Relion® 615 series

Transformer Protection and Control RET615 Application Manual

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-6 and EN 60255-27 for the low voltage directive. The IED is designed in accordance with the international standards of the IEC 60255 series.

Table of contents

Section 1 Introduction

1.1 This manual

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 communication and protocols.

1.3 Product documentation

1.3.1 Product documentation set

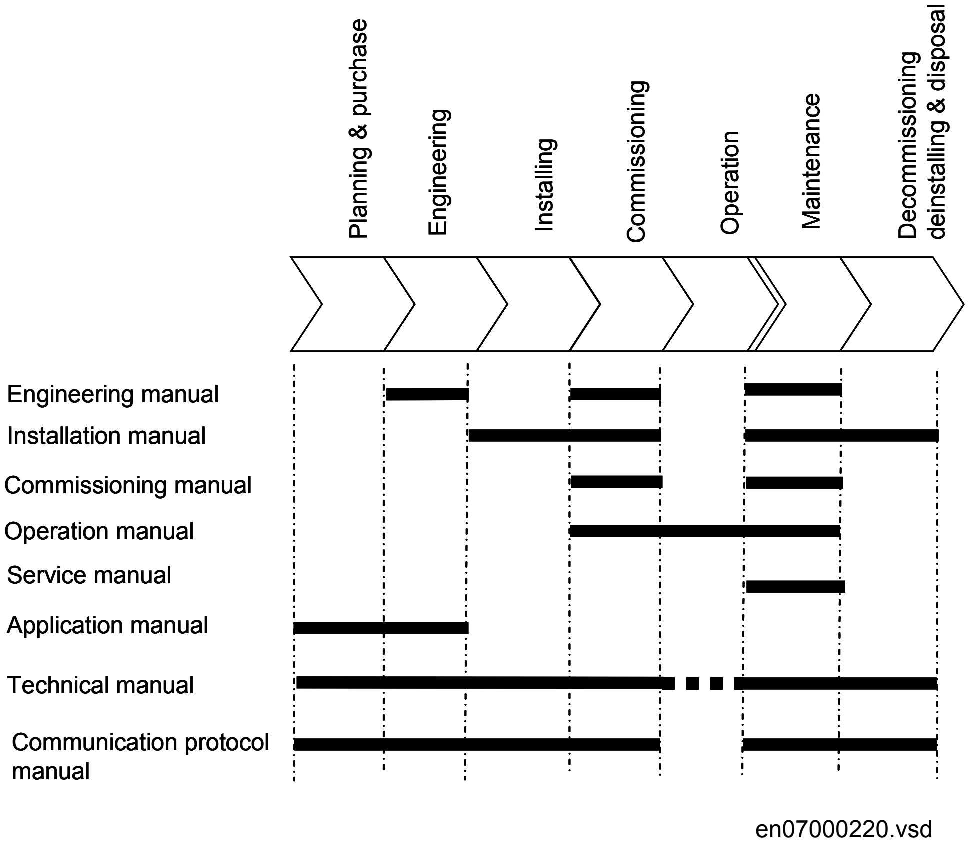


Figure 1: The intended use of manuals in different lifecycles

Engineering Manual contains instructions on how to engineer the IEDs. The manual provides instructions on how to use the different tools for IED engineering. It also includes instructions on how to handle the tool component available to read disturbance files from the IEDs on the basis of the IEC 61850 definitions. It further introduces the diagnostic tool components available for IEDs and the PCM600 tool.

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.

Commissioning Manual contains instructions on how to commission the IED. The manual can also be used as a reference during periodic testing. The manual provides procedures for energizing and checking of external circuitry, setting and configuration as well as verifying settings and performing directional tests. The chapters are organized in chronological order in which the IED should be commissioned.

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 network data to determine the cause of a fault.

Service Manual contains instructions on how to service and maintain the IED. The manual also provides procedures for de-energizing, de-commissioning and disposal of the IED.

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.

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.

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

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.

Some of the manuals are not available yet.

1.3.2 Document revision history

Document revision/date	Product version	History
A/03.07.2009	2.0	First release

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
Installation Manual	1MRS756375
Operation Manual	1MRS756708
Technical Manual	1MRS756887

1.4 Document symbols and conventions

1.4.1 Safety indication symbols

This publication includes icons that point out safety-related conditions or other important information.

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 to 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 should be understood that operation of damaged equipment could, under certain operational conditions, 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

- Abbreviations and acronyms in this manual are spelled out in Glossary. Glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, for example:
  To navigate between the options, use and .
- HMI menu paths are presented in bold, for example:
  Select **Main menu/Information**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press .
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks, for example:
  The corresponding parameter values are "On" and "Off".
- IED input/output messages and monitored data names are shown in Courier font, for example:
  When the function starts, the `START` output is set to TRUE.

1.4.3 Functions, codes and symbols

Table 1: RET615 Functions, codes and symbols

Functionality	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, low stage, instance 2	PHLPTOC2	3I> (2)	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 2	PHIPTOC2	3I>>> (2)	50P/51P (2)
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	I_0> (1)	51N-1 (1)

Table continues on next page

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Non-directional earth-fault protection, low stage, instance 2	EFLPTOC2	I_0> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	I_0>> (1)	51N-2 (1)
Non-directional earth-fault protection, high stage, instance 2	EFHPTOC2	I_0>> (2)	51N-2 (2)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I_2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I_2> (2)	46 (2)
Three-phase thermal overload protection for power transformers, two time constants	T2PTTR1	3Ith>T	49T
Stabilized and instantaneous differential protection for 2W –transformers	TR2PTDF1	3dI>T	87T
Numerical stabilized low impedance restricted earth-fault protection	LREFPNDF1	dI_0Lo>	87NL
High impedance based restricted earth-fault protection	HREFPDIF1	dI_0Hi>	87NH
Circuit breaker failure protection	CCBRBRF1	3I>/I_0>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 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	ESSXSWI1	I ↔ O ES	I ↔ O ES
Tap changer position indication	TPOSSLTC1	TPOSM	84M
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)
Measurement			
Disturbance recorder	RDRE1	-	-
Three-phase current measurement, instance 1	CMMXU1	3I	3I

Table continues on next page

Functionality	IEC 61850	IEC 60617	IEC-ANSI
Three-phase current measurement, instance 2	CMMXU2	3I(B)	3I(B)
Sequence current measurement	CSMSQI1	I_1, I_2, I_0	I_1, I_2, I_0
Residual current measurement, instance 1	RESCMMXU1	I_0	I_n
Residual current measurement, instance 2	RESCMMXU2	I_0(B)	I_n(B)

Section 2 RET615 overview

2.1 Overview

RET615 is a dedicated transformer protection and control IED (intelligent electronic device) for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems. RET615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series IEDs are characterized by their compactness and withdrawable 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

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.0 SP2 or later
- RET615 Connectivity Package Ver. 2.5 or later
    - Parameter Setting
    - Firmware Update
    - Disturbance Handling
    - Signal Monitoring
    - Lifecycle Traceability
    - Signal Matrix
    - Communication Management
    - Configuration Wizard
    - Label Printing
    - IED User Management
    - Differential Characteristics Tool

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

2.3 Physical hardware

The IED consists of two main parts: plug-in unit and case. The plug-in unit 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	8 binary inputs 4 signal output contacts
	X120	AI/BI module	6 phase current inputs (1/5A) 1 residual current input (1/5A)
Case	X130	Optional BIO module	6 binary inputs 3 signal output contacts
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

Rated values of the current and voltage inputs are basic setting parameters of the 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	BI	BO
A	7	-	8 (14)[1)]	10 (13)[1)]
B	7	-	8 (14)[1)]	10 (13)[1)]
C	7	-	8 (14)[1)]	10 (13)[1)]
D	7	-	8 (14)[1)]	10 (13)[1)]

1) With optional BIO module

2.4 Local HMI

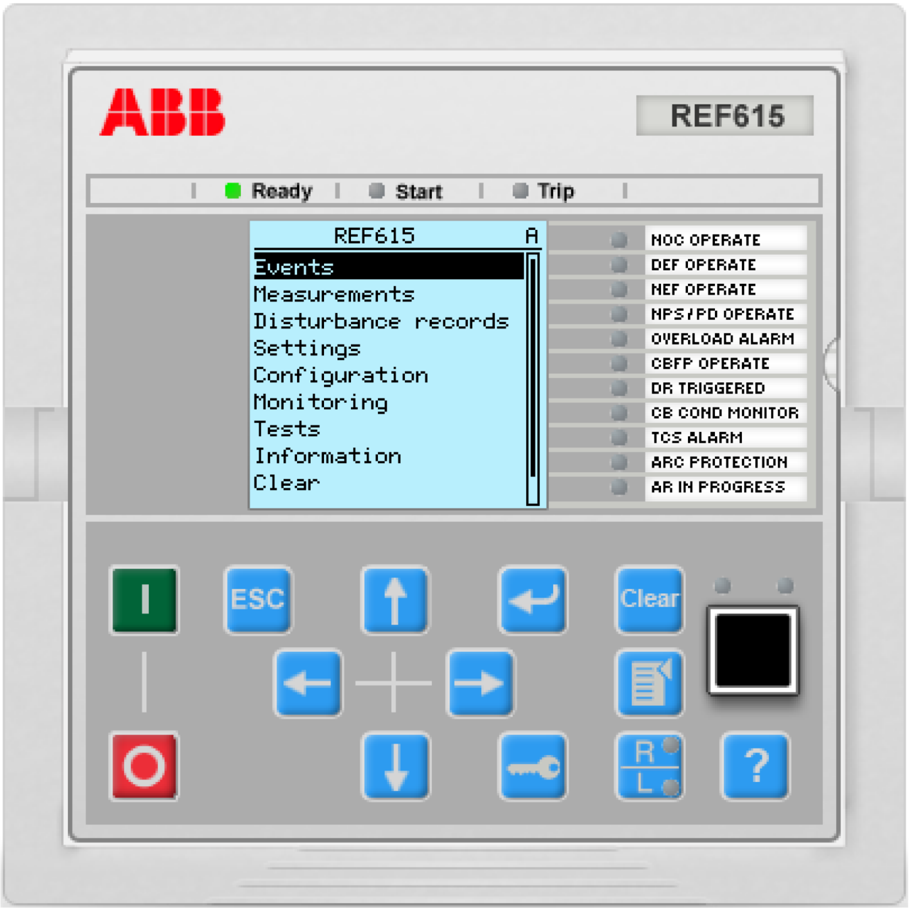


Figure 2: LHMI

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 LCD

The LHMI includes a graphical LCD 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.

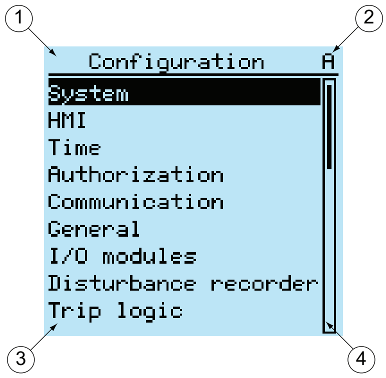


Figure 3: Display layout

1 Header

2 Icon

3 Content

4 Scroll bar (displayed when needed)

2.4.2 LEDs

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

There are also 11 matrix programmable alarm 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 push-buttons you can give open or close commands to one primary object, for example, a circuit breaker, disconnector or switch. The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

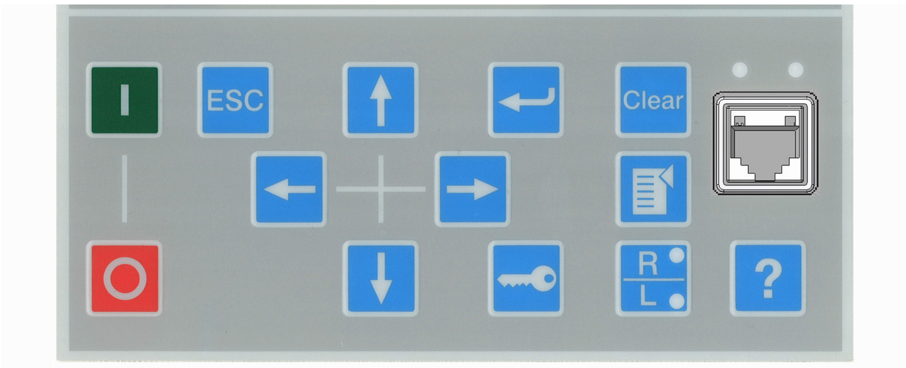


Figure 4: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.5 Web HMI

The WHMI enables the user to access the IED via a web browser. The supported web browser version is Internet Explorer 7.0 or later.

WHMI is disabled by default.

WHMI offers several functions.

- Alarm indications and event lists
- System supervision
- Parameter settings

- Measurement display
- Disturbance records
- Phasor diagram

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

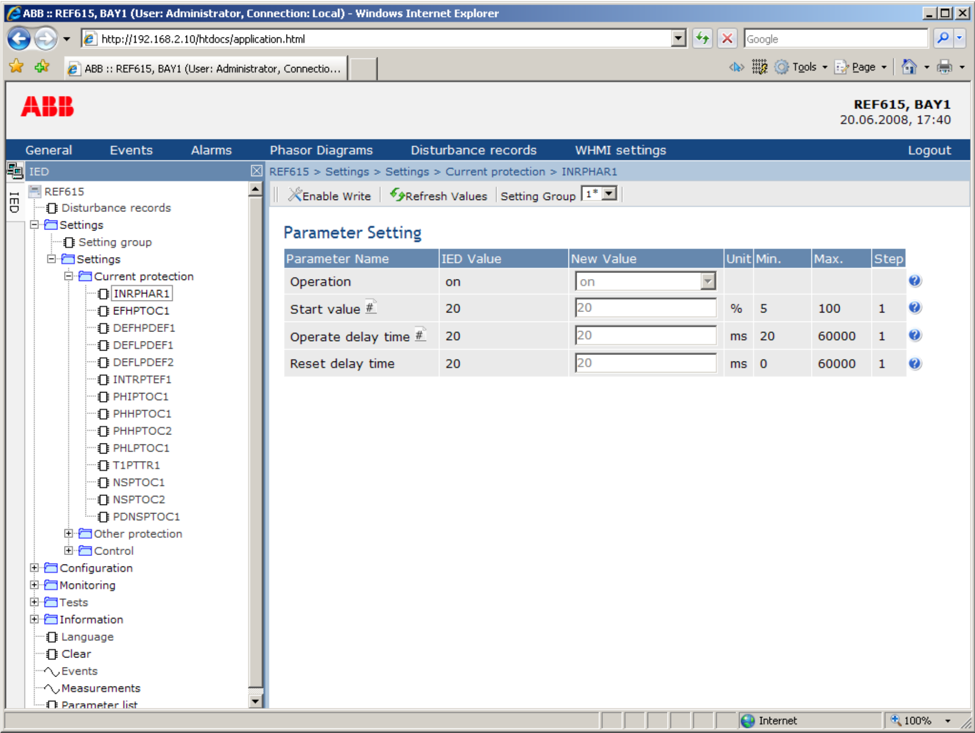


Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting 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 alarm and indication LEDs and textual 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.

2.7 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.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and disturbance file records can be accessed using the IEC 61850 protocol. Disturbance files are available to any Ethernet-based application in the standard COMTRADE format. Further, 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. 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).

Section 3 RET615 variants

3.1 RET615 variant list

3.2 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 which each constitute 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

With Signal Matrix the user can 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 BI's, BO's, function to function connections and alarm LEDs. Signal Matrix has a number of different page views, designated as follows:

- Binary input
- Binary output
- Functions

The functions in different page views are identified by the IEC 61850 names with analogy to the functional diagrams.

3.2.1 Standard configurations

The transformer protection and control IED RET615 is available with four alternative standard configurations.

Table 6: Standard configurations

Description	Std.conf.
Three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the high-voltage (HV) side	A
Three-phase transformer differential protection for two-winding transformers, numerical restricted earth-fault protection for the low-voltage (LV) side	B
Three-phase transformer differential protection for two-winding transformers, high-impedance based restricted earth-fault protection for the high-voltage (HV) side	C
Three-phase transformer differential protection for two-winding transformers, high-impedance based restricted earth-fault protection for the low-voltage (LV) side	D

Table 7: Supported functions

Functionality	A	B	C	D
Protection[1)]				
Stabilized and instantaneous differential protection for two-winding transformers	●	●	●	●
Numerical stabilized low impedance restricted earth-fault protection	●	●	-	-
High impedance based restricted earth-fault protection	-	-	●	●
Master Trip, instance 1	●	●	●	●
Master Trip, instance 2	●	●	●	●
HV-side protection				
Three-phase non-directional overcurrent protection, low stage, instance 1	●	●	●	●
Three-phase non-directional overcurrent protection, high stage, instance 1	●	●	●	●
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	●	●	●	●
Non-directional earth-fault protection, low stage, instance 1	●	-	●	-
Non-directional earth-fault protection, high stage, instance 1	●	-	●	-
Negative-sequence overcurrent protection, instance 1	●	●	●	●
Three-phase thermal overload protection for power transformers, two time constants	●	●	●	●
Circuit breaker failure protection	●	●	●	●
LV-side protection				
Three-phase non-directional overcurrent protection, low stage, instance 2	●	●	●	●
Table continues on next page				

Functionality	A	B	C	D
Three-phase non-directional overcurrent protection, high stage, instance 2	●	●	●	●
Three-phase non-directional overcurrent protection, instantaneous stage, instance 2	●	●	●	●
Non-directional earth-fault protection, low stage, instance 2	-	●	-	●
Non-directional earth-fault protection, high stage, instance 2	-	●	-	●
Negative-sequence overcurrent protection, instance 2	●	●	●	●
Arc protection, instance 1	o	o	o	o
Arc protection, instance 2	o	o	o	o
Arc protection, instance 3	o	o	o	o
Control				
Circuit-breaker control with interlocking	●	●	●	●
Disconnector position indication, instance 1	●	●	●	●
Disconnector position indication, instance 2	●	●	●	●
Disconnector position indication, instance 3	●	●	●	●
Earthing switch indication	●	●	●	●
Tap changer position indication	●	●	●	●
Condition monitoring				
Circuit-breaker condition monitoring	●	●	●	●
Trip circuit supervision, instance 1	●	●	●	●
Trip circuit supervision, instance 2	●	●	●	●
Measurement				
Disturbance recorder	●	●	●	●
Three-phase current measurement, instance 1 (HV side)	●	●	●	●
Three-phase current measurement, instance 2 (LV side)	●	●	●	●
Sequence current measurement (HV side)	●	●	●	●
Residual current measurement, instance 1 (HV side)	●	-	●	-
Residual current measurement, instance 2 (LV side)	-	●	-	●
● = included, o = optional at the time of order				

1) Note that all directional protection functions can also be used in non-directional mode.

3.2.2 Terminal diagrams

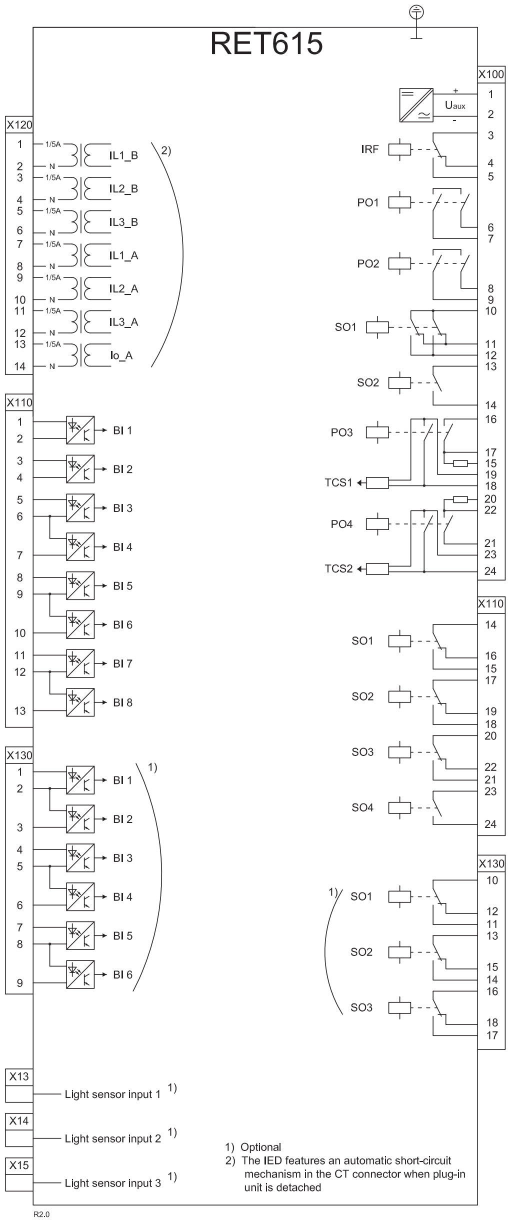


Figure 6: Terminal diagram of standard configurations A-D

3.2.3 Connection diagrams

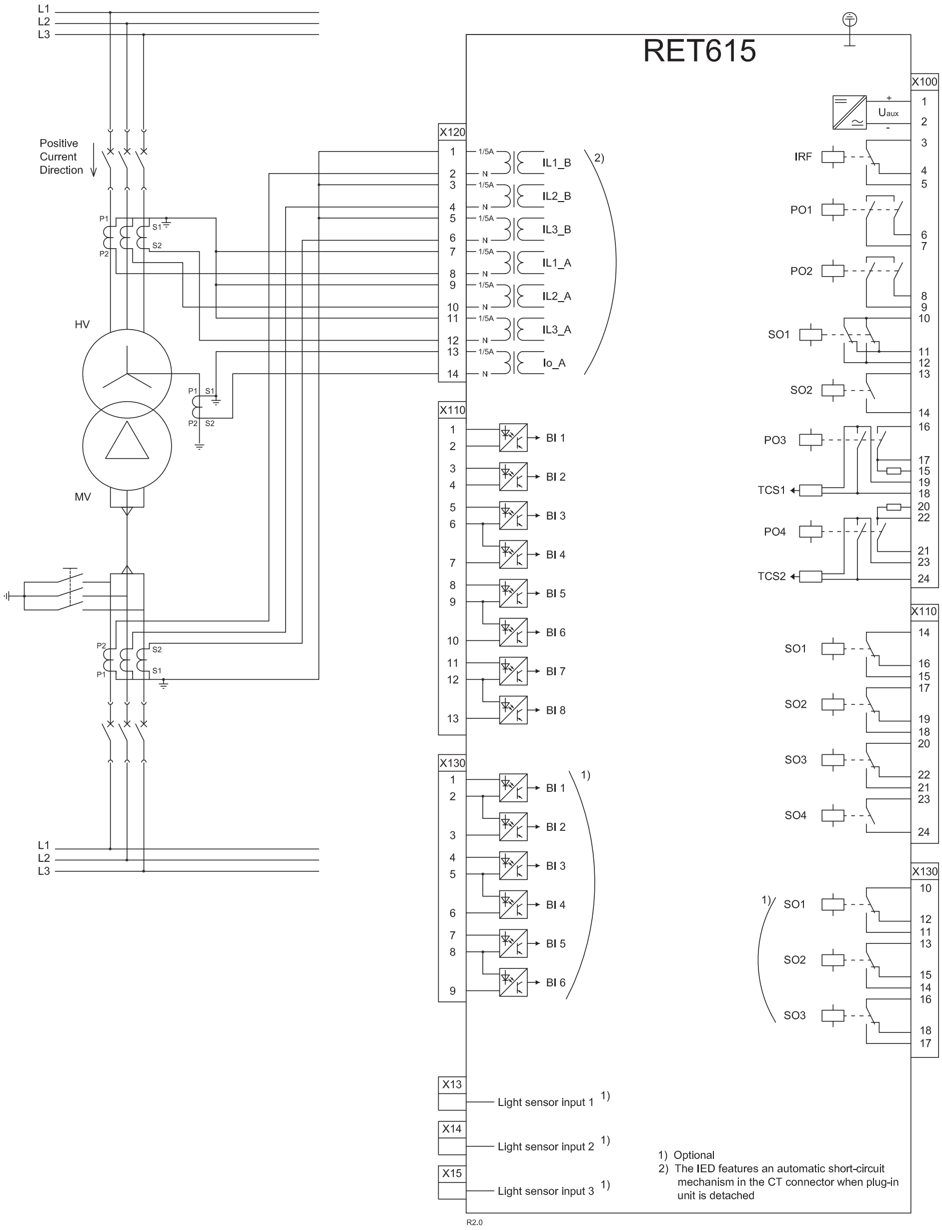


Figure 7: Connection diagram for configuration A (low impedance restricted earth-fault for high-voltage side)

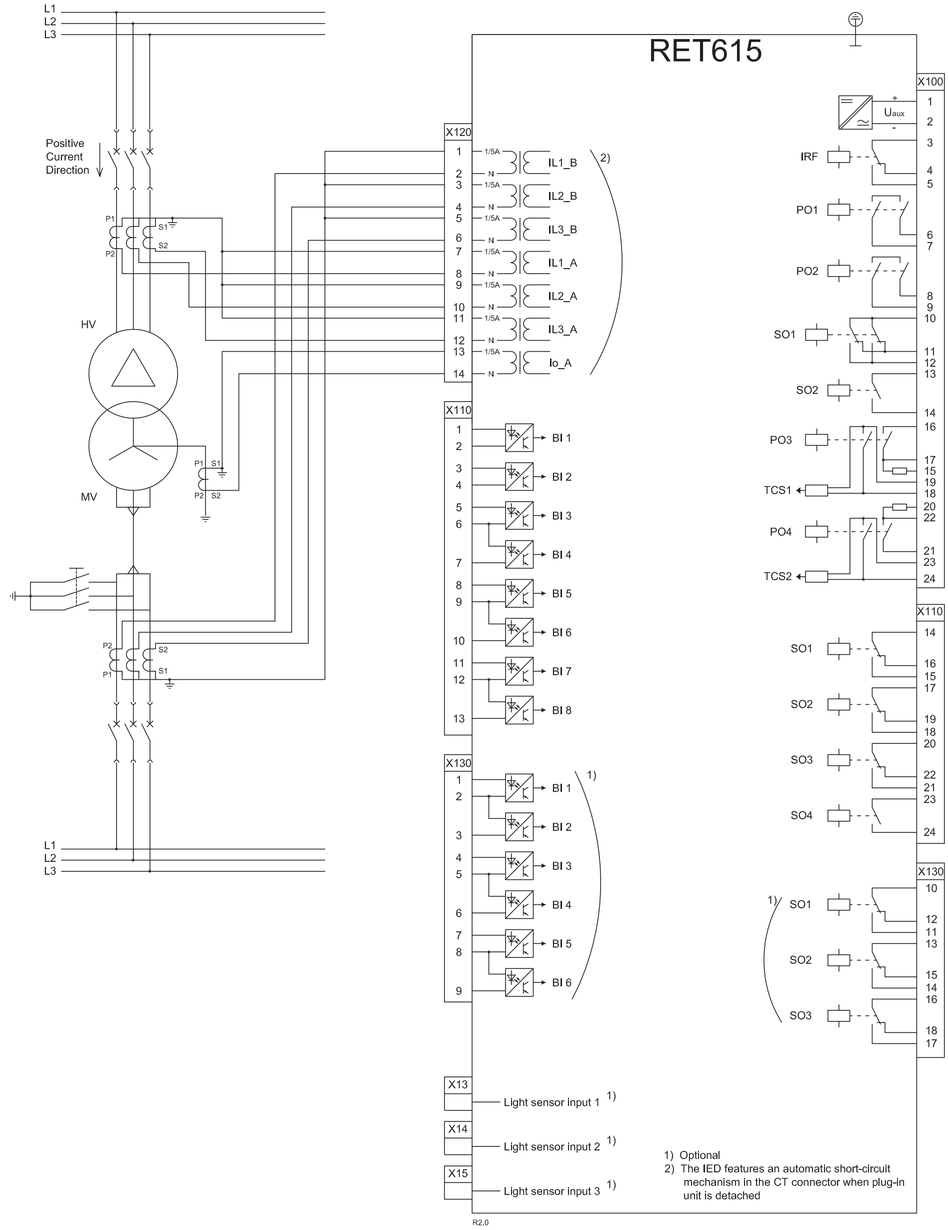


Figure 8: Connection diagram for configuration B (low impedance restricted earth-fault for medium-voltage side)

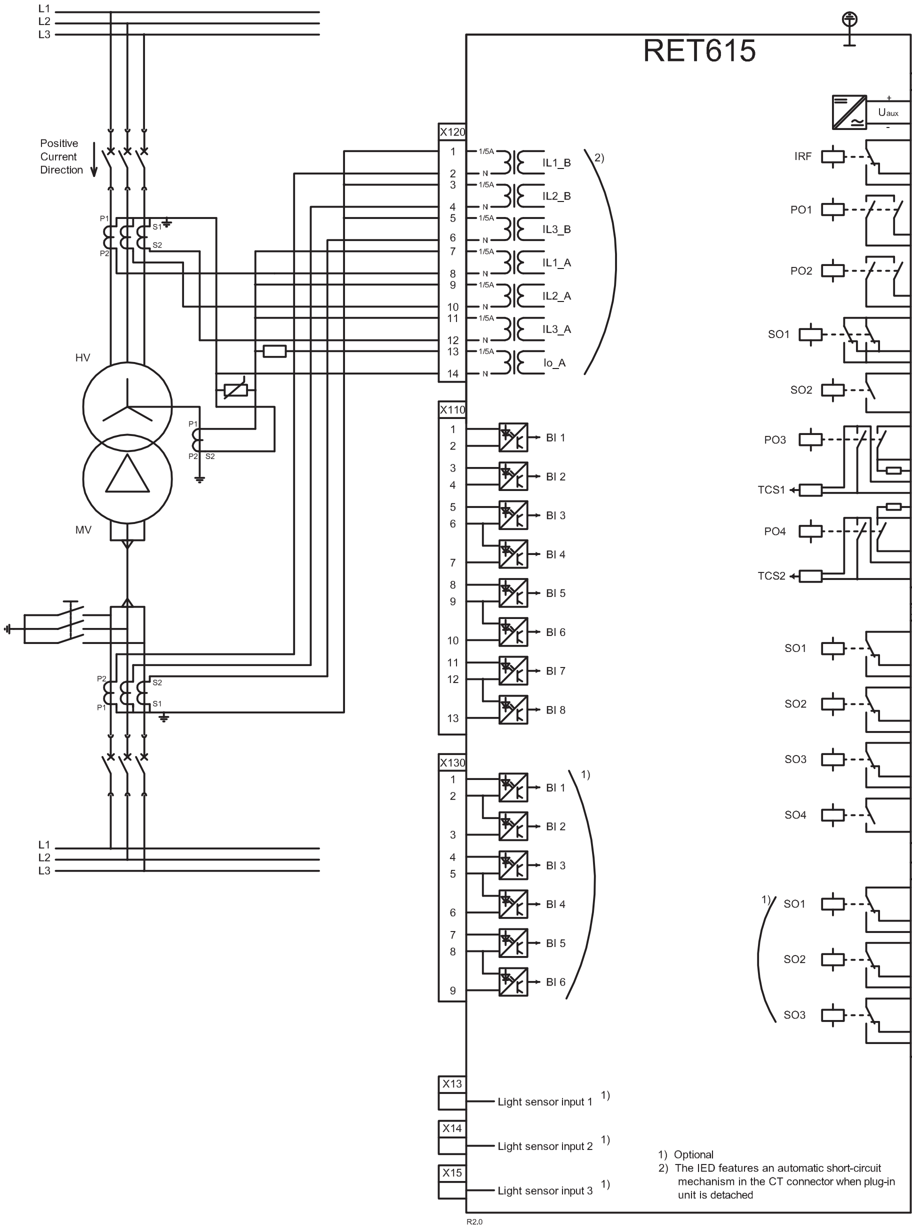


Figure 9: Connection diagram for configuration C (high impedance restricted earth-fault for high-voltage side)

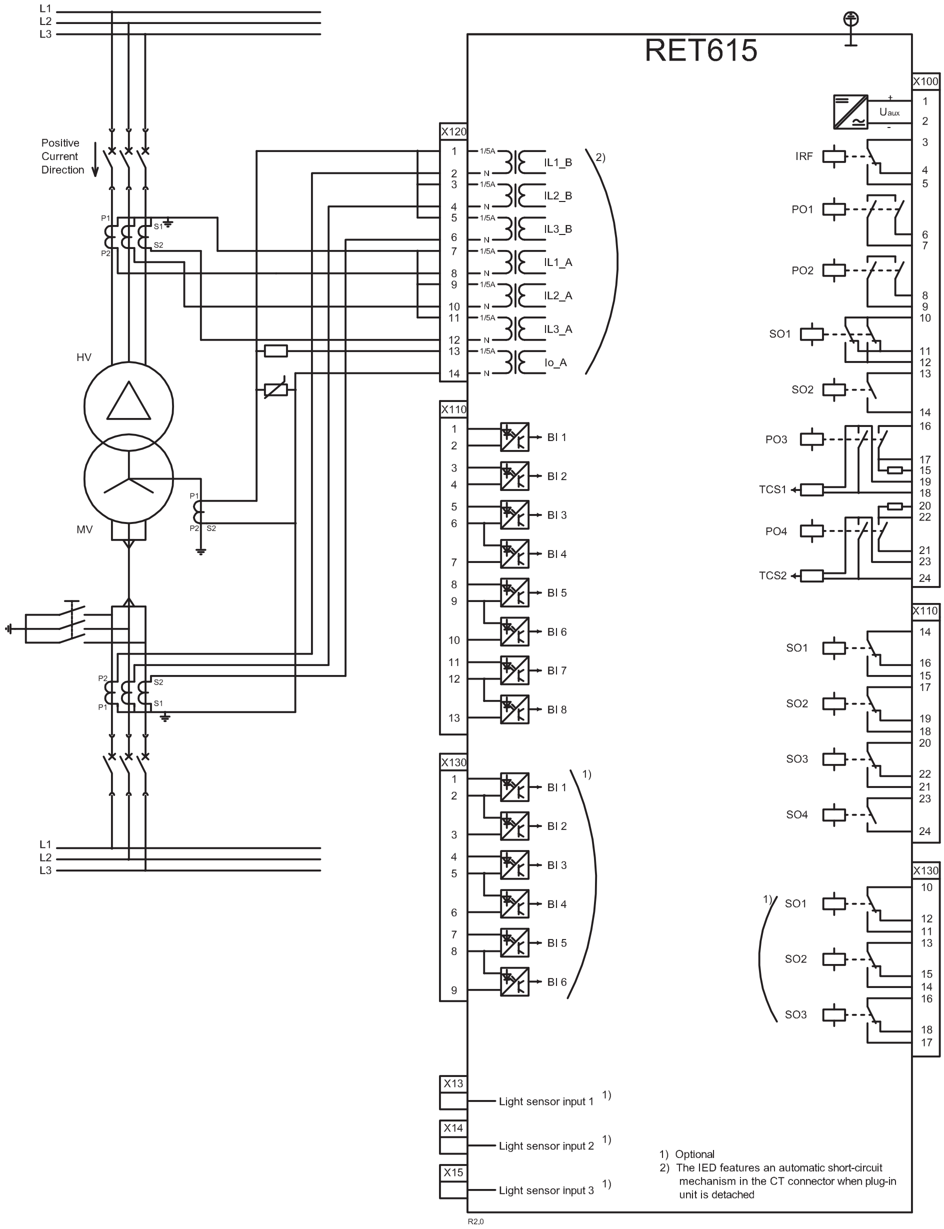


Figure 10: *Connection diagram for configuration D (high impedance restricted earth-fault for medium-voltage side)*

3.3 Standard configuration A including low impedance restricted earth-fault for high-voltage side

3.3.1 Applications

The standard configuration includes three-phase differential, short-circuit, overcurrent, earth-fault, thermal overload and negative-phase sequence protection in power transformer feeders. The standard configuration is mainly intended for protection of the power transformer between current transformers.

The IED with this 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.

3.3.2 Functions

Table 8: Functions included in the RET615 standard configuration with low impedance restricted earth-fault for high-voltage side

Function	IEC 61850	IEC	ANSI
Stabilized and instantaneous differential protection for two–winding transformers	TR2PTDF1	3dI>T	87T
Three-phase non-directional overcurrent protection, low stage (HV side)	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, low stage (LV side)	PHLPTOC2	3I> (2)	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage (HV side)	PHHPTOC1	3I>>(1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage (LV side)	PHHPTOC2	3I>>(2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage (HV side)	PHIPTOC1	3I>>>(1)	50P/51P (1)
Three-phase non-directional overcurrent protection, instantaneous stage (LV side)	PHIPTOC2	3I>>>(2)	50P/51P (2)
Non-directional earth-fault protection, low stage (HV side)	EFLPTOC1	I_0> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage (HV side) (HV side)	EFHPTOC1	I_0>> (1)	51N-2 (1)
Negative-sequence overcurrent protection (HV side)	NSPTOC1	I_2> (1)	46 (1)
Negative-sequence overcurrent protection (LV side)	NSPTOC2	I_2> (2)	46 (2)
Numerical stabilized low impedance restricted earth-fault	LREFPNDF1	dI_0Lo>	87NL
Table continues on next page			

Function	IEC 61850	IEC	ANSI
Three-phase thermal overload protection for power transformers, two time constants (HV side)	T2PTTR1	3Ith>T	49T
Circuit breaker failure protection (HV side)	CCBRBRF1	$3I>/I_0>BF$	51BF/51NBF
Arc protection (LV side)	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Circuit-breaker control	CBXCBR1	I ↔ O CB	I ↔ O CB
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	I ↔ O ES
Circuit breaker condition monitoring (HV side)	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Disturbance recorder	RDRE1	-	-
Three-phase current measurement (HV side)	CMMXU1	3I	3I
Three-phase current measurement (LV side)	CMMXU2	3I (B)	3I (B)
Sequence current measurement (HV side)	CSMSQI1	I_1, I_2, I_0	I_1, I_2, I_0
Residual current measurement (HV side)	RESCMMXU1	I_0	I_0
Tap changer position indication	TPOSSLTC1	TPOSM	84M

3.3.2.1 Default I/O connections

Table 9: Default connections for binary inputs

Binary input	Description	Connector pins
X110-BI1	Blocking of O/C high stage (high voltage) and instantaneous stage (low voltage)	X110-1,2
X110-BI2	External protection trip	X110-3,4
X110-BI3	Circuit breaker low gas pressure indication	X110-5,6
X110-BI4	Circuit breaker spring charged indication	X110-7,6
X110-BI5	High-voltage side disconnector closed	X110-8,9
X110-BI6	High-voltage side disconnector open	X110-10,9
X110-BI7	High-voltage side circuit breaker closed	X110-11,12
X110-BI8	High-voltage side circuit breaker open	X110-13,12
X130-BI1	BCD sign bit (tap changer position)	X130-1,2
X130-BI2	BCD bit 1 LSB	X130-2,3
X130-BI3	BCD bit 2	X130-4,5

Table continues on next page

Binary input	Description	Connector pins
X130-BI4	BCD bit 3	X130-5,6
X130-BI5	BCD bit 4	X130-7,8
X130-BI6	BCD bit 5 MSB	X130-8,9

Table 10: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1 high voltage	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2 low voltage	X100-20-24
X110-SO1	Overcurrent operate alarm	X110-14,15,16
X110-SO2	Differential protection operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Thermal overload and negative phase-sequence protection operate alarm	X110-23,24

Table 11: Default connections for LEDs

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

3.3.3 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, thus not included in the PCM600 functionality.

The analog channels are assigned to different functions as shown in the functional diagrams. The common signal marked with 3I_A represents the three phase currents of the high-voltage side of the transformer and 3I_B represents the three phase currents of the low-voltage side of the transformer. The signal marked with I_0_A represents the measured neutral current measured between the start point of the transformer and grounding.

3.3.3.1 Functional diagrams for protection

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

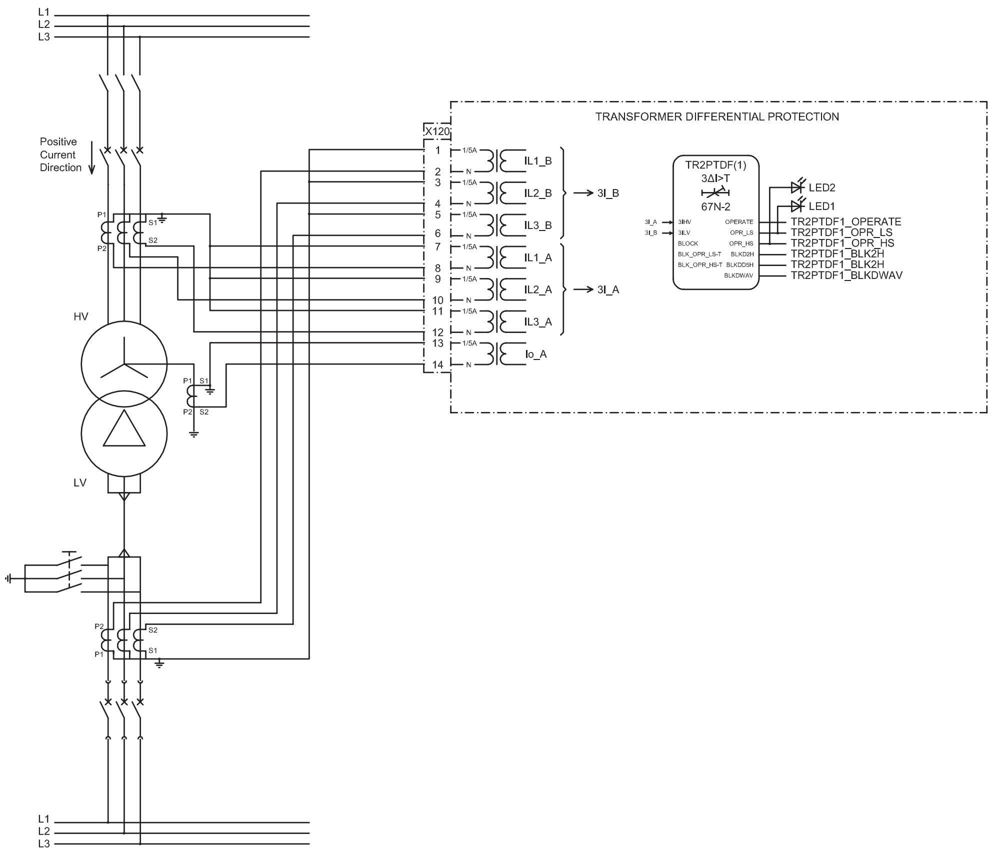


Figure 11: Stabilized and instantaneous differential protection for 2W–transformers

The stabilized and instantaneous differential protection for 2W–transformers (TR2PTDF1) provides protection of power transformer unit including, for example, winding short-circuit and interturn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal.

For transformers having an on-line tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF.

The position indication of the OLTC is recommended for differential protection to increase sensitivity.

All operate signals are connected to the Master Trip 1 and 2 and also to the alarm LEDs. LED 1 is used for biased low-stage operate indication and LED 2 for instantaneous high-stage of the differential protection.

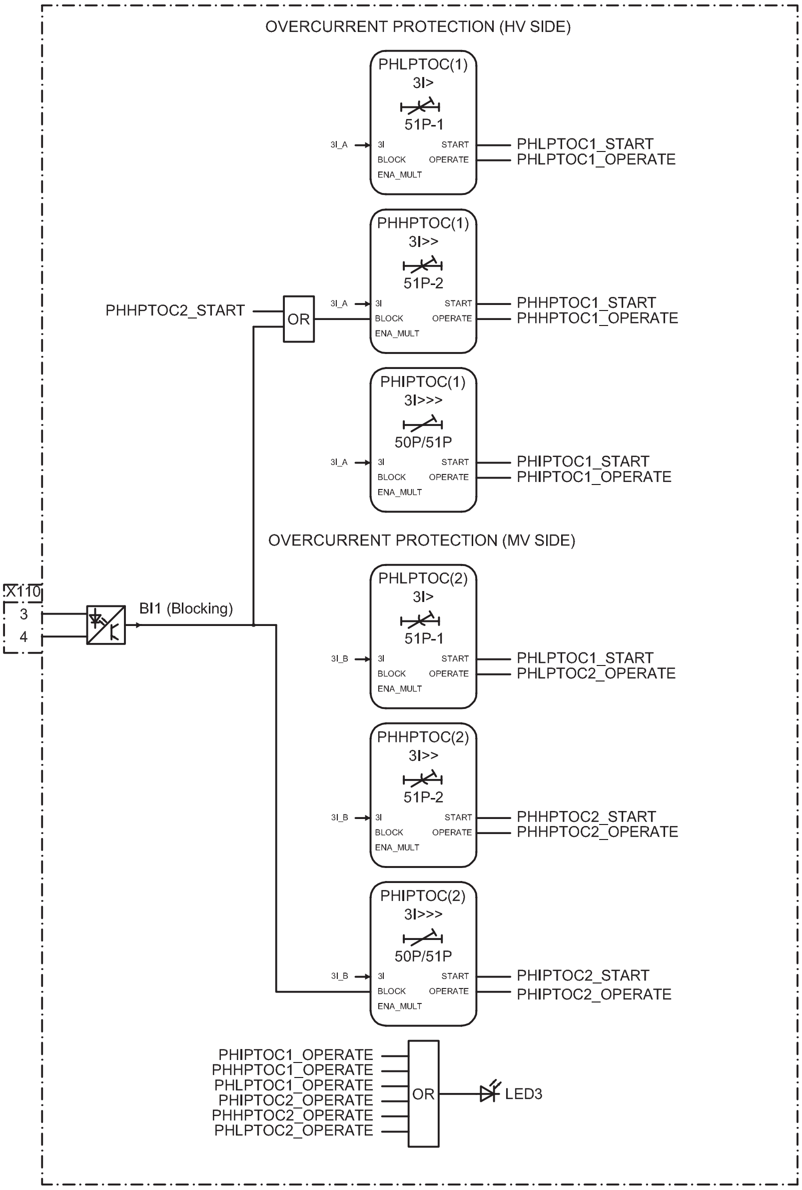


Figure 12: Overcurrent and short-circuit protection

Three stages for both high-voltage and low-voltage sides as a total of six overcurrent stages are offered for overcurrent and short-circuit protection. The high-voltage side high stage (PHHPTOC1) can be blocked by energizing the binary input 1 (X120:1-2) or by starting the high stage of the low-voltage side (PHHPTOC2). Also the low-voltage side instantaneous stage is blocked by activating the binary input (X120_BI1).

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

The operate of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). This output is used for giving a specific alarm of the overcurrent protection operation.

There are four IED variant-specific setting groups. Parameters can be set independently for each setting group.

The active setting group (1...4) can be changed with a parameter. The active setting group can also be changed via a binary input if the binary input is enabled for this. To enable the change of the active setting group via a binary input, connect a free binary input with PCM600 to the ActSG input of the SGCB-block.

Table 12: Binary input states and corresponding active setting groups

BI state	Active setting group
OFF	1
ON	2

The active setting group defined by a parameter is overridden when a binary input is enabled for changing the active setting group.

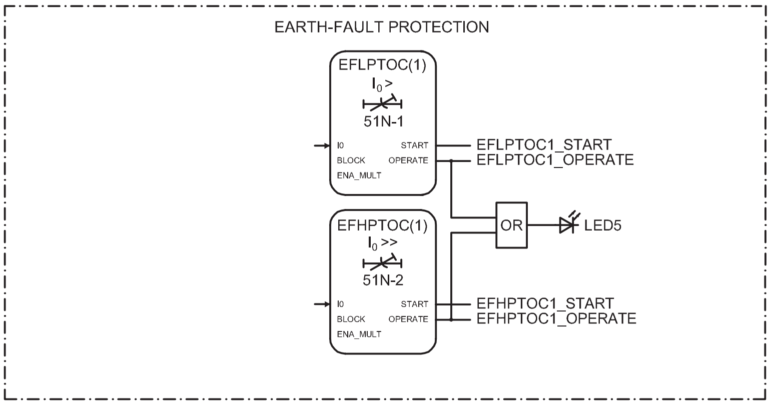


Figure 13: Non-directional earth-fault protection

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

All operate signals are connected to the Master Trip and also to the alarm LEDs. LED 5 is used for non-directional earth-fault protection operate indication.

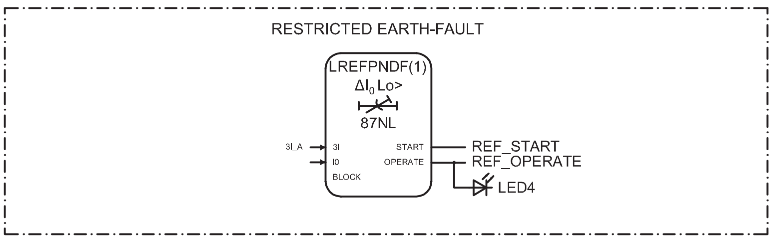


Figure 14: Restricted low-impedance earth-fault protection

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

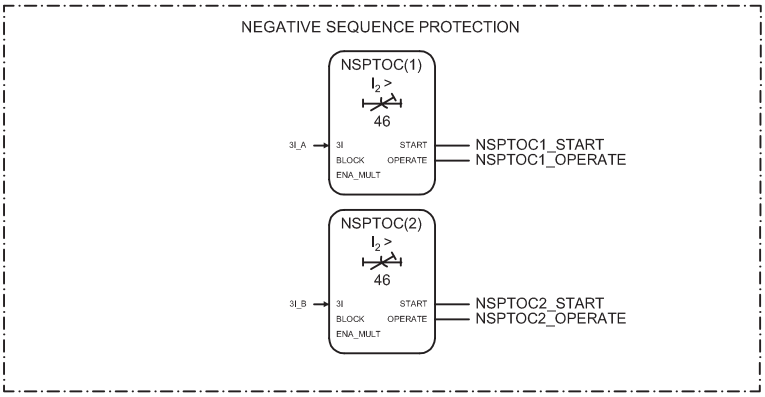


Figure 15: Negative-sequence overcurrent protection

NSPTOC is designed for negative-phase sequence protection whenever the operating characteristic is appropriate. It is applied for the protection of transformers against thermal stress and damage.

NSPTOC1 is measuring negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

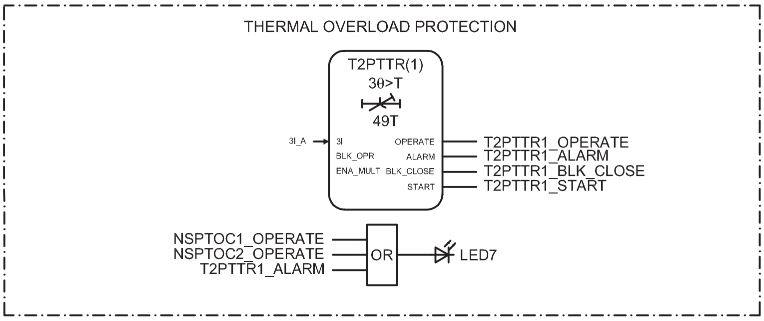


Figure 16: Three-phase thermal overload protection for power transformers

Three-phase thermal overload protection for power transformers (T2PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip 2. LED 7 is used for the thermal overload protection alarm indication, the same as for negative-sequence overcurrent protection operate indication.

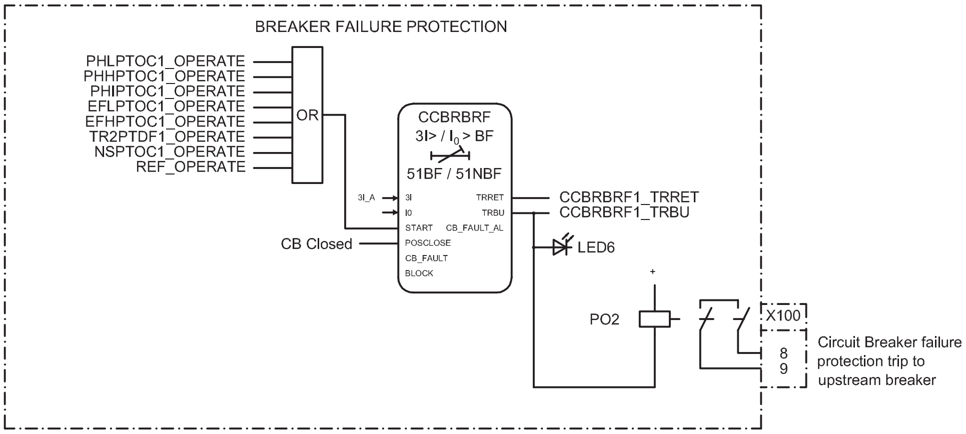


Figure 17: Circuit-breaker failure protection

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 Logic 2. The TRBU output is used for retripping both the high-voltage and low-voltage side circuit breakers through Master Trip 1 and 2. The TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

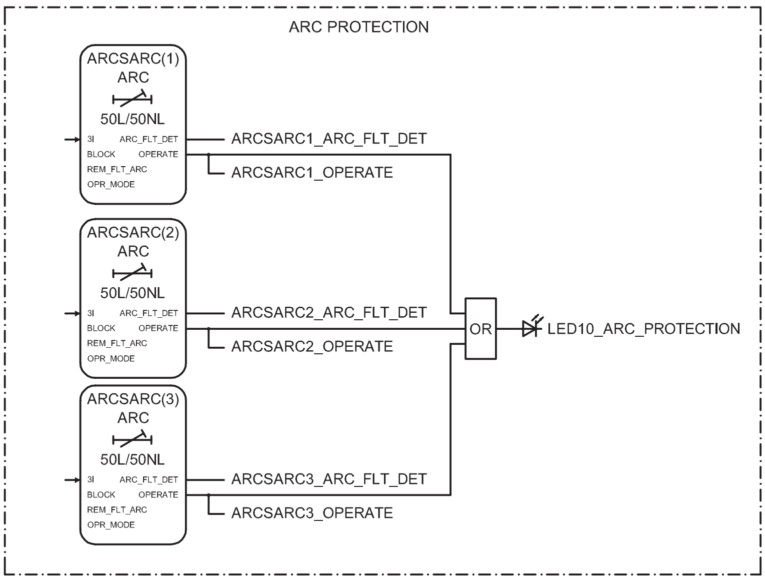


Figure 18: Arc protection

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.

3.3.3.2 Functional diagrams for disturbance recorder and supervision functions

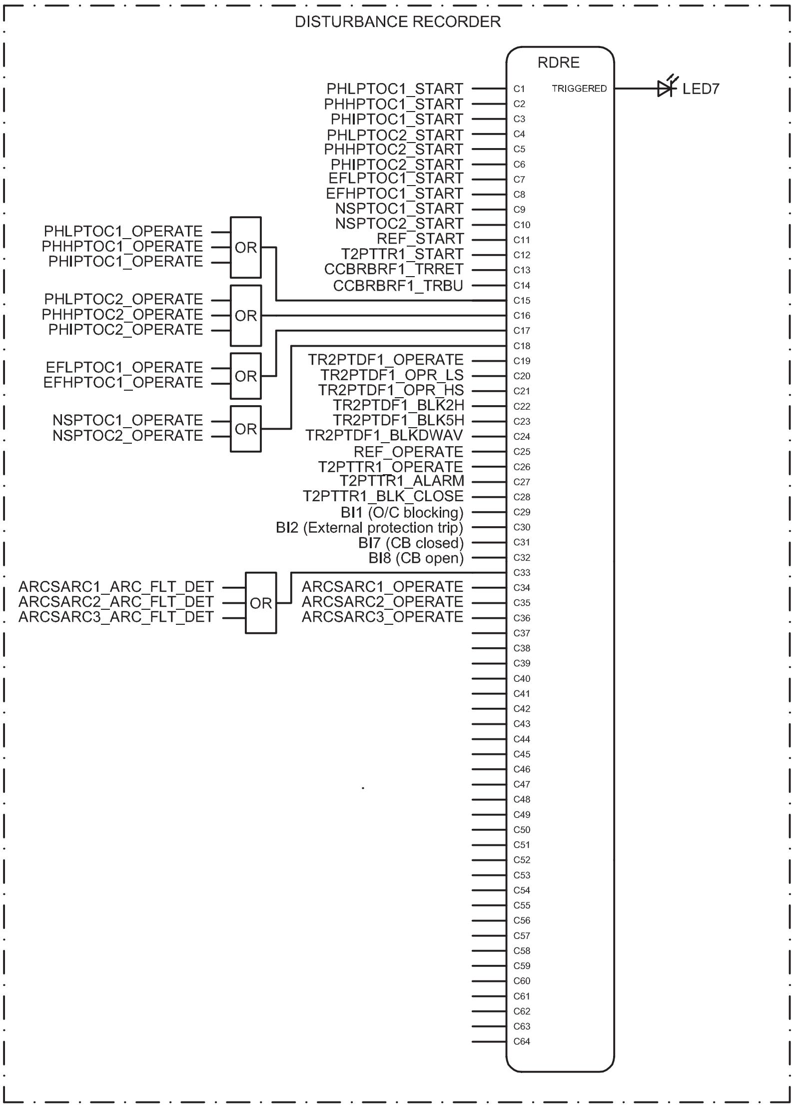


Figure 19: Disturbance recorder

The disturbance recorder has 64 digital inputs out of which 36 are connected as a default. 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 the four binary inputs from X110 are also connected.

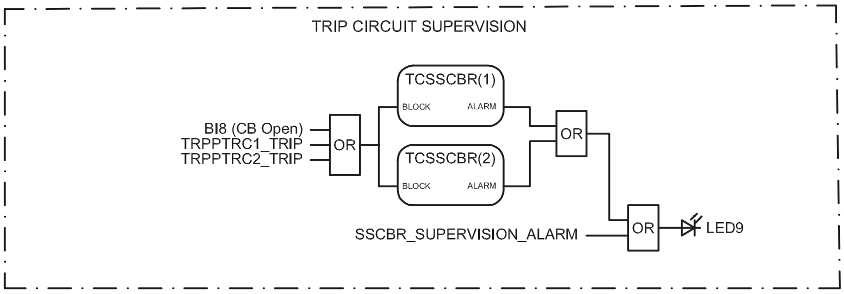


Figure 20: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:16-19) and TCSSCBR2 for PO4 X100:20-23). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC1) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

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

3.3.3.3 Functional diagrams for control and interlocking

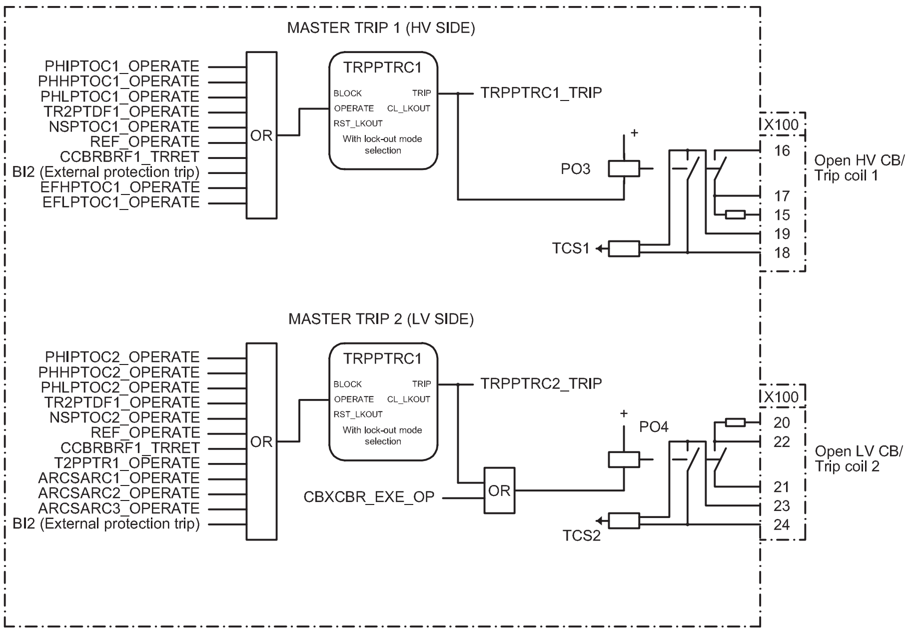


Figure 21: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:16-19).

TRPPTRC1 and 2 provide 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.

The external trip indication is connected also to the alarm LED 11.

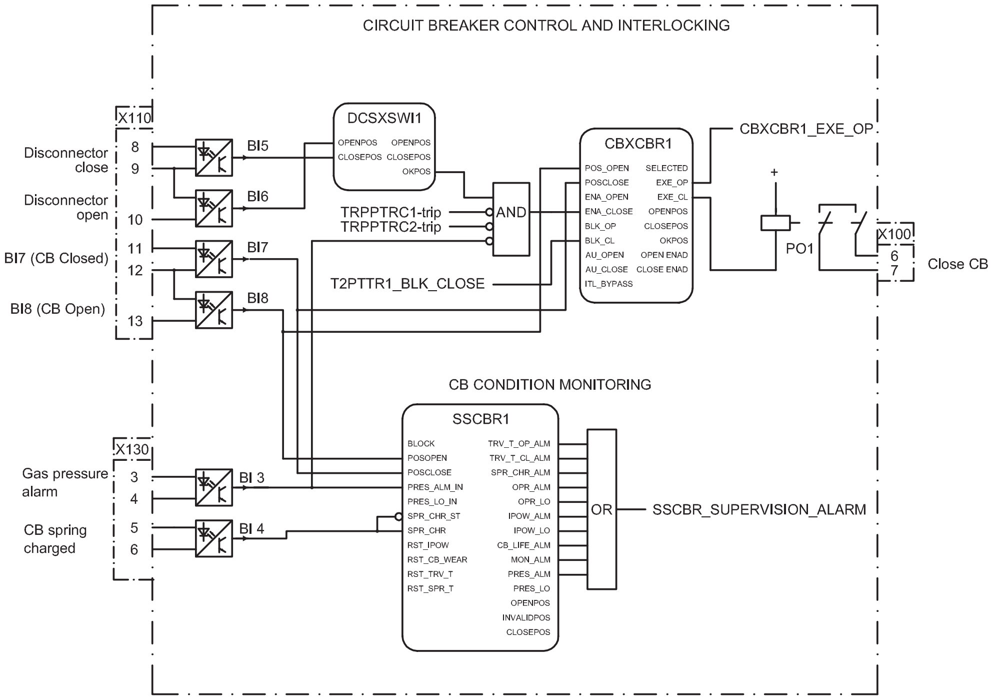


Figure 22: Disconnector position indication

There are three disconnector status blocks (DCSXSWI1…3) available in the IED. The remaining two not described in the functional diagram are available in PCM600 for connection where applicable.

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

Table 13: 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 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 position status 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 non-active trip signal and non-active gas pressure alarm, activates the close-enable signal to the circuit-breaker control function block. The open operation is always enabled.

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 9.

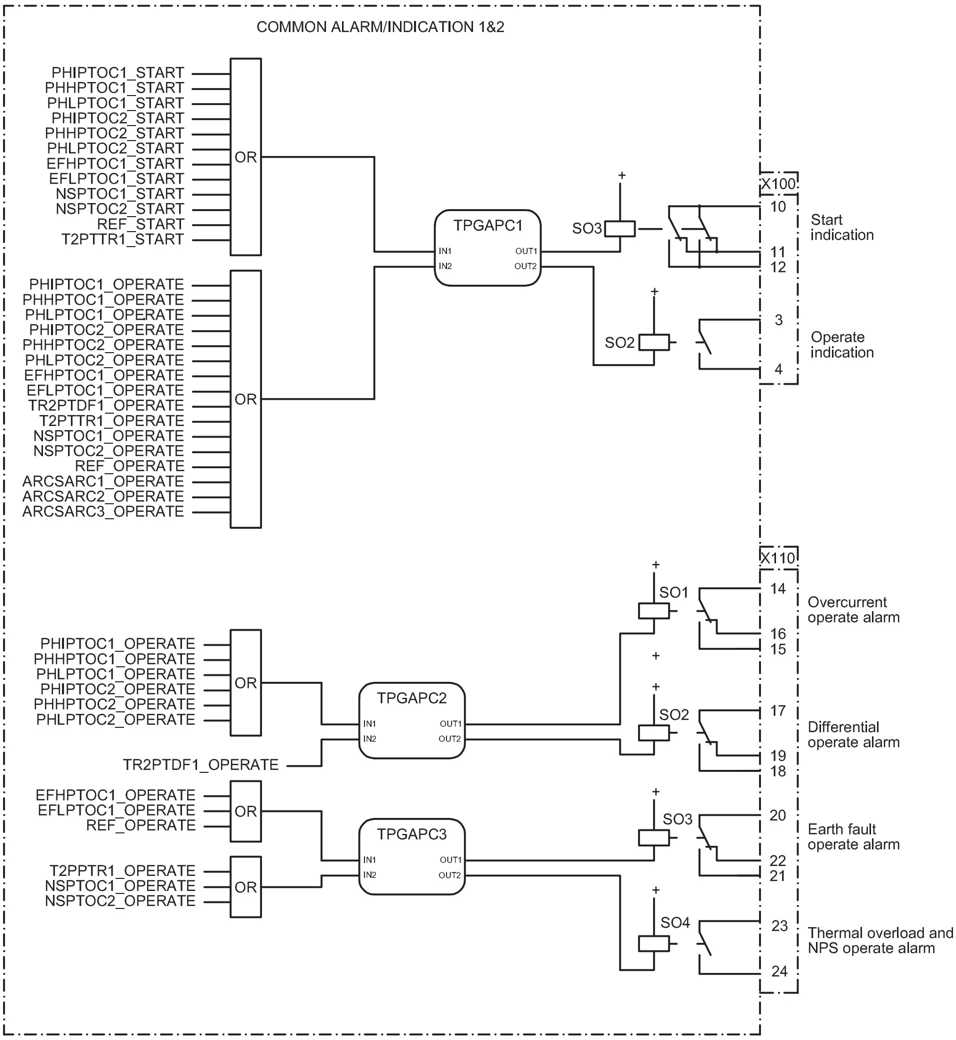


Figure 23: Common alarm/indication 1 and 2

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 SO2 (X100:13-15)
- Operation (trip) of differential protection function SO1 (X110:14-15-16)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-18-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-21-22)
- Operation (trip) of thermal or current negative-sequence 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.

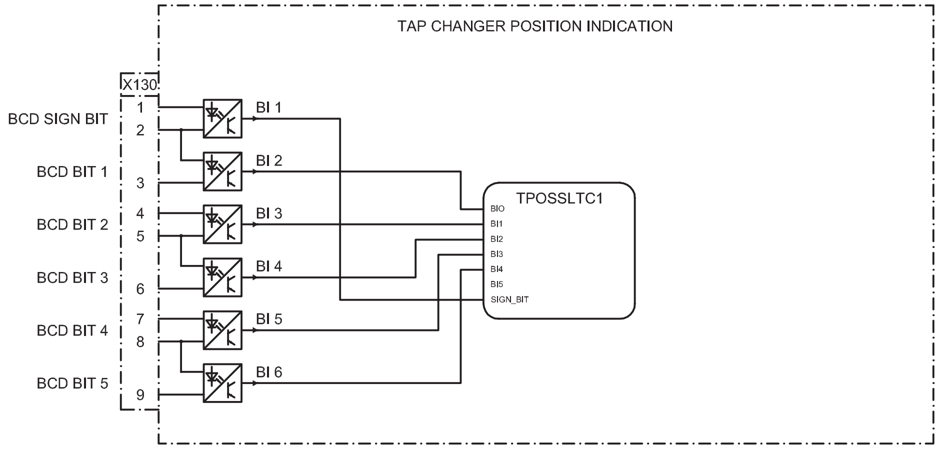


Figure 24: Tap changer position indication

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IEDvia the tap changer position indication function TPOSSLTC1. TPOSSLTC1 is connected to the binary inputs of the X130 BIO card. TPOSSLTC1 uses binary-coded methods to generate the integer value of the tap changer position.

3.4 Standard configuration B including low impedance restricted earth-fault for low-voltage side

3.4.1 Applications

The standard configuration includes three-phase differential, short-circuit, overcurrent, earth-fault, thermal overload and negative-phase sequence protection in power transformer feeders. The standard configuration is mainly intended for protection of the power transformer between current transformers.

The IED with this 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 14: *Functions included in the RET615 standard configuration with low impedance restricted earth-fault for low-voltage side*

Function	IEC 61850	IEC	ANSI
Stabilized and instantaneous differential protection for two–winding transformers	TR2PTDF1	3dI>T	87T
Three-phase non-directional overcurrent protection, low stage (HV side)	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, low stage (LV side)	PHLPTOC2	3I> (2)	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage (HV side)	PHHPTOC1	3I>>(1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage (LV side)	PHHPTOC2	3I>>(2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage (HV side)	PHIPTOC1	3I>>>(1)	50P/51P (1)
Three-phase non-directional overcurrent protection, instantaneous stage (LV side)	PHIPTOC2	3I>>>(2)	50P/51P (2)
Non-directional earth-fault protection, low stage (LV side)	EFLPTOC2	I_0> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage (LV side)	EFHPTOC2	I_0>> (2)	51N-2 (2)
Negative-sequence overcurrent protection (HV side)	NSPTOC1	I_2> (1)	46 (1)
Negative-sequence overcurrent protection (LV side)	NSPTOC2	I_2> (2)	46 (2)
Numerical stabilized low impedance restricted earth-fault	LREFPNDF1	dI_0Lo>	87NL
Three-phase thermal overload protection for power transformers, two time constants (HV side)	T2PTTR1	3Ith>T	49T
Circuit breaker failure protection (HV side)	CCBRBRF1	3I>/I_0>BF	51BF/51NBF
Arc protection (LV side)	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Circuit-breaker control	CBXCBR1	I ↔ O CB	I ↔ O CB
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	I ↔ O ES
Circuit breaker condition monitoring (HV side)	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Disturbance recorder	RDRE1	-	-
Three-phase current measurement (HV side)	CMMXU1	3I	3I

Table continues on next page

Function	IEC 61850	IEC	ANSI
Three-phase current measurement (LV side)	CMMXU2	3I (B)	3I (B)
Sequence current measurement (HV side)	CSMSQI1	I_1, I_2, I_0	I_1, I_2, I_0
Residual current measurement (LV side)	RESCMMXU2	I_0 (B)	I_0 (B)
Tap changer position indication	TPOSSLTC1	TPOSM	84M

3.4.2.1 Default I/O connections

Table 15: Default connections for binary inputs

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

Table 16: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1 high voltage	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2 low voltage	X100-20-24
X110-SO1	Overcurrent operate alarm	X110-14,15,16
X110-SO2	Differential protection operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Thermal overload and negative phase-sequence protection operate alarm	X110-23,24

Table 17: Default connections for LEDs

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

3.4.3 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, thus not included in the PCM600 functionality.

The analog channels are assigned to different functions as shown in the functional diagrams. The common signal marked with 3I_A represents the three phase currents of the high-voltage side of the transformer and 3I_B represents the three phase currents of the low-voltage side of the transformer. The signal marked with I_0_B represents the measured neutral current measured between the start point of the transformer and grounding.

3.4.3.1 Functional diagrams for protection

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

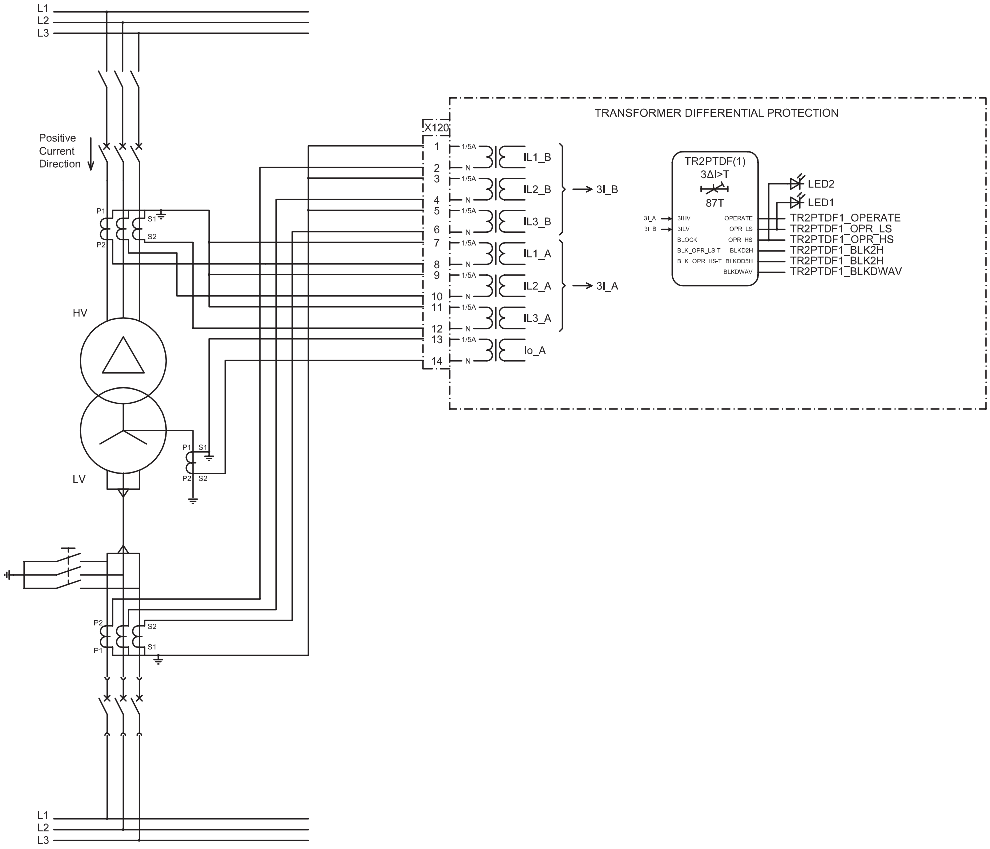


Figure 25: Stabilized and instantaneous differential protection for 2W–transformers

The stabilized and instantaneous differential protection for 2W–transformers (TR2PTDF1) provides protection of power transformer unit including, for example, winding short-circuit and interturn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal.

For transformers having an on-line tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF.

The position indication of the OLTC is recommended for differential protection to increase sensitivity.

All operate signals are connected to the Master Trip 1 and 2 and also to the alarm LEDs. LED 1 is used for biased low-stage operate indication and LED 2 for instantaneous high-stage of the differential protection.

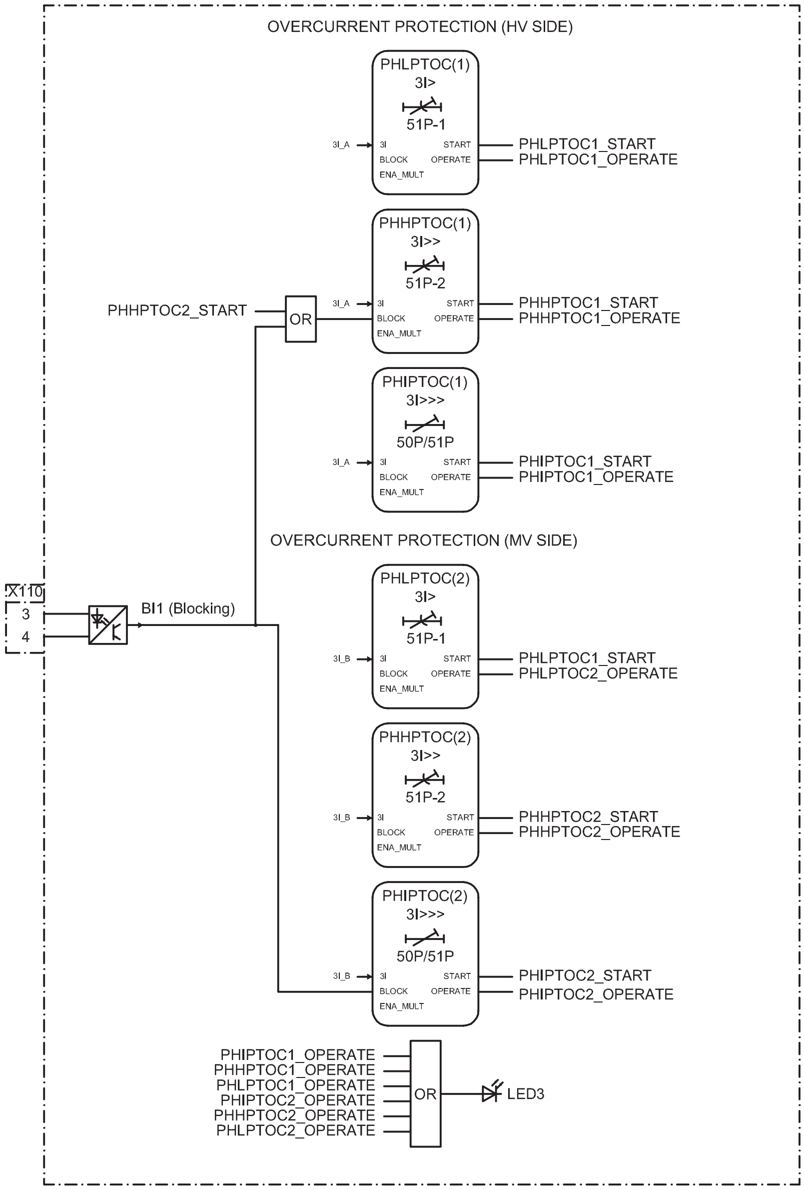


Figure 26: Overcurrent and short-circuit protection

Three stages for both high-voltage and low-voltage sides as a total of six overcurrent stages are offered for overcurrent and short-circuit protection. The high-voltage side high stage (PHHPTOC1) can be blocked by energizing the binary input 1 (X120:1-2) or by starting the high stage of the low-voltage side (PHHPTOC2). Also the low-voltage side instantaneous stage is blocked by activating the binary input (X120_BI1).

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

The operate of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). This output is used for giving a specific alarm of the overcurrent protection operation.

There are four IED variant-specific setting groups. Parameters can be set independently for each setting group.

The active setting group (1...4) can be changed with a parameter. The active setting group can also be changed via a binary input if the binary input is enabled for this. To enable the change of the active setting group via a binary input, connect a free binary input with PCM600 to the ActSG input of the SGCB-block.

Table 18: Binary input states and corresponding active setting groups

BI state	Active setting group
OFF	1
ON	2

The active setting group defined by a parameter is overridden when a binary input is enabled for changing the active setting group.

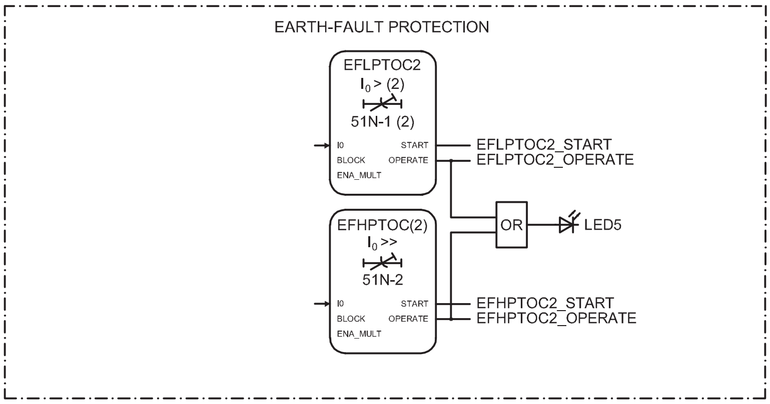


Figure 27: Non-directional earth-fault protection

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

All operate signals are connected to the Master Trip and also to the alarm LEDs. LED 5 is used for non-directional earth-fault protection operate indication.

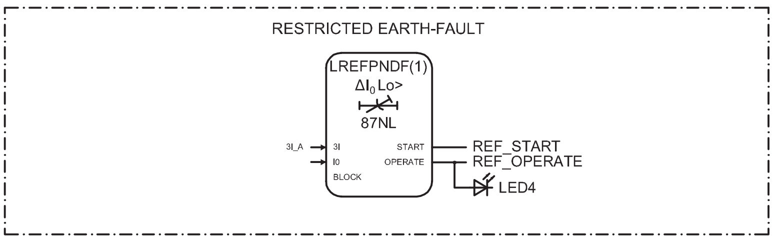


Figure 28: Restricted low-impedance earth-fault protection

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

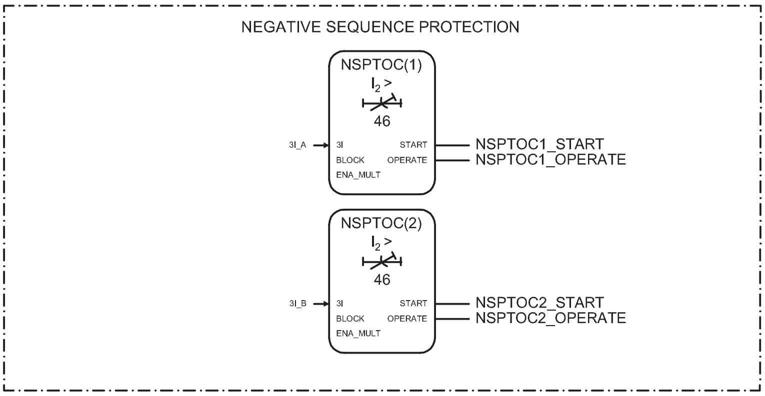


Figure 29: Negative-sequence overcurrent protection

NSPTOC is designed for negative-phase sequence protection whenever the operating characteristic is appropriate. It is applied for the protection of transformers against thermal stress and damage.

NSPTOC1 is measuring negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

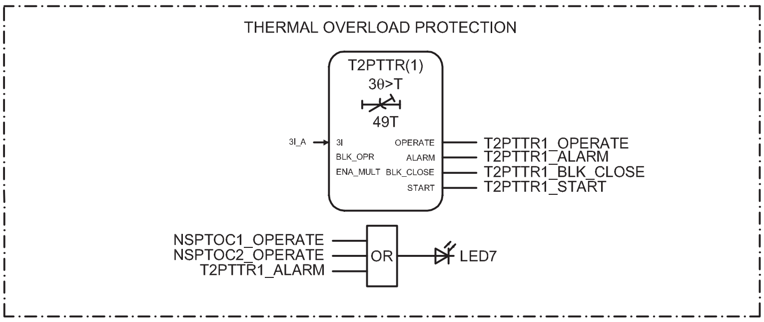


Figure 30: Three-phase thermal overload protection for power transformers

Three-phase thermal overload protection for power transformers (T2PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip 2. LED 7 is used for the thermal overload protection alarm indication, the same as for negative-sequence overcurrent protection operate indication.

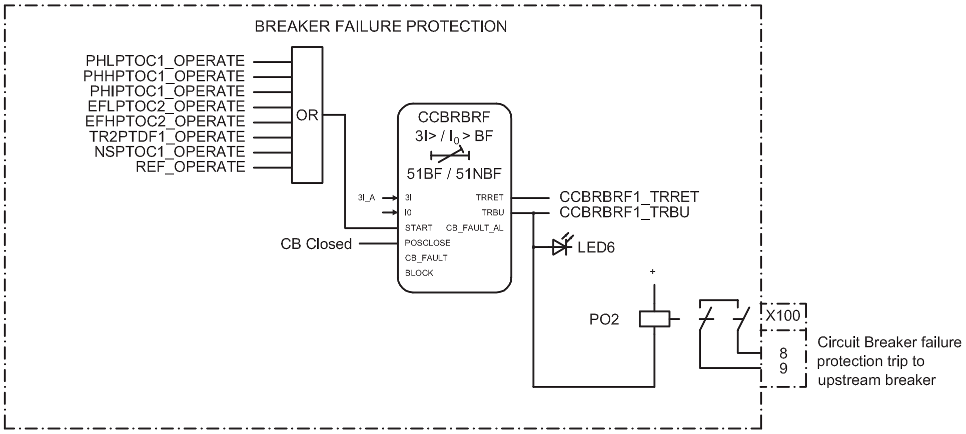


Figure 31: Circuit-breaker failure protection

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 Logic 2. The TRBU output is used for retripping both the high-voltage and low-voltage side circuit breakers through Master Trip 1 and 2. The TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

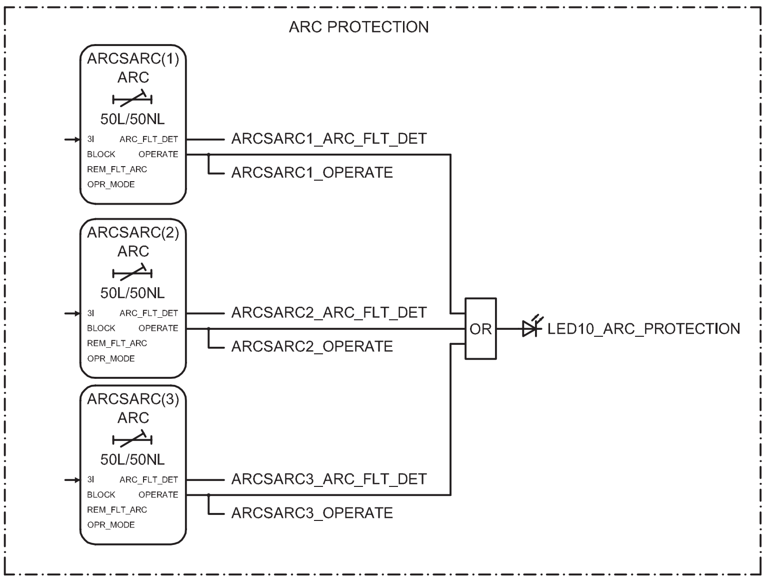


Figure 32: Arc protection

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

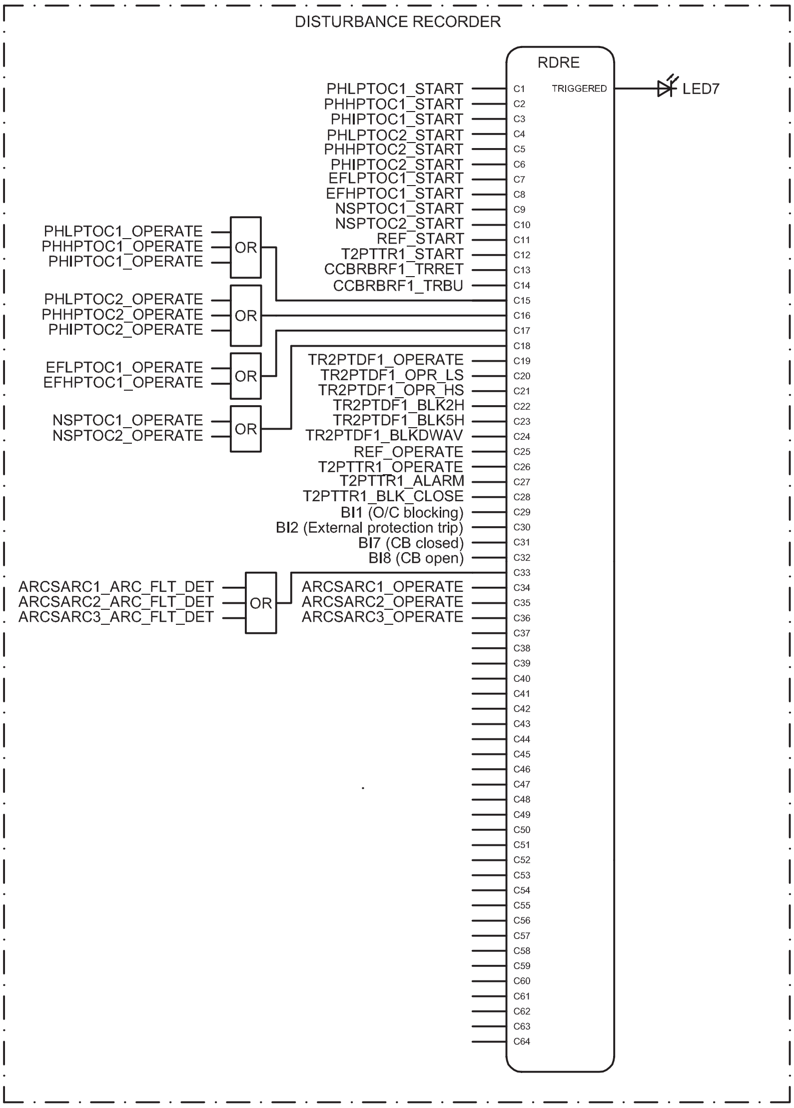


Figure 33: Disturbance recorder

The disturbance recorder has 64 digital inputs out of which 36 are connected as a default. 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 the four binary inputs from X110 are also connected.

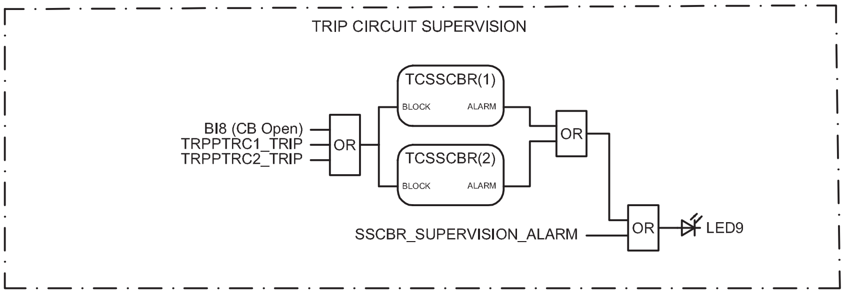


Figure 34: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:16-19) and TCSSCBR2 for PO4 X100:20-23). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC1) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

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

3.4.3.3 Functional diagrams for control and interlocking

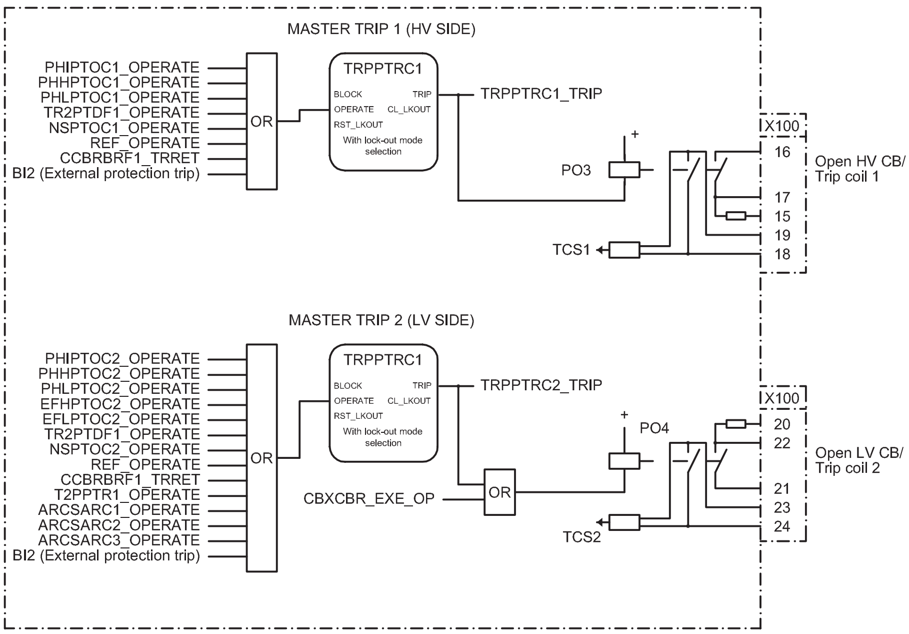


Figure 35: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:16-19).

TRPPTRC1 and 2 provide 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.

The external trip indication is connected also to the alarm LED 11.

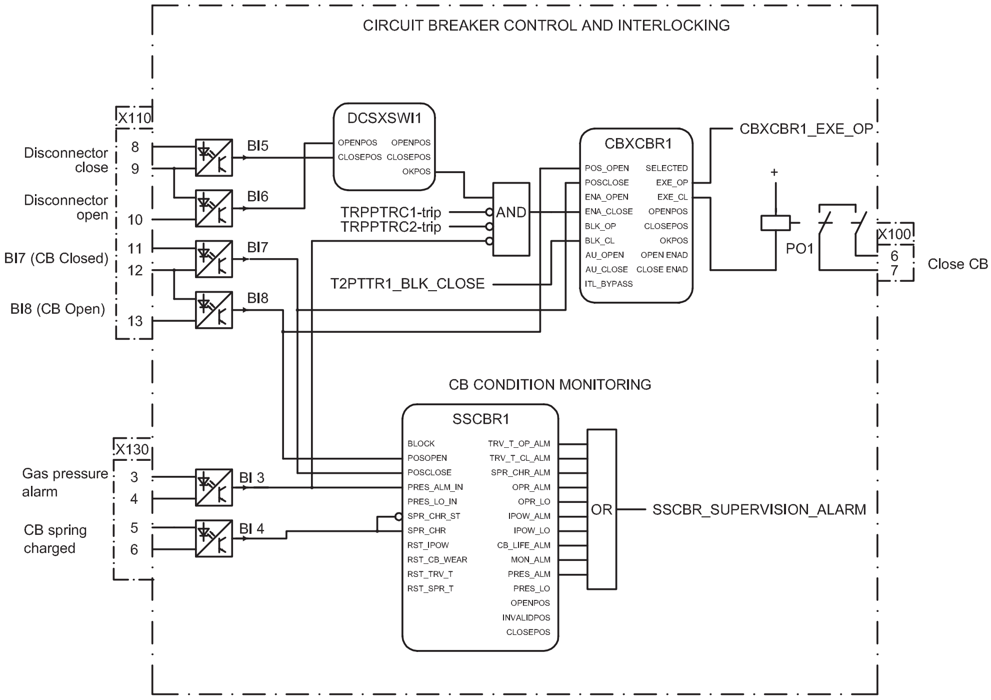


Figure 36: Disconnector position indication

There are three disconnector status blocks (DCSXSWI1…3) available in the IED. The remaining two not described in the functional diagram are available in PCM600 for connection where applicable.

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

Table 19: 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 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 position status 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 non-active trip signal and non-active gas pressure alarm, activates the close-enable signal to the circuit-breaker control function block. The open operation is always enabled.

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 9.

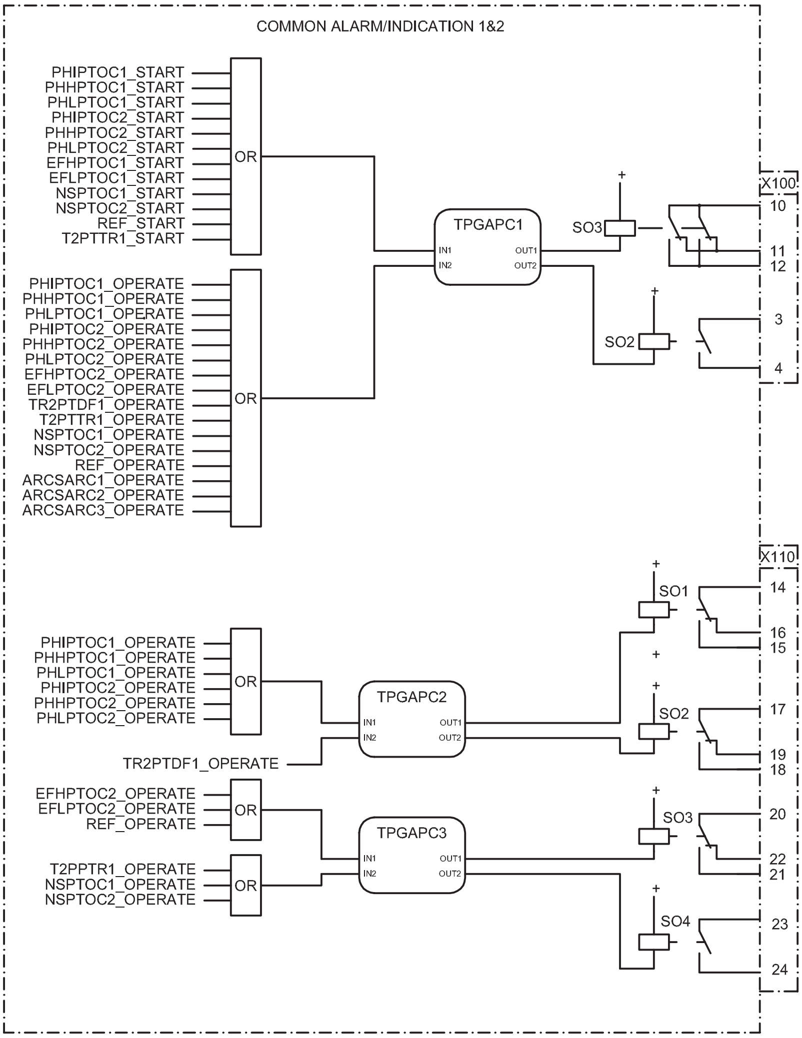


Figure 37: Common alarm/indication 1 and 2

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 SO2 (X100:13-15)
- Operation (trip) of differential protection function SO1 (X110:14-15-16)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-18-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-21-22)
- Operation (trip) of thermal or current negative-sequence 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.

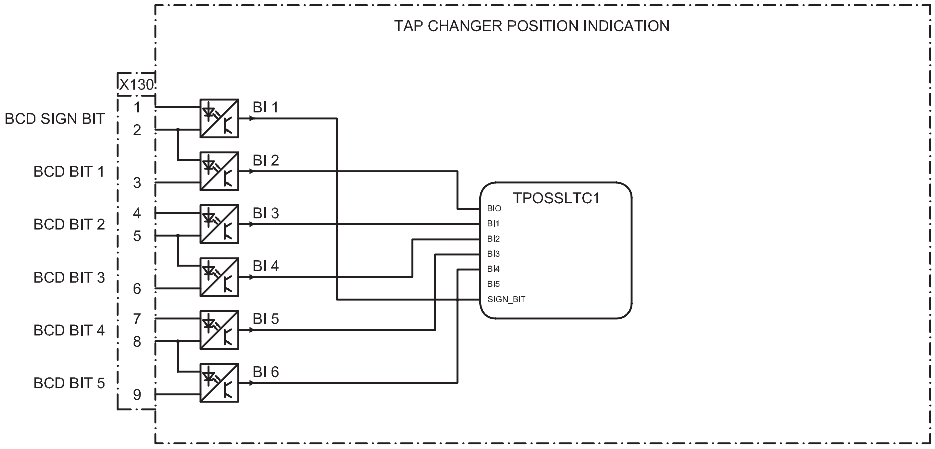


Figure 38: Tap changer position indication

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IEDvia the tap changer position indication function TPOSSLTC1. TPOSSLTC1 is connected to the binary inputs of the X130 BIO card. TPOSSLTC1 uses binary-coded methods to generate the integer value of the tap changer position.

3.5 Standard configuration C including high impedance restricted earth-fault for high-voltage side

3.5.1 Applications

The standard configuration includes three-phase differential, short-circuit, overcurrent, earth-fault, thermal overload and negative-phase sequence protection in power transformer feeders. The standard configuration is mainly intended for protection of the power transformer between current transformers.

The IED with this 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 20: Functions included in the RET615 standard configuration with high impedance restricted earth-fault for high-voltage side

Function	IEC 61850	IEC	ANSI
Stabilized and instantaneous differential protection for two–winding transformers	TR2PTDF1	3dI>T	87T
Three-phase non-directional overcurrent protection, low stage (HV side)	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, low stage (LV side)	PHLPTOC2	3I> (2)	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage (HV side)	PHHPTOC1	3I>>(1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage (LV side)	PHHPTOC2	3I>>(2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage (HV side)	PHIPTOC1	3I>>>(1)	50P/51P (1)
Three-phase non-directional overcurrent protection, instantaneous stage (LV side)	PHIPTOC2	3I>>>(2)	50P/51P (2)
Non-directional earth-fault protection, low stage (HV side)	EFLPTOC1	I_0> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage, using calculated I_0 (HV side)	EFHPTOC1	I_0>> (1)	51N-2 (1)
Negative-sequence overcurrent protection (HV side)	NSPTOC1	I_2> (1)	46 (1)
Negative-sequence overcurrent protection (LV side)	NSPTOC2	I_2> (2)	46 (2)
High impedance-based restricted earth-fault	HREFPDIF1	dI_0Hi>	87NH
Three-phase thermal overload protection for power transformers, two time constants (HV side)	T2PTTR1	3Ith>T	49T
Circuit breaker failure protection (HV side)	CCBRBRF1	3I>/I_0>BF	51BF/51NBF
Arc protection (LV side)	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Circuit-breaker control	CBXCBR1	I ↔ O CB	I ↔ O CB
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	I ↔ O ES
Circuit breaker condition monitoring (MV side)	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Disturbance recorder	RDRE1	-	-
Three-phase current measurement (HV side)	CMMXU1	3I	3I

Table continues on next page

Function	IEC 61850	IEC	ANSI
Three-phase current measurement (LV side)	CMMXU2	3I (B)	3I (B)
Sequence current measurement (HV side)	CSMSQI1	I_1, I_2, I_0	I_1, I_2, I_0
Residual current measurement (HV side)	RESCMMXU1	I_0	I_0
Tap changer position indication	TPOSSLTC1	TPOSM	84M

3.5.2.1 Default I/O connections

Table 21: Default connections for binary inputs

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

Table 22: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1 high voltage	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2 low voltage	X100-20-24
X110-SO1	Overcurrent operate alarm	X110-14,15,16
X110-SO2	Differential protection operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Thermal overload and negative phase-sequence protection operate alarm	X110-23,24

Table 23: Default connections for LEDs

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

3.5.3 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, thus not included in the PCM600 functionality.

The analog channels are assigned to different functions as shown in the functional diagrams. The common signal marked with 3I_A represents the three phase currents of the high-voltage side of the transformer and 3I_B represents the three phase currents of the low-voltage side of the transformer. The signal marked with I_0_A represents the measured neutral current measured between the start point of the transformer and grounding.

3.5.3.1 Functional diagrams for protection

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

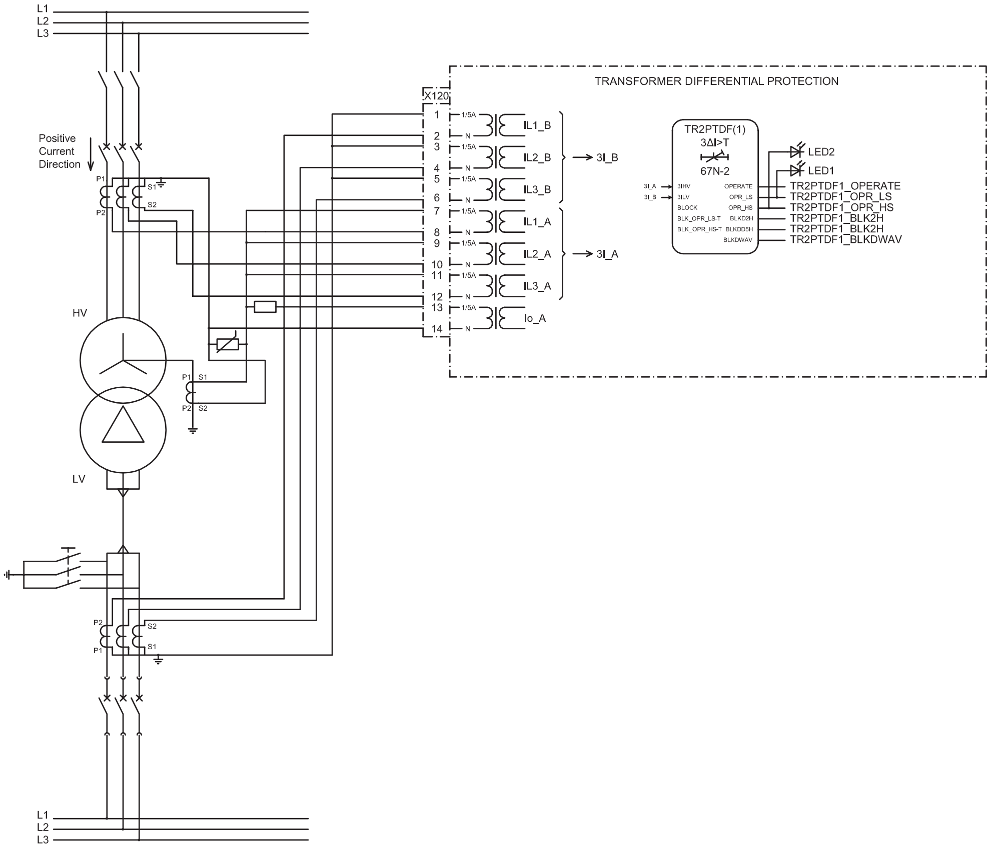


Figure 39: Stabilized and instantaneous differential protection for 2W–transformers

The stabilized and instantaneous differential protection for 2W–transformers (TR2PTDF1) provides protection of power transformer unit including, for example, winding short-circuit and interturn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal.

For transformers having an on-line tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF.

The position indication of the OLTC is recommended for differential protection to increase sensitivity.

All operate signals are connected to the Master Trip 1 and 2 and also to the alarm LEDs. LED 1 is used for biased low-stage operate indication and LED 2 for instantaneous high-stage of the differential protection.

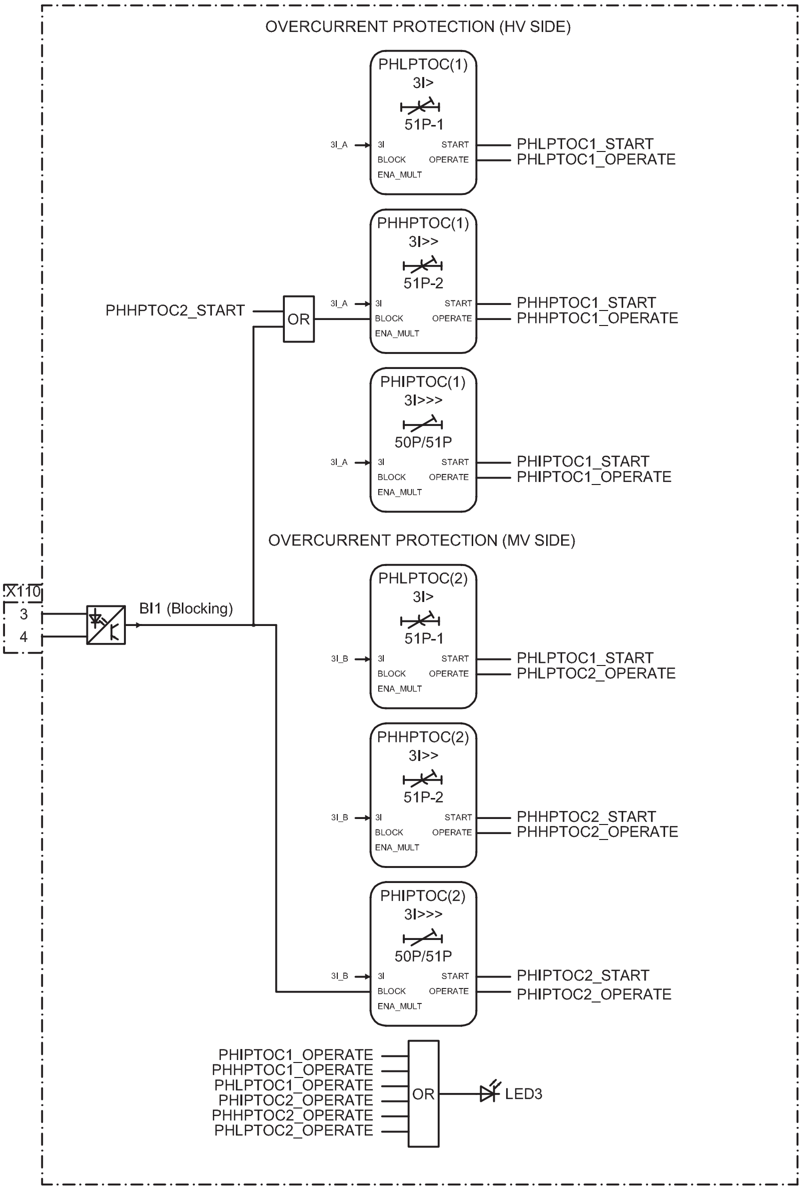


Figure 40: Overcurrent and short-circuit protection

Three stages for both high-voltage and low-voltage sides as a total of six overcurrent stages are offered for overcurrent and short-circuit protection. The high-voltage side high stage (PHHPTOC1) can be blocked by energizing the binary input 1 (X120:1-2) or by starting the high stage of the low-voltage side (PHHPTOC2). Also the low-voltage side instantaneous stage is blocked by activating the binary input (X120_BI1).

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

The operate of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). This output is used for giving a specific alarm of the overcurrent protection operation.

There are four IED variant-specific setting groups. Parameters can be set independently for each setting group.

The active setting group (1...4) can be changed with a parameter. The active setting group can also be changed via a binary input if the binary input is enabled for this. To enable the change of the active setting group via a binary input, connect a free binary input with PCM600 to the ActSG input of the SGCB-block.

Table 24: Binary input states and corresponding active setting groups

BI state	Active setting group
OFF	1
ON	2

The active setting group defined by a parameter is overridden when a binary input is enabled for changing the active setting group.

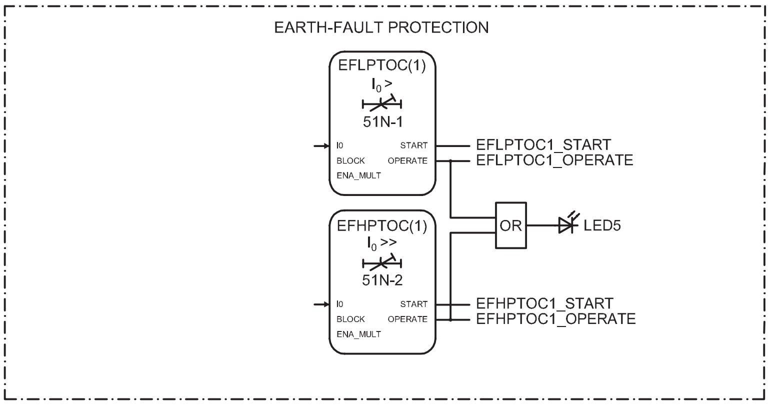


Figure 41: Non-directional earth-fault protection

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

All operate signals are connected to the Master Trip 1 and also to the alarm LEDs. LED 5 is used for non-directional earth-fault protection operate indication.

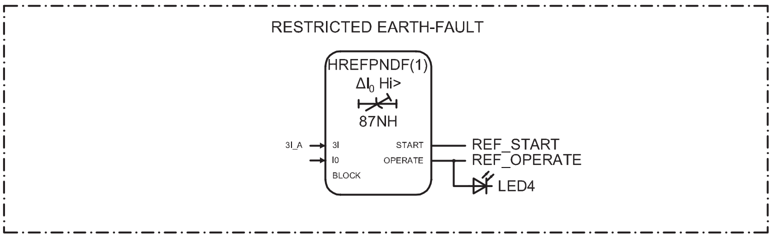


Figure 42: Restricted high-impedance earth-fault protection

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

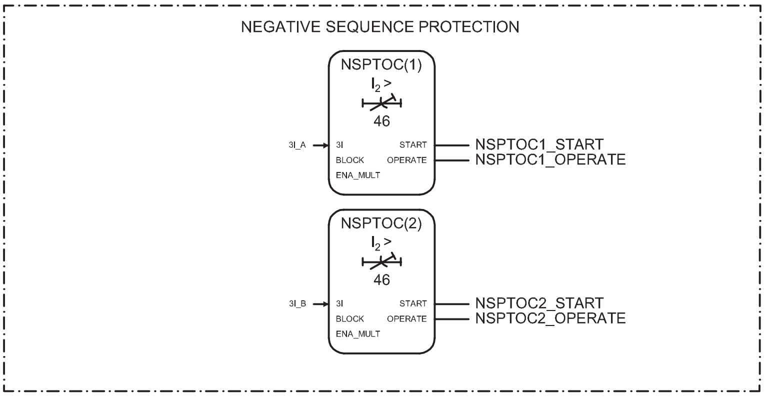


Figure 43: Negative-sequence overcurrent protection

NSPTOC is designed for negative-phase sequence protection whenever the operating characteristic is appropriate. It is applied for the protection of transformers against thermal stress and damage.

NSPTOC1 is measuring negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

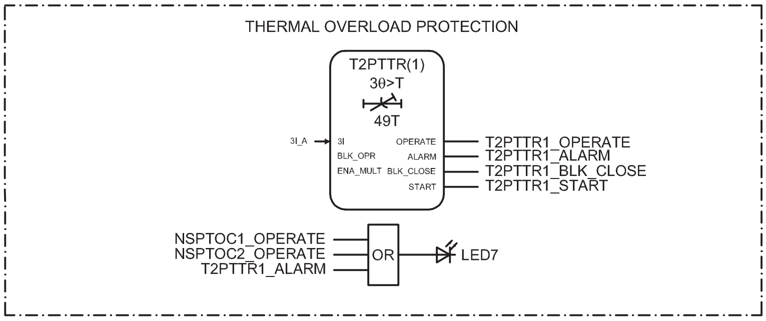


Figure 44: Three-phase thermal overload protection for power transformers

Three-phase thermal overload protection for power transformers (T2PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip 2. LED 7 is used for the thermal overload protection alarm indication, the same as for negative-sequence overcurrent protection operate indication.

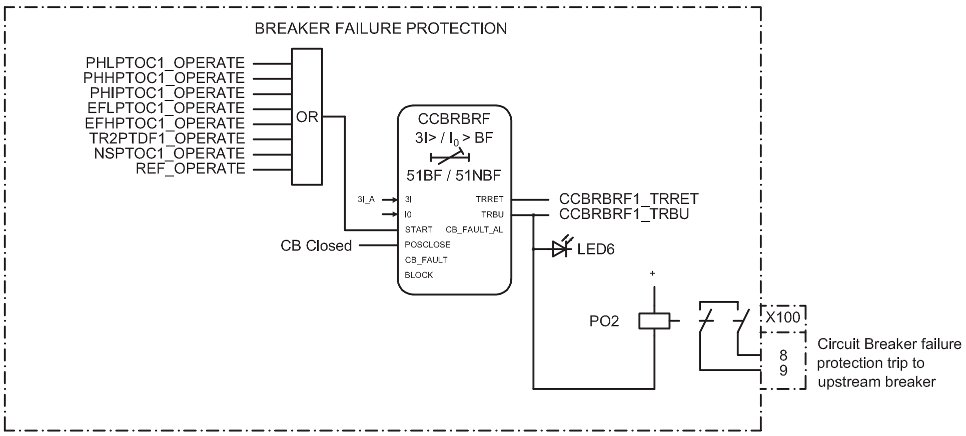


Figure 45: Circuit-breaker failure protection

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 Logic 2. The TRBU output is used for retripping both the high-voltage and low-voltage side circuit breakers through Master Trip 1 and 2. The TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

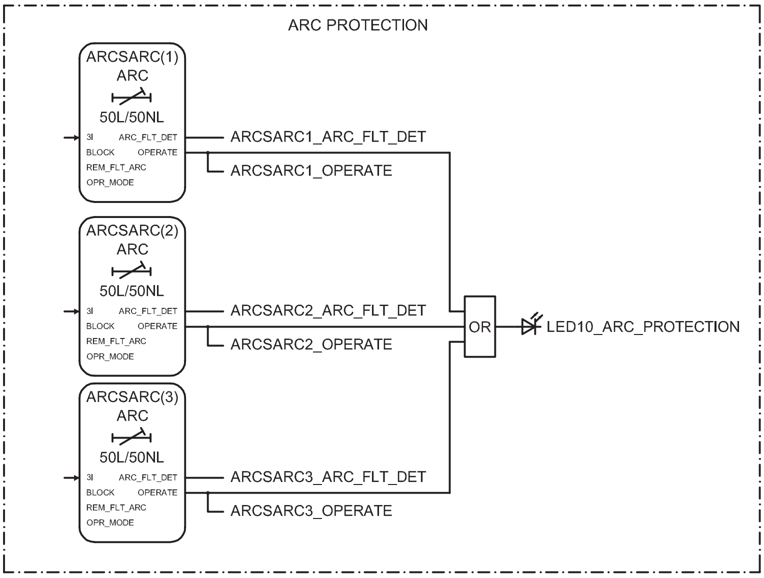


Figure 46: Arc protection

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

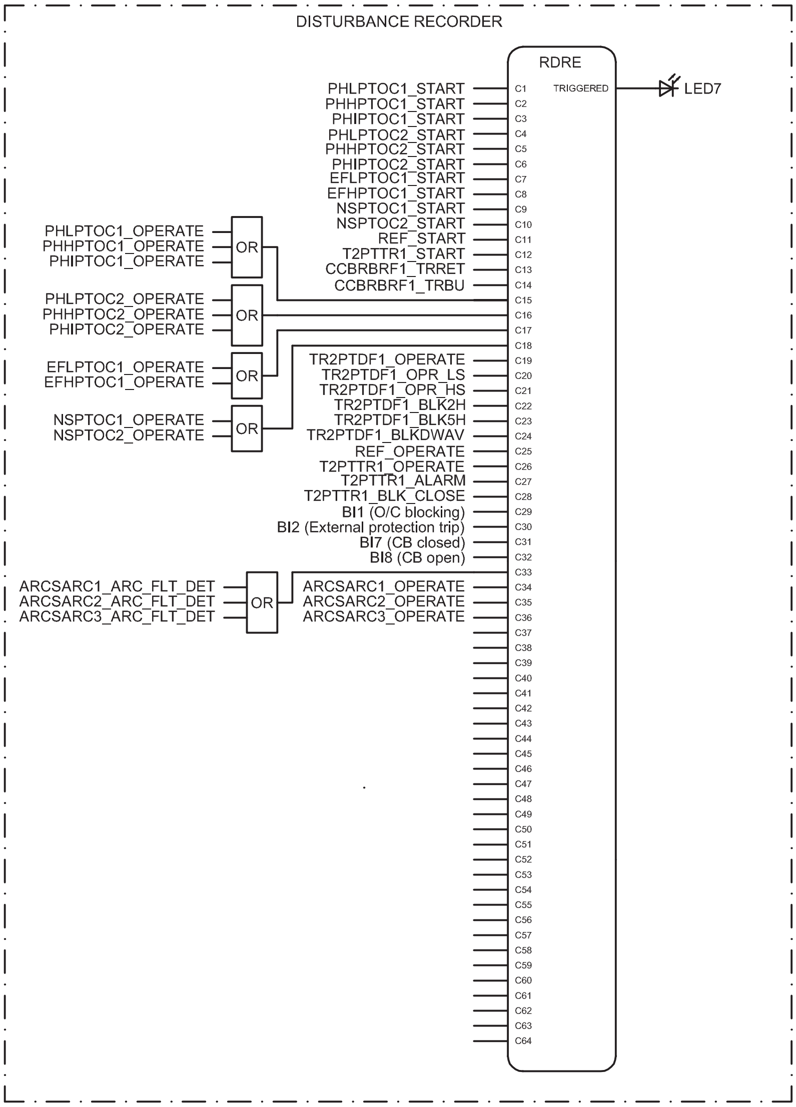


Figure 47: *Disturbance recorder*

The disturbance recorder has 64 digital inputs out of which 36 are connected as a default. 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 the four binary inputs from X110 are also connected.

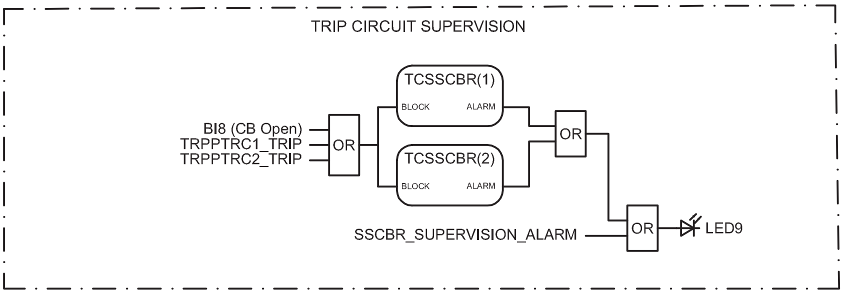


Figure 48: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:16-19) and TCSSCBR2 for PO4 X100:20-23). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC1) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

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

3.5.3.3 Functional diagrams for control and interlocking

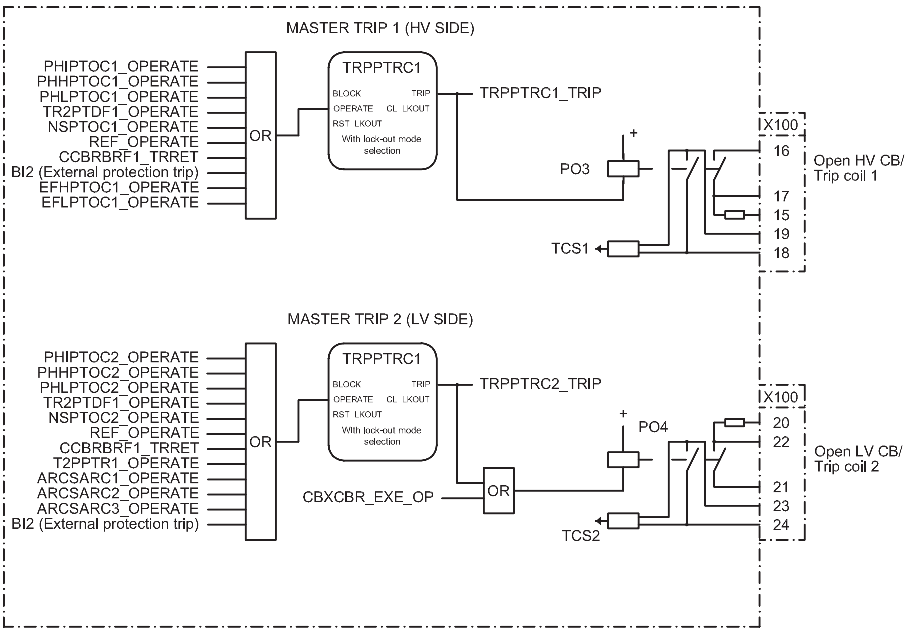


Figure 49: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:16-19).

TRPPTRC1 and 2 provide 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.

The external trip indication is connected also to the alarm LED 11.

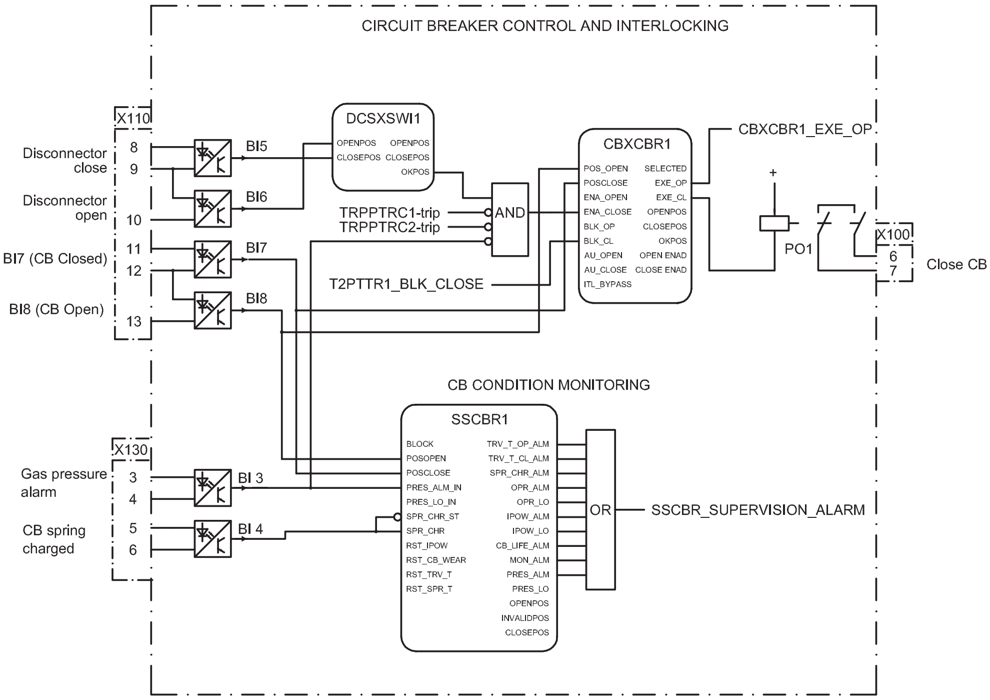


Figure 50: Disconnector position indication

There are three disconnector status blocks (DCSXSWI1…3) available in the IED. The remaining two not described in the functional diagram are available in PCM600 for connection where applicable.

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

Table 25: 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 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 position status 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 non-active trip signal and non-active gas pressure alarm, activates the close-enable signal to the circuit-breaker control function block. The open operation is always enabled.

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 9.

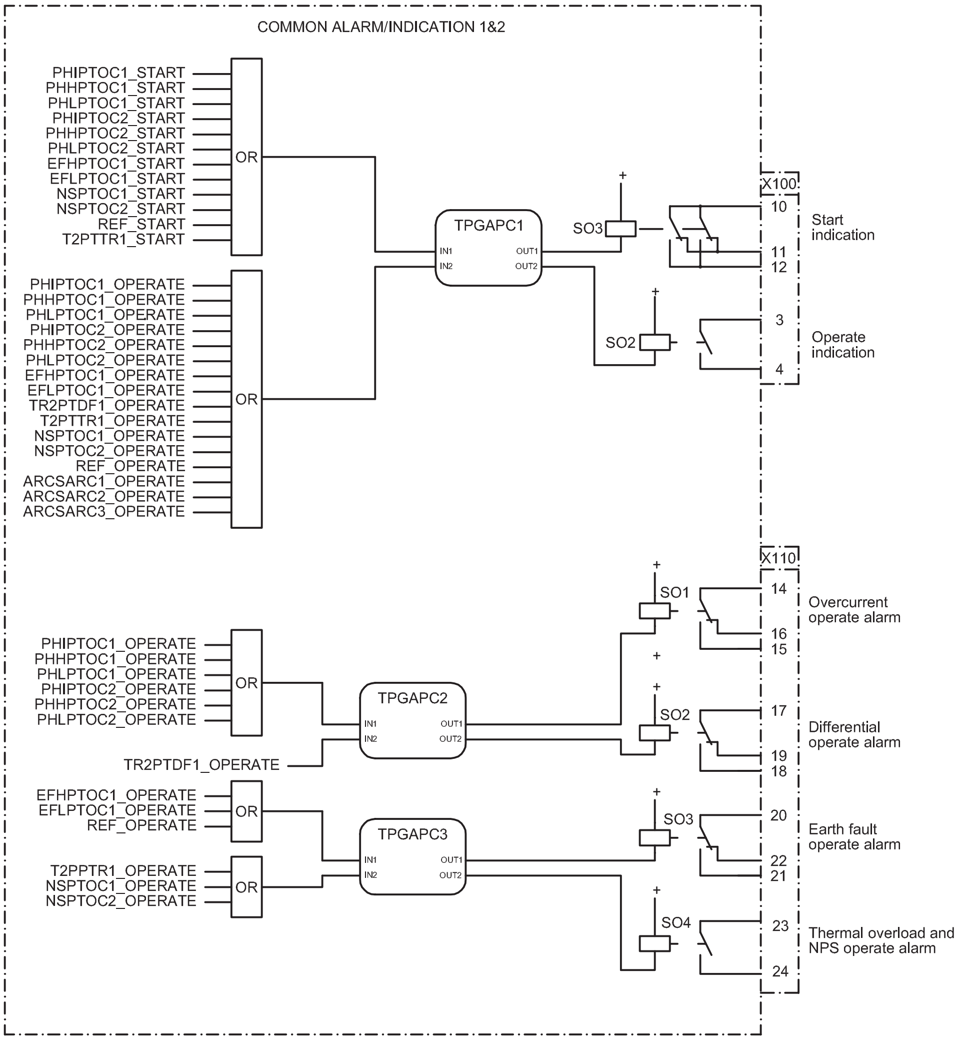


Figure 51: Common alarm/indication 1 and 2

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 SO2 (X100:13-15)
- Operation (trip) of differential protection function SO1 (X110:14-15-16)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-18-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-21-22)
- Operation (trip) of thermal or current negative-sequence 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.

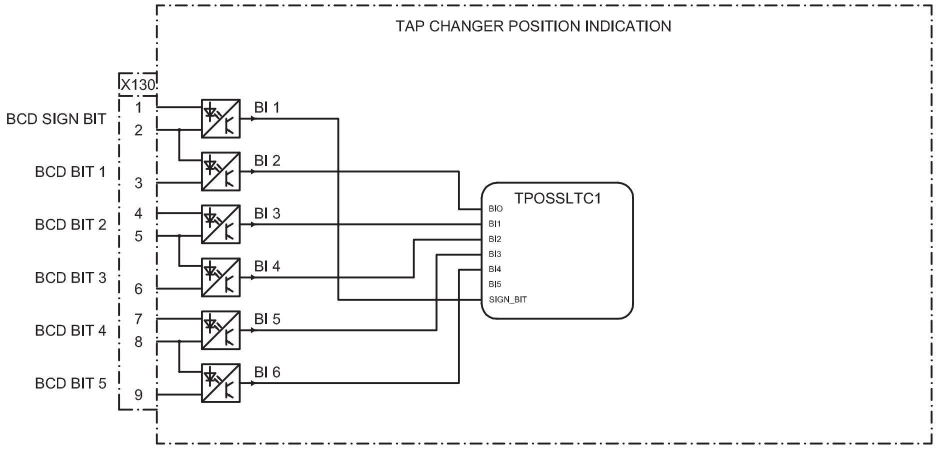


Figure 52: Tap changer position indication

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IEDvia the tap changer position indication function TPOSSLTC1. TPOSSLTC1 is connected to the binary inputs of the X130 BIO card. TPOSSLTC1 uses binary-coded methods to generate the integer value of the tap changer position.

3.6 Standard configuration D including high impedance restricted earth-fault for low-voltage side

3.6.1 Applications

The standard configuration includes three-phase differential, short-circuit, overcurrent, earth-fault, thermal overload and negative-phase sequence protection in power transformer feeders. The standard configuration is mainly intended for protection of the power transformer between current transformers.

The IED with this 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 26: Functions included in the RET615 standard configuration with high impedance restricted earth-fault for low-voltage side

Function	IEC 61850	IEC	ANSI
Stabilized and instantaneous differential protection for two–winding transformers	TR2PTDF1	3dI>T	87T
Three-phase non-directional overcurrent protection, low stage (HV side)	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, low stage (LV side)	PHLPTOC2	3I> (2)	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage (HV side)	PHHPTOC1	3I>>(1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage (LV side)	PHHPTOC2	3I>>(2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage (HV side)	PHIPTOC1	3I>>>(1)	50P/51P (1)
Three-phase non-directional overcurrent protection, instantaneous stage (LV side)	PHIPTOC2	3I>>>(2)	50P/51P (2)
Non-directional earth-fault protection, low stage (LV side)	EFLPTOC2	I_0> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage, using calculated I_0 (LV side)	EFHPTOC2	I_0>> (2)	51N-2 (2)
Negative-sequence overcurrent protection (HV side)	NSPTOC1	I_2> (1)	46 (1)
	NSPTOC2	I_2> (2)	46 (2)
High impedance based restricted earth-fault	HREFPDIF1	dI_0Hi>	87NH
Three-phase thermal overload protection for power transformers, two time constants (HV side)	T2PTTR1	3Ith>T	49T
Circuit breaker failure protection (HV side)	CCBRBRF1	3I>/I_0>BF	51BF/51NBF
Arc protection (LV side)	ARCSARC1	ARC (1)	50L/50NL (1)
	ARCSARC2	ARC (2)	50L/50NL (2)
	ARCSARC3	ARC (3)	50L/50NL (3)
Circuit-breaker control	CBXCBR1	I ↔ O CB	I ↔ O CB
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	I ↔ O ES
Circuit breaker condition monitoring (HV side)	SSCBR1	CBCM	CBCM
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Disturbance recorder	RDRE1	-	-
Three-phase current measurement (HV side)	CMMXU1	3I	3I
Three-phase current measurement (LV side)	CMMXU2	3I (B)	3I (B)

Table continues on next page

Function	IEC 61850	IEC	ANSI
Sequence current measurement (HV side)	CSMSQI1	I_1, I_2, I_0	I_1, I_2, I_0
Residual current measurement (LV side)	RESCMMXU2	I_0 (B)	I_0 (B)
Tap changer position indication	TPOSSLTC1	TPOSM	84M

3.6.2.1 Default I/O connections

Table 27: Default connections for binary inputs

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

Table 28: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Close high-voltage circuit breaker	X100-6,7
X100-PO2	Breaker failure backup trip to upstream breaker	X100-8,9
X100-SO1	General start indication	X100-10,11,(12)
X100-SO2	General operate indication	X100-13,14
X100-PO3	Open circuit breaker/trip coil 1 high voltage	X100-15-19
X100-PO4	Open circuit breaker/trip coil 2 low voltage	X100-20-24
X110-SO1	Overcurrent operate alarm	X110-14,15,16
X110-SO2	Differential protection operate alarm	X110-17,18,19
X110-SO3	Earth fault operate alarm	X110-20,21,22
X110-SO4	Thermal overload and negative phase-sequence protection operate alarm	X110-23,24

Table 29: Default connections for LEDs

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

3.6.3 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, thus not included in the PCM600 functionality.

The analog channels are assigned to different functions as shown in the functional diagrams. The common signal marked with 3I_A represents the three phase currents of the high-voltage side of the transformer and 3I_B represents the three phase currents of the low-voltage side of the transformer. The signal marked with I_0_A represents the measured neutral current measured between the start point of the transformer and grounding.

3.6.3.1 Functional diagrams for protection

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

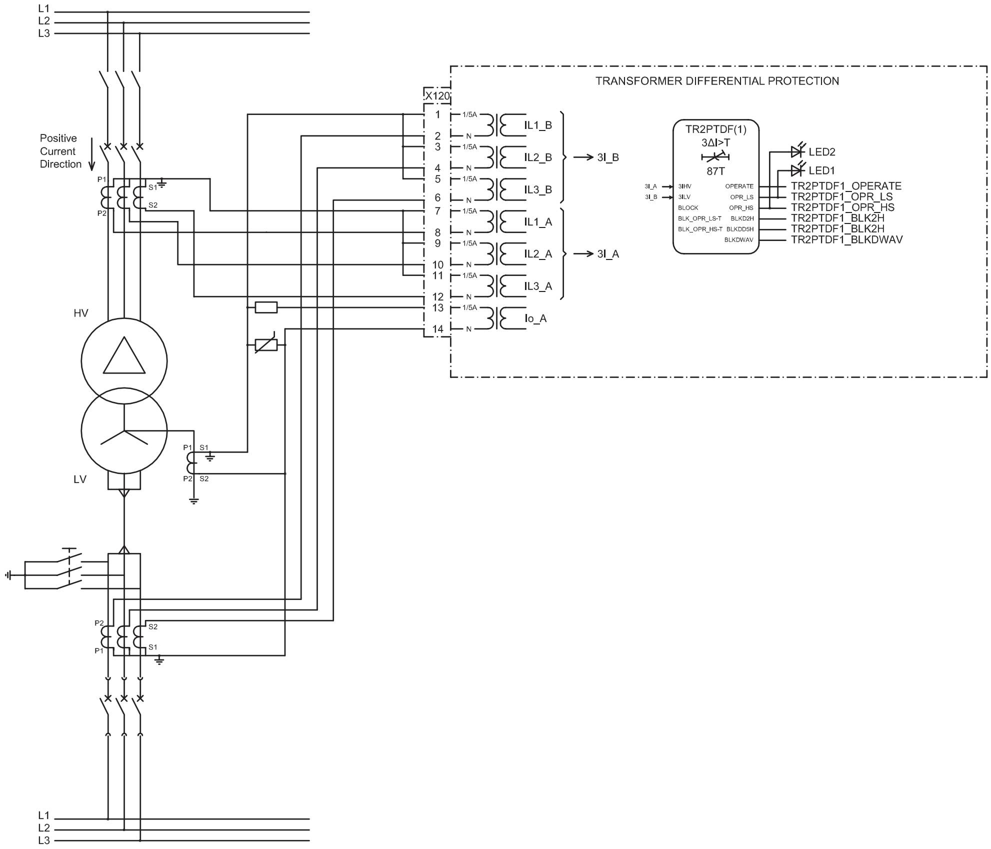


Figure 53: Stabilized and instantaneous differential protection for 2W-transformers

The stabilized and instantaneous differential protection for 2W–transformers (TR2PTDF1) provides protection of power transformer unit including, for example, winding short-circuit and interturn faults. The IED compares the phase currents on both sides of the object to be protected. If the differential current of the phase currents in one of the phases exceed the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operate signal.

For transformers having an on-line tap changer, the tap position information is recommended to be used in differential protection, as the ratio difference of tap changer movements can be corrected in TR2PTDF.

The position indication of the OLTC is recommended for differential protection to increase sensitivity.

All operate signals are connected to the Master Trip 1 and 2 and also to the alarm LEDs. LED 1 is used for biased low-stage operate indication and LED 2 for instantaneous high-stage of the differential protection.

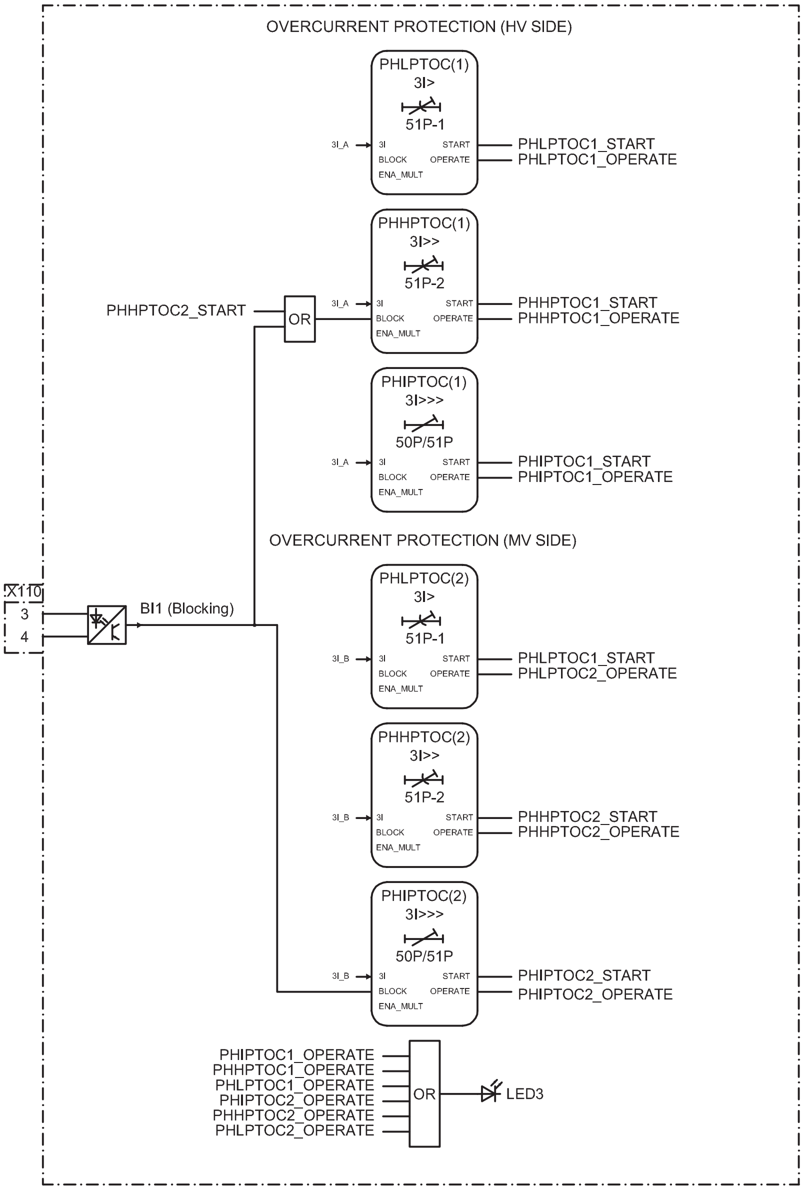


Figure 54: Overcurrent and short-circuit protection

Three stages for both high-voltage and low-voltage sides as a total of six overcurrent stages are offered for overcurrent and short-circuit protection. The high-voltage side high stage (PHHPTOC1) can be blocked by energizing the binary input 1 (X120:1-2) or by starting the high stage of the low-voltage side (PHHPTOC2). Also the low-voltage side instantaneous stage is blocked by activating the binary input (X120_BI1).

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

The operate of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). This output is used for giving a specific alarm of the overcurrent protection operation.

There are four IED variant-specific setting groups. Parameters can be set independently for each setting group.

The active setting group (1...4) can be changed with a parameter. The active setting group can also be changed via a binary input if the binary input is enabled for this. To enable the change of the active setting group via a binary input, connect a free binary input with PCM600 to the ActSG input of the SGCB-block.

Table 30: Binary input states and corresponding active setting groups

BI state	Active setting group
OFF	1
ON	2

The active setting group defined by a parameter is overridden when a binary input is enabled for changing the active setting group.

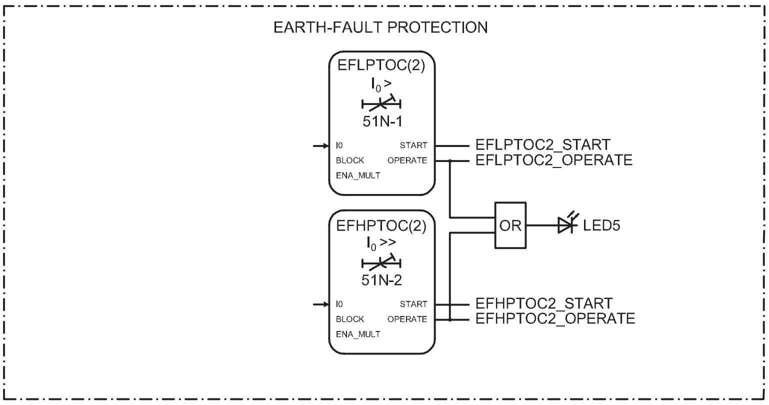


Figure 55: Non-directional earth-fault protection

Two stages are offered for non-directional earth-fault protection. The earth-fault protection uses the residual current calculated from the low-voltage side phase currents.

All operate signals are connected to the Master Trip 2 and also to the alarm LEDs. LED 5 is used for non-directional earth-fault protection operate indication.

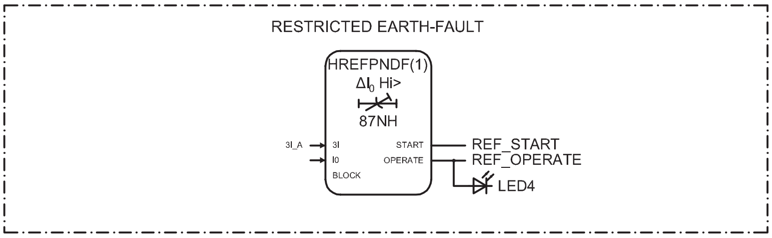


Figure 56: Restricted high-impedance earth-fault protection

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

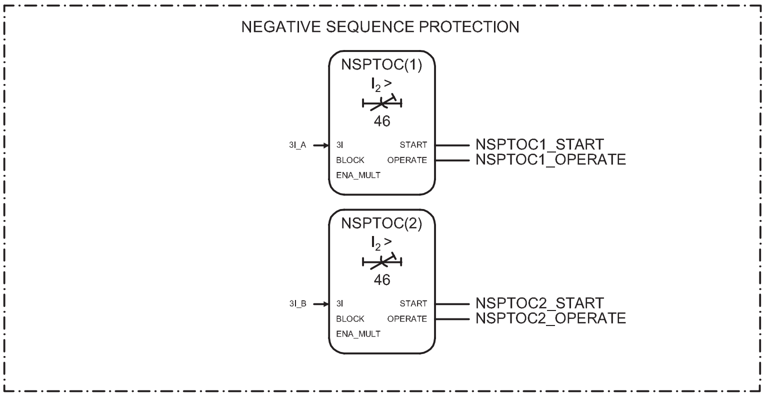


Figure 57: Negative-sequence overcurrent protection

NSPTOC is designed for negative-phase sequence protection whenever the operating characteristic is appropriate. It is applied for the protection of transformers against thermal stress and damage.

NSPTOC1 is measuring negative-sequence current from the high-voltage side and NSPTOC2 from the low-voltage side.

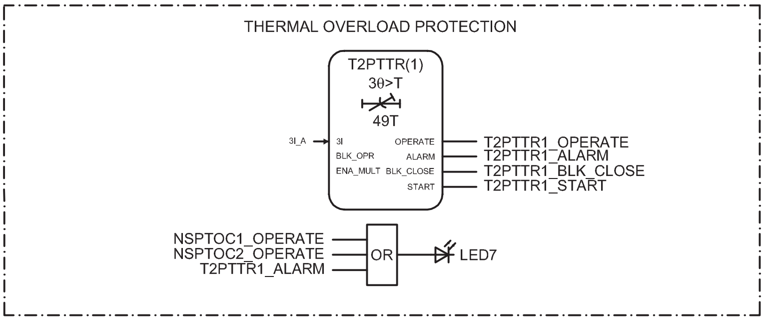


Figure 58: Three-phase thermal overload protection for power transformers

Three-phase thermal overload protection for power transformers (T2PTTR1) provides indication on overload situations. The operate signal of the thermal overload protection is connected to the Master Trip 2. LED 7 is used for the thermal overload protection alarm indication, the same as for negative-sequence overcurrent protection operate indication.

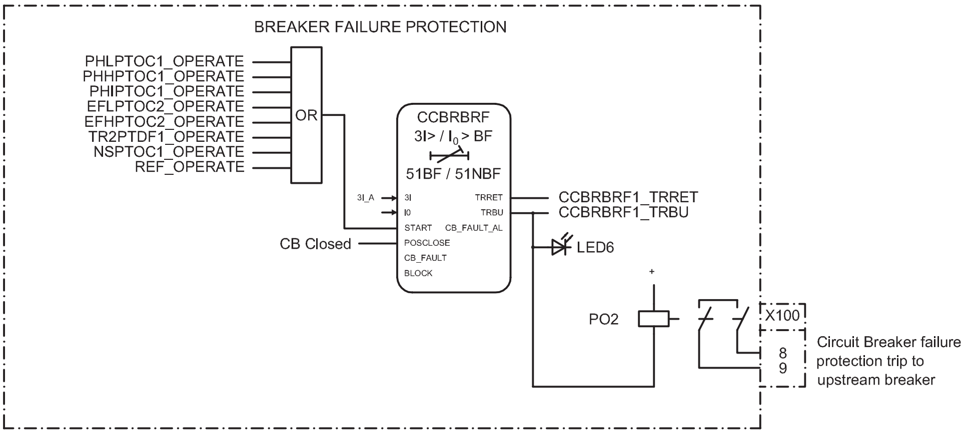


Figure 59: Circuit-breaker failure protection

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 Logic 2. The TRBU output is used for retripping both the high-voltage and low-voltage side circuit breakers through Master Trip 1 and 2. The TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 6 is used for backup (TRBU) operate indication.

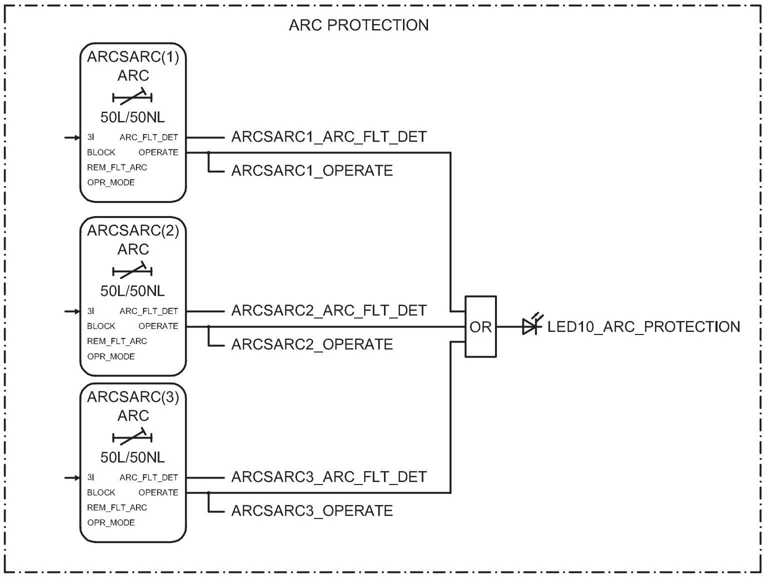


Figure 60: Arc protection

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

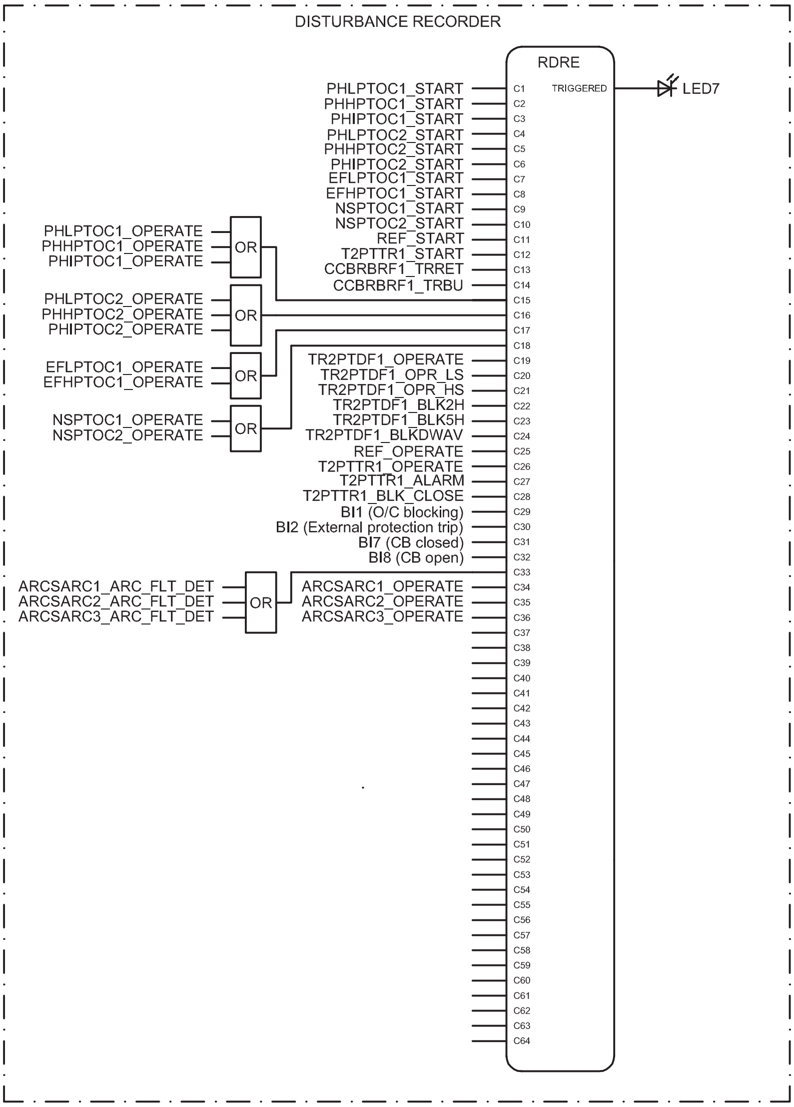


Figure 61: Disturbance recorder

The disturbance recorder has 64 digital inputs out of which 36 are connected as a default. 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 the four binary inputs from X110 are also connected.

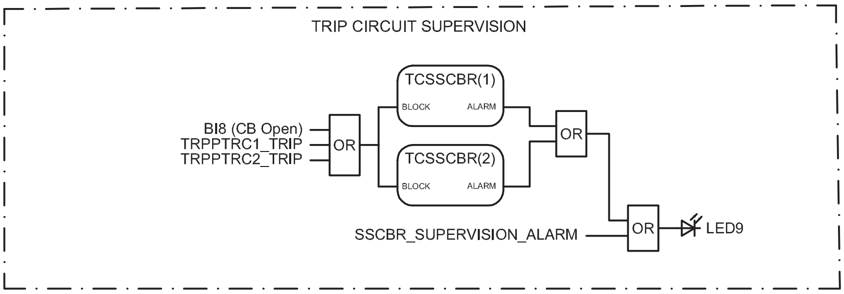


Figure 62: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:16-19) and TCSSCBR2 for PO4 X100:20-23). Both functions are blocked by the Master Trip (TRPPTRC1 and TRPPTRC1) and the circuit breaker open signal. The TCS alarm indication is connected to LED 9.

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

3.6.3.3 Functional diagrams for control and interlocking

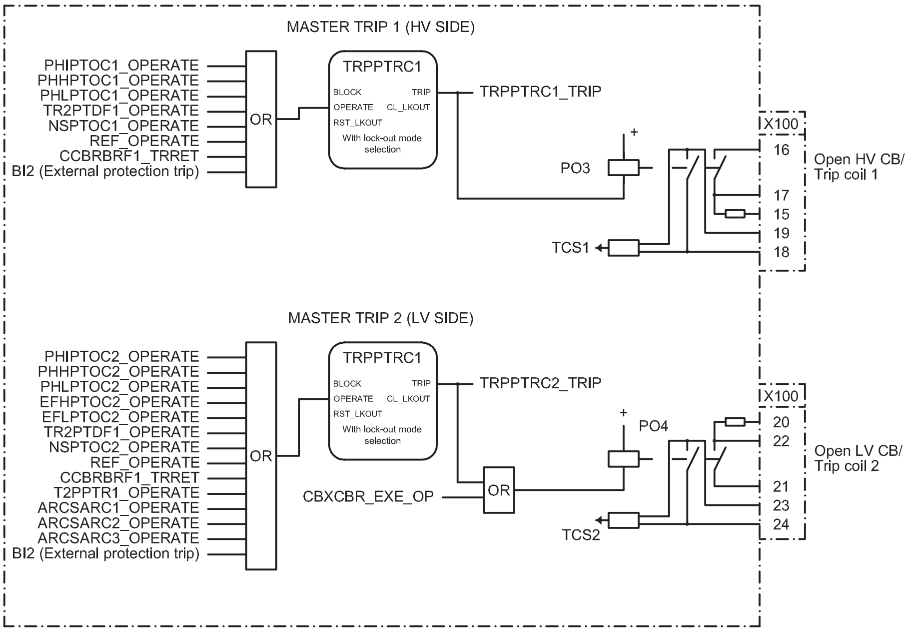


Figure 63: Master Trip

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op are connected directly to the output PO3 (X100:16-19).

TRPPTRC1 and 2 provide 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.

The external trip indication is connected also to the alarm LED 11.

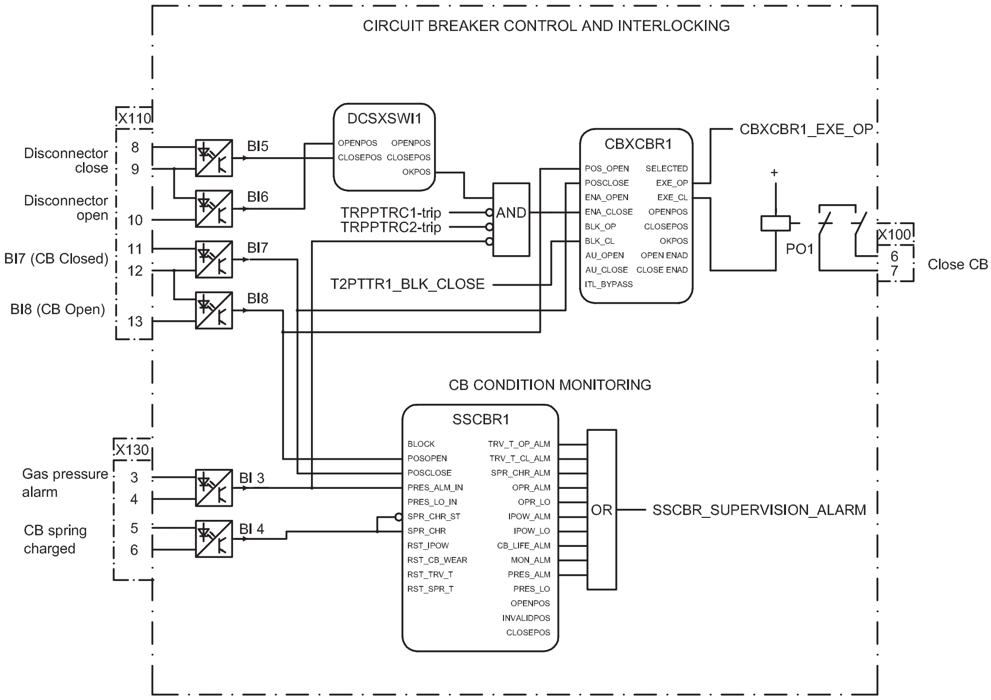


Figure 64: Disconnector position indication

There are three disconnector status blocks (DCSXSWI1…3) available in the IED. The remaining two not described in the functional diagram are available in PCM600 for connection where applicable.

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

Table 31: 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 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 position status 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 non-active trip signal and non-active gas pressure alarm, activates the close-enable signal to the circuit-breaker control function block. The open operation is always enabled.

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 9.

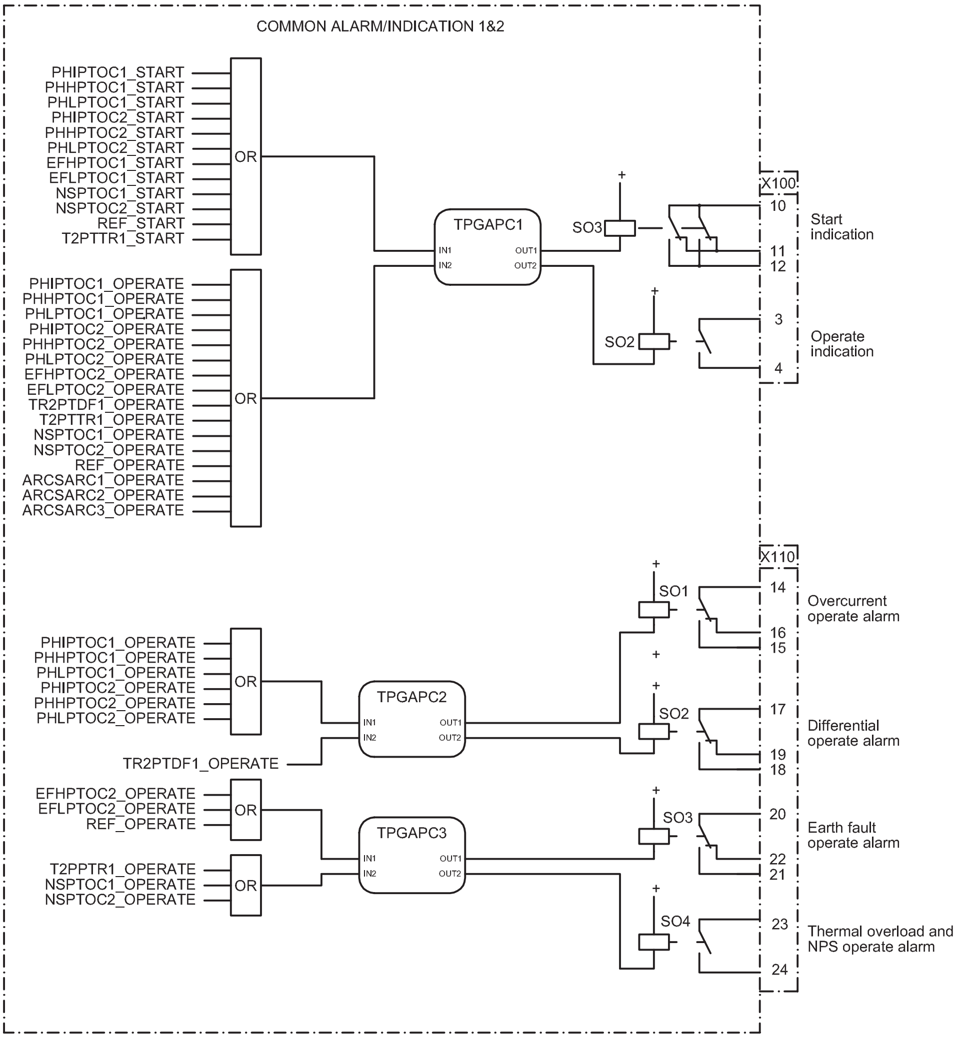


Figure 65: Common alarm/indication 1 and 2

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 SO2 (X100:13-15)
- Operation (trip) of differential protection function SO1 (X110:14-15-16)
- Operation (trip) of any stage of the overcurrent protection function SO2 (X110:17-18-19)
- Operation (trip) of any stage of the earth-fault protection function SO3 (X110:20-21-22)
- Operation (trip) of thermal or current negative-sequence 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.

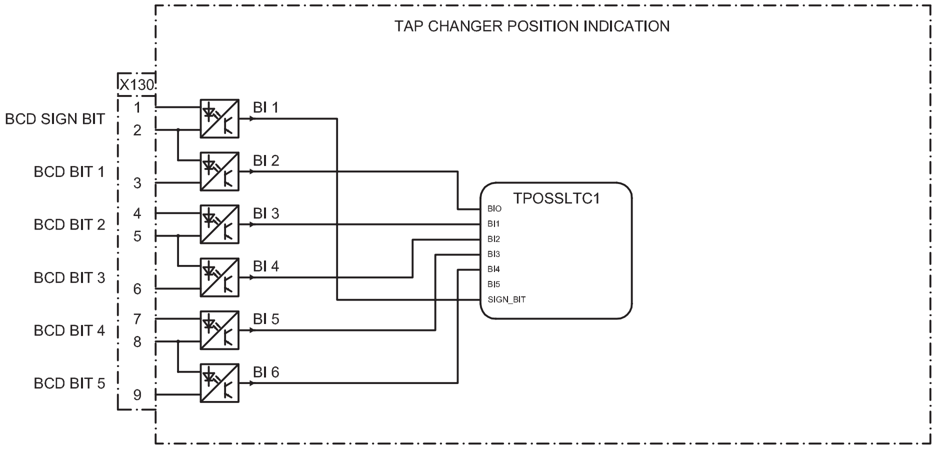


Figure 66: Tap changer position indication

To increase the sensitivity of the stabilized differential function, the tap position information from the tap changer is connected to the IEDvia the tap changer position indication function TPOSSLTC1. TPOSSLTC1 is connected to the binary inputs of the X130 BIO card. TPOSSLTC1 uses binary-coded methods to generate the integer value of the tap changer position.

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 relay settings 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 32: 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 relay.

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

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

The actual accuracy limit factor is calculated using the formula:

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

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

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

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

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

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

I_{kmax} is the highest fault current.

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

Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage of the relay is to operate, then 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 relay inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage O/C protection is defined. The operate time delay caused by the CT saturation is typically small enough when the relay 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 relay operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive relays.

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.

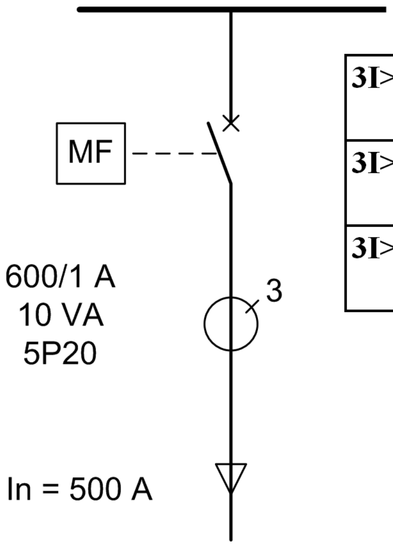
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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

4.1.1.3 Example for non-directional overcurrent protection

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



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

Figure 67: 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 relay (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 relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in 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 relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 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 33: Inputs for phase currents

Terminal	Description
X120-1, 2	I_{L1B}
X120-3, 4	I_{L2B}
X120-5, 6	I_{L3B}
X120-7, 8	I_{L1}
X120-9, 10	I_{L2}
X120-11, 12	I_{L3}

5.1.1.2 Residual current

Table 34: Inputs for residual current

Terminal	Description
X120-13, 14	I_0

5.1.2 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

5.1.3 Binary inputs

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

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

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

Table 37: Optional binary input terminals X130-1...9

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

5.1.4 Optional light sensor inputs

If the 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 38: 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 39: 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.

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

Table 40: Output contacts X100-10...14

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

Table 41: 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

Table 42: Output contacts X130-10...18

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

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection 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 43: IRF contact

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

Section 6 Glossary

100BASE-FX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fibre-optic cabling
100BASE-TX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
BI	Binary input
BO	Binary output
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.
EMC	Electromagnetic compatibility
GOOSE	Generic Object Oriented Substation Event
HMI	Human-machine interface
IEC	International Electrotechnical Commission
IEC 60870-5-103	Communication standard for protective equipment; A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modelling
IED	Intelligent electronic device
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
LV	Low voltage

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
PCM600	Protection and Control IED Manager
PO	Power output
RJ-45	Galvanic connector type
RTU	Remote terminal unit
WAN	Wide area network
WHMI	Web human-machine interface

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