


**Relion® 615 series**

# Line Differential Protection and Control RED615 Application Manual

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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.

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# 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

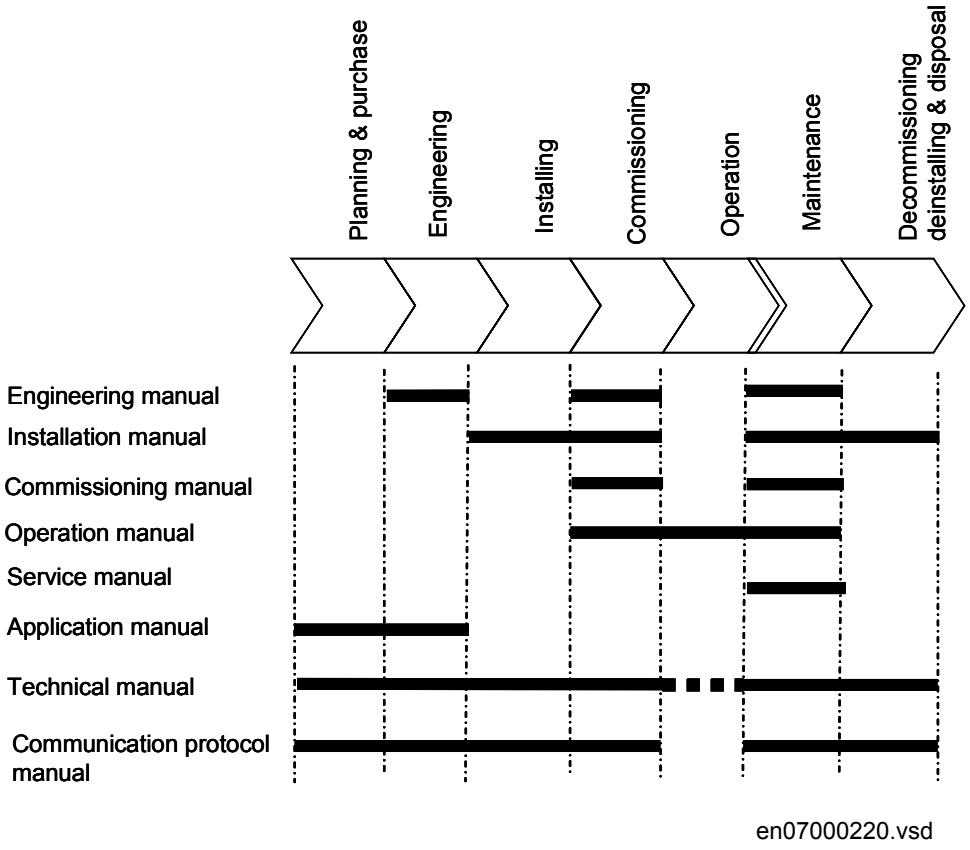



*Figure 1: The intended use of manuals in different lifecycles*

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/03.10.2008 | 1.1 | First release |
| B/03.07.2009 | 2.0 | Content updated to correspond to the product version |

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

### 1.3.3 Related documentation

| Name of the document | Document ID |
|---|---|
| Modbus Communication Protocol Manual | 1MRS756468 |
| DNP3 Communication Protocol Manual | 1MRS756709 |
| IEC 60870-5-103 Communication Protocol Manual | 1MRS756710 |
| IEC 61850 Engineering Guide | 1MRS756475 |
| Installation Manual | 1MRS756375 |
| Operation Manual | 1MRS756708 |
| Technical Manual | 1MRS756887 |
| CT dimensioning, Application Note and Setting Guide | 1MRS756683 |

## 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: RED615 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, 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) |
| Non-directional earth-fault protection, low stage, instance 1 | EFLPTOC1 | $I_0$> (1) | 51N-1 (1) |
| 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) |
| Non-directional earth-fault protection, instantaneous stage | EFIPTOC1 | $I_0$>>> | 50N/51N |

Table continues on next page

| Functionality | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Directional earth-fault protection, low stage, instance 1 | DEFLPDEF1 | $I_0$> → (1) | 67N-1 (1) |
| Directional earth-fault protection, low stage, instance 2 | DEFLPDEF2 | $I_0$> → (2) | 67N-1 (2) |
| Directional earth-fault protection, high stage | DEFHPDEF1 | $I_0$>> → | 67N-2 |
| Transient / intermittent earth-fault protection | INTRPTEF1 | $I_0$> → IEF | 67NIEF |
| Non-directional (cross-country) earth fault protection, using calculated $I_0$ | EFHPTOC1 | $I_0$>> | 51N-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) |
| Phase discontinuity protection | PDNSPTOC1 | $I_2/I_1$> | 46PD |
| Three-phase thermal protection for feeders, cables and distribution transformers | T1PTTR1 | 3Ith>F | 49F |
| Binary signal transfer | BSTGGIO1 | BST | BST |
| Line differential protection and related measurements, stabilized and instantaneous stages | LNPLDF1 | 3dI>L | 87L |
| Circuit breaker failure protection | CCBRBRF1 | 3I>/$I_0$>BF | 51BF/51NBF |
| Three-phase inrush detector | INRPHAR1 | 3I2f> | 68 |
| Master trip, instance 1 | TRPPTRC1 | Master Trip (1) | 94/86 (1) |
| Master trip, instance 2 | TRPPTRC2 | Master Trip (2) | 94/86 (2) |
| **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 |
| Auto-reclosing | DARREC1 | O → I | 79 |
| **Condition Monitoring** | | | |
| Circuit-breaker condition monitoring | SSCBR1 | CBCM | CBCM |
| Trip circuit supervision, instance 1 | TCSSCBR1 | TCS (1) | TCM (1) |
| Trip circuit supervision, instance 2 | TCSSCBR2 | TCS (2) | TCM (2) |
| Current circuit supervision | CCRDIF1 | MCS 3I | MCS 3I |
| Protection communication supervision | PCSRTPC1 | PCS | PCS |
| **Measurement** | | | |
| Disturbance recorder | RDRE1 | - | - |

Table continues on next page

| Functionality | IEC 61850 | IEC 60617 | IEC-ANSI |
|---|---|---|---|
| Three-phase current measurement, instance 1 | CMMXU1 | 3I | 3I |
| 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 voltage measurement | RESVMMXU1 | $U_0$ | $V_n$ |

# Section 2 RED615 overview

## 2.1 Overview

RED615 is a phase-segregated two-end line differential protection and control IED (intelligent electronic device) designed for utility and industrial power systems, including looped and meshed distribution networks with or without decentralized power generation. RED615 is a member of ABB's Relion® family and its 615 protection and control product series. Re-engineered from the ground up, the 615 series has been guided by the IEC 61850 standard for communication and interoperability of substation automation equipment.

The IED provides unit type main protection for overhead lines and cable feeders in distribution networks. The IED also features current-based protection functions for remote back-up for down-stream protection IEDs and local back-up for the line differential main protection. Further, standard configurations B and C also include earth-fault protection.

The IED is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance earthed, compensated (impedance earthed) and solidly earthed networks. Once the 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 |
|---|---|
| 1.1 | Product released |
| 2.0 | • Support for DNP3 serial or TCP/IP<br>• Support for IEC 60870-5-103<br>• New standard configurations B and C<br>• Disturbance recorder upload via WHMI |

### 2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.0 SP2 or later
- RED615 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

- 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)<br>Large (8 lines, 16 characters) |
| | X100 | Auxiliary power/BO module | 48-250 V DC / 100-240 V AC<br>2 normally-open PO contacts<br>1 change-over SO contact<br>1 normally open SO contact<br>2 double-pole PO contacts with TCS<br>1 dedicated internal fault output contact |
| | X110 | BIO module | 8 binary inputs<br>4 signal output contacts |
| | X120 | AI/BI module | Only with configuration B:<br>3 phase current inputs (1/5A)<br>1 residual current input (1/5A or 0.2/1A)[1)]<br>1 residual voltage input (100, 110, 115 or 120 V)<br>3 binary inputs |
| | | | Only with configurations A and C:<br>3 phase current inputs (1/5A)<br>1 residual current input (1/5A)<br>4 binary inputs |
| Case | X130 | Optional BIO module | 6 binary inputs<br>3 signal output contacts |
| | X000 | Communication module | See technical manual for details about different type of communication modules. |

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

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

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



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

*Table 3: Number of physical connections in standard configurations*

| Conf. | Analog channels | | Binary channels | |
|---|---|---|---|---|
| | CT | VT | BI | BO |
| A | 4 | - | 12 (18)[1)] | 10 (13)[1)] |
| B | 4 | 1 | 11 (17)[1)] | 10 (13)[1)] |
| C | 4 | - | 12 (18)[1)] | 10 (13)[1)] |

1) With optional BIO module

## 2.4 Local HMI

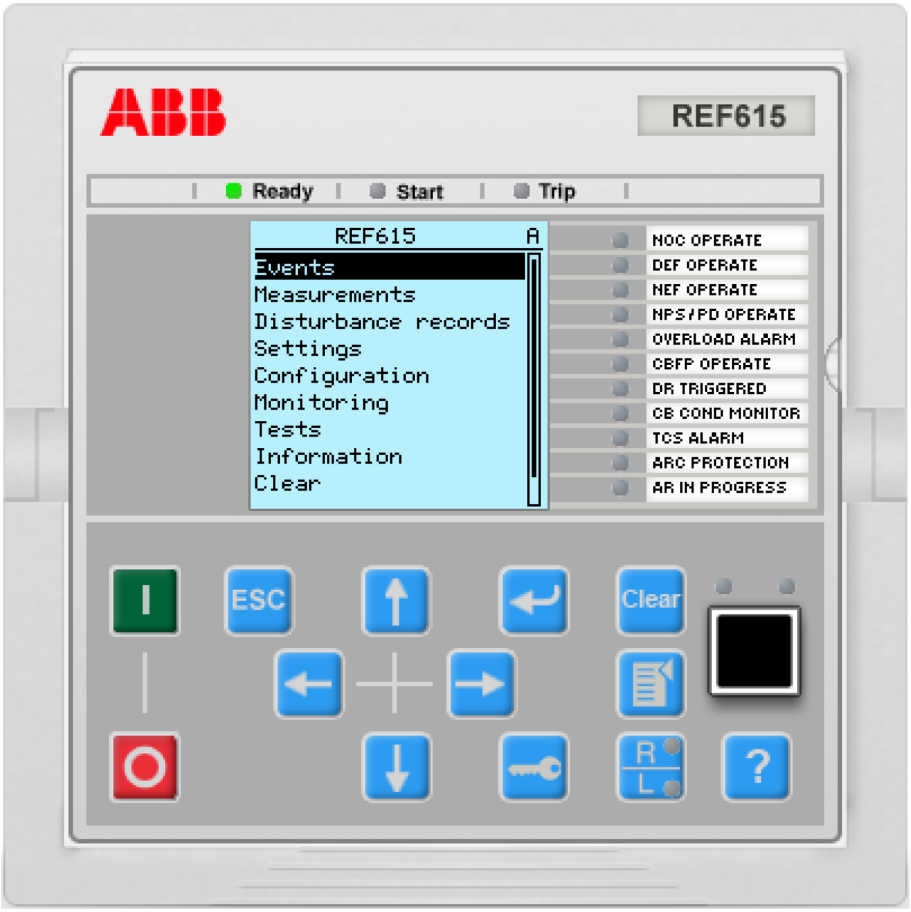



*Figure 2: LHMI*

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<br>10 rows with large screen | 20 |
| Large, variable width (13x14 pixels) | 4 rows<br>8 rows with large screen | min 8 |

The display view is divided into four basic areas.

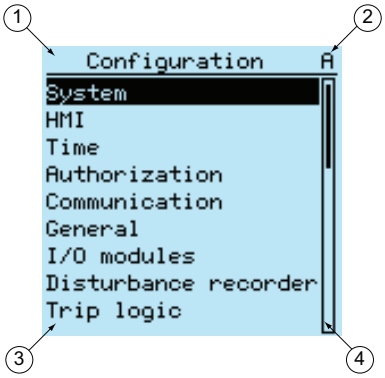



*Figure 3: Display layout*

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.

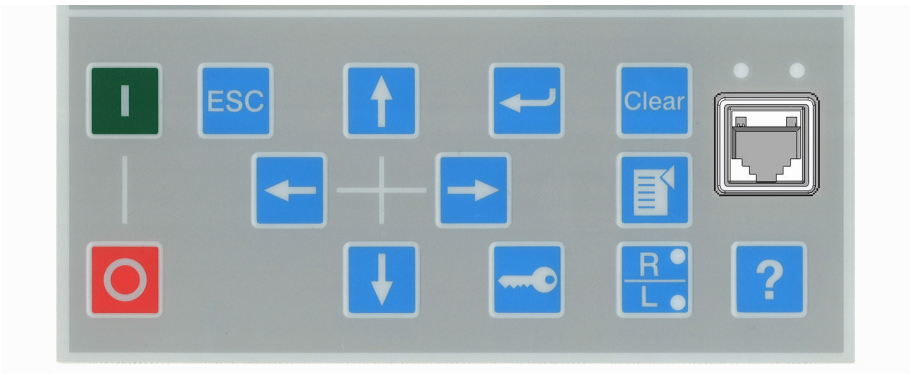



*Figure 4: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port*

## 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.

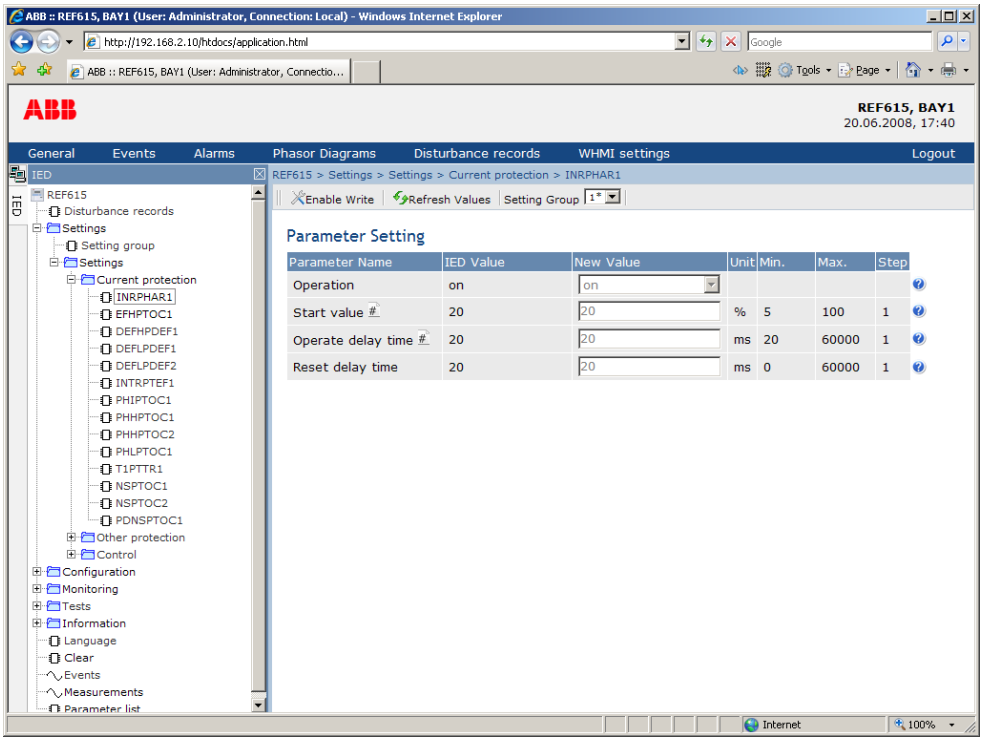



*Figure 5: Example view of the WHMI*

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)<br>• Changing setting groups<br>• Controlling<br>• Clearing alarm and indication LEDs and textual indications |
| ENGINEER | • Changing settings<br>• Clearing event list<br>• Clearing disturbance records<br>• Changing system settings such as IP address, serial baud rate or disturbance recorder settings<br>• Setting the IED to test mode<br>• Selecting language |
| ADMINISTRATOR | • All listed above<br>• Changing password<br>• 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). If connection to a RS-485 network is required, a 9-pin screw-terminal connector, an optional 9-pin D-sub connector or an optional ST-type glass-fibre connector can be used.

Remote-end station time reference:

- Line differential

# Section 3 RED615 variants

## 3.1 RED615 variant list

RED615 is intended for protection and control mainly in medium voltage feeder applications.

The description of the standard configuration covers the full functionality, presenting the functionality, flexibility and external connections of RED615 with the specific configuration as delivered from the factory. The additional BI/O card is not included in the standard configuration.

## 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 line differential protection and control IED RED615 is available with three alternative standard configurations.

*Table 6: Standard configurations*

| Description | Std. conf. |
|---|---|
| Line differential protection | A |
| Line differential protection with directional earth-fault protection | B |
| Line differential protection with non-directional earth-fault protection | C |

*Table 7: Supported functions*

| Functionality | A | B | C |
|---|---|---|---|
| **Protection**[1)] | | | |
| Line differential protection and related measurements, stabilized and instantaneous stages | ● | ● | ● |
| Three-phase non-directional overcurrent, low stage, instance 1 | ● | ● | ● |
| Three-phase non-directional overcurrent, high stage, instance 1 | ● | ● | ● |
| Three-phase non-directional overcurrent, high stage, instance 2 | ● | ● | ● |
| Three-phase non-directional overcurrent, instantaneous stage, instance 1 | ● | ● | ● |
| Non-directional earth-fault protection, low stage (SEF), instance 1 | - | - | ● |
| Non-directional earth-fault protection, low stage, instance 2 | - | - | ● |
| Non-directional earth-fault protection, high stage, instance 1 | - | - | ● |
| Non-directional earth-fault protection, instantaneous stage, instance 1 | - | - | ● |
| Directional earth-fault protection, low stage (SEF), instance 1 | - | ● | - |
| Directional earth-fault protection, low stage, instance 2 | - | ● | - |
| Directional earth-fault protection, high stage, instance 1 | - | ● | - |
| Transient / intermittent earth-fault protection | - | ● | - |
| Non-directional (cross-country) earth-fault protection, using calculated $I_0$ | - | ● | - |
| Negative sequence overcurrent protection, instance 1 | ● | ● | ● |
| Negative sequence overcurrent protection, instance 2 | ● | ● | ● |
| Phase discontinuity protection | - | ● | ● |
| Table continues on next page | | | |

| Functionality | A | B | C |
|---|---|---|---|
| Three-phase thermal protection for feeders, cables and distribution transformers | - | ● | ● |
| Binary signal transfer | ● | ● | ● |
| Circuit-breaker failure protection | ● | ● | ● |
| Three-phase inrush current detector | ● | ● | ● |
| Master trip, instance 1 | ● | ● | ● |
| Master trip, instance 2 | ● | ● | ● |
| **Control** | | | |
| Circuit-breaker control with interlocking | ● | ● | ● |
| Disconnector position indication, instance 1 | ● | ● | ● |
| Disconnector position indication, instance 2 | ● | ● | ● |
| Disconnector position indication, instance 3 | ● | ● | ● |
| Earthing switch indication | ● | ● | ● |
| Auto-reclosing | - | o | o |
| **Condition monitoring** | | | |
| Circuit-breaker condition monitoring | - | ● | ● |
| Trip circuit supervision, instance 1 | ● | ● | ● |
| Trip circuit supervision, instance 2 | ● | ● | ● |
| Current circuit supervision | ● | ● | ● |
| Protection communication supervision | ● | ● | ● |
| **Measurement** | | | |
| Disturbance recorder | ● | ● | ● |
| Three-phase current measurement | ● | ● | ● |
| Sequence current measurement | ● | ● | ● |
| Residual current measurement | - | ● | ● |
| Residual voltage measurement | - | ● | - |
| ● = 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

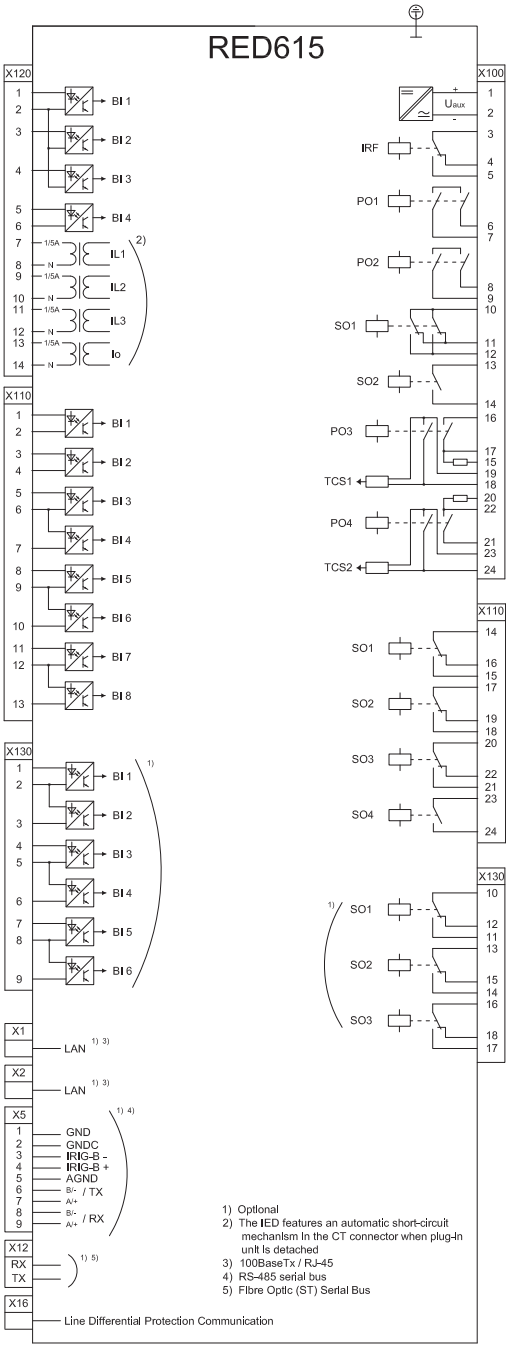



*Figure 6: Terminal diagram for configuration A and C*

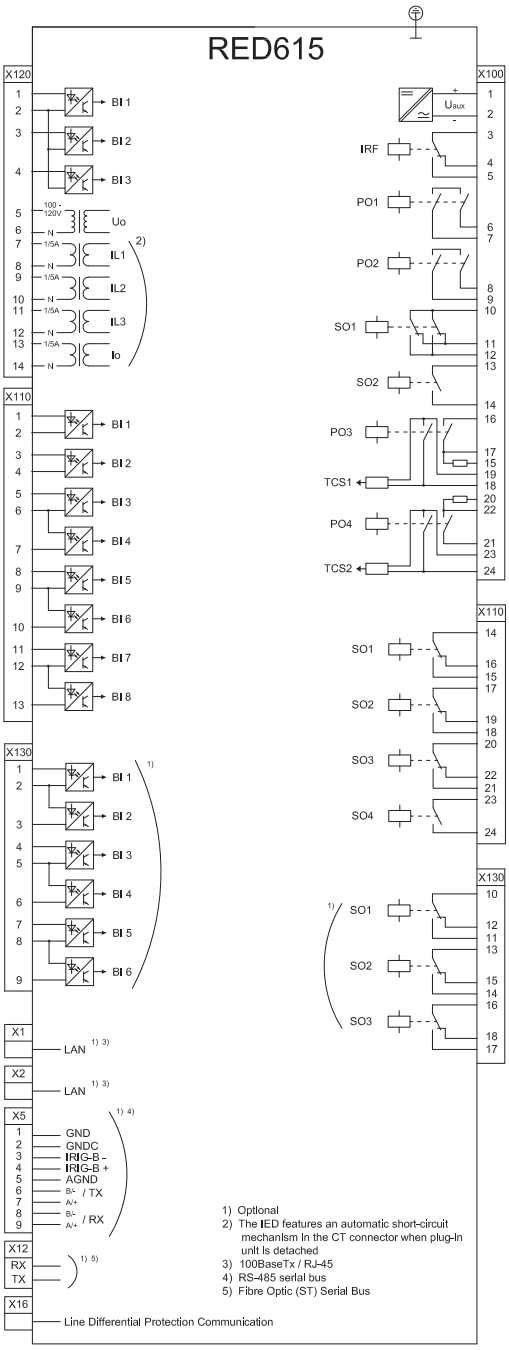



*Figure 7: Terminal diagram for configuration B*

## 3.2.3 Connection diagrams

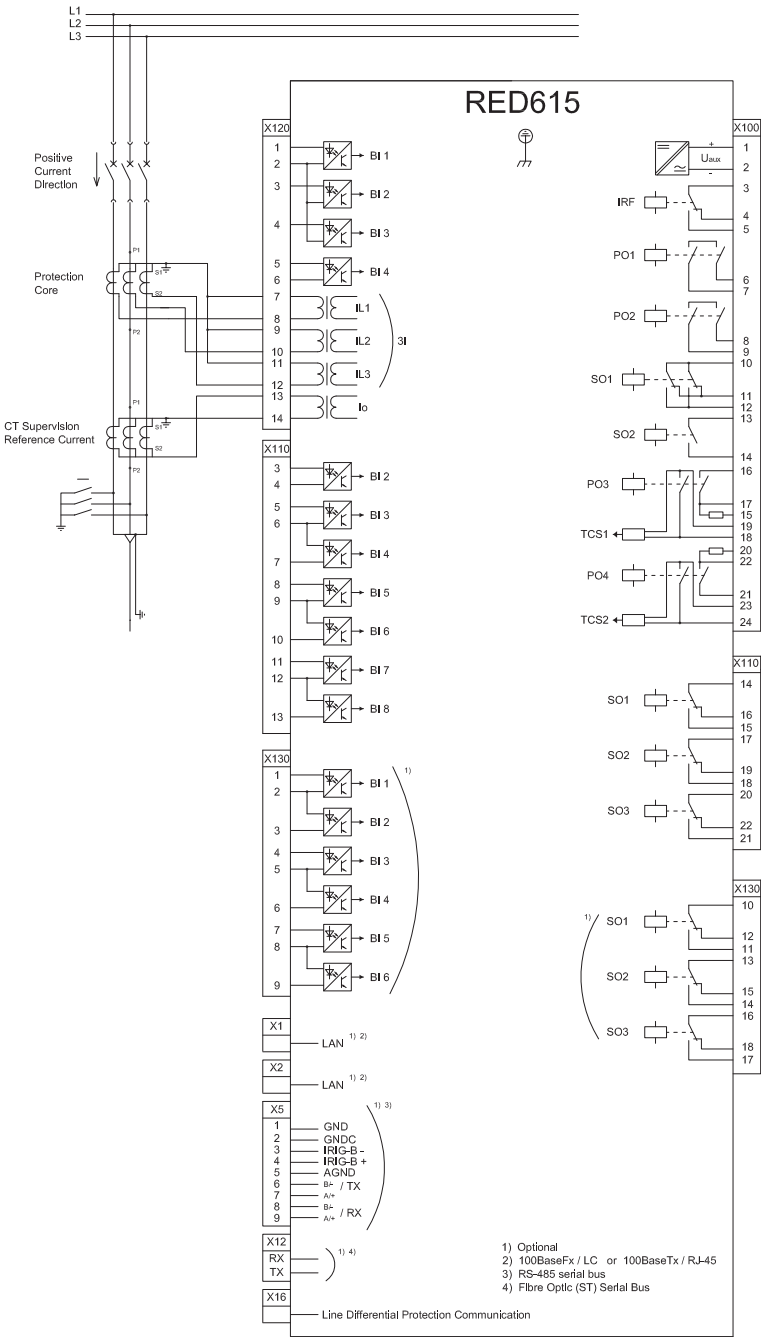



*Figure 8: Connection diagram for configuration A and C (line current differential protection)*

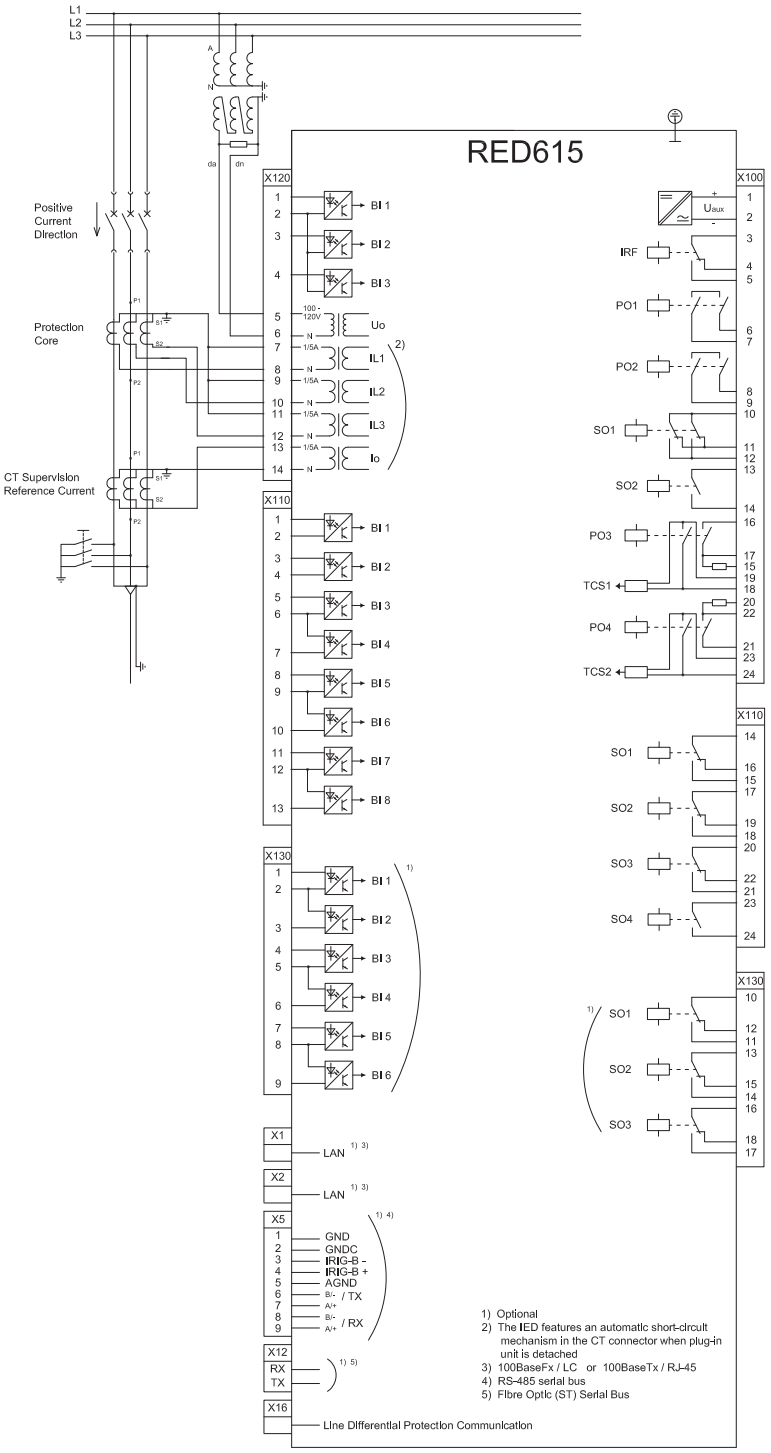



*Figure 9: Connection diagram for configuration B (line current differential protection including directional earth-fault protection and autoreclosing)*

# 3.3 Standard configuration A for line current differential protection

## 3.3.1 Applications

The standard configuration for line current differential protection is mainly intended for cable feeder applications in distribution networks.

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 RED615 standard configuration with line current differential protection*

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Line differential protection and related measurements, stabilized and instantaneous stages | LNPLDF1 | 3dI>L | 87L |
| Three-phase non-directional overcurrent, low stage | PHLPTOC1 | 3I> | 51P-1 |
| Three-phase non-directional overcurrent, high stage, instance 1 | PHHPTOC1 | 3I>> (1) | 51P-2 (1) |
| Three-phase non-directional overcurrent, high stage, instance 2 | PHHPTOC2 | 3I>> (2) | 51P-2 (2) |
| Three-phase non-directional overcurrent, instantaneous stage | PHIPTOC1 | 3I>>> | 50P/51P |
| Negative-sequence overcurrent protection, instance 1 | NSPTOC1 | I2> (1) | 46 (1) |
| Negative-sequence overcurrent protection, instance 2 | NSPTOC2 | I2> (2) | 46 (2) |
| Circuit breaker failure protection | CCBRBRF1 | 3I>/$I_0$>BF | 51BF/51NBF |
| Three-phase inrush detector | INRPHAR1 | 3I2f> | 68 |
| Binary signal transfer | BSTGGIO1 | BST | BST |
| Circuit breaker control with interlocking | CBXCBR1 | O <-> I | O <-> I |
| 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 |
| Trip circuit supervision for two trip coils | TCSSCBR1<br>TCSSCBR2 | TCS (1)<br>TCS (2) | TCM (1)<br>TCM (2) |

Table continues on next page

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Current circuit supervision | CCRDIF1 | CCRDIF | CCRDIF |
| Protection communication supervision | PCSRTPC1 | PCS | PCS |
| Transient disturbance recorder | RDRE1 | - | - |
| Three-phase current measurement | CMMXU1 | 3I | 3I |
| Sequence current measurement | CSMSQI1 | $I_1,I_2,I_0$ | $I_1,I_2,I_0$ |

### 3.3.2.1 Default I/O connections

*Table 9: Default connections for binary inputs*

| Binary input | Description | Connector pins |
|---|---|---|
| X120-BI1 | Blocking input for general use | X120-1,2 |
| X120-BI2 | Circuit breaker close | X120-3,2 |
| X120-BI3 | Circuit breaker open | X120-4,2 |
| X120-BI4 | Lockout reset | X120-5,2 |
| X110-BI2 | External start of breaker failure protection | X110-3,4 |
| X110-BI3 | Setting group change | X110-5,6 |
| X110-BI4 | Binary signal transfer input | X110-7,6 |
| X110-BI5 | Disconnector close/truck in | X110-8,9 |
| X110-BI6 | Disconnector open/truck out | X110-10,9 |
| X110-BI7 | Earth switch close | X110-11,12 |
| X110-BI8 | Earth switch open | X110-13,12 |

*Table 10: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close circuit breaker | X100-6,7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker | X100-8,9 |
| X100-SO1 | Line differential protection trip alarm | X100-10,11,(12) |
| X100-SO2 | Protection communication failure or differential protection not available | X100-13,14 |
| X100-PO3 | Open circuit breaker/trip 1 | X100-15-19 |
| X100-PO4 | Open circuit breaker/trip 2 | X100-20-24 |
| X110-SO1 | Start indication | X110-14,15 |
| X110-SO2 | Operate indication | X110-17,18 |
| X110-SO3 | Binary transfer signal | X110-20,21 |

*Table 11: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Line differential protection biased stage operate |
| 2 | Line differential protection instantaneous stage operate |
| 3 | Line differential protection is not available |
| 4 | Protection communication failure |
| 5 | Current transformer failure detected |
| 6 | Phase or negative sequence component over current |
| 7 | Breaker failure operate |
| 8 | Disturbance recorder triggered |
| 9 | Trip circuit supervision alarm |
| 10 | Binary signal transfer receive |
| 11 | Binary signal transfer send |

## 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, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the eight 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 represents the three phase currents. The signal marked with $I_0$ represents the measured residual current, via a sum connection of second CT cores of the phase current transformers.

### 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.

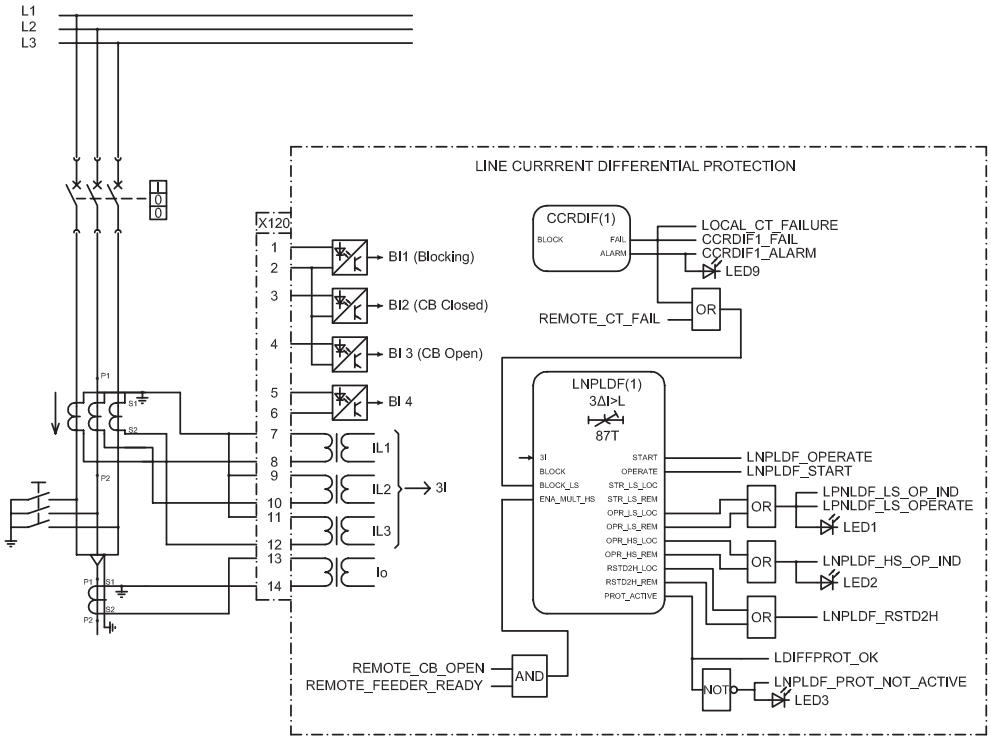



*Figure 10: Line differential protection*

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined setting if the ENA_MULT input is activated. In this configuration it is activated by the open status information of the remote end circuit breaker, disconnectors and earth switch. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12). LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

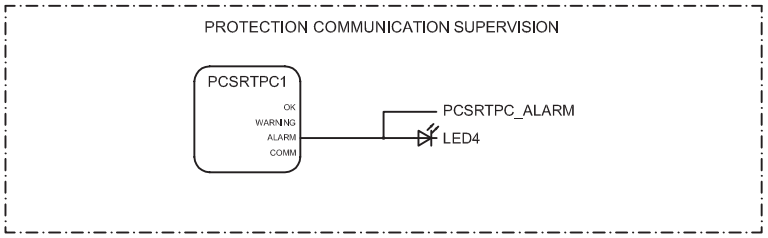



*Figure 11: Protection communication supervision*

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14-15).

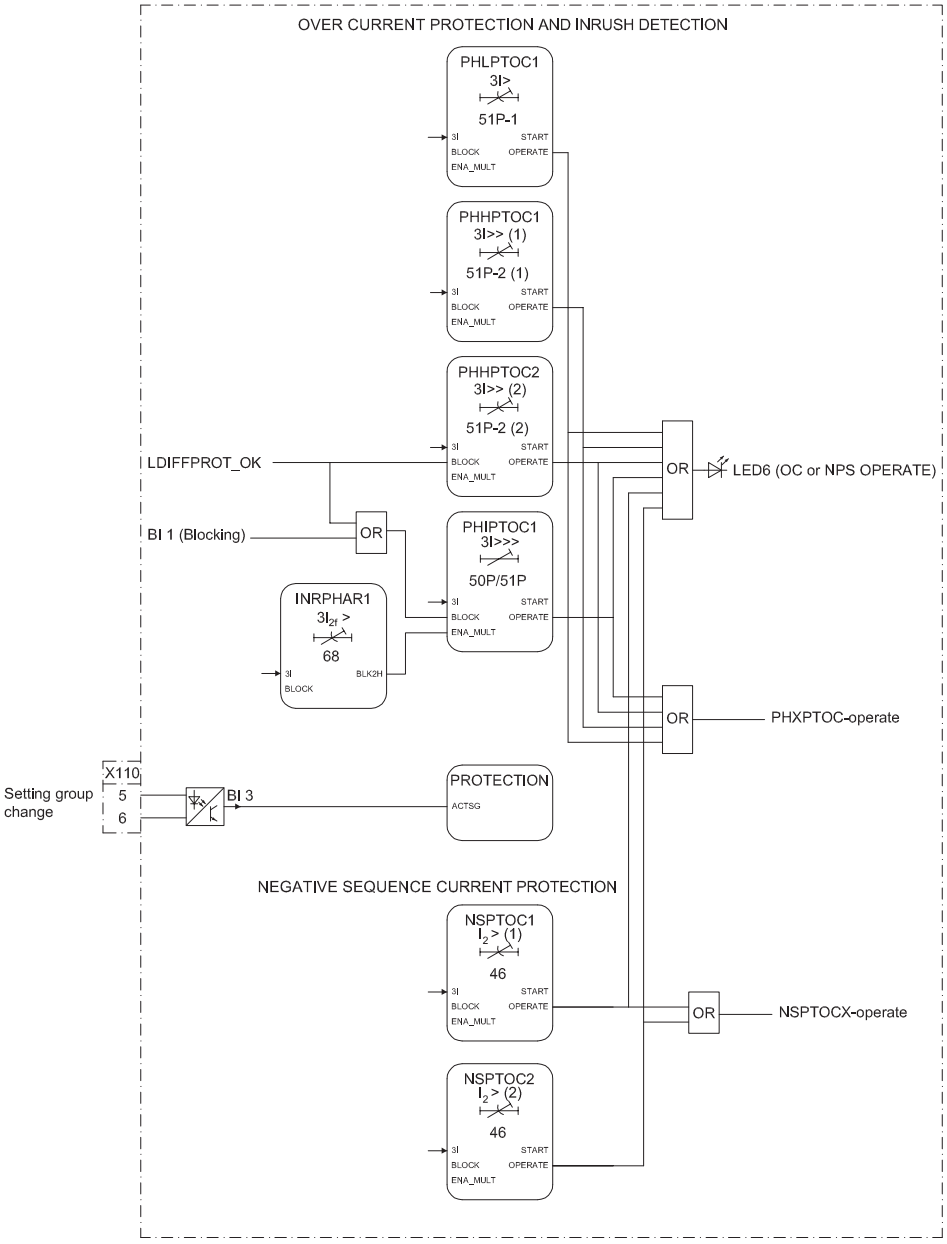



*Figure 12: Overcurrent protection*

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and

NSPTOC2) are offered for phase unbalance protection. The inrush detection block's (INRPHAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

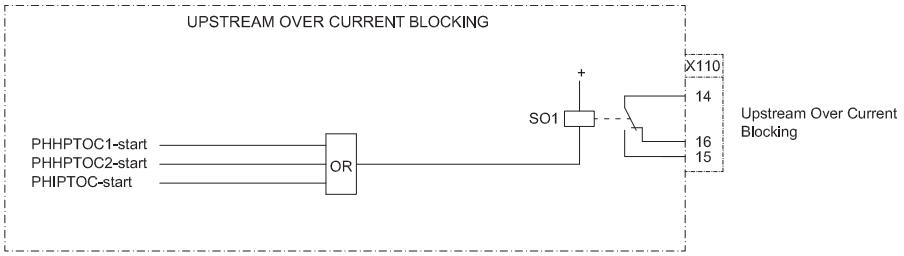



*Figure 13: Blocking of the upstream overcurrent relay*

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

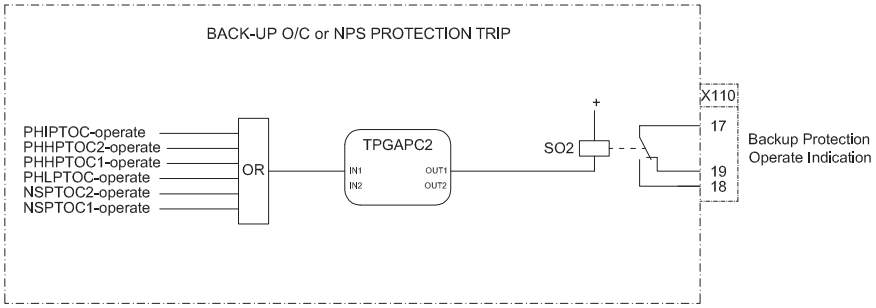



*Figure 14: Indication of overcurrent or NPS overcurrent operation*

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

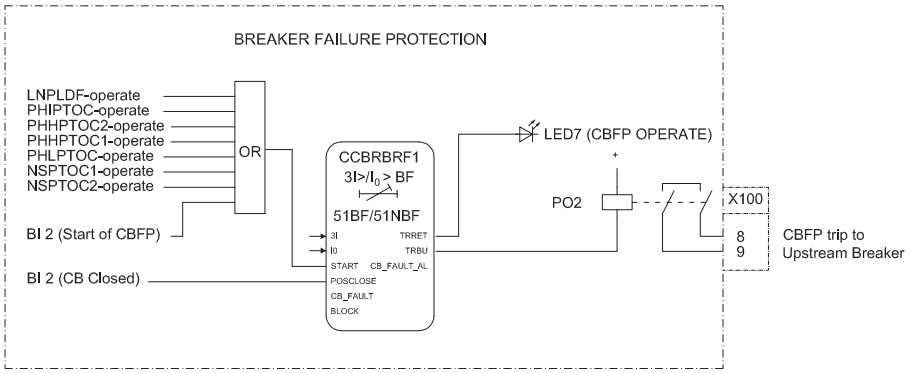



*Figure 15: Circuit breaker failure protection*

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 to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

### 3.3.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

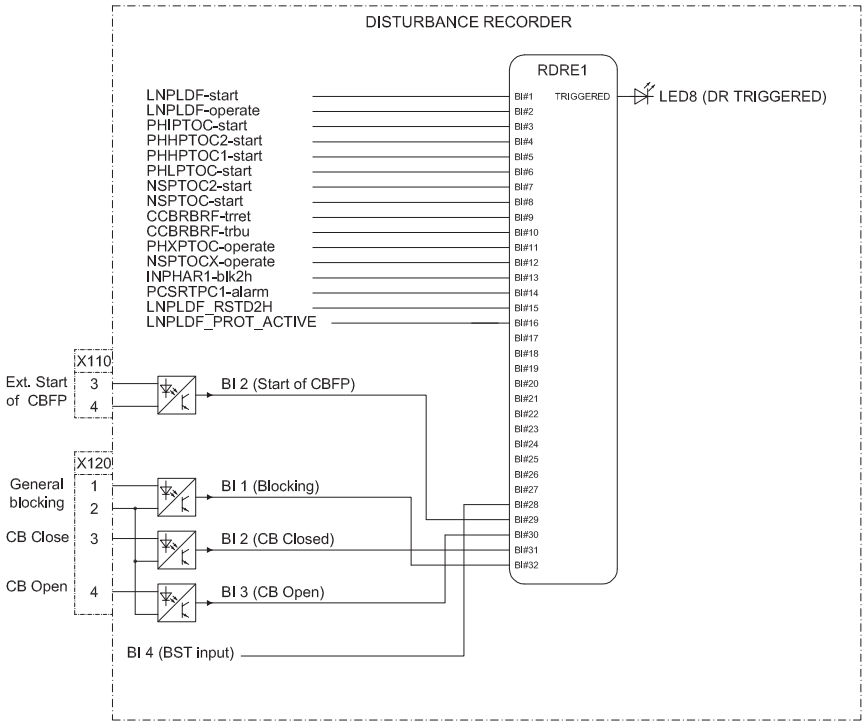



*Figure 16: Disturbance recorder*

The disturbance recorder has 64 digital inputs of which 21 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 five binary inputs from X120 are also connected.

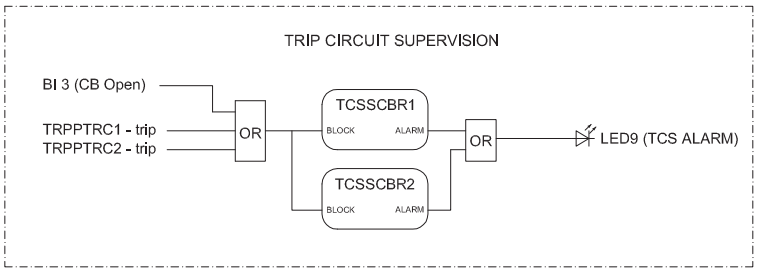



*Figure 17: Trip circuit supervision*

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

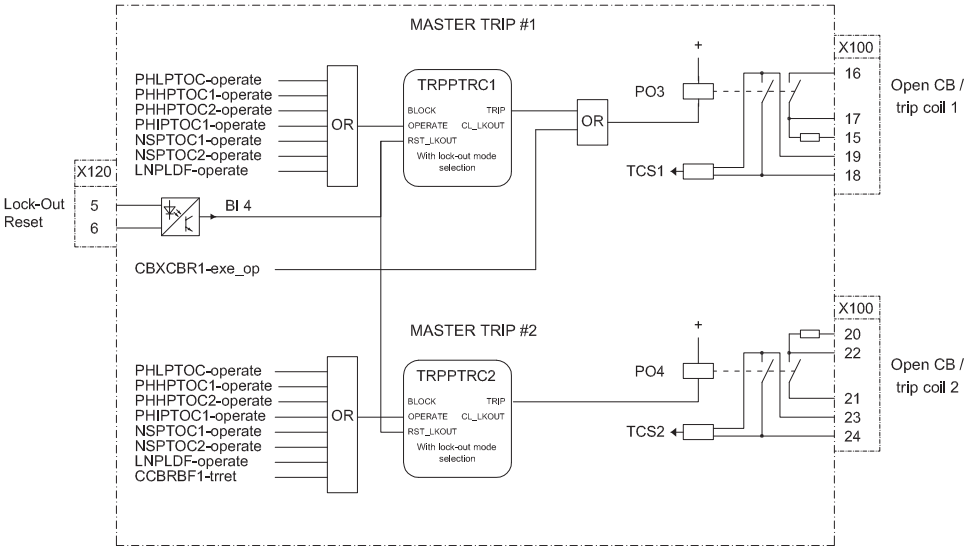



*Figure 18: Master Trip*

The operate signals from the protections are connected to the two trip output contacts PO3 (X100:16-19) and PO4 (X100:20-23) via the corresponding Master Trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1-exe_op is 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.

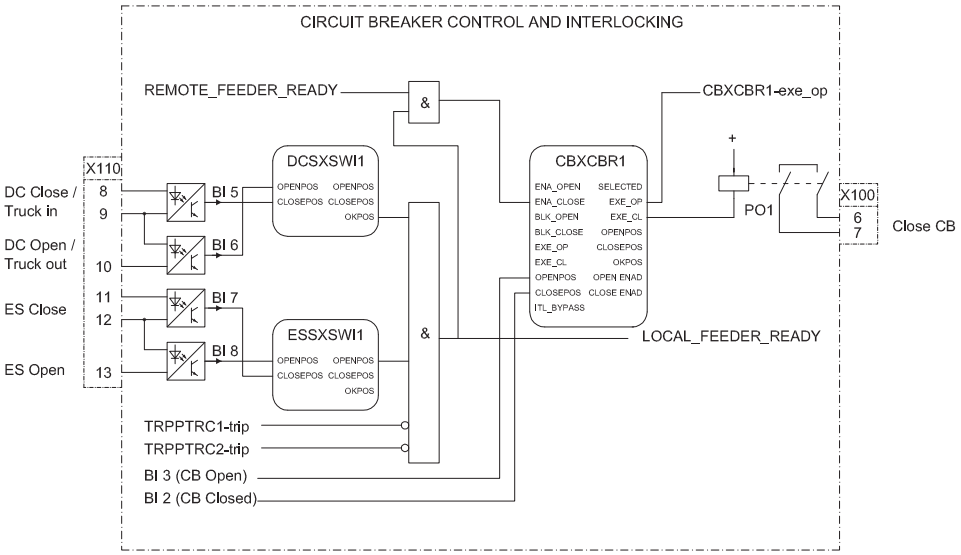



*Figure 19: Circuit breaker control and interlocking*

ENA_CLOSE input enables the closing of the circuit breaker. In the circuit-breaker control function CBXCBR is a combination of the statuses of the Master Trip logics, disconnector and earth switch position indications and remote feeder position indications. Master trip logic, disconnector and earth switch statuses are local feeder ready information to be sent for the remote end. Opening is always enabled.

If the ENA_CLOSE signal is completely removed from CBXCBR with PCM600, the function assumes that the circuit breaker close commands are allowed continuously.

If REMOTE_FEEDER_READY information is missing, for example, in case of protection communication not connected, it disables the breaker closing in the local IED.

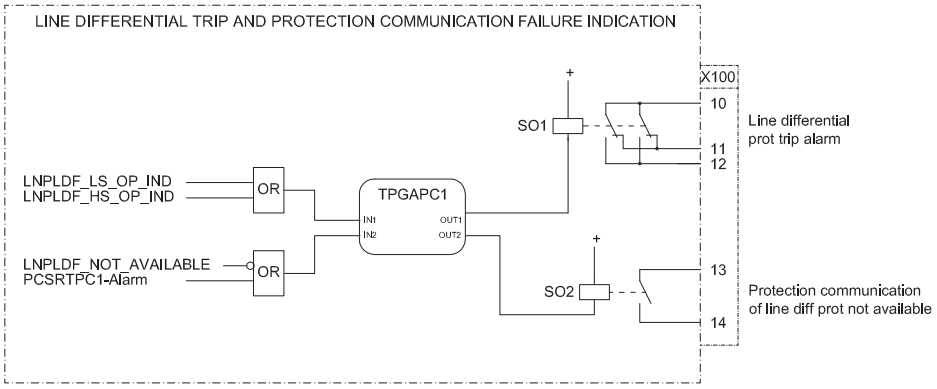



*Figure 20: Line differential trip and protection communication failure indication*

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

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)

TPGAPC1 is a timer and used for setting the minimum pulse length for the outputs.

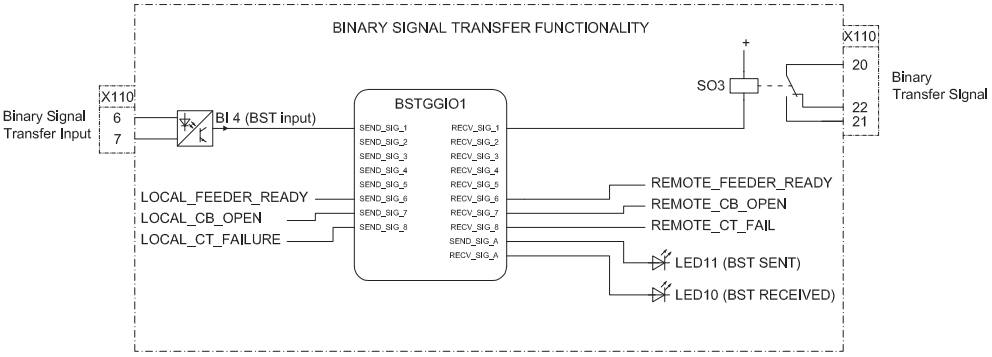



*Figure 21: Binary signal transfer*

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI3 (X110:6-7) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

## 3.4 Standard configuration B for line current differential protection including directional earth-fault protection and autoreclosing

### 3.4.1 Applications

The standard configuration for line current differential protection is mainly intended for cable feeder applications in distribution networks.

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 12: Functions included in the RED615 standard configuration with directional earth-fault protection and autoreclosing*

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Line differential protection and related measurements, stabilized and instantaneous stages | LNPLDF1 | 3dI>L | 87L |
| Three-phase non-directional overcurrent protection, low stage | PHLPTOC1 | 3I> (1) | 51P-1 (1) |
| Three-phase non-directional overcurrent protection, high stage | PHHPTOC1 | 3I>>(1) | 51P-2 (1) |
| | PHHPTOC2 | 3I>>(2) | 51P-2 (2) |
| Three-phase non-directional overcurrent protection, instantaneous stage | PHIPTOC1 | 3I>>>(1) | 50P/51P (1) |
| Directional earth-fault protection, low stage | DEFLPDEF1 | $I_0$>→ (1) | 67N-1 (1) |
| | DEFLPDEF2 | $I_0$>→ (2) | 67N-1 (2) |
| Directional earth-fault protection, high stage | DEFHPDEF1 | $I_0$>>→ | 67N-2 |
| Transient/intermittent earth-fault protection | INTRPTEF1 | $I_0$>→ IEF | 67NIEF |
| Non-directional (cross-country) earth fault, using calculated $I_0$ | EFHPTOC1 | $I_0$>> (1) | 51N-2 (1) |
| Negative-sequence overcurrent protection | NSPTOC1 | $I_2$> (1) | 46 (1) |
| | NSPTOC2 | $I_2$> (2) | 46 (2) |
| Phase discontinuity | PDNSPTOC1 | $I_2/I_1$> | 46PD |
| Three-phase thermal protection for feeders, cables and distribution transformers | T1PTTR1 | 3Ith>F | 49F |
| Circuit breaker failure protection | CCBRBRF1 | 3I>/$I_0$>BF | 51BF/51NBF |
| Three-phase inrush detector | INRPHAR1 | 3I2f> | 62 |
| Binary signal transfer | BSTGGIO1 | BST | BST |
| 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 |
| Autoreclosing | DARREC1 | O → I | 79 |
| Circuit breaker condition monitoring | SSCBR1 | CBCM | CBCM |

Table continues on next page

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Trip circuit supervision | TCSSCBR1 | TCS (1) | TCM (1) |
| | TCSSCBR2 | TCS (2) | TCM (2) |
| Current circuit supervision | CCRDIF1 | MCS 3I | MCS 3I |
| Protection communication supervision | PCSRTPC1 | PCS | PCS |
| Disturbance recorder | RDRE1 | - | - |
| Three-phase current measurement | CMMXU1 | 3I | 3I |
| Sequence current measurement | CSMSQI1 | $I_1$, $I_2$, $I_0$ | $I_1$, $I_2$, $I_0$ |
| Residual current measurement | RESCMMXU1 | $I_0$ | $I_0$ |
| Residual voltage measurement | RESVMMXU1 | $U_0$ | $V_0$ |

### 3.4.2.1 Default I/O connections

*Table 13: Default connections for binary inputs*

| Binary input | Description | Connector pins |
|---|---|---|
| X120-BI1 | Blocking input for general use | X120-1,2 |
| X120-BI2 | Circuit breaker close | X120-3,2 |
| X120-BI3 | Circuit breaker open | X120-4,2 |
| X110-BI1 | Lockout reset | X110-1,2 |
| X110-BI2 | Binary signal transfer input | X110-3,4 |
| X110-BI3 | Circuit breaker low gas pressure alarm | X110-5,6 |
| X110-BI4 | Circuit breaker spring charged indication | X110-7,6 |
| X110-BI5 | Circuit breaker truck in (service position) indication | X110-8,9 |
| X110-BI6 | Circuit breaker truck out (test position) indication | X110-10,9 |
| X110-BI7 | Earthing switch closed indication | X110-11,12 |
| X110-BI8 | Earthing switch open indication | X110-13,12 |

*Table 14: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close circuit breaker | X100-6,7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker | X100-8,9 |
| X100-SO1 | Line differential protection trip alarm | X100-10,11, (12) |
| X100-SO2 | Protection communication failure or differential protection not available | X100-13,14 |
| X100-PO3 | Open circuit breaker/trip 1 | X100-15-19 |
| X100-PO4 | Open circuit breaker/trip 2 | X100-20-24 |
| X110-SO1 | Upstream over current blocking | X110-14,15 |

Table continues on next page

| Binary output | Description | Connector pins |
|---|---|---|
| X110-SO2 | Backup protection operate indication | X110-17,18 |
| X110-SO3 | Binary transfer signal | X110-20,21 |
| X110-SO4 | | X110-20,21 |

*Table 15: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Line differential protection biased stage operated |
| 2 | Line differential protection instantaneous stage operated |
| 3 | Line differential protection is not available |
| 4 | Protection communication failure |
| 5 | Auto reclose in progress |
| 6 | Backup protection operated |
| 7 | Circuit breaker failure protection backup trip operated |
| 8 | Disturbance recorder triggered |
| 9 | Current transformer failure or trip circuit or circuit breaker supervision alarm |
| 10 | Binary signal transfer receive |
| 11 | Binary transfer signal send |

## 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, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED's standard configuration. Exceptions from this rule are the eight 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 represents the three phase currents. The signal marked with $I_0$ represents the measured residual current, via a sum connection of second CT cores of the phase current transformers. The signal marked with $U_0$ represents the measured residual voltage from voltage transformers.

### 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.

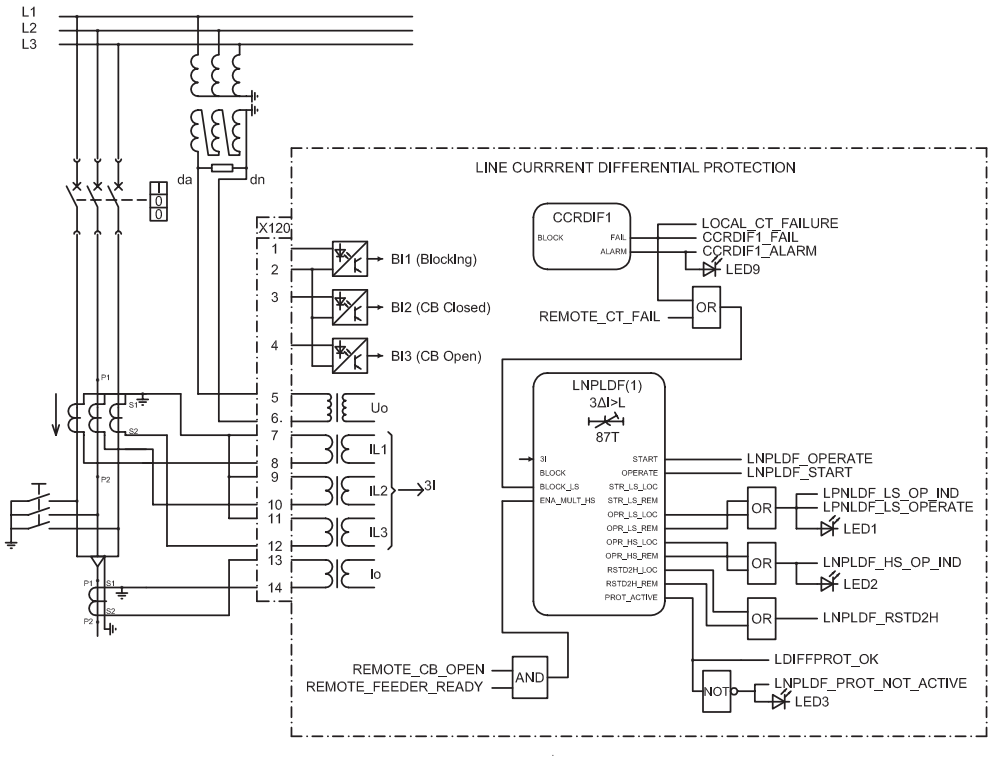



*Figure 22: Line current differential protection*

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined setting if the ENA_MULT input is activated. In this configuration it is activated by the open status information of the remote end circuit breaker, disconnectors and earth switch. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12). LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

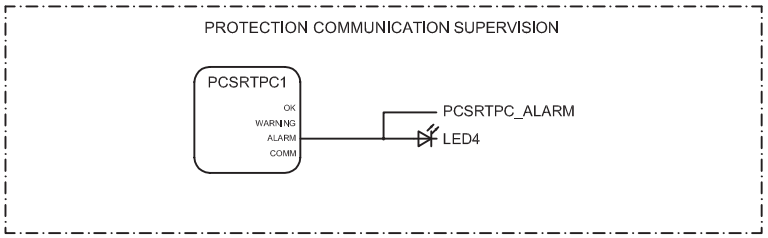



*Figure 23: Protection communication supervision function*

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14).

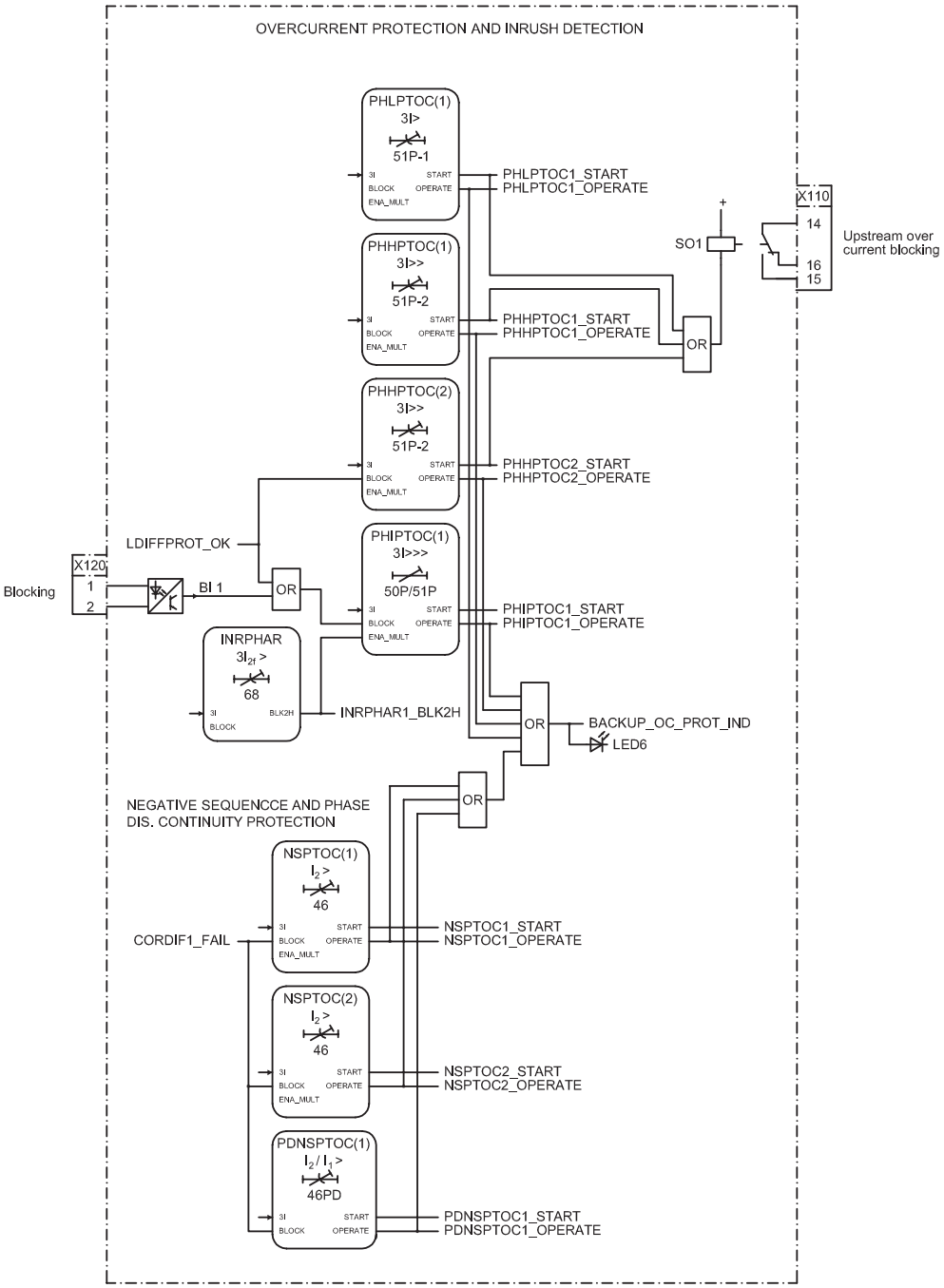



*Figure 24: Overcurrent protection*

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The phase discontinuity protection (PDNSPTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The inrush

detection block's (INRPHAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

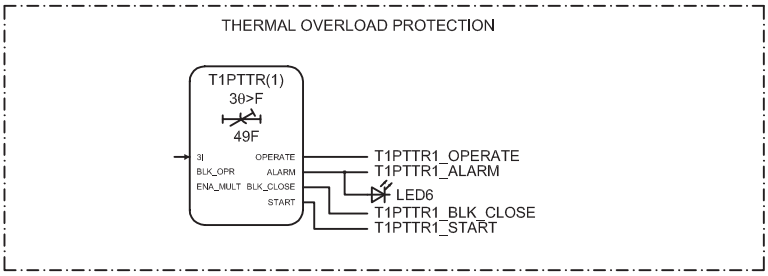



*Figure 25: Thermal overload protection*

The thermal overload protection (T1PTTR1) provides indication on overload situations. Active BLK_CLOSE signal blocks the closing of the circuit breaker. LED 6 is used also for the thermal overload protection alarm indication.

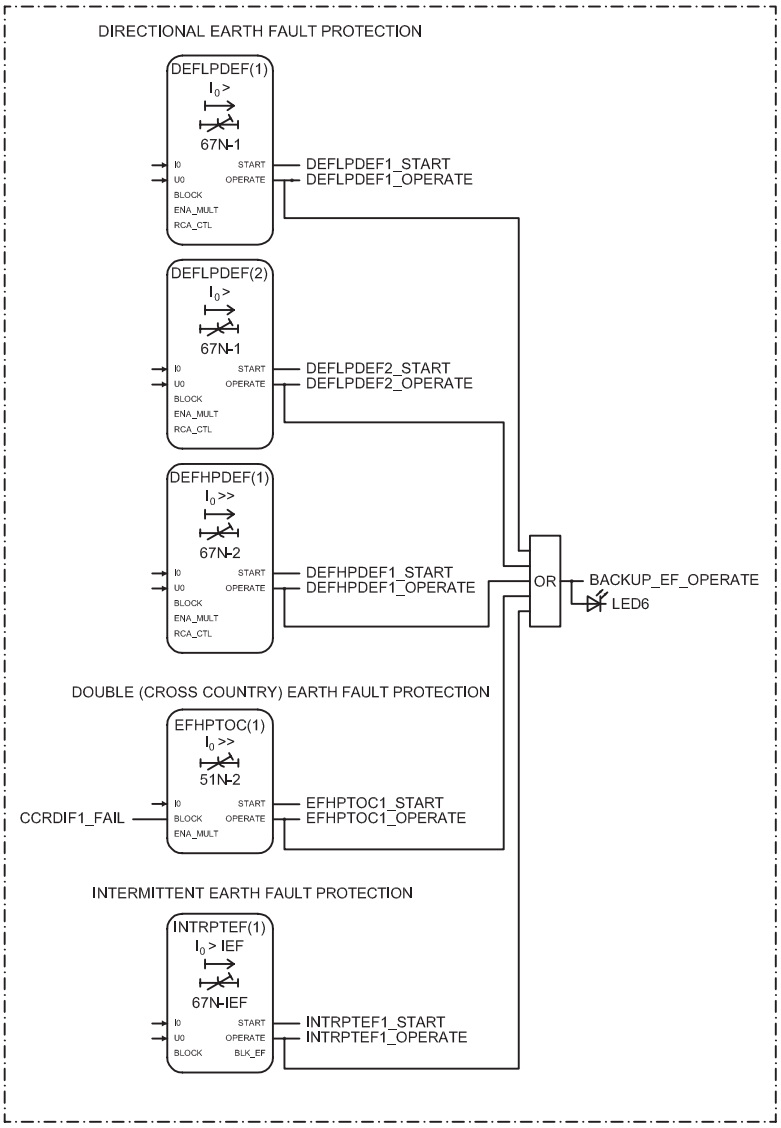



*Figure 26: Earth-fault protection*

Three stages are offered for directional earth-fault protection. In addition, there is a dedicated protection stage (INTRPTEF) either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block (EFHPTOC) is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

All operate signals are connected to the Master Trip and also to the alarm LED2.

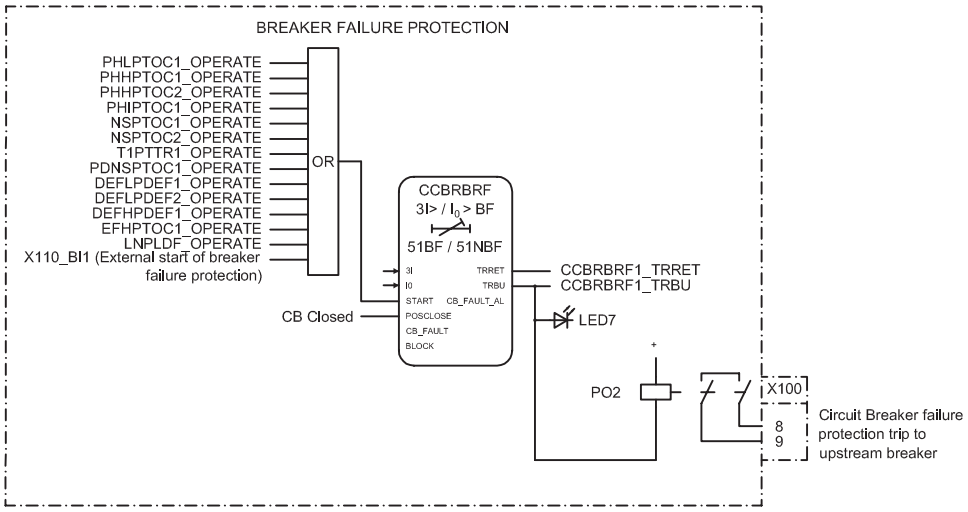



*Figure 27: Circuit breaker failure protection*

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 to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

### 3.4.3.2 Functional diagrams for disturbance recorder and supervision functions

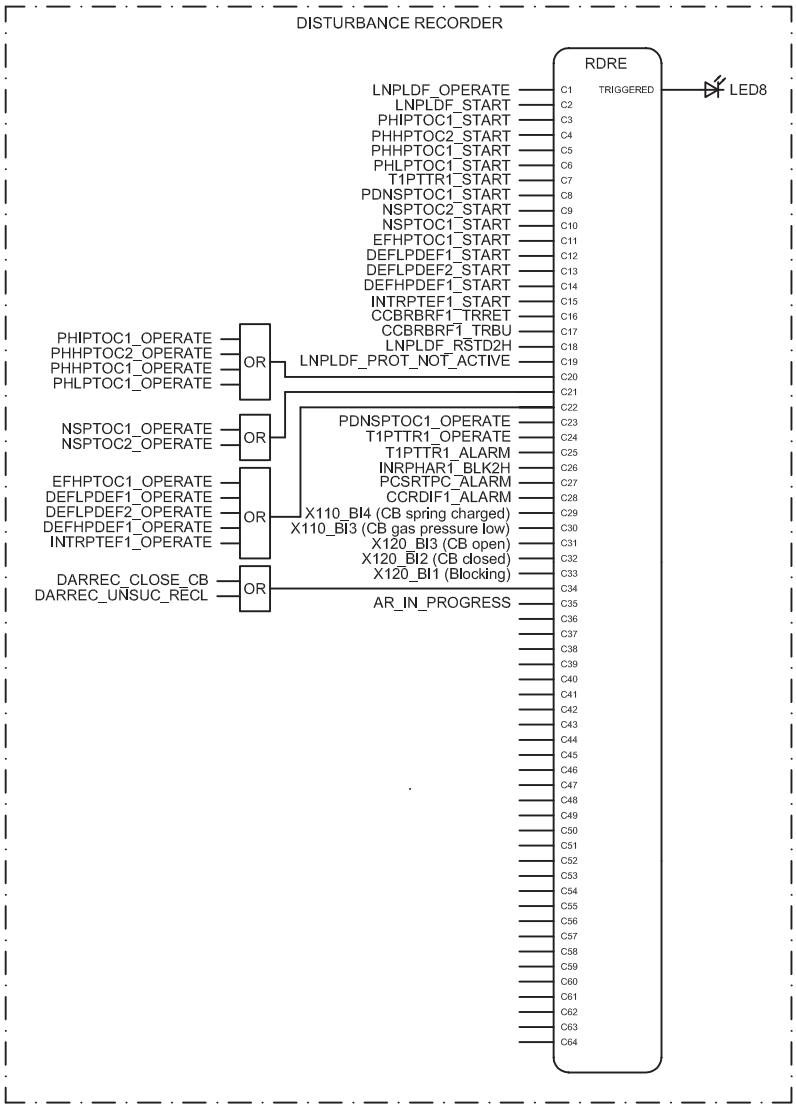



*Figure 28: Disturbance recorder*

The disturbance recorder has 64 digital inputs of which 35 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 five binary inputs from X120 are also connected.

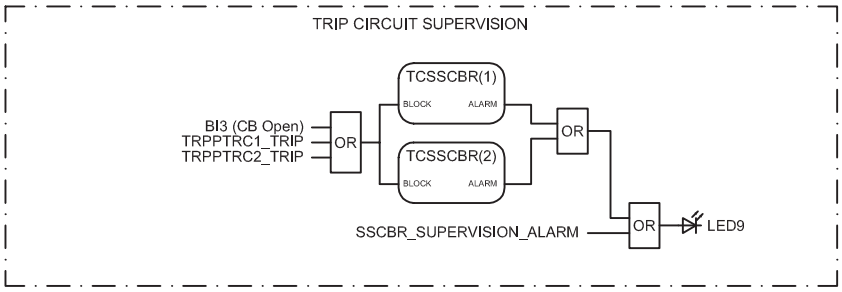



*Figure 29: Trip circuit supervision*

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 X100:20-24). 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

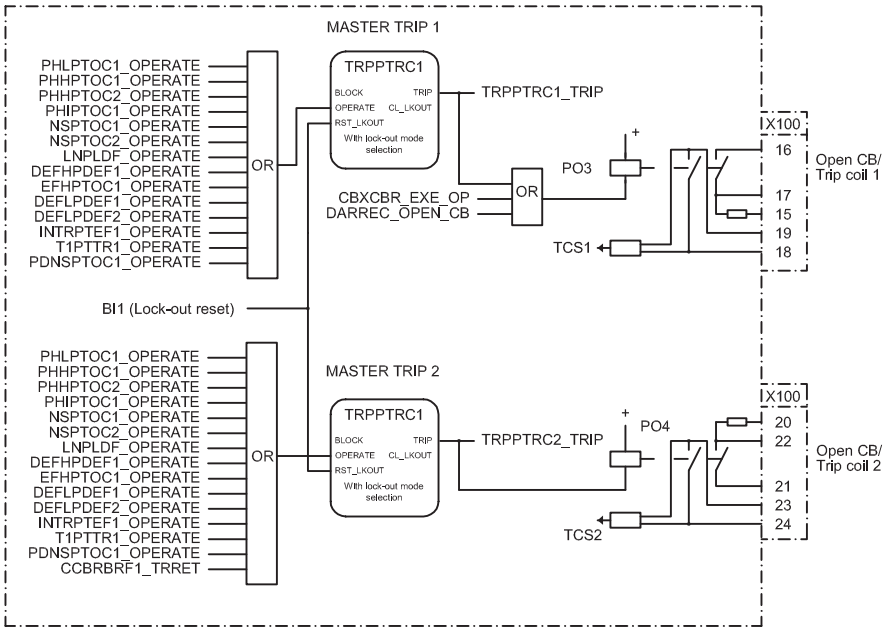



*Figure 30: Master Trip*

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 is connected directly to the output PO3 (X100:15-19).

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.

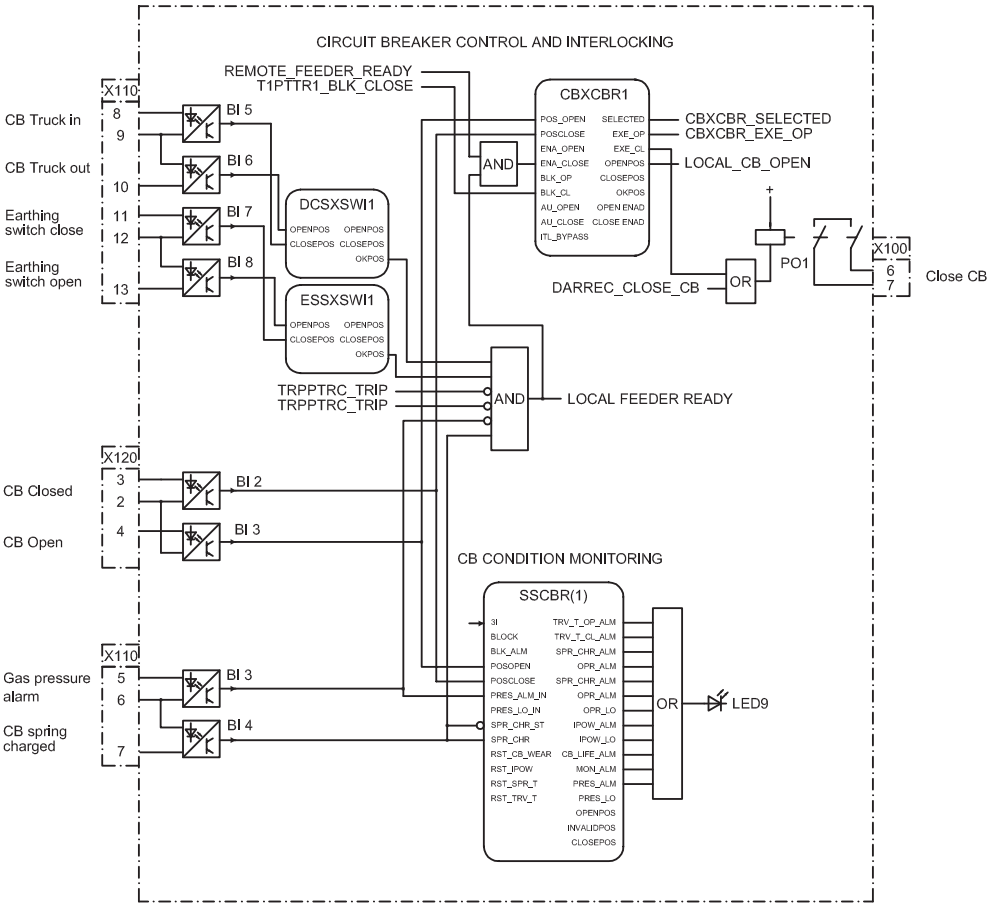



*Figure 31: Circuit breaker control and interlocking*

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 16: Device positions indicated by binary inputs 5 and 6*

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

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. This combination of interlocking conditions is called LOCAL_FEEDER_READY and is transferred also to the remote end via binary signal transfer. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open/in test position or close/in service position. This, together with the open earth switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

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 signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.



If REMOTE_FEEDER_READY information is missing, for example in case of protection communication not connected, it disables the circuit breaker closing in the local IED.

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.

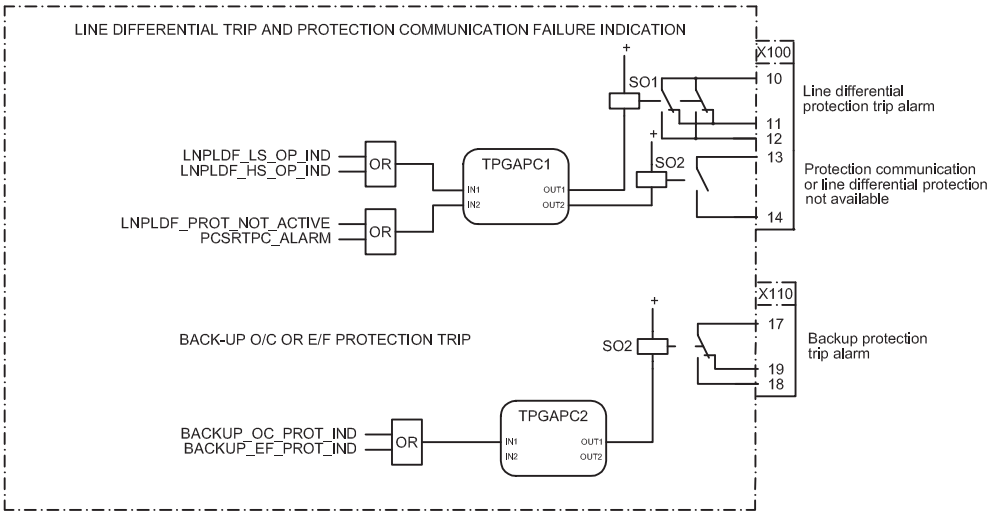



*Figure 32: Line differential trip and protection communication failure indication*

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

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)

TPGAPC1 is a timer and used for setting the minimum pulse length for the outputs.

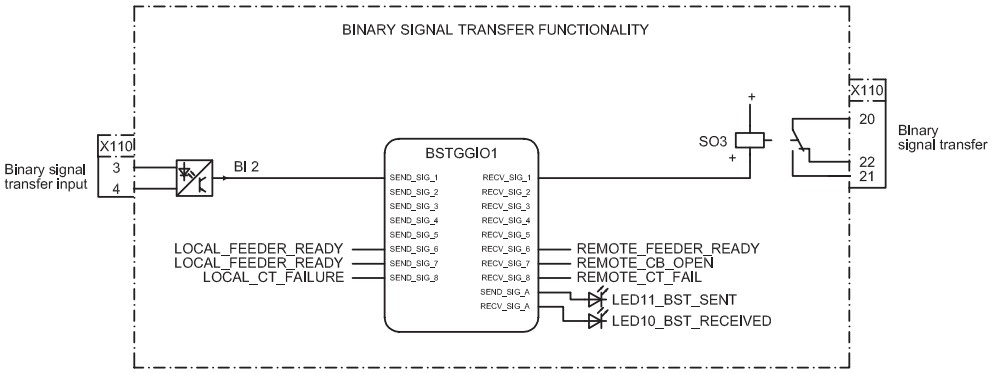



*Figure 33: Binary signal transfer*

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI2 (X110:3-4) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

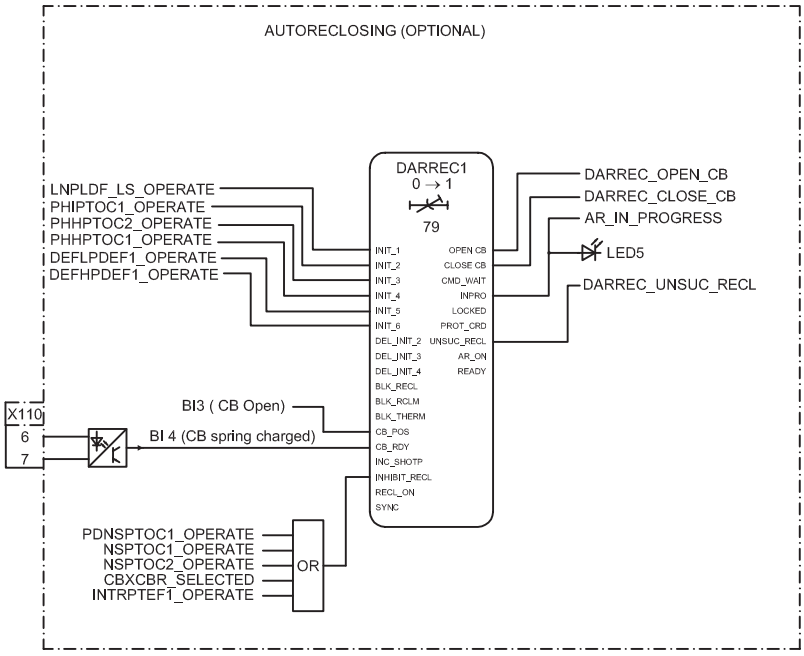



*Figure 34: Autoreclose*

The autoreclose function (DARREC1) is configured to be initiated by operate signals from a number of protection stages through the INIT1...6 inputs. It is possible to create individual autoreclose sequences for each input. DARREC1 can be blocked with the INHIBIT_RECL input. As a default, the operation of some selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks DARREC1 via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclose sequence is expressed with the binary input 4 (X110:6-7) by connecting the input signal to the CB_READY input. In case this signal is completely removed from DARREC1 with PCM600, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to alarm LED 5.

# 3.5 Standard configuration C for line current differential protection including non-directional earth-fault protection and autoreclosing

## 3.5.1 Applications

The standard configuration for line current differential protection is mainly intended for cable feeder applications in distribution networks.

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 17: Functions included in the RED615 standard configuration with non-directional earth-fault protection and autoreclosing*

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Line differential protection and related measurements, stabilized and instantaneous stages | LNPLDF1 | 3dI>L | 87L |
| Three-phase non-directional overcurrent protection, low stage | PHLPTOC1 | 3I> (1) | 51P-1 (1) |
| Three-phase non-directional overcurrent protection, high stage | PHHPTOC1 | 3I>>(1) | 51P-2 (1) |
| | PHHPTOC2 | 3I>>(2) | 51P-2 (2) |
| Three-phase non-directional overcurrent protection, instantaneous stage | PHIPTOC1 | 3I>>>(1) | 50P/51P (1) |
| Non-directional earth-fault protection, low stage | EFLPTOC1 | $I_0$> (1) | 51N-1 (1) |
| | EFLPTOC2 | $I_0$> (2) | 51N-1 (2) |
| Non-directional earth-fault protection, high stage | EFHPTOC1 | $I_0$>> (1) | 51N-2 (1) |
| Non-directional earth-fault protection, instantaneous stage | EFIPTOC1 | $I_0$>>> | 50N/51N |
| Negative-sequence overcurrent protection | NSPTOC1 | $I_2$> (1) | 46 (1) |
| | NSPTOC2 | $I_2$> (2) | 46 (2) |
| Phase discontinuity | PDNSPTOC1 | $I_2/I_1$> | 46PD |
| Three-phase thermal protection for feeders, cables and distribution transformers | T1PTTR1 | 3Ith>F | 49F |
| Circuit breaker failure protection | CCBRBRF1 | 3I>/$I_0$>BF | 51BF/51NBF |
| Table continues on next page | | | |

| Function | IEC 61850 | IEC | ANSI |
|---|---|---|---|
| Three-phase inrush detector | INRPHAR1 | 3I2f> | 62 |
| Binary signal transfer | BSTGGIO1 | BST | BST |
| 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 |
| Autoreclosing | DARREC1 | O → I | 79 |
| Circuit breaker condition monitoring | SSCBR1 | CBCM | CBCM |
| Trip circuit supervision | TCSSCBR1 | TCS (1) | TCM (1) |
| | TCSSCBR2 | TCS (2) | TCM (2) |
| Current circuit supervision | CCRDIF1 | MCS 3I | MCS 3I |
| Protection communication supervision | PCSRTPC1 | PCS | PCS |
| Disturbance recorder | RDRE1 | - | - |
| Three-phase current measurement | CMMXU1 | 3I | 3I |
| Sequence current measurement | CSMSQI1 | $I_1$, $I_2$, $I_0$ | $I_1$, $I_2$, $I_0$ |
| Residual current measurement | RESCMMXU1 | $I_0$ | $I_0$ |

### 3.5.2.1 Default I/O connections

*Table 18: Default connections for binary inputs*

| Binary input | Description | Connector pins |
|---|---|---|
| X120-BI1 | Blocking input for general use | X120-1,2 |
| X120-BI2 | Circuit breaker close | X120-3,2 |
| X120-BI3 | Circuit breaker open | X120-4,2 |
| X120-BI4 | Lockout reset | X120-5,6 |
| X110-BI1 | External start of breaker failure protection | X110-1,2 |
| X110-BI2 | Binary signal transfer input | X110-3,4 |
| X110-BI3 | Circuit breaker low gas pressure alarm | X110-5,6 |
| X110-BI4 | Circuit breaker spring charged indication | X110-7,6 |
| X110-BI5 | Circuit breaker truck in (service position) indication | X110-8,9 |
| X110-BI6 | Circuit breaker truck out (test position) indication | X110-10,9 |
| X110-BI7 | Earthing switch closed indication | X110-11,12 |
| X110-BI8 | Earthing switch open indication | X110-13,12 |

*Table 19: Default connections for binary outputs*

| Binary output | Description | Connector pins |
|---|---|---|
| X100-PO1 | Close circuit breaker | X100-6,7 |
| X100-PO2 | Breaker failure backup trip to upstream breaker | X100-8,9 |
| X100-SO1 | Line differential protection trip alarm | X100-10,11 ,(12) |
| X100-SO2 | Protection communication failure or differential protection not available | X100-13,14 |
| X100-PO3 | Open circuit breaker/trip 1 | X100-15-19 |
| X100-PO4 | Open circuit breaker/trip 2 | X100-20-24 |
| X110-SO1 | Upstream over current blocking | X110-14,15 |
| X110-SO2 | Backup protection operate indication | X110-17,18 |
| X110-SO3 | Binary transfer signal | X110-20,21 |
| X110-SO4 | | X110-20,21 |

*Table 20: Default connections for LEDs*

| LED | Description |
|---|---|
| 1 | Line differential protection biased stage operated |
| 2 | Line differential protection instantaneous stage operated |
| 3 | Line differential protection is not available |
| 4 | Protection communication failure |
| 5 | Autoreclose in progress |
| 6 | Backup protection operated |
| 7 | Circuit failure protection backup trip operated |
| 8 | Disturbance recorder triggered |
| 9 | Current transformer failure or trip circuit or circuit breaker supervision alarm |
| 10 | Binary signal transfer receive |
| 11 | Binary transfer signal send |

## 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, measurements from current transformers and voltage transformers, have fixed connections towards the different function blocks inside the IED’s standard configuration. Exceptions from this rule are the eight 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 represents the three phase currents. The signal marked with $I_0$ represents the measured residual current, via a sum connection of second CT cores of the phase current transformers.

### 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.

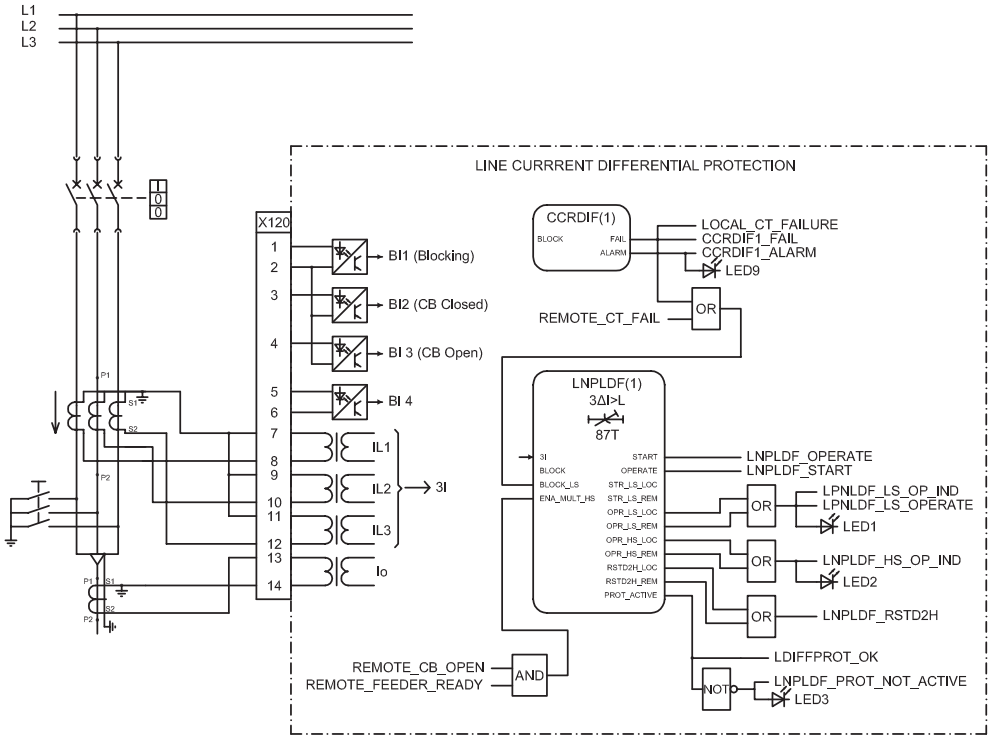



*Figure 35: Line current differential protection*

The line current differential function (LNPLDF) is intended to be the main protection offering exclusive unit protection for the power distribution lines or cables. The stabilized low stage can be blocked if the current transformer failure is detected. The operate value of the instantaneous high stage can be multiplied by a predefined setting if the ENA_MULT input is activated. In this configuration it is activated by the open status information of the remote end circuit breaker, disconnectors and earth switch. The intention of this connection is to lower the setting value of the instantaneous high stage by multiplying with setting *High Op value Mult* in case of internal fault.

The operate signal is connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 1 is used for start or operate of stabilized low stage and LED 2 for start or operate of instantaneous high stage indication. The indication of the high or low stage operation is also connected to the output SO1 (X100:10-11-12).

LED 3 is used to indicate if the line differential is not available. This is due to failures in protection communication or the LNPLDF is set to test mode.

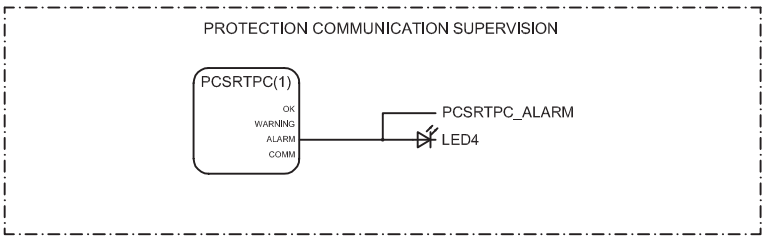



*Figure 36: Protection communication supervision function*

The protection communication supervision function (PCSRTPC) is used in the configuration to block the operation of the line differential function. This way the malfunction of the line differential is prevented. Also the activation of binary signal transfer outputs during protection communication failure is blocked. These are done internally without connections in configurations. The protection communication supervision alarm is connected to alarm LED 4, to disturbance recorder and to signal output SO2 (X100:13-14).

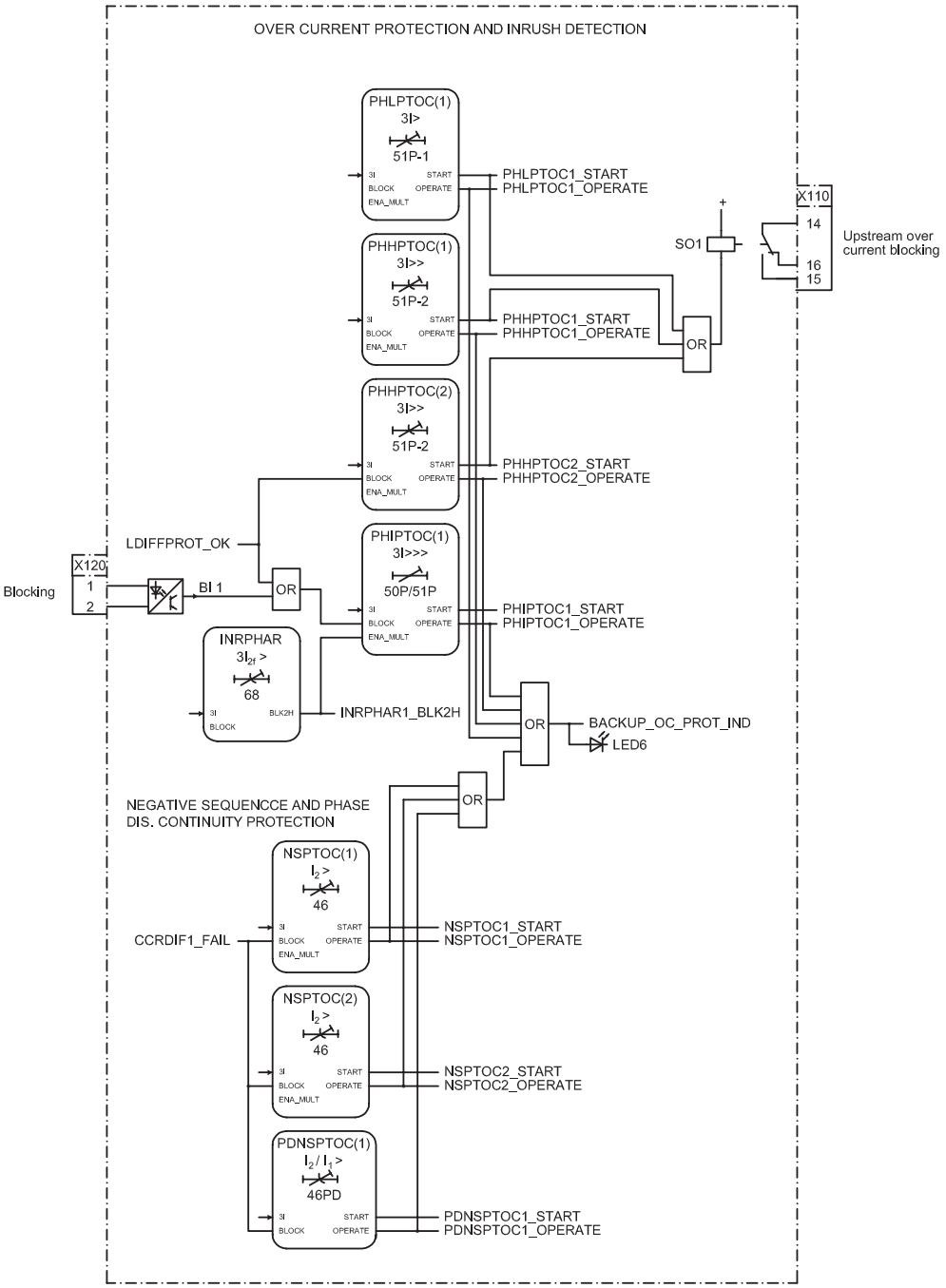



*Figure 37: Overcurrent protection*

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage (PHIPTOC1) can be blocked by energizing the binary input 1 (X120:1-2). Two negative sequence overcurrent stages (NSPTOC1 and NSPTOC2) are offered for phase unbalance protection. The phase discontinuity protection (PDNSPTOC1) provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations. The inrush

detection block's (INRPHAR1) output BLK2H enables multiplying the active settings for instantaneous stage of overcurrent protection.

All operate signals are connected to the Master Trip Logics 1 and 2 and also to the alarm LEDs. LED 6 is used for collective overcurrent and negative-sequence overcurrent protection operate indication.

The upstream blocking from the start of the overcurrent protection functions is connected to the output SO1 (X110:14-15-16). The purpose of this output is to send a blocking signal to the relevant overcurrent protection stage of the IED at the upstream bay.

The indication of the backup overcurrent protection operation is connected to the output SO2 (X110:20-21-22). It can be used, for example, for external alarm purposes.

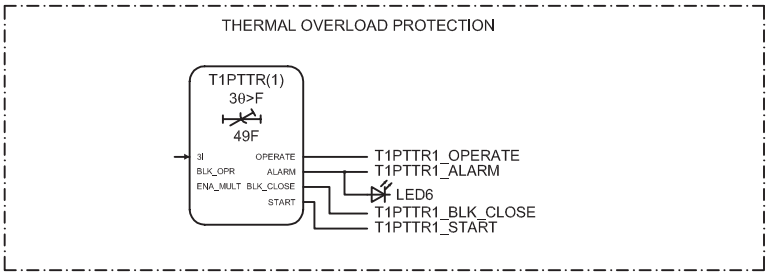



*Figure 38: Thermal overload protection*

The thermal overload protection (T1PTTR1) provides indication on overload situations. Active BLK_CLOSE signal blocks the closing of the circuit breaker. LED 6 is used also for the thermal overload protection alarm indication.

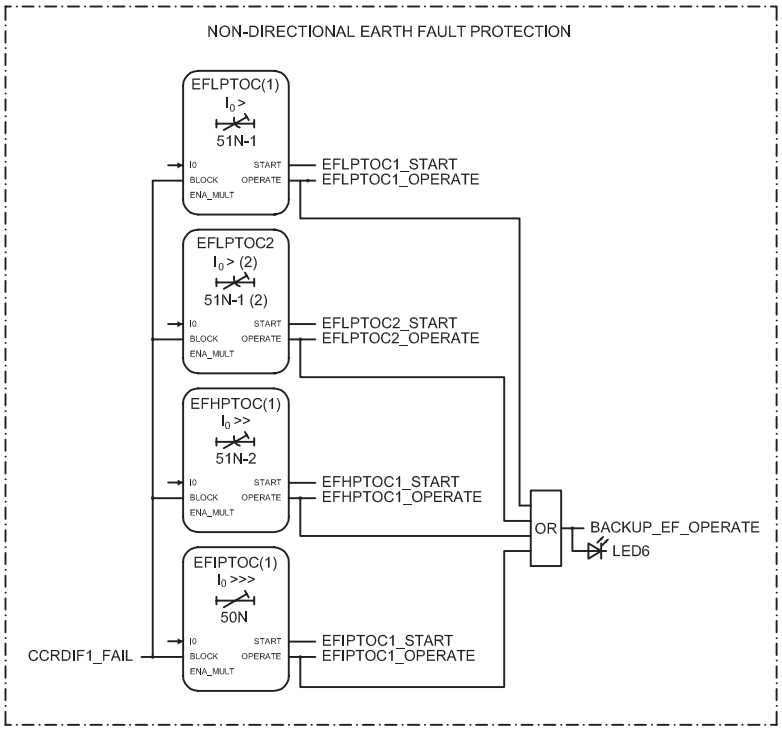



*Figure 39: Earth-fault protection*

Four stages are offered for non-directional earth-fault protection. The earth-fault protection uses measured residual currents. When current circuit failure is detected by CCRDIF1, all earth- fault functions are blocked to inhibit unwanted operation, which can occur due to apparent residual current.

The functionality of CCRDIF1 should be disabled in case the earth-fault protections current signal originates from the phase current transformers via external summation instead of separate balanced-core current transformer.

All operate signals are connected to the Master Trip and also to the alarm LED 6.

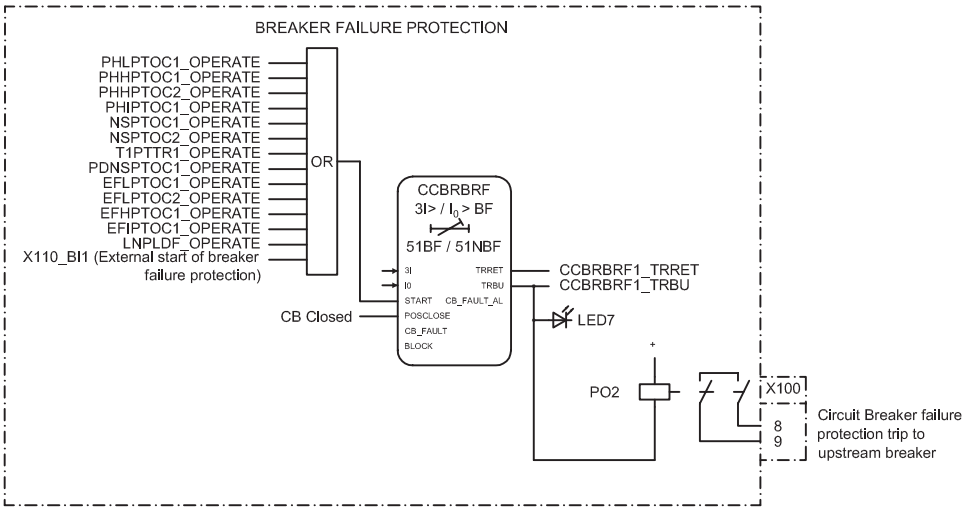



*Figure 40: Circuit breaker failure protection*

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 to give a backup trip to the circuit breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100: 8-9). LED 7 is used for backup (TRBU) operate indication.

### 3.5.3.2 Functional diagrams for disturbance recorder and supervision functions

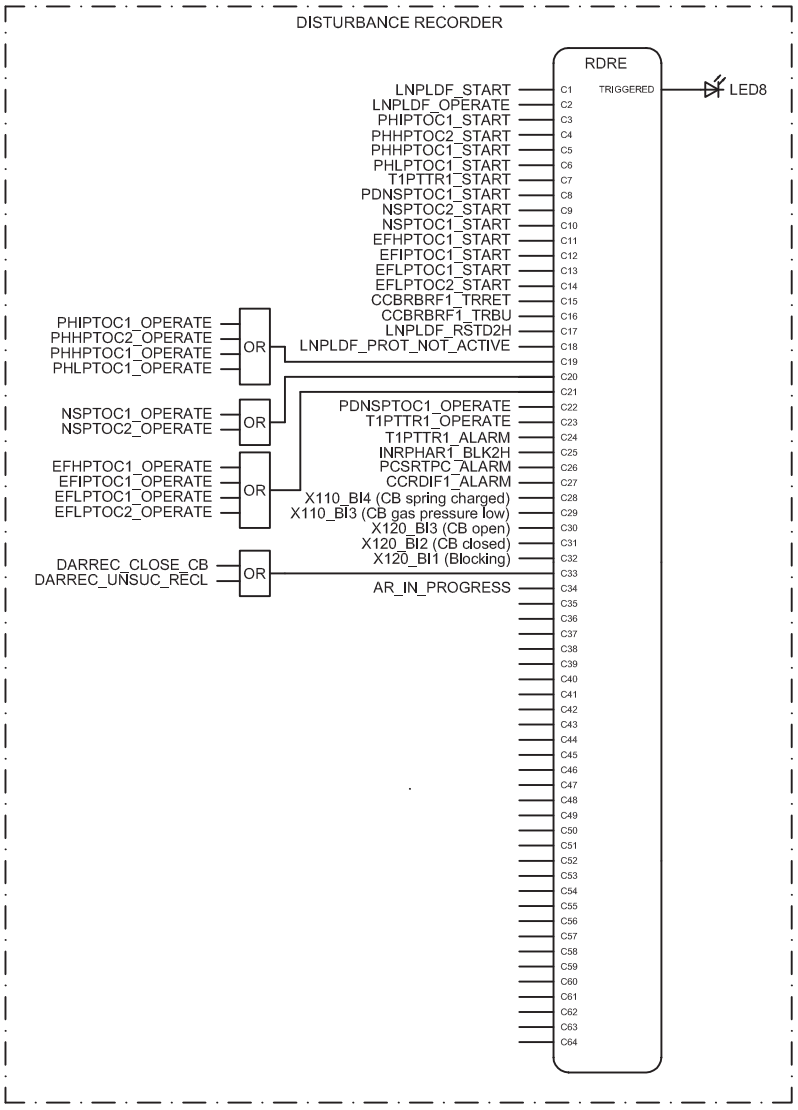



*Figure 41: Disturbance recorder*

The disturbance recorder has 64 digital inputs of which 34 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 five binary inputs from X120 are also connected.

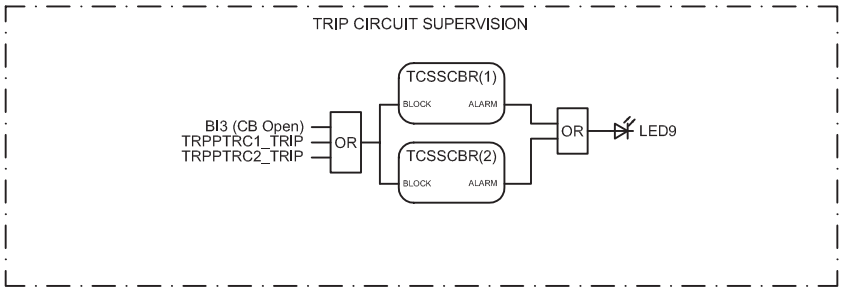



*Figure 42: Trip circuit supervision*

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 X100:20-24). 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

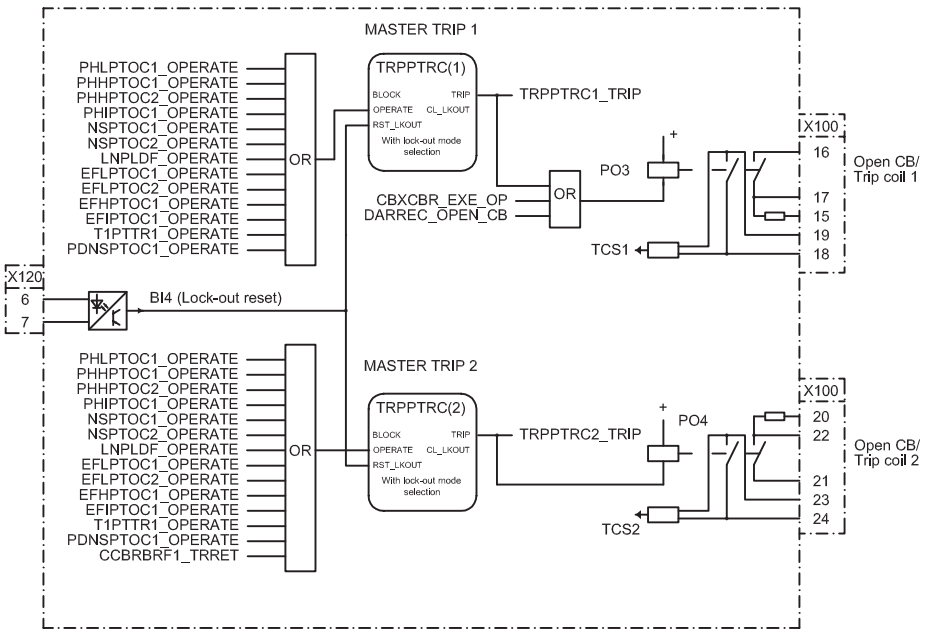



*Figure 43: Master Trip*

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 is connected directly to the output PO3 (X100:15-19).

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.

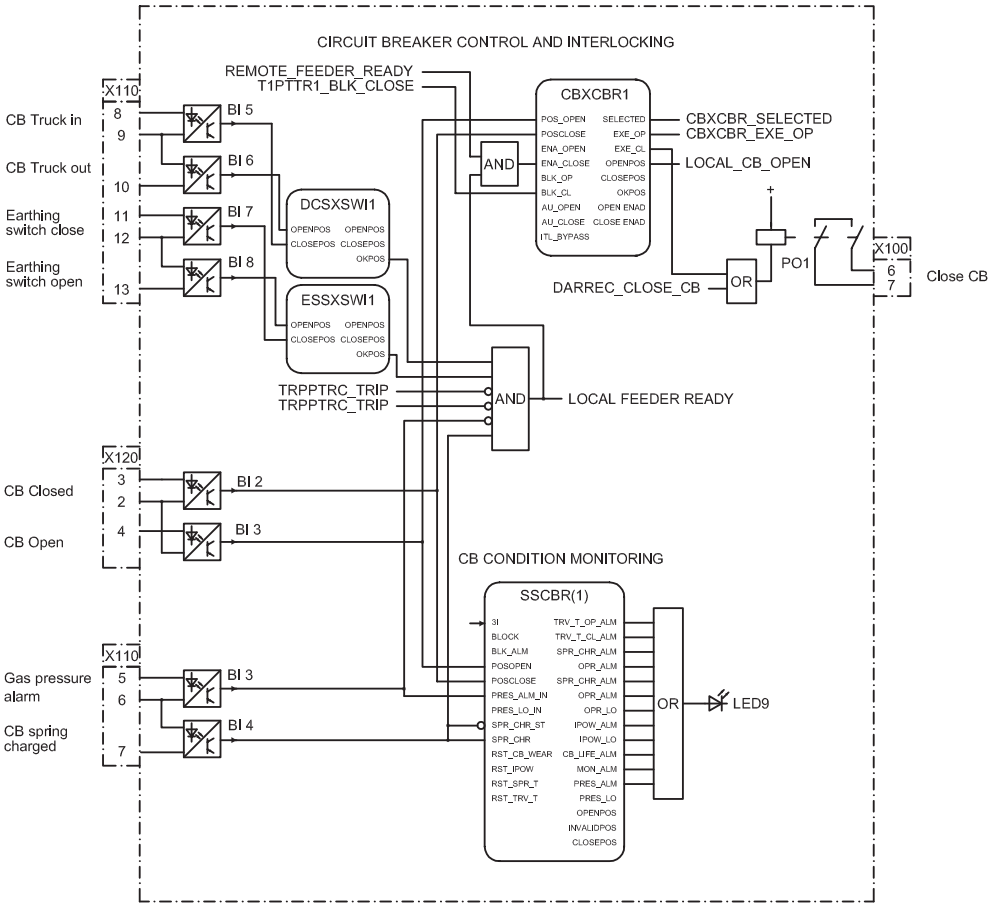



*Figure 44: Circuit breaker control and interlocking*

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 21: Device positions indicated by binary inputs 5 and 6*

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

The binary inputs 7 and 8 (X110:11-13) are designed for the position indication of the line-side earth switch.

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is a combination of the disconnector or breaker truck and earth switch position statuses and the statuses of the master trip logics and gas pressure alarm and circuit-breaker spring charging. This combination of interlocking conditions is called LOCAL_FEEDER_READY and is transferred also to the remote end via binary signal transfer. The OKPOS output from DCSXSWI defines if the disconnector or breaker truck is definitely either open/in test position or close/in service position. This, together with the open earth switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation is always enabled. The auto-recloser close command signals are directly connected to the output contact PO1 (X100:6-7).

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 signal is completely removed from the breaker control function block CBXCBR with PCM600, the function assumes that the breaker close commands are allowed continuously.



If REMOTE_FEEDER_READY information is missing, for example in case of protection communication not connected, it disables the circuit breaker closing in the local IED.

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.

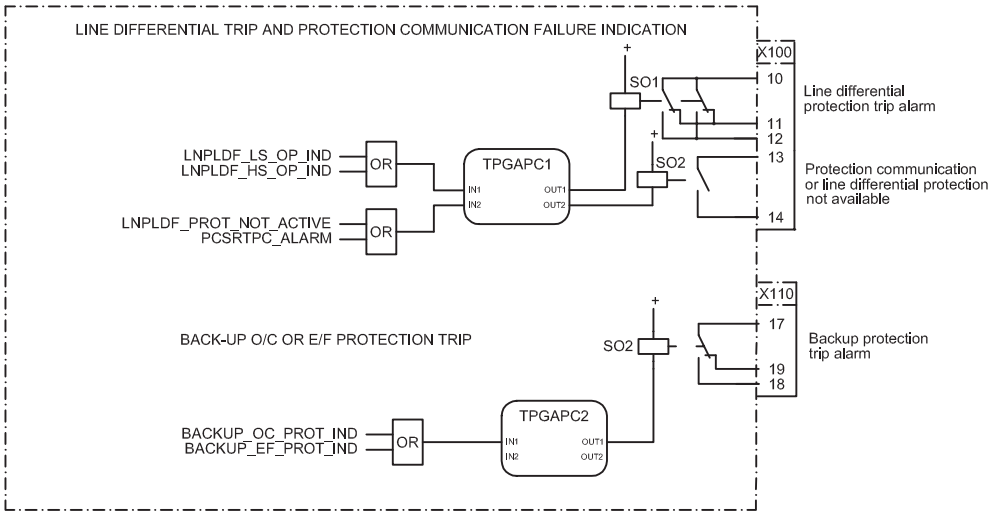



*Figure 45: Line differential trip and protection communication failure indication*

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

- Line differential protection trip alarm SO1 (X100:10-12)
- Protection communication failure or line differential protection not available SO2 (X100:13-15)

TPGAPC1 is a timer and used for setting the minimum pulse length for the outputs.

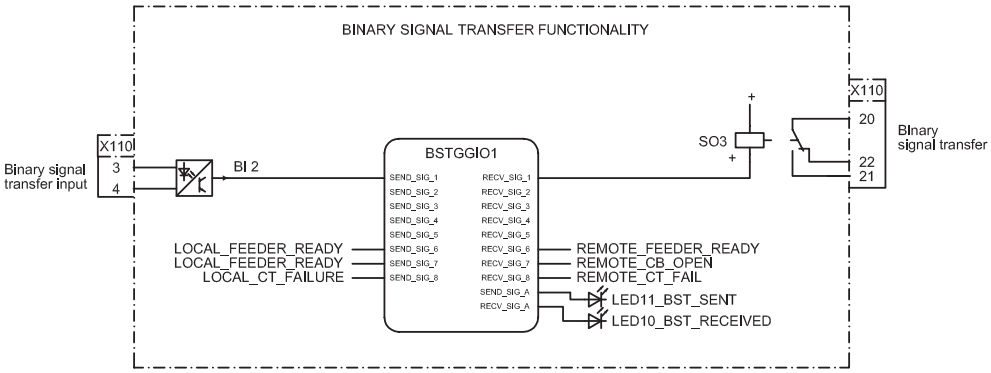



*Figure 46: Binary signal transfer*

The binary signal transfer function (BSTGGIO) is used for changing any binary information which can be used for example in protection schemes, interlocking, and alarms. There are eight separate inputs and corresponding outputs available.

In this configuration one physical input BI2 (X110:3-4) is connected to the binary signal transfer channel one. Local feeder ready and local circuit breaker open information are connected to input 6 and 7. These are interlocking information from control logic. The information of detected current transformer fault is connected to input 8.

As a consequence of sending interlocking information to remote end also receiving of same information locally is needed. Therefore remote feeder ready, remote circuit breaker open and remote current transformer failure are connected to binary signal transfer function outputs. All binary signal transfer outputs are connected to output SO3 (X110:20-21-22).

The receive and send information are connected to alarm LEDs 10 and 11.

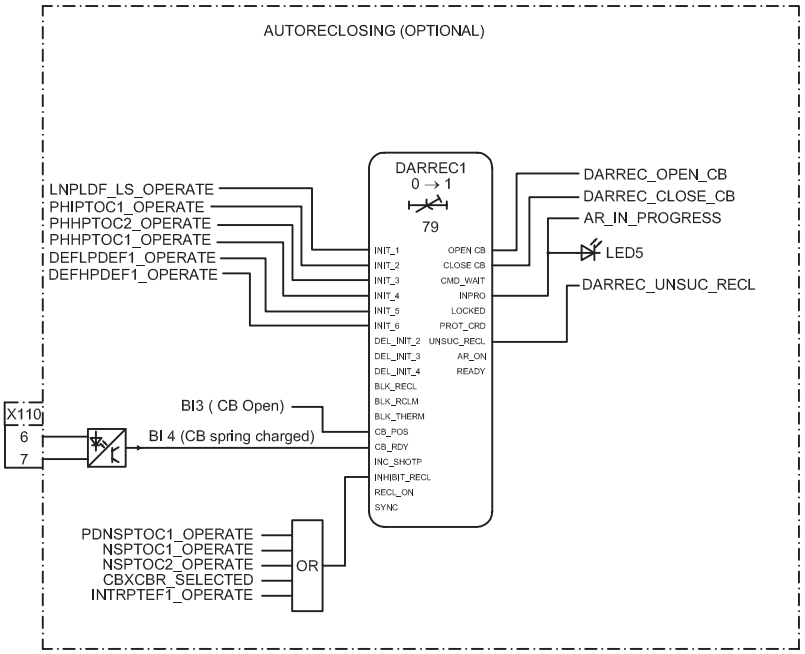



*Figure 47: Autoreclose*

The autoreclose function (DARREC1) is configured to be initiated by operate signals from a number of protection stages through the INIT1...6 inputs. It is possible to create individual autoreclose sequences for each input. DARREC1 can be blocked with the INHIBIT_RECL input. As a default, the operation of some selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks DARREC1 via the CBXCBR-selected signal.

The circuit breaker availability for the autoreclose sequence is expressed with the binary input 4 (X110:6-7) by connecting the input signal to the CB_READY input. In case this signal is completely removed from DARREC1 with PCM600, the function assumes that the breaker is available all the time.

The autoreclose sequence in progress indication is connected to alarm LED 5.

# 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 22: 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:

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

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.

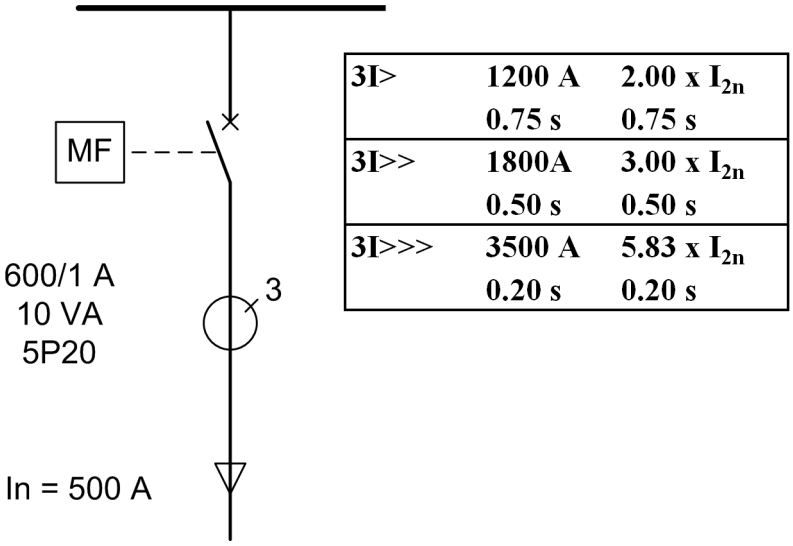



*Figure 48: Example of three-stage overcurrent protection*

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 23: Inputs for phase currents*

| Terminal | Description |
|---|---|
| X120-7, 8 | $I_{L1}$ |
| X120-9, 10 | $I_{L2}$ |
| X120-11, 12 | $I_{L3}$ |

#### 5.1.1.2 Residual current

*Table 24: Inputs for residual current*

| Terminal | Description |
|---|---|
| X120-13, 14 | $I_0$ |

#### 5.1.1.3 Residual voltage

*Table 25: Additional residual voltage input included in configuration B*

| Terminal | Description |
|---|---|
| X120-5, 6 | $U_0$ |

### 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 26: Auxiliary voltage supply*

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

## 5.1.3 Binary inputs

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

*Table 27: Binary input terminals X110-1...13*

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

*Table 28: Binary input terminals X120-1...6*

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

*Table 29: Binary input terminals X130-1...9*

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

1) Optional

# 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 30: 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 31: 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 32: 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 33: 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 34: 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-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 |
| LCD | Liquid crystal display |
| LED | Light-emitting diode |
| LHMI | Local human-machine interface |
| Modbus | A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices. |
| Modbus TCP/IP | Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices |

| | |
|---|---|
| NPS | Negative phase sequence |
| PCM600 | Protection and Control IED Manager |
| PO | Power output |
| RJ-45 | Galvanic connector type |
| RS-485 | Serial link according to EIA standard RS485 |
| RTU | Remote terminal unit |
| SO | Signal output |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TCS | Trip-circuit supervision |
| WAN | Wide area network |
| WHMI | Web human-machine interface |

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