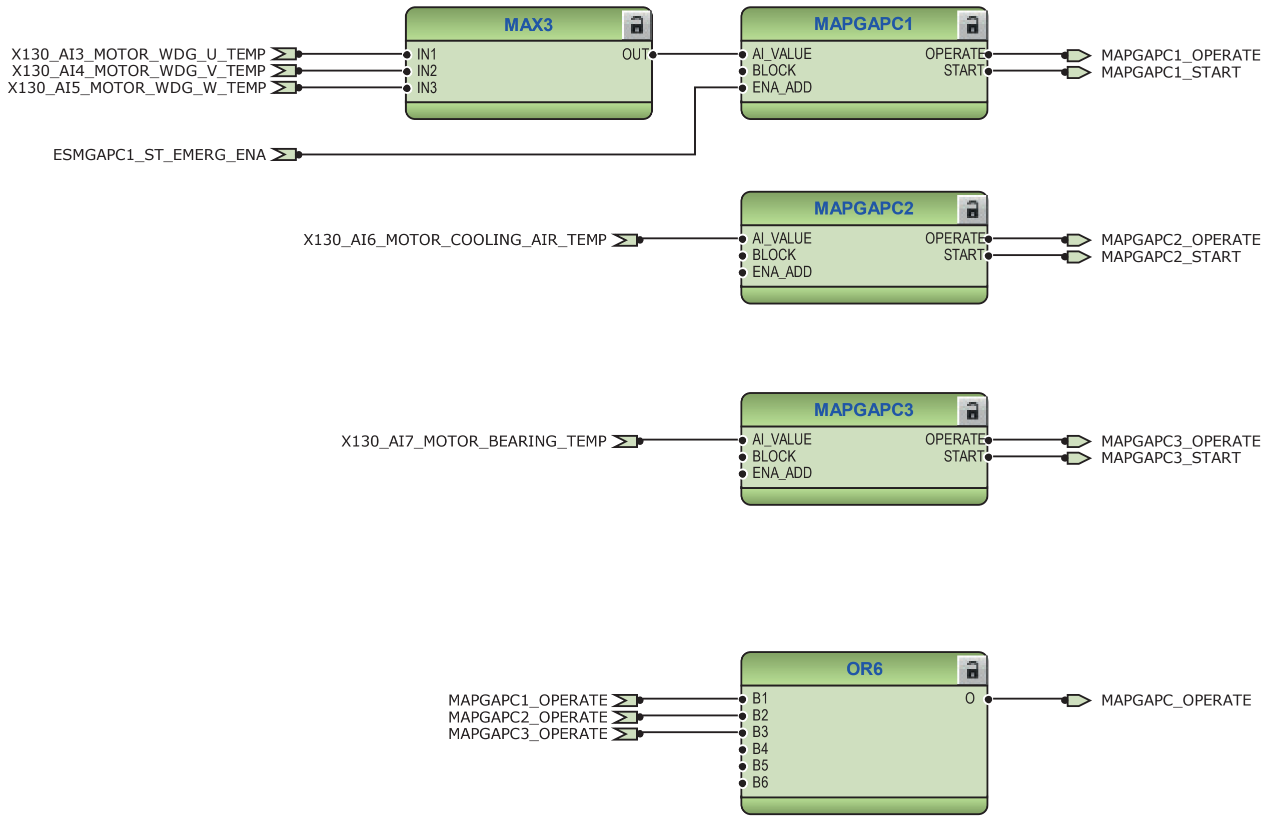


Figure 28: Multipurpose mA/RTD monitoring

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

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

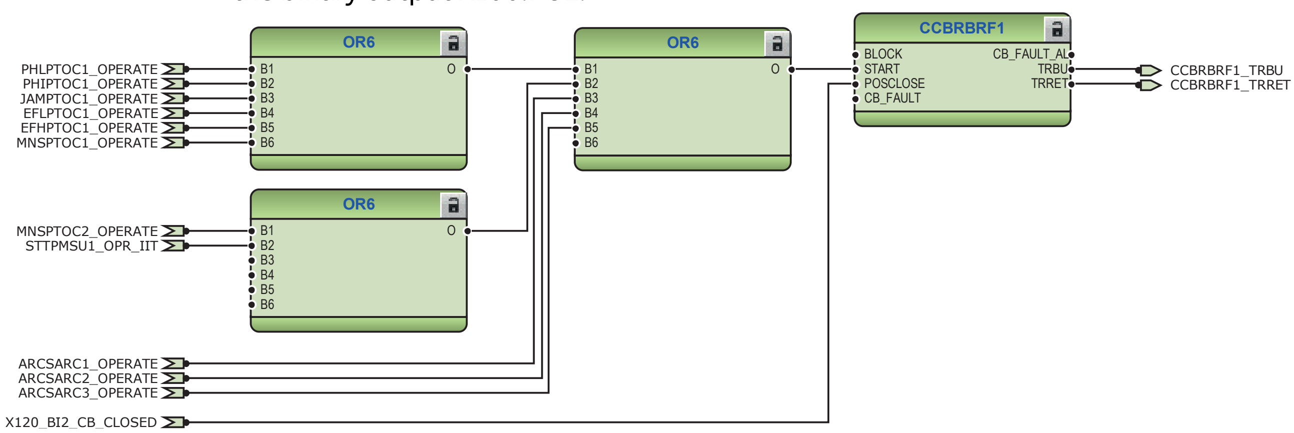


Figure 29: Circuit breaker failure protection function

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

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

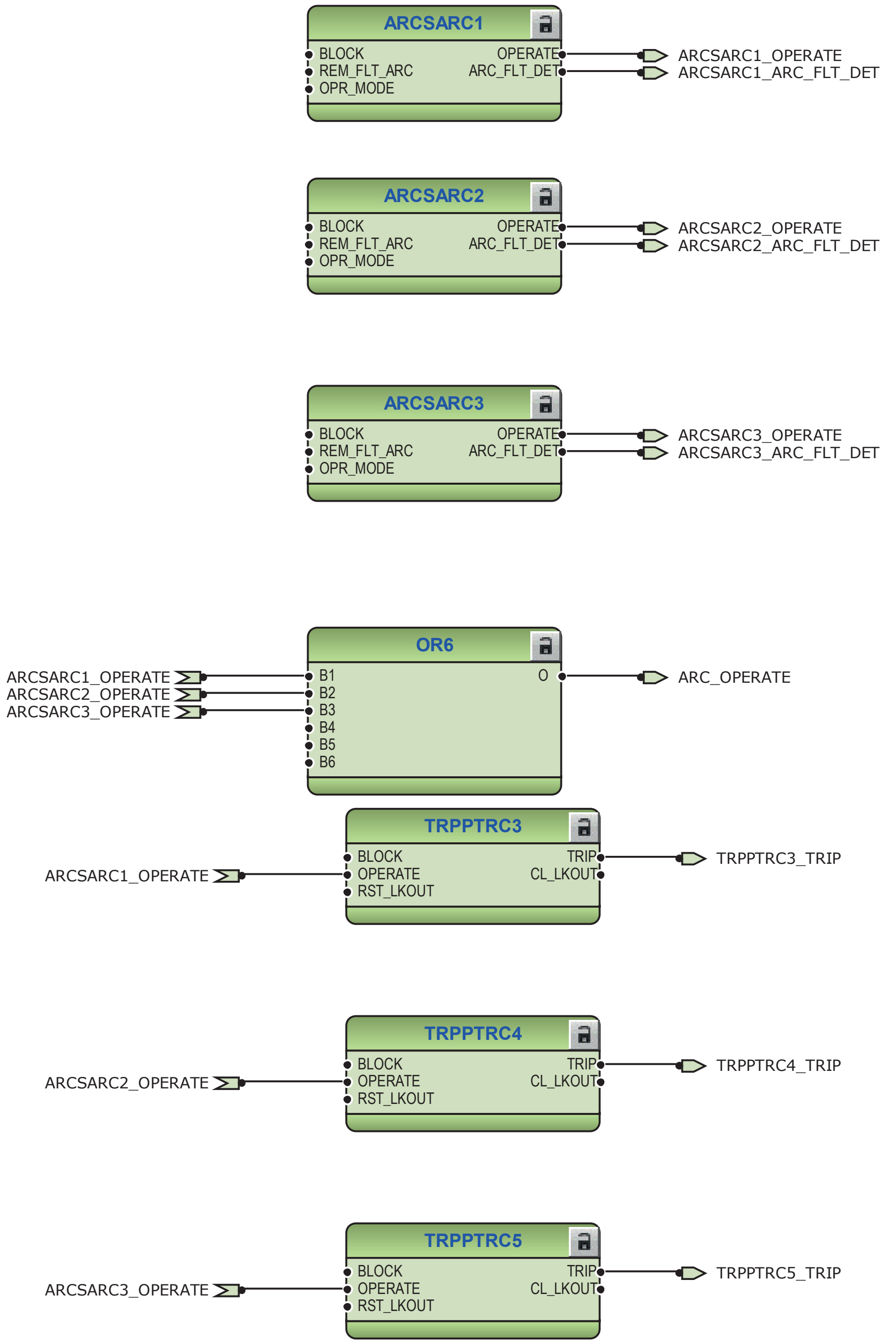


Figure 30: Arc protection with dedicated HSO

General start and operate 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.

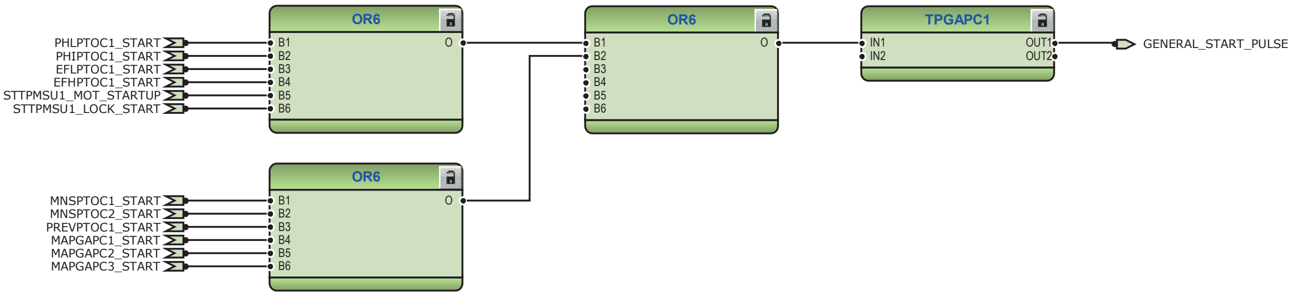


Figure 31: General start and operate signals

The operate signals from the protection functions are connected to trip logics TRPPTRC1. 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...4 are also available if the IED is ordered with high speed binary outputs options.

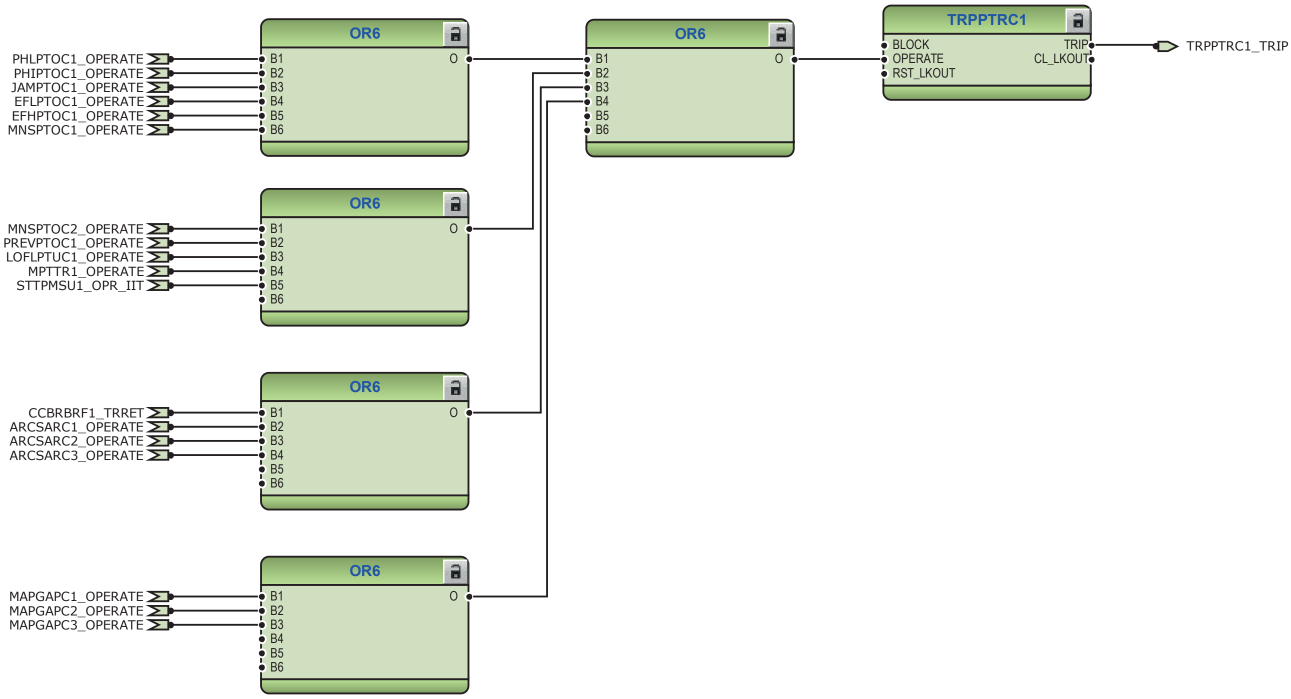


Figure 32: Trip logic TRPPTRC1

3.3.3.2 Functional diagrams for disturbance recorder

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

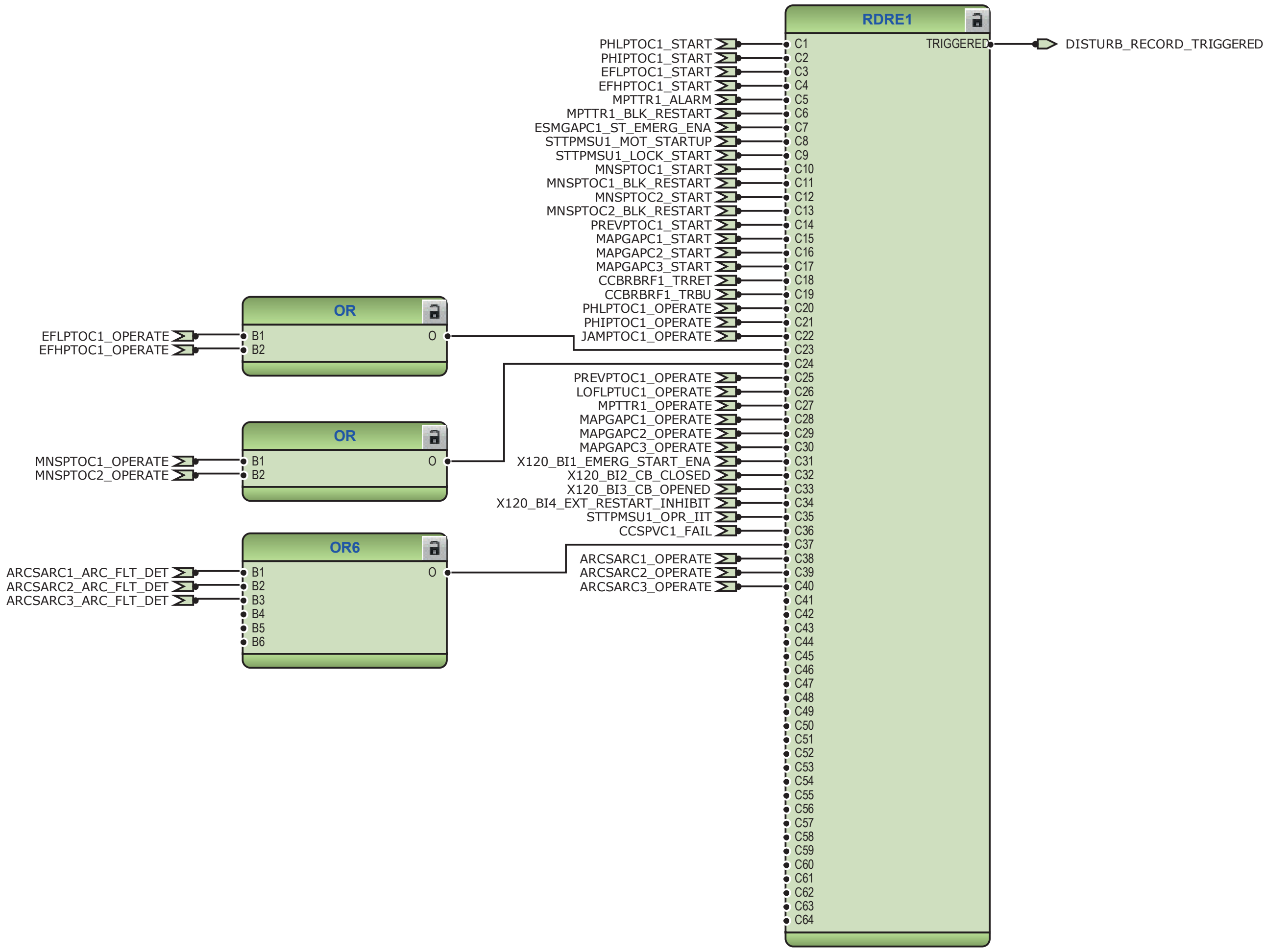


Figure 33: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measuring circuits. When a failure is detected, it 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.

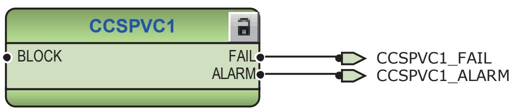


Figure 34: Current circuit supervision function

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

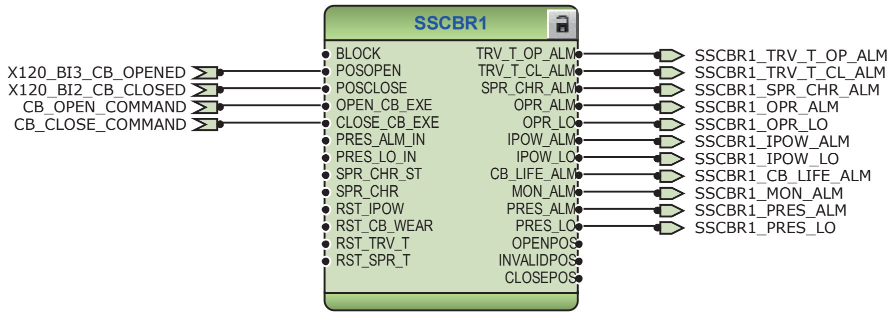


Figure 35: Circuit-breaker condition monitoring function

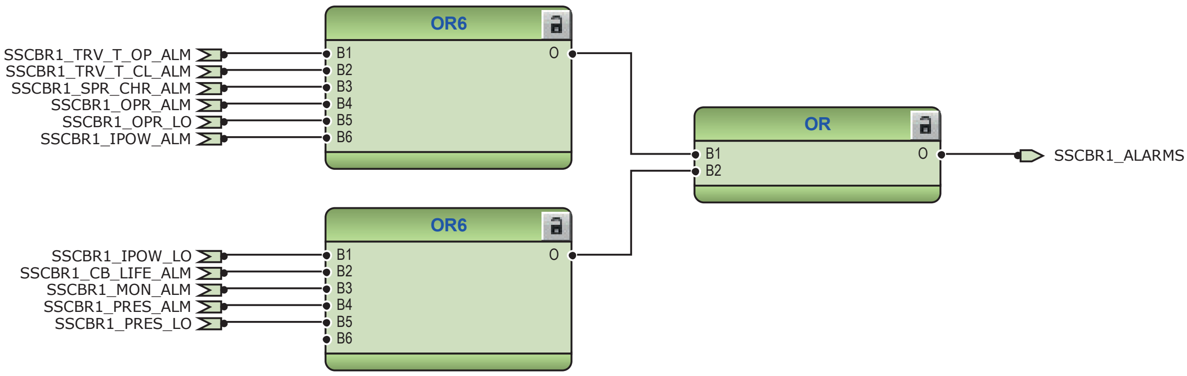


Figure 36: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 for master trip and TCSSCBR2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1 is blocked by the master trip TRPPTRC1 and the circuit breaker open signal. The trip circuit supervision function TCSSCBR2 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.

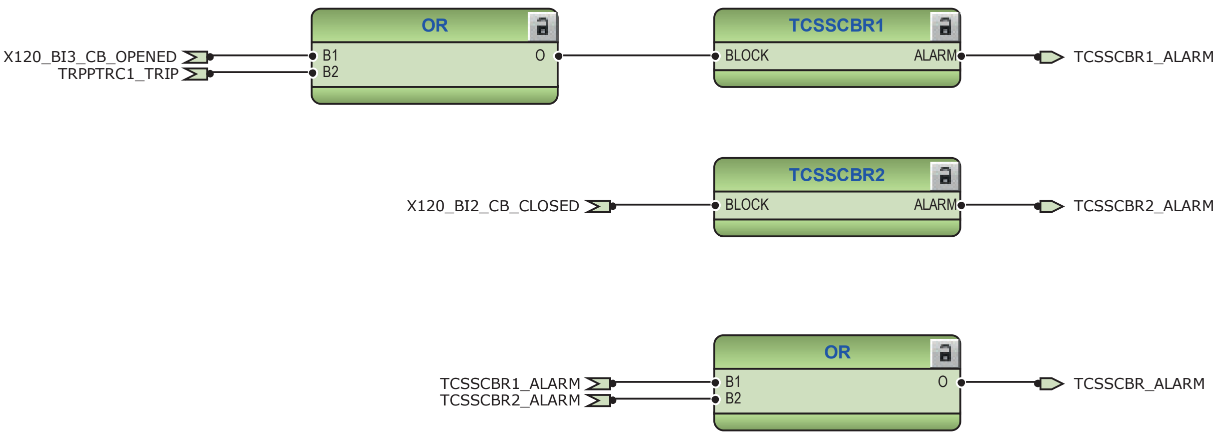


Figure 37: Trip circuit supervision function

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 earth-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.

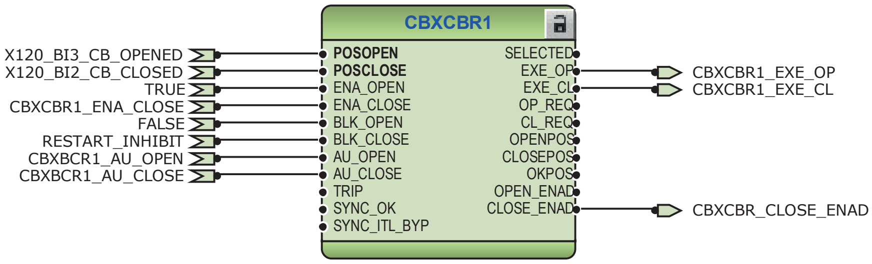


Figure 38: Circuit breaker 1 control logic

Figure 39: Signals for closing coil of circuit breaker 1

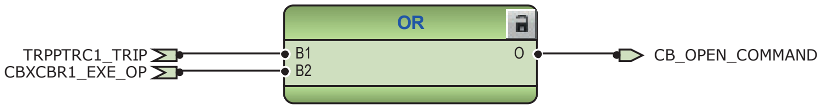


Figure 40: Signals for opening coil of circuit breaker 1

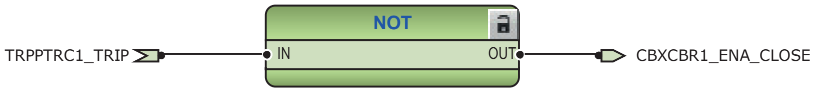


Figure 41: Circuit breaker 1 close enable logic

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

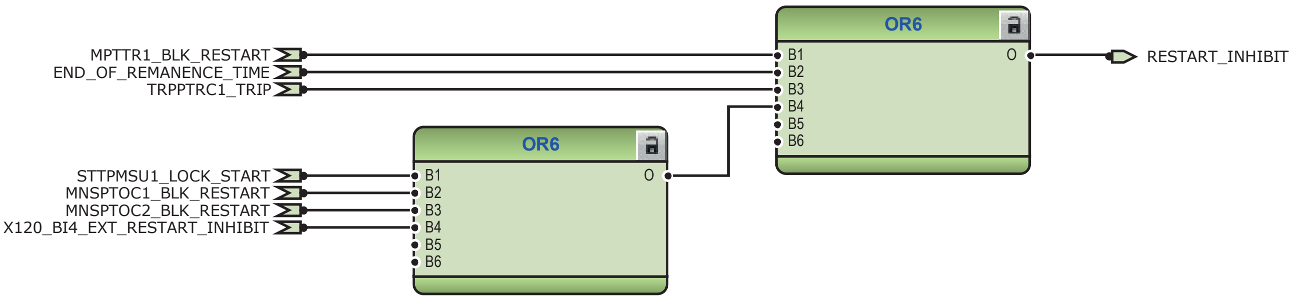


Figure 42: Circuit breaker 1 close blocking logic

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 is activated and the X100:PO1 output is closed.

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

- An active trip command
- 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 IED in local or remote mode.

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

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

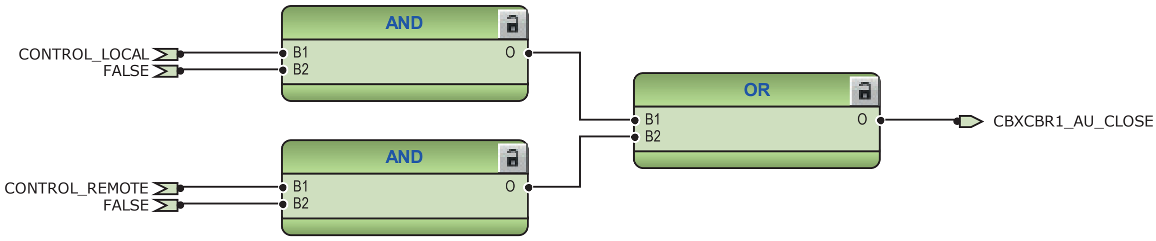


Figure 43: External closing command for circuit breaker 1

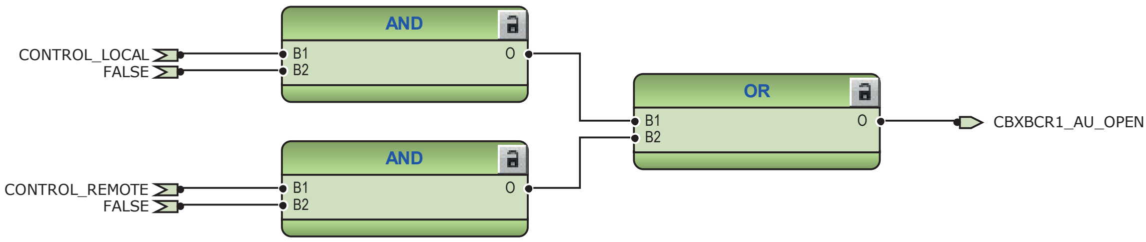


Figure 44: External opening command for circuit breaker 1

3.3.3.5 Functional diagrams for measurement functions

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

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

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

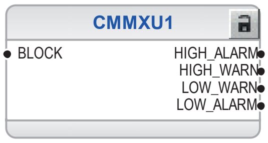


Figure 45: Current measurement: Three-phase current measurement

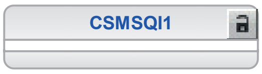


Figure 46: Current measurement: Sequence current measurement

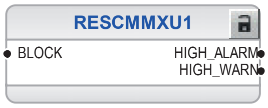


Figure 47: Current measurement: Residual current measurement

Figure 48: Other measurement: Data monitoring

Figure 49: Other measurement: Load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

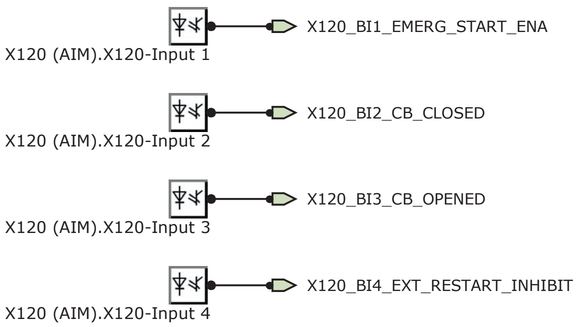


Figure 50: Default binary inputs - X120

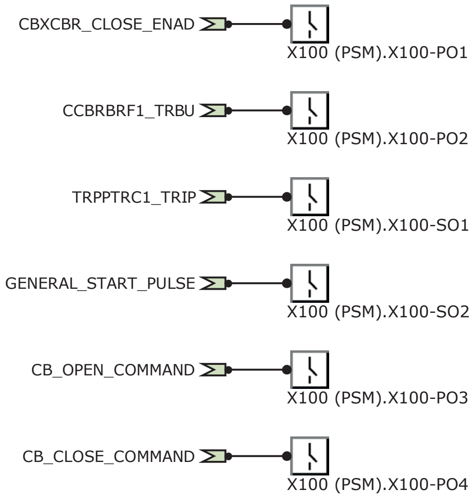


Figure 51: Default binary outputs - X100

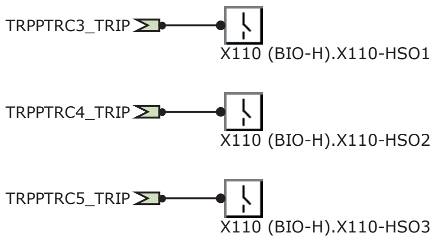


Figure 52: Default binary outputs - X110

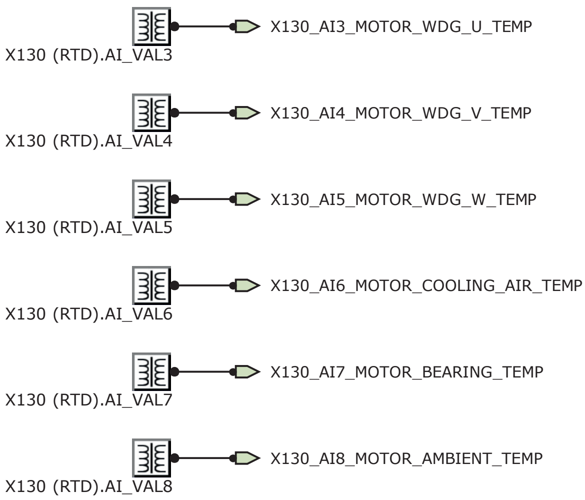


Figure 53: Default mA/RTD inputs - X130

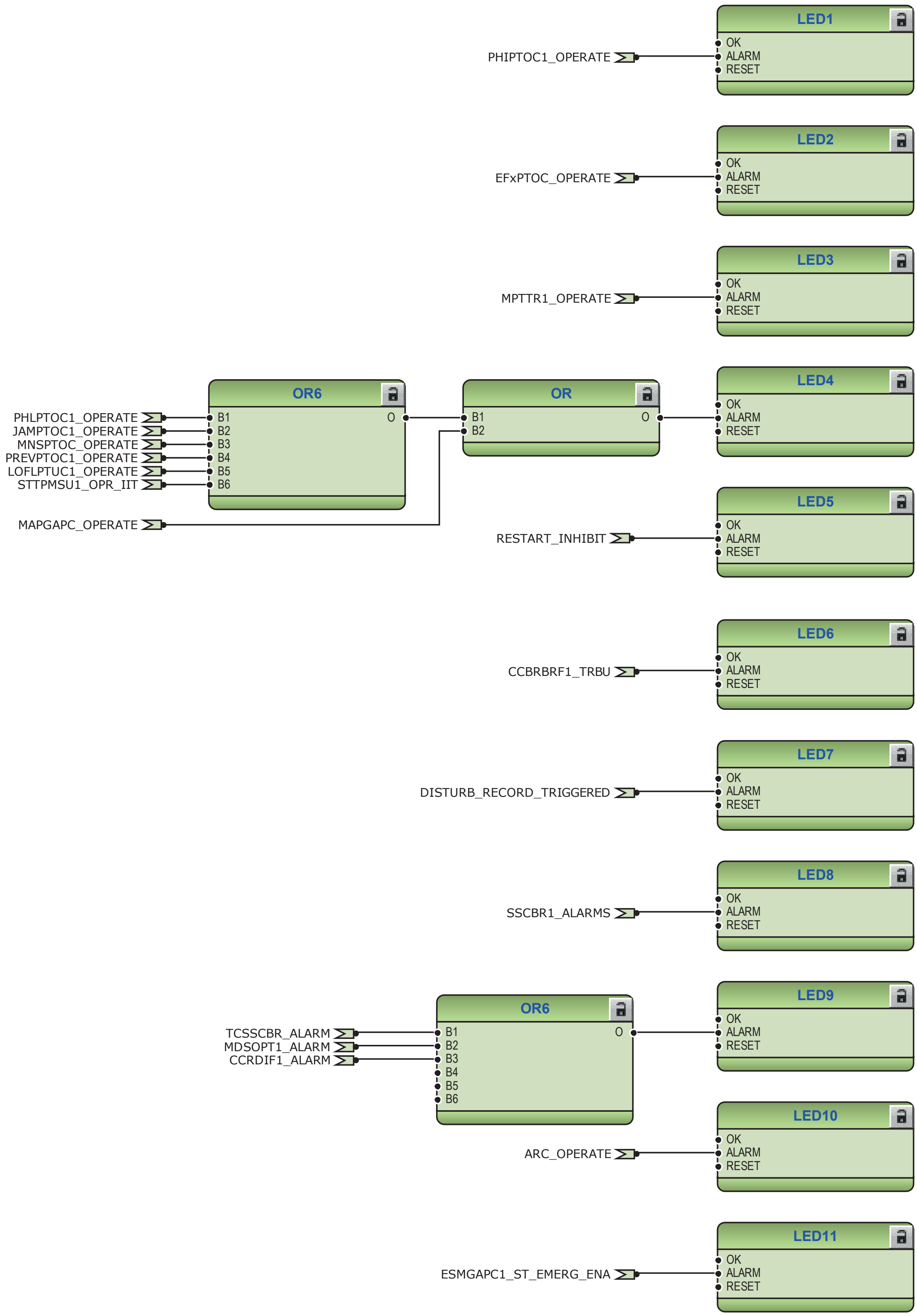


Figure 54: Default LED connections

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.

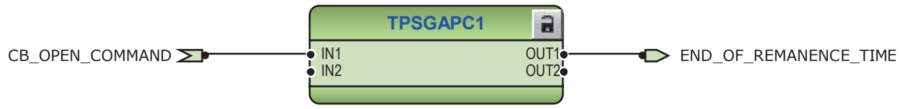


Figure 55: Timer logic for remanence voltage to disappear

3.3.3.8 Other functions

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 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

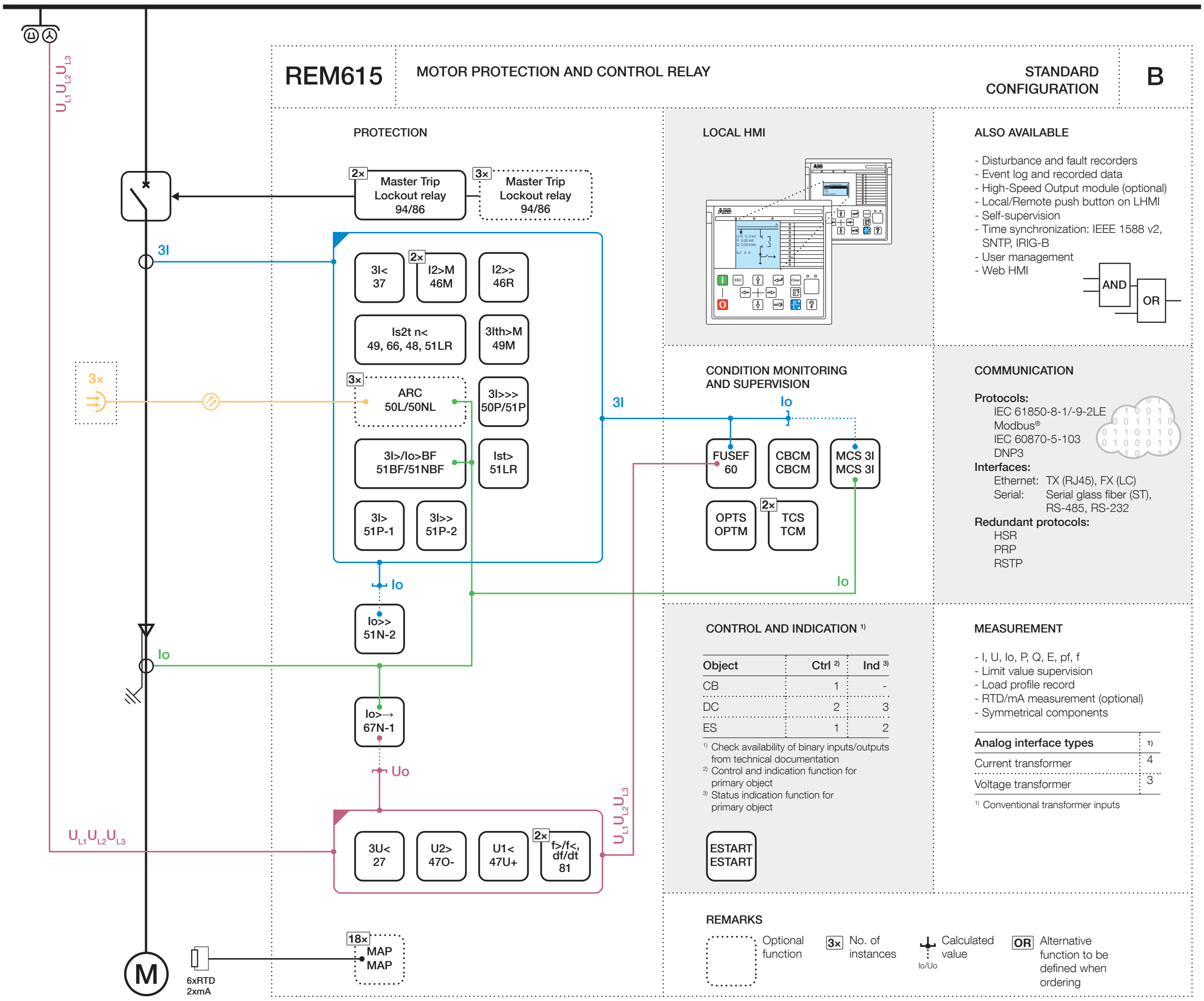


Figure 56: Functionality overview for standard configuration B

3.4.2.1 Default I/O connections

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

Table 17: Default connections for binary inputs

Binary input	Description
X110-BI1	Emergency restart inhibit
X110-BI2	External trip
X110-BI3	Circuit breaker closed
X110-BI4	Circuit breaker open
X110-BI5	Voltage transformer secondary MCB open
X110-BI6	Emergency start
X110-BI7	Lockout reset
X110-BI8	Setting group change

Table 18: Default connections for mA/RTD inputs

RTD/mA input	Description
X130-AI1	–
X130-AI2	–
X130-AI3	Motor winding U temperature
X130-AI4	Motor winding V temperature
X130-AI5	Motor winding W temperature
X130-AI6	Motor cooling air temperature
X130-AI7	Motor bearing temperature
X130-AI8	Motor ambient temperature

Table 19: Default connections for binary outputs

Binary output	Description
X100-PO1	Restart enable
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Open command (for contractor application)
X100-SO2	Start indication
X100-PO3	Open circuit breaker/trip
X100-PO4	Close circuit breaker
X110-SO1	Motor startup indication
X110-SO2	Thermal overload alarm
X110-SO3	Voltage protection alarm
X110-SO4	Start indication
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 20: Default connections for LEDs

LED	Description
1	Short-circuit protection operate
2	Earth-fault protection operate
3	Thermal overload protection operate
4	Combined operate indication of the other protection functions
5	Motor restart inhibit
6	Breaker failure protection operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	TCS, motor runtime counter or measuring circuit fault alarm
10	Arc protection operate
11	Emergency start enabled

3.4.2.2 Default disturbance recorder settings

Table 21: 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 22: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHIPTOC2 - start	Positive or Rising
3	DEFLPDEF1 - start	Positive or Rising
4	EFHPTOC1 - start	Positive or Rising
5	MPTTR1 - alarm	Level trigger off
6	MPTTR1 - blk restart	Level trigger off
7	ESMGAPC1 - st emerg ena	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
8	STTPMSU1 - mot startup	Positive or Rising
9	STTPMSU1 - lock start	Level trigger off
10	MNSPTOC1 - start	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - start	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - start	Positive or Rising
15	PHPTUV1 - start	Positive or Rising
16	PSPTUV1 - start	Positive or Rising
17	NSPTOV1 - start	Positive or Rising
18	FRPFRQ1 - start	Positive or Rising
19	FRPFRQ2 - start	Positive or Rising
20	MAPGAPC1 - start	Positive or Rising
21	MAPGAPC2 - start	Positive or Rising
22	MAPGAPC3 - start	Positive or Rising
23	CCBRBRF1 - trret	Level trigger off
24	CCBRBRF1 - trbu	Level trigger off
25	PHLPTOC1 - operate	Level trigger off
26	PHIPTOC2 - operate	Level trigger off
27	JAMPTOC1 - operate	Level trigger off
28	DEFLPDEF1 - operate	Level trigger off
	EFHPTOC2 - operate	
29	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
30	PREVPTOC1 - operate	Level trigger off
31	LOFLPTUC1 - operate	Level trigger off
32	MPTTR1 - operate	Level trigger off
33	PHPTUV1 - operate	Level trigger off
34	PSPTUV1 - operate	Level trigger off
35	NSPTOV1 - operate	Level trigger off
36	FRPFRQ1 - operate	Level trigger off
37	FRPFRQ2 - operate	Level trigger off
38	MAPGAPC1 - operate	Level trigger off
39	MAPGAPC2 - operate	Level trigger off
40	MAPGAPC3 - operate	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 opened	Level trigger off
46	X110BI7 - rst lockout	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
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	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
54	ARCSARC1 - operate	Positive or Rising
55	ARCSARC2 - operate	Positive or Rising
56	ARCSARC3 - operate	Positive or Rising

3.4.3 Functional diagrams

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

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

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

Two overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional low stage PHLPTOC1 can be used for overcurrent protection whereas instantaneous stage PHIPTOC1 can be used for short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation.

The motor load jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

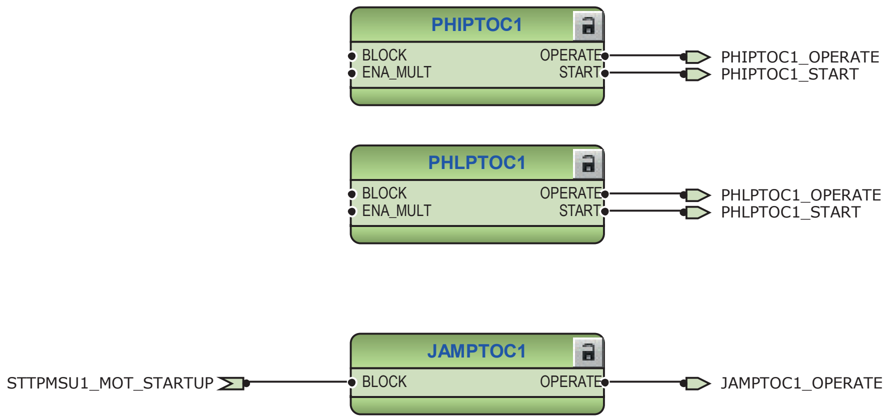


Figure 57: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 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.

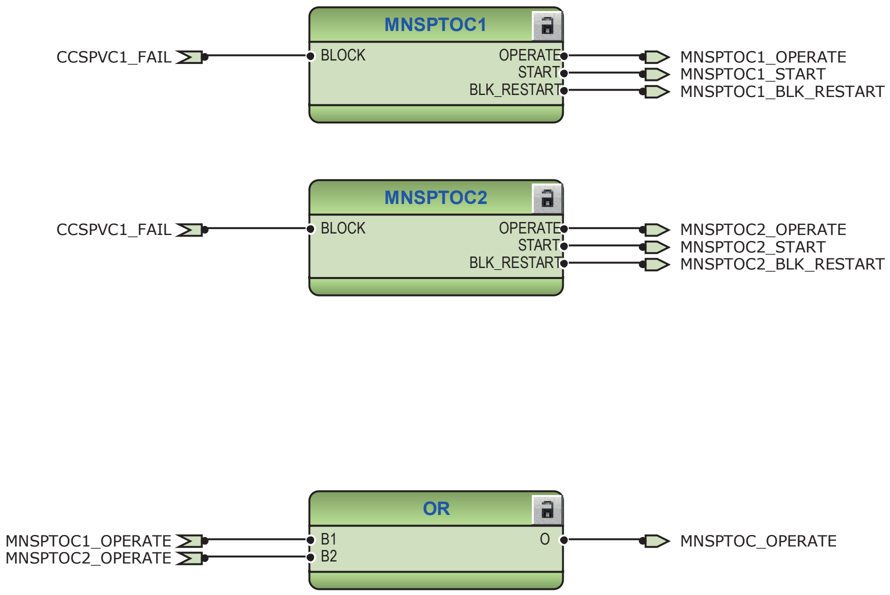


Figure 58: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1 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.

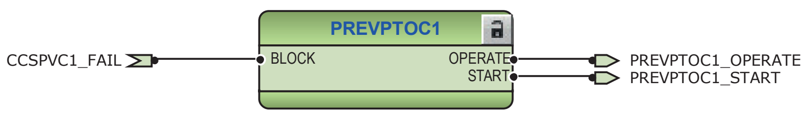


Figure 59: Phase reversal protection function

One stage is provided for non-directional earth-fault protection EFHPTOC1 to detect phase-to-earth faults that may be result of, for example, insulation ageing. In addition, there is a directional protection stage DEFLPDEF1 which can also be used as a low stage non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth 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 earth-fault are blocked by the activation of instantaneous stage of overcurrent protection.

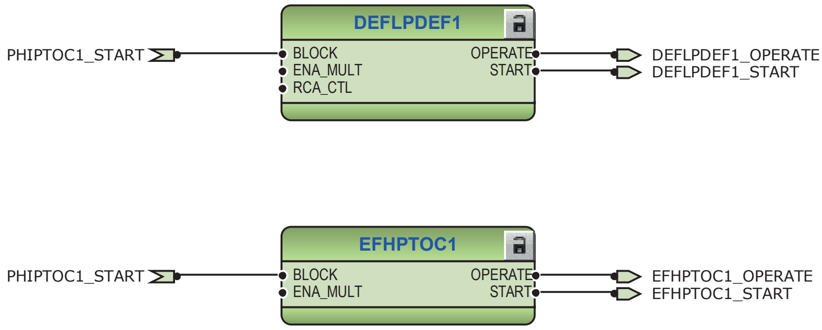


Figure 60: Earth-fault protection functions

The emergency start function ESMGAPC1 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 start signal, various events occur.

- The calculated thermal level in MPTTR1 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 is set slightly below the set restart inhibit value to allow at least one motor start-up.
- The set start value of the MAPGAPC1 function is increased (or decreased) depending on the *Start 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.

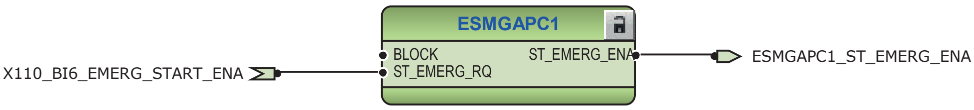


Figure 61: Motor emergency start-up function

The thermal overload protection for motors MPTTR1 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 IED is ordered with 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.

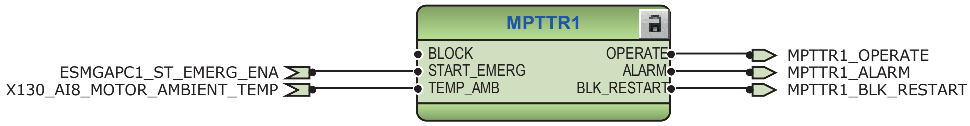


Figure 62: Thermal overcurrent protection function

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.

- An active trip command
- 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, the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1 and STTPMSU1 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 IED at the infeeding bay.

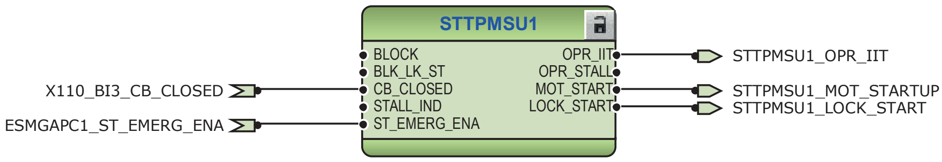


Figure 63: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1 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.

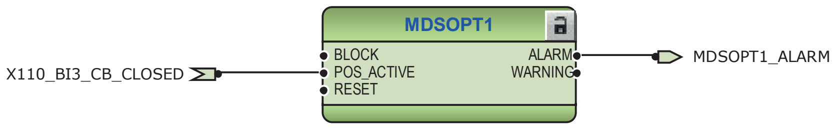


Figure 64: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

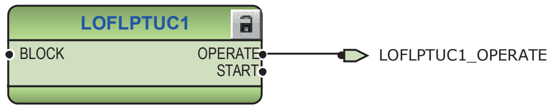


Figure 65: Loss of load protection function

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.

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 and MAPGAPC3 functions.

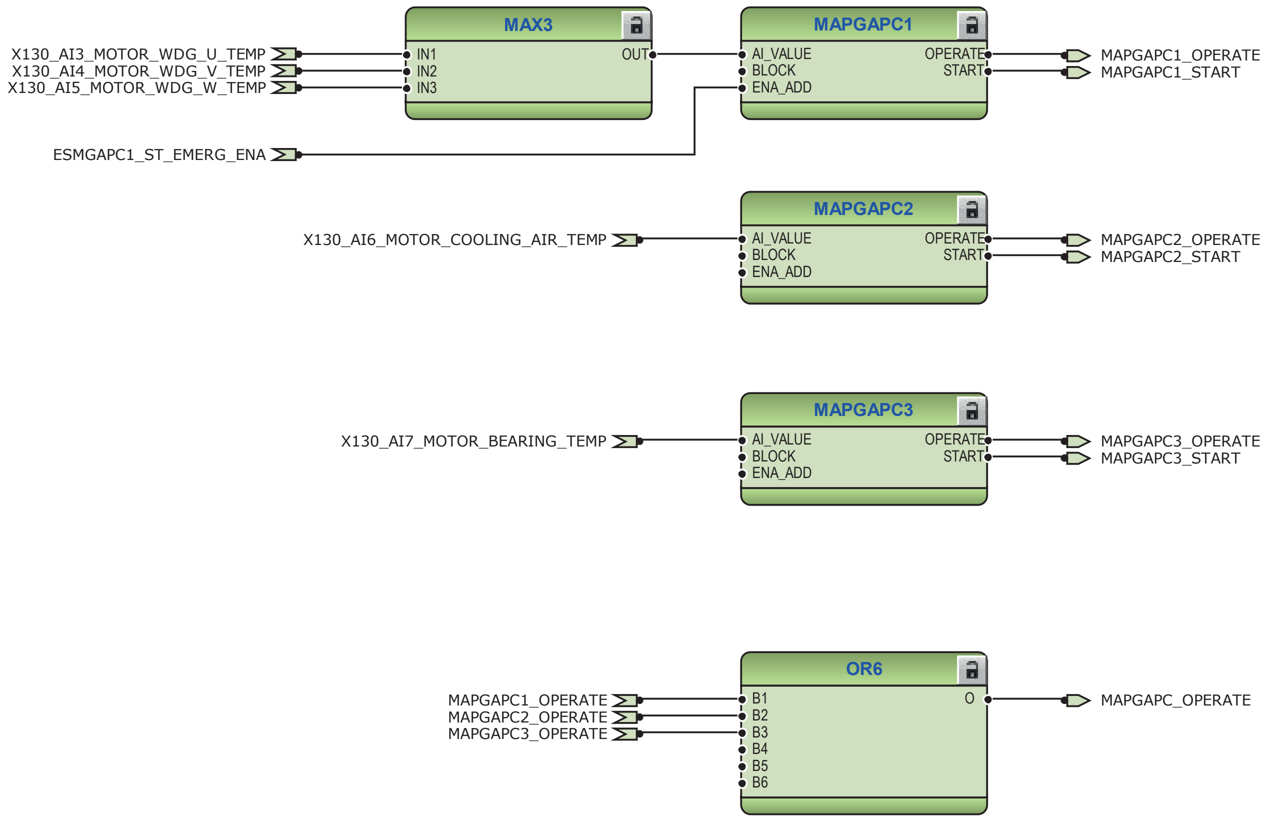


Figure 66: Multipurpose mA/RTD monitoring

The three-phase undervoltage protection PHPTUV1 offers protection against abnormal phase voltage conditions. The positive-sequence undervoltage protection PSPTUV1 and negative-sequence overvoltage protection NSPTOV1 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 in addition is also blocked during motor start-up to prevent unwanted operation in case of a short voltage drop.

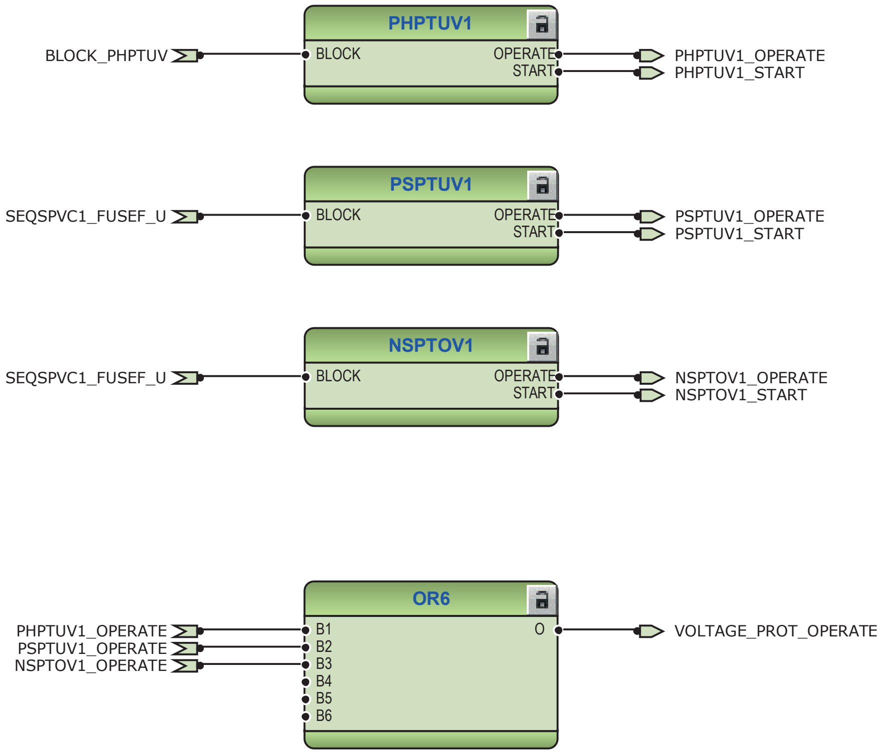


Figure 67: Voltage protection function

Two frequency protection stages FRPFRQ1 and FRPFRQ2 are offered. These functions are used to protect the motor against abnormal power system frequency.

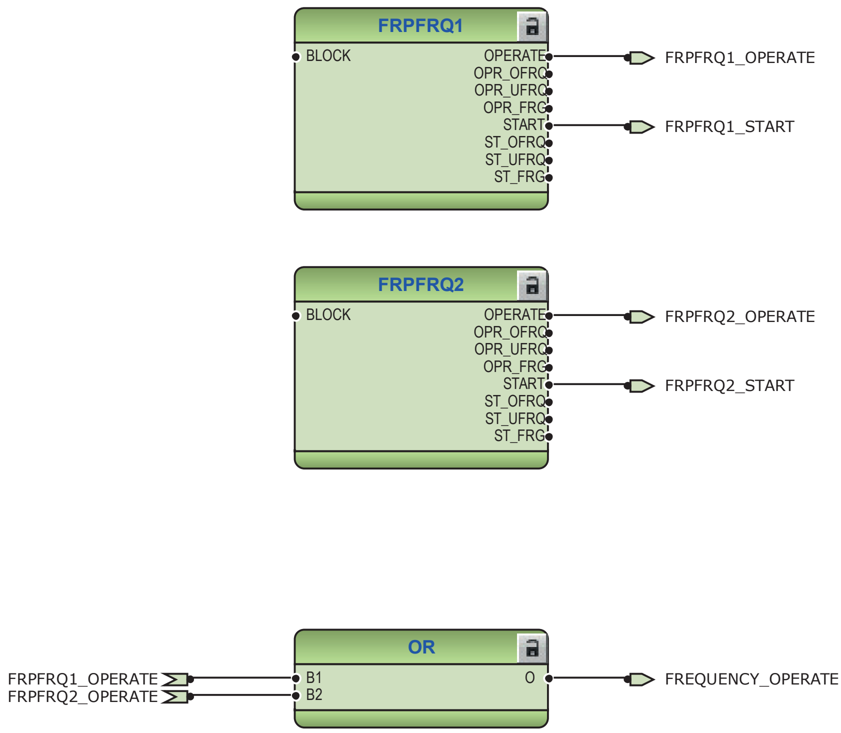


Figure 68: Frequency protection function

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

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

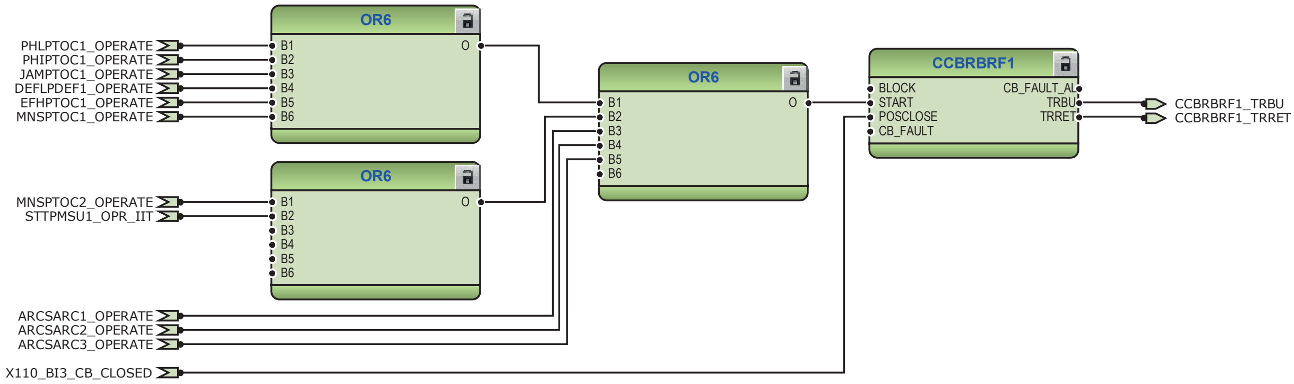


Figure 69: Circuit breaker failure protection function

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

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

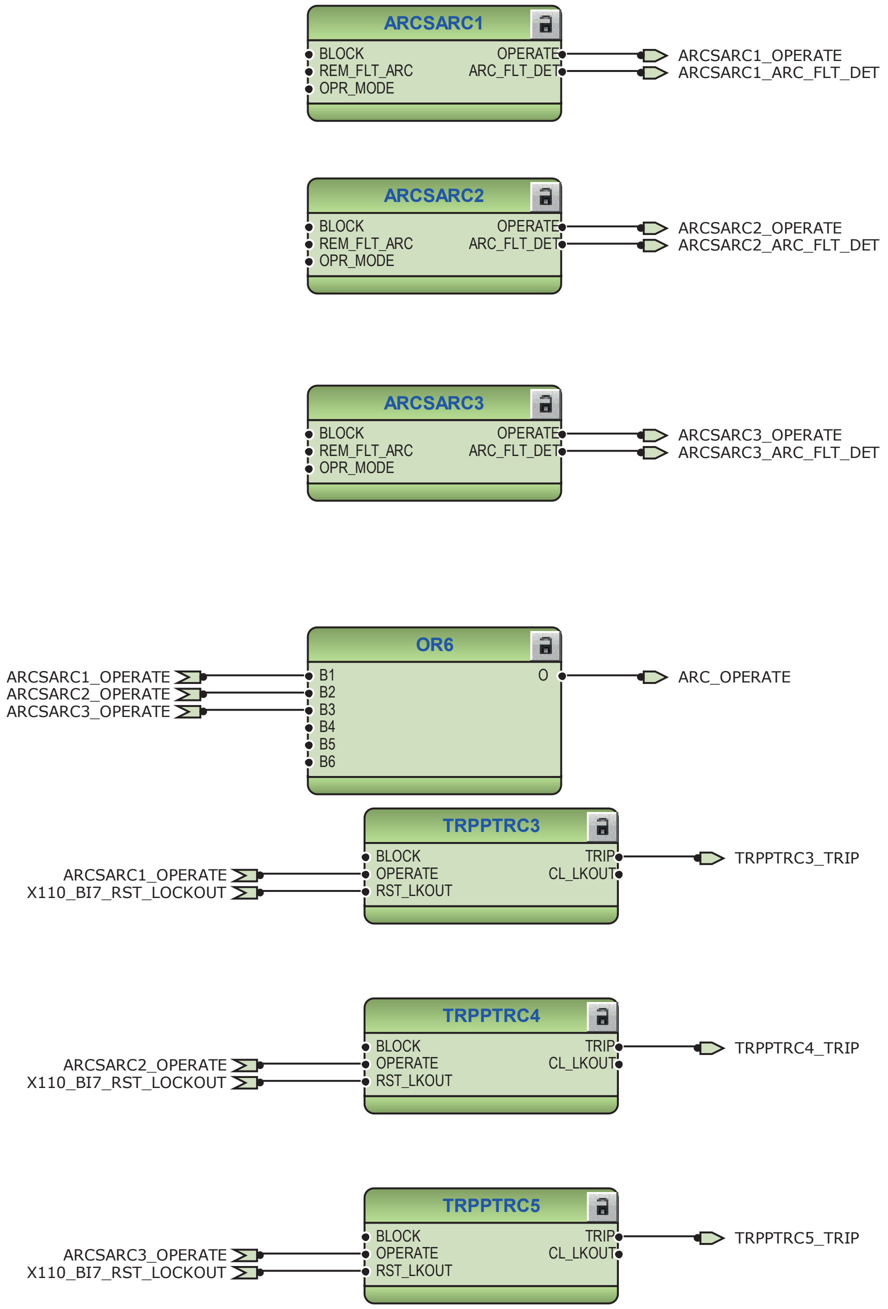


Figure 70: Arc protection with dedicated HSO

General start and operate 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.

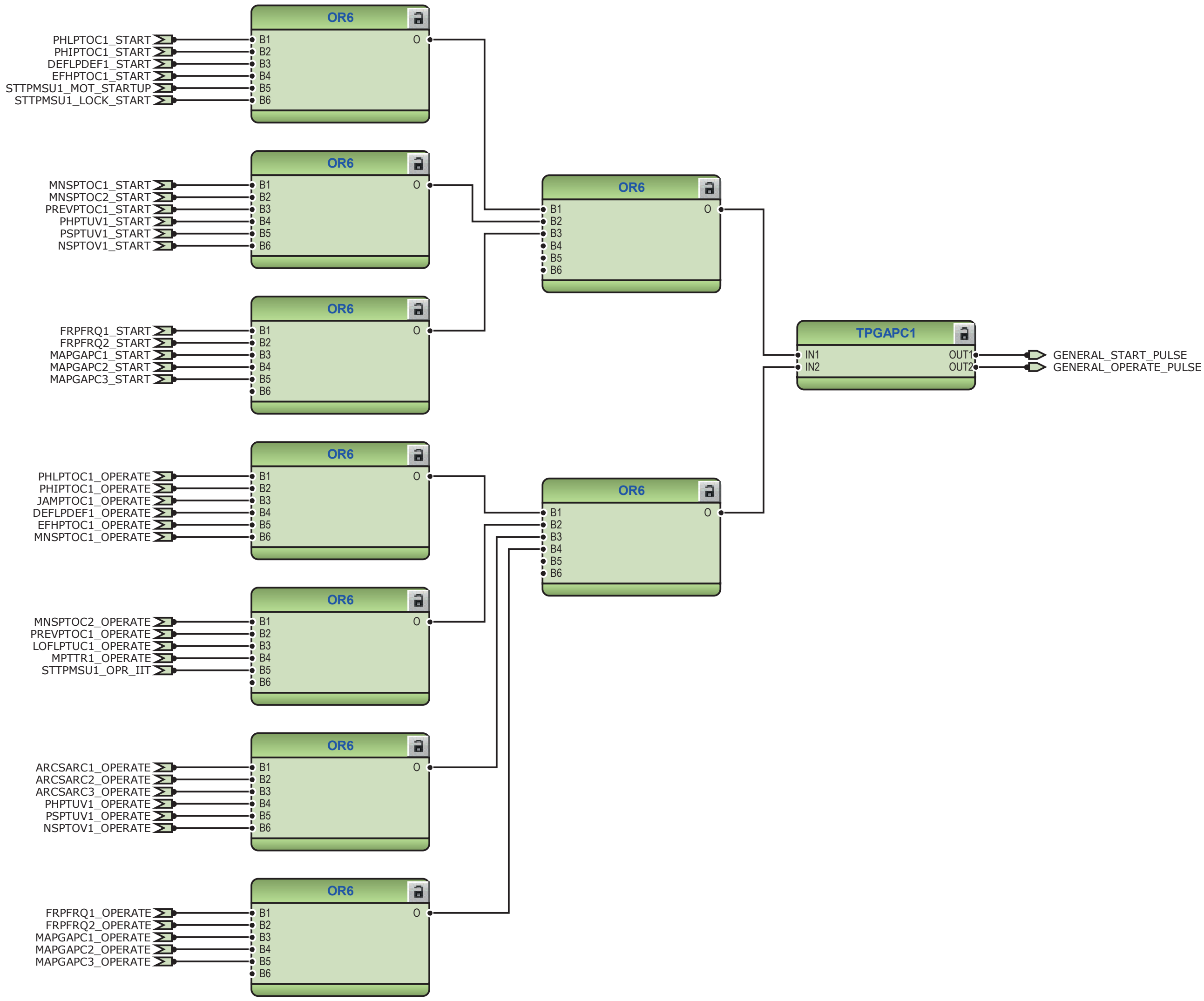


Figure 71: General start and operate signals

The operate signals from the protection functions are connected to trip logics TRPPTRC1. The output of these trip logic functions is available at binary output X100:PO3 and also at 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, binary input X110:BI7 can be assigned to `RST_LKOUT` input of the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

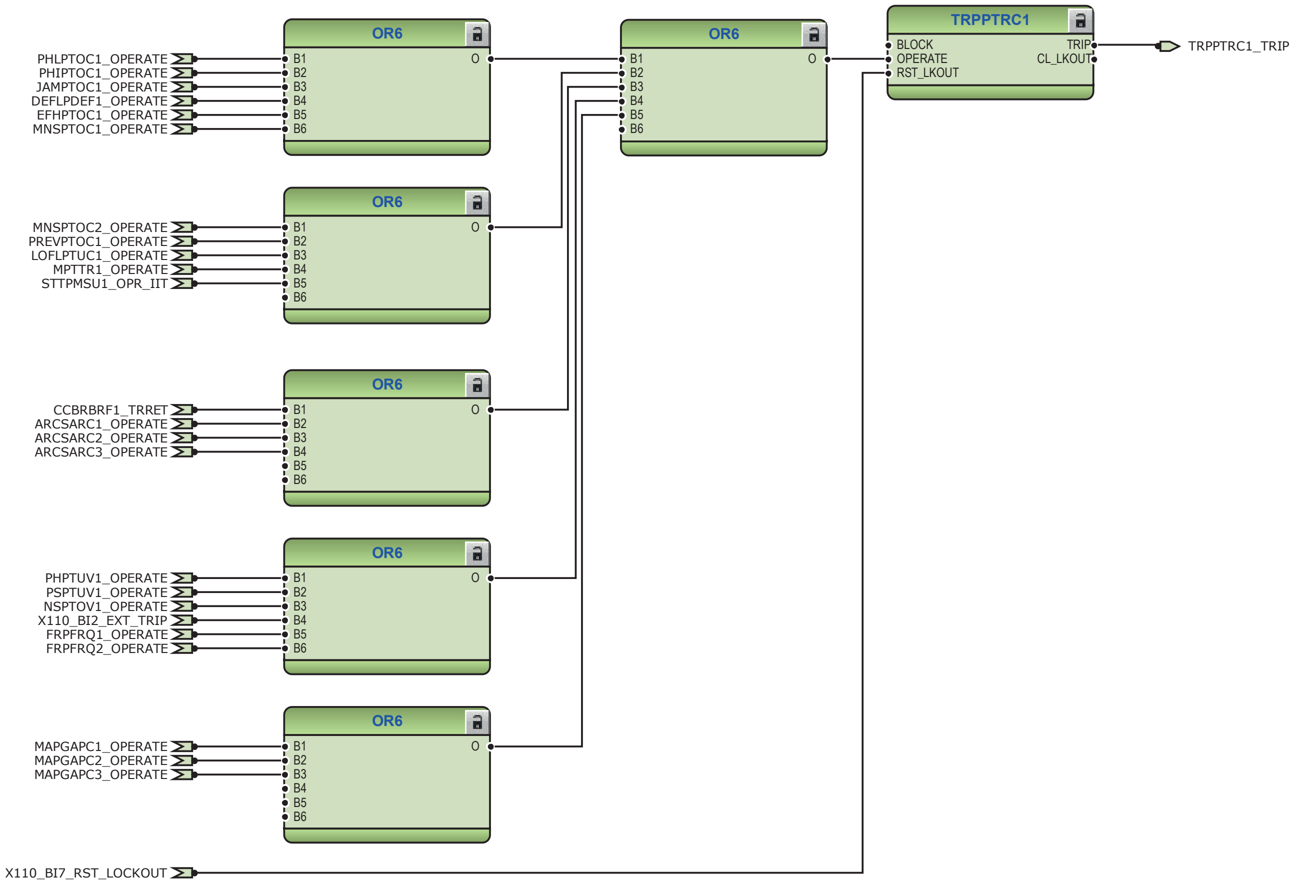


Figure 72: Trip logic TRPPTRC1

3.4.3.2 Functional diagrams for disturbance recorder

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

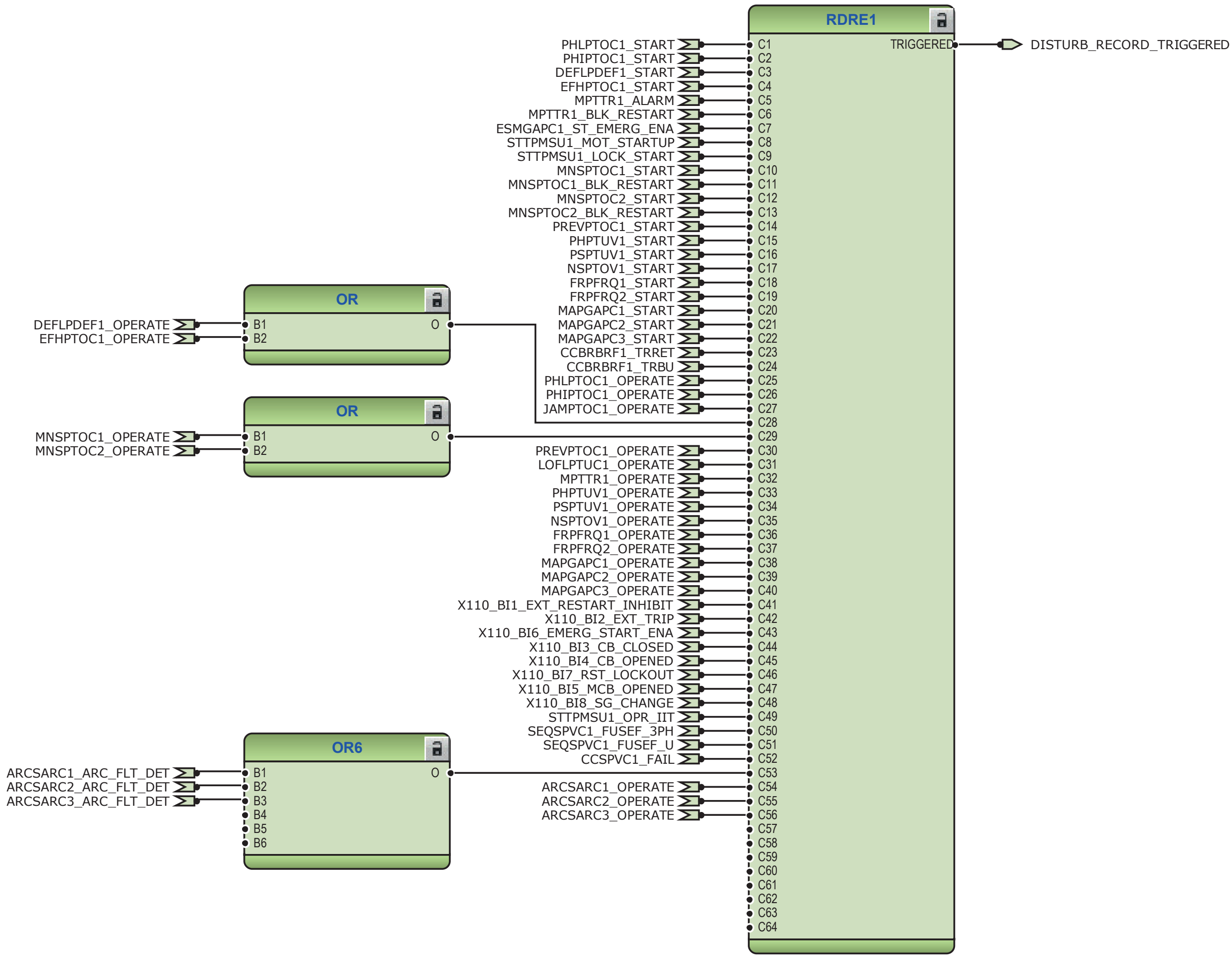


Figure 73: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

CCSPVC1 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.

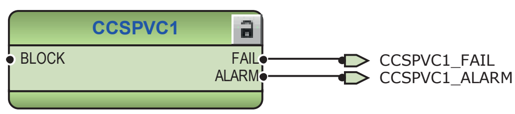


Figure 74: Current circuit supervision function

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

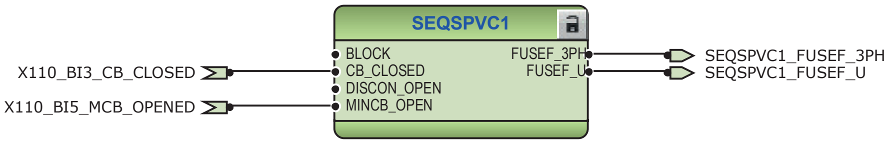


Figure 75: Fuse failure supervision function

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

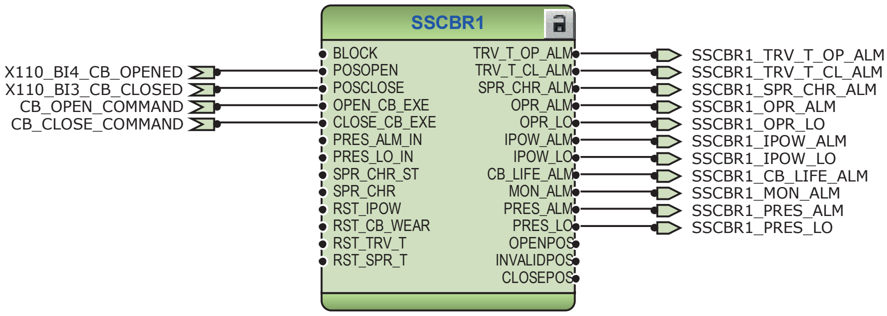


Figure 76: Circuit-breaker condition monitoring function

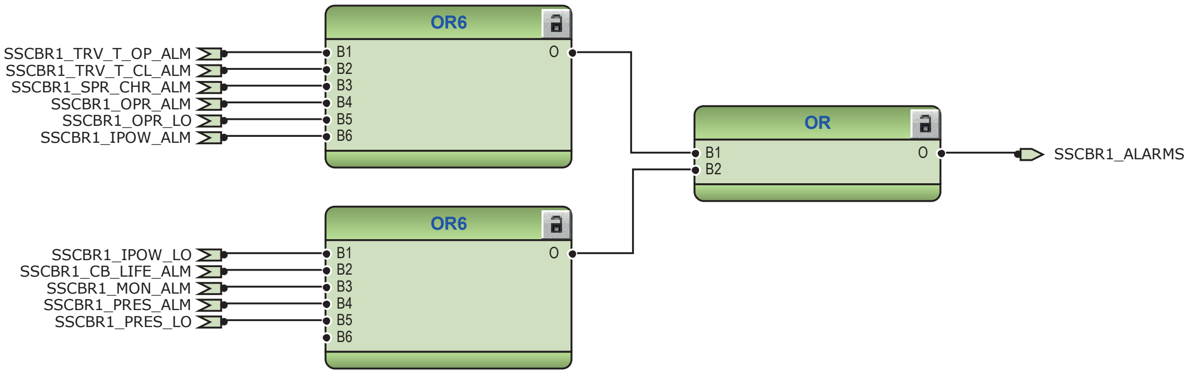


Figure 77: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 for master trip and TCSSCBR2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1 is blocked by the master trip TRPPTRC1 and the circuit breaker open signal. The trip circuit supervision TCSSCBR2 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.

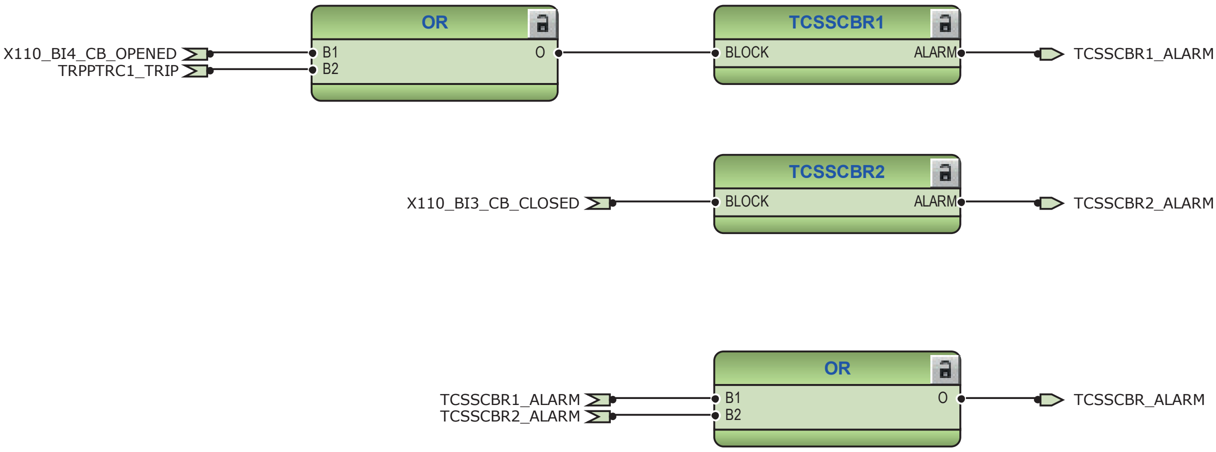


Figure 78: Trip circuit supervision function

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 earth-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.

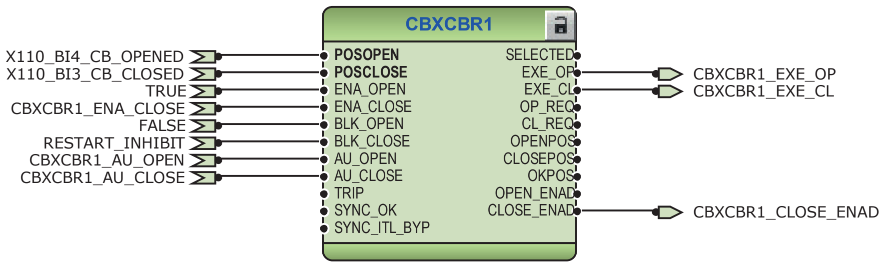


Figure 79: Circuit breaker 1 control logic

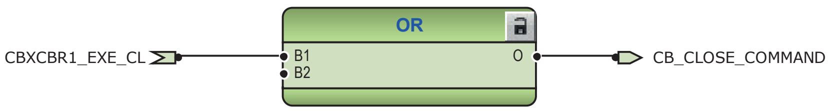


Figure 80: Signals for closing coil of circuit breaker 1

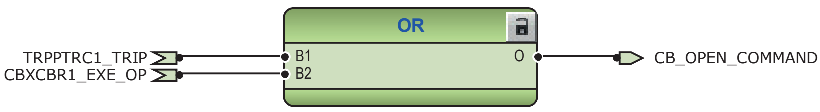


Figure 81: Signals for opening coil of circuit breaker 1

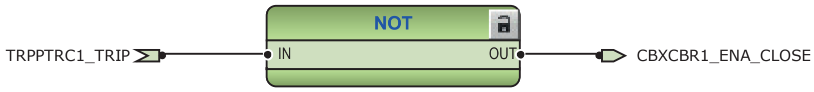


Figure 82: Circuit breaker 1 close enable logic

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

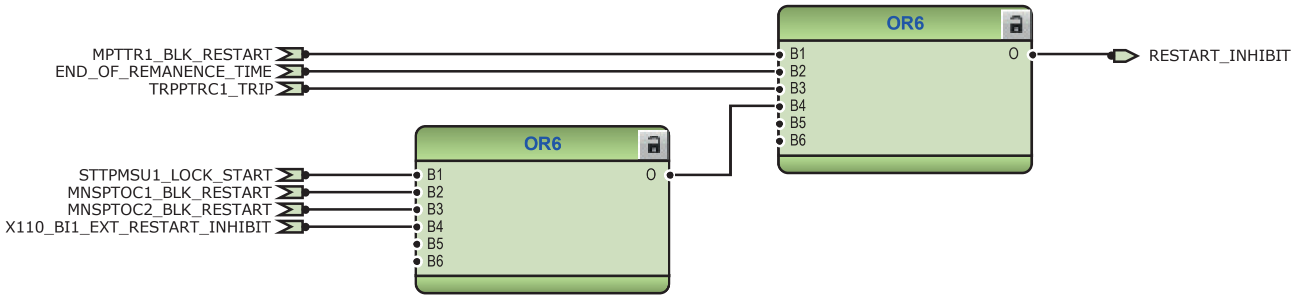


Figure 83: Circuit breaker 1 close blocking logic

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 is activated and the X100:PO1 output is closed.

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

- An active trip command
- 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 IED in local or remote mode.

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

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

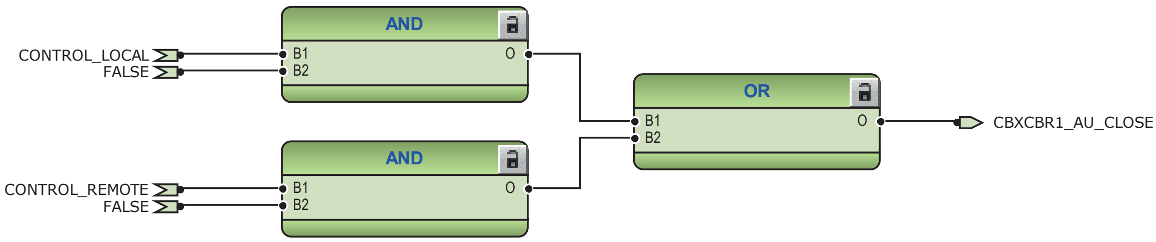


Figure 84: External closing command for circuit breaker 1

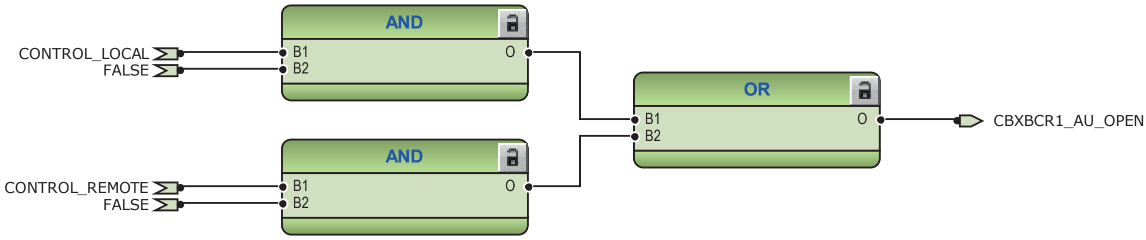


Figure 85: External opening command for circuit breaker 1

3.4.3.5 Functional diagrams for measurements functions

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

The three-phase voltage inputs to the IED 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.

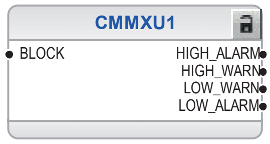


Figure 86: Current measurement: Three-phase current measurement

Figure 87: Current measurement: Sequence current measurement

Figure 88: Current measurement: Residual current measurement

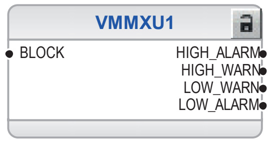


Figure 89: Voltage measurement: Three-phase voltage measurement

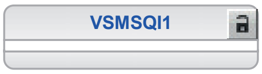


Figure 90: Voltage measurement: Sequence voltage measurement

Figure 91: Other measurement: Frequency measurement

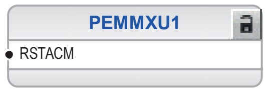


Figure 92: Other measurement: Three-phase power and energy measurement

Figure 93: Other measurement: Data monitoring

Figure 94: Other measurement: Load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

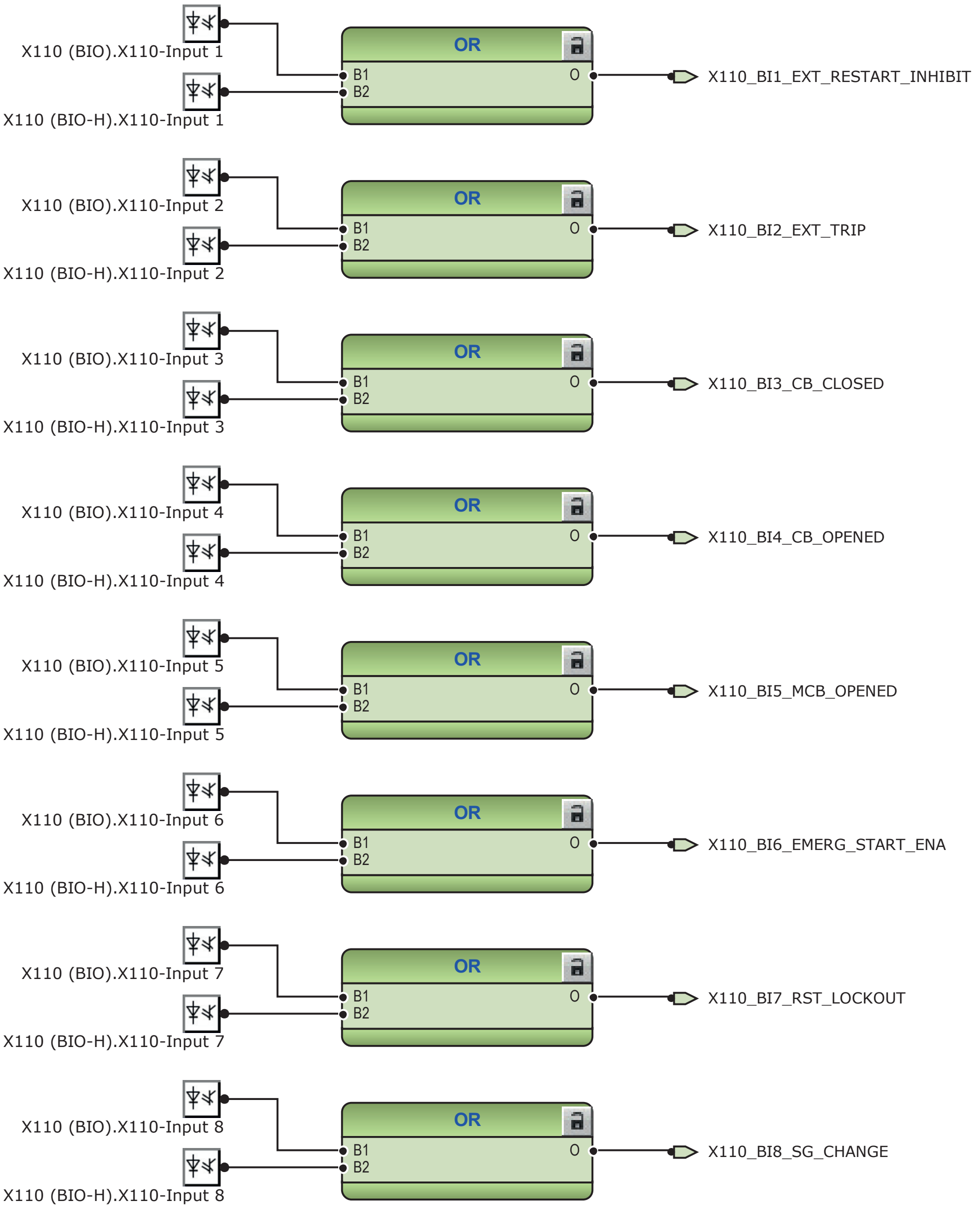


Figure 95: Default binary inputs - X110

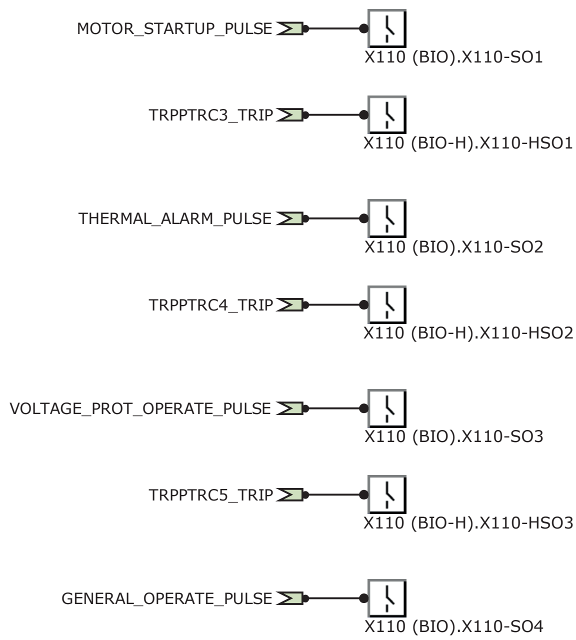


Figure 96: Default binary outputs - X110

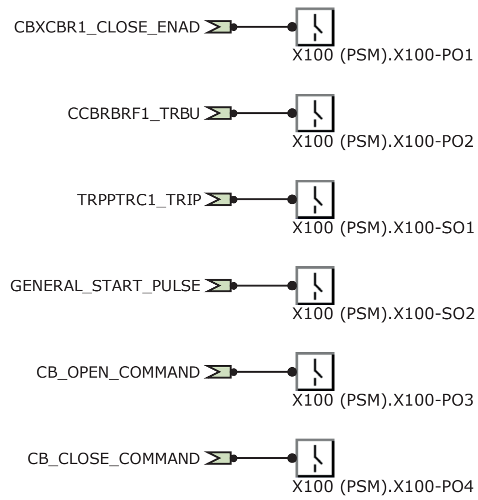


Figure 97: Default binary outputs - X100

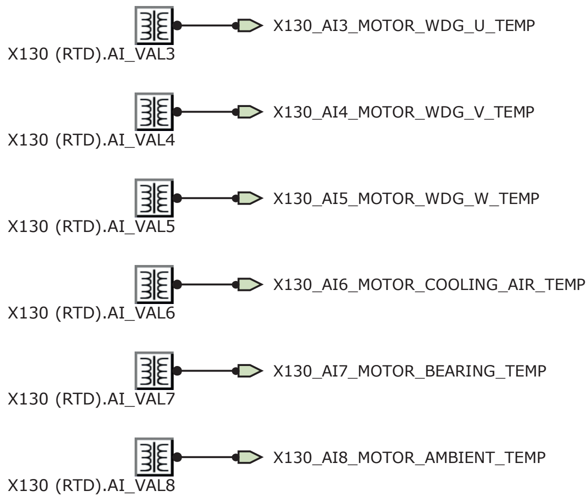
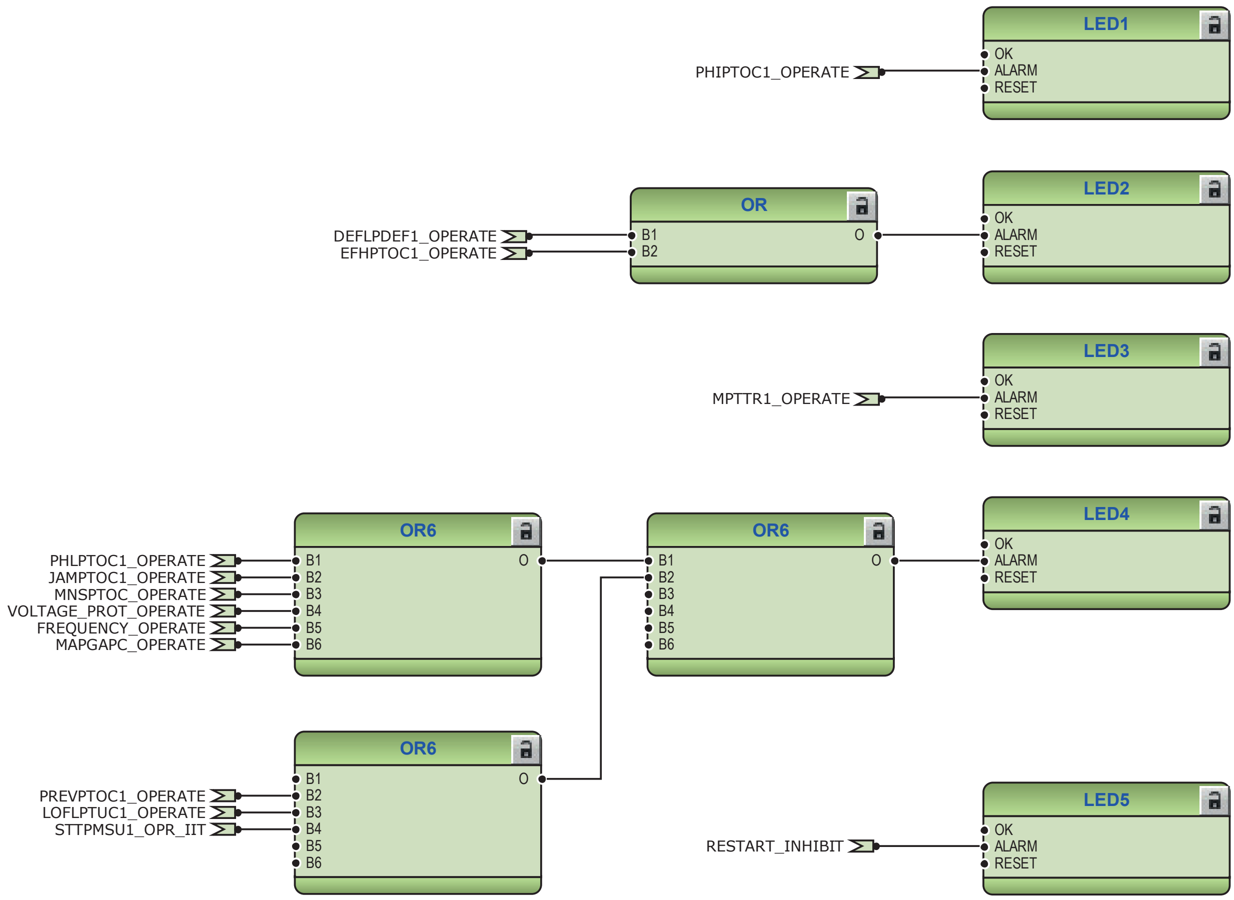


Figure 98: Default mA/RTD inputs X130



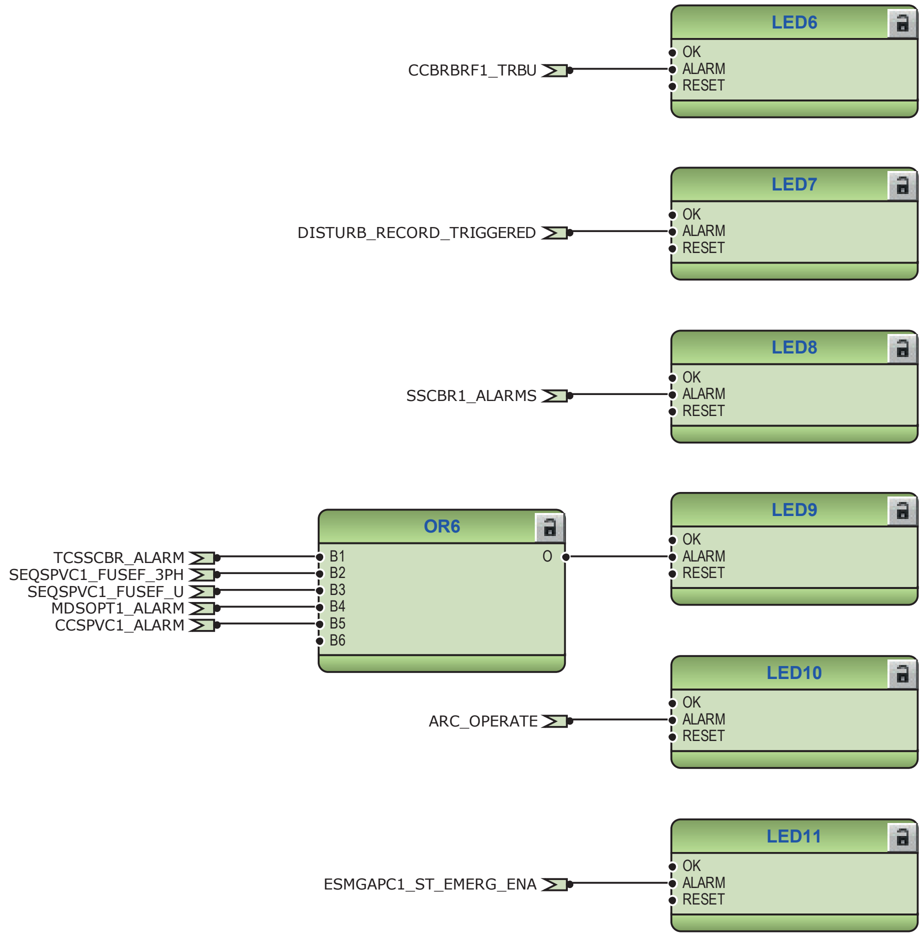


Figure 99: Default LED connections

3.4.3.7 Functional diagrams for other timer logics

The configuration also includes voltage operate, motor startup and thermal alarm, blocking logic for phase under voltage protection and 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.

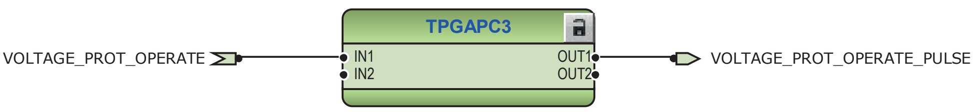


Figure 100: Timer logic for voltage protection operate alarm

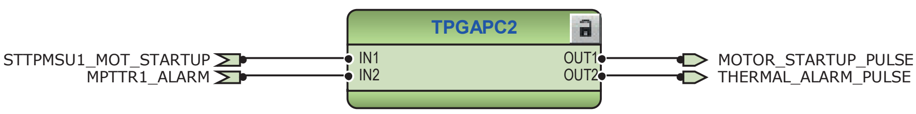


Figure 101: Timer logic for motor startup and thermal alarm

Add signals for blocking phase undervoltage protection.

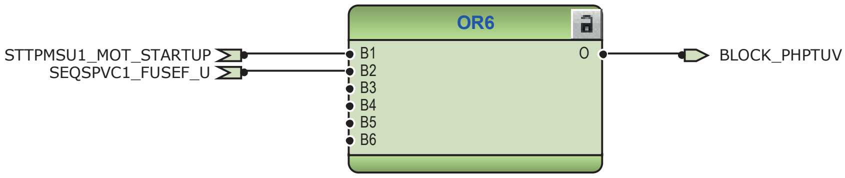


Figure 102: Blocking logic for phase undervoltage protection

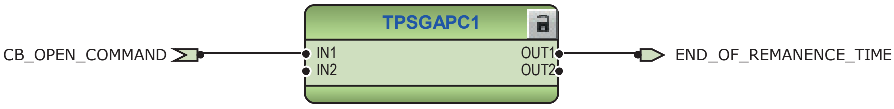


Figure 103: Timer logic for remanence voltage to disappear

3.4.3.8 Other functions

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.

3.5 Standard configuration C

3.5.1 Applications

The standard configuration for motor protection with current and voltage based protection and measurements functions 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.

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

3.5.2 Functions

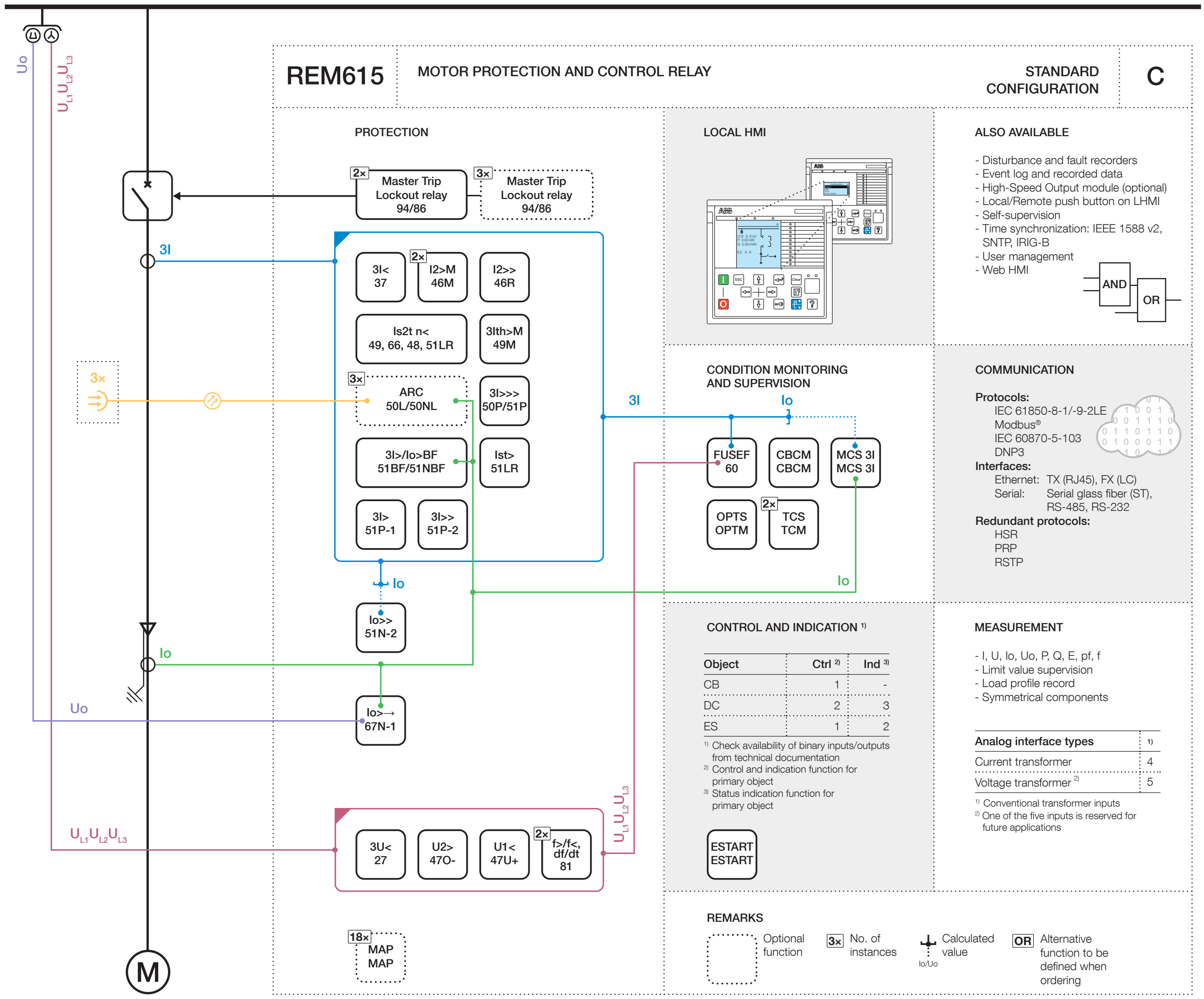


Figure 104: Functionality overview for standard configuration C

3.5.2.1 Default I/O connections

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

Table 23: Default connections for binary inputs

Binary input	Description
X110-BI1	MCB open
X110-BI2	Setting group change
X110-BI3	Rotation direction
X110-BI4	Speed switch (motor running)
X110-BI5	Disconnector close/circuit breaker truck in
X110-BI6	Disconnector close/circuit breaker truck out
X110-BI7	Earth-switch close
X110-BI8	Earth-switch open
X120-BI1	Emergency start enable
X120-BI2	Circuit breaker closed
X120-BI3	Circuit breaker open
X120-BI4	Lock-out reset
X130-BI1	External restart inhibit
X130-BI2	External trip
X130-BI3	Gas pressure alarm
X130-BI4	Circuit breaker spring charged

Table 24: Default connections for binary outputs

Binary output	Description
X100-PO1	Restart enable
X100-PO2	Breaker failure backup trip to upstream breaker
X100-SO1	Open command (for contractor application)
X100-SO2	Operate indication
X100-PO3	Open circuit breaker/trip
X100-PO4	Close circuit breaker
X110-SO1	Motor startup indication
X110-SO2	Thermal overload alarm
X110-SO3	Protection start alarm
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 25: Default connections for LEDs

LED	Description
1	Short-circuit protection operate
2	Earth-fault protection operate
3	Thermal overload protection operate
4	Combined operate indication of the other protection functions
5	Motor restart inhibit
6	Breaker failure protection operate
7	Disturbance recorder triggered
8	Circuit breaker condition monitoring alarm
9	TCS, motor runtime counter or measuring circuit fault alarm
10	Arc protection operate
11	Emergency start enabled

3.5.2.2 Default disturbance recorder settings

Table 26: Default disturbance recorder analog channels

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

Table 27: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHIPTOC2 - start	Positive or Rising
3	DEFLPDEF1 - start	Positive or Rising
4	EFHPTOC1 - start	Positive or Rising
5	MPTTR1 - alarm	Level trigger off
6	MPTTR1 - blk restart	Level trigger off
7	ESMGAPC1 - st emerg ena	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
8	STTPMSU1 - mot startup	Positive or Rising
9	STTPMSU1 - lock start	Level trigger off
10	MNSPTOC1 - start	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - start	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - start	Positive or Rising
15	PHPTUV1 - start	Positive or Rising
16	PSPTUV1 - start	Positive or Rising
17	NSPTOV1 - start	Positive or Rising
18	FRPFRQ1 - start	Positive or Rising
19	FRPFRQ2 - start	Positive or Rising
20	CCBRBRF1 - trret	Level trigger off
21	CCBRBRF1 - trbu	Level trigger off
22	PHLPTOC1 - operate	Level trigger off
23	PHIPTOC2 - operate	Level trigger off
24	JAMPTOC1 - operate	Level trigger off
25	DEFLPDEF1 - operate	Level trigger off
	EFHPTOC2 - operate	
26	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
27	PREVPTOC1 - operate	Level trigger off
28	LOFLPTUC1 - operate	Level trigger off
29	MPTTR1 - operate	Level trigger off
30	PHPTUV1 - operate	Level trigger off
31	PSPTUV1 - operate	Level trigger off
32	NSPTOV1 - operate	Level trigger off
33	FRPFRQ1 - operate	Level trigger off
34	FRPFRQ2 - operate	Level trigger off
35	X120BI1 - emerg start ena	Level trigger off
36	X120BI2 - CB closed	Level trigger off
37	X120BI3 - CB opened	Level trigger off
38	X130BI1 - ext restart inhibit	Level trigger off
39	X130BI2 - ext trip	Positive or Rising
40	X130BI3 - gas pressure alarm	Level trigger off
41	X130BI4 - CB spring charged	Level trigger off
42	X110BI1 - MCB opened	Level trigger off
43	X110BI2 - SG changed	Level trigger off
44	X110BI3 - rotate direction	Level trigger off
45	X110BI4 - speed switch	Level trigger off
46	STTPMSU1 - opr iit	Positive or Rising

Table continues on the next page

Channel	ID text	Level trigger mode
47	STTPMSU1 - opr stall	Positive or Rising
48	SEQSPVC1 - fusef 3ph	Level trigger off
49	SEQSPVC1 - fusef u	Level trigger off
50	CCSPVC1 - fail	Level trigger off
51	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
52	ARCSARC1 - operate	Positive or Rising
53	ARCSARC2 - operate	Positive or Rising
54	ARCSARC3 - operate	Positive or Rising

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 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 residual voltage to the protection relay is fed from either residually connected VTs, an open delta connected VT or calculated internally.

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 IEDs protection functionality in detail and according to the factory set default connections.

Two overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional low stage PHLPTOC1 can be used for overcurrent protection whereas instantaneous stage PHIPTOC1 can be used for short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation. The motor load jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

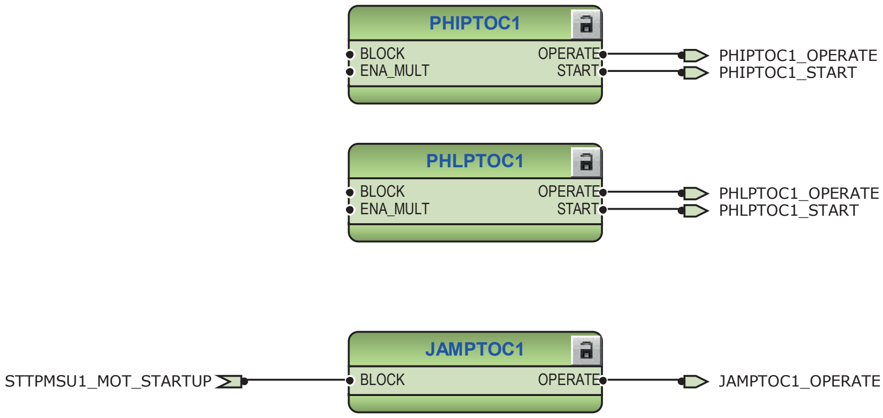


Figure 105: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 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.

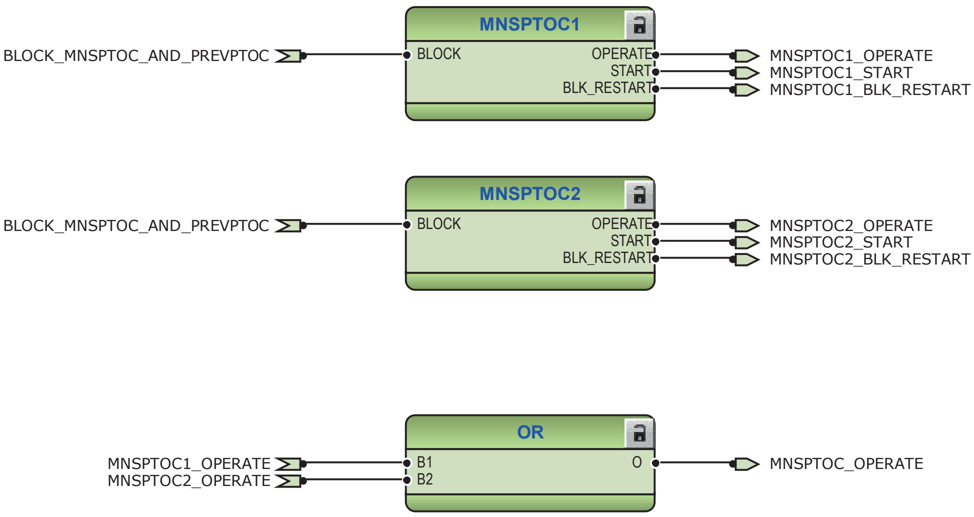


Figure 106: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1 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 or when the network rotation direction changes.

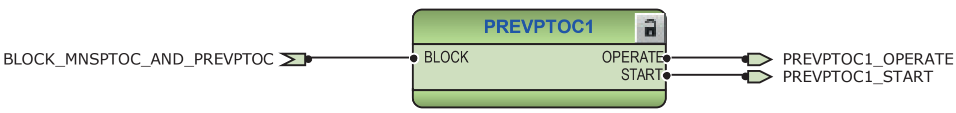


Figure 107: Phase reversal protection function

One stage is provided for non-directional earth-fault protection EFHPTOC1 to detect phase-to-earth faults that may be the result of, for example, insulation ageing. A directional protection stage DEFLPDEF1 can also be used as a low stage non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth 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 earth-fault are blocked by the activation of instantaneous stage of overcurrent protection.

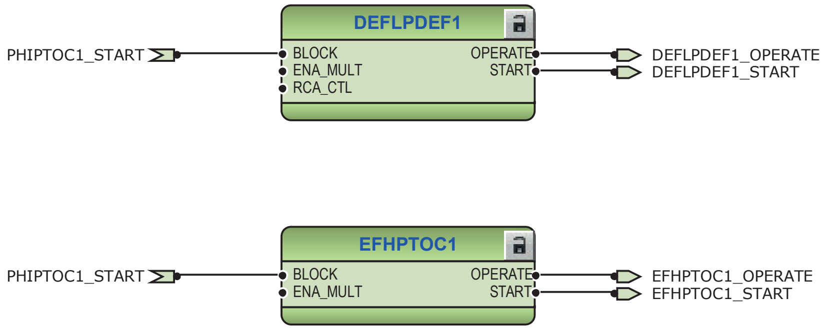


Figure 108: Earth-fault protection functions

The emergency start function ESMGAPC1 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 start signal, various events occur.

- The calculated thermal level in MPTTR1 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 is set slightly below the set restart inhibit value to allow at least one motor start-up.
- 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.

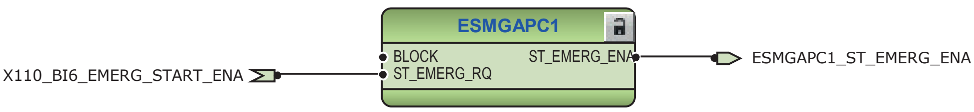


Figure 109: Motor emergency start-up function

The thermal overload protection for motors MPTTR1 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.

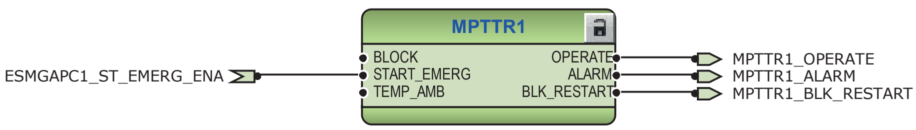


Figure 110: Thermal overcurrent protection function

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. Re-closing 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.

- An active trip command
- Motor start-up supervision has issued lockout
- Motor unbalance function has issued restart blocking
- An external restart inhibit is activated by a binary input X130:BI1

With the motor start-up supervision function STTPMSU1, the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1 and STTPMSU1 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 IED at the infeeding bay.

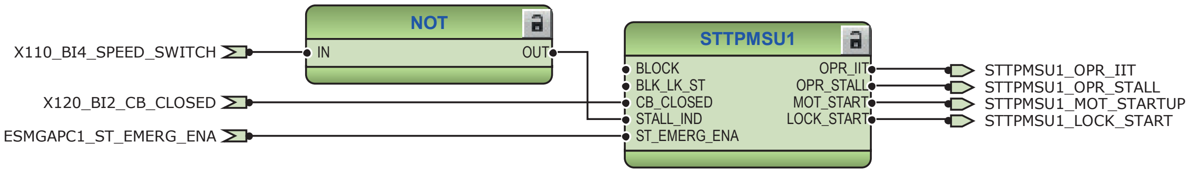


Figure 111: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1 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.

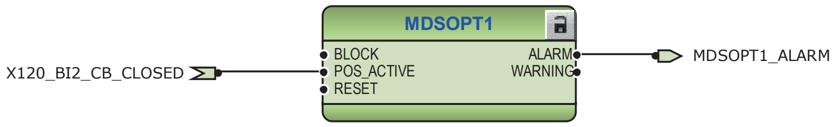


Figure 112: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

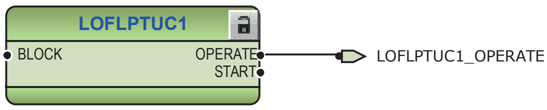


Figure 113: Loss of load

The three-phase undervoltage protection PHPTUV1 offers protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV and negative-sequence overvoltage protection NSPTOV 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 in addition is also blocked during motor start-up to prevent unwanted operation in case of short voltage drop, whereas positive and negative sequence protection is blocked when the network rotation direction changes.

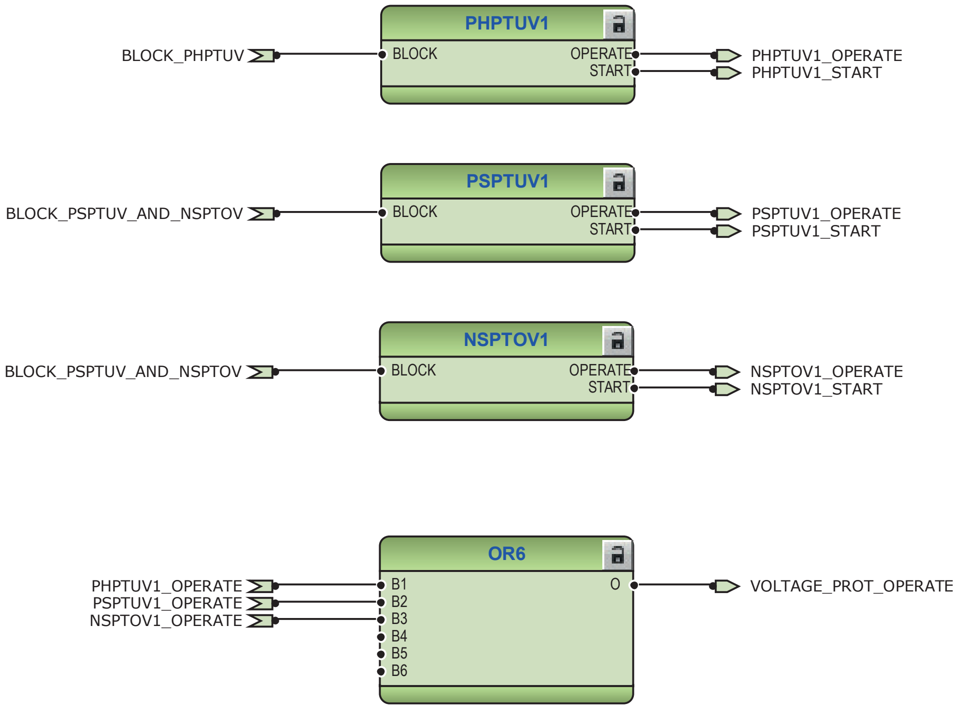


Figure 114: Undervoltage and sequence voltage protection function

Two frequency protection stages FRPFRQ1 and FRPFRQ2 are offered. These functions are used to protect the motor against an abnormal power system frequency.

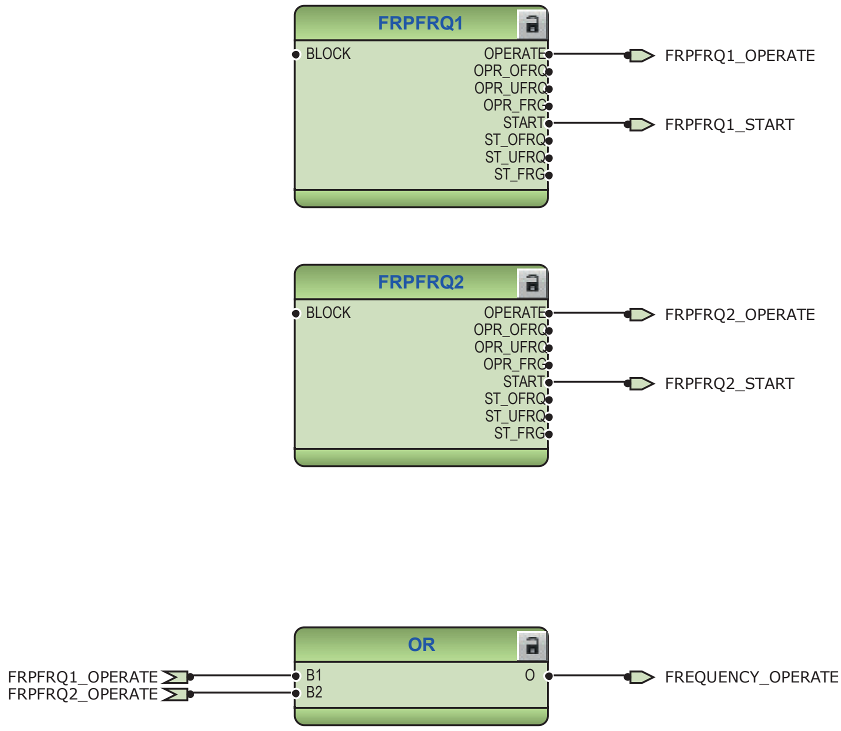


Figure 115: Frequency protection function

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

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

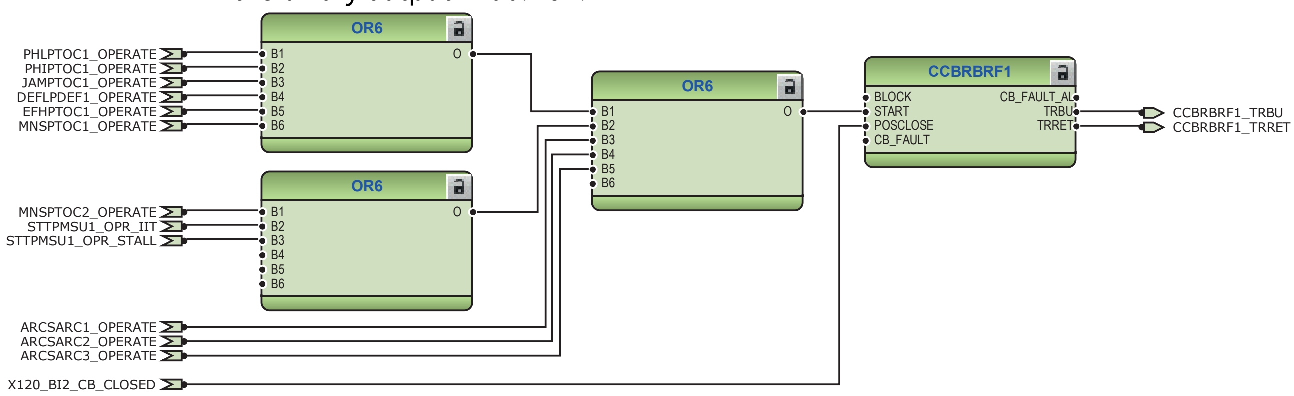


Figure 116: Circuit breaker failure protection function

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

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

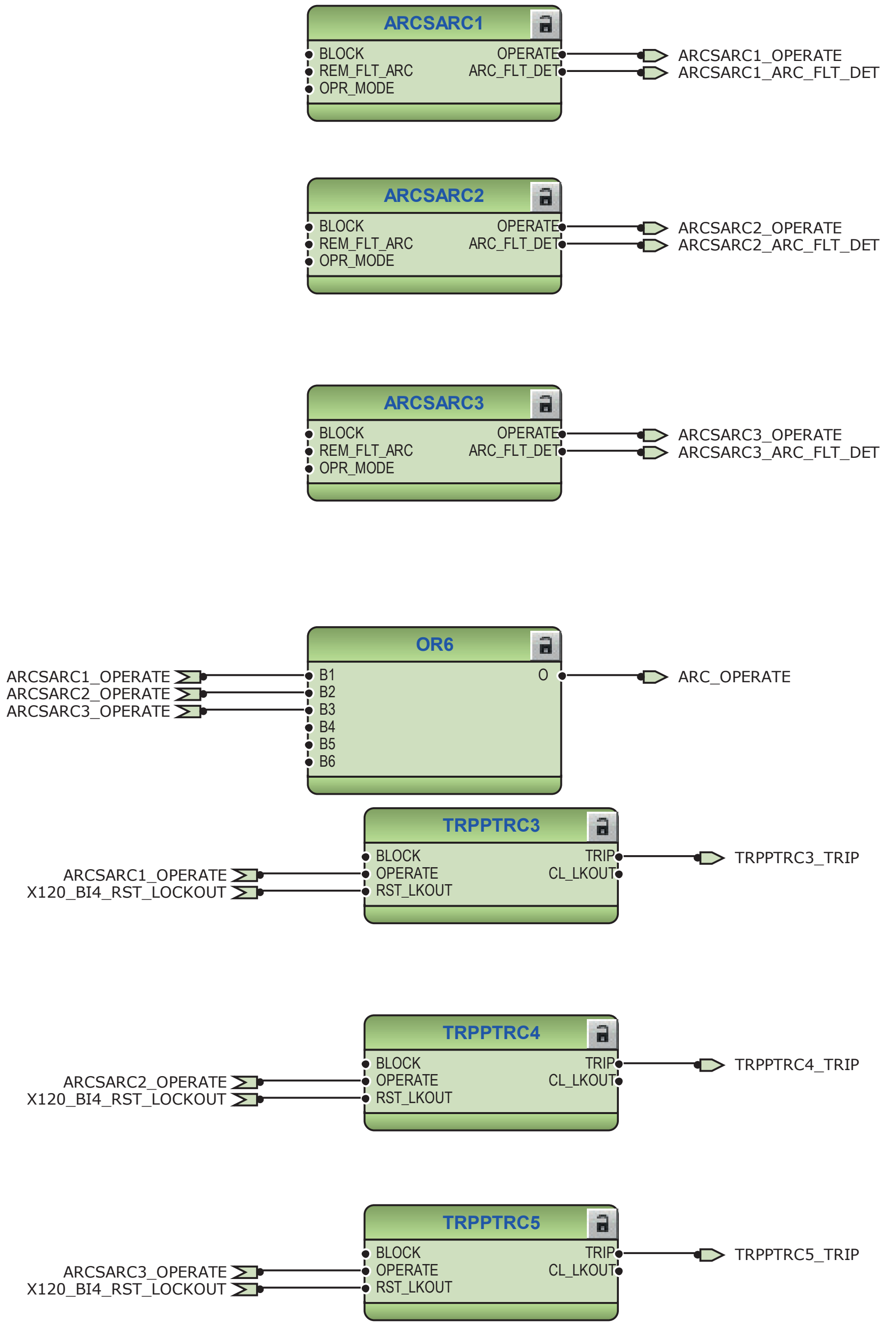


Figure 117: Arc protection with dedicated HSO

General start and operate 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.

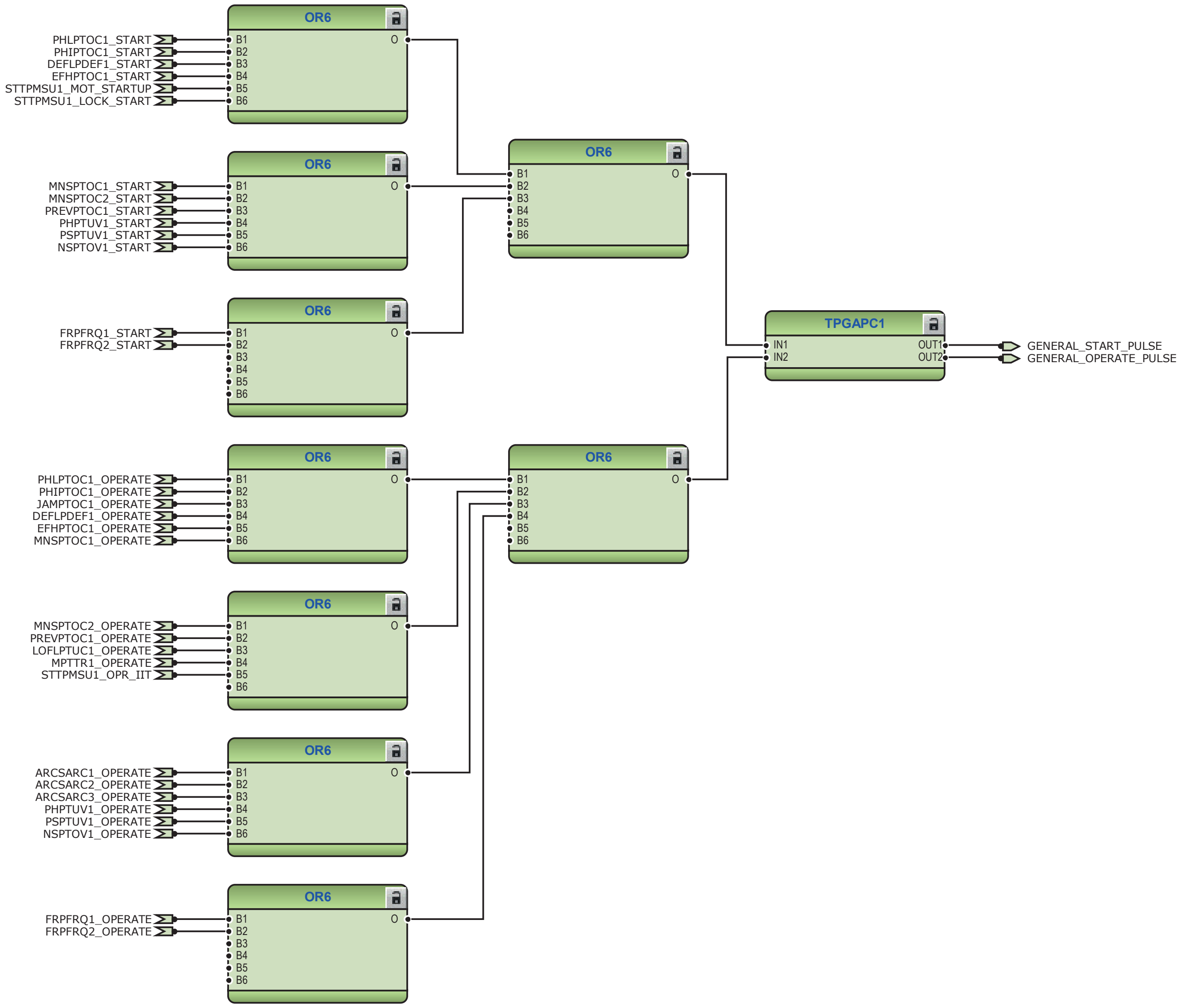


Figure 118: General start and operate signals

The operate signals from the protections are connected to trip logics TRPPTRC1. The output of these trip logic functions is available at binary output X100:PO3 and also at 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, binary input X120:BI4 can be assigned to RST_LKOUT input of the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4 are also available if the IED is ordered with high speed binary outputs options.

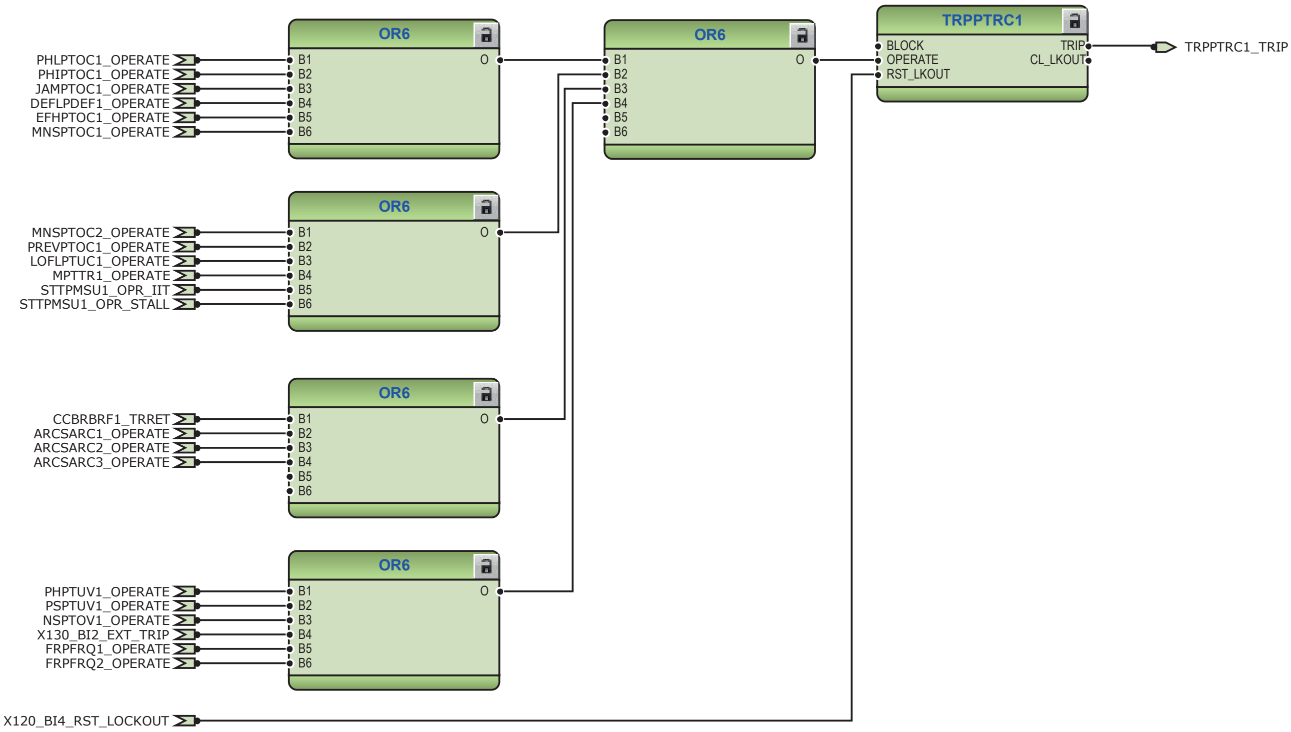


Figure 119: Trip logic TRPPTRC1

3.5.3.2 Functional diagrams for disturbance recorder

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

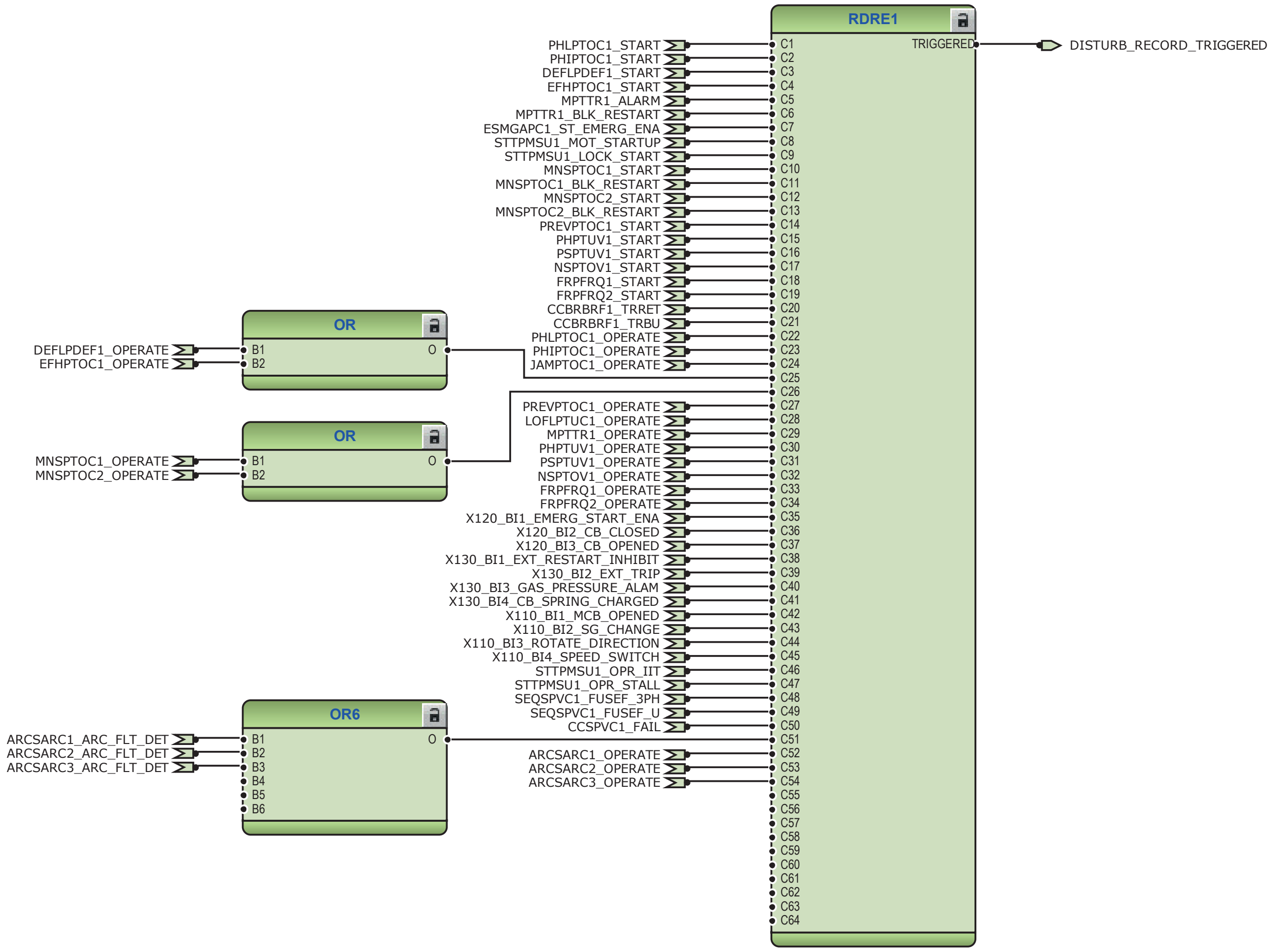


Figure 120: Disturbance recorder

3.5.3.3 Functional diagrams for condition monitoring

CCSPVC1 detects failures in the current measurement 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.

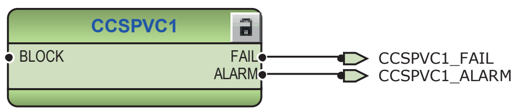


Figure 121: Current circuit supervision function

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

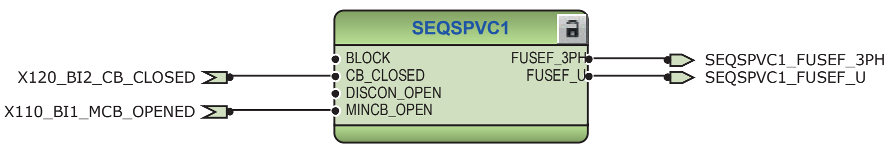


Figure 122: Fuse failure supervision function

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

Set the parameters for SSCBR1 properly.

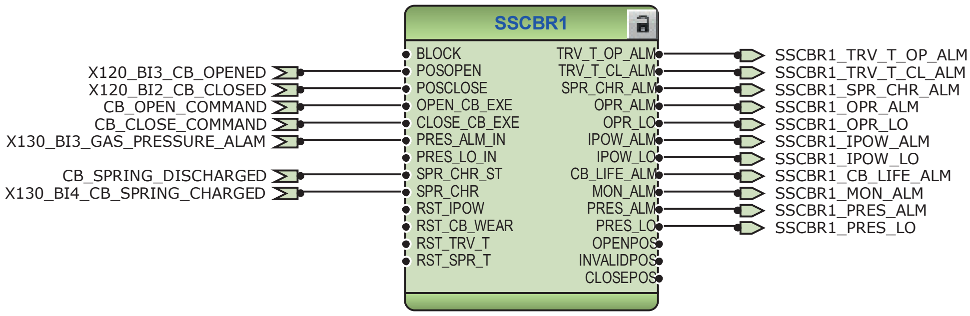


Figure 123: Circuit-breaker condition monitoring function

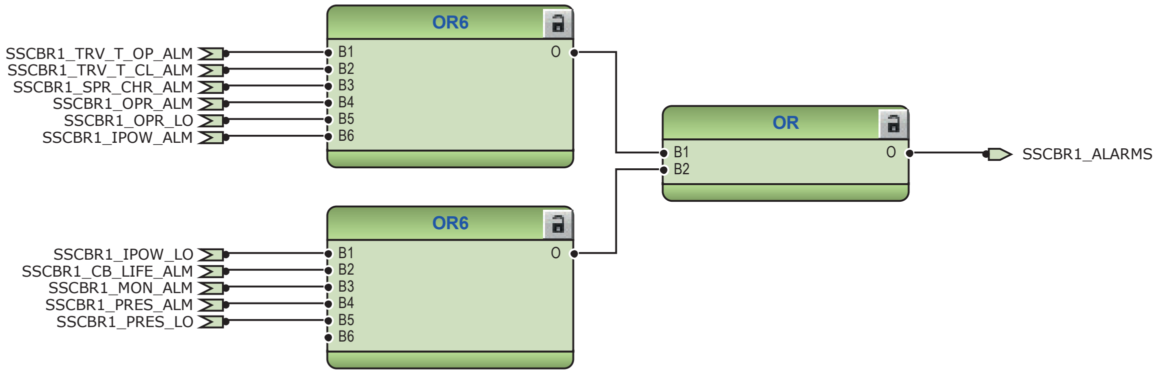


Figure 124: Logic for circuit breaker monitoring alarm

Figure 125: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 for master trip and TCSSCBR2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1 is blocked by the master trip TRPPTRC1 and the circuit breaker open signal. The trip circuit supervision TCSSCBR2 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.

Set the parameters for TCSSCBR1 properly.

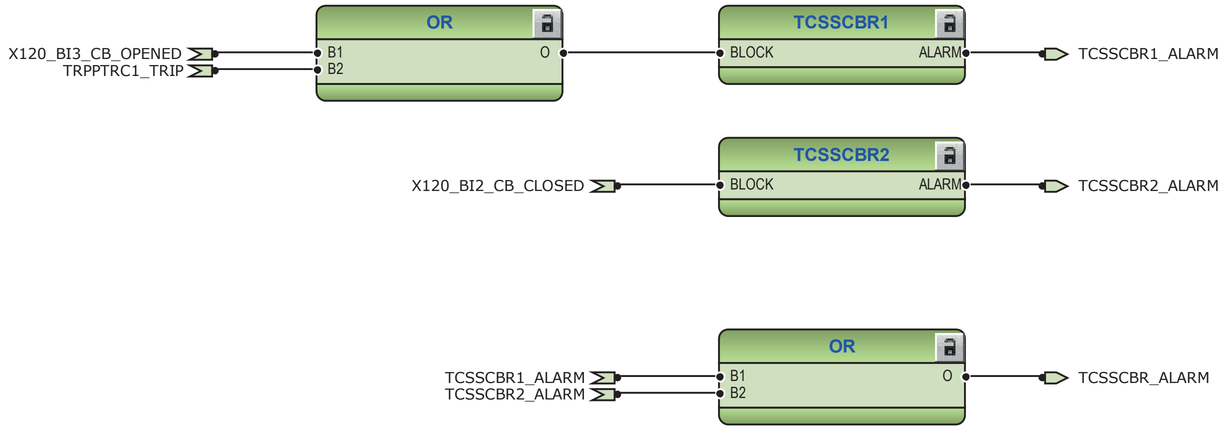


Figure 126: Trip circuit supervision function

3.5.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1 respectively.

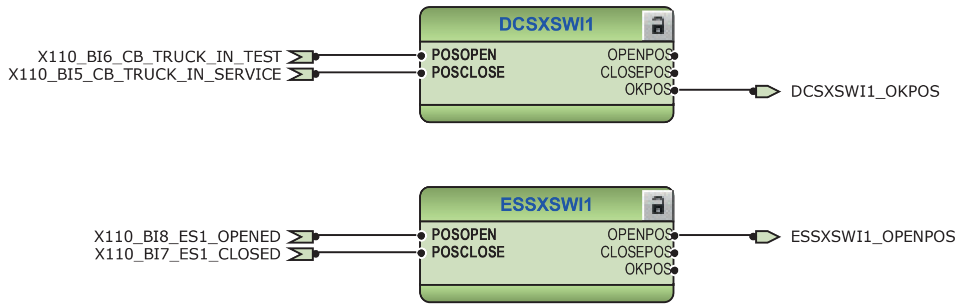


Figure 127: Disconnector and earth-switch control logic

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

The `OKPOS` output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or close (in service position). This output, together with the open earth-switch and non-active trip signals, activates the close-enable signal to the circuit-breaker control function block. The open operation for circuit breaker is always enabled.

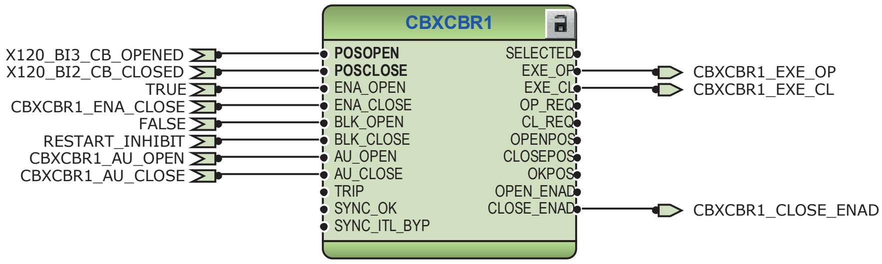


Figure 128: Circuit breaker control logic: Circuit breaker 1

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

Figure 129: Circuit breaker control logic: Signals for closing coil of circuit breaker 1

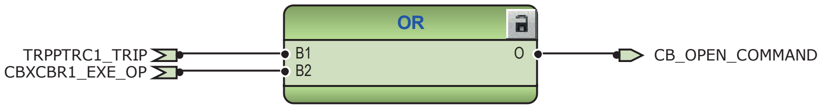


Figure 130: Circuit breaker control logic: Signals for opening coil of circuit breaker 1

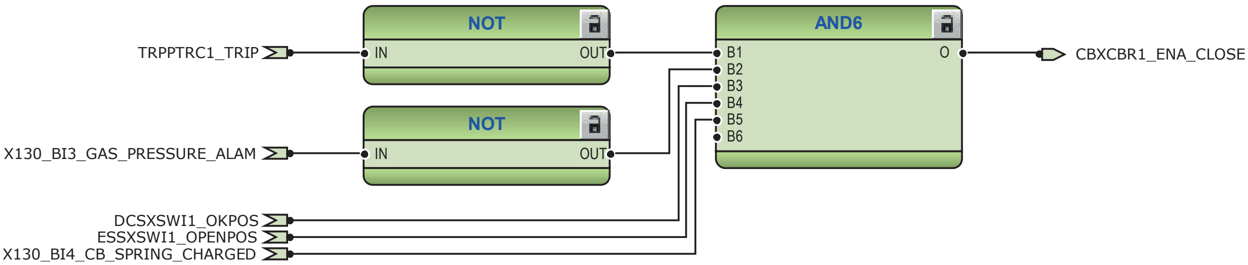


Figure 131: Circuit breaker close enable logic

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

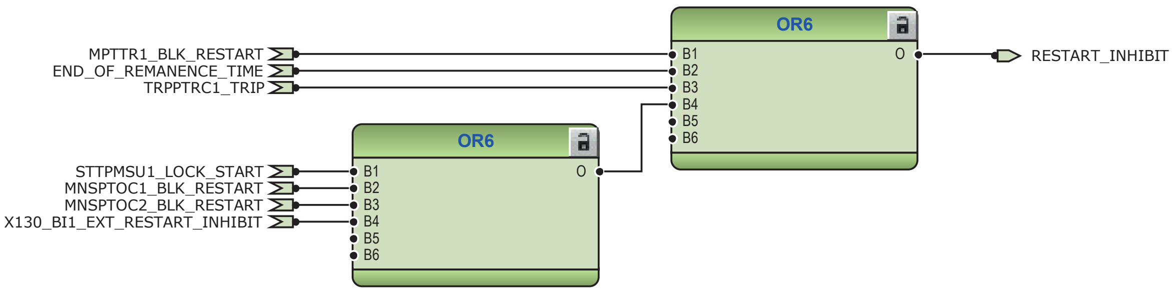


Figure 132: Circuit breaker close blocking logic

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 is activated and the X100:PO1 output is closed.

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

- An active trip command
- Motor start-up supervision has issued lockout
- Motor unbalance function has issued restart blocking
- An external restart inhibit is activated by a binary input X130:BI1
- Thermal protection has issued blocked restart
- Time during which remanence voltage is present

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

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

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

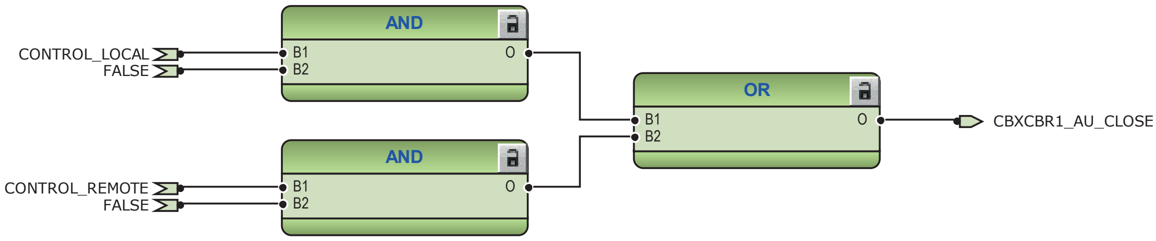


Figure 133: External closing command for circuit breaker

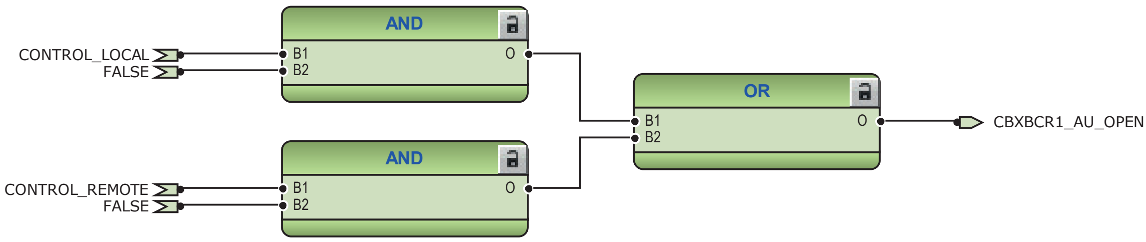


Figure 134: External opening command for circuit breaker

3.5.3.5 Functional diagrams for measurement functions

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

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

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.

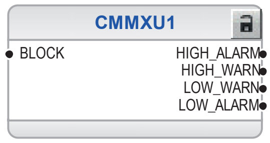


Figure 135: Current measurement: Three-phase current measurement

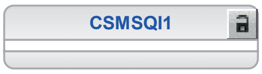


Figure 136: Current measurement: Residual current measurement

Figure 137: Current measurement: Sequence current measurement

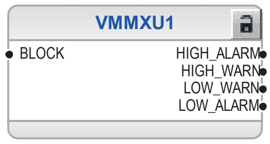


Figure 138: Voltage measurement: Three-phase voltage measurements

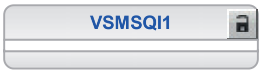


Figure 139: Voltage measurement: Residual voltage measurements

Figure 140: Voltage measurement: Sequence voltage measurements

Figure 141: Other measurements: Frequency measurement

Figure 142: Other measurements: Three-phase power and energy measurement

Figure 143: Other measurements: Data monitoring

Figure 144: Other measurements: Load profile record

3.5.3.6 Functional diagrams for I/O and alarms LEDs

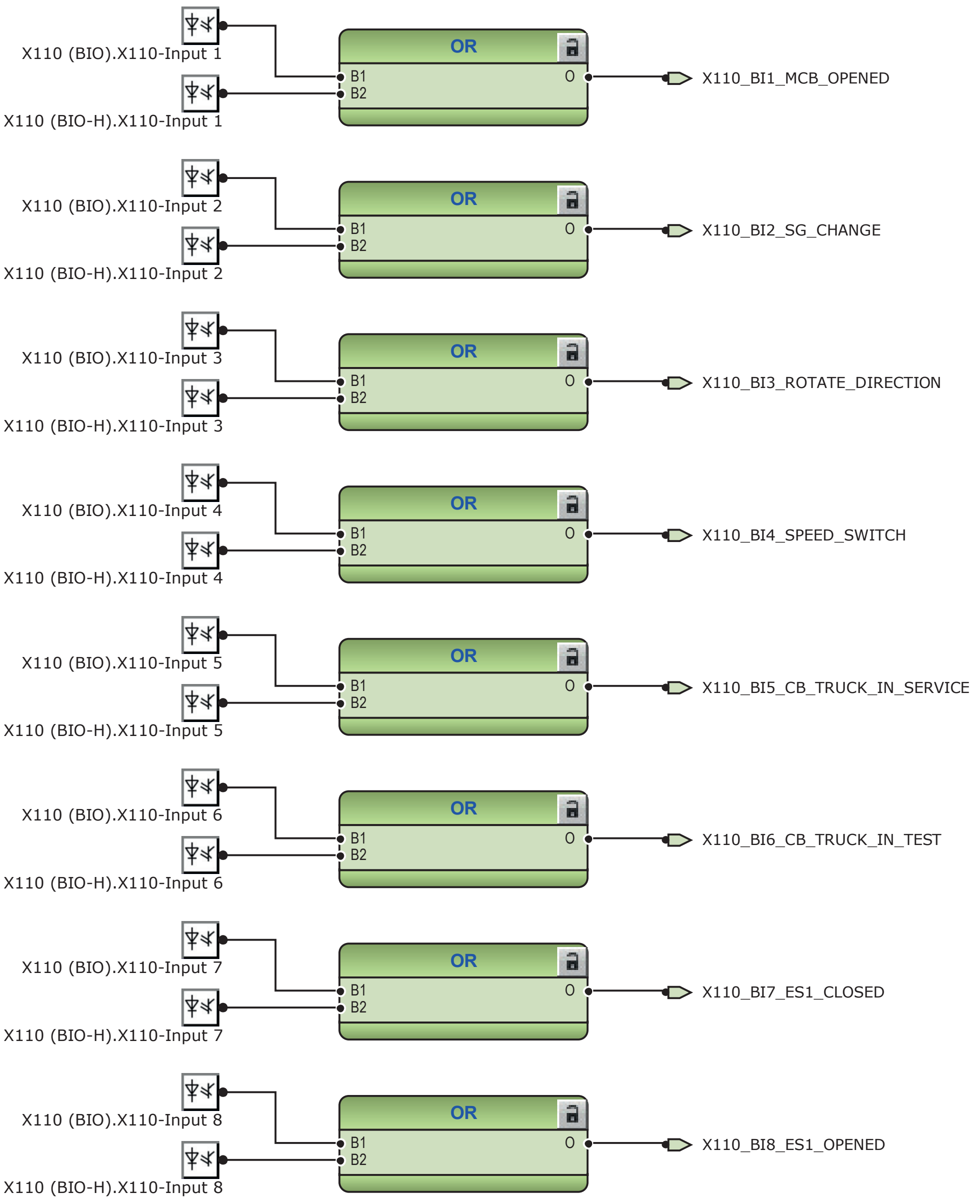


Figure 145: Default binary inputs - X110

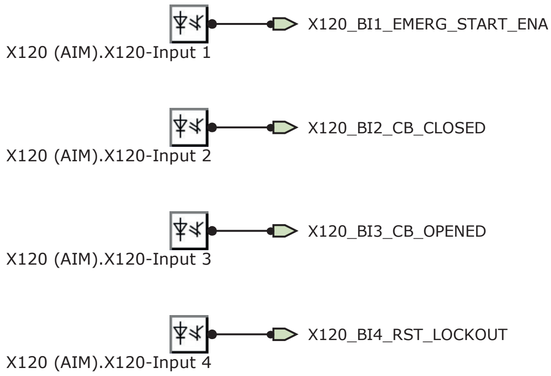


Figure 146: Default binary inputs - X120

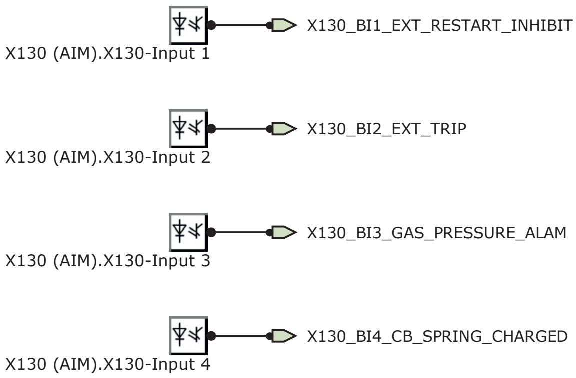


Figure 147: Default binary inputs - X130

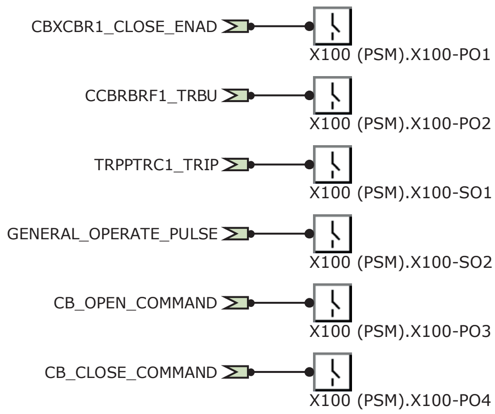


Figure 148: Default binary outputs - X100

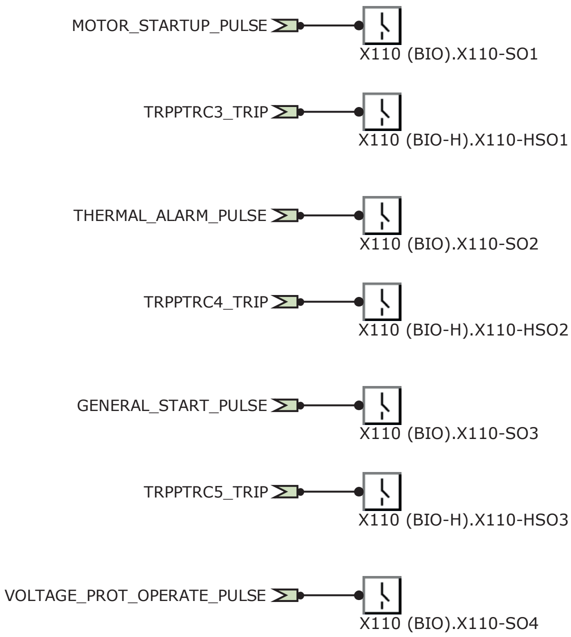
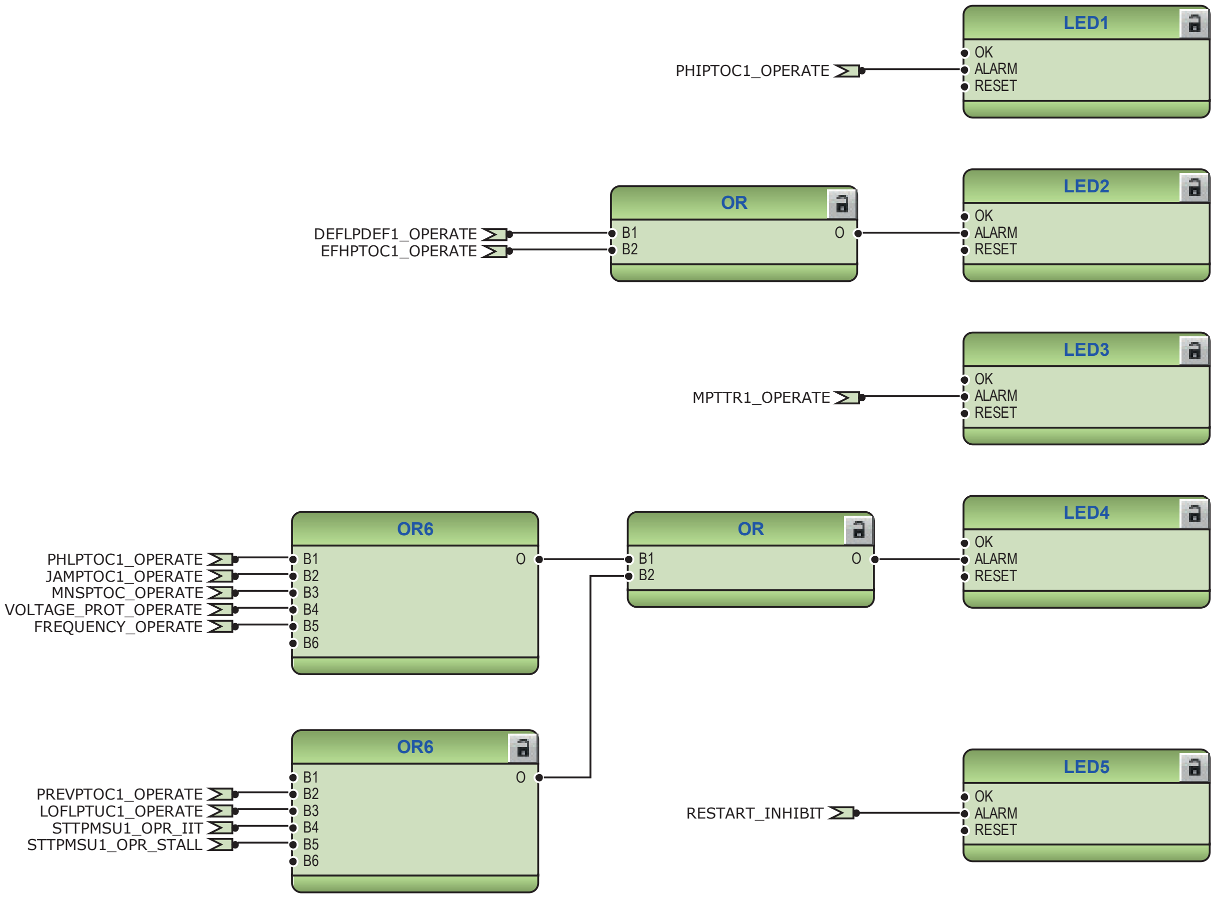


Figure 149: Default binary outputs - X110



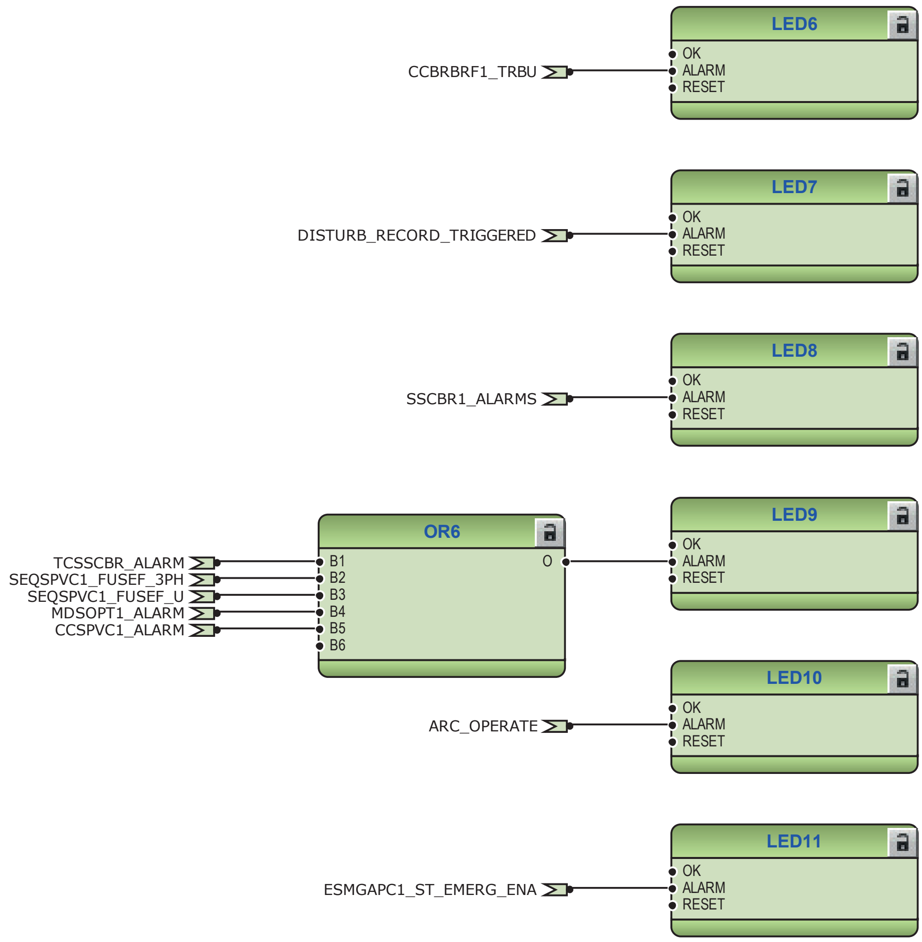


Figure 150: Default LED connection

3.5.3.7 Functional diagrams for other timer logics

The configuration also includes voltage operate, motor start-up and thermal alarm, blocking logic for phase under voltage protection, blocking logic for sequence voltage protection, blocking logic for phase reversal and negative-sequence overcurrent protection and 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. Re-closing 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.

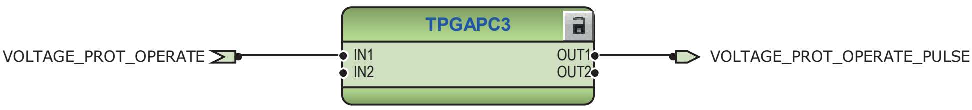


Figure 151: Timer logic for voltage protection operate alarm

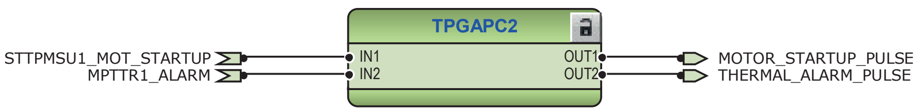


Figure 152: Timer logic for motor start-up and thermal alarm

Add the signals for blocking positive-sequence undervoltage protection and negative-sequence overvoltage protection.

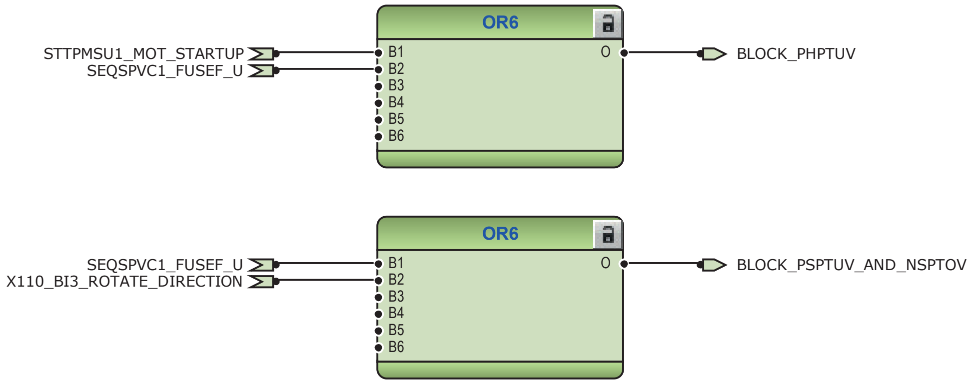


Figure 153: Blocking logic for phase undervoltage and sequence voltage protection

Add the signals for blocking phase reversal and negative-sequence overcurrent protection.

Figure 154: Blocking logic for phase reversal and negative-sequence overcurrent protection

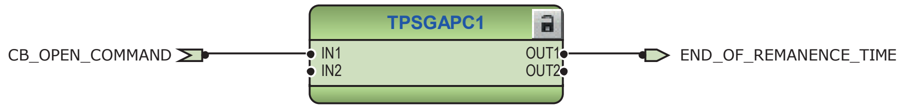


Figure 155: Timer logic for remanence voltage to disappear

3.5.3.8 Other functions

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.

3.6 Standard configuration D

3.6.1 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.

3.6.2 Functions

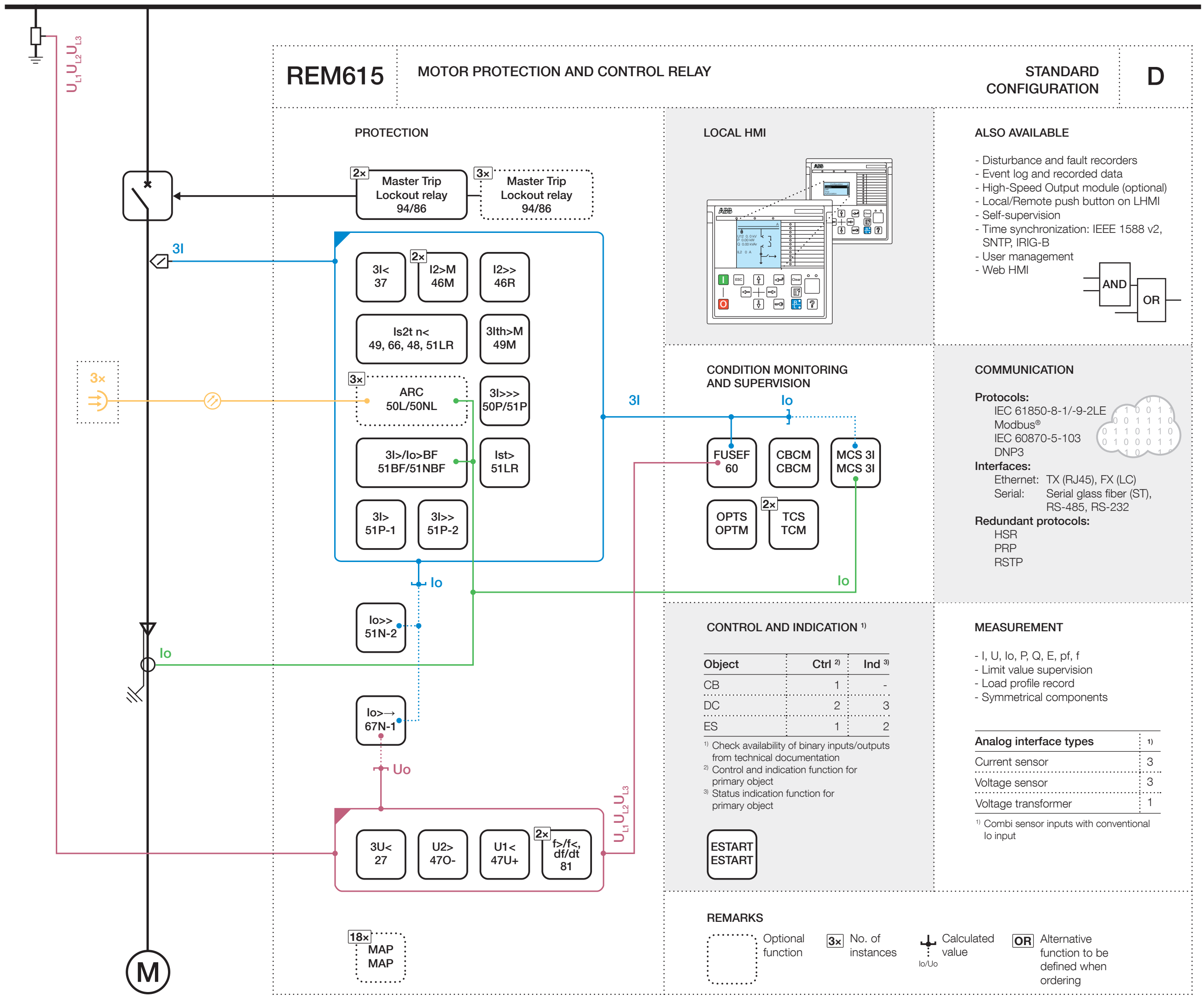


Figure 156: Functionality overview for standard configuration D

3.6.2.1 Default I/O connections

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

Table 28: Default connections for binary inputs

Binary input	Description
X110-BI1	Circuit breaker plug not inserted
X110-BI2	Circuit breaker spring discharged
X110-BI3	Circuit breaker in opened position
X110-BI4	Circuit breaker in closed position
X110-BI5	Circuit breaker truck in test
X110-BI6	Circuit breaker truck in service
X110-BI7	Earthing switch in opened position
X110-BI8	Earthing switch in closed position

Table 29: Default connections for binary outputs

Binary input	Description
X100-PO1	Release for circuit breaker closing
X100-PO2	Circuit breaker close command
X100-SO1	Release for circuit breaker truck
X100-SO2	Release for earthing switch
X100-PO3	Circuit breaker open command
X100-PO4	Circuit breaker failed signal - Retrip
X110-HSO1	Arc protection instance 1 operate activated
X110-HSO2	Arc protection instance 2 operate activated
X110-HSO3	Arc protection instance 3 operate activated

Table 30: Default connections for LEDs

LED	Description
1	Circuit breaker close enabled
2	Short-circuit protection operated
3	Earth-fault protection operated
4	Loss of load protection operated
5	Other protection function operated
6	–
7	Thermal overload protection operated
8	Undervoltage or frequency protection operated
9	Supervision alarm
10	Circuit breaker condition monitoring alarm
11	–

3.6.2.2 Default disturbance recorder settings

Table 31: 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 32: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - start	Positive or Rising
2	PHIPTOC2 - start	Positive or Rising
3	DEFLPDEF1 - start	Positive or Rising
4	EFHPTOC1 - start	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 - start	Positive or Rising
11	MNSPTOC1 - blk restart	Level trigger off
12	MNSPTOC2 - start	Positive or Rising
13	MNSPTOC2 - blk restart	Level trigger off
14	PREVPTOC1 - start	Positive or Rising
15	PHPTUV1 - start	Positive or Rising
16	PSPTUV1 - start	Positive or Rising
17	NSPTOV1 - start	Positive or Rising
18	FRPFRQ1 - start	Positive or Rising
19	FRPFRQ2 - start	Positive or Rising
20	CCBRBRF1 - trret	Level trigger off
21	CCBRBRF1 - trbu	Level trigger off
22	PHLPTOC1 - operate	Level trigger off

Table continues on the next page

Channel	ID text	Level trigger mode
23	PHIPTOC2 - operate	Level trigger off
24	JAMPTOC1 - operate	Level trigger off
25	DEFLPDEF1 - operate	Level trigger off
	EFHPTOC2 - operate	
26	MNSPTOC1 - operate	Level trigger off
	MNSPTOC2 - operate	
27	PREVPTOC1 - operate	Level trigger off
28	LOFLPTUC1 - operate	Level trigger off
29	MPTTR1 - operate	Level trigger off
30	PHPTUV1 - operate	Level trigger off
31	PSPTUV1 - operate	Level trigger off
32	NSPTOV1 - operate	Level trigger off
33	FRPFRQ1 - operate	Level trigger off
34	FRPFRQ2 - operate	Level trigger off
35	X110BI1 - plug out	Level trigger off
36	X110BI2 - spring dischraged	Level trigger off
37	X110BI4 - CB closed	Level trigger off
38	X110BI3 - CB opened	Level trigger off
39	STTPMSU1 - opr iit	Positive or Rising
40	STTPMSU1 - opr stall	Positive or Rising
41	CCSPVC1 - fail	Level trigger off
42	ARCSARC1 - ARC flt det	Level trigger off
	ARCSARC2 - ARC flt det	
	ARCSARC3 - ARC flt det	
43	ARCSARC1 - operate	Positive or Rising
44	ARCSARC2 - operate	Positive or Rising
45	ARCSARC3 - operate	Positive or Rising

3.6.3 Functional diagrams

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

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

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

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 IEDs protection functionality in detail and according to the factory set default connections.

Two overcurrent stages are offered for overcurrent and short-circuit protection. The non-directional low stage PHLPTOC1 can be used for overcurrent protection whereas instantaneous stage PHIPTOC1 can be used for short-circuit protection. The operation of PHIPTOC1 is not blocked as default by any functionality and it should be set over the motor start current level to avoid unnecessary operation.

The motor load jam protection function JAMPTOC1 is blocked by the motor start-up protection function.

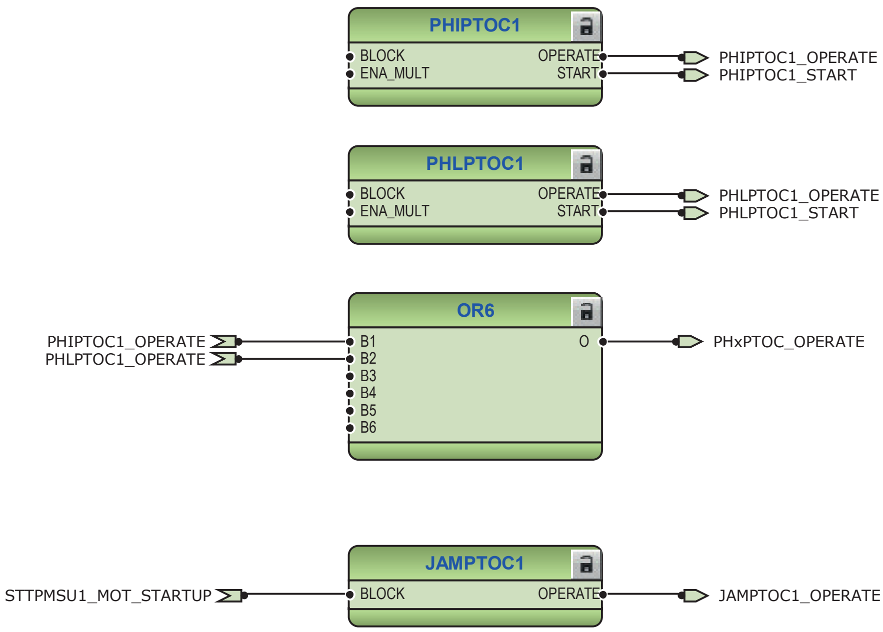


Figure 157: Overcurrent protection functions

Two negative-sequence overcurrent protection stages MNSPTOC1 and MNSPTOC2 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.

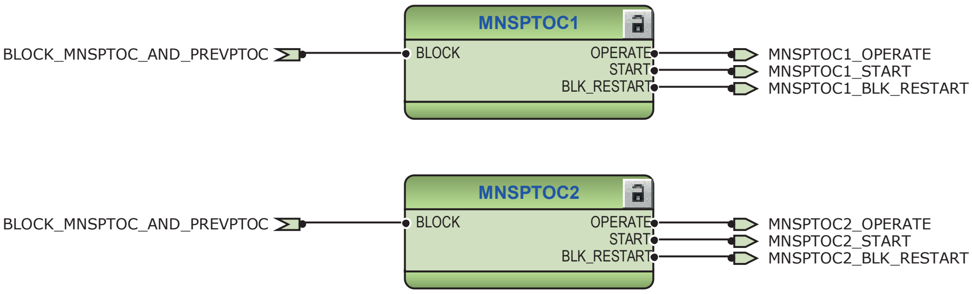


Figure 158: Negative-sequence overcurrent protection function

The phase reversal protection PREVPTOC1 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.

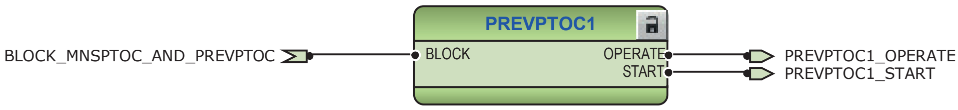


Figure 159: Phase reversal protection function

One stage is provided for non-directional earth-fault protection EFHPTOC1 to detect phase-to-earth faults that may be result of, for example, insulation ageing. In addition, there is a directional protection stage DEFLPDEF1 which can also be used as a low stage non-directional earth-fault protection without residual voltage requirement. However, the residual voltage can help to detect earth 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 earth-fault are blocked by the activation of instantaneous stage of overcurrent protection.

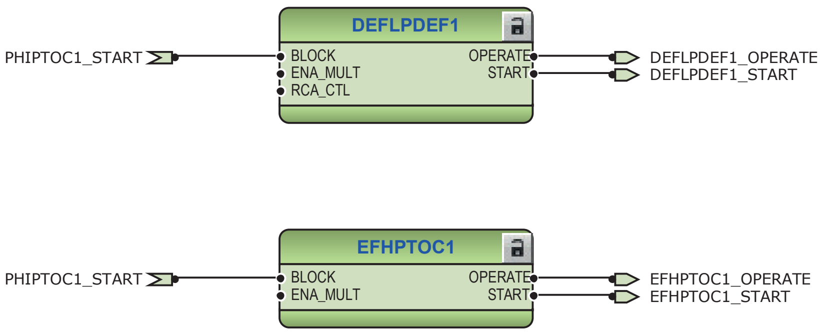


Figure 160: Earth-fault protection functions

The emergency start function ESMGAPC1 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 is energized. However it should be noted that by default no binary inputs are provided to perform emergency start operation.

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

- The calculated thermal level in MPTTR1 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 is set slightly below the set restart inhibit value to allow at least one motor start-up.

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

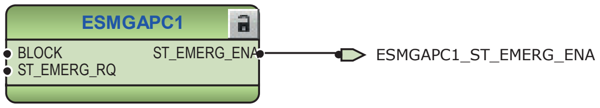


Figure 161: Motor emergency start-up function

The thermal overload protection for motors MPTTR1 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.

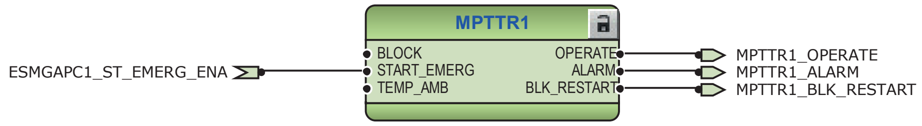


Figure 162: Thermal overcurrent protection function

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. Re-closing 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.

- An active trip command
- Motor start-up supervision has issued lockout
- Motor unbalance function has issued restart blocking
- Thermal protection has issued restart blocking

With the motor start-up supervision function STTPMSU1 the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor. When the emergency start request is activated by ESMGAPC1 and STTPMSU1 is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

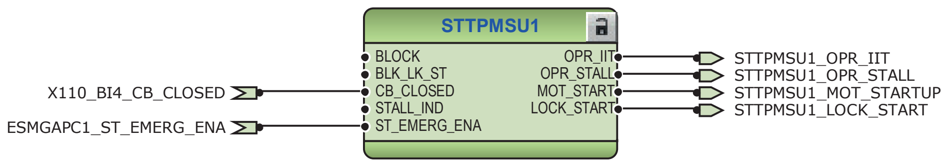


Figure 163: Motor start-up supervision function

The runtime counter for machines and devices MDSOPT1 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.

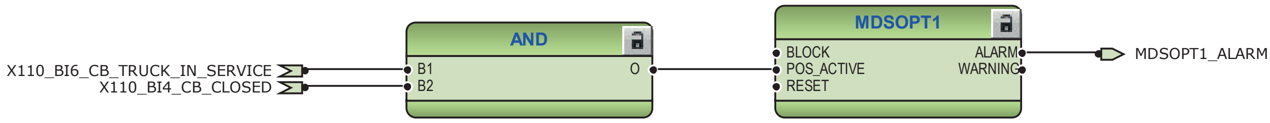


Figure 164: Motor runtime counter

The loss of load situation is detected by LOFLPTUC1. The loss of load situation occurs, for example, if there is a damaged pump or a broken conveyor.

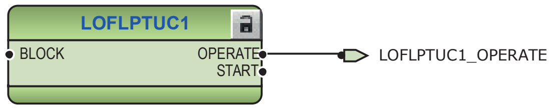


Figure 165: Loss of load

The three-phase undervoltage protection PHPTUV1 offers protection against abnormal phase voltage conditions. Positive-sequence undervoltage protection PSPTUV1 and negative-sequence overvoltage protection NSPTOV1 functions are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order.

The three-phase undervoltage protection PHPTUV1 is blocked during motor start-up to prevent unwanted operation. A failure in the voltage measuring circuit can be detected by the fuse failure function. The activation can be used to block undervoltage protection functions as well as voltage based unbalance protection functions to avoid faulty tripping however that is not included in configuration by default.

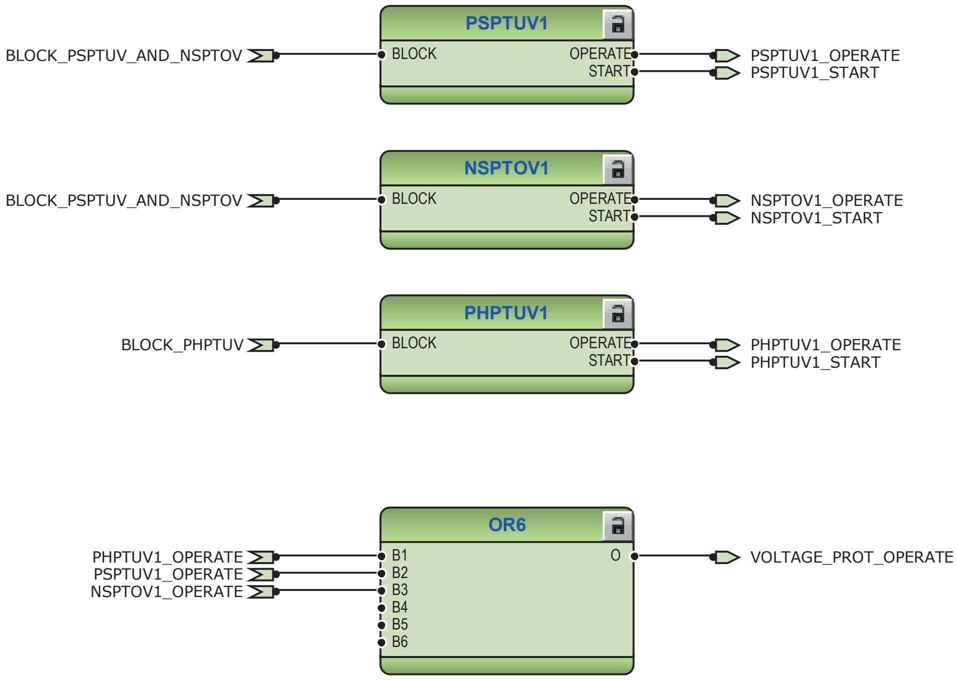


Figure 166: Undervoltage and sequence voltage protection function

Two frequency protection stages FRPFRQ1 and FRPFRQ2 are offered. These functions are used to protect the motor against an abnormal power system frequency.

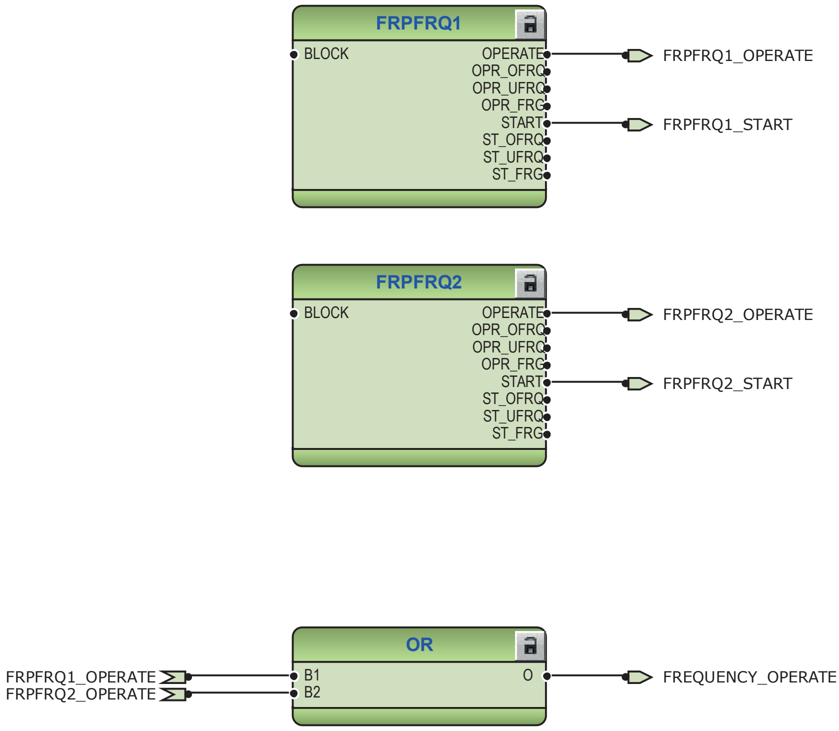


Figure 167: Frequency protection function

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

The circuit breaker failure protection function has two operating outputs: `TRRET` and `TRBU`. The `TRRET` operate output is used for retripping its own breaker through `TRPPTRC2_TRIP`. The same `TRRET` output is also connected to the binary output X100:PO4.

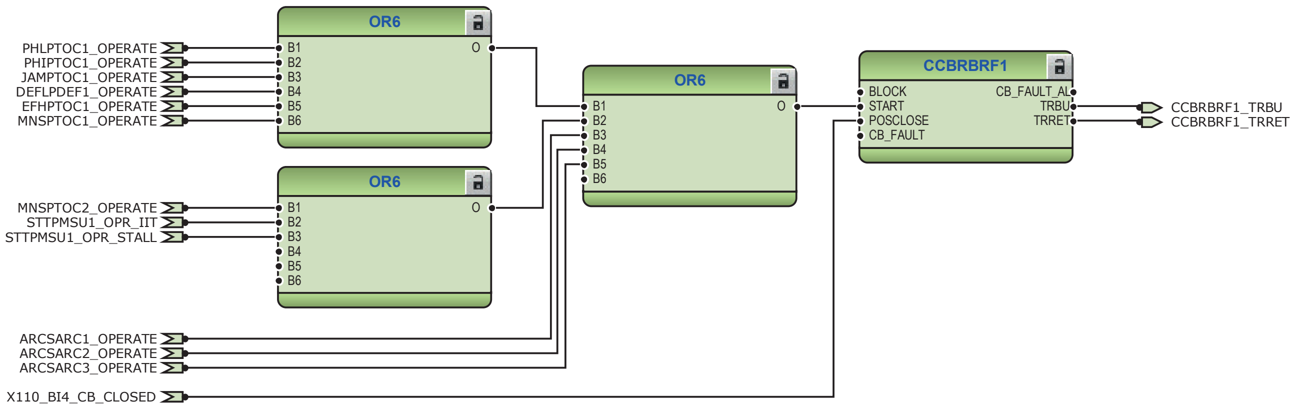


Figure 168: Circuit breaker failure protection function

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

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

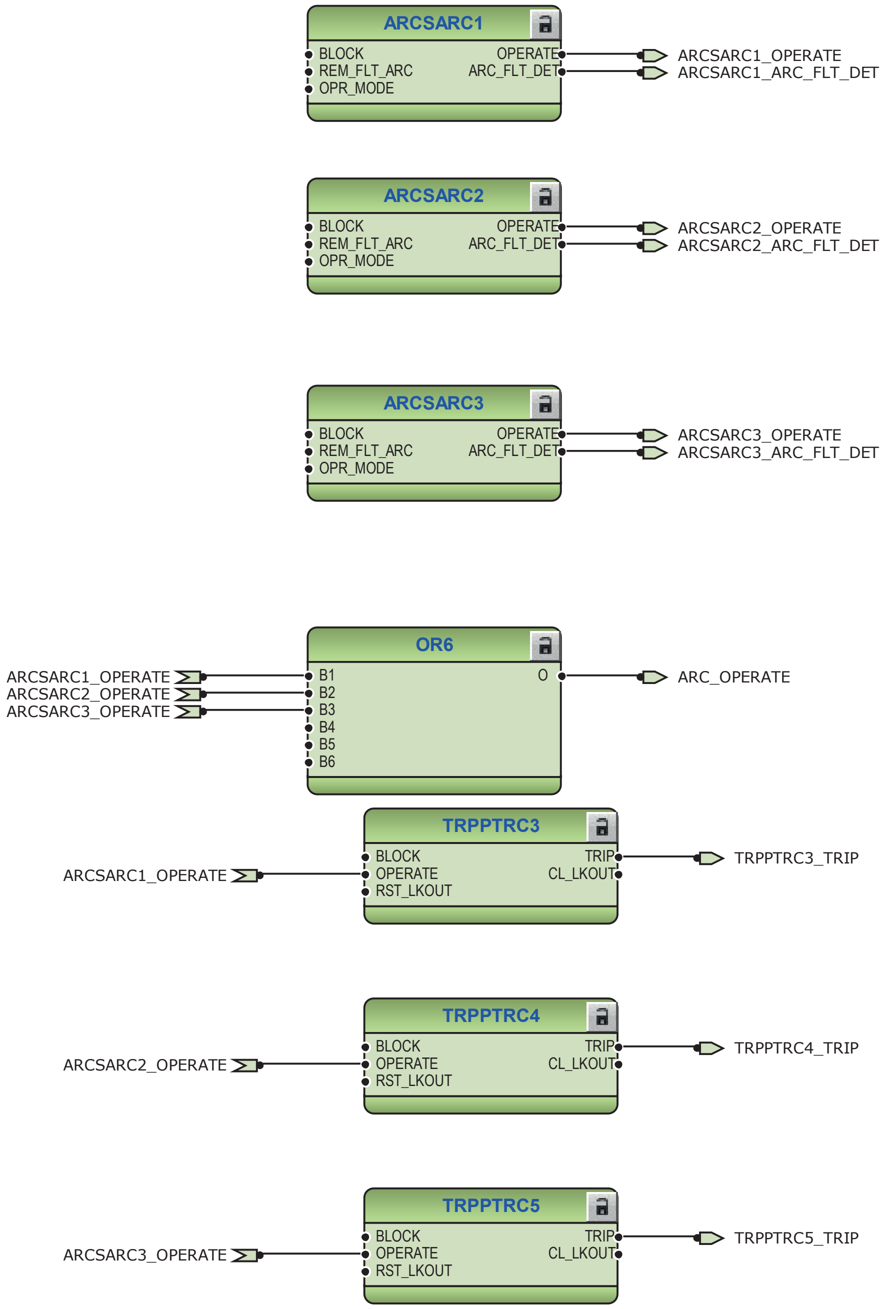


Figure 169: Arc protection with dedicated HSO

General start and operate from all the functions are connected to minimum pulse timer TPGAPC for setting the minimum pulse length for the outputs.

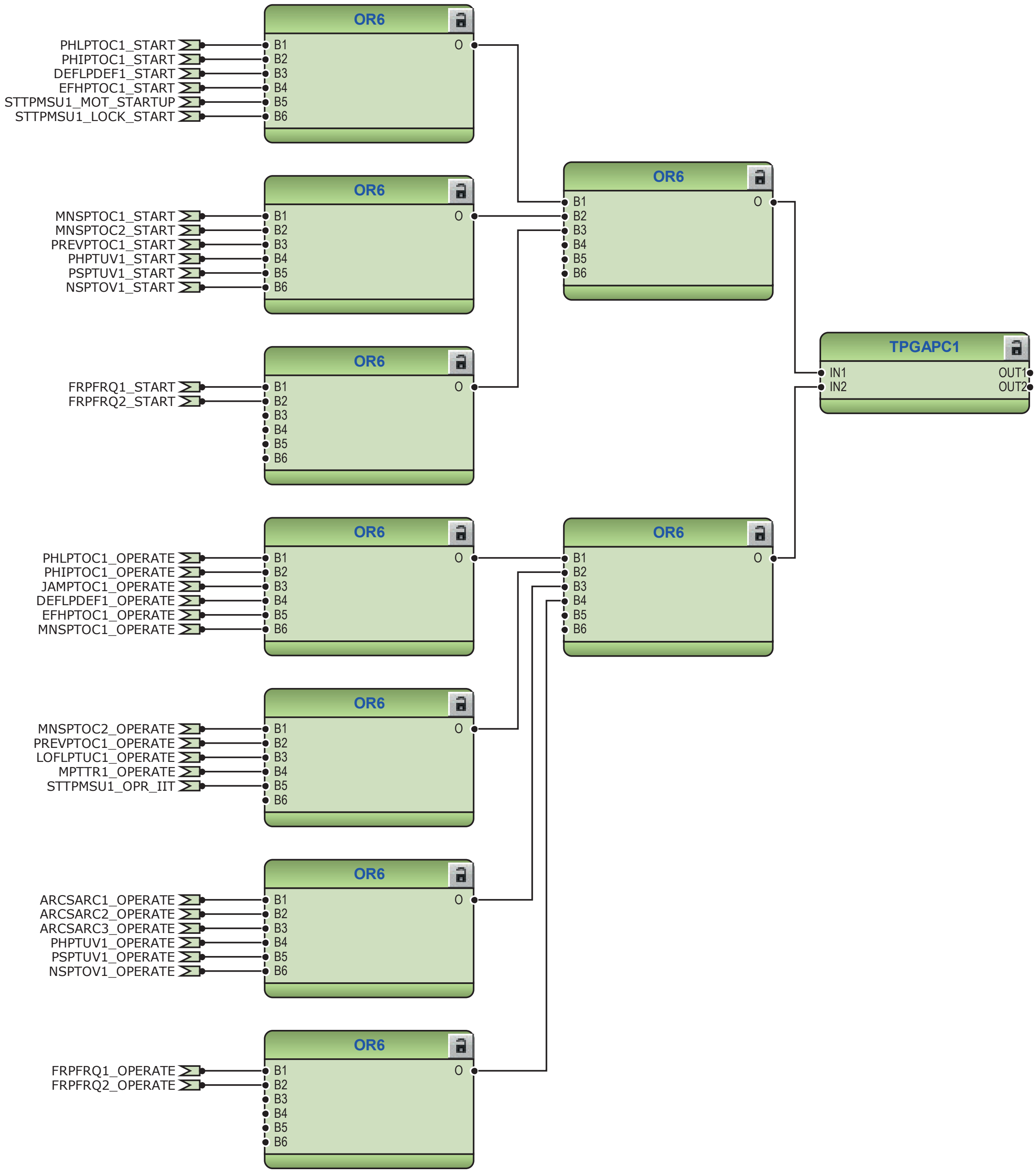


Figure 170: General start and operate signals

The operate signals from the protection functions are connected to the two trip logics TRPPTRC1 and TRPPTRC2. The output from TRPPTRC1 trip logic functions is available at binary output X100:PO3. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is required, 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...4 are also available if the IED is ordered with high speed binary outputs options.

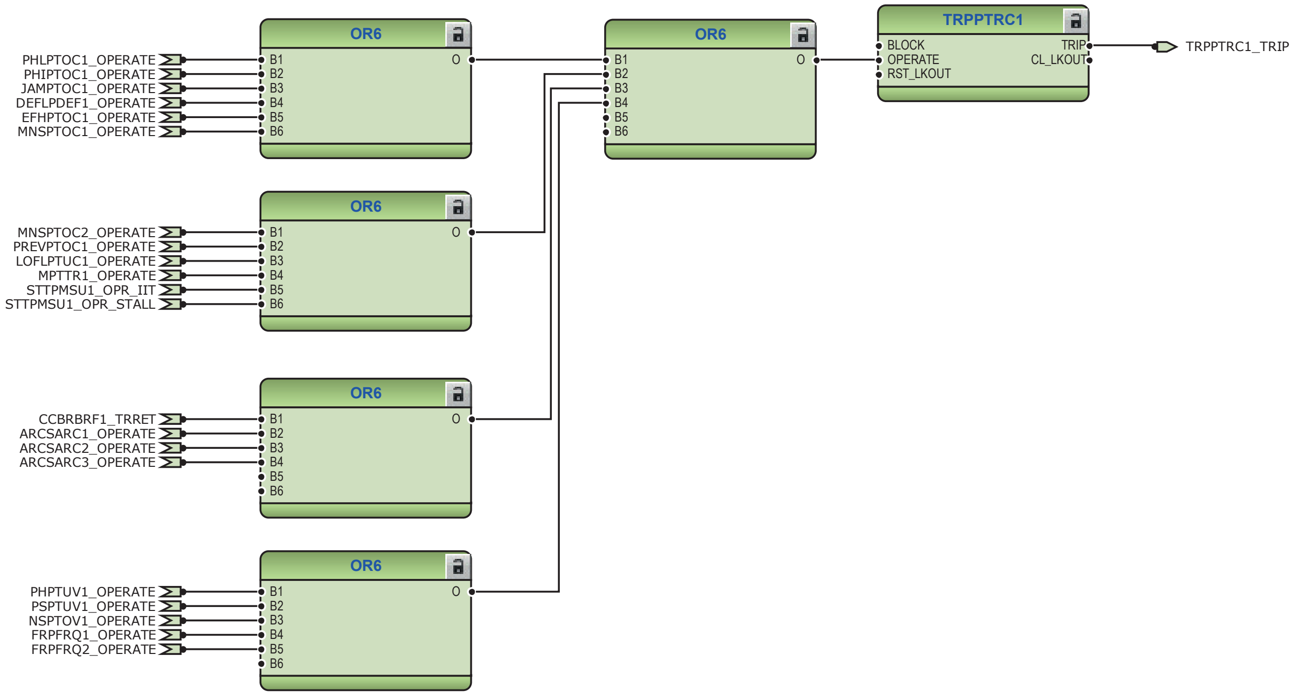


Figure 171: Trip logic TRPPTRC1

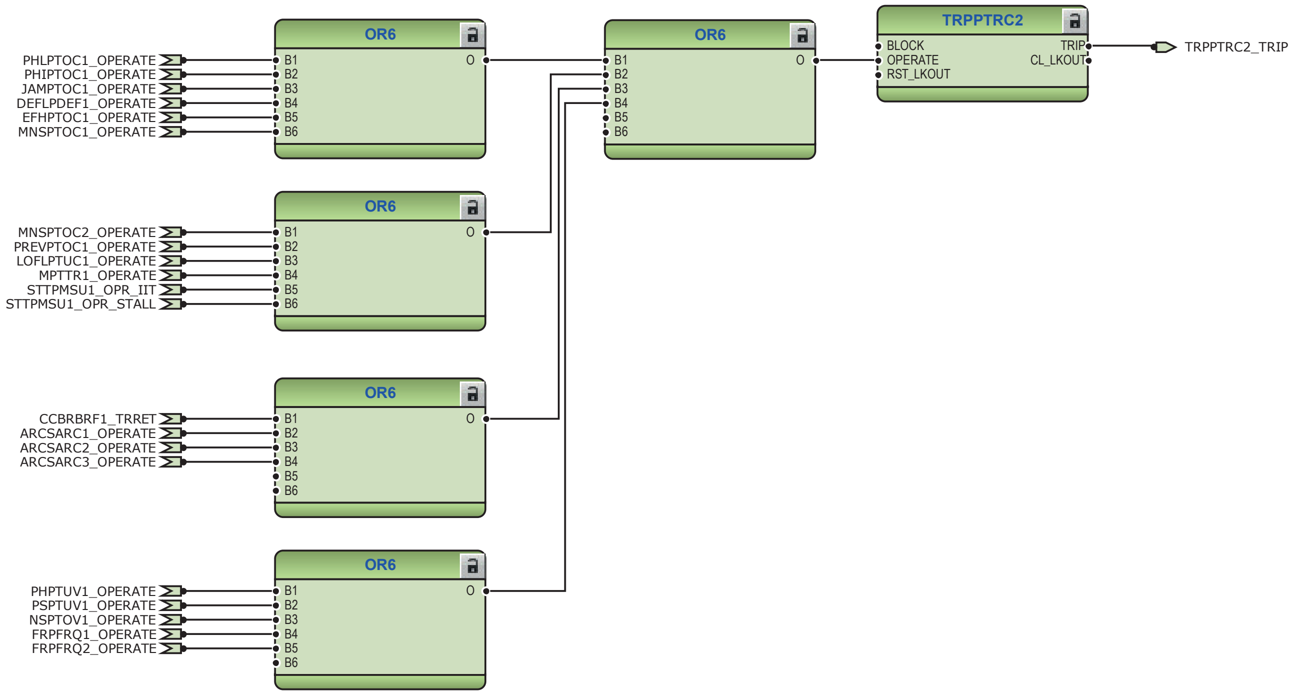


Figure 172: Trip logic TRPPTRC1

3.6.3.2 Functional diagrams for disturbance recorder

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

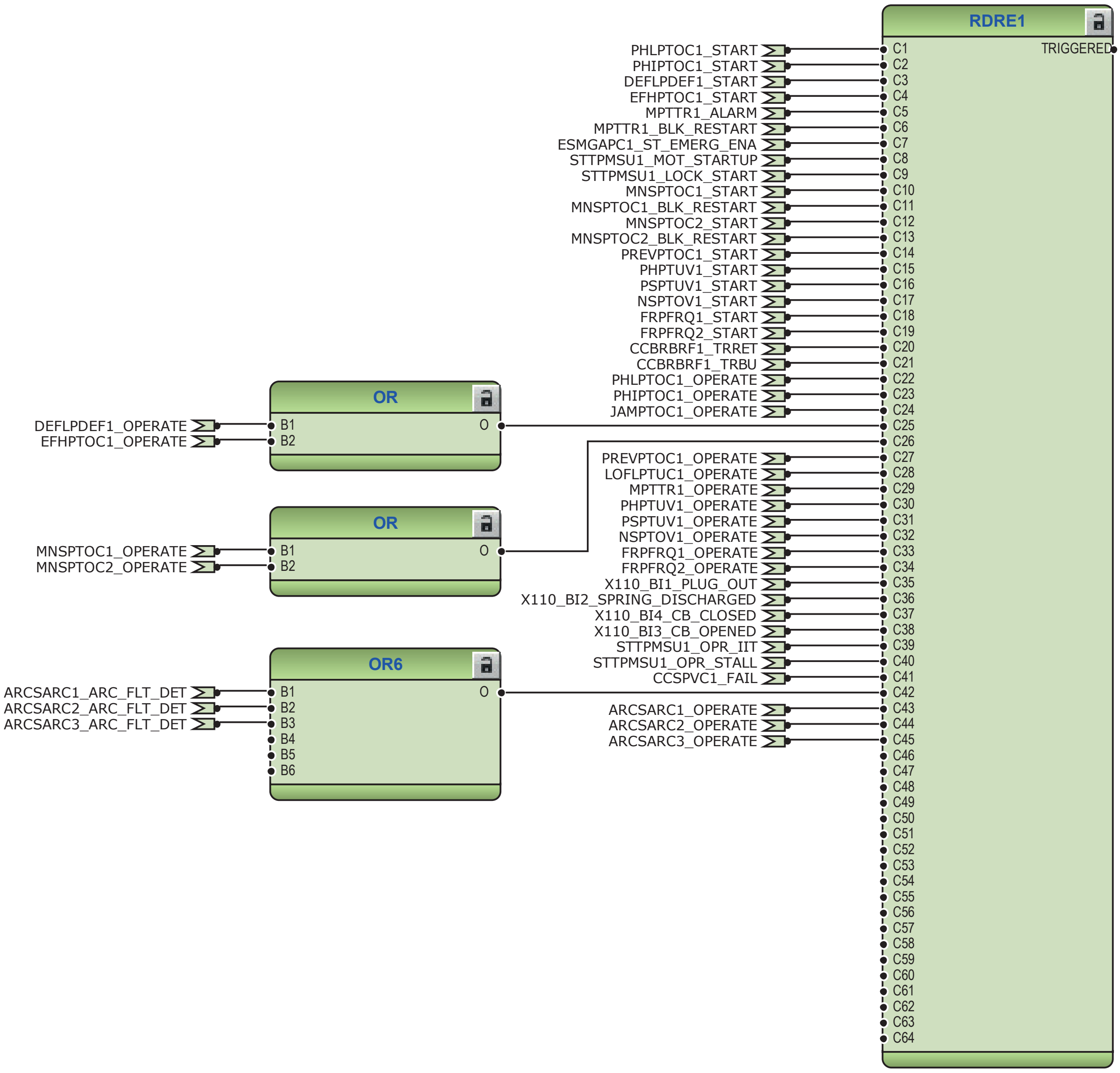


Figure 173: Disturbance recorder

3.6.3.3 Functional diagrams for condition monitoring

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

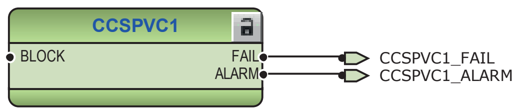


Figure 174: Current circuit supervision function

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

Set the parameters for SSCBR1 properly.

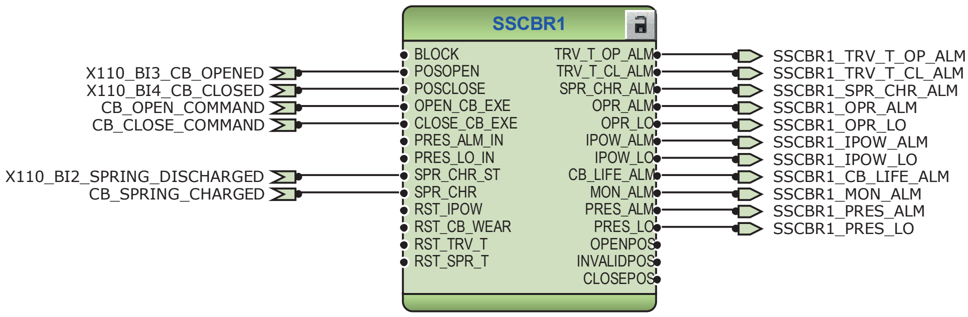


Figure 175: Circuit-breaker condition monitoring function

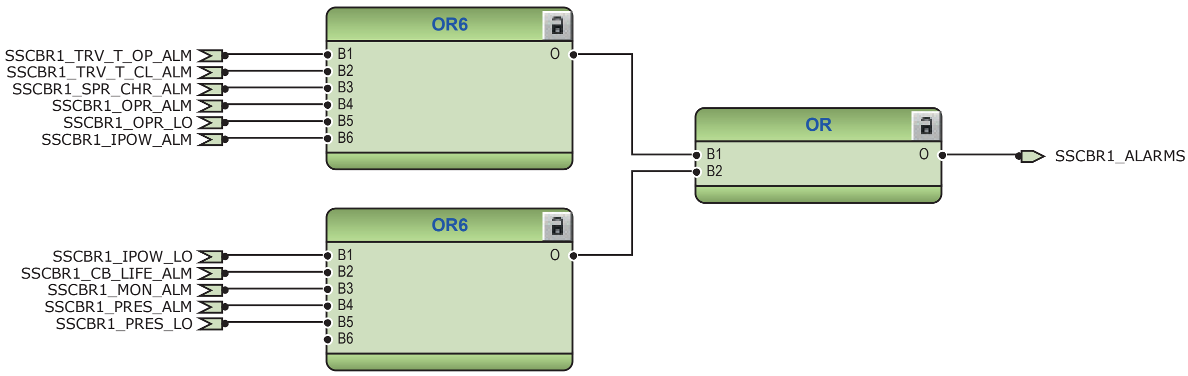


Figure 176: Logic for circuit breaker monitoring alarm

Figure 177: Logic for start of circuit breaker spring charging

Two separate trip circuit supervision functions are included: TCSSCBR1 for power output X100:PO3 for master trip and TCSSCBR2 for power output X100:PO4 for circuit breaker closing. The trip circuit supervision TCSSCRB1 is blocked by both the master trips TRPPTRC1 and TRPPTRC2 and the binary input X110:BI1 indicating IED plug out. The trip circuit supervision TCSSCBR2 is blocked by the circuit breaker closing signal or by the binary input X110:BI1 indicating IED plug out.

It is assumed that there is external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR1 properly.

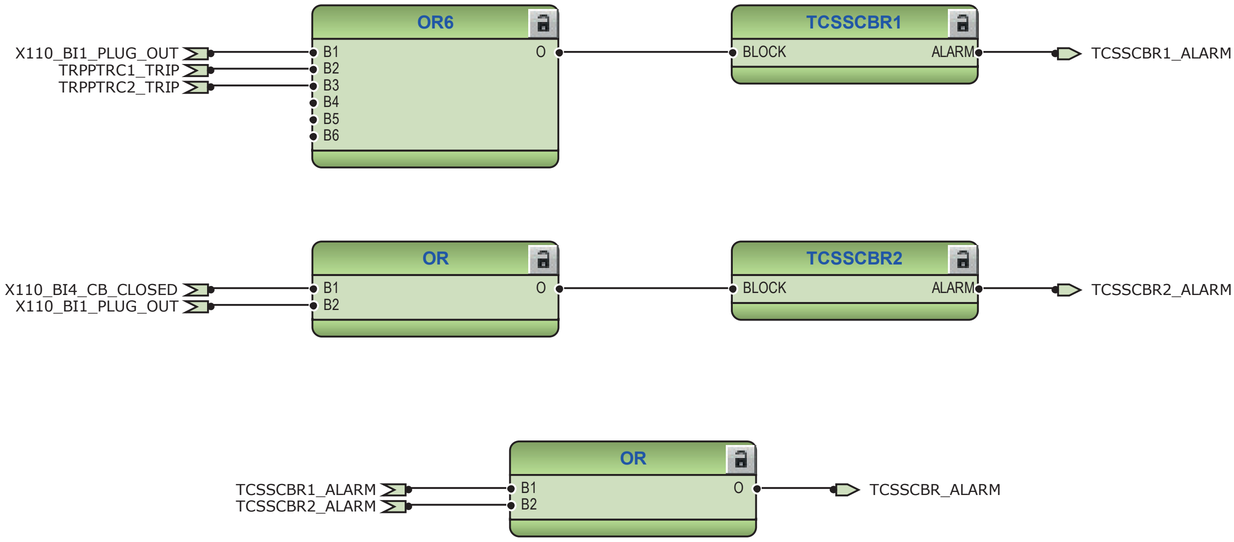


Figure 178: Trip circuit supervision function

3.6.3.4 Functional diagrams for control and interlocking

Two types of disconnector and earthing switch function blocks are available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration. The disconnector (CB truck) and line side earthing switch status information is connected to DCSXSWI1 and ESSXSI1.

The configuration also includes closed enable interlocking logic for disconnector and earthing switch. These signals are available for binary outputs X100:SO1 and X100:SO2.

Any additional signals required by the application can be connected for enable operation with earthing switch.

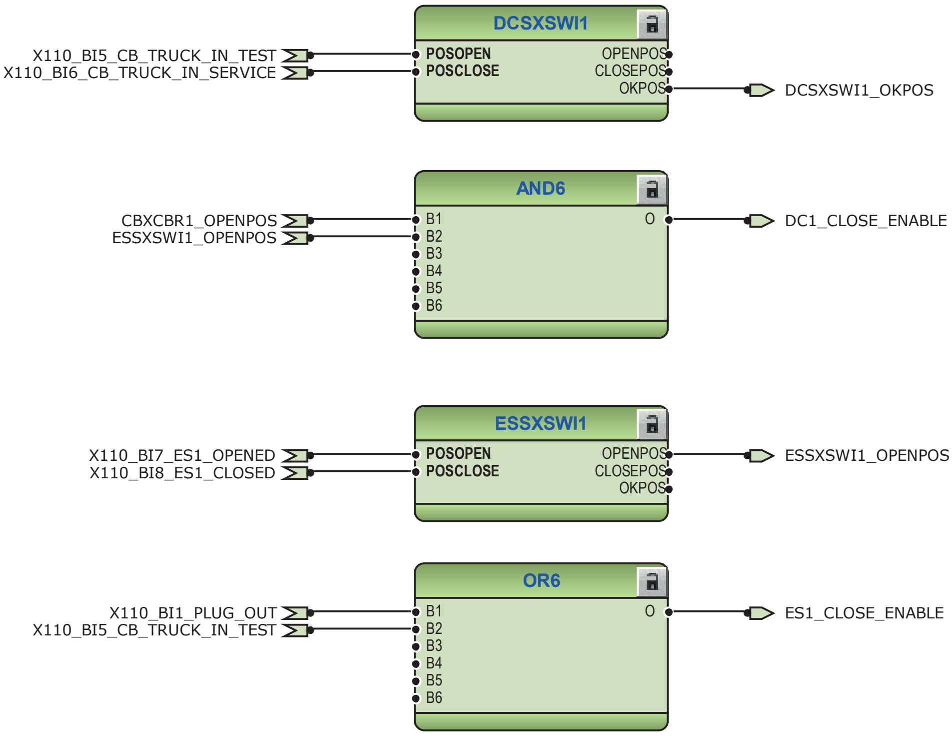


Figure 179: Disconnector and earth-switch control logic

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

The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is either open (in test position) or close (in service position). This output, together with the open earth-switch and non-active trip signals, spring charged status and non-active trip circuit supervision alarm, activates the close-enable signal to the circuit-breaker control function block. The open operation for circuit breaker is always enabled.

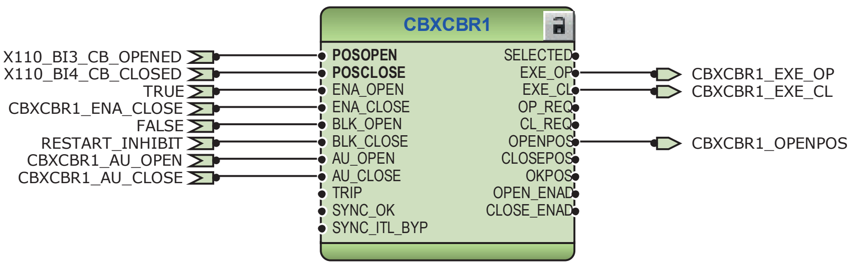


Figure 180: Circuit breaker control logic: Circuit breaker 1

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

Figure 181: Circuit breaker control logic: Signal for closing of circuit breaker 1

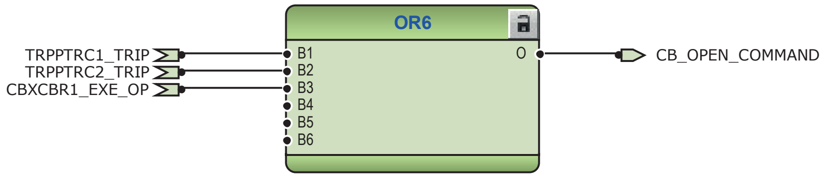


Figure 182: Circuit breaker control logic: Signal for opening of circuit breaker 1

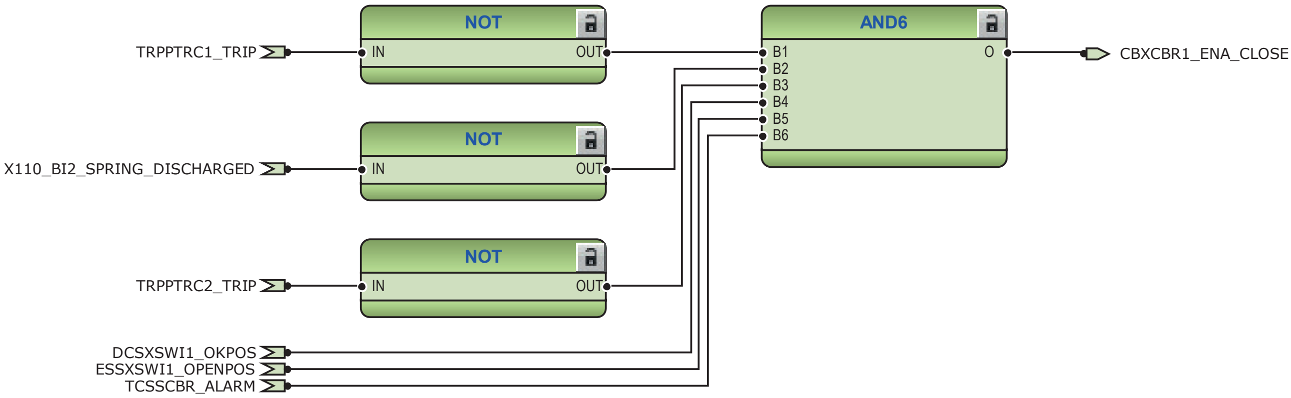


Figure 183: Circuit breaker close enable logic

Connect the higher-priority conditions before ending the closing of circuit breaker. This condition cannot be bypassed with bypass feature of the function.

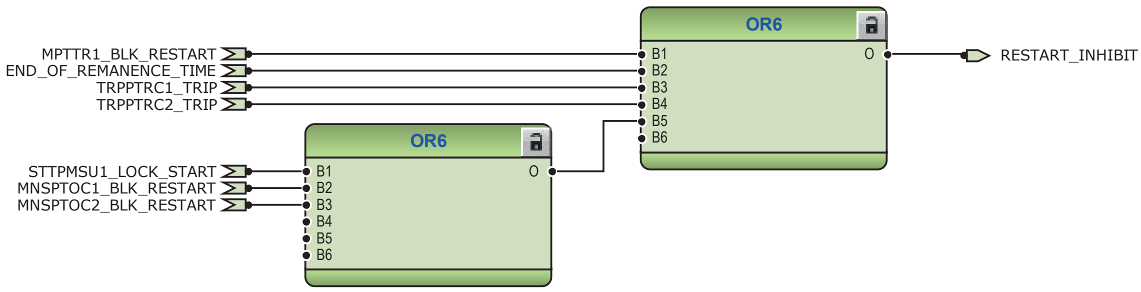


Figure 184: Circuit breaker close blocking logic

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 is activated and the X100:PO1 output is closed.

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

- An active trip command
- Motor start-up supervision has issued lockout
- Motor unbalance function has issued restart blocking
- Thermal protection has issued blocked restart
- Time during which remanence voltage is present

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

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

Connect any additional signal applicable for the configuration for closing and opening of circuit breaker in local or remote mode.

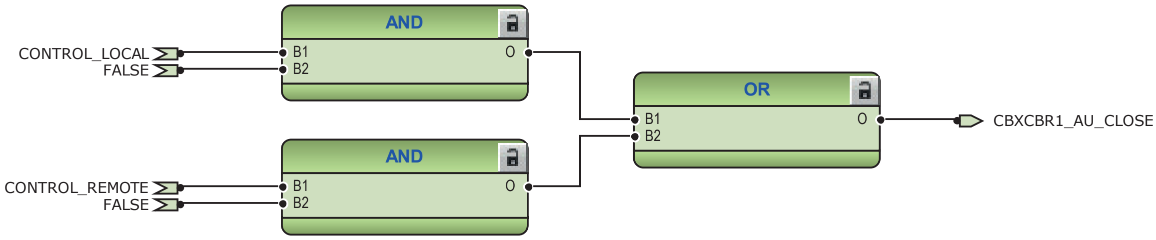


Figure 185: External closing command for circuit breaker

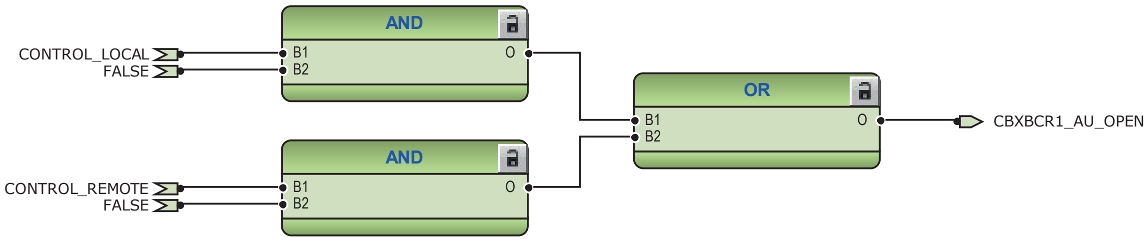


Figure 186: External opening command for circuit breaker

3.6.3.5 Functional diagrams for measurement functions

The phase current inputs to the IED are measured by the three-phase current measurement function CMMXU1. The three-phase current input is connected to the X131, X132 and X133 card in the back panel for the three-phases. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current. The residual current input is connected to the X130 card in the back panel.

The three-phase bus side phase voltage inputs to the IED are measured by the three-phase voltage measurement function VMMXU1 respectively. The three-phase current input is connected to the X131, X132 and X133 card in the back panel for the three-phases. 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, the 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.

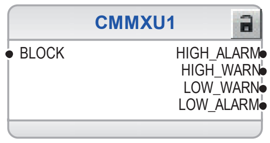


Figure 187: Current measurement: Three-phase current measurement

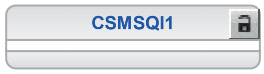


Figure 188: Current measurement: Sequence current measurements

Figure 189: Current measurement: Residual current measurements

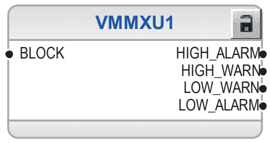


Figure 190: Voltage measurement: Three-phase voltage measurement

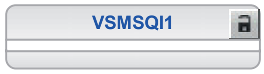


Figure 191: Voltage measurement: Sequence voltage measurement

Figure 192: Other measurement: Frequency measurement

Figure 193: Other measurement: Three-phase power and energy measurement

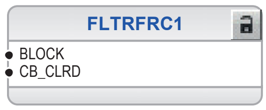


Figure 194: Other measurement: Data monitoring

Figure 195: Other measurement: Load profile record

3.6.3.6 Functional diagrams for I/O and alarm LEDs

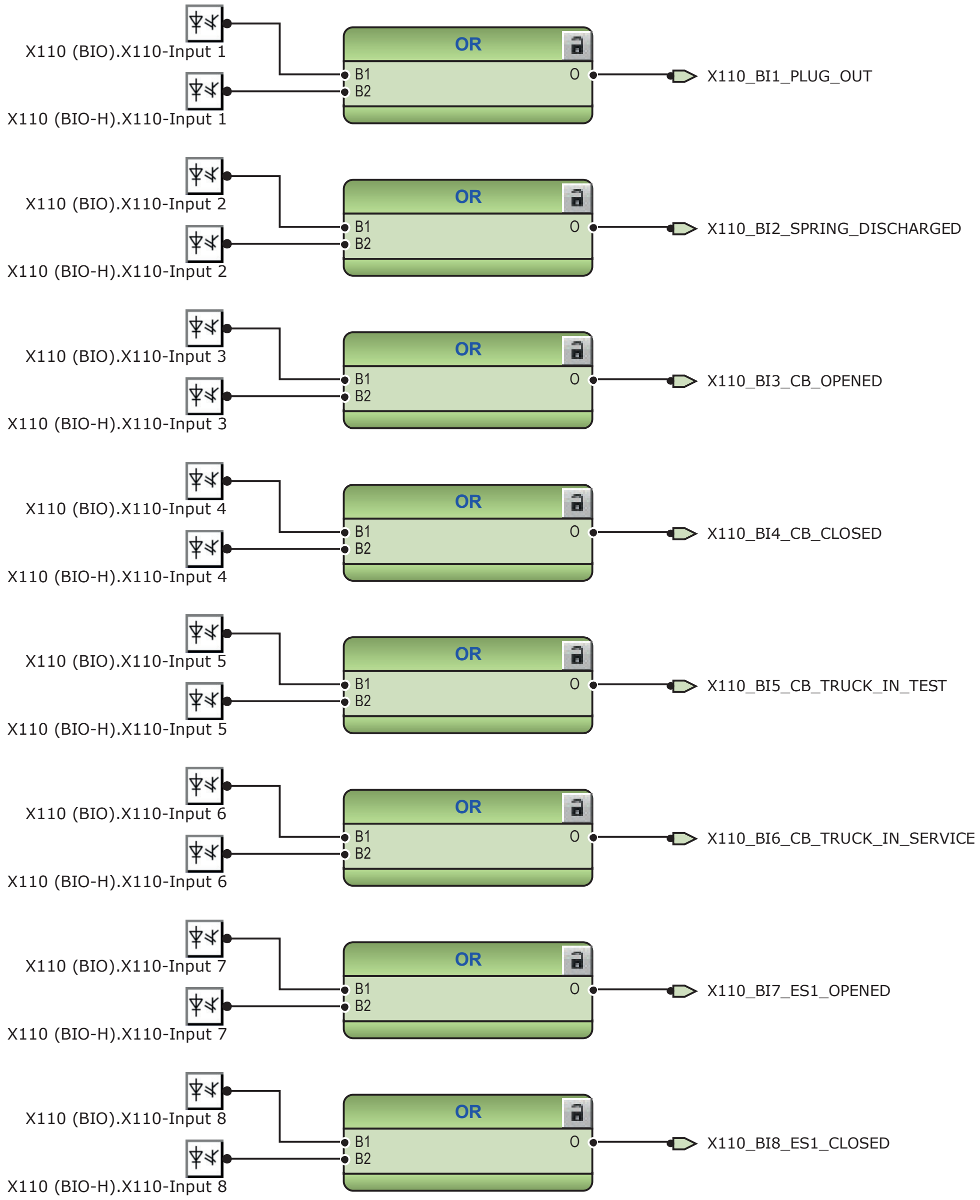


Figure 196: Binary inputs - X110 terminal block

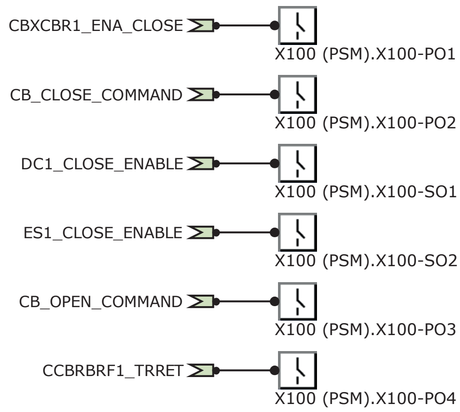
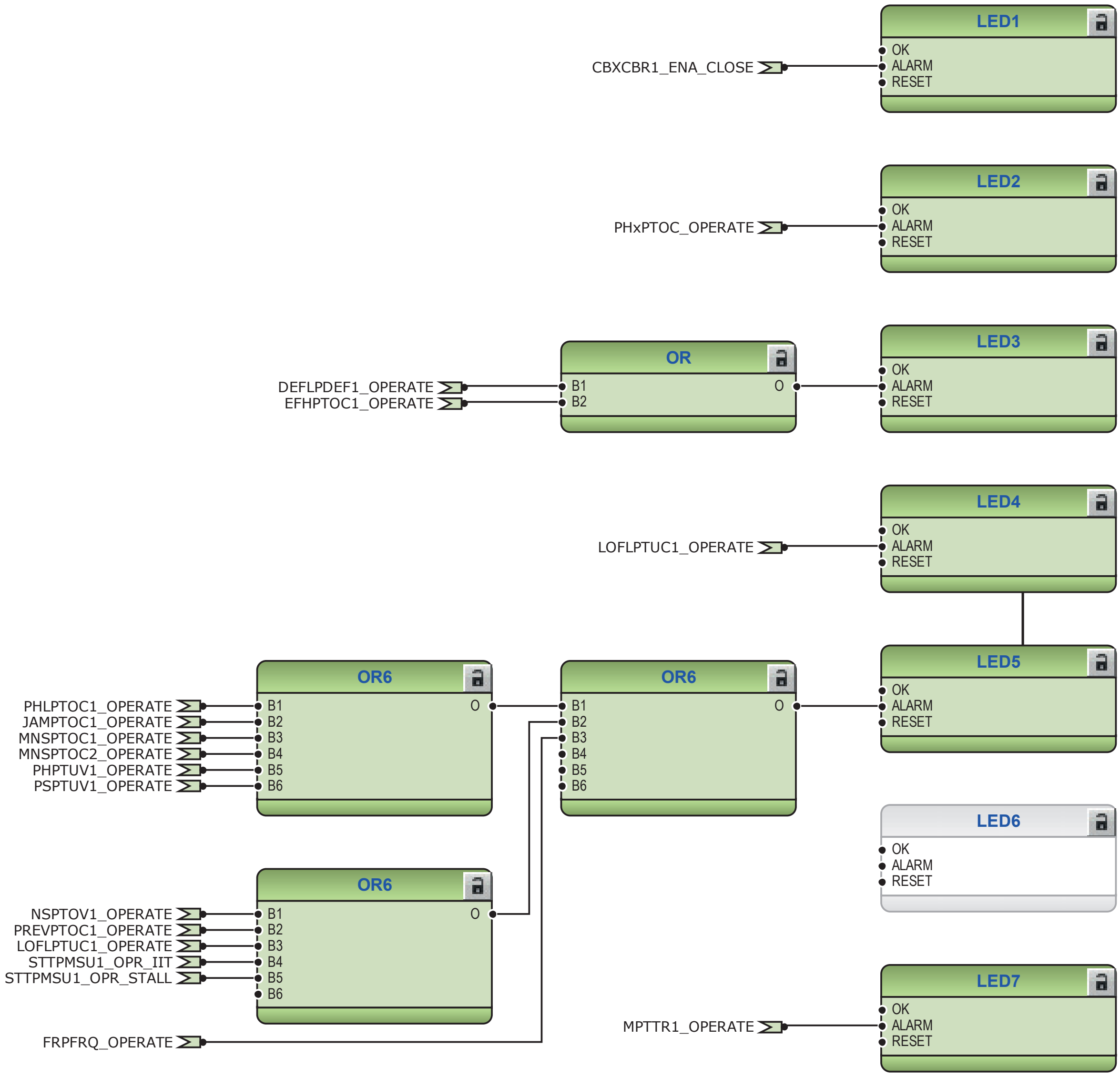


Figure 197: Binary outputs - X100 terminal block

Figure 198: Binary outputs - X110 terminal block


LED1
OK
ALARM
RESET
CBXCBR1_ENA_CLOSE
LED2
PHxPTOC_OPERATE
OR
B1
B2
O
DEFLPDEF1_OPERATE
EFHPTOC1_OPERATE
LED3
LED4
LOFLPTUC1_OPERATE
LED5
OR6
B3
B4
B5
B6
PHLPTOC1_OPERATE
JAMPTOC1_OPERATE
MNSPTOC1_OPERATE
MNSPTOC2_OPERATE
PHPTUV1_OPERATE
PSPTUV1_OPERATE
LED6
NSPTOV1_OPERATE
PREVPTOC1_OPERATE
LOFLPTUC1_OPERATE
STTPMSU1_OPR_IIT
STTPMSU1_OPR_STALL
FRPFRQ_OPERATE
LED7
MPTTR1_OPERATE

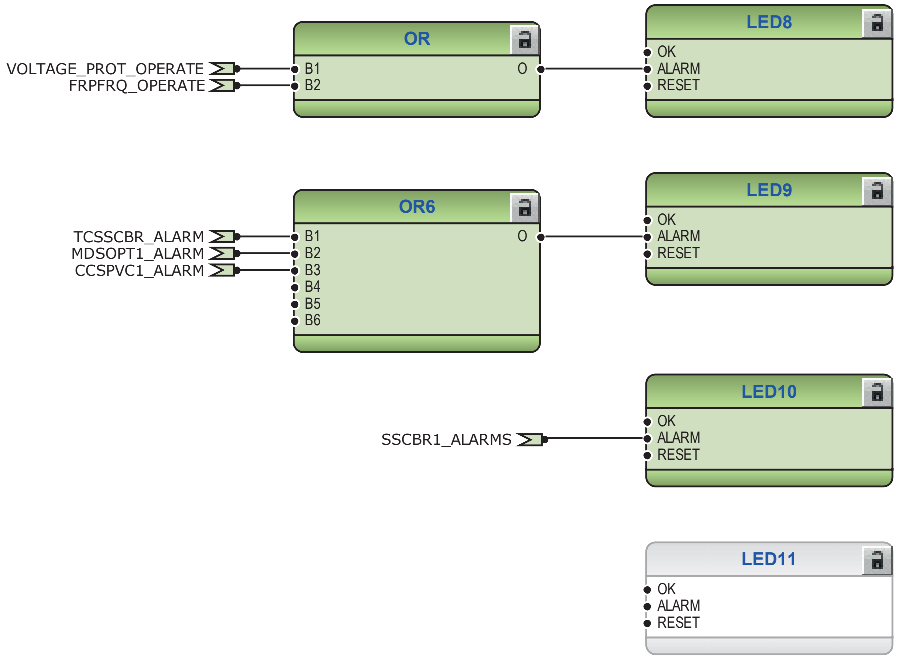


Figure 199: Default LED connections

3.6.3.7 Functional diagrams for other timer logics

The configuration also includes voltage operate, motor start-up and thermal alarm, blocking logic for phase under voltage protection, blocking logic for phase revesal and negative-sequence overcurrent protection and 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. Re-closing 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.

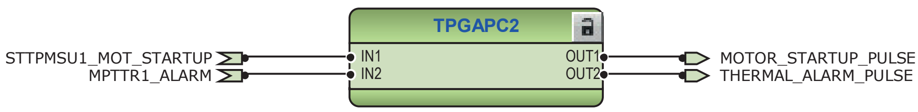


Figure 200: Timer logic for motor start-up and thermal alarm

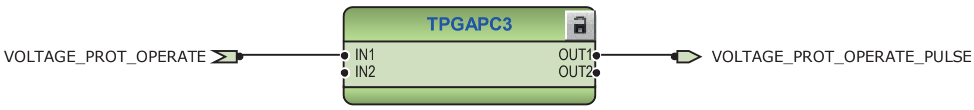


Figure 201: Timer logic for voltage protection operate alarm

Add the signals for blocking phase undervoltage protection.

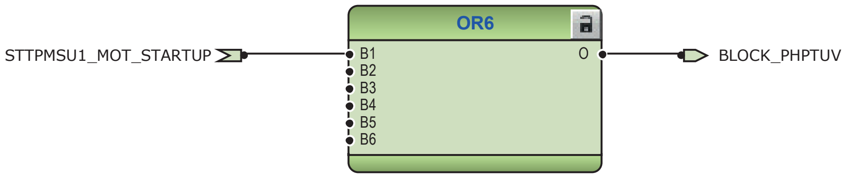


Figure 202: Blocking logic for phase undervoltage and sequence voltage protection

Add the signals for blocking phase reversal and negative-sequence overcurrent protection.

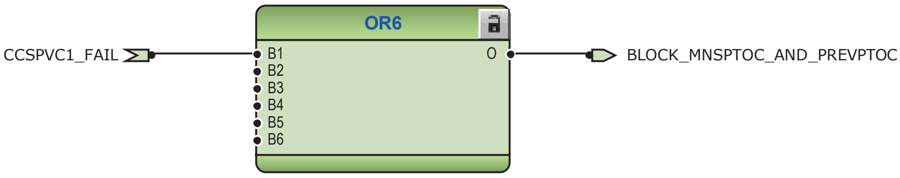


Figure 203: Blocking logic for phase reversal and negative-sequence overcurrent protection

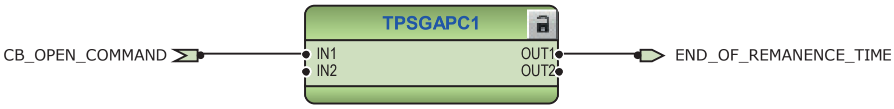


Figure 204: Timer logic for remanence voltage to disappear

3.6.3.8 Other functions

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.

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

Current transformer selection

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

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

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

I_{kmax} is the highest fault current.

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

Recommended start current settings

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

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

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

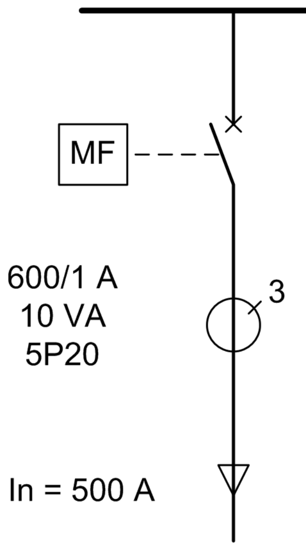
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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

4.1.1.3 Example for non-directional overcurrent protection

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



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

Figure 205: Example of three-stage overcurrent protection

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in *Figure 205*). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in *Figure 205*.

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

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, B and C

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

5.1.1.2 Residual current

Table 35: Residual current input included in configurations A, B and C

Terminal	Description
X120:13-14	Io

Table 36: Residual current input included in configuration D

Terminal	Description
X130:1-2	Io

5.1.1.3 Phase voltages

Table 37: Phase voltage inputs included in configuration B

Terminal	Description
X120:1-2	U1
X120:3-4	U2
X120:5-6	U3

Table 38: Phase voltage inputs included in configuration C

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

5.1.1.4 Residual voltage

Table 39: Residual voltage input included in configuration C

Terminal	Description
X130:17-18	Uo

5.1.1.5 Sensor inputs

Table 40: Combi sensor inputs included in configuration D

Terminal	Description
X131	IL1 U1
X132	IL2 U2
X133	IL3 U3

5.1.2 Auxiliary supply voltage input

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

Table 41: Auxiliary voltage supply

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

5.1.3 Binary inputs

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

Binary inputs of slot X110 are available with configurations B, C and D and optional for A.

Table 42: 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 43: 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 configurations A and C.

Table 44: 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 are optional for configuration B.

Table 45: Binary input terminals X130:1-9

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

Binary inputs of slot X130 are available with configuration C.

Table 46: Binary input terminals X130:1-8 with AIM0006 module

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

5.1.4 Optional light sensor inputs

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

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

Table 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

RTD/mA inputs are optional for configurations A and B.

Table 48: RTD/mA inputs

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

2 Common ground for RTD channels 1-3
3 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 (TCS resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCS1 input), NO
X100:19	PO3 (TCS1 input), NO
X100:20	PO4, NO (TCS resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCS2 input), NO
X100:24	PO4 (TCS2 input), NO

5.2.2 Outputs for signalling

SO output contacts can be used for signalling on start and tripping of the protection relay. On delivery from the factory, the start 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 optional for configuration A.

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

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

Table 52: Optional high-speed output contacts X110:15-24 with BIO0007

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

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

Table 53: Output contacts X130:10-18

Terminal	Description
X130:10 X130:11 X130:12	SO1, common SO1, NO SO1, NC
X130:13 X130:14 X130:15	SO2, common SO2, NO SO2, NC
X130:16 X130:17 X130:18	SO3, common SO3, NO 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 U_{aux} disconnected
X100:5	Closed; no IRF, and U_{aux} connected

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
ASCII	American Standard Code for Information Interchange
BI	Binary input
BIO	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
I/O	Input/output
IEC	International Electrotechnical Commission

Table continues on the next page

IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2	A communication protocol based on the IEC 61850 standard series
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IED	Intelligent electronic device
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LE	Light Edition
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
PTP	Precision Time Protocol
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

Table continues on the next page

Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SMV	Sampled measured values
SNTP	Simple Network Time Protocol
SO	Signal output
TCS	Trip-circuit supervision
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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