Relion® 615 series

Motor Protection and Control REM615 Application Manual

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ABB

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Table of contents

Section 1 Introduction

1.1 This manual

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

1.2 Intended audience

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

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

1.3 Product documentation

1.3.1 Product documentation set

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.

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

The engineering guide provides information for IEC 61850 engineering of the 615 series protection IEDs with PCM600 and IET600. This guide concentrates especially on the configuration of GOOSE communication with these tools. The guide can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. For more details on tool usage, see the PCM600 documentation.

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also

recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and other supported protocols.

The installation manual contains instructions on how to install the IED. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the IED should be installed.

The operation manual contains instructions on how to operate the IED once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the IED. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The point list manual describes the outlook and properties of the data points specific to the IED. The manual should be used in conjunction with the corresponding communication protocol manual.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

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

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

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS756468
DNP3 Communication Protocol Manual	1MRS756709
IEC 60870-5-103 Communication Protocol Manual	1MRS756710
IEC 61850 Engineering Guide	1MRS756475

Table continues on next page

Name of the document	Document ID
Engineering Manual	1MRS757121
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887

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 in this manual 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 .
- HMI menu paths are presented in bold.
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
  To save the changes in non-volatile 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".
- IED input/output messages and monitored data names are shown in Courier font.
  When the function starts, the START output is set to TRUE.

1.4.3 Functions, codes and symbols

Table 1: REM615 functions, codes and symbols

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, 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 motors	MNSPTOC1	I2>M (1)	46M (1)
	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Arc protection	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Multi-purpose 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)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
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	I <-> O ESC
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)
Emergergency startup	ESMGAPC1	ESTART	ESTART
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
RTD/mA measurement	XRGGIO130	X130 (RTD)	X130 (RTD)
Frequency measurement	FMMXU1	f	f

Section 2 REM615 overview

2.1 Overview

REM615 is a dedicated motor protection and control IED (intelligent electronic device) 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 IEDs 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 IED has been given the application-specific settings, it can directly be put into service.

The 615 series IEDs support a range of communication protocols including IEC 61850 with GOOSE messaging, IEC 60870-5-103, Modbus® and DNP3.

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 fibre 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

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.4 SP1 or later
- REM615 Connectivity Package Ver. 4.0 or later
  - Parameter Setting
  - Firmware Update
  - Disturbance Handling
  - Signal Monitoring
  - Lifecycle Traceability
  - Signal Matrix
  - Communication Management
  - Configuration Wizard
  - Label Printing
  - IED User Management
  - Application Configuration
  - Graphical Display Editor
  - Event Viewer

Download connectivity packages from the ABB Web site http://www.abb.com/substationautomation

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 multi-purpose protection (configurations A and B only)

2.3 Physical hardware

The IED 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 (4 lines, 16 characters) Large (8 lines, 16 characters)
	X100	Auxiliary power/BO module	48-250 V DC/100-240 V AC; or 24-60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BIO module[1)]	8 binary inputs 4 signal output contacts
	X120	AI/BI module	3 phase current inputs (1/5A) 1 residual current input (1/5A or 0.2/1A)[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 6 RTD sensor inputs
		Optional BIO module	Optional for configuration B: 6 binary inputs 3 signal output contacts
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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

Rated values of the current and voltage inputs are basic setting parameters of the 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.

Table 3: Number of physical connections in standard configurations

Conf.	Analog channels			Binary channels	
	CT	VT	RTD/mA	BI	BO
A	4	-	6/2[1)]	4 (12)[2)]	6 (10)[2)]
B	4	3	-	8 (14)[2)]	10 (13)[2)]
			6/2[1)]	8	10
C	4	5[3)]	-	16	10

1) With optional RTD/mA module
2) With optional BIO module
3) One of the five channels reserved for future applications

2.4 Local HMI

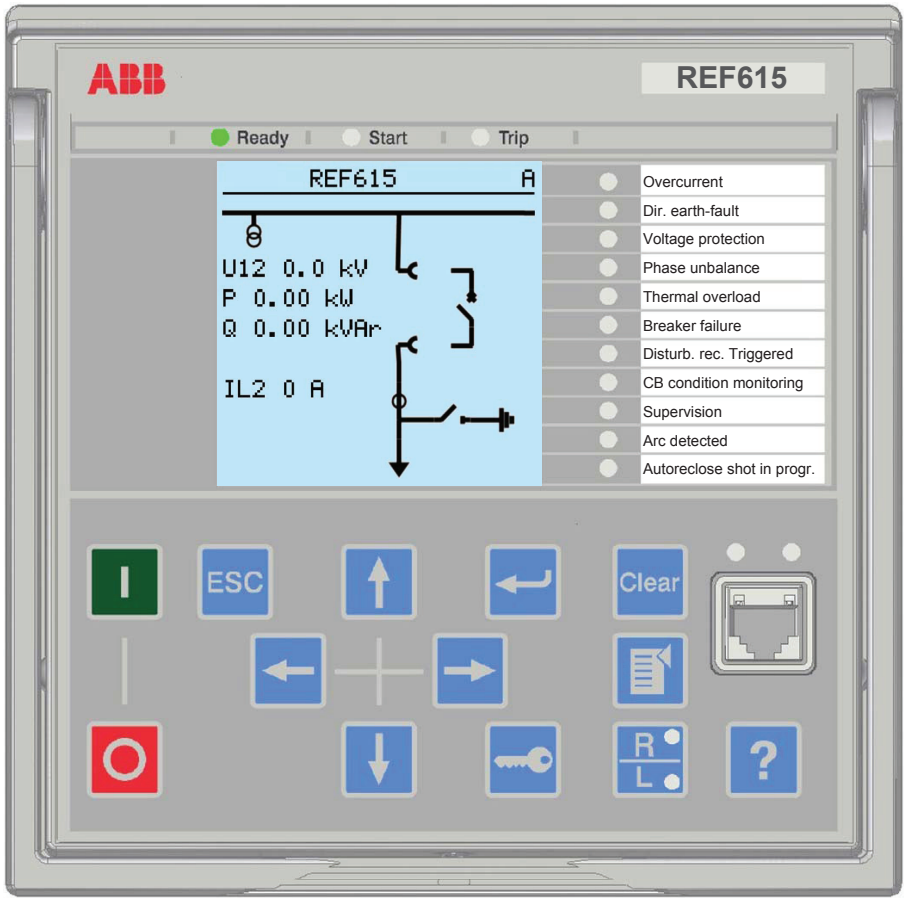

Figure 1: Example of 615 series LHMI

The LHMI of the IED contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

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: Characters and rows on the view

Character size	Rows in view	Characters on row
Small, mono-spaced (6x12 pixels)	5 rows 10 rows with large screen	20
Large, variable width (13x14 pixels)	4 rows 8 rows with large screen	min 8

The display view is divided into four basic areas.

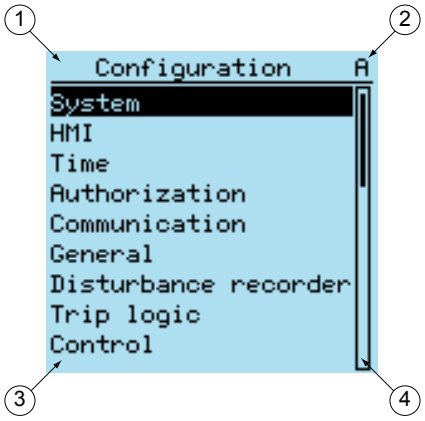

Figure 2: Display layout

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

2.4.2 LEDs

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

There are also 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.

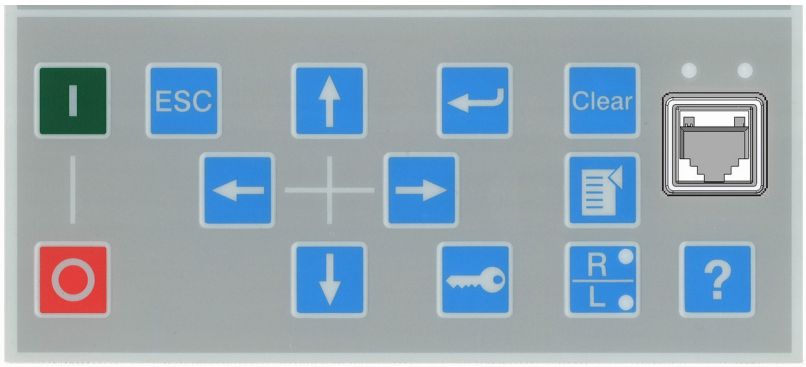

Figure 3: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.5 Web HMI

The WHMI enables the user to access the IED via a Web browser. The supported Web browser versions are Internet Explorer 7.0, 8.0 or 9.0.

WHMI is disabled by default.

WHMI offers several functions.

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

- Disturbance records
- Phasor diagram
- Single-line diagram

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

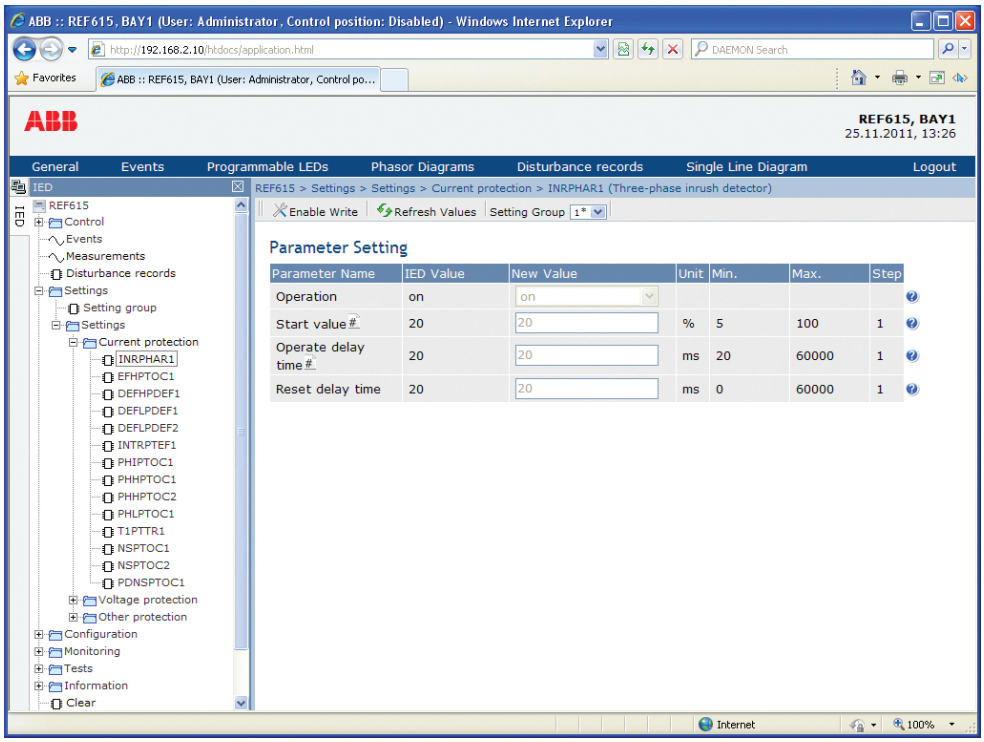

Figure 4: Example view of the WHMI

The WHMI can be accessed locally and remotely.

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

2.6 Authorization

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

The default passwords can be changed with Administrator user rights.

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

Table 5: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with  (only locally) • Changing setting groups • Controlling • Clearing indications
ENGINEER	• Changing settings • Clearing event list • Clearing disturbance records • Changing system settings such as IP address, serial baud rate or disturbance recorder settings • Setting the IED 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

615 series IEDs offer a large set of event logging functions. Normal process related events can be viewed by the normal user with Event Viewer in PCM600. Critical system and IED security related events are logged to a separate non-volatile audit trail for the administrator.

Audit trail is a chronological record of system activities that enable the reconstruction and examination of the sequence of events and/or changes in an event. Past user and process events can be examined and analyzed in a consistent method with the help of Event List and Event Viewer in PCM600. The IED stores 2048 system events to non-volatile audit trail. Additionally, 1024 process events are stored in non-volatile event list. Both audit trail and event list work according to the FIFO principle.

User audit trail is defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined usernames or user categories. The user audit trail events are supported in IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 6: Audit trail events

Enum	Explanation/note
Configuration change	Configuration files changed
Firmware change	
Setting group remote	User changed setting group remotely
Table continues on next page	

Enum	Explanation/note
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
Setting commit	Settings has been changed
Time change	
View audit log	Administrator accessed audit trail
Login	
Logout	
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period

PCM600 Event Viewer can be used to view the audit trail events together with normal events. Since only the administrator has the right to read audit trail, authorization must be properly configured in PCM600. The audit trail cannot be reset but PCM600 Event Viewer can filter data. Some of the audit trail events are interesting also as normal process events.

To expose the audit trail events also as normal process events, define the level parameter via **Configuration/Authorization/ Authority logging.**

Table 7: Audit trail events

Audit trail event	Authority logging				
	None	Configuration change	Setting group	Setting group, control	Settings edit
Configuration change		x	x	x	x
Firmware change		x	x	x	x
Setting group remote			x	x	x
Setting group local			x	x	x
Control remote				x	x
Control local				x	x
Test on				x	x
Test off				x	x
Setting commit					x
Time change					
View audit log					
Login					

Table continues on next page

Audit trail event	Authority logging				
Logout					
Firmware reset					
Audit overflow					

2.7 Communication

The IED supports a range of communication protocols including IEC 61850, IEC 60870-5-103, Modbus® and DNP3. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the IEDs, 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 standard COMTRADE file format. The IED can send and receive binary signals from other IEDs (so called horizontal communication) using the IEC61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Further, the IED supports sending and receiving of analog values using GOOSE messaging. The IED meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard. The IED can simultaneously report events to five different clients on the station bus.

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

For the correct operation of redundant 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 IED itself does not support link-down detection or RSTP. The ring recovery process is based on the aging of MAC addresses and link-up/link-down events can cause temporary breaks in communication. For better performance of the self-healing loop, it is recommended that the external switch furthest from the 615 IED loop is assigned as the root switch (bridge priority = 0) and the bridge priority increases towards the IED loop. The end links of the IED loop can be attached to the same external switch or to two adjacent external switches. Self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all IEDs.

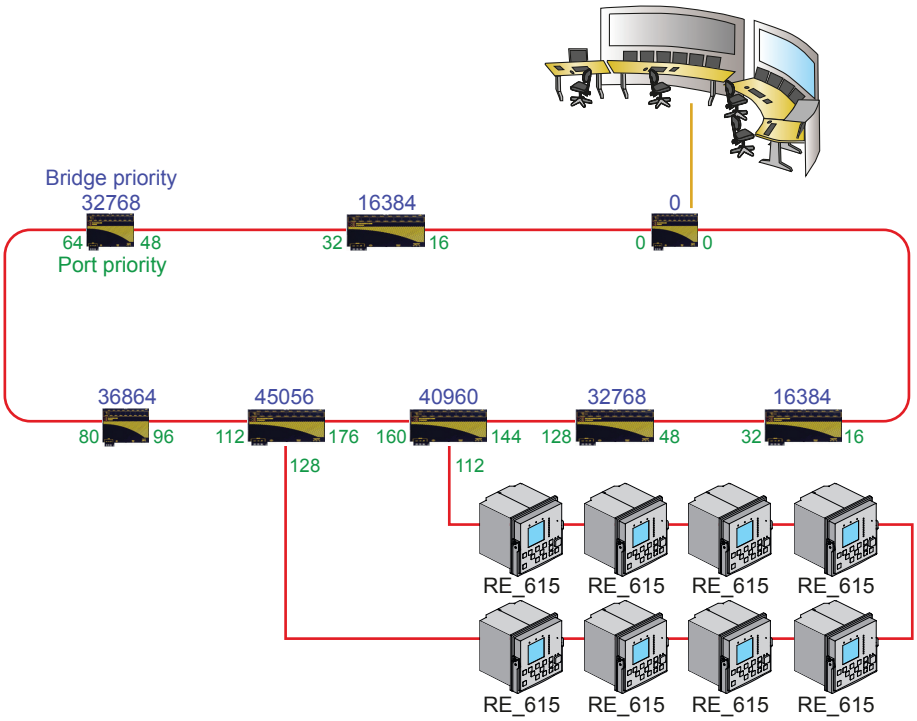

Figure 5: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to thirty 615 series IEDs. If more than 30 IEDs are to be connected, it is recommended that the network is split into several rings with no more than 30 IEDs per ring.

Section 3 REM615 standard configurations

3.1 Standard configuration

REM615 is available in three 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 IED 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 IED configuration can be adapted to user-specific application requirements.

Table 8: Standard configuration

Description	Std.conf.
Motor protection, optional RTD/mA inputs	A
Motor protection with current, voltage and frequency based protection and measurement functions, optional RTD/mA inputs	B
Motor protection with current, voltage and frequency based protection and measurements functions	C

Table 9: Supported functions

Functionality	A	B	C
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	●	●	●
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	●	●	●
Non-directional earth-fault protection, low stage, instance 1	●1)	-	-
Non-directional earth-fault protection, high stage, instance 1	●1)	●2)	●2)
Directional earth-fault protection, low stage, instance 1	-	●1)3)	●1)4)
Three-phase undervoltage protection, instance 1	-	●	●
Positive-sequence undervoltage protection, instance 1	-	●	●
Negative-sequence overvoltage protection, instance 1	-	●	●
Frequency protection, instance 1	-	●	●
Frequency protection, instance 2	-	●	●
Negative-sequence overcurrent protection for motors, instance 1	●	●	●
Negative-sequence overcurrent protection for motors, instance 2	●	●	●
Loss of load supervision	●	●	●

Table continues on next page

Functionality	A	B	C
Motor load jam protection	●	●	●
Motor start-up supervision	●	●	●
Phase reversal protection	●	●	●
Thermal overload protection for motors	●	●	●
Circuit breaker failure protection	●	●	●
Master trip, instance 1	●	●	●
Master trip, instance 2	●	●	●
Arc protection, instance 1	o	o	o
Arc protection, instance 2	o	o	o
Arc protection, instance 3	o	o	o
Multi-purpose protection, instance 1[5)]	o	o	-
Multi-purpose protection, instance 2[5)]	o	o	-
Multi-purpose protection, instance 3[5)]	o	o	-
Multi-purpose protection, instance 4[5)]	o[6)]	o[6)]	-
Multi-purpose protection, instance 5[5)]	o[6)]	o[6)]	-
Multi-purpose protection, instance 6[5)]	o[6)]	o[6)]	-
Control			
Circuit-breaker control	●[6)]	●[6)]	●[6)]
Disconnector control, instance 1	●[6)]	●[6)]	●[6)]
Disconnector control, instance 2	●[6)]	●[6)]	●[6)]
Earthing switch control	●[6)]	●[6)]	●[6)]
Disconnector position indication, instance 1	●[6)]	●[6)]	●
Disconnector position indication, instance 2	●[6)]	●[6)]	●[6)]
Disconnector position indication, instance 3	●[6)]	●[6)]	●[6)]
Earthing switch indication, instance 1	●[6)]	●[6)]	●
Earthing switch indication, instance 2	●[6)]	●[6)]	●[6)]
Emergency startup	●	●	●
Condition monitoring			
Circuit-breaker condition monitoring	●	●	●
Trip circuit supervision, instance 1	●	●	●
Trip circuit supervision, instance 2	●	●	●
Current circuit supervision	●	●	●
Fuse failure supervision	-	●	●
Runtime counter for machines and devices	●	●	●
Measurement			
Disturbance recorder	●	●	●
Three-phase current measurement, instance 1	●	●	●
Sequence current measurement	●	●	●
Residual current measurement, instance 1	●	●	●

Table continues on next page

Functionality	A	B	C
Three-phase voltage measurement	-	●	●
Residual voltage measurement	-	-	●
Sequence voltage measurement	-	●	●
Three-phase power and energy measurement	-	●	●
RTD/mA measurement	o	o	-
Frequency measurement	-	●	●
● = included, o = optional at the time of order			

1) I_0 selectable by parameter, I_0 measured as default
2) I_0 selectable by parameter, I_0 calculated as default.
3) U_0 calculated and negative sequence voltage selectable by parameter, U_0 calculated as default
4) U_0 selectable by parameter, U_0 measured as default
5) Multi-purpose protection is used for, for example, RTD/mA based protection.
6) Available in IED and SMT but not connected to anything in logic.

3.1.1 Addition of control functions for primary devices and the use of binary inputs and outputs

If extra control functions intended for controllable primary devices are added to the configuration, additional binary inputs and/or outputs are needed to complement the standard configuration.

If the number of inputs and/or outputs in a standard configuration is not sufficient, it is possible either to modify the chosen IED 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 IED.

The external I/O module's binary inputs and outputs of 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 IED's standard configuration.

The suitability of the IED's binary outputs which have been selected for primary device control should be carefully verified, for example make and carry and breaking capacity. If the requirements for the primary device control circuit are not met, using external auxiliary relays should be considered.

3.2 Connection diagrams

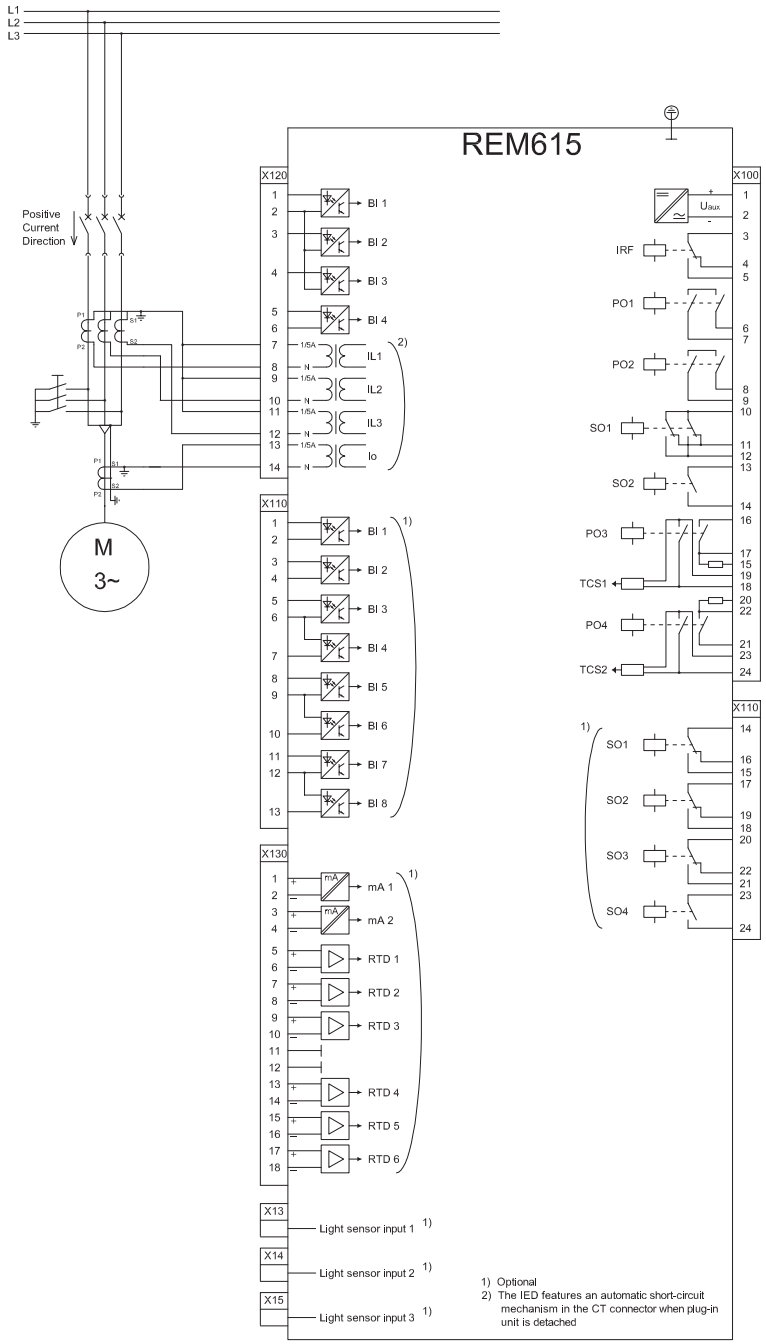

Figure 6: Connection diagram for the A configuration

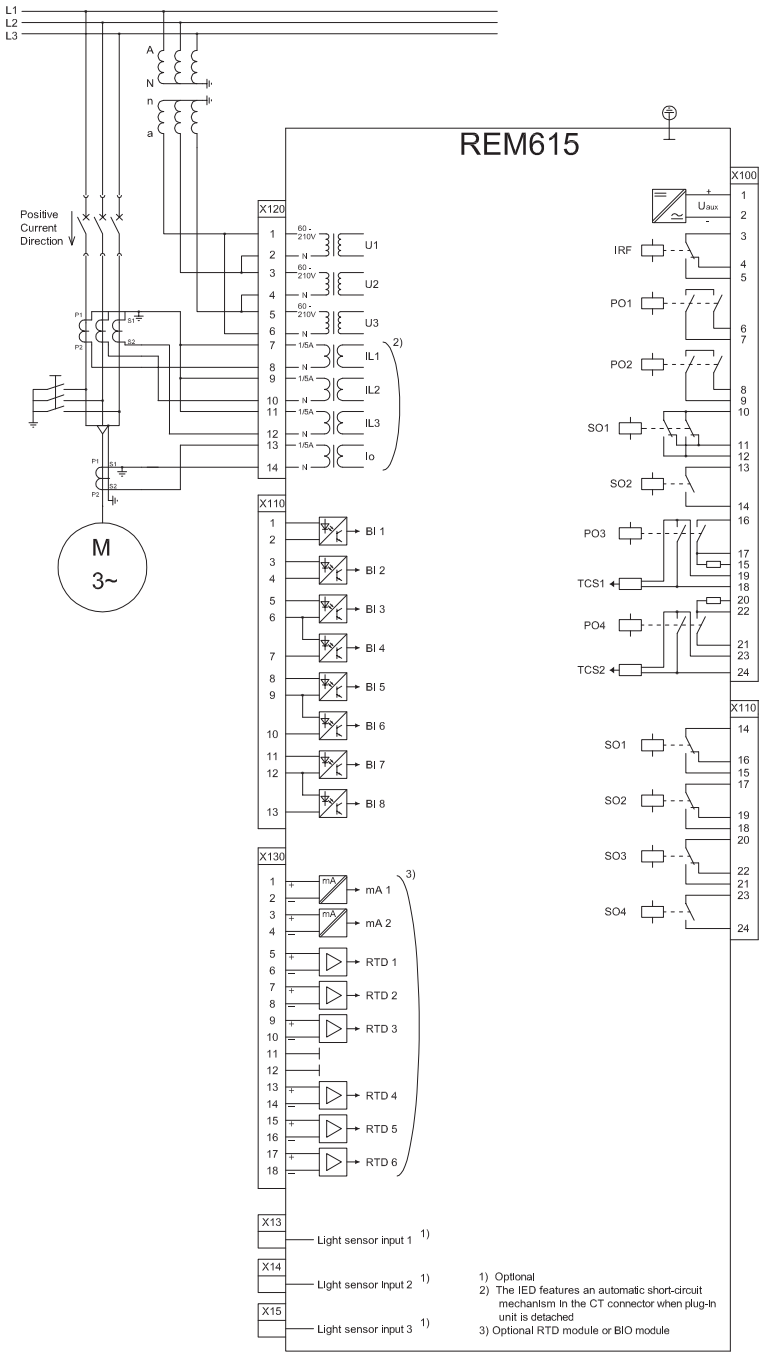

Figure 7: Connection diagram for the B configuration

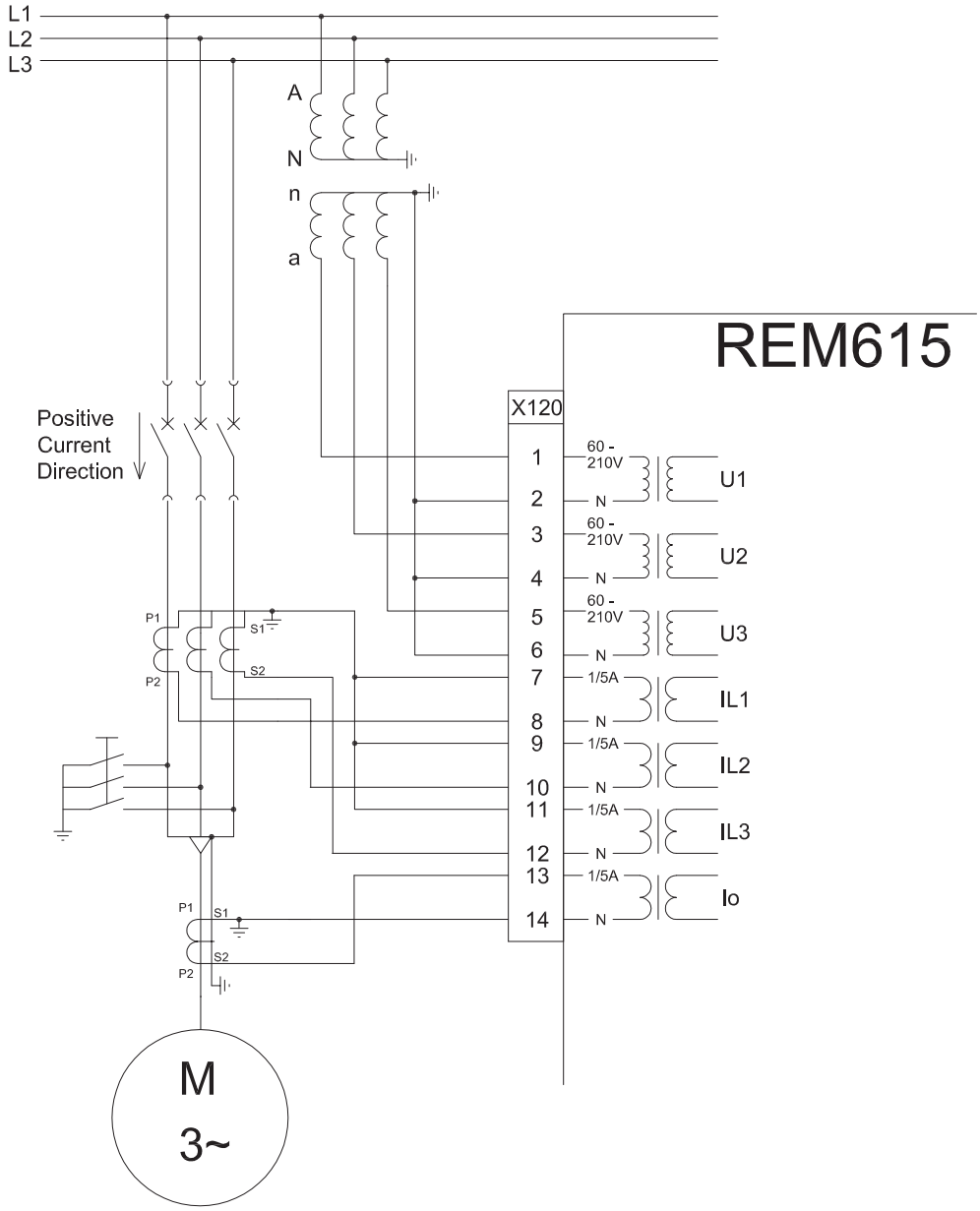

Figure 8: Connection diagram for the B configuration (motor protection with phase-to-earth voltage measurement)

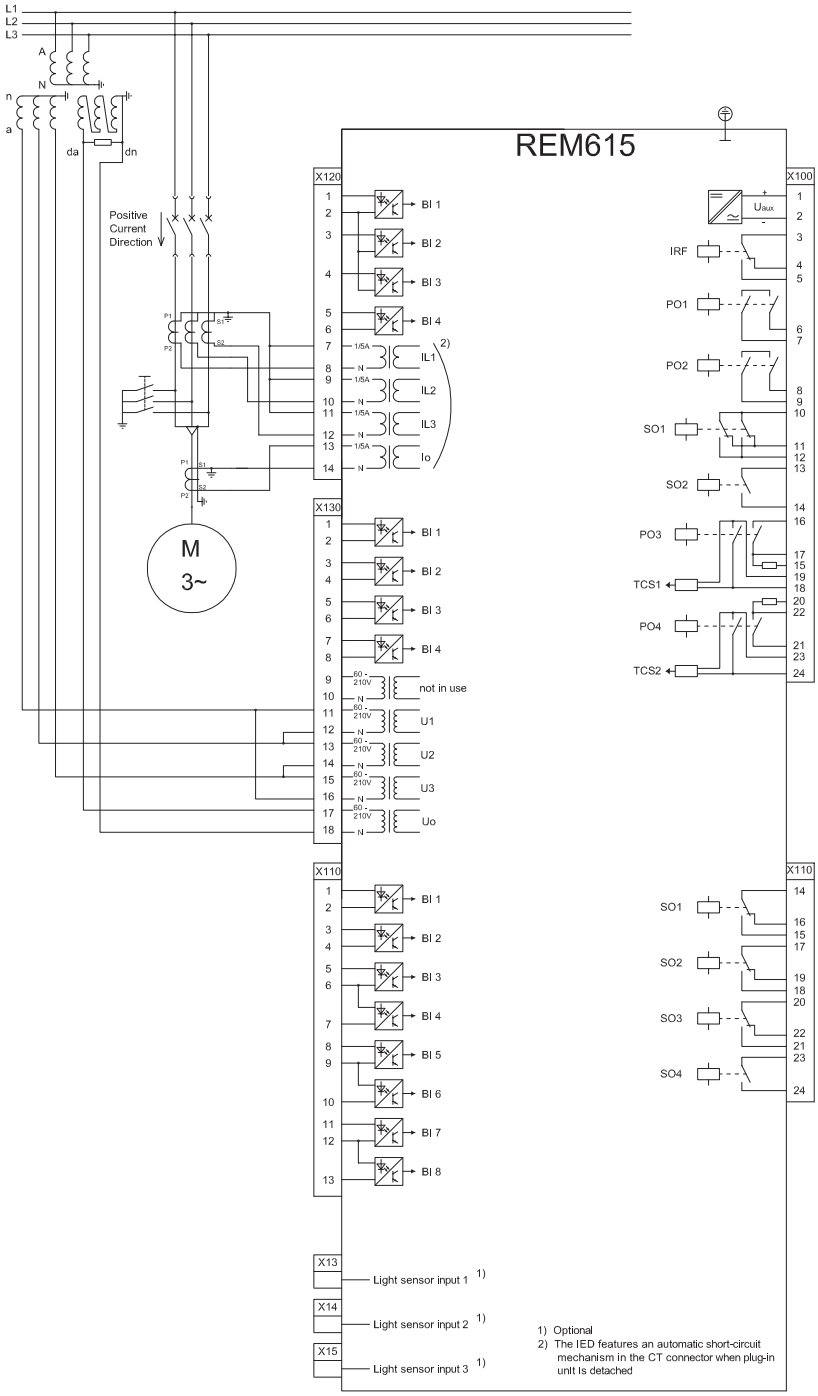

Figure 9: Connection diagram for the C configuration

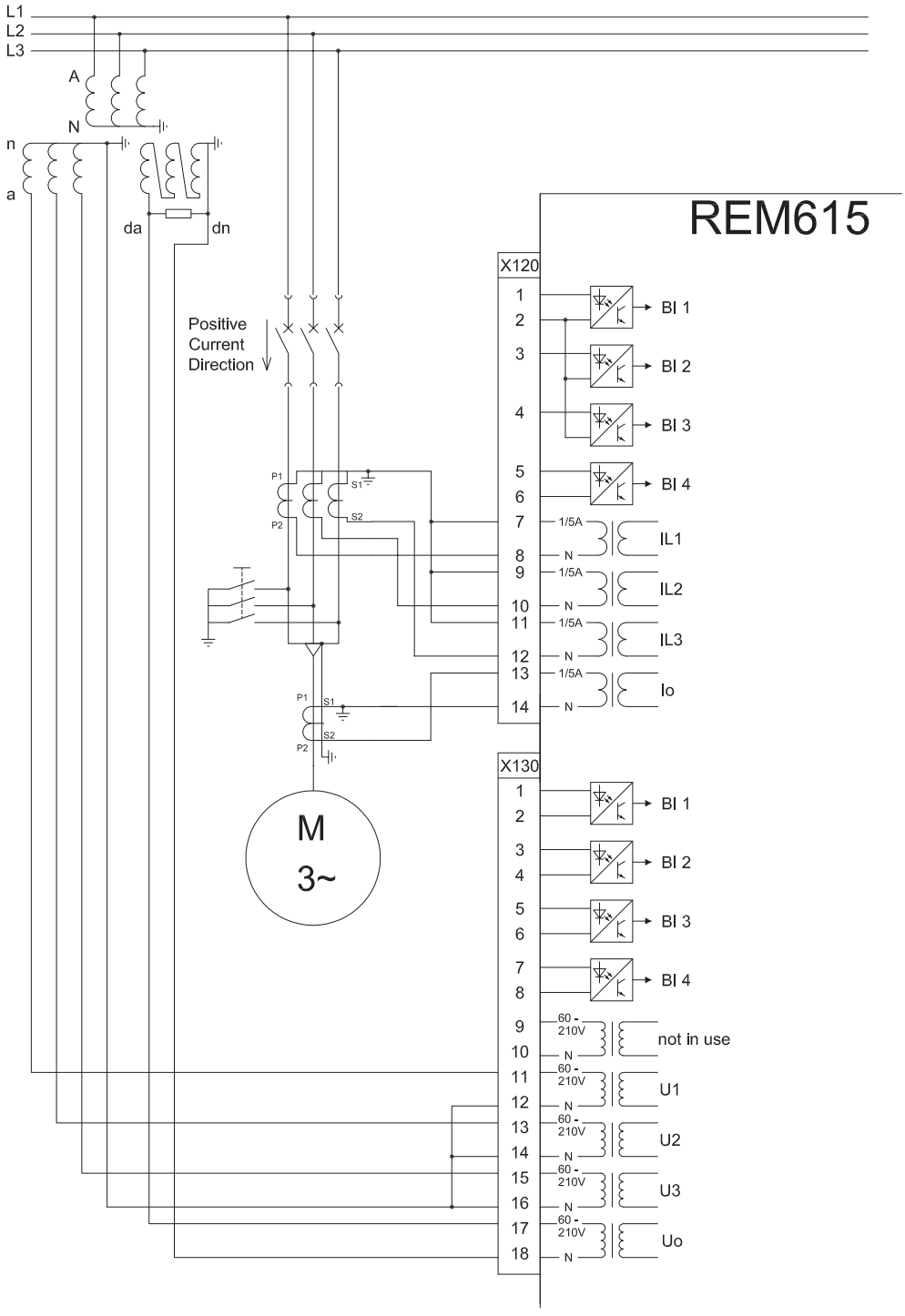

Figure 10: Connection diagram for the C configuration (motor protection with phase-to-earth voltage measurement)

3.3 Presentation of standard configurations

Functional diagrams

The functional diagrams describe the IED's functionality from the protection, measuring, condition monitoring, disturbance recording, control and interlocking perspective. Diagrams show the default functionality with simple symbol logics forming principle diagrams. The external connections to primary devices are also shown, stating the default connections to measuring transformers. The positive measuring direction of directional protection functions is towards the outgoing feeder.

The functional diagrams are divided into sections with each section constituting one functional entity. The external connections are also divided into sections. Only the relevant connections for a particular functional entity are presented in each section.

Protection function blocks are part of the functional diagram. They are identified based on their IEC 61850 name but the IEC based symbol and the ANSI function number are also included. Some function blocks, such as PHHPTOC, are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name, IEC symbol and ANSI function number are appended with a running number, that is an instance number, from one upwards. If the block has no suffix after the IEC or ANSI symbol, the function block has been used, that is, instantiated, only once. The IED’s internal functionality and the external connections are separated with a dashed line presenting the IED’s physical casing.

Signal Matrix and Application Configuration

With Signal Matrix and Application Configuration in PCM600, it is possible to modify the standard configuration according to the actual needs. The IED 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. The Signal Matrix is used for GOOSE signal input engineering and for making cross-references between the physical I/O signals and the function blocks. The Signal Matrix tool cannot be used for adding or removing function blocks, for example, GOOSE receive function blocks. The Application Configuration tool is used for these kind of operations. If a function block is removed with Application Configuration, the function related data disappears from the menus as well as from the 61850 data model, with the exception of some basic function blocks, which are mandatory and thus cannot be removed from the IED configuration by removing them from the Application Configuration.

3.4 Standard configuration A

3.4.1 Applications

The standard configuration 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 IED 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 IED 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

Table 10: Functions included in the standard configuration A

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection for motors, instance 1	MNSPTOC1	I2>M (1)	46M (1)
Negative-sequence overcurrent protection for motors, instance 2	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Multi-purpose protection, instance 1	MAPGAPC1	MAP (1)	MAP (1)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Multi-purpose protection, instance 2	MAPGAPC2	MAP (2)	MAP (2)
Multi-purpose protection, instance 3	MAPGAPC3	MAP (3)	MAP (3)
Multi-purpose protection, instance 4	MAPGAPC4	MAP (4)	MAP (4)
Multi-purpose protection, instance 5	MAPGAPC5	MAP (5)	MAP (5)
Multi-purpose protection, instance 6	MAPGAPC6	MAP (6)	MAP (6)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Emergergency startup	ESMGAPC1	ESTART	ESTART
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
RTD/mA measurement	XRGGIO130	X130 (RTD)	X130 (RTD)

3.4.2.1 Default I/O connections

Table 11: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	Emergency start	X120-1,2
X120-BI2	Circuit breaker closed	X120-3,2
X120-BI3	Circuit breaker open	X120-4,2
X120-BI4	External restart inhibit	X120-5,6

Table 12: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Restart enable	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Open command (for contactor applications)	X100-10,11,(12)
X100-SO2	Start indication	X100-13,14
X100-PO3	Open circuit breaker/trip	X100-15-19
X100-PO4	Close circuit breaker	X100-20-24

Table 13: Default connections for RDT/mA inputs

RTD/mA input	Default usage	Connector pins
X130-AI1		X130-1,2
X130-AI2		X130-3,4
X130-AI3	Motor winding U temperature	X130-5,6,11c
X130-AI4	Motor winding V temperature	X130-7,8,11c
X130-AI5	Motor winding W temperature	X130-9,10,11c
X130-AI6	Motor cooling air temperature	X130-13,14,12c
X130-AI7	Motor bearing temperature	X130-15,16,12c
X130-AI8	Motor ambient temperature	X130-17,18,12c

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
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 15: Default analog channel selection and text settings

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

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

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, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a core balance current transformer.

3.4.3.1 Functional diagrams for protection

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

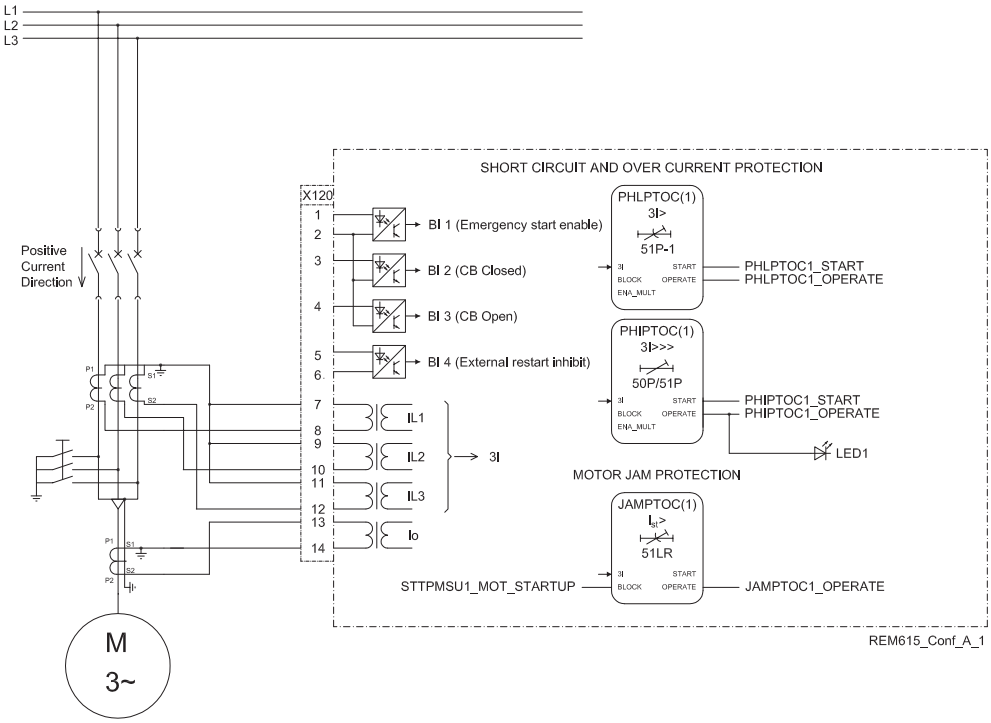

Figure 11: Overcurrent protection

Two overcurrent stages are offered for overcurrent and short-circuit protection. The motor jam protection function (JAMPTOC1) is blocked by the motor startup protection function. PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the 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.

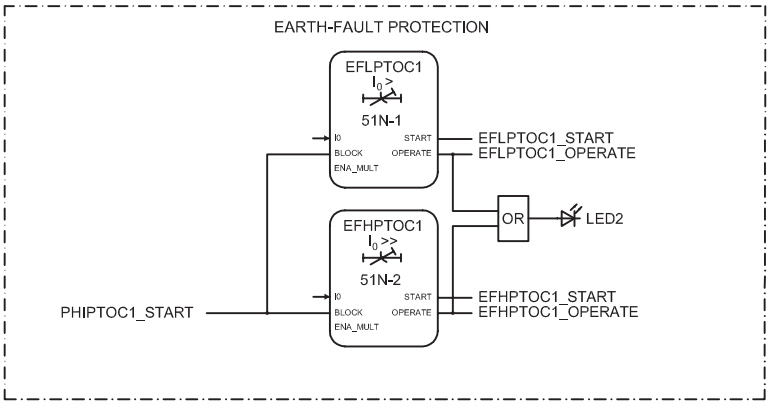

Figure 12: Non-directional earth-fault protection

Two non-directional earth-fault stages (EFLPTOC1 and EFHPTOC1) are offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing.

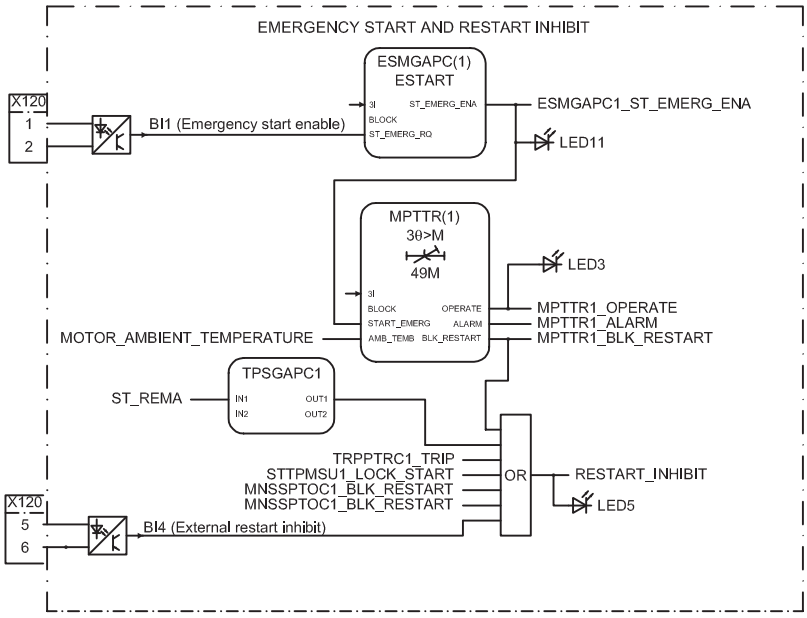

Figure 13: Emergency start and restart inhibit

The emergency start function (ESMGAPC1) allows motor startups although the calculated thermal level or cumulative startup time counter are 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:

- Calculated thermal level in MPTTR1 is set slightly below the restart inhibit level to allow at least one motor startup
- Value of the cumulative startup time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor startup
- 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 of ten minutes has expired.

The thermal overload protection function (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. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor.

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 circuit breaker opening. Reclosing after a too short period

of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1.

The restart inhibit is also activated when there is:

- An active trip command or
- Motor startup supervision has issued lockout or
- Motor unbalance function has issued restart blocking or
- An external restart inhibit is activated by a binary input (X120:BI4).

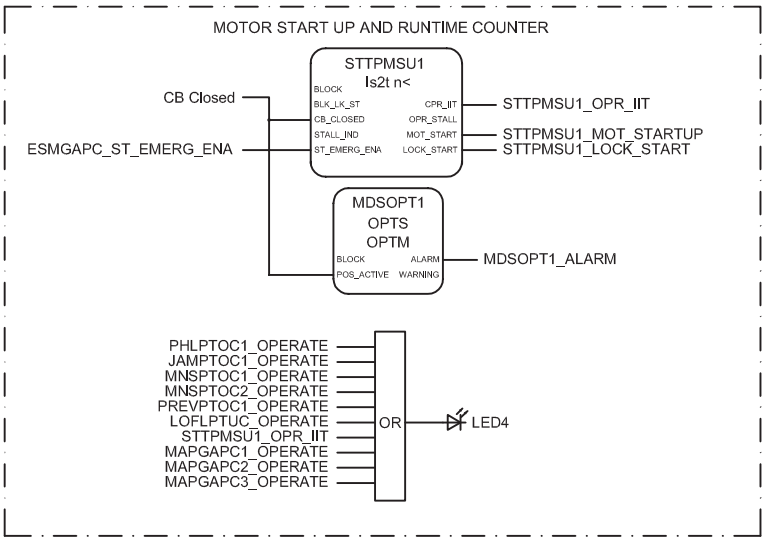

Figure 14: Motor startup supervision

With the motor startup 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 motor running time counter (MDSOPT1) provides history data since last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 9.

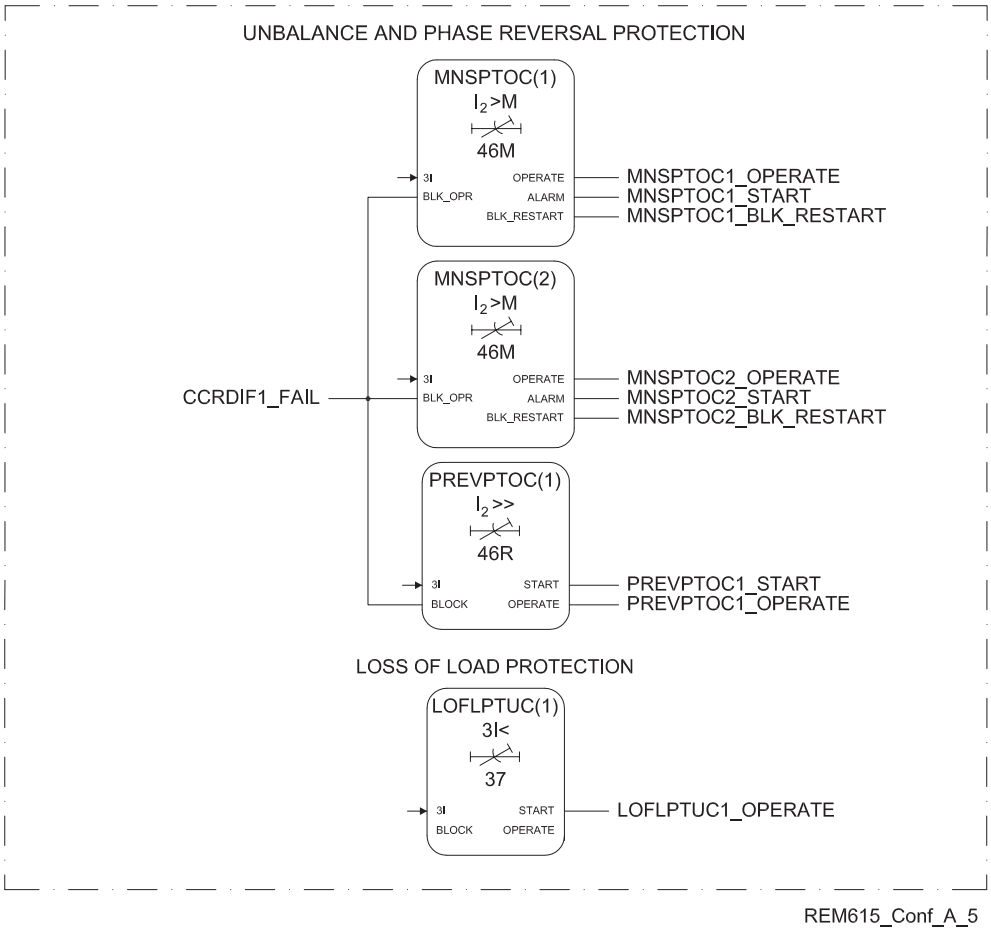

Figure 15: Phase unbalance protection

Two negative-sequence overcurrent stages (MNSPTOC1 and MNSPTOC2) are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The phase reversal protection (PREVPTOC1) is based on the calculated negative phase-sequence current. It detects too high NPS 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 protection and phase reversal protection are blocked if the current circuit supervision detects failure in the current measuring circuit.

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

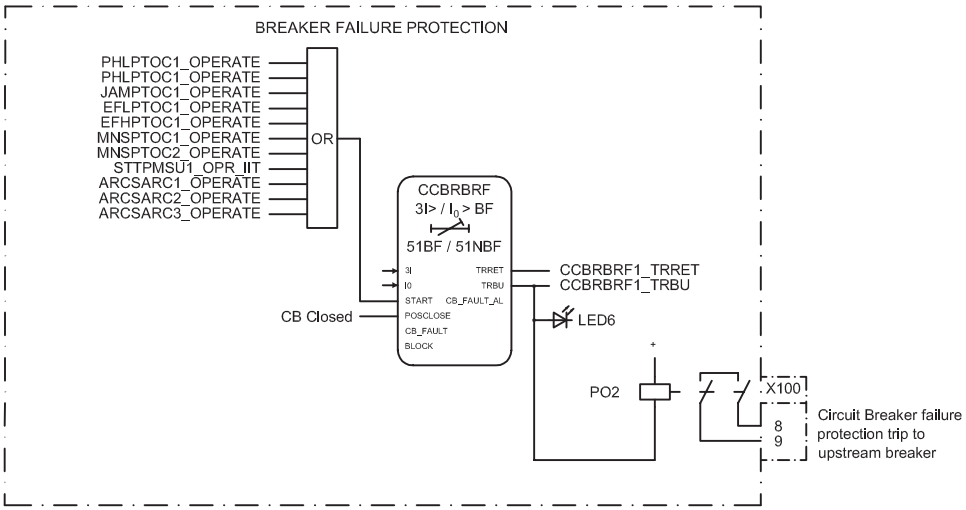

Figure 16: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip 1 again. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

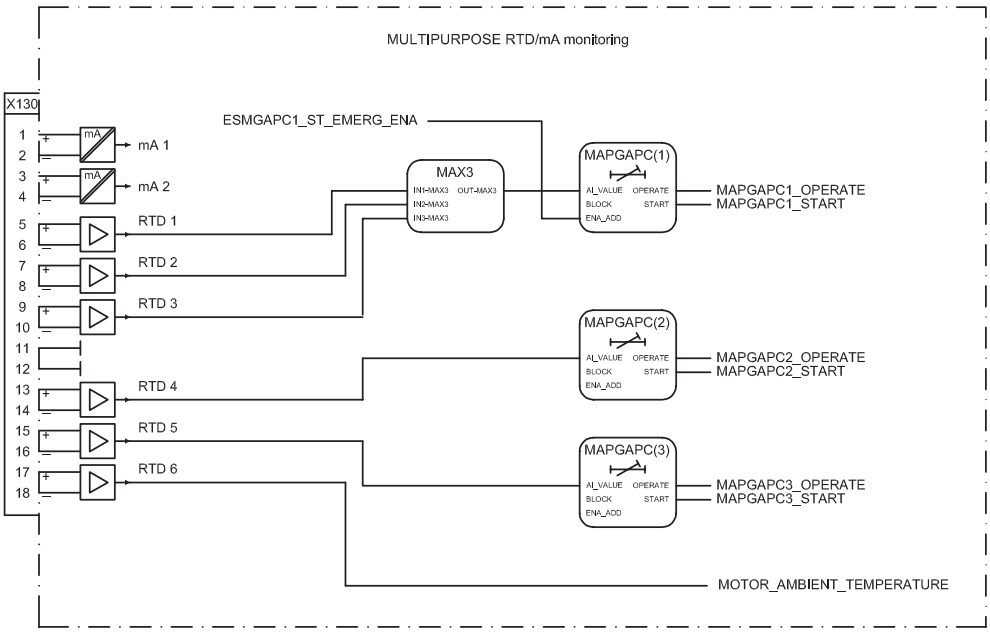

Figure 17: Multipurpose RTD/mA monitoring

RTD/mA monitoring functionality provides several temperature measurements for motor protection. Temperature of the motor windings U, V and W are measured with inputs RTD1 (X130-5,6,11c), RTD2 (X130-7,8,11c) and RTD3 (X130-9,10,11c). Measured values are connected from function X130 (RTD) to function MAX3. Maximum temperature value is then connected to the multipurpose analog protection block MAPGAPC1.

Motor cooling air temperature and motor bearing temperature can be measured with inputs RTD4 (X130-13,14,12c) and RTD5 (X130-15,16,12c). The protection functionality from these temperatures are provided by MAPGAPC2 and MAPGAPC3 functions.

Motor ambient temperature can be measured with input RTD6 (X130-17,18,12c) and it is connected to the thermal overload protection function (MPTTR1).

The operation signals are connected to alarm LED 4.

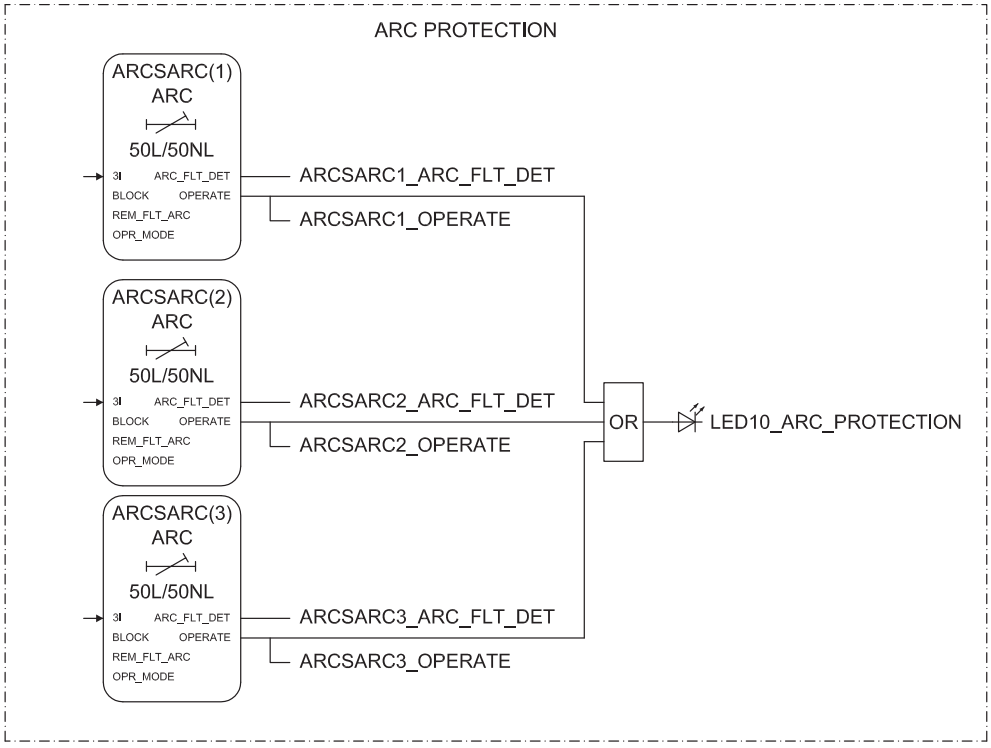

Figure 18: Arc protection

Arc protection (ARCSARC1...3) is 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 signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

3.4.3.2 Functional diagrams for disturbance recorder and supervision functions

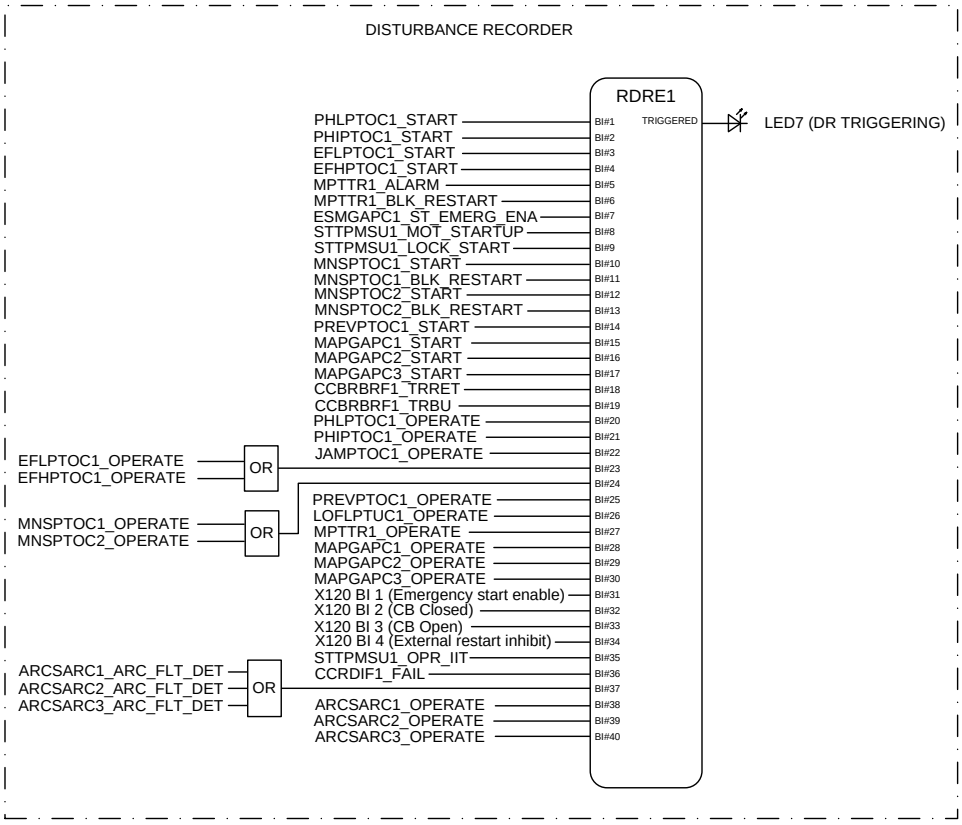

Figure 19: Disturbance recorder

All start and operate signals 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 ARC protection signals and 4 binary inputs are also connected.

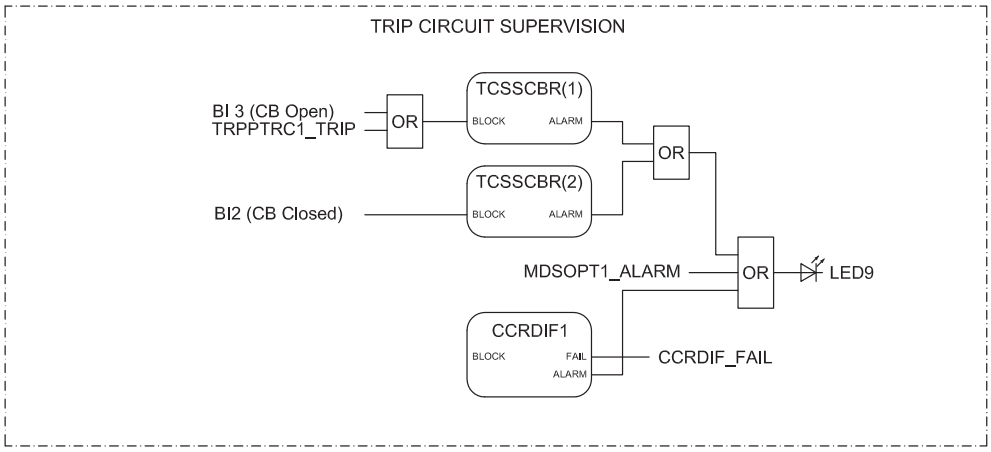

Figure 20: Supervision functions

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) for Master Trip and TCSSCBR2 for PO4 (X100:20-24) for circuit breaker closing. The trip circuit supervision 1 is blocked by the Master Trip (TRPPTRC1) and the circuit-breaker open position signal. The trip circuit supervision 2 is used for circuit breaker closing and therefore blocked when the circuit breaker is closed. The trip circuit supervision alarm indication is connected to LED 9.

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

The motor runtime counter alarm is connected also to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.4.3.3 Functional diagrams for control and interlocking

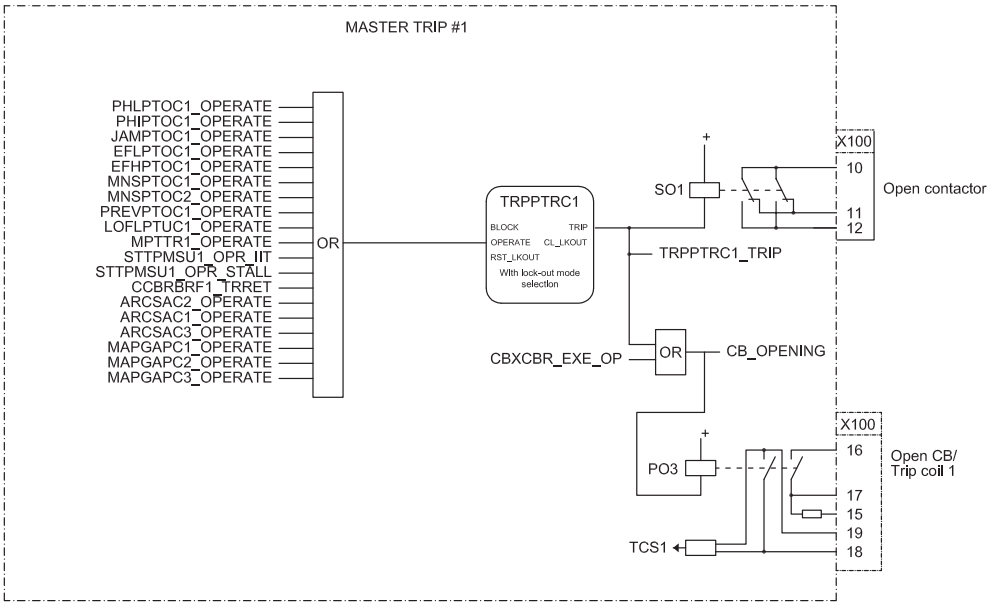

Figure 21: Master Trip

The operate signals from the protections are connected to the trip output contact PO3 (X100:15-19) via the corresponding Master Trip (TRPPTRC1). Open control commands to the circuit breaker from the local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

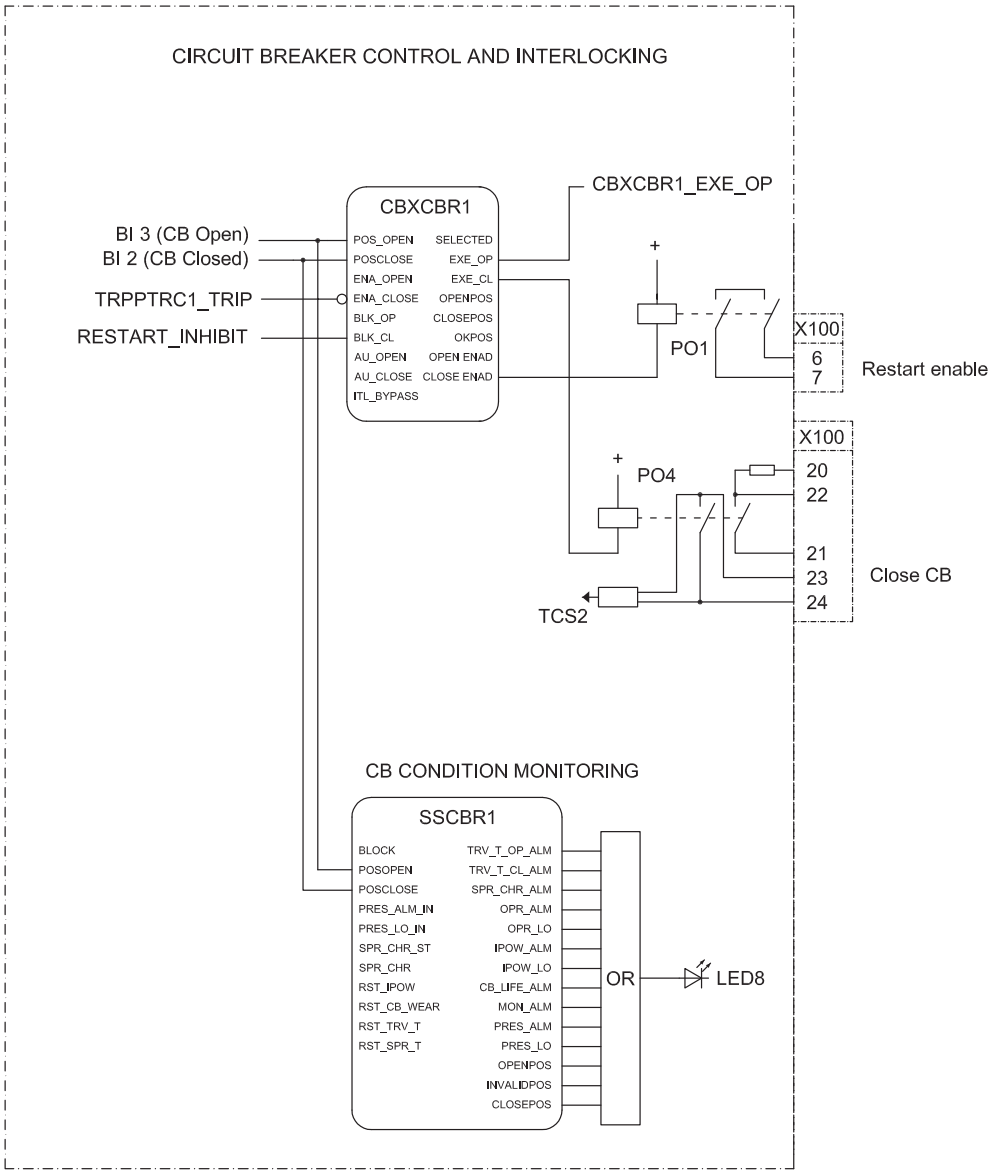

Figure 22: Circuit breaker control

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the master trip logics. The open operation is always enabled.

When the motor restart is inhibited, the BLK_CLOSE input is activated and closing of the breaker is not possible. When all conditions of the circuit breaker closing are fulfilled, the CLOSE_ENAD output of the CBXCBR1 is activated and PO1 output (X100:6-7) is closed.

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block CBXCBR with

PCM600, the function assumes that the breaker close commands are allowed continuously.

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

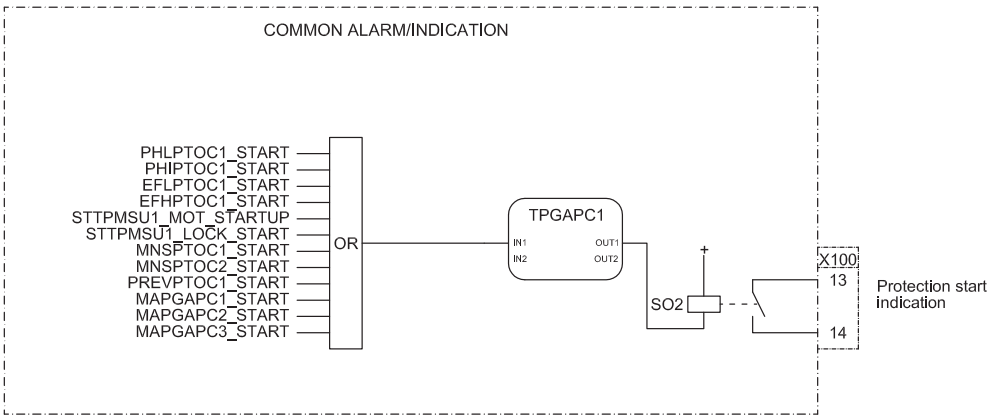

Figure 23: Common alarm/indication

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO2 (X100:13-14)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.5 Standard configuration B

3.5.1 Applications

The standard configuration 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. There is also an option for RTD/mA measurement and protection.

The IED 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 IED 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

Table 16: Functions included in the standard configuration B

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O- (1)
Frequency protection, instance 1	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
Frequency protection, instance 2	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
Negative-sequence overcurrent protection for motors, instance 1	MNSPTOC1	I2>M (1)	46M (1)
Negative-sequence overcurrent protection for motors, instance 2	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Multi-purpose protection, instance 1	MAPGAPC1	MAP (1)	MAP (1)
Multi-purpose protection, instance 2	MAPGAPC2	MAP (2)	MAP (2)
Multi-purpose protection, instance 3	MAPGAPC3	MAP (3)	MAP (3)
Multi-purpose protection, instance 4	MAPGAPC4	MAP (4)	MAP (4)
Multi-purpose protection, instance 5	MAPGAPC5	MAP (5)	MAP (5)
Multi-purpose protection, instance 6	MAPGAPC6	MAP (6)	MAP (6)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Emergergency startup	ESMGAPC1	ESTART	ESTART
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
RTD/mA measurement	XRGGIO130	X130 (RTD)	X130 (RTD)
Frequency measurement	FMMXU1	f	f

3.5.2.1 Default I/O connections

Table 17: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	External restart inhibit	X110-1,2
X110-BI2	External trip	X110-3,4
X110-BI3	Circuit breaker closed	X110-5,6
X110-BI4	Circuit breaker open	X110-7,6
X110-BI5	Voltage transformer secondary MCB open	X110-8,9

Table continues on next page

Binary input	Description	Connector pins
X110-BI6	Emergency start	X110-10,9
X110-BI7	Lockout reset	X110-11,12
X110-BI8	Setting group change	X110-13,12

Table 18: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Restart enable	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Open command (for contactor applications)	X100-10,11,(12)
X100-SO2	Start indication	X100-13,14
X100-PO3	Open circuit breaker/trip	X100-15-19
X100-PO4	Close circuit breaker	X100-20-24
X110-SO1	Motor startup indication	X110-14,15,16
X110-SO2	Thermal overload alarm	X110-17,18,19
X110-SO3	Voltage protection alarm	X110-20,21,22
X110-SO4	Start indication	X110-23,24

Table 19: Default connections for RDT/mA inputs

RTD/mA input	Default usage	Connector pins
X130-AI1		X130-1,2
X130-AI2		X130-3,4
X130-AI3	Motor winding U temperature	X130-5,6,11c
X130-AI4	Motor winding V temperature	X130-7,8,11c
X130-AI5	Motor winding W temperature	X130-9,10,11c
X130-AI6	Motor cooling air temperature	X130-13,14,12c
X130-AI7	Motor bearing temperature	X130-15,16,12c
X130-AI8	Motor ambient temperature	X130-17,18,12c

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

Table continues on next page

LED	Description
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 21: Default analog channel selection and text settings

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

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

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, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED’s standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder’s parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer.

The EFHPTOC protection function block for non-directional earth-faults uses the calculated residual current originating from the measured phase currents.

3.5.3.1 Functional diagrams for protection

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

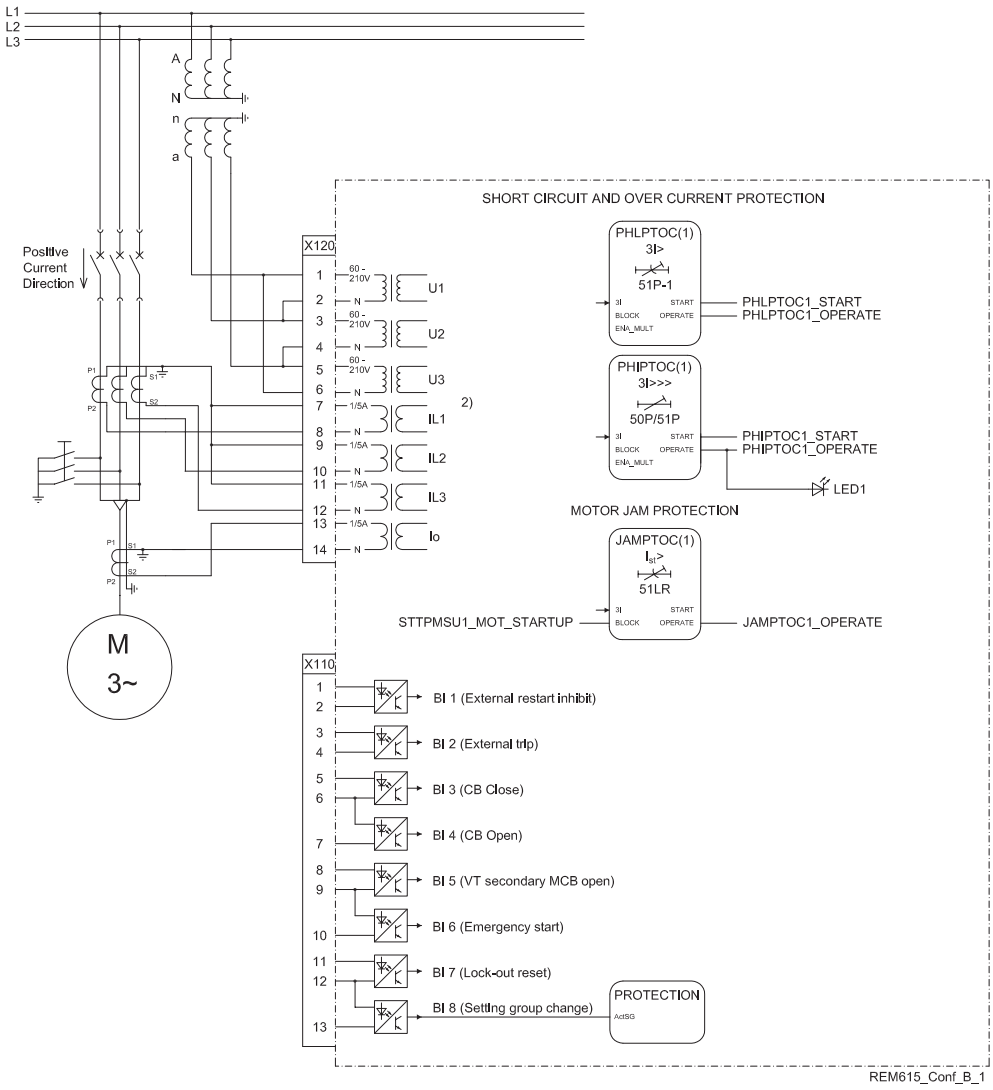

Figure 24: Overcurrent protection

Two overcurrent stages are offered for overcurrent and short-circuit protection. The motor jam protection function (JAMPTOC1) is blocked by the motor startup protection function. PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the 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.

Depending on the selected operation mode, the active setting group can be changed either with a parameter or via binary input.

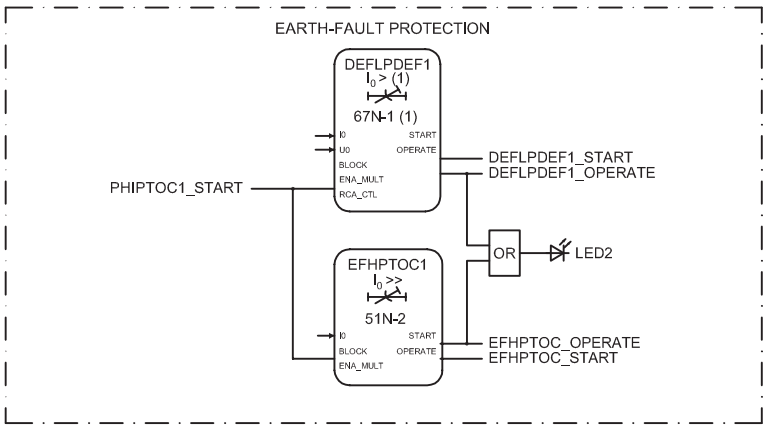

Figure 25: Non-directional earth-fault protection

One stage non-directional earth-fault protection (EFHPTOC1) is offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing. In addition, there is a directional protection stage (DEFLPDEF1) which can be also 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 startup.

The earth- fault protection is blocked when the short circuit protection (PHIPTOC1) is started. The operation of the earth-fault protection functions is connected to alarm LED 2.

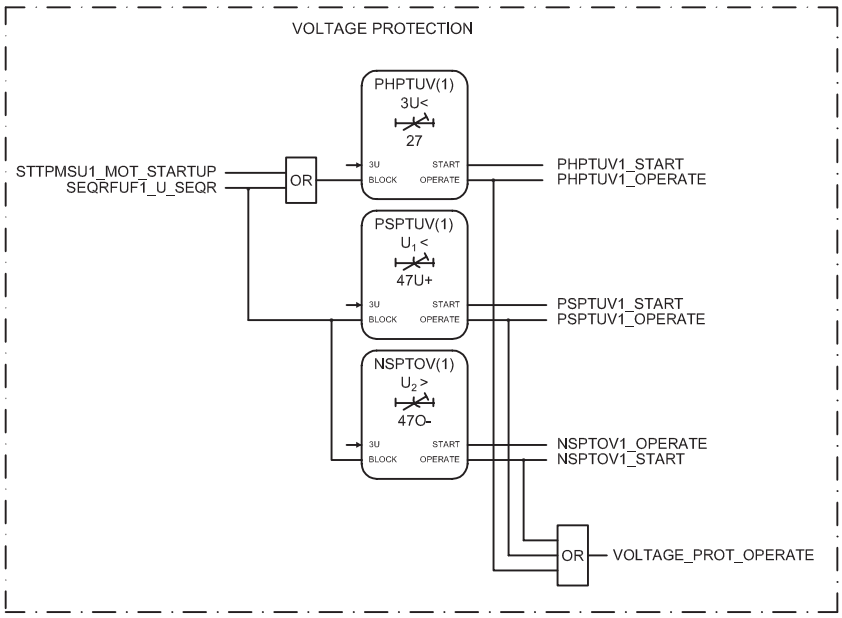

Figure 26: Voltage protection

For voltage protection three-phase undervoltage (PHPTUV1), positive-sequence undervoltage (PSPTUV1) and negative-sequence overvoltage (NSPTOV1) protection functions are offered. The three-phase undervoltage protection is blocked during motor startup to prevent unwanted operation in case there is a short voltage drop. Also if the fuse failure is detected, the undervoltage function is blocked.

The positive-sequence undervoltage and negative-sequence overvoltage protections are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order. The positive-sequence undervoltage and negative-sequence overvoltage functions are blocked by default if the fuse failure is detected.

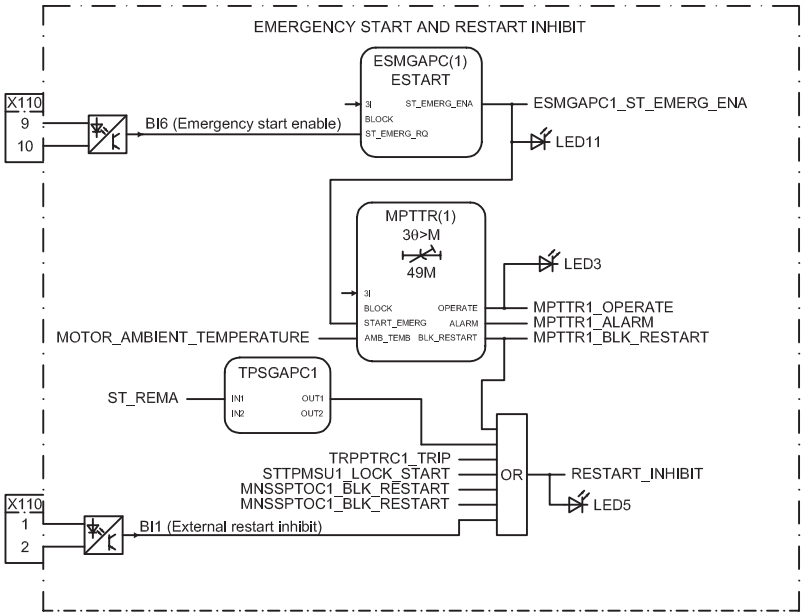

Figure 27: Emergency start and restart inhibit

The emergency start function (ESMGAPC1) allows motor startups although the calculated thermal level or cumulative startup time counter are 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:

- Calculated thermal level in MPTTR1 is set slightly below the restart inhibit level to allow at least one motor startup
- Value of the cumulative startup time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor startup
- 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 of ten minutes has expired.

The thermal overload protection function (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. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor.

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 circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1.

The restart inhibit is also activated when there is:

- An active trip command or
- Motor startup supervision has issued lockout or
- Motor unbalance function has issued restart blocking or
- An external restart inhibit is activated by a binary input (X120:BI4).

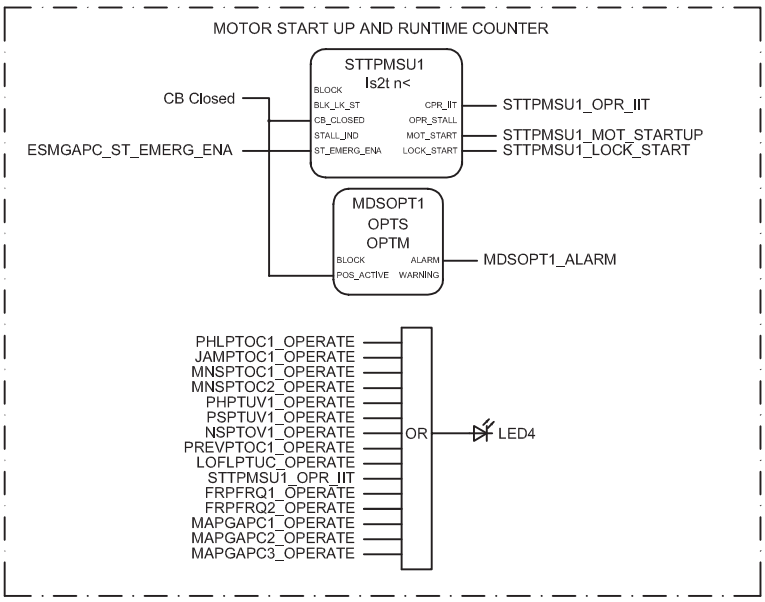

Figure 28: Motor startup supervision

With the motor startup 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 startup is connected to the output SO1 (X110:14-15-16). The output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

The motor running time counter (MDSOPT1) provides history data since last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 9.

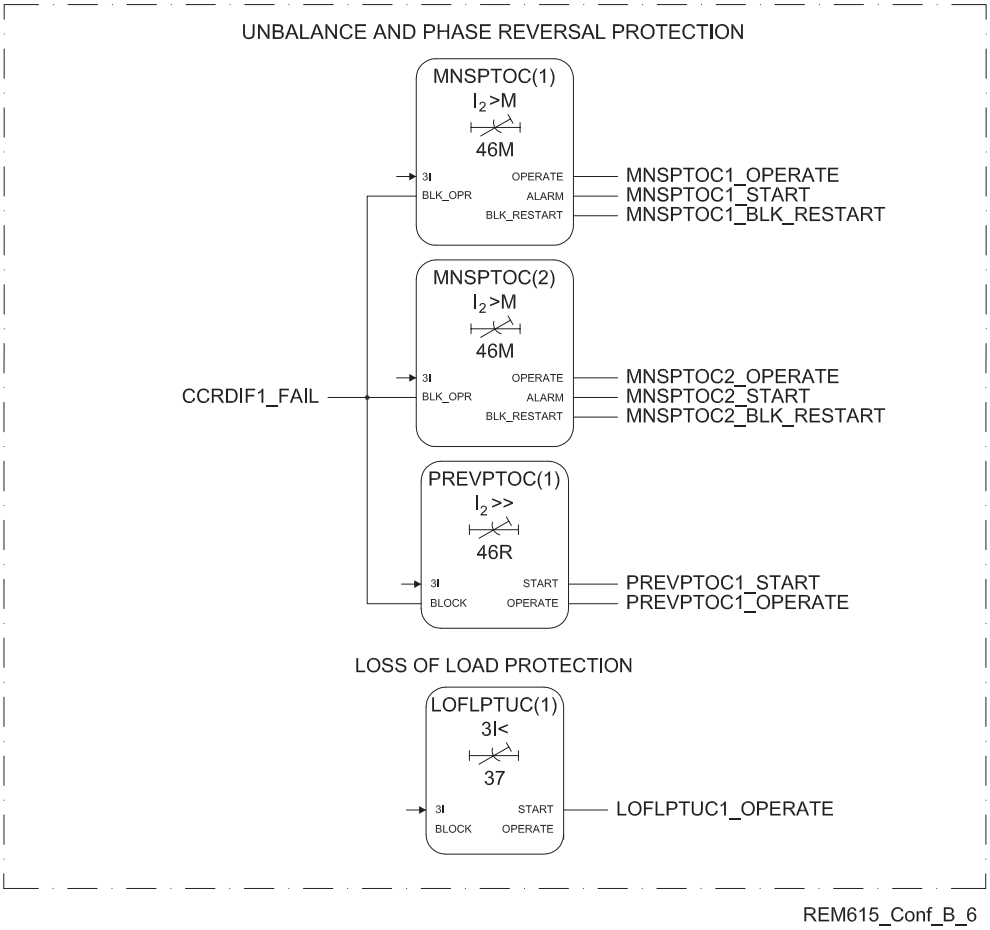

Figure 29: Phase unbalance protection

Two negative-sequence overcurrent stages (MNSPTOC1 and MNSPTOC2) are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The phase reversal protection (PREVPTOC1) is based on the calculated negative phase-sequence current. It detects too high NPS 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 protection and phase reversal protection are blocked if the current circuit supervision detects failure in the current measuring circuit.

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

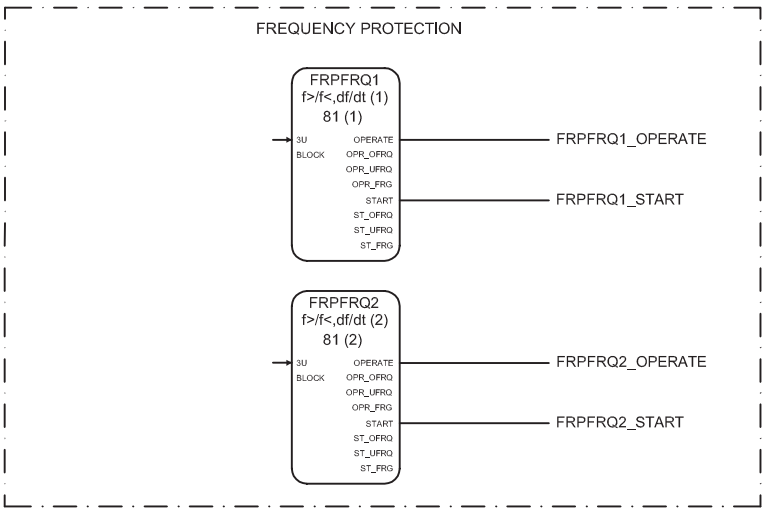

Figure 30: Frequency failure protection

The selectable underfrequency or overfrequency protection (FRPFRQ) prevents damage to network components under unwanted frequency conditions.

The function contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. The operation signal is connected to alarm LED 4.

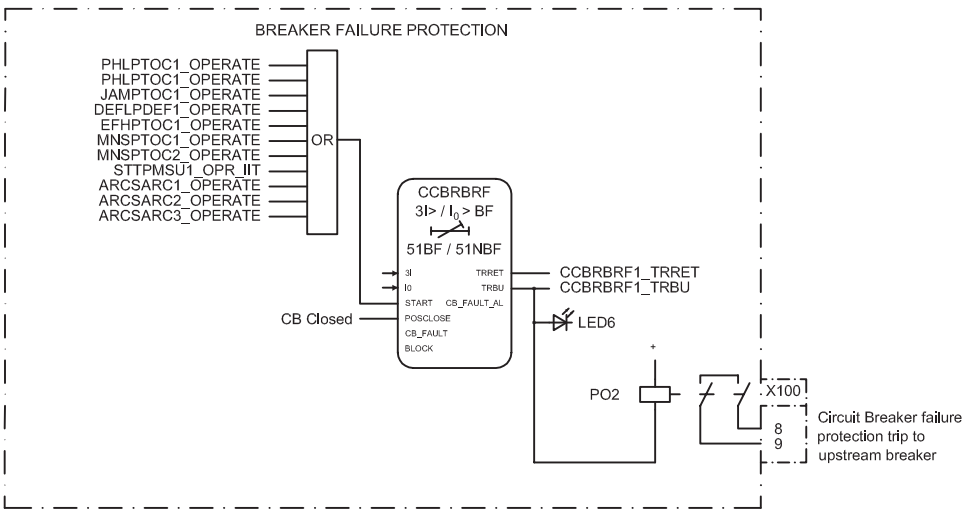

Figure 31: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip 1 again. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

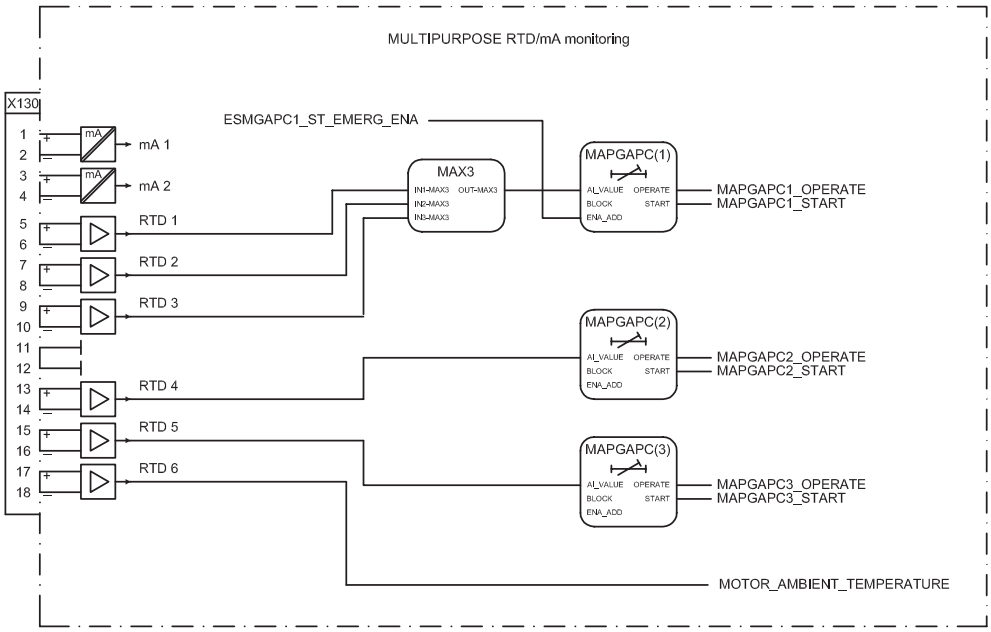

Figure 32: Multipurpose RTD/mA monitoring

RTD/mA monitoring functionality provides several temperature measurements for motor protection. Temperature of the motor windings U, V and W are measured with inputs RTD1 (X130-5,6,11c), RTD2 (X130-7,8,11c) and RTD3 (X130-9,10,11c). Measured values are connected from function X130 (RTD) to function MAX3. Maximum temperature value is then connected to the multipurpose analog protection block MAPGAPC1.

Motor cooling air temperature and motor bearing temperature can be measured with inputs RTD4 (X130-13,14,12c) and RTD5 (X130-15,16,12c). The protection functionality from these temperatures are provided by MAPGAPC2 and MAPGAPC3 functions.

Motor ambient temperature can be measured with input RTD6 (X130-17,18,12c) and it is connected to the thermal overload protection function (MPTTR1).

The operation signals are connected to alarm LED 4.

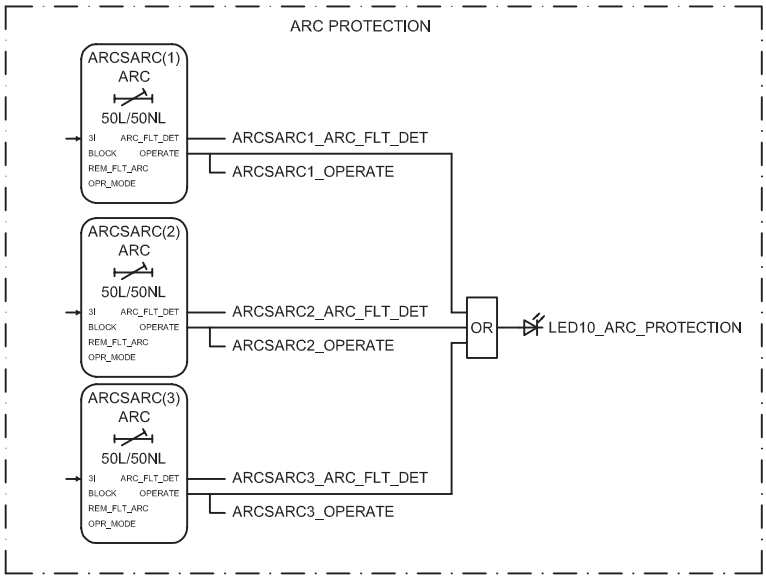

Figure 33: Arc protection

Arc protection (ARCSARC1...3) is 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 signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

3.5.3.2 Functional diagrams for disturbance recorder and supervision functions

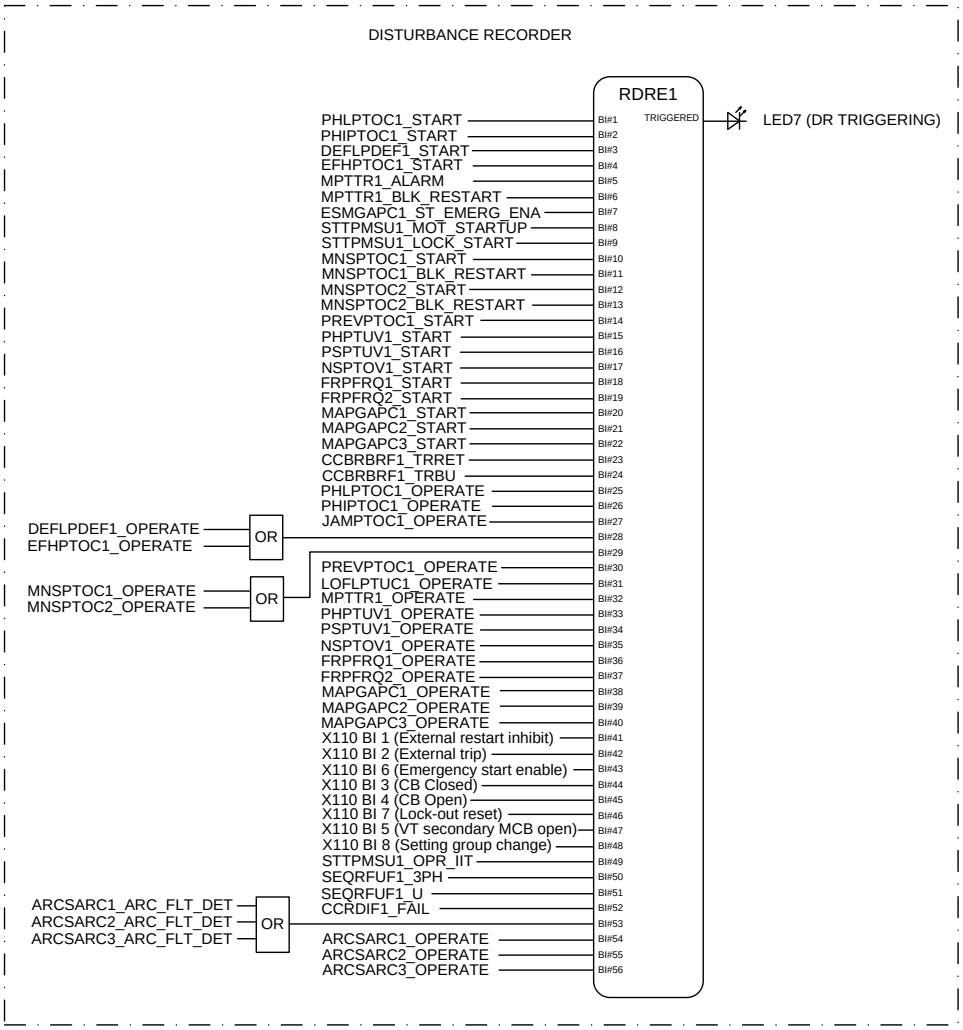

Figure 34: Disturbance recorder

All start and operate signals 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 ARC protection signals and 8 binary inputs are also connected.

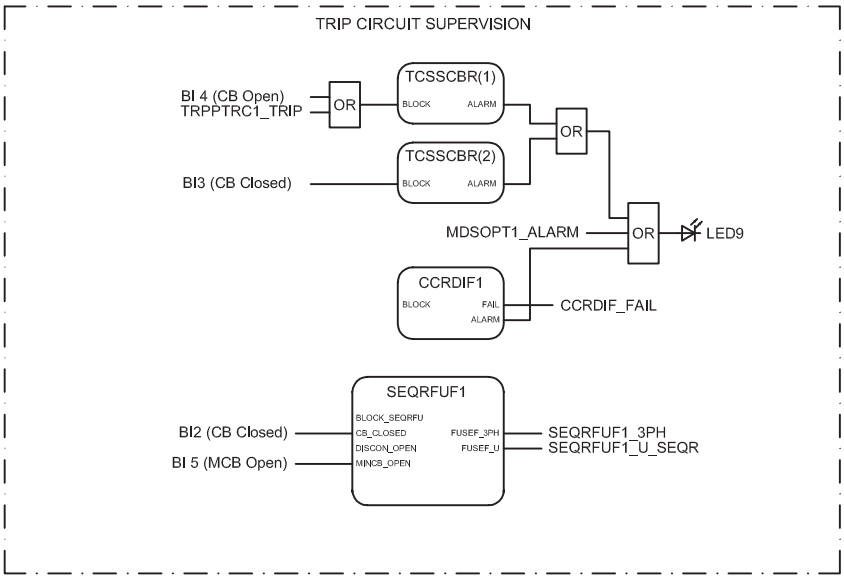

Figure 35: Supervision functions

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) for Master Trip and TCSSCBR2 for PO4 (X100:20-24) for circuit breaker closing. The trip circuit supervision 1 is blocked by the Master Trip (TRPPTRC1) and the circuit-breaker open position signal. The trip circuit supervision 2 is used for circuit breaker closing and therefore blocked when the circuit breaker is closed. The trip circuit supervision alarm indication is connected to LED 9.

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

The motor runtime counter alarm is connected also to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.5.3.3 Functional diagrams for control and interlocking

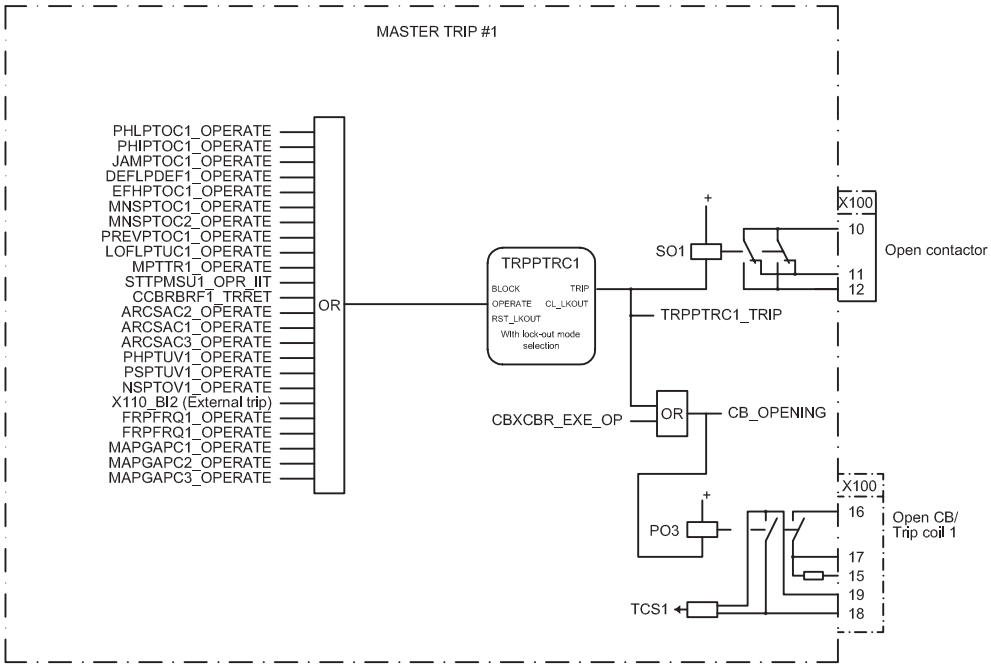

Figure 36: Master Trip

The operate signals from the protections are connected to the trip output contact PO3 (X100:15-19) via the corresponding Master Trip (TRPPTRC1). Open control commands to the circuit breaker from the local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

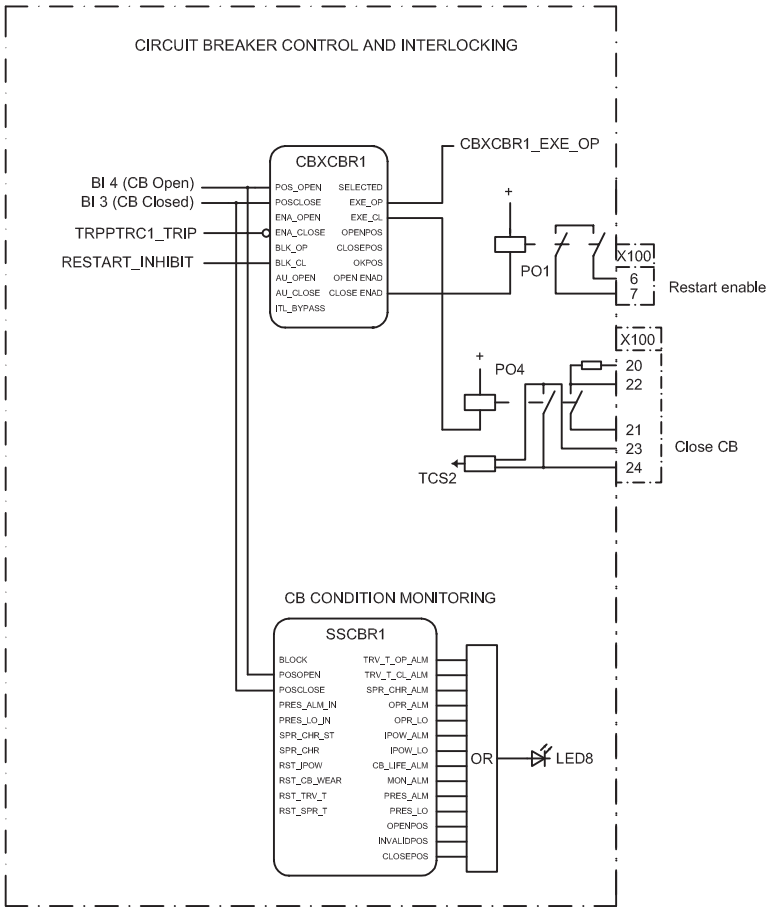

Figure 37: Circuit breaker control

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the master trip logics. The open operation is always enabled.

When the motor restart is inhibited, the BLK_CLOSE input is activated and closing of the breaker is not possible. When all conditions of the circuit breaker closing are fulfilled, the CLOSE_ENAD output of the CBXCBR1 is activated and PO1 output (X100:6-7) is closed.

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

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

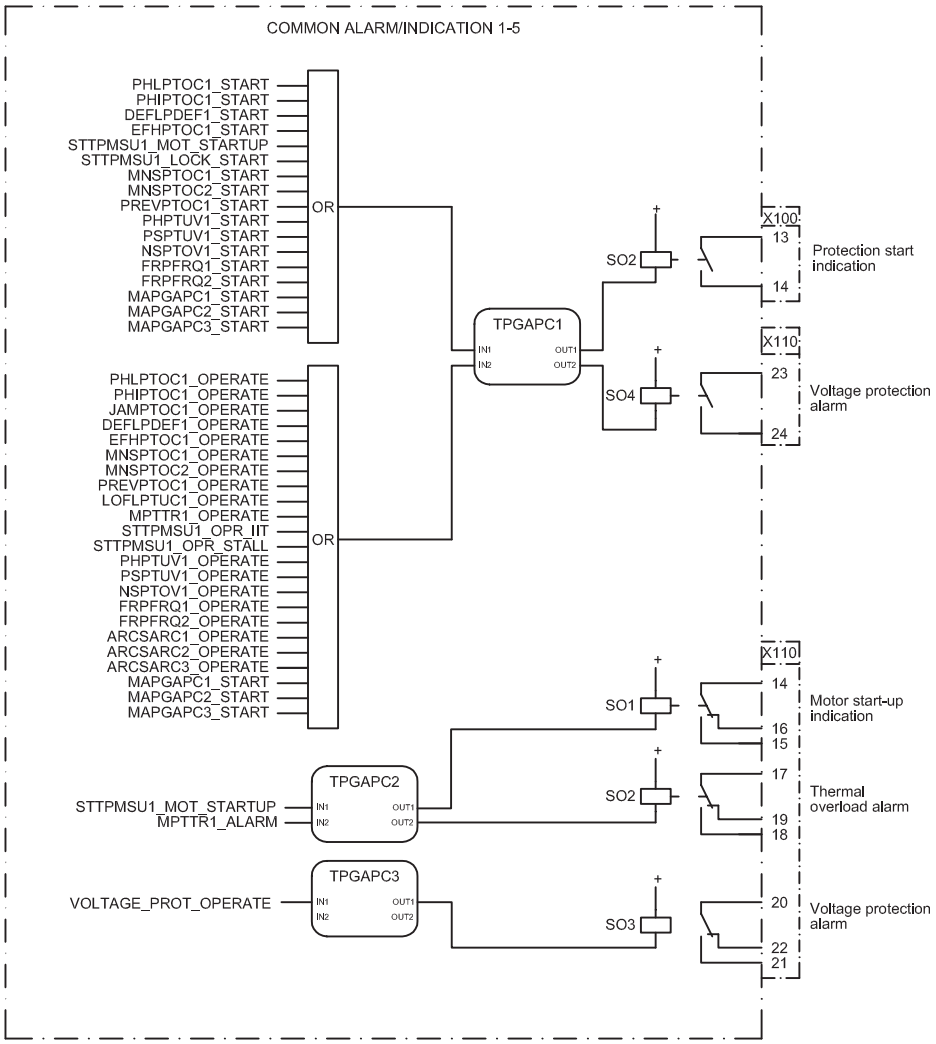

Figure 38: Common alarm/indication 1-5

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO4 (X110:23-24)
- Motor startup indication to upstream level SO1 (X110:14-16)
- Motor thermal overload alarm indication SO2 (X110:17-19)
- Operation (trip) of any voltage protection function SO3 (X110:20-22)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

3.6 Standard configuration C

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 IED 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 IED 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

Table 22: Functions included in the standard configuration C

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Three-phase undervoltage protection, instance 1	PHPTUV1	3U< (1)	27 (1)
Positive-sequence undervoltage protection, instance 1	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	U2> (1)	47O- (1)
Frequency protection, instance 1	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
Frequency protection, instance 2	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
Negative-sequence overcurrent protection for motors, instance 1	MNSPTOC1	I2>M (1)	46M (1)
Negative-sequence overcurrent protection for motors, instance 2	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Arc protection, instance 1	ARCSARC1	ARC (1)	50L/50NL (1)
Arc protection, instance 2	ARCSARC2	ARC (2)	50L/50NL (2)
Arc protection, instance 3	ARCSARC3	ARC (3)	50L/50NL (3)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Disconnector control, instance 1	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
Disconnector control, instance 2	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC	I <-> O ESC
Disconnector position indication, instance 1	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
Disconnector position indication, instance 2	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
Disconnector position indication, instance 3	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication, instance 1	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
Earthing switch indication, instance 2	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Emergergency startup	ESMGAPC1	ESTART	ESTART
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM	CBCM
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCRDIF1	MCS 3I	MCS 3I
Fuse failure supervision	SEQRFUF1	FUSEF	60
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In
Three-phase voltage measurement	VMMXU1	3U	3U
Residual voltage measurement	RESVMMXU1	Uo	Vn
Sequence voltage measurement	VSMSQI1	U1, U2, U0	U1, U2, U0
Three-phase power and energy measurement	PEMMXU1	P, E	P, E
Frequency measurement	FMMXU1	f	f

3.6.2.1 Default I/O connections

Table 23: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	MCB open	X110-1,2
X110-BI2	Setting group change	X110-3,4
X110-BI3	Rotation direction	X110-5,6
X110-BI4	Speed switch (motor running)	X110-7,6
X110-BI5	Disconnector close/circuit breaker truck in	X110-8,9
X110-BI6	Disconnector open/circuit breaker truck out	X110-10,9
X110-BI7	Earth switch close	X110-11,12
X110-BI8	Earth switch open	X110-13,12
X120-BI1	Emergency start enable	X120-1,2
X120-BI2	Circuit breaker closed	X120-3,2
X120-BI3	Circuit breaker open	X120-4,2
X120-BI4	Lock-out reset	X120-5,6
X130-BI1	External restart inhibit	X130-1,2
X130-BI2	External trip	X130-3,4
X130-BI3	Gas pressure alarm	X130-5,6
X130-BI4	Circuit breaker spring charged	X130-7,6

Table 24: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Restart enable	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	Open command (for contactor applications)	X100-10,11,(12)
X100-SO2	Operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip	X100-15-19
X100-PO4	Close circuit breaker	X100-20-24
X110-SO1	Motor startup indication	X110-14,15,16
X110-SO2	Thermal overload alarm	X110-17,18,19
X110-SO3	Protection start indication	X110-20,21,22
X110-SO3	Voltage protection alarm	X110-23,24

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
Table continues on next page	

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

3.6.2.2 Default disturbance recorder settings

Table 26: Default analog channel selection and text settings

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

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

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, if necessary.

The analog channels have fixed connections towards the different function blocks inside the IED’s standard configuration. Exceptions from this rule are the 12 analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder’s parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents and 3U the three phase voltages. The signal marked with Io represents the measured residual current via a core balance current transformer. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for non-directional earth-faults uses the calculated residual current originating from the measured phase currents.

3.6.3.1 Functional diagrams for protection

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

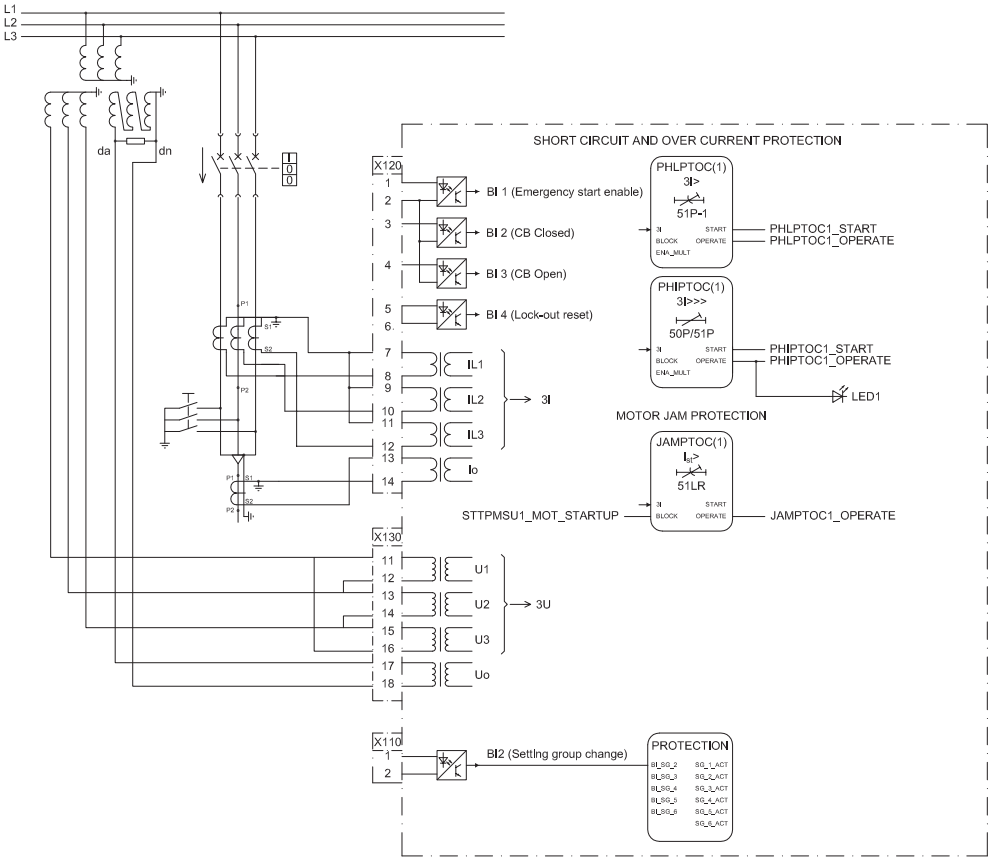

Figure 39: Overcurrent protection

Two overcurrent stages are offered for overcurrent and short-circuit protection. The motor jam protection function (JAMPTOC1) is blocked by the motor startup protection function. PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the 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.

Depending on the selected operation mode, the active setting group can be changed either with a parameter or via binary input.

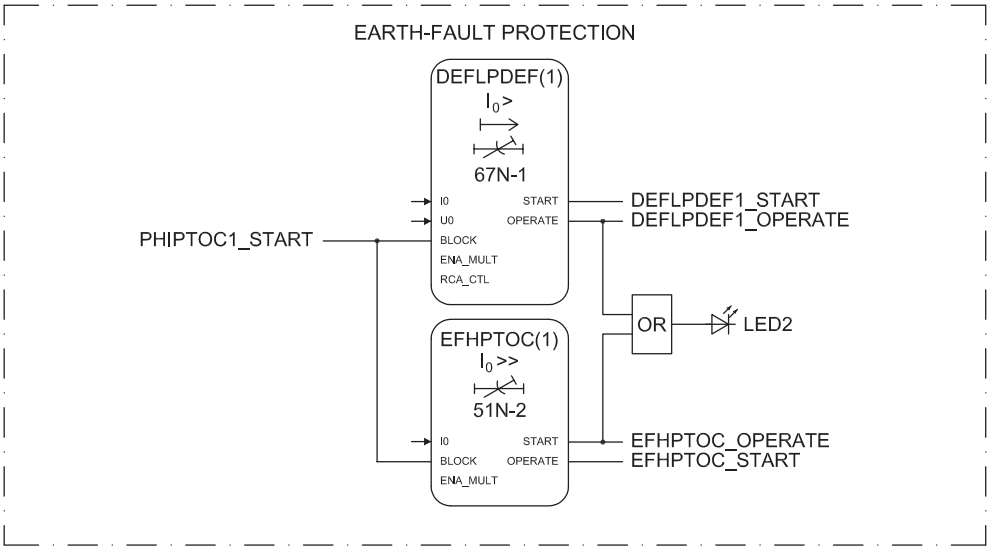

Figure 40: Non-directional earth-fault protection

One stage non-directional earth-fault protection (EFHPTOC1) is offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing. In addition, there is a directional protection stage (DEFLPDEF1) which can be also 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 startup.

The earth- fault protection is blocked when the short circuit protection (PHIPTOC1) is started. The operation of the earth-fault protection functions is connected to alarm LED 2.

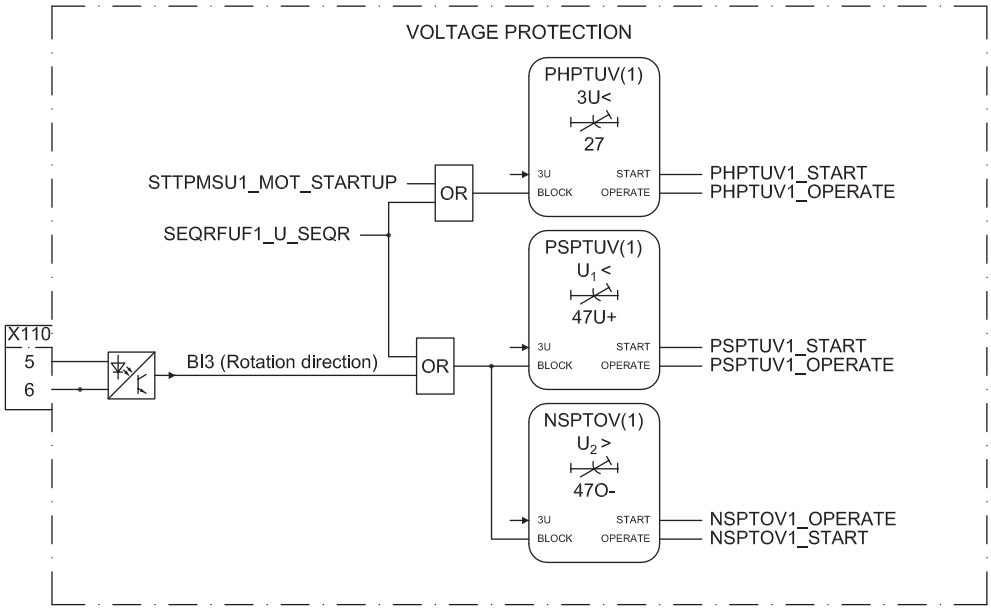

Figure 41: Voltage protection

For voltage protection three-phase undervoltage (PHPTUV1), positive-sequence undervoltage (PSPTUV1) and negative-sequence overvoltage (NSPTOV1) protection functions are offered. The three-phase undervoltage protection is blocked during motor startup to prevent unwanted operation in case there is a short voltage drop. Also if the fuse failure is detected, the undervoltage function is blocked.

The positive-sequence undervoltage and negative-sequence overvoltage protections are included to protect the machine against single-phasing, excessive unbalance between phases and abnormal phase order. The positive-sequence undervoltage and negative-sequence overvoltage functions are blocked by default when the network rotation direction changes (X110_BI3 is active) or if the fuse failure is detected.

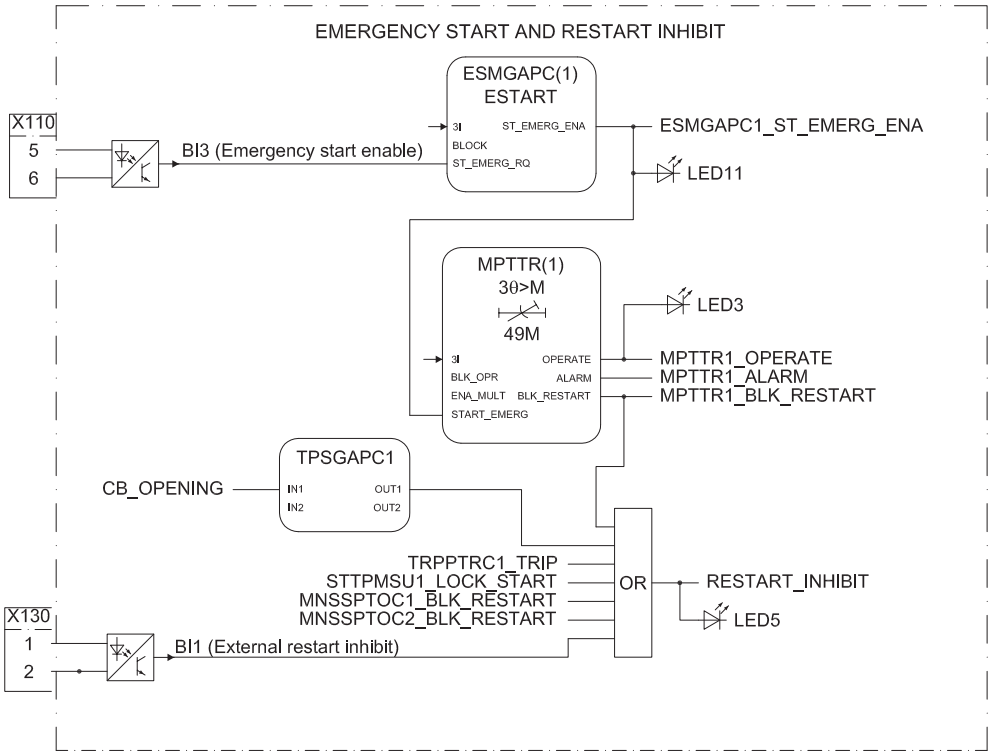

Figure 42: Emergency start and restart inhibit

The emergency start function (ESMGAPC1) allows motor startups although the calculated thermal level or cumulative startup timer counter are blocking 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:

- Calculated thermal level in MPTTR1 is set slightly below the restart inhibit level to allow at least one motor startup
- Value of the cumulative startup time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor startup
- 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 of ten minutes has expired.

The thermal overload protection function (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. When the thermal overload function has issued a restart blocking, which inhibits the closing of the breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor.

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 circuit breaker opening. Reclosing after a too short period

of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1.

The restart inhibit is also activated when there is:

- An active trip command or
- Motor startup supervision has issued lockout or
- Motor unbalance function has issued restart blocking or
- An external restart inhibit is activated by a binary input (X130:BI1).

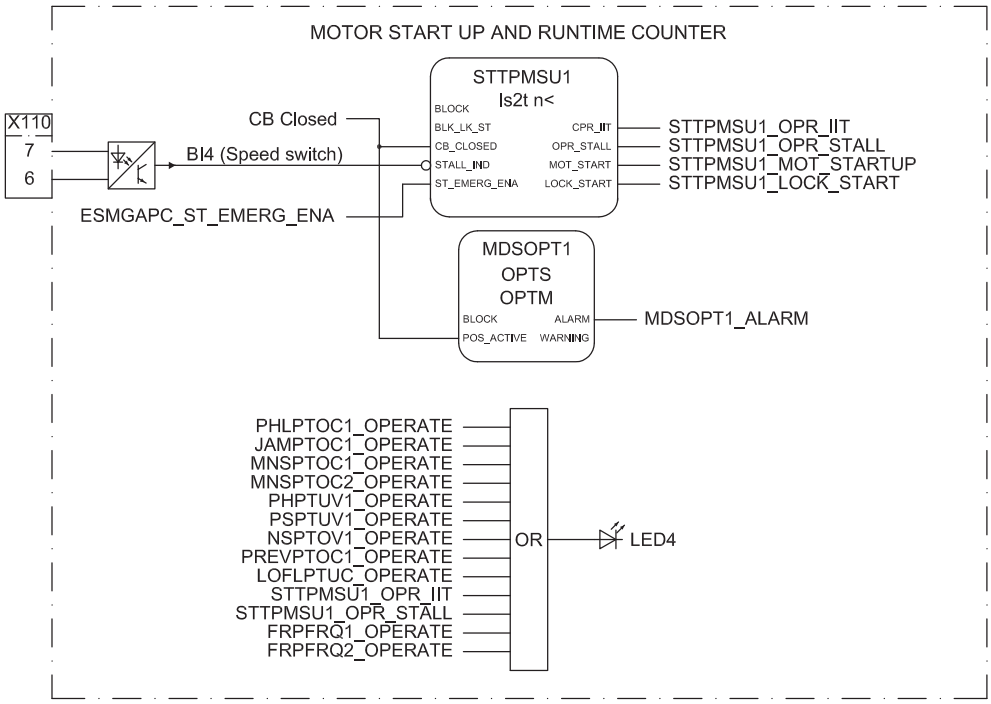

Figure 43: Motor startup supervision

With the motor startup 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 startup is connected to the output SO1 (X110:14-15-16). The output is used for sending a blocking signal to the relevant overcurrent protection stage of the IED at the infeeding bay.

The motor running time counter (MDSOPT1) provides history data since last commissioning. The counter counts the total number of motor running hours and is incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 9.

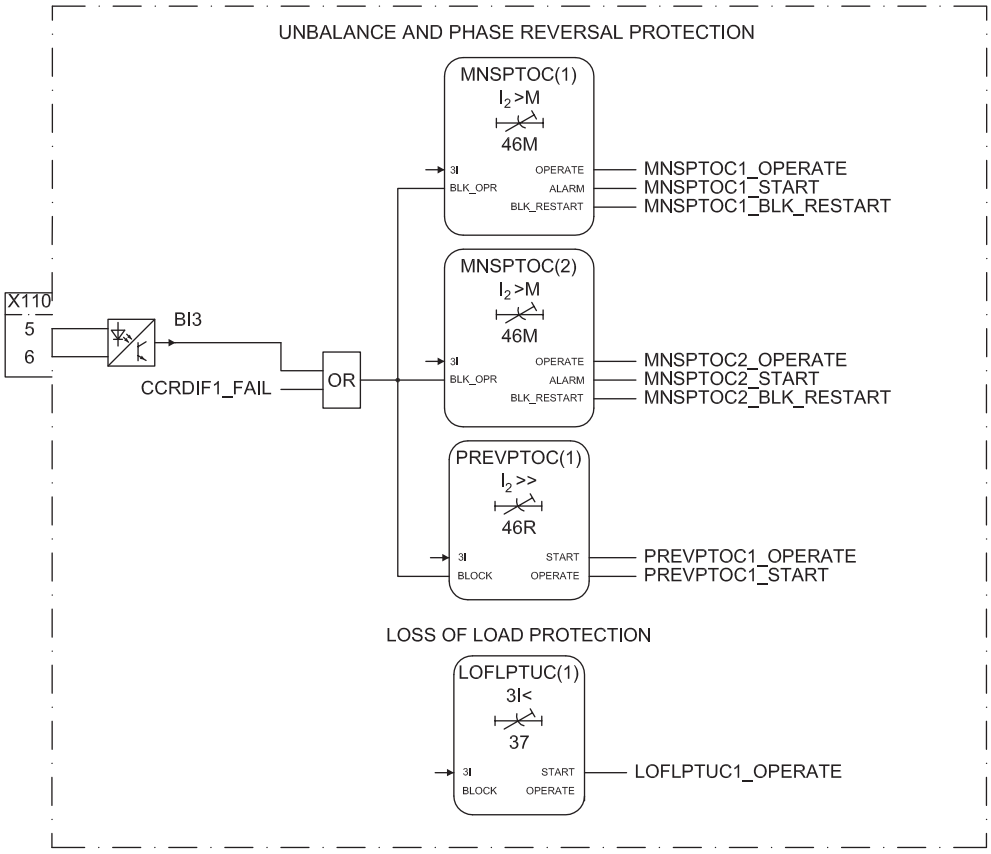

Figure 44: Phase unbalance protection

Two negative-sequence overcurrent stages (MNSPTOC1 and MNSPTOC2) are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The phase reversal protection (PREVPTOC1) is based on the calculated negative phase-sequence current. It detects too high NPS 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 protection and phase reversal protection are blocked if the current circuit supervision detects failure in the current measuring circuit.

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

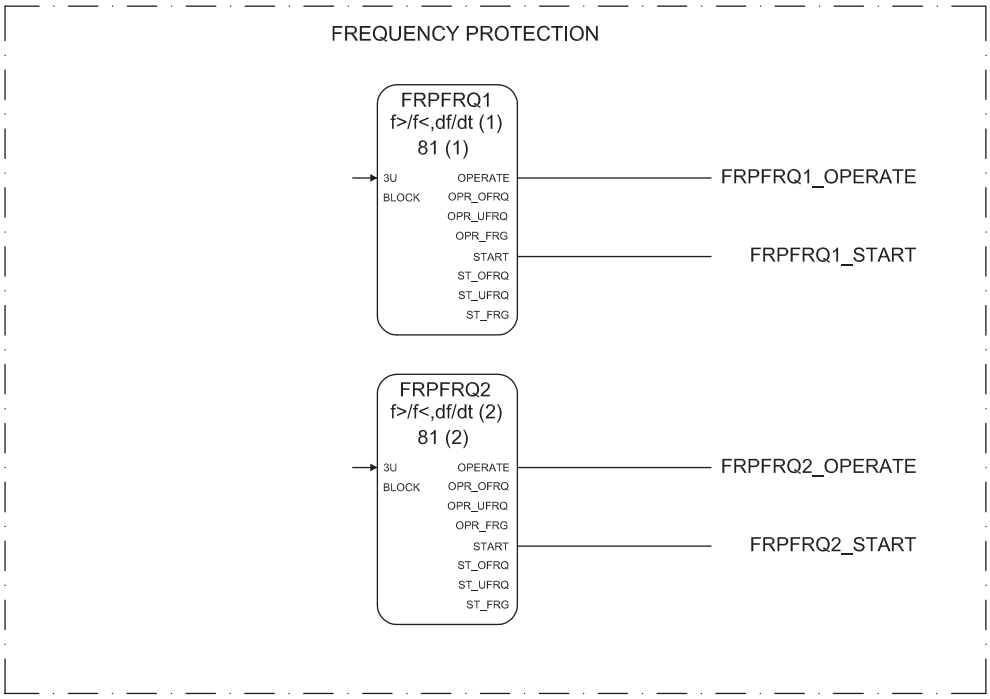

Figure 45: Frequency protection

Two frequency protection stages (FRPFRQ1 and PFRQ2) are offered. These functions are used to protect the motor against abnormal power system frequency.

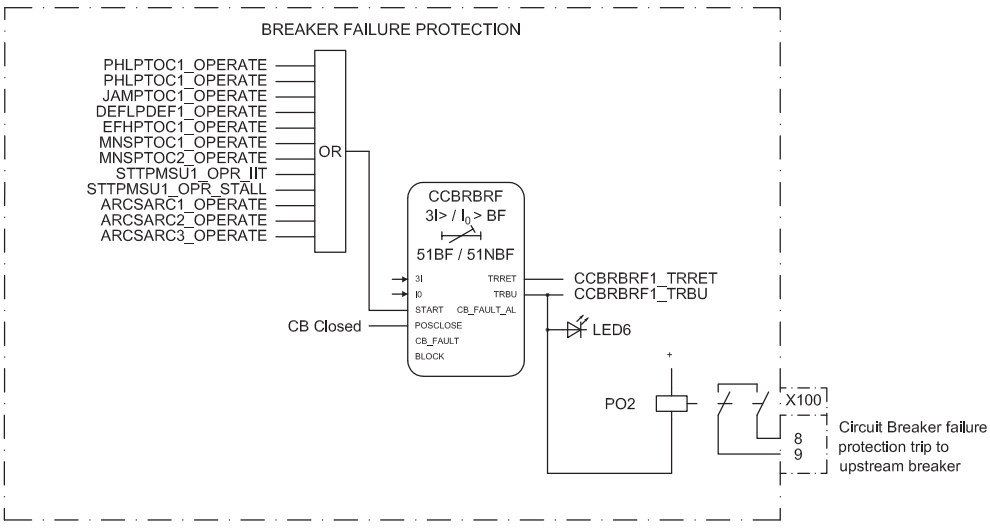

Figure 46: Circuit breaker failure protection

The circuit-breaker failure protection (CCBRBRF1) is initiated via the start input by a number of different protection stages in the IED. CCBRBRF1 offers different operating modes associated with the circuit-breaker position and the measured phase and residual currents.

CCBRBRF1 has two operating outputs: TRRET and TRBU. The TRRET operate output is used for retripping its own circuit breaker through the Master Trip 1 again. The TRBU output is used to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

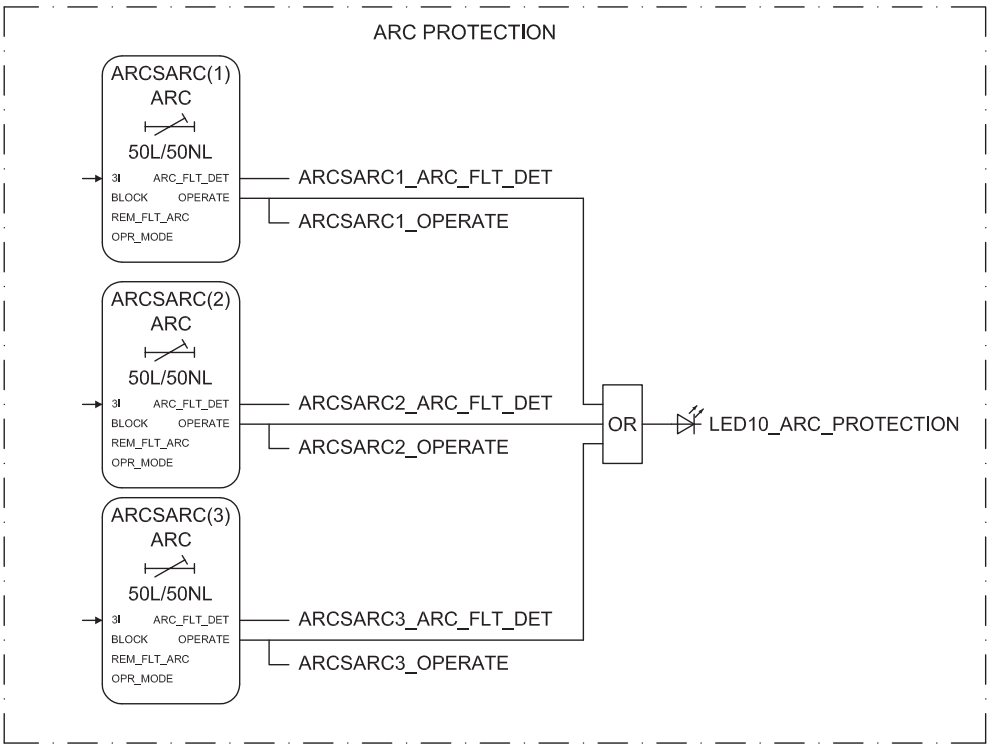

Figure 47: Arc protection

Arc protection (ARCSARC1...3) is 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 signals from the arc protection function blocks are connected to the Master Trip and also to the alarm LED 10 as a common operate indication.

3.6.3.2 Functional diagrams for disturbance recorder and supervision functions

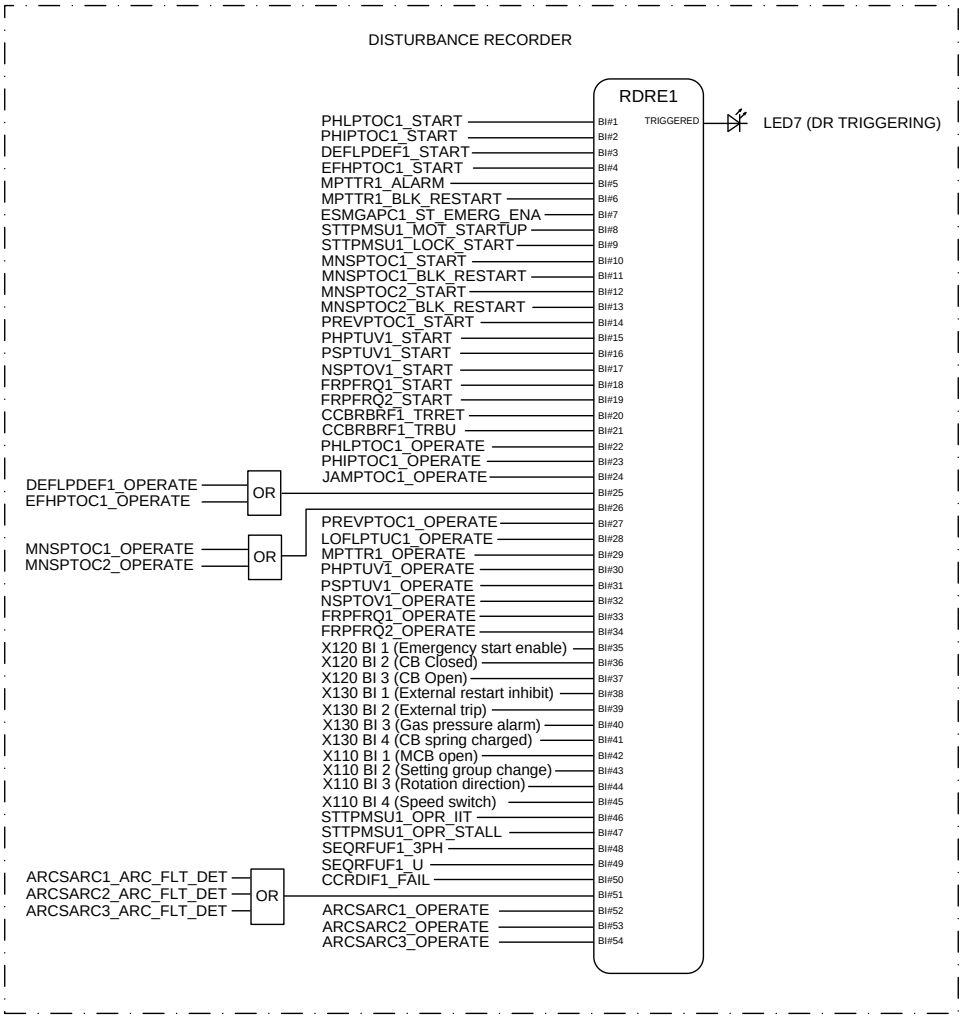

Figure 48: Disturbance recorder

All start and operate signals 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 ARC protection signals and 4 binary inputs are also connected.

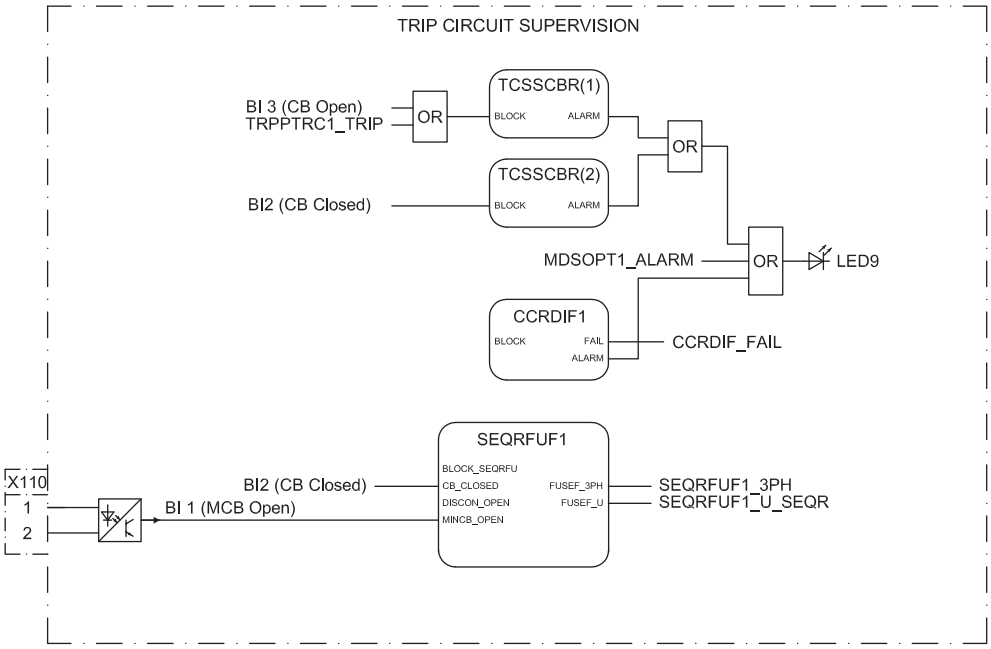

Figure 49: Supervision functions

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) for Master Trip and TCSSCBR2 for PO4 (X100:20-24) for circuit breaker closing. The trip circuit supervision 1 is blocked by the Master Trip (TRPPTRC1) and the circuit-breaker open position signal. The trip circuit supervision 2 is used for circuit breaker closing and therefore blocked when the circuit breaker is closed. The trip circuit supervision alarm indication is connected to LED 9.

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

The motor runtime counter alarm is connected also to the alarm LED 9.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the alarm LED 9.

Failures in current measuring circuits are detected by CCRDIF. When a failure is detected, blocking signal is activated in current protection functions that are measuring calculated sequence component currents, and unnecessary operation can be avoided. The alarm signal is connected to the alarm LED 9.

3.6.3.3 Functional diagrams for control and interlocking

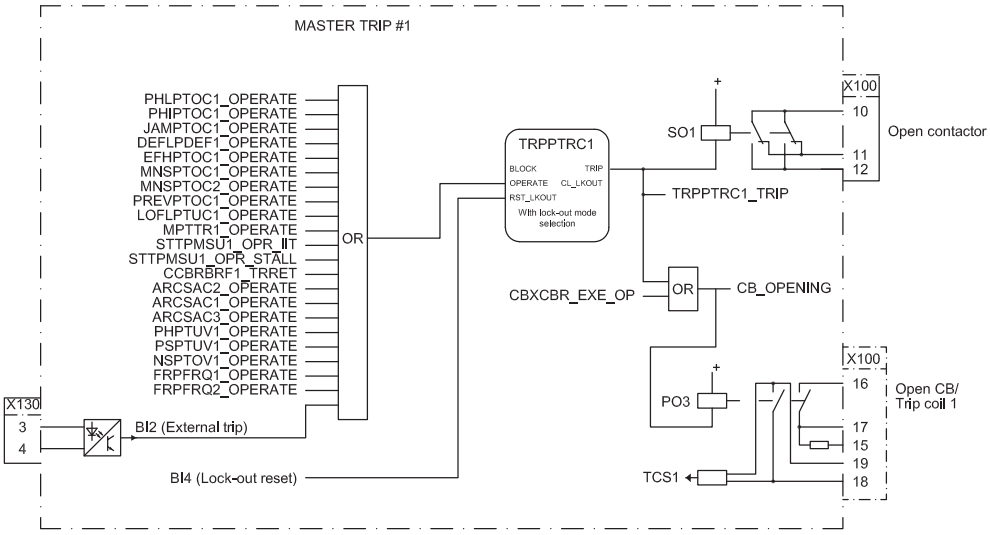

Figure 50: Master Trip

The operate signals from the protections are connected to the trip output contact PO3 (X100:15-19) via the corresponding Master Trip (TRPPTRC1). Open control commands to the circuit breaker from the local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a push button.

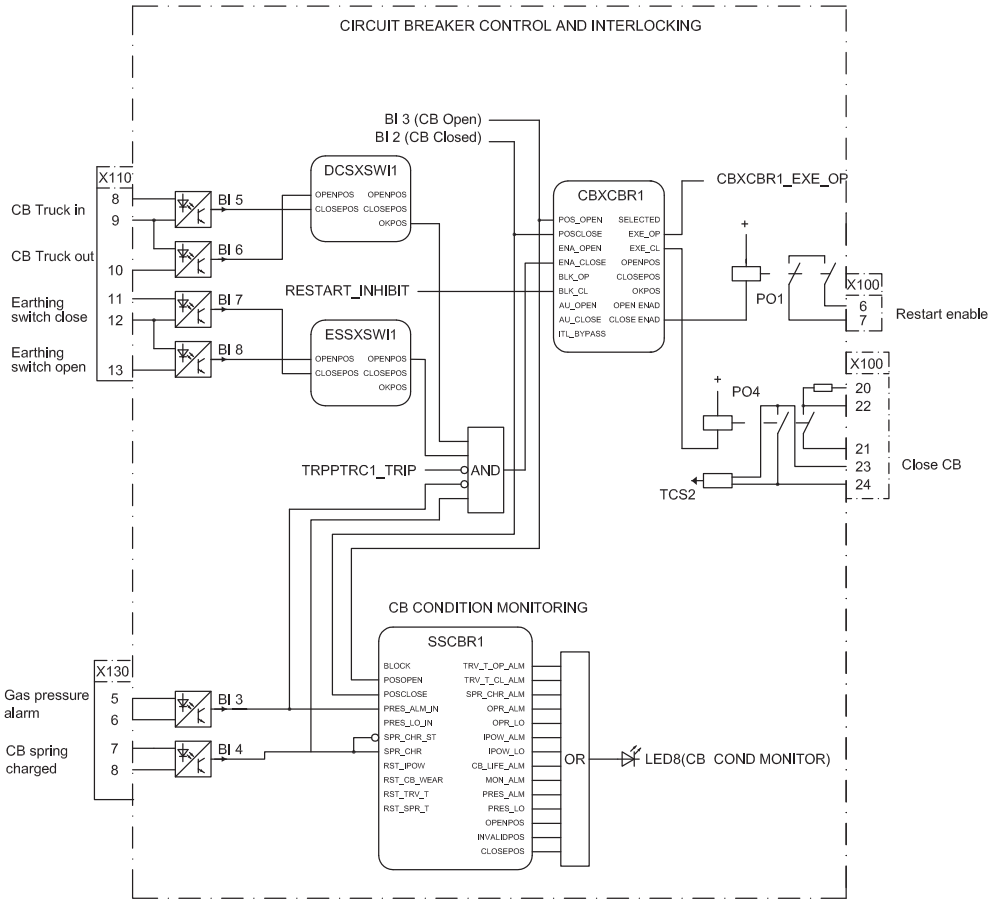

Figure 51: Circuit breaker control

There are two types of disconnector and earthing switch blocks available. DCSXSWI1...3 and ESSXSWI1...2 are status only type, and DCXSWI1...2 and ESXSWI1 are controllable type. By default, the status only blocks are connected in standard configuration logic. If controllable operation is preferred, the controllable type of disconnector and earthing switch blocks can be used instead of the status only type. The connection and configuration of the control blocks can be done using PCM600.

The binary inputs 5 and 6 of the additional card X110 are used for busbar disconnector (DCSXSWI1) or circuit-breaker truck position indication.

Table 27: Device positions indicated by binary inputs 5 and 6

Primary device position	Input to be energized	
	Input 5 (X110:8-9)	Input 6 (X110:10-9)
Busbar disconnector closed	x	
Busbar disconnector open		x
Circuit breaker truck in service position	x	
Circuit breaker truck in test position		x

The binary inputs 7 and 8 (X110:1-13) are designed for the position indication of the line-side earthing switch.

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 statuses and the statuses of the Master Trip logics and gas pressure alarm and circuit-breaker spring charging. The OKPOS output from the DCSXSWI block defines if the disconnector or the breaker truck is definitely either open (in test position) or close (in service position). This, together with the open earth-switch and non-active trip signal, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled.

When the motor restart is inhibited, the BLK_CLOSE input is activated and closing of the breaker is not possible. When all conditions of the circuit breaker closing are fulfilled, the CLOSE_ENAD output of the CBXCBR1 is activated and PO1 output (X100:6-7) is closed.

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

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

The circuit breaker condition monitoring function (SSCBR) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision methods. The corresponding supervision alarm signals are routed to LED 8.

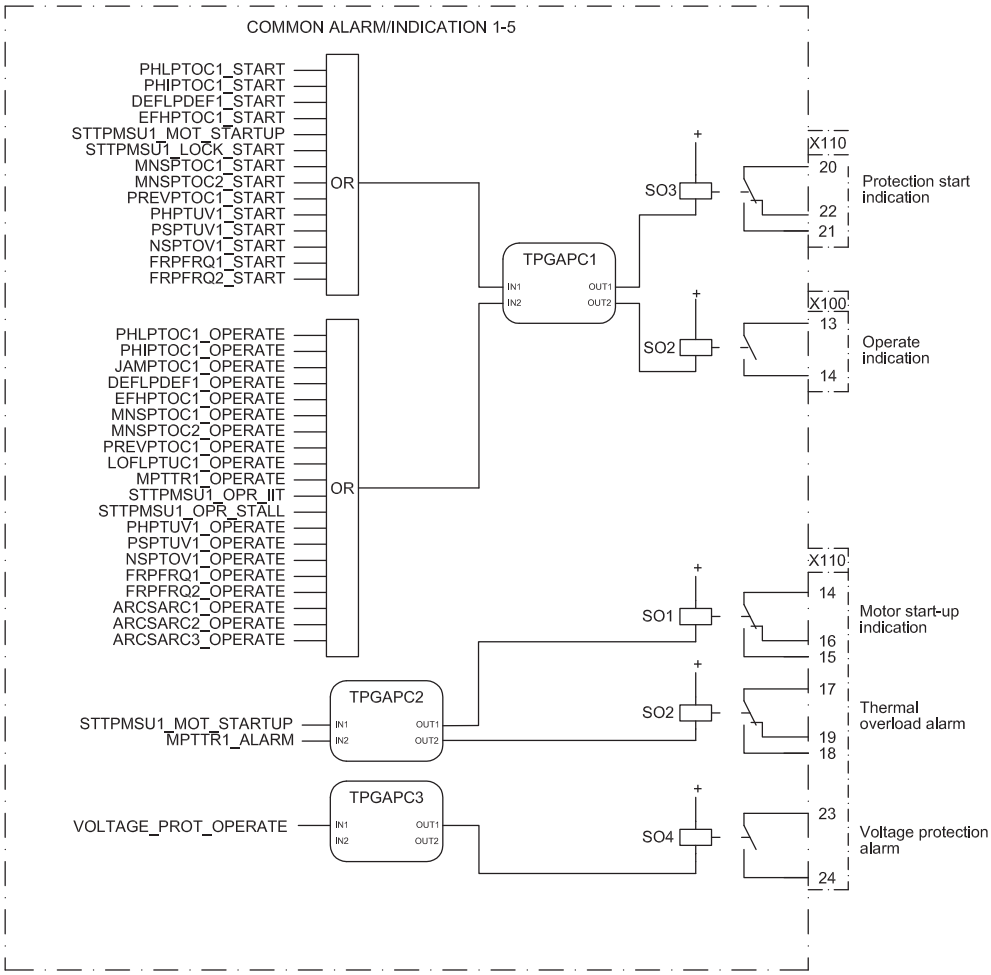

Figure 52: Common alarm/indication 1-5

The signal outputs from the IED are connected to give dedicated information on:

- Start of any protection function SO3 (X110:20-22)
- Operation (trip) of any protection function SO2 (X100:13-14)
- Motor startup indication to upstream level SO1 (X110:14-16)
- Motor thermal overload alarm indication SO2 (X110:17-19)
- Operation (trip) of any voltage protection function SO4 (X110:23-24)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are four generic timers (TPGAPC1..4) available in the IED. The remaining ones not described in the functional diagram are available in PCM600 for connection where applicable.

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for non-directional 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 IED 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 28: 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 IED.

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 IED.

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

The actual accuracy limit factor is calculated using the formula:

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

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

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

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

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the IED 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 IED. 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 x (I_{kmin} / I_{1n})

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

The factor 0.7 takes into account the protection IED 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 IED operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive IEDs.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time the 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:

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

The *Current start value* is the primary pickup current setting of the IED.

4.1.1.3 Example for non-directional overcurrent protection

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

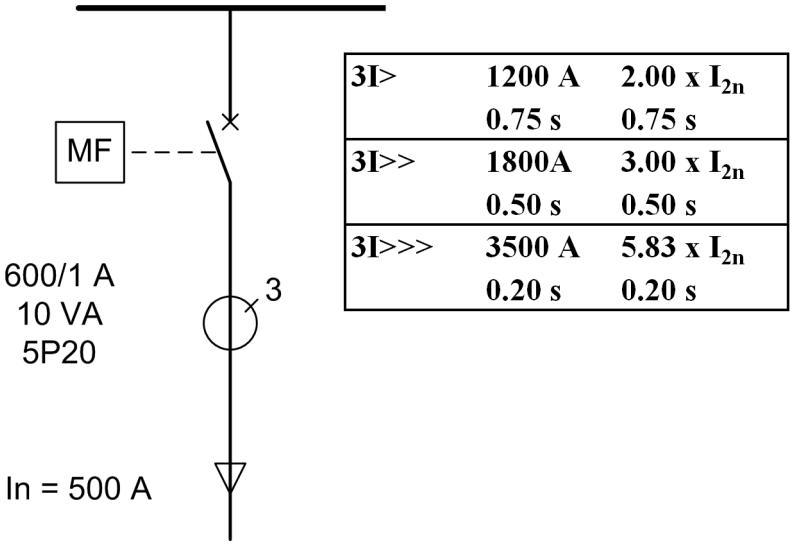

Figure 53: Example of three-stage overcurrent protection

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 IED (not visible in the figure above). 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 IED 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 the figure above.

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

Section 5 IED physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase currents

The IED 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 29: Phase currents

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

5.1.1.2 Residual current

Table 30: Residual current input

Terminal	Description
X120-13, 14	Io

5.1.1.3 Phase voltages

Table 31: Phase voltage inputs included in configuration B

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

Table 32: 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 33: Residual voltage input included in configuration C

Terminal	Description
X130-17, 18	Uo

5.1.2 RTD/mA inputs

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

Table 34: RTD/mA inputs

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

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

5.1.3 Auxiliary supply voltage input

The auxiliary voltage of the IED 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 IED.

Table 35: Auxiliary voltage supply

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

5.1.4 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 IED settings.

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

Table 36: Binary input terminals X110-1...13

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

Binary inputs of slot X120 are available with configurations A and C.

Table 37: Binary input terminals X120-1...6

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

Binary inputs of slot X130 are optional for configuration B.

Table 38: Binary input terminals X130-1...9

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

Binary inputs of slot X130 are available with configuration C.

Table 39: Binary input terminals X130-1...8

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

5.1.5 Optional light sensor inputs

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

The IED 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 an IED, the light sensor inputs are included in the communication module.

Table 40: Light sensor input connectors

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

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. On delivery from the factory, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 41: 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

Output contacts SO1 and SO2 in slot X100 or SO1, SO2, SO3 and SO4 in slot X110 or SO1, SO2 and SO3 in slot X130 (optional) can be used for signalling on start and tripping of the IED. On delivery from the factory, the start and alarm signals from all the protection stages are routed to signalling outputs.

Table 42: 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 43: Output contacts X110-14...24

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

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

Table 44: Output contacts X130-10...18

Terminal	Description
X130-10	SO1, common
X130-11	SO1, NO
X130-12	SO1, NC
X130-13	SO2, common
X130-14	SO2, NO
X130-15	SO2, NC

Table continues on next page

Terminal	Description
X130-16	SO3, common
X130-17	SO3, NO
X130-18	SO3, NC

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection IED. Under normal operating conditions, the IED 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 output contact drops off and the contact closes (X100/3-4).

Table 45: IRF contact

Terminal	Description
X100-3	IRF, common
X100-4	Closed; IRF, or U_{aux} disconnected
X100-5	Closed; no IRF, and U_{aux} connected

Section 6 Glossary

615 series	Series of numerical IEDs for low-end protection and supervision applications of utility substations, and industrial switchgear and equipment
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CT	Current transformer
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
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
I/O	Input/output
IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IED	Intelligent electronic device
IET600	Integrated Engineering Toolbox in PCM600
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
LAN	Local area network
LC	Connector type for glass fibre cable

LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
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
NPS	Negative phase sequence
PCM600	Protection and Control IED Manager
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol
RTD	Resistance temperature detector
RTU	Remote terminal unit
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
WAN	Wide area network
WHMI	Web human-machine interface

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