



Relion® 670 series

# Generator protection REG670 ANSI Installation and commissioning manual

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**ABB**





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# Section 1      Introduction

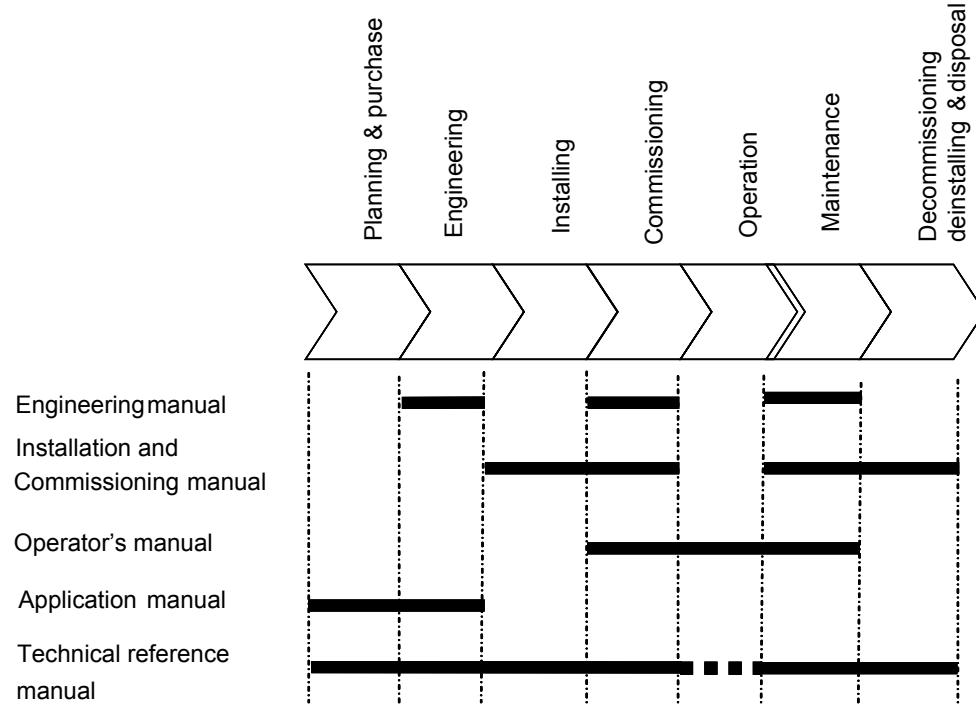
## About this chapter

This chapter introduces the user to the manual.

### 1.1      Introduction to the installation and commissioning manual

#### 1.1.1    About the complete set of manuals for an IED

The user's manual (UM) is a complete set of five different manuals:



**The Application Manual (AM)** contains application descriptions, setting guidelines and setting parameters sorted per function. The application manual should be used to

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find out when and for what purpose a typical protection function could be used. The manual should also be used when calculating settings.

**The Technical Reference Manual (TRM)** contains application and functionality descriptions and it lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The technical reference manual should be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

**The Installation and Commissioning Manual (ICM)** contains instructions on how to install and commission the protection IED. The manual can also be used as a reference during periodic testing. The manual covers procedures for mechanical and electrical installation, energizing and checking of external circuitry, setting and configuration as well as verifying settings and performing directional tests. The chapters are organized in the chronological order (indicated by chapter/section numbers) in which the protection IED should be installed and commissioned.

**The Operator's Manual (OM)** contains instructions on how to operate the protection IED during normal service once it has been commissioned. The operator's manual can be used to find out how to handle disturbances or how to view calculated and measured network data in order to determine the cause of a fault.

**The Engineering Manual (EM)** contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and DNP3.

## 1.1.2

### About the installation and commissioning manual

The installation and commissioning manual contains the following chapters:

- The chapter [Safety information](#) presents warning and note signs, that the user should pay attention to.
- The chapter [Overview](#) is a summary of the major tasks faced when installing and commissioning an IED.
- The chapter [Unpacking and checking the IED](#) explains how to take delivery of the IED.
- The chapter [Installing the IED](#) explains how to install the IED.
- The chapter [Checking the external optical and electrical connections](#) explains how to check that the IED is properly connected to the protection system.
- The chapter [Energizing the IED](#) explains how to start the IED.
- The chapter [Set up PCM 600 communication link per IED](#) describes the communication between PCM600 and the IED.
- The chapter [Establishing connection and verifying the SPA/IEC- communication](#) contains explains how to enter SPA/IEC settings and verifying the communication.

- The chapter [Establishing connection and verifying the LON communication](#) contains a reference to another document.
- The chapter [Establishing connection and verifying the IEC 61850 communication](#) contains explains how to enter IEC 61850 settings and verifying the communication.
- The chapter [Configuring the IED and changing settings](#)” explains how to write settings and configure the IED.
- The chapter [Verifying settings by secondary injection](#) contains instructions on how to verify that each included function operates correctly according to the set values.
- The chapter [Commissioning and maintenance of the fault clearing system](#) discusses maintenance tests and other periodic maintenance measures.
- The chapter [Fault tracing and repair](#) explains how to troubleshoot.
- The chapter [Glossary](#) is a list of terms, acronyms and abbreviations used in ABB technical documentation.

## 1.1.3 Intended audience

### General

The installation and commissioning manual addresses the personnel responsible for the installation, commissioning, maintenance and taking the protection in and out of normal service.

### Requirements

The installation and commissioning personnel must have a basic knowledge in handling electronic equipment. The commissioning and maintenance personnel must be well experienced in using protection equipment, test equipment, protection functions and the configured functional logics in the protection.

## 1.1.4 Related documents

Documents related to REG670	Identity number
Operator's manual	1MRK 502 028-UUS
Installation and commissioning manual	1MRK 502 029-UUS
Technical reference manual	1MRK 502 027-UUS
Application manual	1MRK 502 030-UUS
Product guide customized	1MRK 502 031-BUS
Connection and Installation components	1MRK 513 003-BEN
Test system, COMBITEST	1MRK 512 001-BEN
Accessories for 670 series IEDs	1MRK 514 012-BEN

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670 series SPA and signal list	1MRK 500 092-WUS
IEC 61850 Data objects list for 670 series	1MRK 500 091-WUS
Engineering manual 670 series	1MRK 511 240-UUS
Buyer's guide REG 216	1MRB520004-BEN
Communication set-up for Relion 670 series	1MRK 505 260-UEN

More information can be found on [www.abb.com/substationautomation](http://www.abb.com/substationautomation).

## 1.1.5 Revision notes

Revision	Description
-	First issue for 670 series version 1.2
A	Maintenance updates, PR corrections
B	Maintenance updates, PR corrections

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## Section 2 Safety information

### 2.1 Symbols on the product



All warnings must be observed.



Read the entire manual before doing installation or any maintenance work on the product. All warnings must be observed.



Do not touch the unit in operation. The installation shall take into account the worst case temperature.

### 2.2 Warnings

Observe the warnings during all types of work related to the product.



Only electrically skilled persons with the proper authorization and knowledge of any safety hazards are allowed to carry out the electrical installation.



National and local electrical safety regulations must always be followed. Working in a high voltage environment requires serious approach to avoid human injuries and damage to equipment.



Do not touch circuitry during operation. Potentially lethal voltages and currents are present.



Always use suitable isolated test pins when measuring signals in open circuitry. Potentially lethal voltages and currents are present.



Never connect or disconnect a wire and/or a connector to or from a IED during normal operation. Hazardous voltages and currents are present that may be lethal. Operation may be disrupted and IED and measuring circuitry may be damaged.



Dangerous voltages can occur on the connectors, even though the auxiliary voltage has been disconnected.



Always connect the IED to protective ground, regardless of the operating conditions. This also applies to special occasions such as bench testing, demonstrations and off-site configuration. This is class 1 equipment that shall be grounded.



Never disconnect the secondary connection of current transformer circuit without short-circuiting the transformer's secondary winding. Operating a current transformer with the secondary winding open will cause a massive potential build-up that may damage the transformer and may cause injuries to humans.



Never remove any screw from a powered IED or from a IED connected to powered circuitry. Potentially lethal voltages and currents are present.



Take adequate measures to protect the eyes. Never look into the laser beam.



The IED with accessories should be mounted in a cubicle in a restricted access area within a power station, substation or industrial or retail environment.



Whenever changes are made in the IED, measures should be taken to avoid inadvertent tripping.



The IED contains components which are sensitive to electrostatic discharge. ESD precautions shall always be observed prior to touching components.



Always transport PCBs (modules) using certified conductive bags.



Do not connect live wires to the IED. Internal circuitry may be damaged



Always use a conductive wrist strap connected to protective ground when replacing modules. Electrostatic discharge (ESD) may damage the module and IED circuitry.



Take care to avoid electrical shock during installation and commissioning.



Changing the active setting group will inevitably change the IEDs operation. Be careful and check regulations before making the change.



Avoid touching the enclosure of the coupling capacitor REX061 unit and the shunt resistor REX062 unit. The surface may be hot during normal operation. The temperature can rise 50°C in REX061 and 65°C in REX062 above the ambient temperature.

## 2.3

### Note signs



Observe the maximum allowed continuous current for the different current transformer inputs of the IED. See technical data.

## Section 3      Overview

### About this chapter

This chapter outlines the installation and commissioning of the IED.

### 3.1      Commissioning and installation overview

The settings for each function must be calculated before the commissioning task can start. A configuration, done in the configuration and programming tool, must also be available if the IED does not have a factory configuration downloaded.

The IED is unpacked and visually checked. It is preferably mounted in a cubicle or on a wall. The connection to the protection system has to be checked in order to verify that the installation is successful.



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## Section 4

## Unpacking and checking the IED

### About this chapter

This chapter describes the delivery and the unpacking of the IED

### 4.1

### Taking delivery, unpacking and checking

#### Procedure

1. Remove the transport casing.
2. Visually inspect the IED.
3. Check that all items are included in accordance with the delivery documents.  
Once the IED has been started make sure that the software functions ordered have been included in the delivery.
4. Check for transport damages.  
If transport damage is discovered appropriate action must be taken against the latest carrier and the nearest ABB office or representative should be informed. ABB should be notified immediately if there are any discrepancies in relation to the delivery documents.
5. Storage  
If the IED is to be stored before installation, this must be done in the original transport casing in a dry and dust free place. Observe the environmental requirements stated in the technical data.



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## Section 5      Installing the IED

### About this chapter

This chapter describes how to install the IED.

#### 5.1

### Checking environmental conditions and mounting space

The mechanical and electrical environmental conditions at the installation site must be within the limits described in the technical manual and IEC61255-1, normal environment.

- Avoid installation in dusty, damp places.  
Avoid places susceptible to rapid temperature variations, powerful vibrations and shocks, surge voltages of high amplitude and fast rise time, strong induced magnetic fields or similar extreme conditions.
- Check that sufficient space is available.  
Sufficient space is needed at the front and rear of the IED to allow access to wires and optical fibers and to enable maintenance and future modifications.
- Ensure that convection cooling through the ventilation holes at the top and bottom of the case is possible to minimize the heating effect within the IED.
  1. Ensure that the amount of dust around the IED is minimized, so that the cooling effect is not reduced.  
It is recommended to install the 670 series IED in a cubicle with an IP4X ingress protection according to IEC 60529, at least at the top surface, to prevent dust and limited size materials from falling through the ventilation holes at top and bottom of the IED case. The effect of airborne contaminants will also be reduced if ventilation of the cubicle is limited.
  2. Check that no combustible materials are present in the cubicle.

## 5.2 Dimensions

### 5.2.1 Case without rear cover

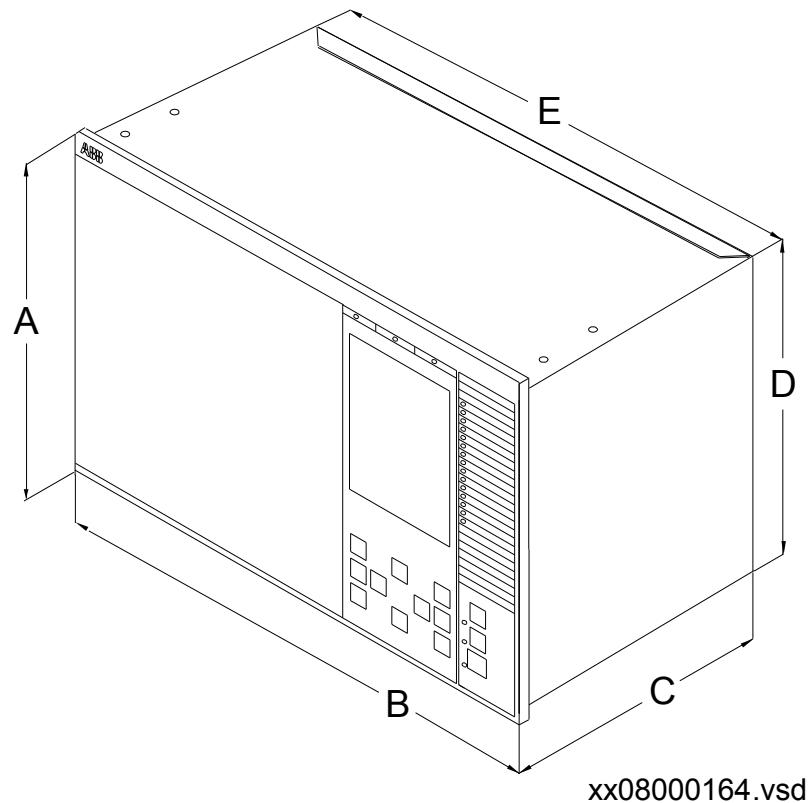
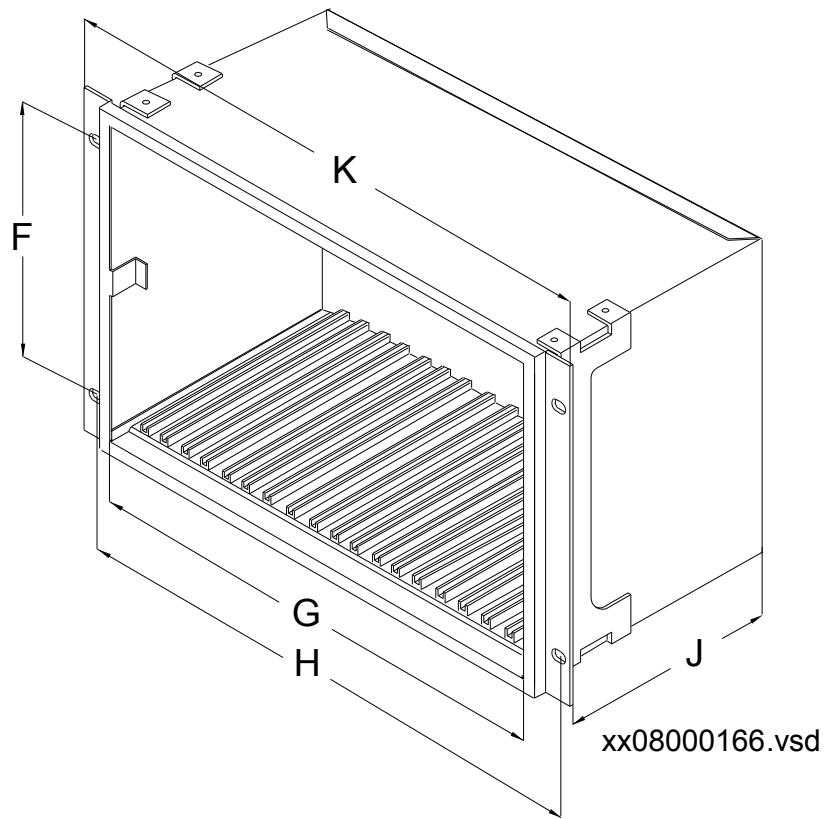


Figure 1: Case without rear cover



*Figure 2: Case without rear cover with 19" rack mounting kit*

Case size (inches)	A	B	C	D	E	F	G	H	J	K
6U, 1/2 x 19"	10.47	8.81	7.92	9.96	8.10	7.50	8.02	-	7.39	-
6U, 3/4 x 19"	10.47	13.23	7.92	9.96	12.52	7.50	12.44	-	7.39	-
6U, 1/1 x 19"	10.47	17.65	7.92	9.96	16.94	7.50	16.86	18.31	7.39	19.00
The H and K dimensions are defined by the 19" rack mounting kit										

## 5.2.2

### Case with rear cover

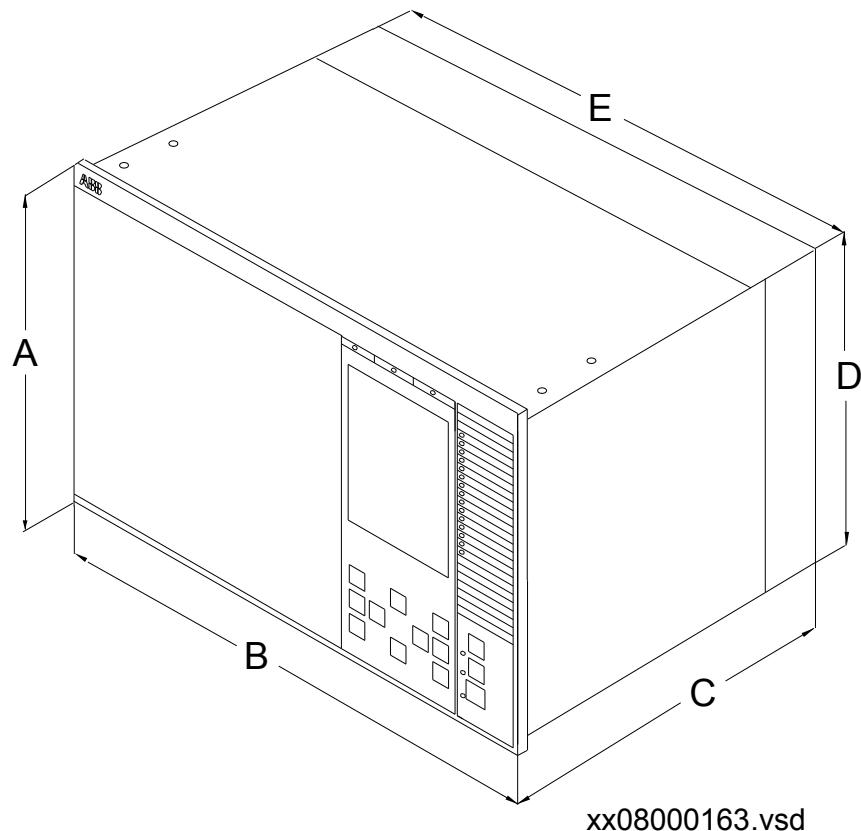


Figure 3: Case with rear cover

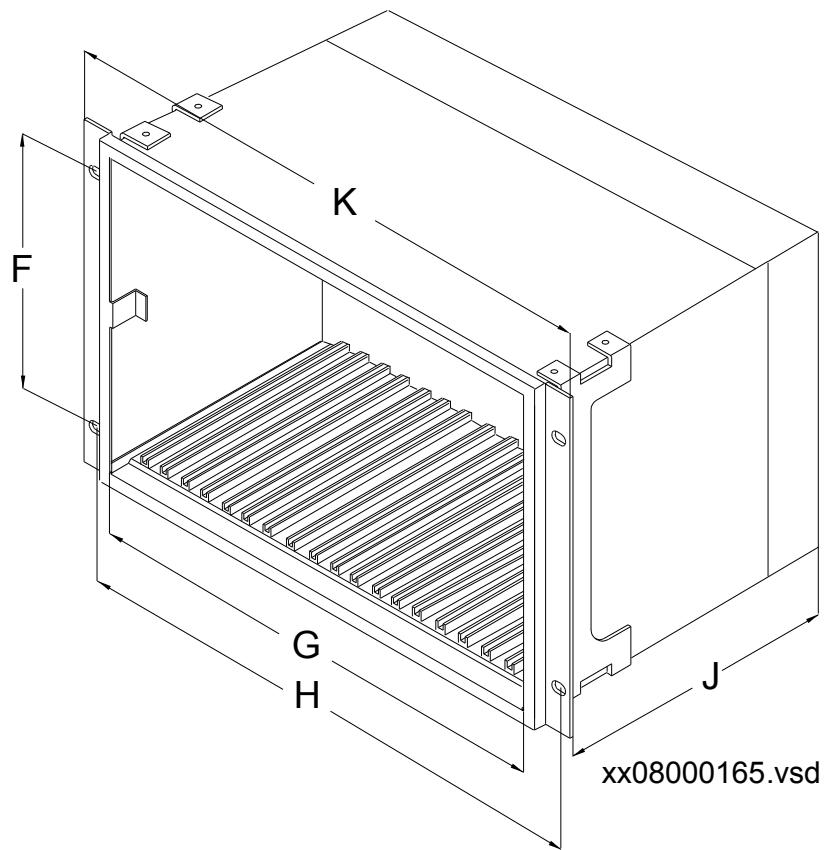


Figure 4: Case with rear cover and 19" rack mounting kit

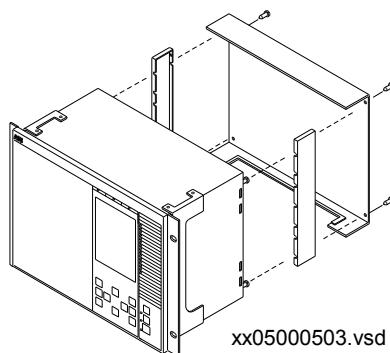


Figure 5: Rear cover case with details

## Section 5 Installing the IED

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Case size (inches)	A	B	C	D	E	F	G	H	J	K
6U, 1/2 x 19"	10.47	8.81	9.53	10.07	8.10	7.50	8.02	-	9.00	-
6U, 3/4 x 19"	10.47	13.23	9.53	10.07	12.52	7.50	12.4	-	9.00	-
6U, 1/1 x 19"	10.47	17.65	9.53	10.07	16.86	7.50	16.86	18.31	9.00	19.00

The H and K dimensions are defined by the 19" rack mounting kit.

### 5.2.3 Flush mounting dimensions

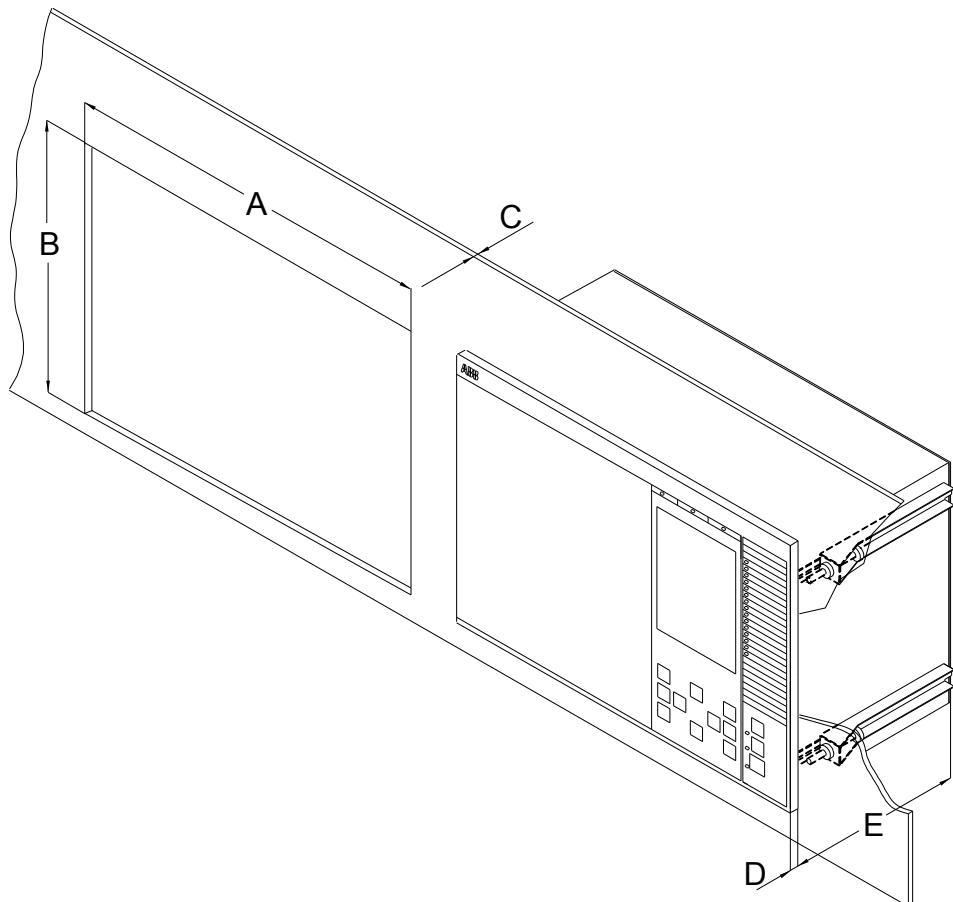
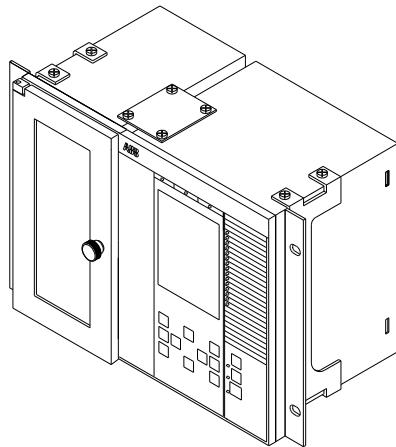


Figure 6: Flush mounting

Case size Tolerance	Cut-out dimensions (inches)			
	A +/0.04	B +/0.04	C	D
6U, 1/2 x 19"	8.27	10.01	0.16–0.39	0.49
6U, 3/4 x 19"	12.69	10.01	0.16–0.39	0.49
6U, 1/1 x 19"	17.11	10.01	0.16–0.39	0.49
E = 188.6 mm without rear protection cover, 229.6 mm with rear protection cover				

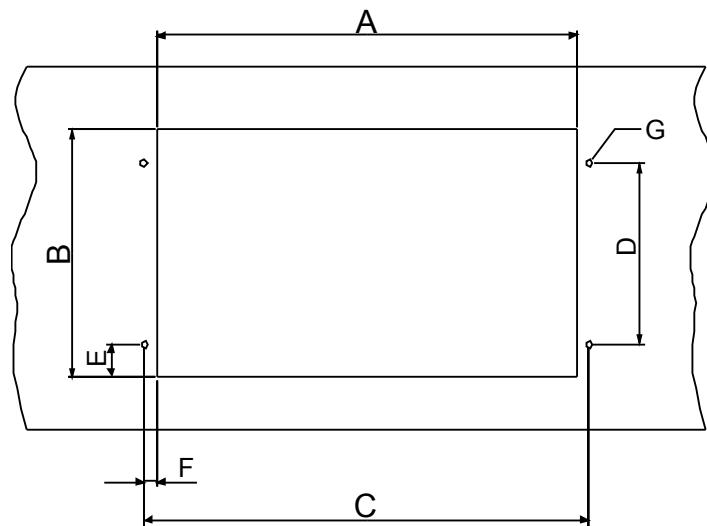
## 5.2.4

### Side-by-side flush mounting dimensions



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Figure 7: A 1/2 x 19" size 670 series IED side-by-side with RHGS6.



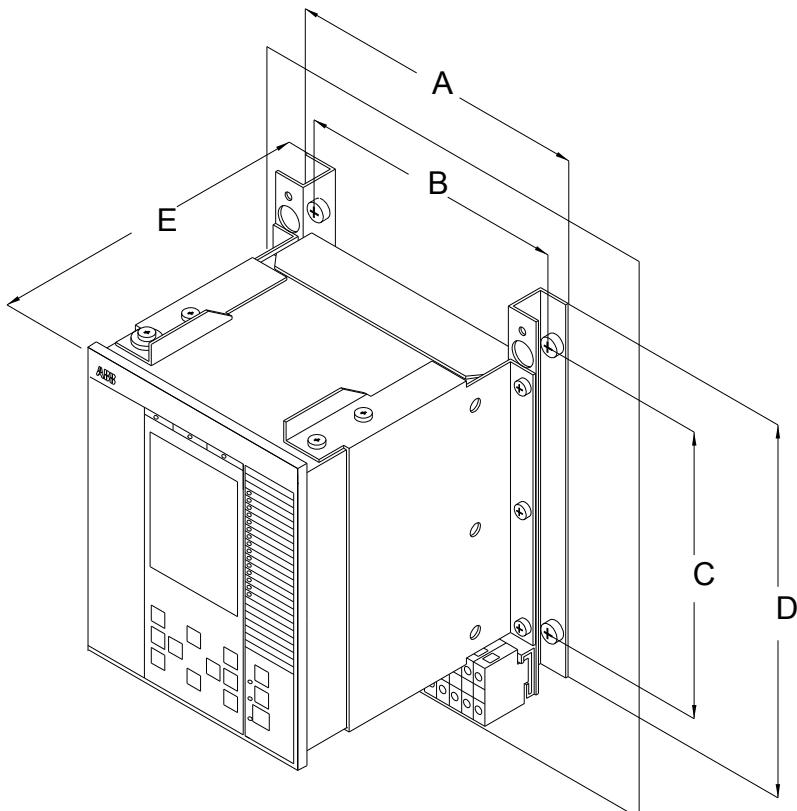
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*Figure 8: Panel-cut out dimensions for side-by-side flush mounting*

Case size (inches) Tolerance	A $\pm 0.04$	B $\pm 0.04$	C $\pm 0.04$	D $\pm 0.04$	E $\pm 0.04$	F $\pm 0.04$	G $\pm 0.04$
6U, 1/2 x 19"	8.42	10.21	9.46	7.50	1.35	0.52	0.25 diam
6U, 3/4 x 19"	12.85	10.21	13.89	7.50	1.35	0.52	0.25 diam
6U, 1/1 x 19"	17.27	10.21	18.31	7.50	1.35	0.52	0.25 diam

## 5.2.5

### Wall mounting dimensions



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*Figure 9:* Wall mounting

Case size (inches)	A	B	C	D	E
6U, 1/2 x 19"	10.50	10.52	10.74	15.36	9.57
6U, 3/4 x 19"	15.92	14.94	10.74	15.36	9.57
6U, 1/1 x 19"	20.31	19.33	10.74	15.36	9.57

## 5.3 Mounting methods and details

### 5.3.1 Mounting the IED

The IED can be rack, wall or flush mounted with the use of different mounting kits, see figure [10](#).

An additional box of type RHGS can be mounted to one side of a 1/2 or 3/4 IED.

The different mounting kits contain all parts needed including screws and assembly instructions. The following mounting kits are available:

- Flush mounting kit
- 19" Panel (rack) mounting kit
- Wall mounting kit
- Side-by-side mounting kit

The same mounting kit is used for side-by-side rack mounting and side-by-side flush mounting.



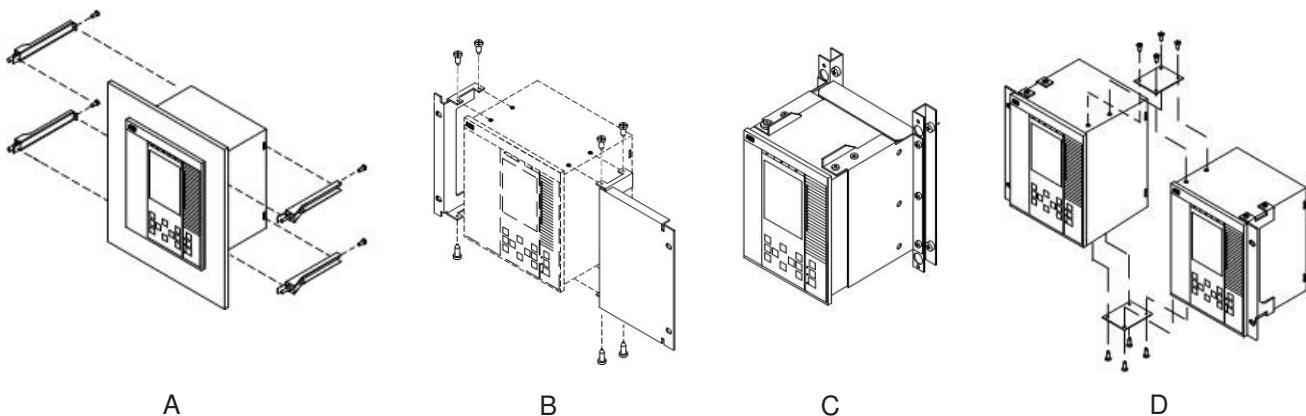
The mounting kits must be ordered separately when ordering an IED. They are available as options on the ordering sheet in *Accessories for 670 series IED*, see section ["Related documents"](#).



Generally, all the screws included in delivered mounting kits are of Torx type and a screwdriver of the same type is needed (Tx10, Tx15, Tx20 and Tx25).



If other type of screws are to be used, be sure to use the dimensions of the screws that are given in this guide.



*Figure 10: Different mounting methods*

Description

- A Flush mounting
- B 19" Panel rack mounting
- C Wall mounting
- D Side-by-side rack or flush mounting

### 5.3.2 **Flush mounting**

#### 5.3.2.1 **Overview**

The flush mounting kit are utilized for case sizes:

- 1/2 x 19"
- 3/4 x 19"
- 1/1 x 19"
- 1/4 x 19" (RHGS6 6U)

Only a single case can be mounted in each cut-out on the cubicle panel, for class IP54 protection.



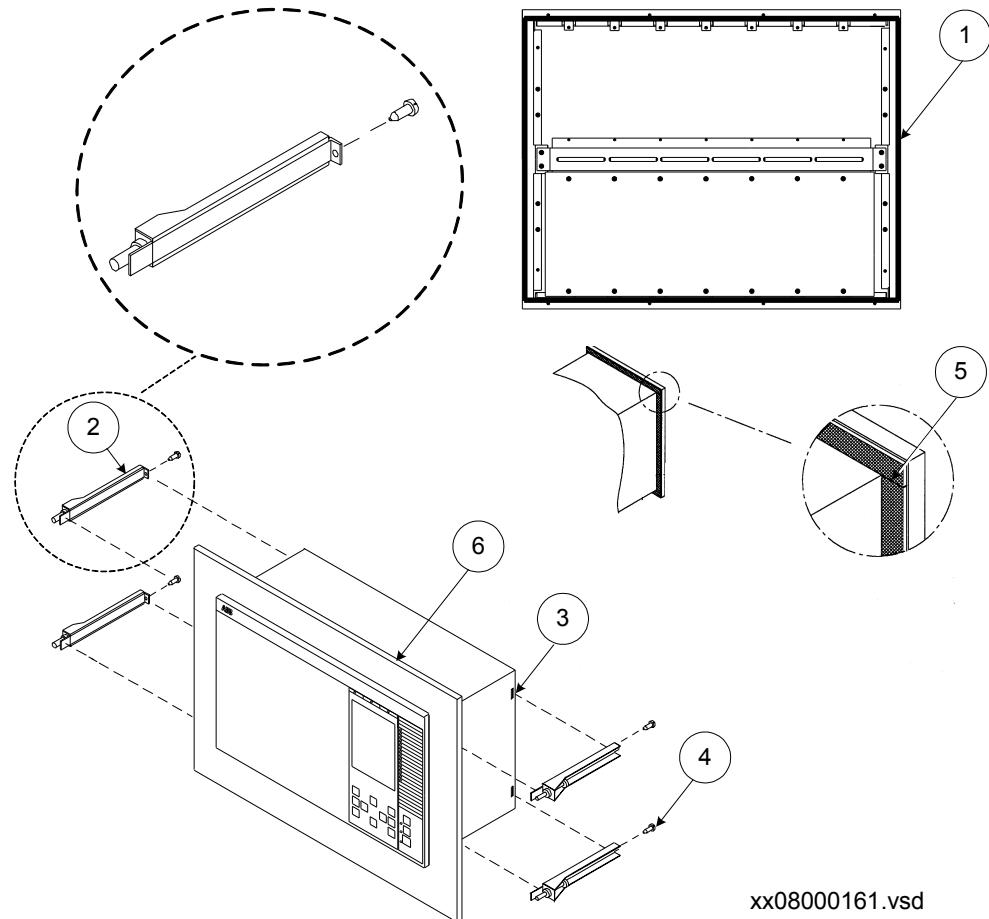
Flush mounting cannot be used for side-by-side mounted IEDs when IP54 class must be fulfilled. Only IP20 class can be obtained when mounting two cases side-by-side in one (1) cut-out.



To obtain IP54 class protection, an additional factory mounted sealing must be ordered when ordering the IED.

### 5.3.2.2

### Mounting procedure for flush mounting



*Figure 11: Flush mounting details.*

PosNo	Description	Quantity	Type
1	Sealing strip, used to obtain IP54 class. The sealing strip is factory mounted between the case and front plate.	-	-
2	Fastener	4	-
3	Groove	-	-
4	Screw, self tapping	4	2.9x9.5 mm
5	Joining point of sealing strip	-	-
6	Panel	-	-

### Procedure

1. Cut an opening in the panel (6).  
See section "[Flush mounting dimensions](#)" regarding dimensions.
2. Carefully press the sealing strip (1) around the IEDs collar. Cut the end of the sealing strip a few mm to long to make the joining point (5) tight.  
The sealing strip is delivered with the mounting kit. The strip is long enough for the largest available IED.
3. Insert the IED into the opening (cut-out) in the panel.
4. Add and lock the fasteners (2) to the IED.  
Thread a fastener into the groove at the back end of the IED. Insert and lightly fasten the locking screw (4). Next, thread a fastener on the other side of the IED, and lightly fasten its locking screw. Lock the front end of the fastener in the panel, using the M5x25 screws.  
Repeat the procedure with the remaining two fasteners.

### 5.3.3 19" panel rack mounting

#### 5.3.3.1 Overview

All IED sizes can be mounted in a standard 19" cubicle rack by using the for each size suited mounting kit which consists of two mounting angles and fastening screws for the angles.

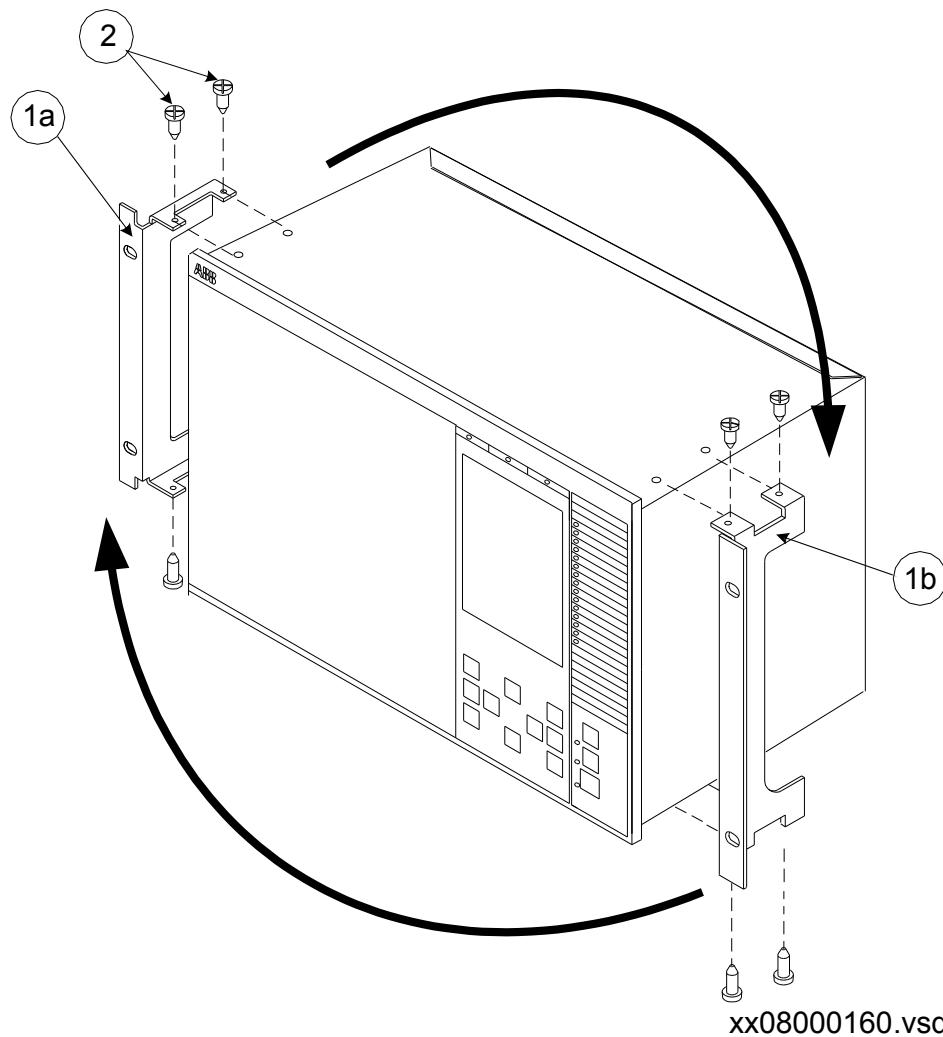
The mounting angles are reversible which enables mounting of IED size 1/2 x 19" or 3/4 x 19" either to the left or right side of the cubicle.



Please note that the separately ordered rack mounting kit for side-by-side mounted IEDs, or IEDs together with RHGS cases, is to be selected so that the total size equals 19".



When mounting the mounting angles, be sure to use screws that follows the recommended dimensions. Using screws with other dimensions than the original may damage the PCBs inside the IED.

**5.3.3.2**
**Mounting procedure for 19" panel rack mounting**


*Figure 12: 19" panel rack mounting details*

Pos	Description	Quantity	Type
1a, 1b	Mounting angels, which can be mounted, either to the left or right side of the case.	2	-
2	Screw	8	M4x6

**Procedure**

1. Carefully fasten the mounting angles (1a, 1b) to the sides of the IED.

- 
- 1. Use the screws (2) supplied in the mounting kit.
  - 2. Place the IED assembly in the 19" panel.
  - 3. Fasten the mounting angles with appropriate screws.

## 5.3.4 Wall mounting

### 5.3.4.1 Overview

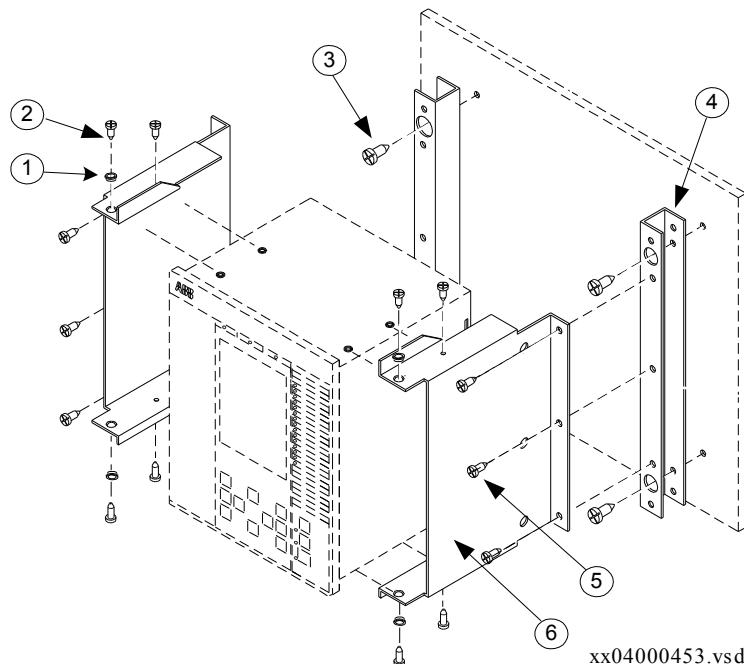
All case sizes, 1/2 x 19", 3/4 x 19", 1/1 x 19", can be wall mounted. It is also possible to mount the IED on a panel or in a cubicle.



When mounting the side plates, be sure to use screws that follows the recommended dimensions. Using screws with other dimensions than the original may damage the PCBs inside the IED.



If fiber cables are bent too much, the signal can be weakened. Wall mounting is therefore not recommended for communication modules with fiber connection; Serial SPA/IEC 60870-5-103, DNP3 and LON communication module (SLM), Optical Ethernet module (OEM) and Line data communication module (LDCM).

**5.3.4.2**
**Mounting procedure for wall mounting**


*Figure 13: Wall mounting details.*

PosNo	Description	Quantity	Type
1	Bushing	4	-
2	Screw	8	M4x10
3	Screw	4	M6x12 or corresponding
4	Mounting bar	2	-
5	Screw	6	M5x8
6	Side plate	2	-

**Procedure**

1. Mount the mounting bars onto the wall (4).  
See section "["Wall mounting dimensions"](#)" for mounting dimensions.  
Depending on the wall different preparations may be needed like drilling and inserting plastic or expander plugs (concrete/plasterboard walls) or threading (metal sheet wall).
2. Make all electrical connections to the IED terminal.

It is much easier to do this without the unit in place.

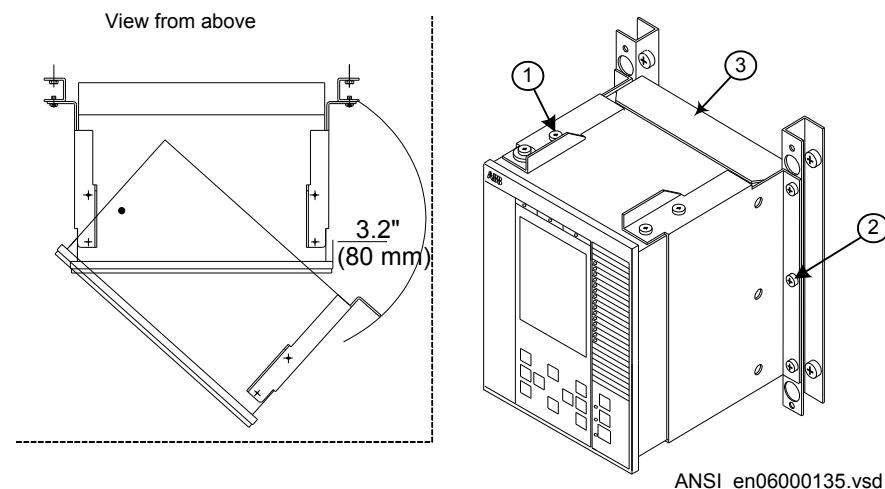
3. Mount the side plates to the IED.
4. Mount the IED to the mounting bars.

#### 5.3.4.3

#### How to reach the rear side of the IED

The IED can be equipped with a rear protection cover, which is recommended to use with this type of mounting. See figure 14.

To reach the rear side of the IED, a free space of 3.2 inches is required on the unhinged side.



*Figure 14: How to reach the connectors on the rear side of the IED.*

PosNo	Description	Type
1	Screw	M4x10
2	Screw	M5x8
3	Rear protection cover	-

#### Procedure

1. Remove the inner screws (1), upper and lower on one side.
2. Remove all three fixing screws (2), on the opposite side, from wall support.
3. The IED can now be swung out for access to the connectors, after removing any rear protection.

### 5.3.5

## Side-by-side 19" rack mounting

#### 5.3.5.1

### Overview

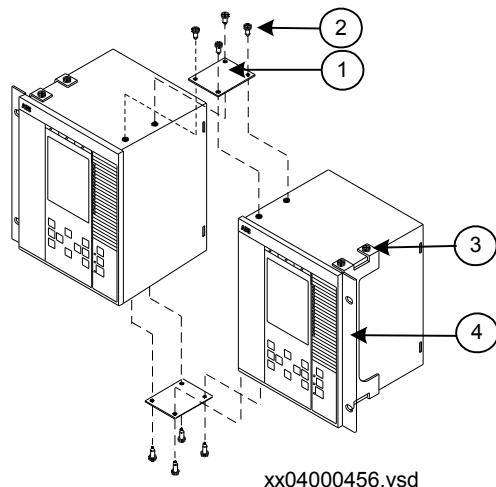
IED case sizes, 1/2 x 19" or 3/4 x 19" and RHGS cases, can be mounted side-by-side up to a maximum size of 19". For side-by-side rack mounting, the side-by-side mounting kit together with the 19" rack panel mounting kit must be used. The mounting kit has to be ordered separately.



When mounting the plates and the angles on the IED, be sure to use screws that follows the recommended dimensions. Using screws with other dimensions than the original may damage the PCBs inside the IED.

#### 5.3.5.2

### Mounting procedure for side-by-side rack mounting



*Figure 15: Side-by-side rack mounting details.*

PosNo	Description	Quantity	Type
1	Mounting plate	2	-
2, 3	Screw	16	M4x6
4	Mounting angle	2	-

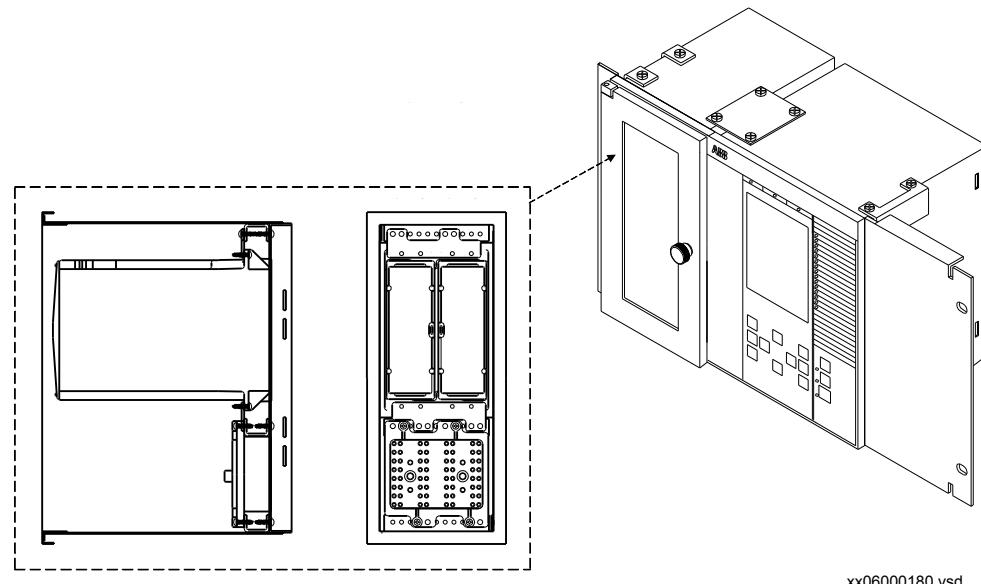
### Procedure

1. Place the two IEDs next to each other on a flat surface.
2. Fasten a side-by-side mounting plate (1).  
Use four of the delivered screws (2, 3).
3. Carefully turn the two IEDs up-side down.
4. Fasten the second side-by-side mounting plate.  
Use the remaining four screws.
5. Carefully fasten the mounting angles (4) to the sides of the IED.  
Use the screws available in the mounting kit.
6. Place the IED assembly in the rack.
7. Fasten the mounting angles with appropriate screws.

### 5.3.5.3

#### IED in the 670 series mounted with a RHGS6 case

An 1/2 x 19" or 3/4 x 19" size IED can be mounted with a RHGS (6 or 12 depending on IED size) case. The RHGS case can be used for mounting a test switch of type RTXP 24. It also has enough space for a terminal base of RX 2 type for mounting of, for example, a DC-switch or two trip IEDs.



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*Figure 16: IED in the 670 series (1/2 x 19") mounted with a RHGS6 case containing a test switch module equipped with only a test switch and a RX2 terminal base*

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## 5.3.6 Side-by-side flush mounting

### 5.3.6.1 Overview

It is not recommended to flush mount side by side mounted cases if IP54 is required. If your application demands side-by-side flush mounting, the side-by-side mounting details kit and the 19" panel rack mounting kit must be used. The mounting kit has to be ordered separately. The maximum size of the panel cut out is 19".



With side-by-side flush mounting installation, only IP class 20 is obtained. To reach IP class 54, it is recommended to mount the IEDs separately. For cut out dimensions of separately mounted IEDs, see section ["Flush mounting"](#).



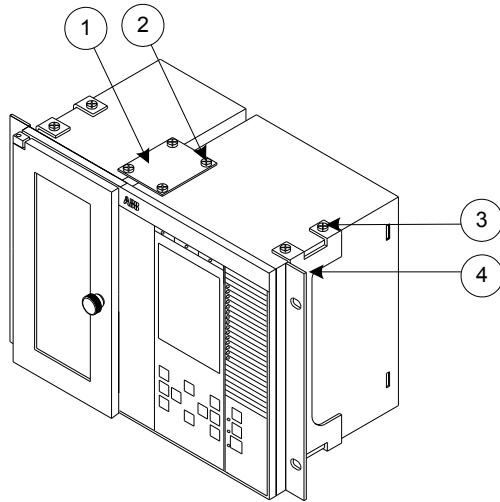
When mounting the plates and the angles on the IED, be sure to use screws that follows the recommended dimensions. Using screws with other dimensions than the original may damage the PCBs inside the IED.



Please contact factory for special add on plates for mounting FT switches on the side (for 1/2 19" case) or bottom of the relay.

### 5.3.6.2

### Mounting procedure for side-by-side flush mounting



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Figure 17: Side-by-side flush mounting details (RHGS6 side-by-side with 1/2 x 19" IED).

PosNo	Description	Quantity	Type
1	Mounting plate	2	-
2, 3	Screw	16	M4x6
4	Mounting angle	2	-

#### Procedure

1. Make a panel cut-out.  
For panel cut out dimension, see section ["Side-by-side flush mounting dimensions"](#).
2. Carefully press the sealing strip around the IED collar. Cut the end of the sealing strip little longer to make the joining point tight.  
Repeat the same procedure with the second case.  
The sealing strip is delivered with the mounting kit. The strip is long enough for the largest available IED.
3. Place the two IEDs next to each other on a flat surface.
4. Fasten a side-by-side mounting plate (1).

- Use four of the delivered screws (2, 3).
5. Carefully turn the two IEDs up-side down.
  6. Fasten the second side-by-side mounting plate.  
Use the remaining four screws.
  7. Carefully fasten the mounting angles (4) to the sides of the IED.  
Use the fixing screws available in the mounting kit.
  8. Insert the IED into the cut-out.
  9. Fasten the mounting angles with appropriate screws.

### 5.3.7

### Mounting the injection unit REX060

The injection unit REX060 case size is 6U, 1/2 x 19". REX060 can be rack, wall or flush mounted in the same way as the IED. See the particular mounting instructions for guidance.

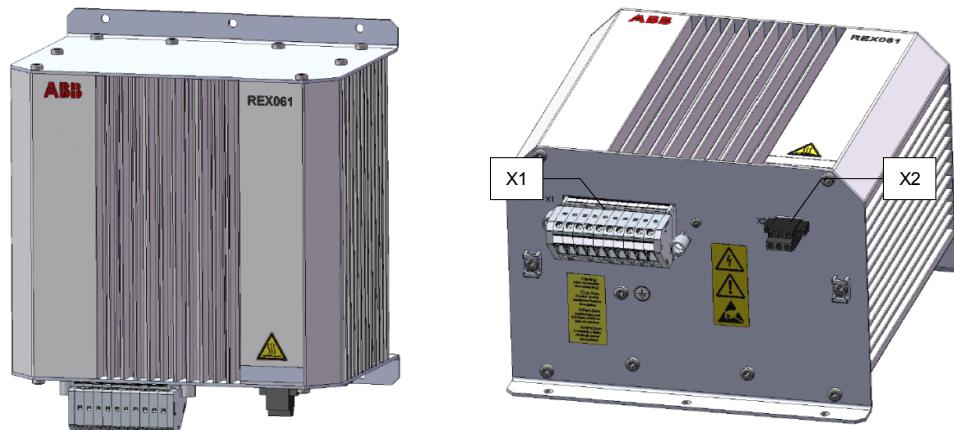
REX060 shall be mounted close to the IED. It is recommended that they are mounted in the same cubicle.

### 5.3.8

### Mounting the coupling capacitor unit REX061 and shunt resistor unit REX062

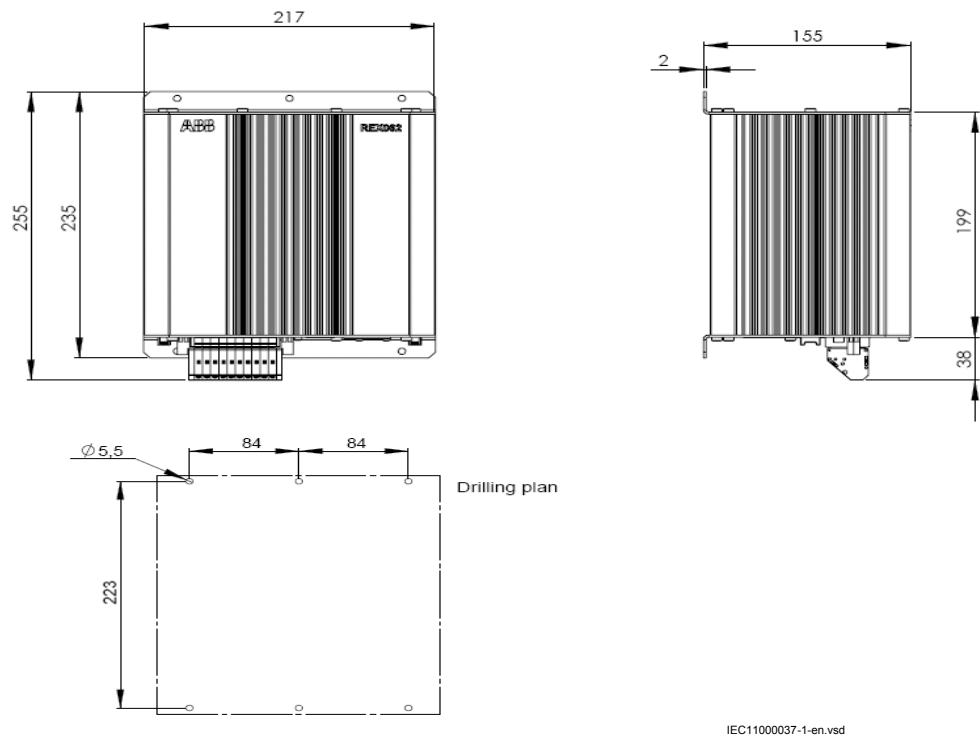
#### 5.3.8.1

#### Coupling capacitor unit REX061



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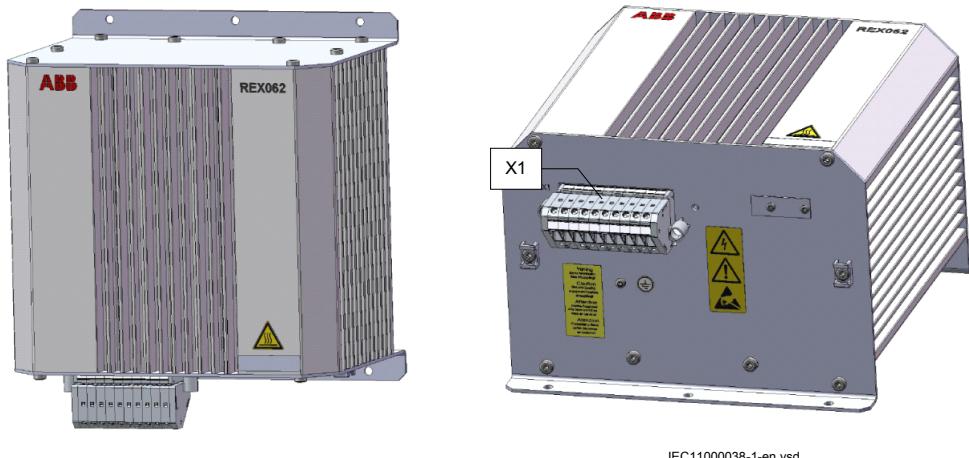
*Figure 18: Coupling capacitor unit REX061*



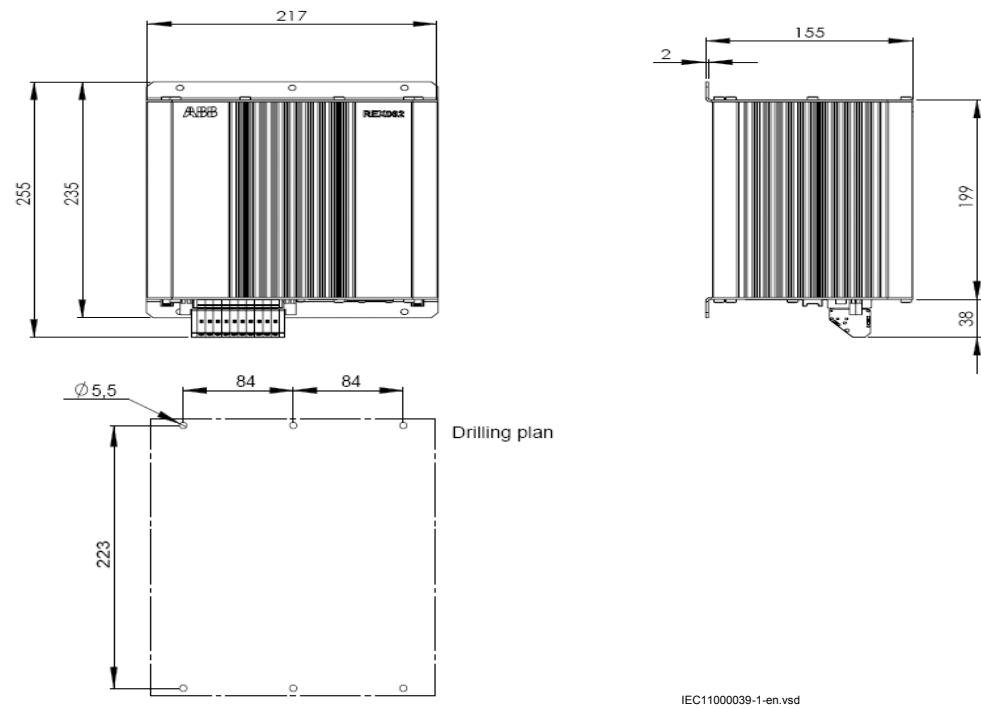
*Figure 19: Measure and drilling plan*

REX061 shall be mounted close to the generator in order to limit the exposure of the field circuit. Alternatively it can be located in the excitation cubicle.

### 5.3.8.2 Shunt resistor unit REX062



*Figure 20: Shunt resistor unit REX062*



*Figure 21: REX062 measures and drilling plan*

REX062 shall be mounted close to the IED. It is recommended that REX060 and REX062 are mounted in the same cubicle as the IED.

## 5.4 Making the electrical connection to REG670

### 5.4.1 IED connectors

#### 5.4.1.1 Overview

The quantity and designation of connectors depend upon the type and size of the IED. The rear cover plates are prepared with space for the maximum of HW options for each case size and the cut-outs that are not in use are covered with a plate from factory.

## Overview

**Table 1:** *Basic modules*

Module	Description
Combined backplane module (CBM)	A backplane PCB that carries all internal signals between modules in an IED. Only the TRM (when included) is not connected directly to this board.
Universal backplane module (UBM)	A backplane PCB that forms part of the IED backplane with connectors for TRM (when included), ADM etc.
Power supply module (PSM)	Including a regulated DC/DC converter that supplies auxiliary voltage to all static circuits. <ul style="list-style-type: none"><li>• An internal fail alarm output is available.</li></ul>
Numerical module (NUM)	Module for overall application control. All information is processed or passed through this module, such as configuration, settings and communication.
Local Human machine interface (LHMI)	The module consists of LED:s, an LCD, a push button keyboard and an ethernet connector used to connect a PC to the IED.
Transformer input module (TRM)	Transformer module that galvanically separates the internal circuits from the VT and CT circuits. It has 12 analog inputs.
Analog digital conversion module (ADM)	Slot mounted PCB with A/D conversion.

**Table 2:** *Application specific modules*

Module	Description
Binary input module (BIM)	Module with 16 optically isolated binary inputs
Binary output module (BOM)	Module with 24 single outputs or 12 double-pole command outputs including supervision function
Binary I/O module (IOM)	Module with 8 optically isolated binary inputs, 10 outputs and 2 fast signalling outputs.
Line data communication modules (LDCM), short range, medium range, long range, X21	Modules used for digital communication to remote terminal.
Serial SPA/LON/IEC 60870-5-103/DNP3 communication modules (SLM)	Used for SPA/LON/IEC 60870-5-103/DNP3 communication
Optical ethernet module (OEM)	PMC board for IEC 61850 based communication.
mA input module (MIM)	Analog input module with 6 independent, galvanically separated channels.
IRIG-B Time synchronization module (IRIG-B)	Module with 2 inputs. One is used for handling both pulse-width modulated signals and amplitude modulated signals and one is used for optical input type ST for PPS time synchronization.

### 5.4.1.2

### Front side connectors



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*Figure 22: IED front side connector*

PosNo Description

- 1 IED serial communication port with RJ45 connector
- 2 Ethernet cable with RJ45 connectors



The cable between PC and the IED serial communication port shall be a crossed-over Ethernet cable with RJ45 connectors. If the connection are made via a hub or switch, a standard Ethernet cable can be used.

### 5.4.1.3 Rear side connectors

**Table 3:** Designations for 1/2 x 19" casing with 1 TRM slot

Front view	Module	Rear Positions
	PSM	X11
	BIM, BOM, SOM, IOM or MIM	X31 and X32 etc. to X51 and X52
	SLM	X301:A, B, C, D
	LDCM, IRIG-B or RS485	X302
	LDCM or RS485	X303
	OEM	X311:A, B, C, D
	LDCM, RS485 or GTM	X312, 313
	TRM	X401

**Table 4:** Designations for 3/4 x 19" casing with 1 TRM slot

Front view												3/4x19"	Module	Rear Positions
P40	P31	P30	P10	P9	P8	P7	P6	P5	P4	P3	P1		PSM	X11
													BIM, BOM, SOM, IOM or MIM	X31 and X32 etc. to X101 and X102
													SLM	X301:A, B, C, D
													LDCM, IRIG-B or RS485	X302
													LDCM or RS485	X303
													OEM	X311:A, B, C, D
													LDCM, RS485 or GTM	X312, X313
													TRM	X401

Rear view												6U
X11	X31	X41	X51	X61	X71	X81	X91	X101	X301			
									○A			
									○B			
									○C	X311		
									○D	○A		
									○B	○C		
									○D	○A		
									X302	○B		
									X303	○C		
									X312	○D		
									X313			

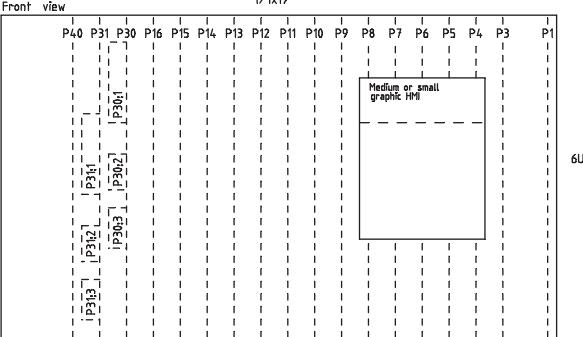
## Section 5 Installing the IED

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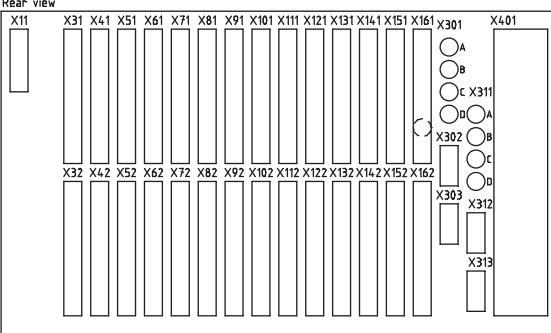
**Table 5:** Designations for 3/4 x 19" casing with 2 TRM slot

Front view	Module	Rear Positions
	PSM	X11
	BIM, BOM, SOM, IOM or MIM	X31 and X32 etc. to X71 and X72
	SLM	X301:A, B, C, D
	LDCM, IRIG-B or RS485	X302
	LDCM or RS485	X303
	OEM	X311:A, B, C, D
	LDCM, RS485 or GTM	X312, X313, X322, X323
	TRM 1	X401
	TRM 2	X411

**Table 6:** Designations for 1/1 x 19" casing with 1 TRM slot

Front view	Module	Rear Positions
 <p>1/1x19"</p> <p>Medium or small graphic HMI</p> <p>6U</p>	PSM	X11
	BIM, BOM, SOM, IOM or MIM	X31 and X32 etc. to X161 and X162
	SLM	X301:A, B, C, D
	LDCM, IRIG-B or RS485	X302
	LDCM or RS485	X303
	OEM	X311:A, B, C, D
	LDCM,RS485 or GTM	X312, X313
	TRM	X401

Rear view
 <p>X11 X31 X41 X51 X61 X71 X81 X91 X101 X111 X121 X131 X141 X151 X161 X301 X401</p> <p>A B C D</p> <p>X301-X313</p>

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**Table 7:** Designations for 1/1 x 19" casing with 2 TRM slots

Front view	1/1x19"																		Module	Rear Positions
P41	P40	P32	P31	P30	P13	P12	P11	P10	P9	P8	P7	P6	P5	P4	P3	P1		PSM	X11	
[P221]	[P222]	[P223]	[P21]	[P31]	[P32]	[P33]	[P34]	[P35]	[P361]	[P362]	[P363]	[P364]	[P365]	[P366]	[P367]	[P368]	Medium or small graphic HMI	BIM, BOM, SOM, IOM or MIM	X31 and X32 etc. to X131 and X132	
[P313]	[P312]	[P311]	[P310]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	SLM	X301:A, B, C, D	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	LDCM, IRIG-B or RS485	X302	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	LDCM or RS485	X303	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	OEM	X311:A, B, C, D	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	LDCM, RS485 or GTM	X312, X313, X322, X323	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	TRM 1	X401	
[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	[P305]	[P304]	[P303]	[P302]	[P301]	[P300]	[P309]	[P308]	[P307]	[P306]	TRM 2	X411	
Rear view																				
X11	X31	X41	X51	X61	X71	X81	X91	X101	X111	X121	X131	X301	X401	X411						
												(A)								
												(B)								
												(C)	X311 X321							
												(D)	A A							
												(A)	B B							
												(B)	C C							
												(C)	D D							
												(D)								
												X302	X312 X322							
												X303	X312 X323							
												X313	X323							

Transformer input module (TRM)

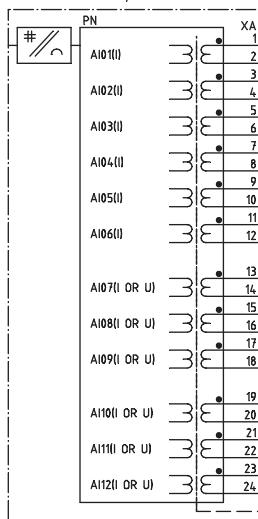


Table continues on next page

*Figure 23: Transformer input module (TRM)*

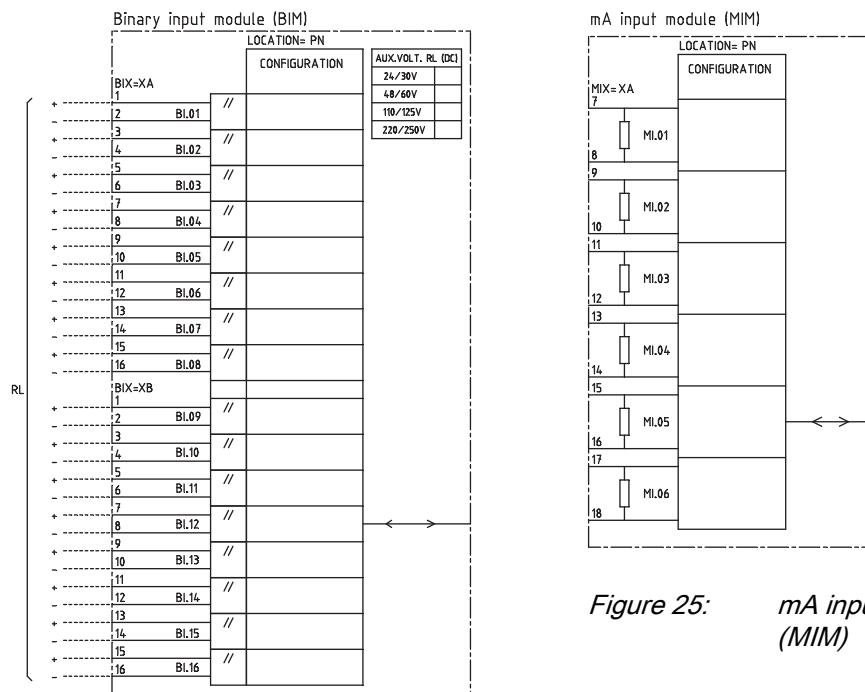
- Indicates high polarity

Current/voltage configuration (50/60 Hz)	CT/VT-input designation according to figure 23											
	AI01	AI02	AI03	AI04	AI05	AI06	AI07	AI08	AI09	AI10	AI11	AI12
12I, 1A	1A	1A	1A	1A	1A	1A	1A	1A	1A	1A	1A	1A
12I, 5A	5A	5A	5A	5A	5A	5A	5A	5A	5A	5A	5A	5A
9I+3V, 1A	1A	1A	1A	1A	1A	1A	1A	1A	110-220 V	110-220 V	110-220 V	
9I+3V, 5A	5A	5A	5A	5A	5A	5A	5A	5A	110-220 V	110-220 V	110-220 V	
5I, 1A+4I, 5A+3V	1A	1A	1A	1A	1A	5A	5A	5A	110-220 V	110-220 V	110-220 V	
7I+5V, 1A	1A	1A	1A	1A	1A	1A	1A	110-220 V	110-220 V	110-220 V	110-220 V	
7I+5V, 5A	5A	5A	5A	5A	5A	5A	5A	110-220 V	110-220 V	110-220 V	110-220 V	
6I, 5A+1I, 1A+5V	5A	5A	5A	5A	5A	5A	1A	110-220 V	110-220 V	110-220 V	110-220 V	
3I, 5A+4I, 1A+5V	5A	5A	5A	1A	1A	1A	1A	110-220 V	110-220 V	110-220 V	110-220 V	
3IM, 1A+4IP, 1A+5V	1AM *)	1AM *)	1AM *)	1A	1A	1A	1A	110-220 V	110-220 V	110-220 V	110-220 V	
3IM, 5A+4IP, 5A+5V	5AM *)	5AM *)	5AM *)	5A	5A	5A	5A	110-220 V	110-220 V	110-220 V	110-220 V	
6I+6V, 1A	1A	1A	1A	1A	1A	1A	110-220 V					
6I+6V, 5A	5A	5A	5A	5A	5A	5A	110-220 V					
3I, 5A+3I, 1A+6V	5 A	5 A	5 A	1A	1A	1A	110-220 V					
6I, 1A	1A	1A	1A	1A	1A	1A	-	-	-	-	-	-
6I, 5A	5A	5A	5A	5A	5A	5A	-	-	-	-	-	-

\*) Metering

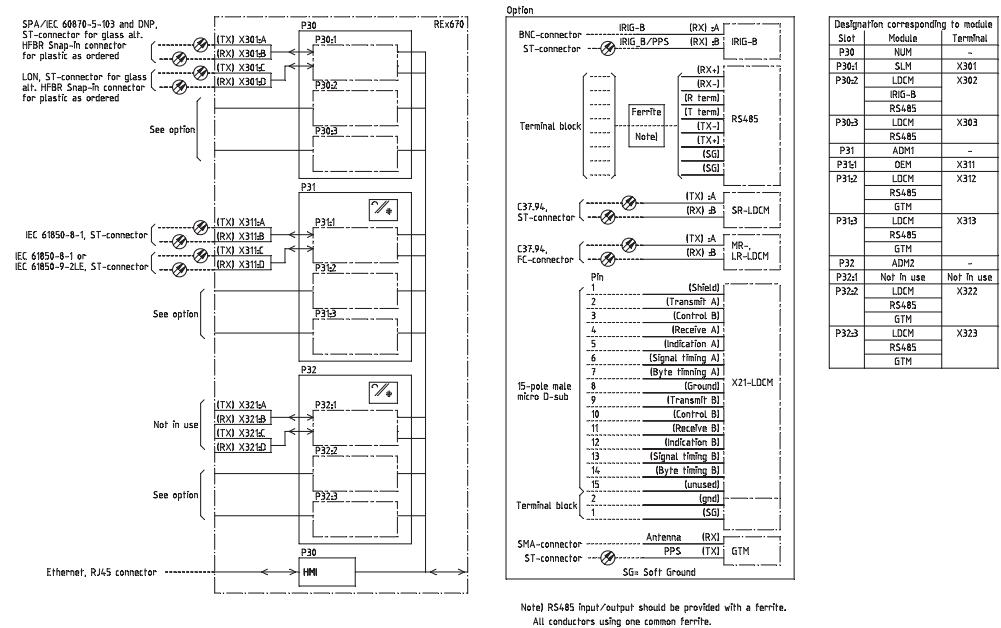


Note that internal polarity can be adjusted by setting of analog input CT neutral direction and/or on SMAI pre-processing function blocks.

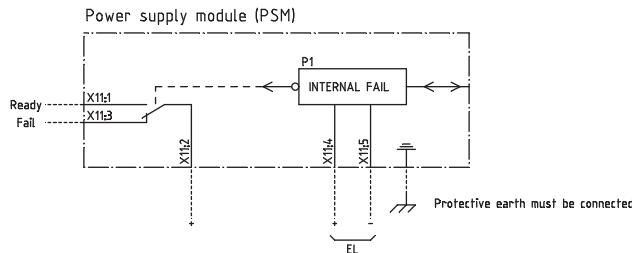


**Figure 24:** *Binary input module (BIM). Input contacts named XA corresponds to rear position X31, X41, and so on, and input contacts named XB to rear position X32, X42, and so on.*

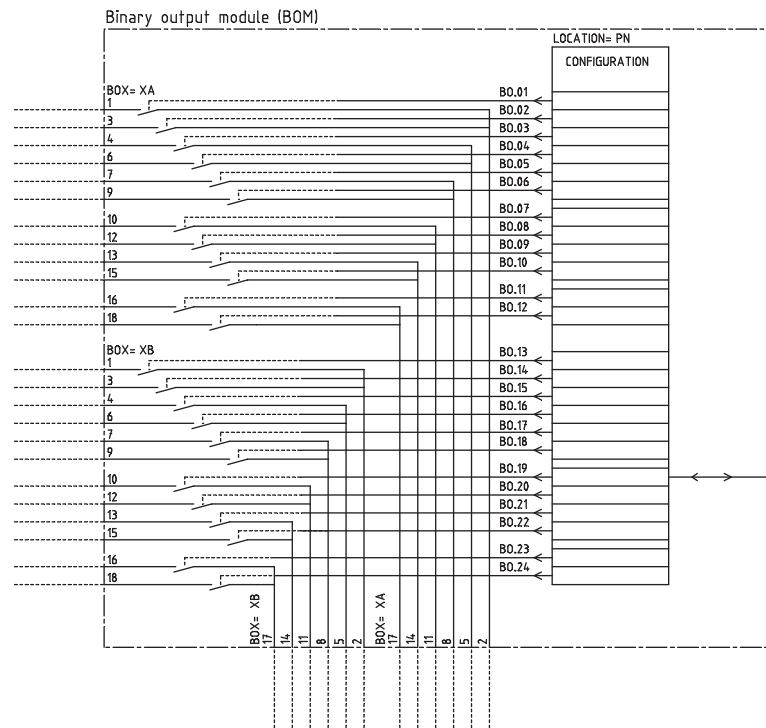
**Figure 25:** *mA input module (MIM)*



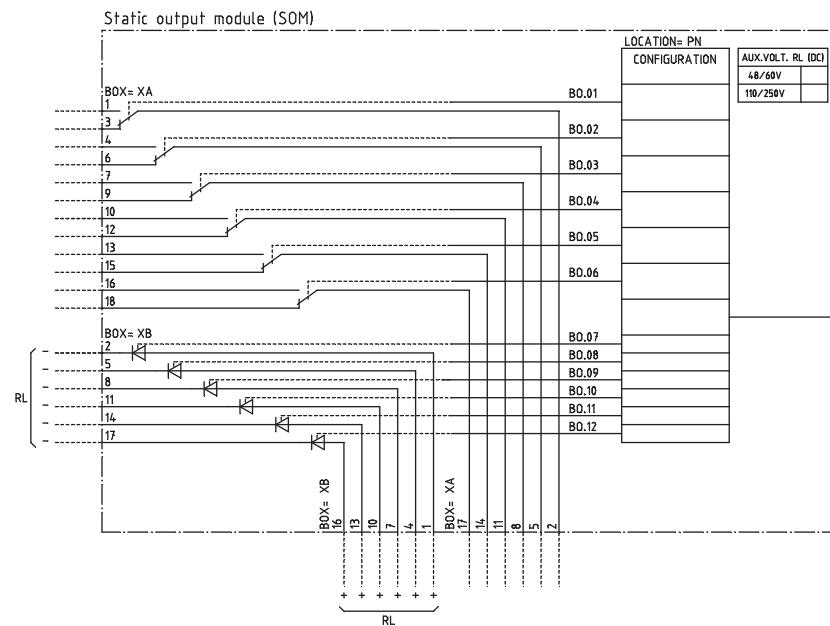
*Figure 26: IED with basic functionality and communication interfaces*



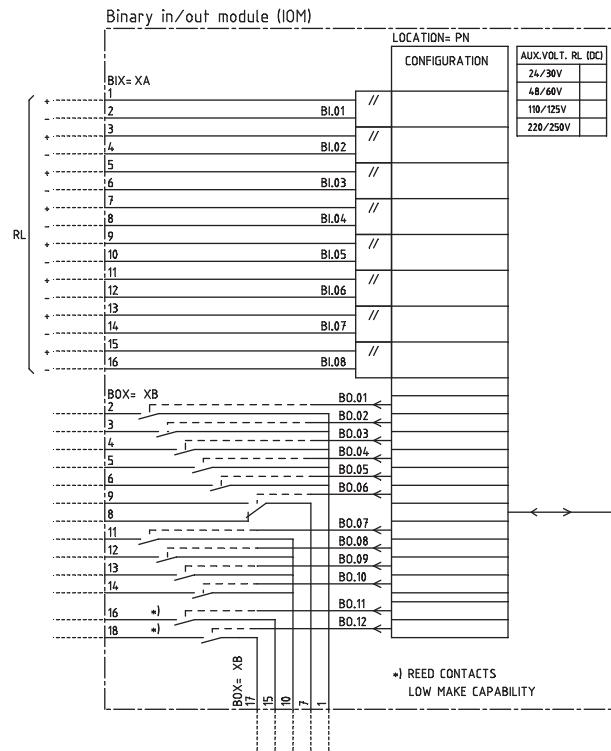
*Figure 27: Power supply module (PSM)*



*Figure 28: Binary output module (BOM). Output contacts named XA corresponds to rear position X31, X41, and so on, and output contacts named XB to rear position X32, X42, and so on.*



*Figure 29:      Static output module (SOM)*



*Figure 30: Binary in/out module (IOM). Input contacts named XA corresponds to rear position X31, X41, and so on, and output contacts named XB to rear position X32, X42, and so on.*

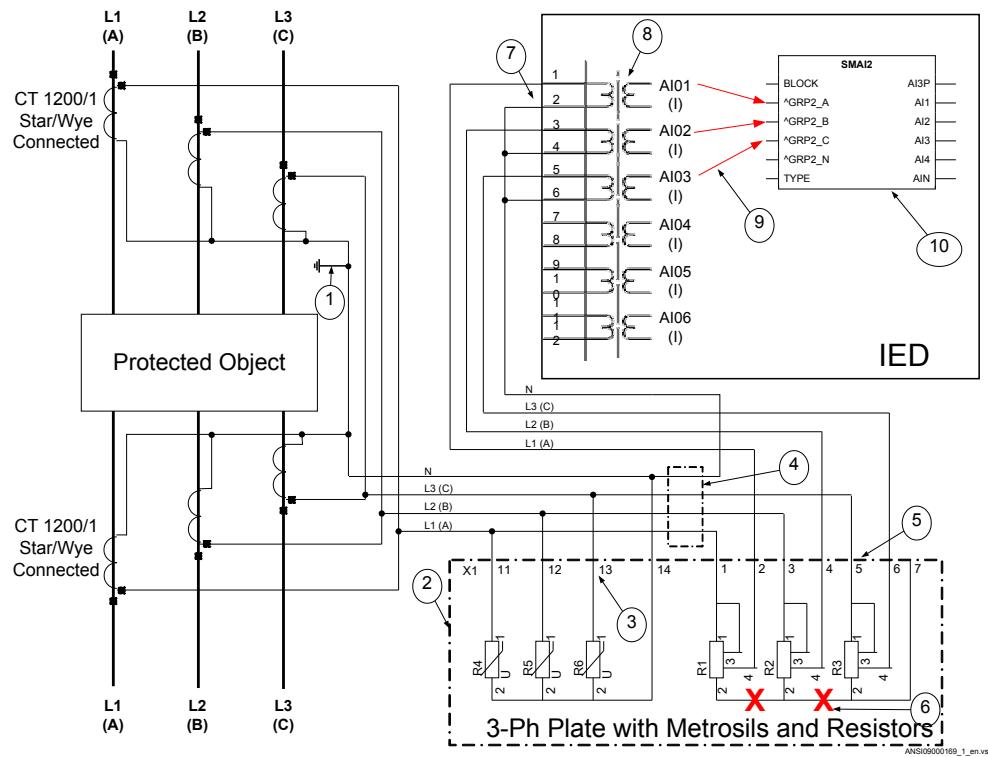
#### 5.4.1.4 Connection examples for high impedance differential protection



**WARNING! USE EXTREME CAUTION!** Dangerously high voltages might be present on this equipment, especially on the plate with resistors. Do any maintenance ONLY if the primary object protected with this equipment is de-energized. If required by national law or standard, enclose the plate with resistors with a protective cover or in a separate box.

#### Connections for three-phase high impedance differential protection

Generator, reactor or busbar differential protection is a typical application for three-phase high impedance differential protection. Typical CT connections for three-phase high impedance differential protection scheme are shown in figure 31.



*Figure 31: CT connections for high impedance differential protection*

Pos      Description

1      Scheme grounding point



Note that it is of outmost importance to insure that only one grounding point exist in such scheme.

2      Three-phase plate with setting resistors and metrosils.

3      Necessary connection for three-phase metrosil set. Shown connections are applicable for both types of three-phase plate.

4      Position of optional test switch for secondary injection into the high impedance differential IED.

5      Necessary connection for setting resistors. Shown connections are applicable for both types of three-phase plate.

6      The factory made star point on a three-phase setting resistor set.



**Shall be removed** for installations with 650 and 670 series IEDs. This star point is required for RADHA schemes only.

7      How to connect three individual phase currents for high impedance scheme to three CT inputs in the IED.

- 
- 8 Transformer input module, where the current inputs are located.

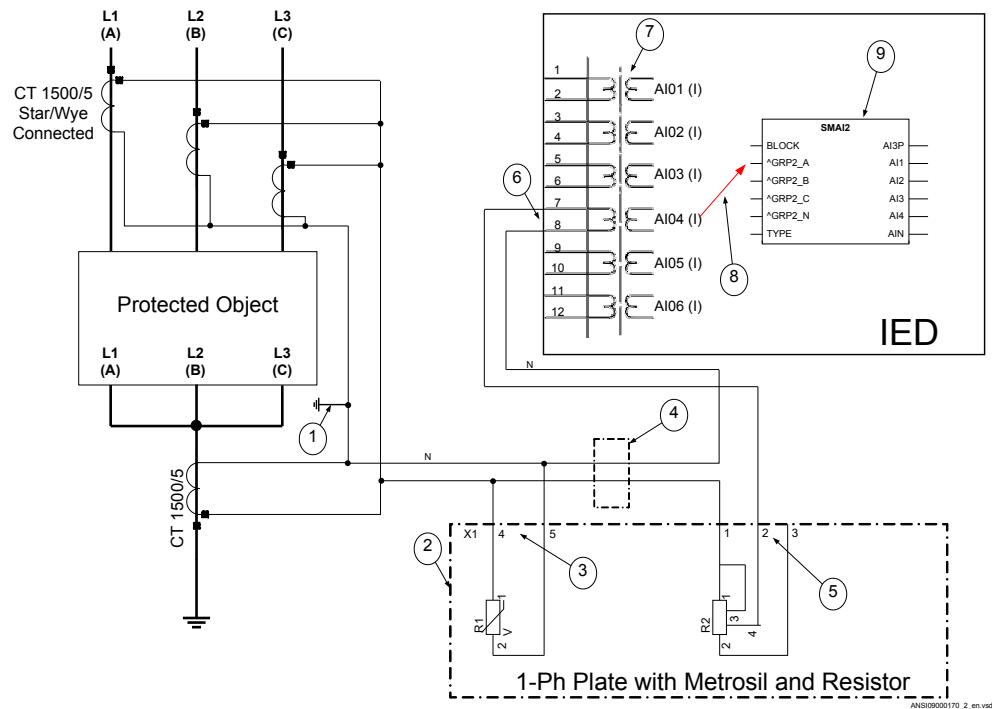


Note that the CT ratio for high impedance differential protection application must be set as one.

- For main CTs with 1A secondary rating the following setting values shall be entered:  $CTprim = 1A$  and  $CTsec = 1A$
  - For main CTs with 5A secondary rating the following setting values shall be entered:  $CTprim = 5A$  and  $CTsec = 5A$
  - The parameter  $CTStarPoint$  shall be always left to the default value *ToObject*.
- 9 Three connections made in the Signal Matrix, which connect these three current inputs to the first three input channels of the preprocessing function block (10). For high impedance differential protection preprocessing function block in 3ms task shall be used.
- 10 Preprocessing block, to digitally filter the connected analogue inputs. Preprocessing block outputs AI1, AI2 and AI3 shall be connected to three instances of 1Ph high impedance differential protection HZPDIF (87) function blocks, for example instance 1, 2 and 3 of HZPDIF (87) in the configuration tool.

### Connections for 1Ph High impedance differential protection HZPDIF (87)

Restricted earth fault protection REFPDIF (87N) is a typical application for 1Ph High impedance differential protection HZPDIF (87). Typical CT connections for high impedance based REFPDIF (87N) protection scheme are shown in figure [32](#).



*Figure 32: CT connections for restricted earth fault protection*

Pos      Description

1      Scheme grounding point



Note that it is of outmost importance to insure that only one grounding point exist in such scheme.

- 2      One-phase plate with stabilizing resistor and metrosil.
- 3      Necessary connection for the metrosil. Shown connections are applicable for both types of one-phase plate.
- 4      Position of optional test switch for secondary injection into the high impedance differential IED.
- 5      Necessary connection for stabilizing resistor. Shown connections are applicable for both types of one-phase plate.
- 6      How to connect REFPDIF (87N) high impedance scheme to one CT input in IED.

- 
- 7 Transformer input module where this current input is located.



Note that the CT ratio for high impedance differential protection application must be set as one.

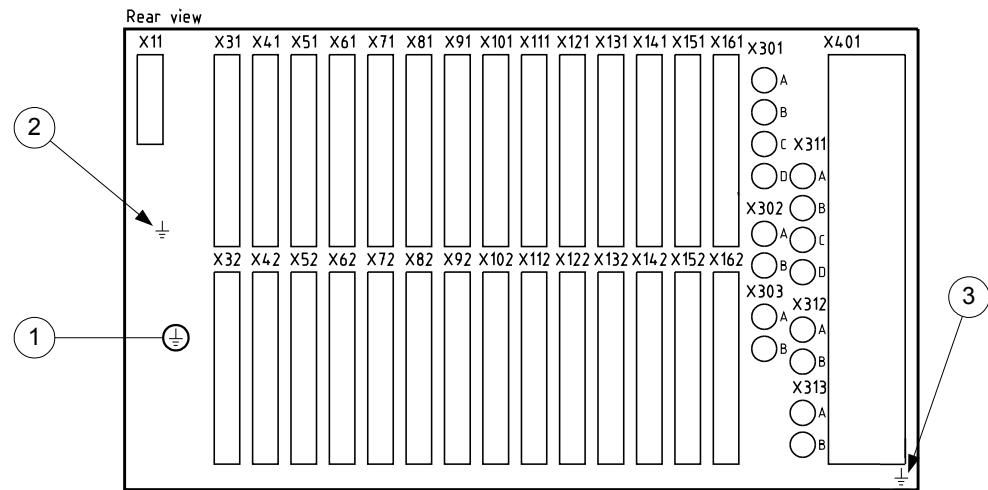
- For main CTs with 1A secondary rating the following setting values shall be entered:  $CTprim = 1A$  and  $CTsec = 1A$
  - For main CTs with 5A secondary rating the following setting values shall be entered:  $CTprim = 5A$  and  $CTsec = 5A$
  - The parameter  $CTStarPoint$  shall always be left to the default value *ToObject*
- 8 Connection made in the Signal Matrix, which connects this current input to first input channel of the preprocessing function block (9). For high impedance differential protection preprocessing function block in 3ms task shall be used.
- 9 Preprocessing block, which has a task to digitally filter the connected analogue inputs. Preprocessing block output AI1 shall be connected to one instances of 1Ph high impedance differential protection function HZPDIF (87) (for example, instance 1 of HZPDIF (87) in the configuration tool).

### 5.4.2

### Connecting to protective ground

Connect the protective grounding screw (pos 1 in figure [33](#)) on the rear of the IED to the closest possible grounding point in the cubicle. Electrical codes and standards require that protective ground cables are green/yellow conductors with a cross section area of at least  $2.5 \text{ mm}^2$  (AWG14). The Power supply module (PSM), Transformer input modules (TRM) and the enclosure are all separately grounded, see figure [33](#) below.

The cubicle must be properly connected to the station grounding system. Use a conductor with a core cross section area of at least  $4 \text{ mm}^2$  (AWG 12).



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*Figure 33: Rear view of IED showing grounding points.*

Pos	Description
1	Main protective ground to chassis
2	Grounding screw to Power supply module (PSM)
3	Grounding screw to Transformer input module (TRM). (There is one ground connection per TRM)



Use the main protective ground screw (1) for connection to the stations grounding system. Grounding screws for PSM module (2) and TRM module (3) must be fully tightened to secure protective ground connection of these modules.

### 5.4.3

### Connecting the power supply module

The wiring from the cubicle terminal block to the IED terminals (see Figure 27 for PSM connection diagram) must be made in accordance with the established guidelines for this type of equipment. The wiring should have a minimum cross-sectional area of 1.0 mm<sup>2</sup> and a voltage rating of 250 V. Branch circuit protection must be provided in the power supply wiring to the IED, and if necessary it must be possible to disconnect manually from the power supply. Fuse or circuit breaker up to 6 A and 250 V should be close to the equipment. It is recommended to separate the instrument transformer leads from the other cables, that is, they should not be run in the same cable ducts or

---

loom. The connections are made on connector X11. For location of connector X11, refer to section ["Rear side connectors"](#).

#### 5.4.4

#### Connecting to CT and VT circuits

CTs and VTs are connected to the 24-pole connector of the Transformer input module (TRM) on the rear side of the IED. Connection diagram for TRM is shown in figure 23.

Use a solid conductor with a cross section area between 2.5-6 mm<sup>2</sup> (AWG14-10) or a stranded conductor with a cross section area between 2.5-4 mm<sup>2</sup> (AWG14-12).

If the IED is equipped with a test-switch of type RTXP 24, COMBIFLEX wires with 20 A sockets must be used to connect the CT and VT circuits.

Connectors on TRM (for location see section ["Rear side connectors"](#)) for current and voltage transformer circuits are so called “feed-through IED blocks” and are designed for conductors with cross sectional area up to 4 mm<sup>2</sup> (AWG 12). The screws used to fasten the conductors should be tightened with a torque of 1Nm.

Connector terminals for CT and VT circuits, as well as terminals for binary input and output signals, can be of either ringlug or compression connection type, depending on ANSI/IEC standards, or customers choice.



*Figure 34:* Examples of ringlug terminals



*Figure 35:* Examples of standard compression connection terminals

**Table 8:** CT and VT circuit connectors

Connector type	Rated voltage and current	Maximum conductor area
Screw compression type	250 V AC, 20 A	4 mm <sup>2</sup> (AWG12) 2 x 2.5 mm <sup>2</sup> (2 x AWG14)
Terminal blocks suitable for ring lug terminals	250 V AC, 20 A	4 mm <sup>2</sup> (AWG12)

### 5.4.4.1 Configuration for analog CT inputs

The secondary rated current of the CT (that is, 1A or 5A) determines the choice of TRM in the IED. Two TRMs are available, One is dimensioned for an input current of 5A and the other for an input of 1A. If the CT rated secondary current does not match the TRM input current rating adjustments can be made in settings depending on the tolerance of the TRM.

## 5.4.5

## Connecting the binary input and output signals

Auxiliary power and signals are connected using voltage connectors. Signal wires are connected to a female connector, see figure 36, which is then plugged into the corresponding male connector, see figure 37, located at the rear of the IED. For location of BIM, BOM and IOM refer to section "[Rear side connectors](#)". Connection diagrams for BIM, BOM and IOM are shown in figure 24, figure 28 and figure 30.

If the IED is equipped with a test-switch of type RTXP 24, COMBIFLEX wires with 20 A sockets, 1.5mm<sup>2</sup> (AWG16) conductor area must be used to connect the auxiliary power.

### Procedure

1. Connect signals to the female connector

All wiring to the female connector should be done before it is plugged into the male part and screwed to the case. The conductors can be of rigid type (solid, stranded) or of flexible type.

The female connectors accept conductors with a cross section area of 0.2-2.5 mm<sup>2</sup> (AWG 24-14). If two conductors are used in the same terminal, the maximum permissible cross section area is 0.2-1 mm<sup>2</sup> (AWG 24-18).

If two conductors, each with area 1.5 mm<sup>2</sup> (AWG 16) need to be connected to the same terminal, a ferrule must be used, see figure 38. This ferrule, is applied with the by Phoenix recommended crimping tool. The fastening screw shall be tightened with a torque of 0.4 Nm (This torque applies to all binary connectors).

2. Plug the female connector to the corresponding back-side mounted male connector
3. Lock the female connector by fastening the lock screws

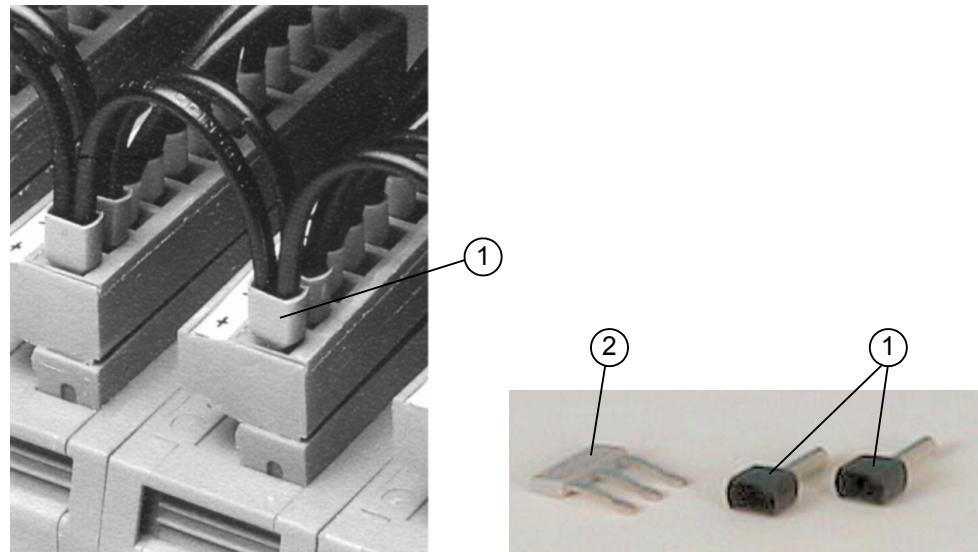


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*Figure 36: A female connector*



*Figure 37:* Board with male connectors



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*Figure 38:* Cable connectors

PosNo Description

1 Is ferrule,

2 A bridge connector, is used to jump terminal points in a connector.

*Table 9:* Binary I/O connection system

Connector type	Rated voltage	Maximum conductor area
Screw compression type	250 V AC	2.5 mm <sup>2</sup> (AWG14) 2 × 1 mm <sup>2</sup> (2 x AWG18)
Terminal blocks suitable for ring lug terminals	300 V AC	3 mm <sup>2</sup> (AWG14)



Because of limitations of space, when ring lug terminal is ordered for Binary I/O connections, one blank slot is necessary between two adjacent IO cards. Please refer to the ordering particulars for details.

#### 5.4.6

#### Making the screen connection

When using screened cables always make sure screens are grounded and connected according to applicable engineering methods. This may include checking for appropriate grounding points near the IED, for instance, in the cubicle and/or near the source of measuring. Ensure that ground connections are made with short (max. 10 cm) conductors of an adequate cross section, at least  $6 \text{ mm}^2$  (AWG10) for single screen connections.

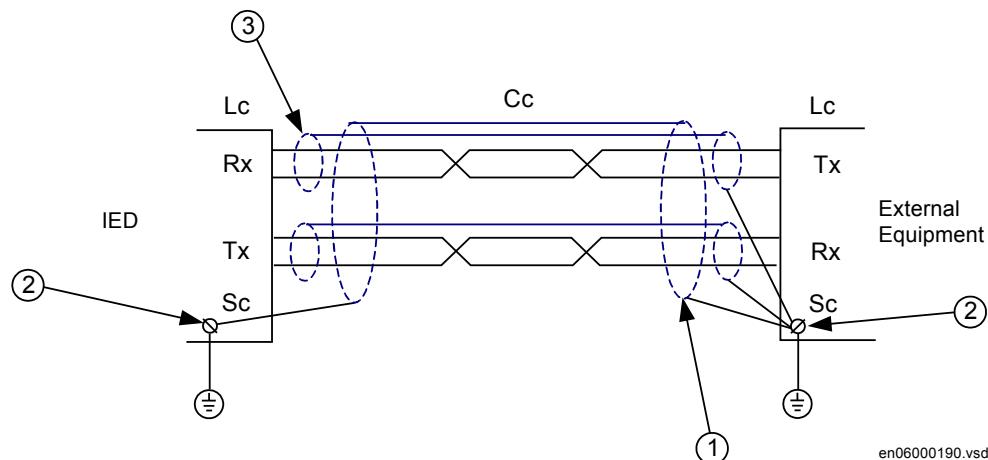


Figure 39: Communication cable installation.

PosNo	Description
1	Outer shield
2	Protective ground screw
3	Inner shield



Inner shielding of the cable shall be grounded at the external equipment end only. At the IED terminal end, the inner shield must be isolated from protective ground.

## 5.5

# Making the electrical connection to the rotor and stator injection equipment

### 5.5.1

## Connectors for injection unit REX060, coupling capacitor unit REX061 and shunt resistor unit REX062

#### 5.5.1.1

### Injection unit REX060

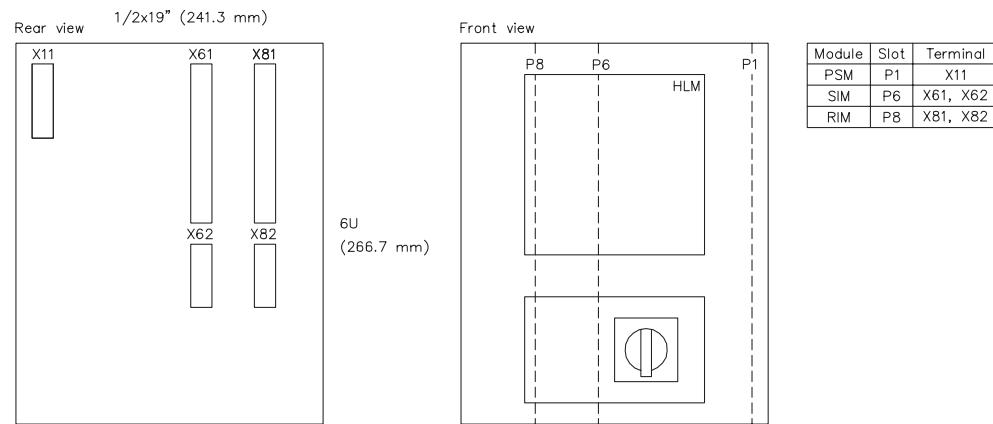


Figure 40: Designation for REX060 unit casing

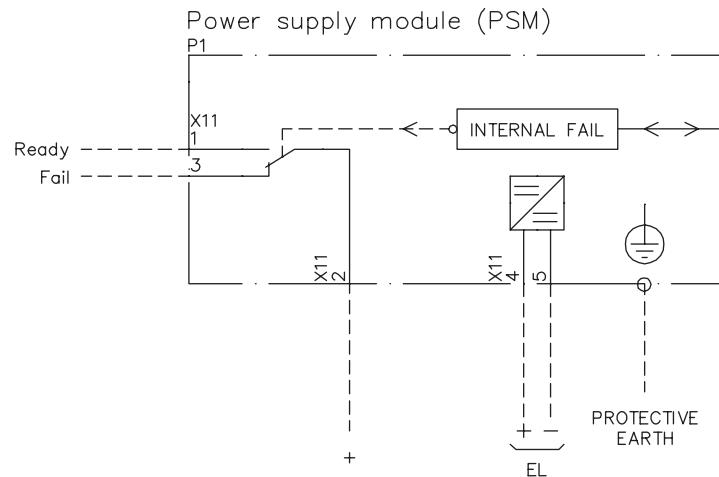
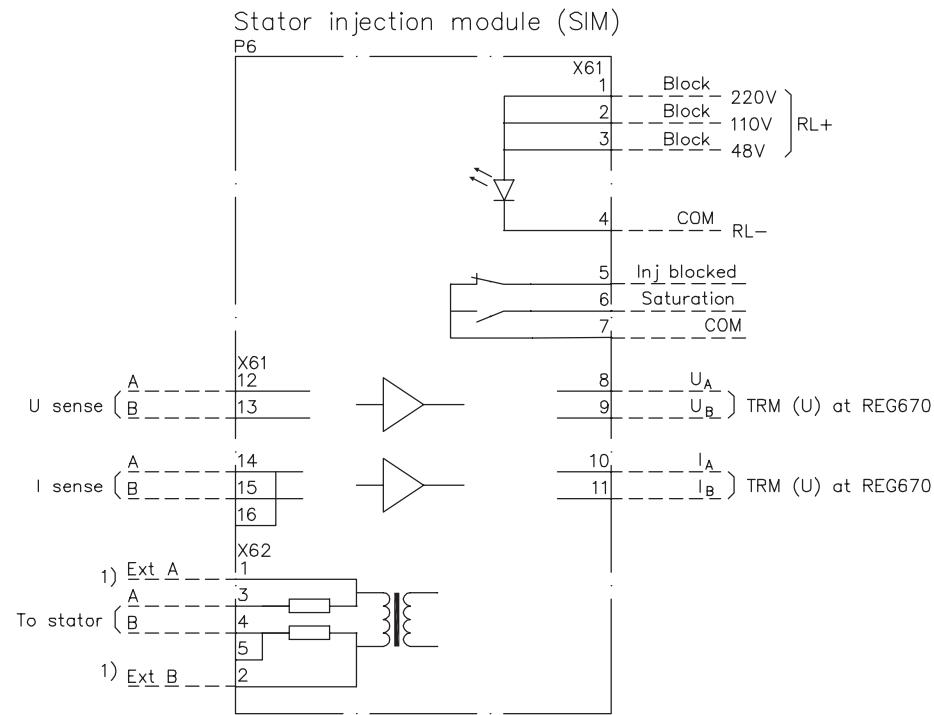


Figure 41: Power supply module



1) Alternative connections to optional Shunt resistor unit (REX062) for high-resistance grounding via a distribution transformer or terminal earthing transformer.

Figure 42: *Stator injection module*

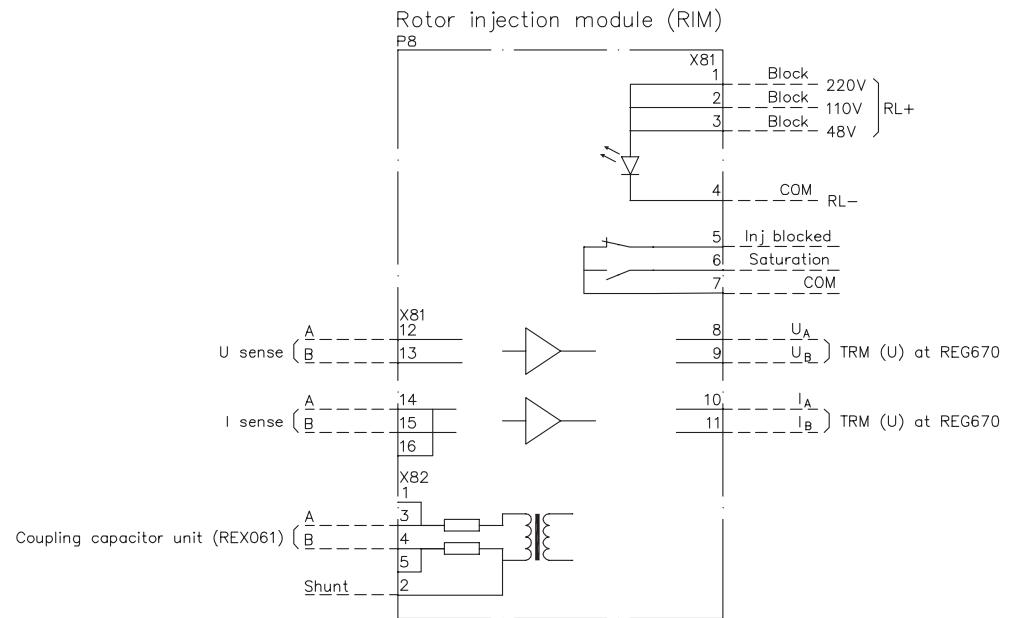
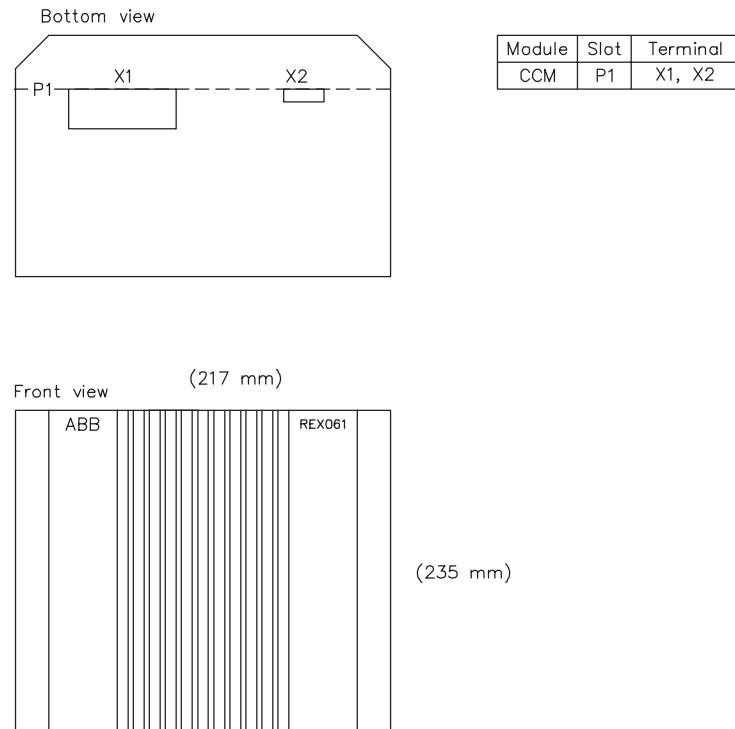


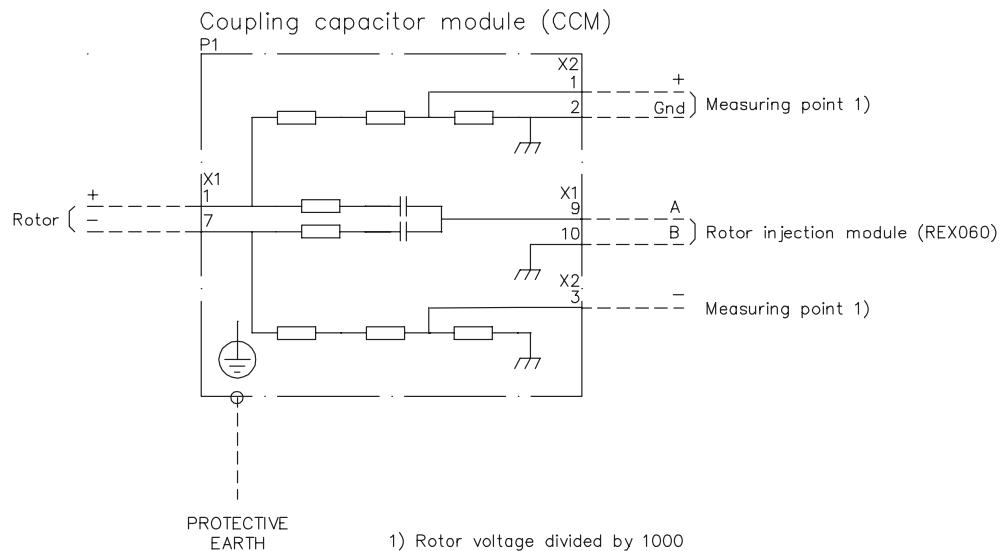
Figure 43: Rotor injection module

### 5.5.1.2

### Coupling capacitor unit REX061



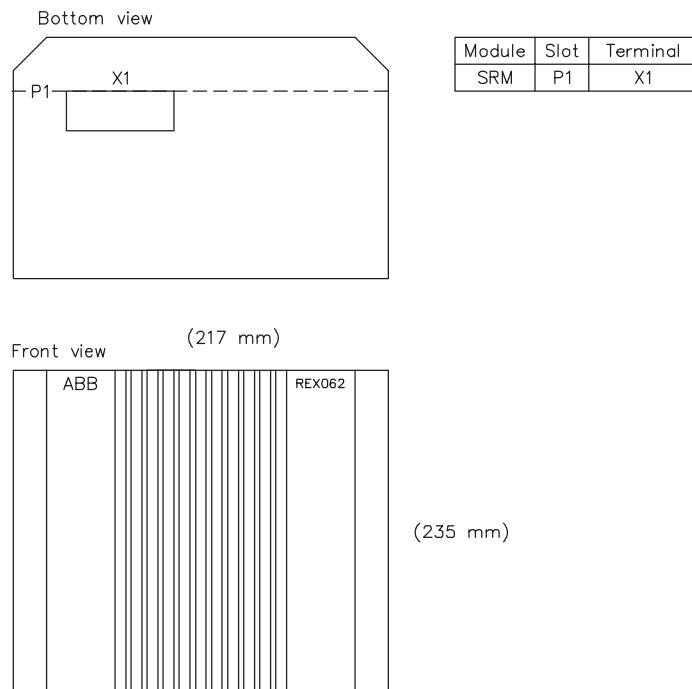
*Figure 44: Designation for capacitor unit casing*



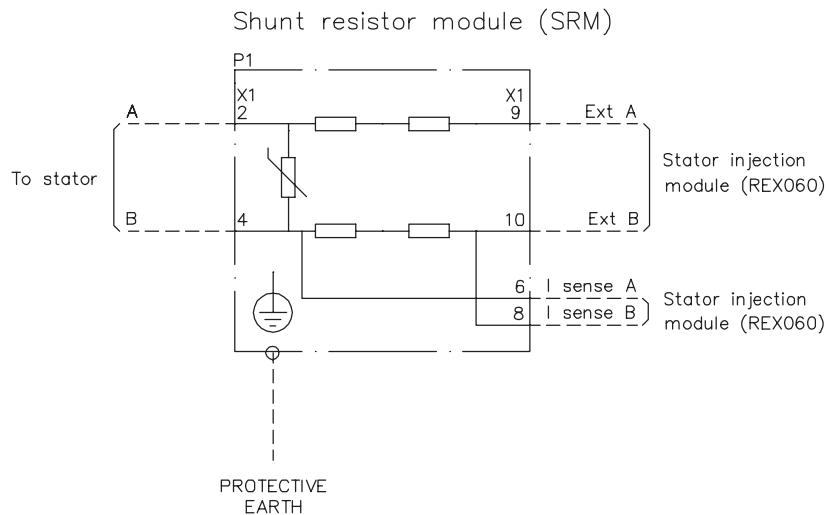
*Figure 45: Coupling capacitor module*

### 5.5.1.3

### Shunt resistor unit REX062



*Figure 46: Designation for shunt resistor unit casing*



*Figure 47: Shunt resistor module*

## 5.5.2

### Connecting injection unit REX060, coupling capacitor unit REX061 and shunt resistor unit REX062

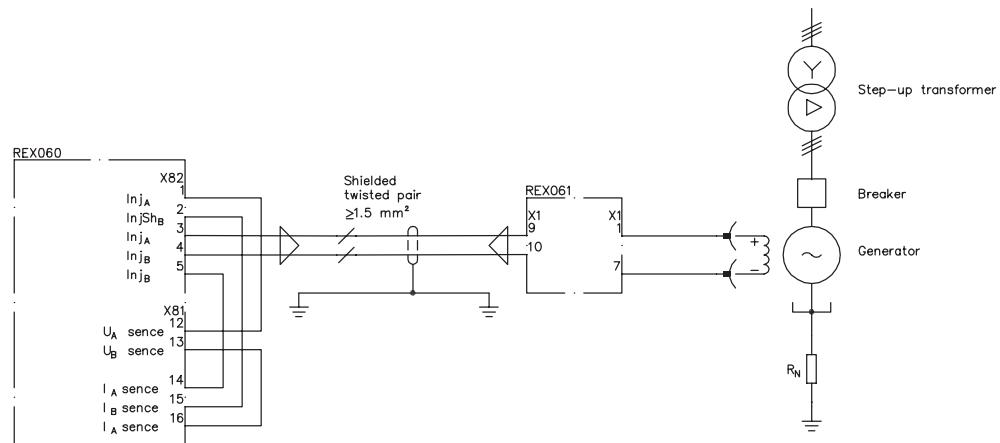
The figures below show typical installations for rotor and stator earth fault protection, where injection unit REX060, coupling capacitor unit REX061 and with and without shunt resistor unit REX062.

The injection unit REX060 should be installed close to the IED in the same cubicle, in any case within 10 m distance of the IED.

The shunt resistor unit, REX062, should preferably also be installed in the same cubicle, if used in the application.

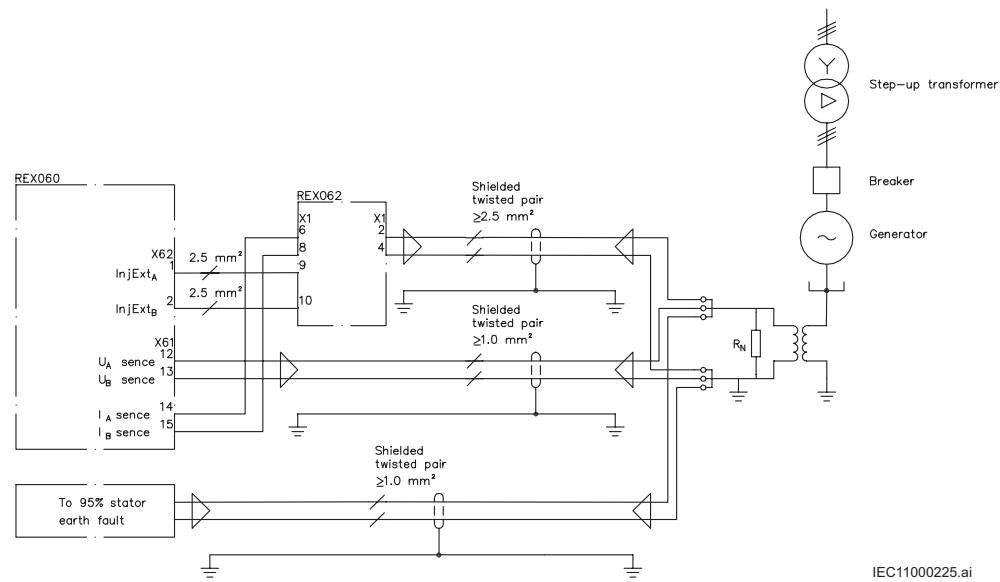
Cable length between REX060 and generator should preferable not exceed 75 m, in any case not exceed 150 m. The recommended cable area for distances up to 75 m is  $2.5 \text{ mm}^2$ . The cable area should be increased to  $4 \text{ mm}^2$  for distances between 75 m and 150 m.

Cable length between REX062 and generator should preferable not exceed 75 m, in any case not exceed 150 m. The recommended cable area for distances up to 75 m is  $2.5 \text{ mm}^2$ . The cable area should be increased to  $4 \text{ mm}^2$  for distances between 75 m and 150 m.

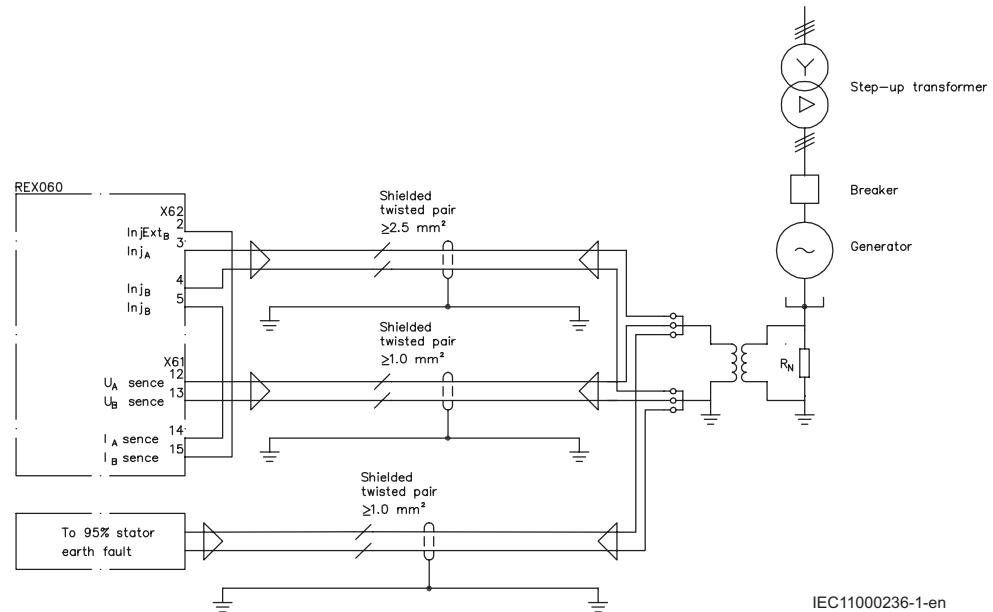


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*Figure 48: Rotor connection example*



**Figure 49:** Stator connection example, with REX062



**Figure 50:** Stator connection example, without REX062

For connection details regarding REX060, REX061 and REX062, refer to *REG670 Technical Reference manual*, section *Connection diagram*

## REX060 connections

*Table 10: Power X11*

No	Signal
1	Ready, Power off NO binary out
2	Power off common binary out
3	Fail, Power off NC binary out
4	Power input positive
5	Power input negative

*Table 11: Stator IED and sense connection X61*

No	Signals
1	Block injection, 220V binary in
2	Block injection, 110V binary in
3	Block injection, 48V binary in
4	Block injection, Common binary in
5	Injection Blocked NC binary out
6	Voltage/Current Saturation NO binary out
7	Common binary out
8	Voltage A, analog out
9	Voltage B analog out
10	Current A analog out
11	Current B analog out
12	Voltage sense A
13	Voltage sense B
14	Current sense A (same as 16)
15	Current sense B
16	Current sense A (same as 14)
17	-
18	-

**Table 12:** *Stator injection connection X62*

No	Signal
1	Injection, via extern shunt resistor
2	Injection return, via extern shunt resistor
3	Injection
4	Injection return (same as 5)
5	Injection return (same as 4)

**Table 13:** *Rotor injection and IED connection X81*

No	Signal
1	Block injection, 220V binary in
2	Block injection, 110V binary in
3	Block injection, 48V binary in
4	Block injection, Common binary in
5	Injection Blocked NC binary out
6	Voltage/Current Saturation NO binary out
7	Common binary out
8	Voltage A, analog out
9	Voltage B analog out
10	Current A analog out
11	Current B analog out
12	Voltage sense A
13	Voltage sense B
14	Current sense A (same as 16)
15	Current sense B
16	Current sense A (same as 14)
17	-
18	-

**Table 14:** *Rotor injection connection X82*

No	Signal
1	Injection (same as 3)
2	Injection, inside shunt resistor
3	Injection (same as 1)
4	Injection return (same as 5)
5	Injection return (same as 4)

Connect each signal connector terminal of screw compression type with one 0.5 to 2.5 mm<sup>2</sup> wire or with two 0.5 to 1.0 mm<sup>2</sup> wires.

Grounding (PE), protective earth is a separate 4 mm screw terminal, as a part of the metallic chassis.

### REX061 Capacitor unit connections

*Table 15: Injection and rotor connection X1*

No	Signal
1	Rotor positive pole
2	-
3	Positive pole
4	-
5	Negative pole
6	-
7	Rotor negative pole
8	-
9	Rotor injection
10	Injection ground. Internally connected to chassis and PE

*Table 16: Measurement connector X2*

No	Signal
1	Rotor + voltage divided by 1 000
2	Ground
3	Rotor - voltage divided by 1 000

X1 connector. Connect each signal connector terminal of screw compression type with one 0.14 to 6 mm<sup>2</sup> wire or with two 0.14 to 1.5 mm<sup>2</sup> wires.

X2 connector. Connect each signal connector terminal of screw compression type with one 0.5 to 2.5 mm<sup>2</sup> wire or with two 0.5 to 1.0 mm<sup>2</sup> wires.

Grounding (PE). Protective earth is a separate 4 mm screw terminal.

## REX062 Shunt resistor unit connections

*Table 17: Injection via shunt resistors connection X1*

No	Signal
1	-
2	Injection
3	-
4	Injection return
5	-
6	Current sense output
7	-
8	Current sense output
9	Injection input, External shunt
10	Injection input return, External shunt

X1 connector. Connect each signal connector terminal of screw compression type with one 0.14 to 6 mm<sup>2</sup> wire or with two 0.14 to 1.5 mm<sup>2</sup> wires.

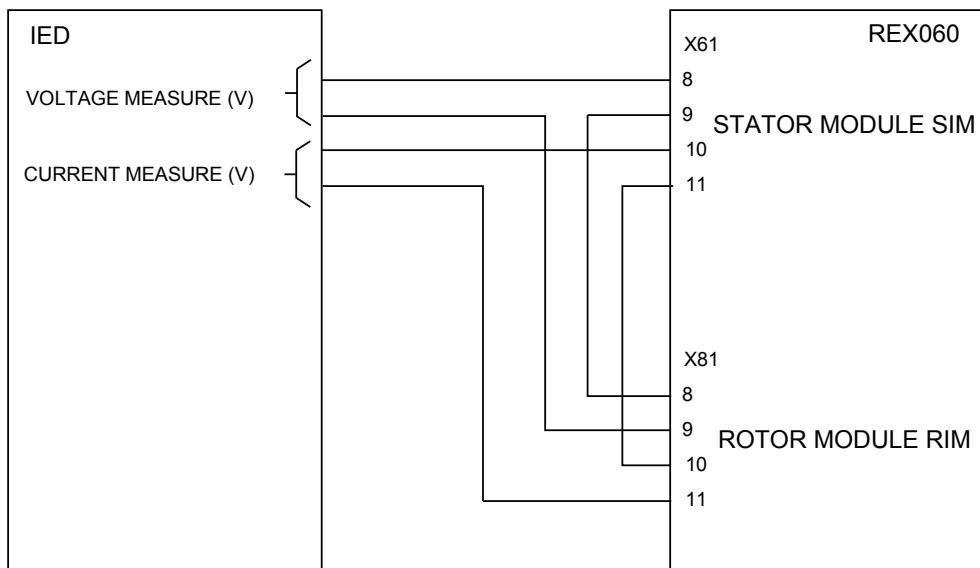
Grounding (PE). Protective earth is a separate 4 mm screw terminal.

### 5.5.3

## Connecting and setting voltage inputs

There are two different methods for connecting the IED to the REX060 injection unit if both stator and rotor protection is used, either using two analog input channels on the IED for both rotor and stator voltage and current measurements, or two analog IED input channels for the rotor and another two IED channels for the stator measurements.

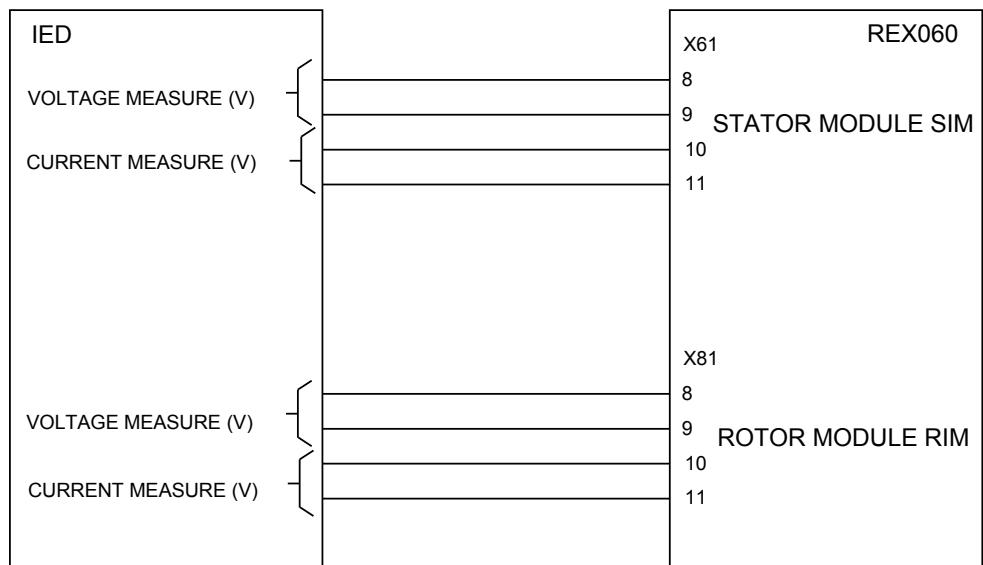
1. The same voltage input is used for both stator and rotor voltage measurement and another voltage input is used for both stator and rotor current measurement. The REX060 outputs to IED are connected in series.



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*Figure 51: Connection to IED with two analogue voltage inputs*

2. Two different voltage inputs are used for stator and rotor voltage measurement and two other voltage inputs are used for stator and rotor current measurement. This means that the inputs for STTIPHIZ (64S) is separated from the inputs for ROTIPHIZ (64R).



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*Figure 52: Separate analogue inputs for stator STTIPHIZ (64S) and rotor ROTIPHIZ (64R) protection*

If sufficient number of analog voltage inputs are available in IED, alternative 2 with separate inputs for STTIPHIZ (64S) and ROTIPHIZ (64R) is recommended.

Some settings are required for the analog voltage inputs. Set the voltage ratio for the inputs to 1/1, for example, VTSecx = 100 V VTPrimx = 0.1 kV

The analogue inputs are linked to a pre-processor block in the Signal Matrix Tool. This pre-processor block must have the same cycle time, 8 ms, as the function blocks for STTIPHIZ (64S) and ROTIPHIZ (64R).

The default parameter settings are used for the pre-processor block.

Note that it is possible to connect two REG670 in parallel to the REX060 injection unit in order to obtain redundant measurement in two separate IEDs. However, at commissioning both REG670 IEDs must be connected during calibration procedure.



It is of outmost importance that REX060, REX061 and REX062 chassis are all solidly grounded. Grounding (PE), protective ground is a separate 4 mm screw terminal, as a part of the metallic chassis.

## 5.6 Making the optical connections

### 5.6.1 Connecting station communication interfaces

The IED can be equipped with an optical ethernet module (OEM), see figure [26](#), needed for IEC 61850 communication and a serial communication module (SLM), see figure [26](#) for LON, SPA, IEC 60870-5-103 or DNP3 communication. In such cases optical ports are provided on the rear side of the case for connection of the optical fibers. For location of OEM and SLM, refer to section "[Rear side connectors](#)".

- Optical ports X311: A, B (Tx, Rx) and X311: C, D (Tx, Rx) on OEM are used for IEC 61850-8-1 communication. Both ports AB and CD shall be connected when redundant IEC 61850-8-1 communication is used. Connectors are of ST type. When OEM is used, the protection plate for the galvanic connection must not be removed.
- Optical port X301: A, B (Tx, Rx) on SLM module is used for SPA, IEC 60870-5-103 or DNP3 communication. Connectors are of ST type (glass) or HFBR Snap in (plastic).
- Optical port X301: C, D (Tx, Rx) on SLM module is used for LON communication. Connectors are of ST type (glass) or HFBR Snap in (plastic).

The optical fibers have Transmission (Tx) and Reception (Rx) connectors, and they should be attached to the Tx and Rx connectors of OEM and SLM module (Tx cable to Rx connector, Rx cable to Tx connector).

Connectors are generally color coded; connect blue or dark grey cable connectors to blue or dark grey (receive) back-side connectors. Connect black or grey cable connectors to black or grey (transmit) back-side connectors.



The fiber optical cables are very sensitive to handling. Do not bend too sharply. The minimum curvature radius is 15 cm for the plastic fiber cables and 25 cm for the glass fiber cables. If cable straps are used to fix the cables, apply with loose fit.

Always hold the connector, never the cable, when connecting or disconnecting optical fibers. Do not twist, pull or bend the fiber. Invisible damage may increase fiber attenuation thus making communication impossible.



Please, strictly follow the instructions from the manufacturer for each type of optical cables/connectors.

## 5.6.2

## Connecting remote communication interfaces LDCM

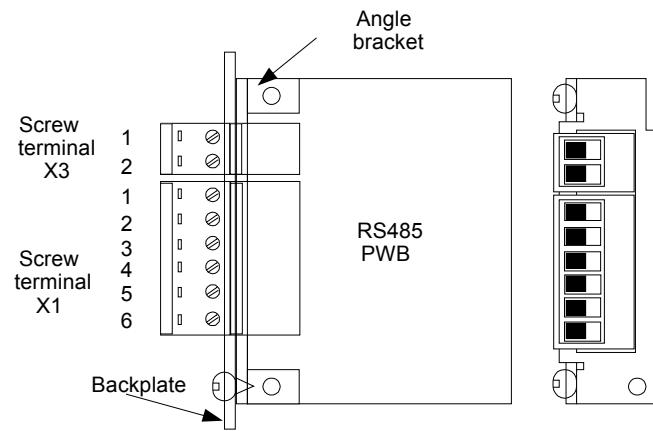
The Line Data Communication Module (LDCM), see figure [26](#) is the hardware used for the transfer of binary and analog signal data between IEDs in different protection schemes on the IEEE/ANSI C37.94 protocol. The optical ports on the rear side of the IED are X312 and X313. For location of LDCM, refer to section ["Rear side connectors"](#).

## 5.7

## Installing the serial communication cable for RS485

### 5.7.1

### RS485 serial communication module



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*Figure 53: The connection plate to the backplate with connectors and screws. This figure also shows the pin numbering from the component side*

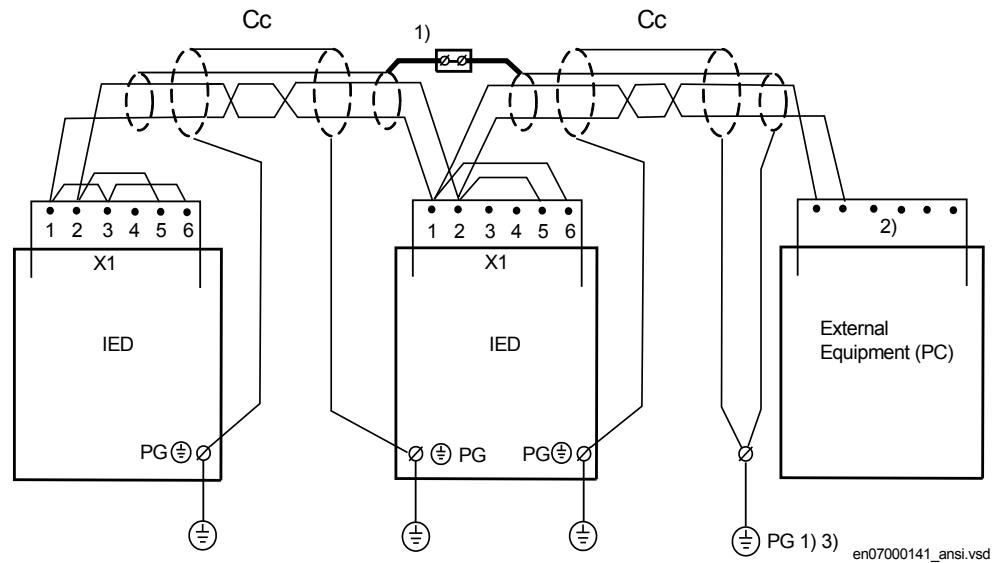
Pin	Name 2-wire	Name 4-wire	Description
x3:1			soft ground
x3:2			soft ground
x1:1	RS485 +	TX+	Receive/transmit high or transmit high
x1:2	RS485 –	TX-	Receive/transmit low or transmit low
x1:3	Term	T-Term	Termination resistor for transmitter (and receiver in 2-wire case) (connect to TX+)

Table continues on next page

Pin	Name 2-wire	Name 4-wire	Description
x1:4	reserved	R-Term	Termination resistor for receiver (connect to RX +)
x1:5	reserved	RX-	Receive low
x1:6	reserved	RX+	Receive high
2-wire:	Connect pin X1:1 to pin X1:6 and pin X1:2 to pin X1:5.		
Termination (2-wire):	Connect pin X1:1 to pin X1:3		
Termination (4-wire):	Connect pin X1:1 to pin X1:3 and pin X1:4 to pin X1:6		

The distance between ground points should be < 1200 m (3000 ft), see figure [54](#) and [55](#). Only the outer shielding is connected to the protective ground at the IED. The inner and outer shieldings are connected to the protective ground at the external equipment. Use insulating tape for the inner shield to prevent contact with the protective ground. Make sure that the terminals are properly grounded with as short connections as possible from the ground screw, for example to an grounded frame.

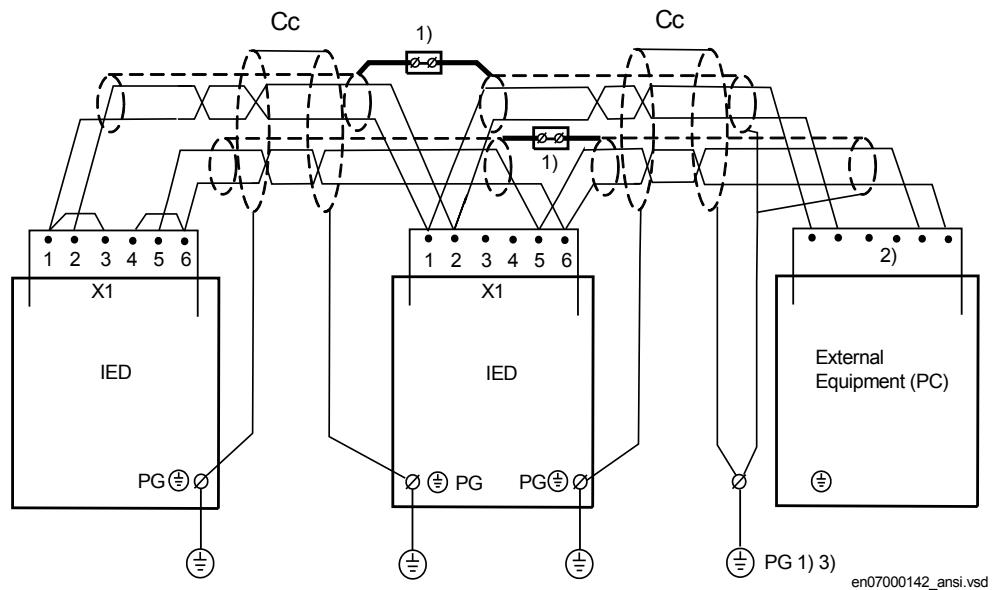
The IED and the external equipment should preferably be connected to the same battery.



*Figure 54: Communication cable installation, 2-wire*

Where:

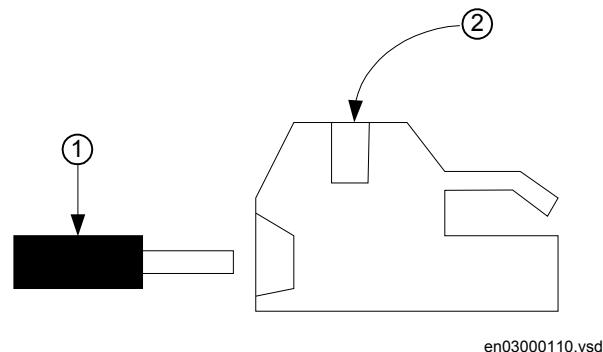
- 1 The inner shields shall be connected together (with an isolated terminal block) and only have **one grounding point** in the whole system, preferably at the external equipment (PC).  
The outer shield shall be connected to Protective Ground (PG) in every cable end that is, to PG at all IED terminals and to PG at External equipment (PC). The first IED will have only one cable end but all others of course two.
  - 2 Connect according to installation instructions for the actual equipment, observe the 120 ohms termination.
  - 3 The protective ground should be close to the external equipment (< 2m)
- Cc      Communication cable  
PE      Protective ground screw



*Figure 55: Communication cable installation, 4-wire*

Where:

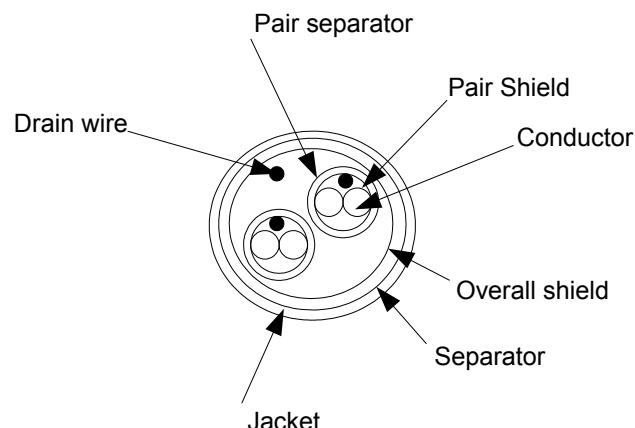
- 1 The inner shields shall be connected together (with an isolated terminal block) and only have **one grounding point** in the whole system, preferably at the external equipment (PC).  
The outer shield shall be connected to Protective Ground (PG) in every cable end that is, to PG at all IED terminals and to PG at External equipment (PC). The first IED will have only one cable end but all others of course two.
  - 2 Connect according to installation instructions for the actual equipment, observe the 120 ohms termination.
  - 3 The protective ground should be close to the external equipment (< 2m)
- Cc      Communication cable  
PG      Protective ground screw



*Figure 56: Cable contact, Phoenix: MSTB2.5/6-ST-5.08 1757051*

Where:

- 1      is cable
- 2      is screw



*Figure 57: Cross section of communication cable*

The EIA standard RS-485 specifies the RS485 network. An informative excerpt is given in section ["Installing the serial communication cable for RS485 SPA/IEC"](#).

## 5.7.2

### Installing the serial communication cable for RS485 SPA/IEC

*Informative excerpt from EIA Standard RS-485 - Electrical Characteristics of Generators and Receivers for Balanced Digital Multipoint Systems*

### RS-485 Wire - Media dependent Physical layer

#### 1 Normative references

EIA Standard RS-485 - Electrical Characteristics of Generators and Receivers for Balanced Digital Multipoint Systems

#### 2 Transmission method

RS-485 differential bipolar signaling

##### 2.1 Differential signal levels

Two differential signal levels are defined:

**A+** =line A positive with respect to line B

**A-** =line A negative with respect to line B

##### 2.2 Galvanic isolation

The RS485 circuit shall be isolated from ground by:

$R_{iso} \geq 10 \text{ M}\Omega$

$C_{iso} \leq 10 \text{ pF}$

Three isolation options exist:

- a) The entire node electronics can be galvanically isolated
- b) The bus interface circuit can be isolated form the rest of node electronics by optoisolators, transformer coupling or otherwise.
- c) The RS485 chip can include built-in isolation

##### 2.3 Bus excitation and signal conveyance

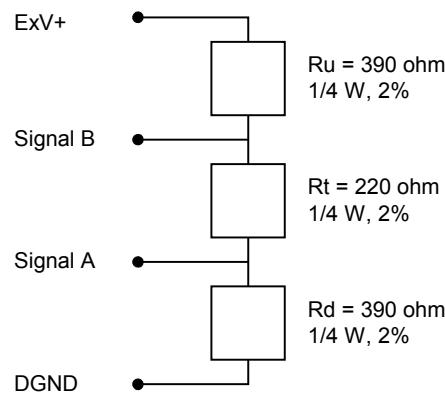
###### 2.3.1 Requirements

- a) The RS485 specification requires the Signal A and Signal B wires.
- b) Each node also requires (5 V) Excitation of the RS485 termination network.
- c)  $V_{im}$  - the common mode voltage between any pair of RS485 chips may not exceed 10 V.
- d) A physical ground connection between all RS485 circuits will reduce noise.

###### 2.3.2 Bus segment termination network

The termination network below required at each end of each Bus Ph-segment.

Table continues on next page



ExV is supplied by the Node at end of the Bus Segment

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*Figure 58: RS-485 bus segment termination*

ExV is supplied by the Node at end of the Bus Segment

The specifications of the components are:

- a)  $R_u$       + 5 V to Signal B      =  $390 \Omega, 0.25 \text{ W} \pm 2.5\%$
- b)  $R_t$       Signal B to Signal A      =  $220 \Omega, 0.25 \text{ W} \pm 2.5\%$
- c)  $R_d$       Signal A to GND      =  $390 \Omega, 0.25 \text{ W} \pm 2.5\%$

### 2.3.3 Bus power distribution

The end node in each Ph-segment applies 5 V bus excitation power to the Termination network via the Excitation pair ( $\text{ExV}+$  and GND) used in the Type 3 Physical layer specification.

## 5.7.3

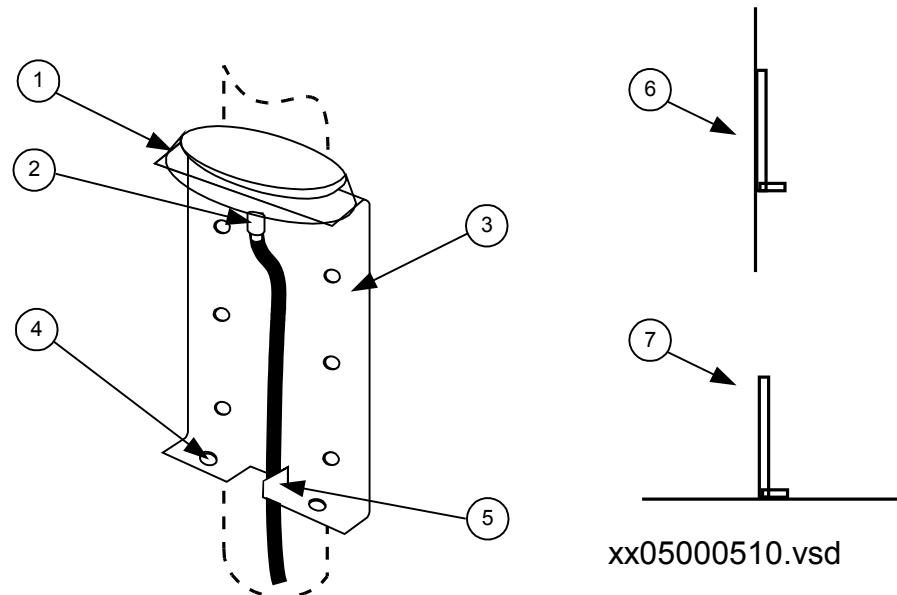
### Data on RS485 serial communication module cable

<b>Type:</b>	Twisted-pair S-STP (Screened – Screened Twisted Pair)
<b>Shield:</b>	Individual foil for each pair with overall copper braid
<b>Length:</b>	Maximum 1200 m (3000 ft) from one system ground to the next system ground (includes length from platform point to system ground on both sides)
<b>Temp:</b>	According to application
<b>Impedance:</b>	$120 \Omega$
<b>Capacitance:</b>	Less than or equal to 42 pF/m
<b>Example:</b>	Belden 9841, Alpha wire 6412, 6413

## 5.8 Installing the GPS antenna

### 5.8.1 Antenna installation

The antenna is mounted on a console for mounting on a horizontal or vertical flat surface or on an antenna mast.

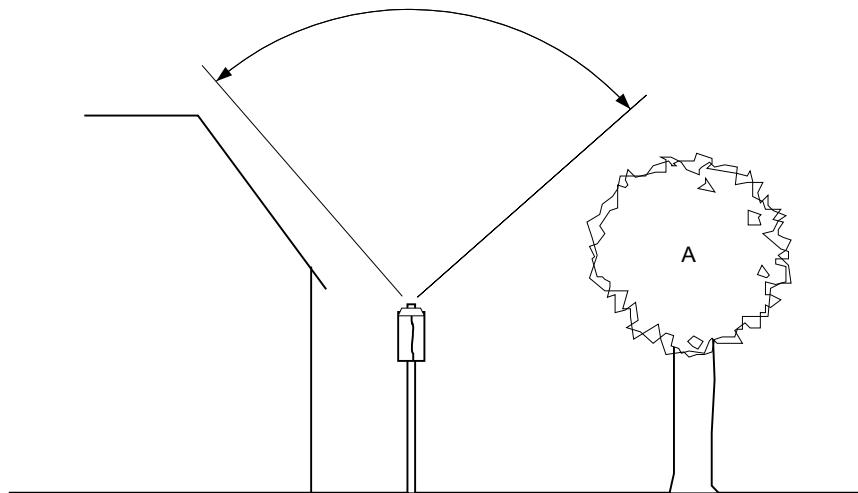


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PosNO	Description
1	GPS antenna
2	TNC connector
3	Console, 78x150 mm
4	Mounting holes 5.5 mm
5	Tab for securing of antenna cable
6	Vertical mounting position (on antenna mast etc.)
7	Horizontal mounting position

Mount the antenna and console clear of flat surfaces such as buildings walls, roofs and windows to avoid signal reflections. If necessary, protect the antenna from animals and birds which can affect signal strength. Also protect the antenna against lightning.

Always position the antenna and its console so that a continuous clear line-of-sight visibility to all directions is obtained, preferably more than 75%. A minimum of 50% clear line-of-sight visibility is required for un-interrupted operation.



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*Figure 59: Antenna line-of-sight*

### 5.8.2 Electrical installation

Use a 50 ohm coaxial cable with a male TNC connector on the antenna end and a male SMA connector on the receiver end to connect the antenna to the IED. Choose cable type and length so that the total attenuation is max. 26 dB at 1.6 GHz. A suitable antenna cable is supplied with the antenna.

The antenna has a female TNC connector to the antenna cable. For location of GPS time module (GTM), refer to section "["Rear side connectors"](#)". Connection diagram for GTM is shown in figure [26](#).



Make sure that the antenna cable is not charged when connected to the antenna or to the receiver. Short-circuit the end of the antenna cable with some metal device, then connect to the antenna. When the antenna is connected to the cable, connect the cable to the receiver. The IED must be switched off when the antenna cable is connected.

### **5.8.3**

### **Lightning protection**

The antenna should be mounted with adequate lightning protection, that is the antenna mast must not rise above a neighboring lightning conductor.

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## Section 6

# Checking the external optical and electrical connections

### About this chapter

This chapter describes what to check to ensure correct connection to the external circuitry, such as the auxiliary power supply, CT's and VT's. These checks must be made with the protection IED de-energized.

## 6.1

### Overview

The user must check the installation which includes verifying that the IED is connected to the other parts of the protection system. This is done with the IED and all connected circuits de-energized.

## 6.2

### Checking VT circuits

Check that the wiring is in strict accordance with the supplied connection diagram.



Correct possible errors before continuing to test the circuitry.

Test the circuitry.

- Polarity check
- VT circuit voltage measurement (primary injection test)
- Grounding check
- Phase relationship
- Insulation resistance check

The polarity check verifies the integrity of circuits and the phase relationships. The check must be performed as close to the IED as possible.

The primary injection test verifies the VT ratio and the wiring all the way from the primary system to the IED. Injection must be performed for each phase-to-neutral

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circuit and each phase-to-phase pair. In each case, voltages in all phases and neutral are measured.

## 6.3

## Checking CT circuits



Check that the wiring is in strict accordance with the supplied connection diagram.

The CTs must be connected in accordance with the circuit diagram provided with the IED, both with regards to phases and polarity. The following tests shall be performed on every primary CT connected to the IED:

- Primary injection test to verify the current ratio of the CT, the correct wiring up to the protection IED and correct phase sequence connection (that is A, B, C.)
- Polarity check to prove that the predicted direction of secondary current flow is correct for a given direction of primary current flow. This is an essential test for the proper operation of the differential function.
- CT secondary loop resistance measurement to confirm that the current transformer secondary loop DC resistance is within specification and that there are no high resistance joints in the CT winding or wiring.
- CT excitation test in order to confirm that the current transformer is of the correct accuracy rating and that there are no shorted turns in the current transformer windings. Manufacturer's design curves must be available for the current transformer to compare the actual results.
- Grounding check of the individual CT secondary circuits to verify that each three-phase set of main CTs is properly connected to the station ground and only at one electrical point.
- Insulation resistance check.
- Phase identification of CT shall be made.



Both the primary and the secondary sides must be disconnected from the line and the IED when plotting the excitation characteristics.



If the CT secondary circuit ground connection is removed without the current transformer primary being de-energized, dangerous voltages may result in the secondary CT circuits.

## 6.4 Checking the power supply

Check that the auxiliary supply voltage remains within the permissible input voltage range under all operating conditions. Check that the polarity is correct before powering the IED.

## 6.5 Checking the binary I/O circuits

### 6.5.1 Binary input circuits

Preferably, disconnect the binary input connector from the binary input cards. Check all connected signals so that both input level and polarity are in accordance with the IED specifications.

### 6.5.2 Binary output circuits

Preferably, disconnect the binary output connector from the binary output cards. Check all connected signals so that both load and polarity are in accordance with IED specifications.

## 6.6 Checking optical connections

Check that the Tx and Rx optical connections are correct.



An IED equipped with optical connections requires a minimum depth of 180 mm (7.2 inches) for plastic fiber cables and 275 mm (10.9 inches) for glass fiber cables. Check the allowed minimum bending radius from the optical cable manufacturer.



## Section 7      Energizing the IED and REX060

### About this chapter

This chapter describes the start-up sequence and what to check once the IED has been energized.

### 7.1      Checking the IED operation

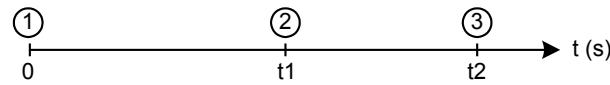
Check all connections to external circuitry to ensure correct installation, before energizing the IED and carrying out the commissioning procedures.

The user could also check the software version, the IED's serial number and the installed modules and their ordering number to ensure that the IED is according to delivery and ordering specifications.

Energize the power supply of the IED to pickup. This could be done in a number of ways, from energizing a whole cubicle to energizing a single IED. The user should re-configure the IED to activate the hardware modules in order to enable the self supervision function to detect possible hardware errors. Set the IED time if no time synchronization source is configured. Check also the self-supervision function in **Main menu/Diagnostics/Monitoring** menu in local HMI to verify that the IED operates properly.

### 7.2      Energizing the IED

When the IED is energized, the green LED starts flashing instantly. After approximately 55 seconds the window lights up and the window displays 'IED Startup'. The main menu is displayed and the upper row should indicate 'Ready' after about 90 seconds. A steady green light indicates a successful startup.



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Figure 60: Typical IED start-up sequence

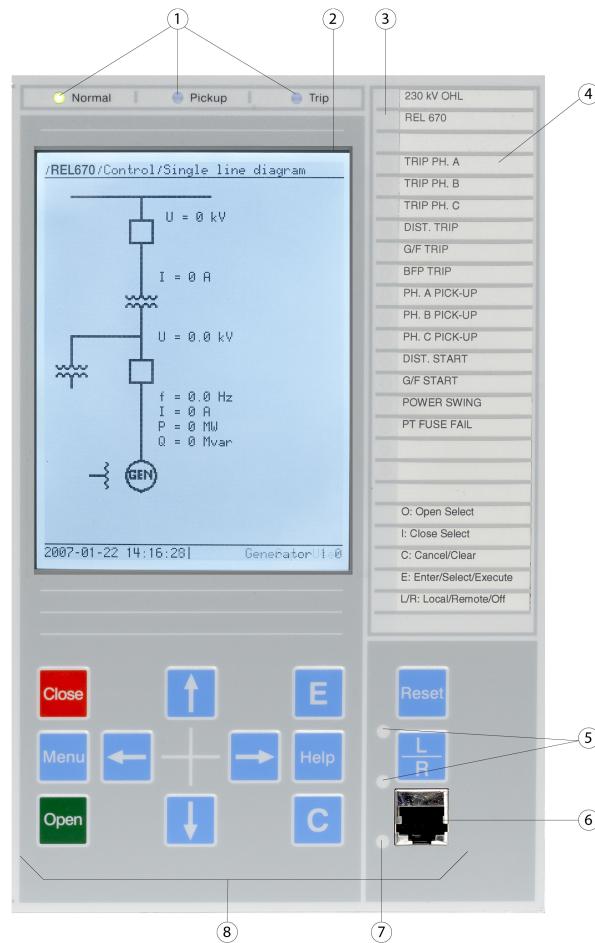
- 1 IED energized. Green LED instantly starts flashing
- 2 LCD lights up and "IED startup" is displayed
- 3 The main menu is displayed. A steady green light indicates a successful startup.

If the upper row in the window indicates 'Fail' instead of 'Ready' and the green LED flashes, an internal failure in the IED has been detected. See section "[Checking the self supervision function](#)" in this chapter to investigate the fault.

An example of the local HMI is shown in figure 61.

## 7.3 Design

The different parts of the medium size local HMI are shown in figure 61. The local HMI exists in an IEC version and in an ANSI version. The difference is on the keypad operation buttons and the yellow LED designation.



*Figure 61: Medium size graphic HMI*

- 1 Status indication LEDs
- 2 LCD
- 3 Indication LEDs
- 4 Label
- 5 Local/Remote LEDs
- 6 RJ45 port
- 7 Communication indication LED
- 8 Keypad

## 7.4 Checking the self supervision signals

### 7.4.1 Reconfiguring the IED

I/O modules configured as logical I/O modules (BIM, BOM or IOM) are supervised.

I/O modules that are not configured are not supervised.

Each logical I/O module has an error flag that indicates signal or module failure. The error flag is also set when the physical I/O module of the correct type is not detected in the connected slot.

### 7.4.2 Setting the IED time

This procedure describes how to set the IED time from the local HMI.

1. Display the set time dialog.  
Navigate to **Main menu/Settings/Time/System time**  
Press the *E* button to enter the dialog.
2. Set the date and time.  
Use the *Left* and *Right* arrow buttons to move between the time and date values (year, month, day, hours, minutes and seconds). Use the *Up* and *Down* arrow buttons to change the value.
3. Confirm the setting.  
Press the *E* button to set the calendar and clock to the new values.

### 7.4.3 Checking the self supervision function

#### 7.4.3.1 Determine the cause of an internal failure

This procedure describes how to navigate the menus in order to find the cause of an internal failure when indicated by the flashing green LED on the HMI module.

Procedure

1. Display the general diagnostics menu.  
Navigate the menus to:  
**Diagnostics/IED status/General**
2. Scroll the supervision values to identify the reason for the failure.  
Use the arrow buttons to scroll between values.

## 7.4.4

### Self supervision HMI data

*Table 18: Signals from the General menu in the diagnostics tree.*

Indicated result	Possible reason	Proposed action
InternFail OK	No problem detected.	None.
InternFail Fail	A failure has occurred.	Check the rest of the indicated results to find the fault.
InternWarning OK	No problem detected.	None.
InternWarning Warning	A warning has been issued.	Check the rest of the indicated results to find the fault.
NUM-modFail OK	No problem detected.	None.
NUM-modFail Fail	The main processing module has failed.	Contact your ABB representative for service.
NUM-modWarning OK	No problem detected.	None.
NUM-modWarning Warning	There is a problem with: • the real time clock. • the time synchronization.	Set the clock. If the problem persists, contact your ABB representative for service.
ADC-module OK	No problem detected.	None.
ADC-module Fail	The AD conversion module has failed.	Contact your ABB representative for service.
CANP 9 BIM1 Fail	IO module has failed.	Check that the IO module has been configured and connected to the IOP1- block. If the problem persists, contact your ABB representative for service.
RealTimeClock OK	No problem detected.	None.
RealTimeClock Warning	The real time clock has been reset.	Set the clock.
TimeSync OK	No problem detected.	None.
TimeSync Warning	No time synchronization.	Check the synchronization source for problems. If the problem persists, contact your ABB representative for service.

## 7.5

### REX060 start up sequence

When the injection unit REX060 is energized, the ABB logotype is shown followed by current REX060 revision status. When the start up sequence is completed, the main menu (normal display content) is shown. The duration of the start up sequence is a few seconds.



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## Section 8

# Set up the PCM600 communication link per IED

### About this chapter

This chapter describes the communication between the IED and PCM600.

## 8.1

### Setting up communication between PCM600 and the IED

The communication between the IED and PCM600 is independent of the communication protocol used within the substation or to the NCC.

The communication media is always Ethernet and the used protocol is TCP/IP.

Each IED has an RJ-45 Ethernet interface connector on the front. The front Ethernet connector shall be used for communication with PCM600.

When an Ethernet-based station protocol is used, PCM600 communication can use the same Ethernet port and IP address.

To connect PCM600 to the IED, two basic variants must be considered.

- Direct point-to-point link between PCM600 and the IED front port. The front port can be seen as a service port.
- Indirect link via a station LAN or from remote via a network.

The physical connection and the IP address must be configured in both cases to enable communication.

The communication procedures are the same in both cases.

1. If needed, set the IP address for the IEDs.
2. Set up the PC or workstation for a direct link (point-to-point), or
3. Connect the PC or workstation to the LAN/WAN network.
4. Configure the IED IP addresses in the PCM600 project for each IED to match the IP addresses of the physical IEDs.

#### Setting up IP addresses

The IP address and the corresponding mask must be set via the LHMI for each available Ethernet interface in the IED. Each Ethernet interface has a default factory IP address when the IED is delivered. This is not given when an additional Ethernet interface is installed or an interface is replaced.

- The default IP address for the IED front port is 10.1.150.3 and the corresponding subnet mask is 255.255.255.0, which can be set via the local HMI path **Main menu/Settings/General settings/Communication/Ethernet configuration/Front port**.
- The default IP address for the IED rear port is 192.168.1.10 and the corresponding subnet mask is 255.255.255.0, which can be set via the local HMI path **Main menu/Settings/General settings/Communication/Ethernet configuration/Rear OEM - port AB and Rear OEM - port CD**.



The front and rear port IP addresses cannot belong to the same subnet or communication will fail. It is recommended to change the IP address of the front port, if the front and rear port are set to the same subnet.

#### Setting up the PC or workstation for point-to-point access to IEDs front port

A special cable is needed to connect two physical Ethernet interfaces together without a hub, router, bridge or switch in between. The Tx and Rx signal wires must be crossed in the cable to connect Tx with Rx on the other side and vice versa. These cables are known as cross over cables. The maximum length should be about 2 m. The connector type is RJ-45.

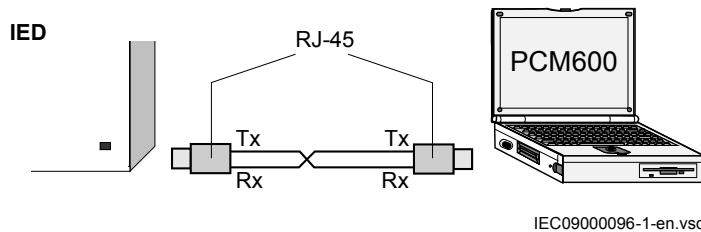


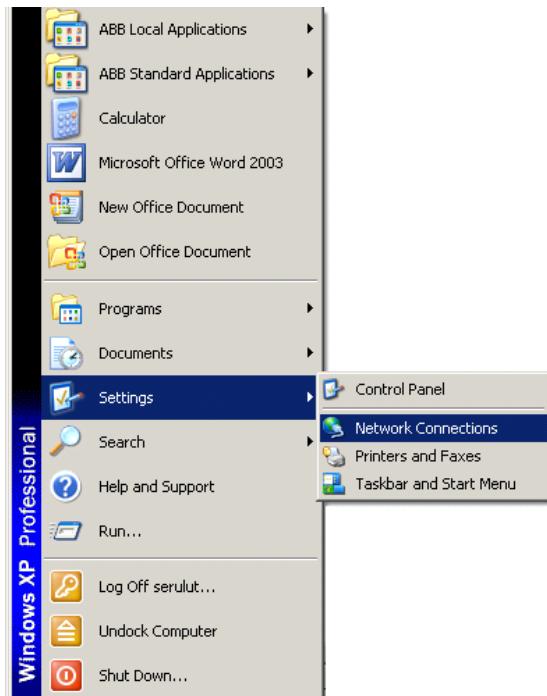
Figure 62: Point-to-point link between IED and PCM600 using a null-modem cable

The following description is an example valid for standard PCs using Microsoft Windows operating system. The example is taken from a Laptop with one Ethernet interface.



Administrator rights are required to change the PC communication setup. Some PCs have the feature to automatically detect that Tx signals from the IED are received on the Tx pin on the PC. Thus, a straight (standard) Ethernet cable can be used.

1. Select **Network Connections** in the PC.



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Figure 63: Select: Network connections

2. Select **Properties** in the status window.



Figure 64: Right-click Local Area Connection and select Properties

3. Select the TCP/IP protocol from the list of configured components using this connection and click **Properties**.

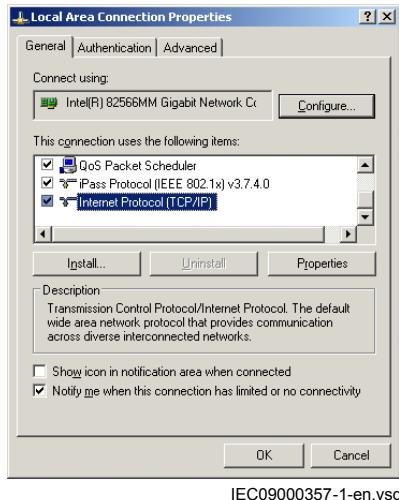
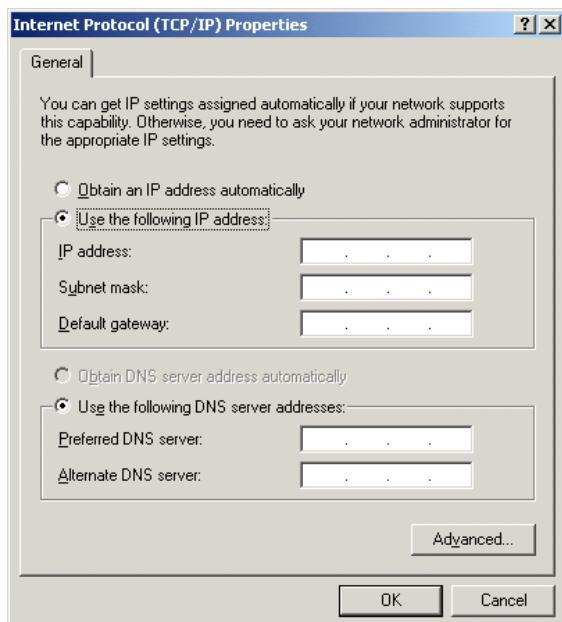


Figure 65: Select the TCP/IP protocol and open Properties

4. Select **Use the following IP address** and define *IP address* and *Subnet mask* if the front port is used and if the *IP address* is not set to be obtained automatically by the IED, see [Figure 66](#). The IP address must be different from the IP address chosen for the IED.



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*Figure 66: Select: Use the following IP address*

5. Use the *ping* command to verify connectivity with the IED.
6. Close all open windows and start PCM600.

#### **Setting up the PC to access the IED via a network**

This task depends on the used LAN/WAN network.



The PC and IED must belong to the same subnetwork for this set-up to work.



## Section 9

# Configuring the IED and changing settings

### About this chapter

This chapter describes how to change IED settings, either through a PC or the local HMI, and download a configuration to the IED in order to make commissioning possible.

The chapter does not contain instructions on how to create a configuration or calculate settings. Please consult the application manual for further information about how to calculate settings.

## 9.1

### Overview

The customer specific values for each setting parameter and a configuration file have to be available before the IED can be set and configured, if the IED is not delivered with a configuration.

Use the configuration tools in PCM600 to verify that the IED has the expected configuration. A new configuration is done with the application configuration tool. The binary outputs can be selected from a signal list where the signals are grouped under their function names. It is also possible to specify a user-defined name for each input and output signal.

Each function included in the IED has several setting parameters, which have to be set in order to make the IED behave as intended. A factory default value is provided for each parameter. A setting file can be prepared using the Parameter Setting tool, which is available in PCM600.

All settings can be

- Entered manually through the local HMI.
- Written from a PC, either locally or remotely using PCM600. Front or rear port communication has to be established before the settings can be written to the IED.



It takes a minimum of three minutes for the IED to save the new settings, during this time the DC supply must not be turned off.

The IED uses a FLASH disk for storing configuration data and process data like counters, object states, Local/Remote switch position etc. Since FLASH memory is

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used, measures have been taken in software to make sure that the FLASH disk is not worn out by too intensive storing of data. These mechanisms make it necessary to think about a couple of issues in order to not loose configuration data, especially at commissioning time.

After the commissioning is complete, the configuration data is always stored to FLASH, so that is not an issue. But other things, like objects states and the Local/Remote switch position is stored in a slightly different way, where the save of data to FLASH is performed more and more seldom to eliminate the risk of wearing out the FLASH disk. In worst case, the time between saves of this kind of data is around one hour.

This means, that to be absolutely sure that all data have been saved to FLASH, it is necessary to leave the IED with auxiliary power connected after all the commissioning is done (including setting the Local/Remote switch to the desired position) for at least one hour after the last commissioning action performed on the IED.

After that time has elapsed, it will be safe to turn the IED off, no data will be lost.

## 9.2 Entering settings through the local HMI

### Procedure

1. Set each function included in the IED in the local HMI.
2. Browse to the function to be set and enter the appropriate value.
3. Find the parameters for each function in the local HMI

The operator's manual is structured in a similar way to the local HMI and provides a detailed guide to the use of the local HMI including paths in the menu structure and brief explanations of most settings and measurements. See the technical reference manual for a complete list of setting parameters for each function. Some of the included functions may not be used. In this case the user can set the parameter *Operation = Disabled* to disable the function.

## 9.3 Configuring analog CT inputs

The analog input channels must be configured to get correct measurement results as well as correct protection functionality. Because all protection algorithms in the IED utilize the primary system quantities, it is extremely important to make sure that connected current transformer settings are done properly. These data are calculated by

the system engineer and normally set by the commissioning personnel from the local HMI or from PCM600.

The analog inputs on the transformer input module are dimensioned for either 1A or 5A. Each transformer input module has a unique combination of current and voltage inputs. Make sure the input current rating is correct and that it matches the order documentation.

The primary CT data are entered via the HMI menu under **Main menu/Settings/General Settings/Analog modules/AnalogInputs**

The following parameter shall be set for every current transformer connected to the IED:

*Table 19: CT configuration*

Parameter description	Parameter name	Range	Default
Rated CT primary current in A	CT Prim Input	from -10000 to +10000	0

This parameter defines the primary rated current of the CT. For two set of CTs with ratio 1000/1 and 1000/5 this parameter is set to the same value of 1000 for both CT inputs. Negative values (that is -1000) can be used in order to reverse the direction of the CT current by software for the differential function. This might be necessary if two sets of CTs have different neutral (WYE) point locations in relation to the protected busbar. It is recommended that this parameter is set to zero, for all unused CT inputs.

For main CTs with 2A rated secondary current, it is recommended to connect the secondary wiring to the 1A input and to set the rated primary current to one half times its true value. For example, a CT with a primary secondary current ratio of 1000/2A can be treated as a 500/1A CT.



Take the rated permissive overload values for the current inputs into consideration.

## 9.4

## Writing settings and configuration from a PC

### 9.4.1

### Writing an application configuration to the IED

When writing a configuration to the IED with the application configuration tool, the IED is automatically set in configuration mode. When the IED is set in configuration mode, all functions are blocked. The red LED on the IED flashes, and the green LED is lit while the IED is in the configuration mode.

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When the configuration is written and completed, the IED is automatically set into normal mode. For further instructions please refer to the users manuals for PCM600.

## Section 10

# Calibrating injection based sensitive rotor earth fault protection

### 10.1

## Commissioning process

The commissioning process utilizes the commissioning tool ICT. The instructions for the process cover installation, calibration, commissioning, monitoring and auditing for the sensitive rotor earth fault ROTIPHIZ (64R) function.

### 10.2

## Commissioning tool ICT

The sensitive rotor earth fault protection function in IED require a number of settings. The settings  $k1$ ,  $k2$  and the reference impedance require measurements on the generator performed by the ICT (injection commissioning tool). The factors are derived in connection to the calibration measurements during commissioning. ICT is an integrated part of the PCM600 tool.

Furthermore, ICT also assists the commissioning engineer to perform a successful installation because of its structure and validating capabilities. During installation, commissioning and calibration, ICT performs various tests to verify that the installation is acceptable and the calibration successful. Besides carrying out the actual tests, ICT also provides the commissioning engineer with tips if needed during the commissioning.

When ICT is started, rotor earth fault protection is chosen.

There are five different parts of the ICT tool to be performed at commissioning and operation:

1. Installing
2. Calibrating
3. Commissioning
4. Monitoring
5. Auditing

Before proceeding make sure that all necessary connections are in place.

## Installing

When the injection is started, check that the injected voltage and current are within the permissible limits. If not, adjust the settings in the injection unit REX060. The ICT tool will check automatically for slight differences between actual injected and set injection frequency (for example, due to accuracy of the REX060 hardware). Set manually the actual frequency value measured by ICT in the IED via PST.

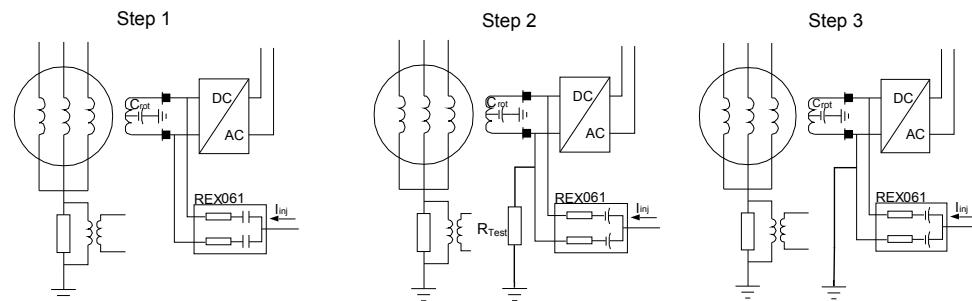
The high accuracy of this frequency is essential for proper operation of the protection under different operating conditions.

## Calibrating

The calibration is based on three measurement steps:

1. The injection is made to the faultless generator and the measured complex impedance is stored.
2. A known resistance is connected between the generator neutral point and ground. The injection is made to the generator and the measured complex impedance is stored.
3. The generator neutral point is directly short-circuited to the ground. The injection is made to the generator and the measured complex impedance is stored.

The sequence of the commissioning calibration measurements is shown in the figure below.



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*Figure 67: Different steps at calibration measurements*

The sequence of the calibration session follows a scheme shown in the tool.

- Calibration sequence 1: The injection must be activated and the rotor must be left with no impedance connected. The ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in

a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.

- Calibration sequence 2: A known resistor is connected between the rotor winding and ground. The value of the resistance is the input to ICT. The ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.
- Calibration sequence 3: The ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.

After the three measurements ICT calculates the complex factors  $k1$  and  $k2$ . The reference impedance  $RefRI + jRefXI$  is also calculated. After this the values are downloaded to the parameter setting in PCM600. From PCM600 the settings are downloaded to IED.

During the three measurements described above a check is made that there are sufficient changes in the measured impedance in order to guarantee that there is no primary fault from the beginning or other problems due to the installation or calibration procedure.

Now the reference impedance is derived for one operational state. It might be necessary to make measurements to derive reference impedance for other operational cases. For information on this, see Commissioning below.

### **Commissioning**

There is a possibility to have two different reference impedances. The need to change the reference impedance is due to different operating conditions of the machine.

In the commissioning part of ICT this can be done. For each operation state of interest a measurement is performed. If the reference impedance differs from the first one, calculated under the calibration session, the new reference impedance is stored by the command; *Submit toParameter Setting*.

If more than one reference impedance are to be used, there must be a logic configured to detect such changes in the operation states that requires a change of reference impedance.

### **Monitoring**

In the monitoring part the calibration can be checked by applying the known fault resistance and compare it with the actual function measurement. It is also possible to identify operational states where change of reference impedance is required.

### Auditing

In the auditing part calibration and commissioning reports are made.

## 10.3

### Launching injection commissioning tool (ICT)

1. To launch the Injection commissioning tool (ICT), right-click **REG670** in the PCM plant structure and select the **Injection commissioning**.
2. In the ICT toolbar, select the **Rotor Earth Fault** function.



Figure 68: ICT toolbar

3. Select the **Installing** tab if it was not already selected by default after the ICT was launched.  
The first thing that needs to be ensured prior to calibration is that the measured voltage and current signal on the injected frequency is present/found, and that the amplitude of these is within the permitted limits.
4. Make sure you have not attached any additional impedance in parallel with the stator circuit.
5. Activate the injection by turning the injection switch to on position on the injection unit REX060.
6. Select the **Start reading from IED** button from the ICT toolbar to start performing continuous measurements.
7. Verify that the bars/voltage levels for both the voltage and current on the injected frequency have acceptable level.  
The bars must be green and the function status field must also indicate OK.
8. Check that the actual injected frequency is close enough to the injection frequency set on the injection unit (REX060).  
If the voltage and/or current level(s)/frequencies are not reasonable, or the ICT indicates other warnings/abnormalities in the function status field, verify that the HW connections are proper (cables etc.), and selected gains and injection frequency on the REX060 is properly selected. Then repeat steps 3 to 6. Note that the *FreqInjected* setting in Parameter setting for the specific function must correspond with the chosen injection frequency on the REX060 HMI for that function.

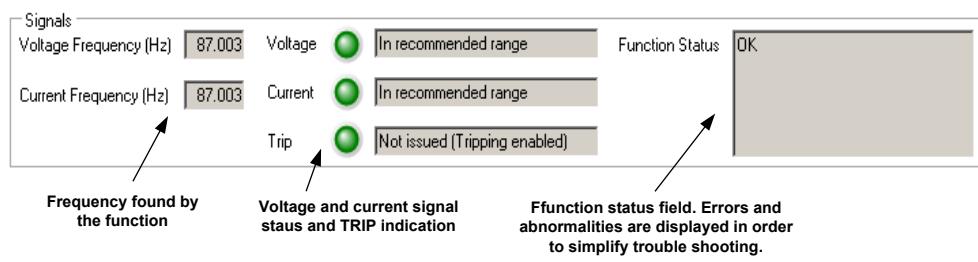


Figure 69: ICT signals and function indication panel

9. When you are ready to perform calibration, select the **Submit and save in report** button. ICT will now forward a more accurate frequency to *Parameter setting*. In *Parameter setting*, write the newly acquired parameter to IED.

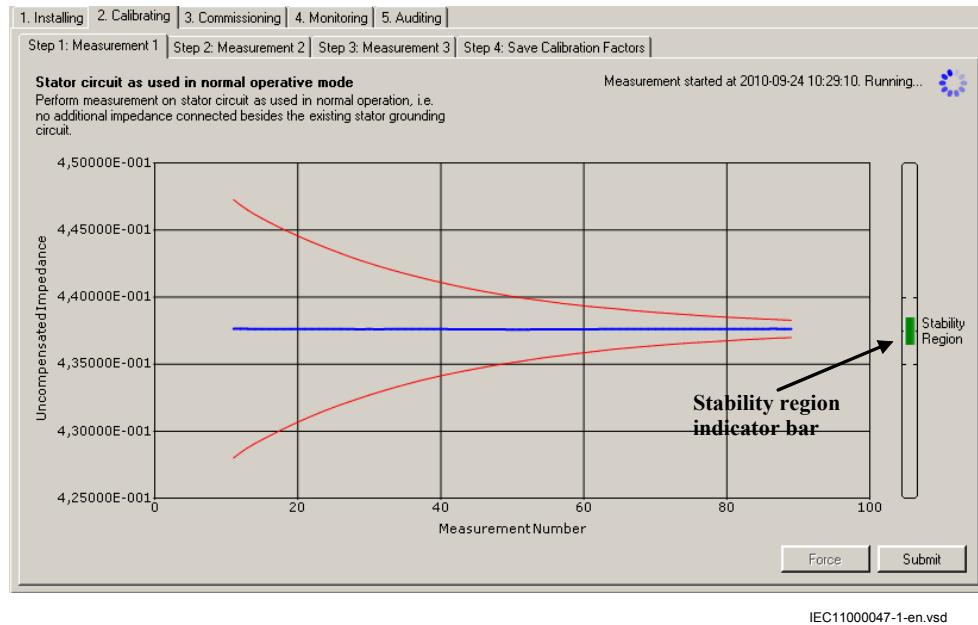
## 10.4 Performing calibration

1. From the **Calibration** tab, select the first sub tab, i.e. **Step1: Calibration step 1**.
2. Make sure you have not attached any additional impedance in parallel with the rotor.
3. From the ICT toolbar, select the **Start reading from IED** button.  
ICT now performs continuous measurements and after the tenth measurement it starts to update the graph. Notice that the stability region indicator bar reduces in size.



It is very important that calibration steps 1 to 3 is performed in the proper order. If not, the calibration might fail.

4. When the bar has reached the stability region (turned green), select the **Submit** button.  
ICT automatically shifts to the second calibration sub tab, **Step2: Calibration step 2**.



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*Figure 70: ICT calibration tab 1 including the stability region indicator bar*

5. Attach an  $10\text{k}\Omega$  known fault ( $10\text{k}\Omega$  resistance to ground).
6. Type 10000 in the real part of the **Connected impedance** field and leave the imaginary part field empty.  
This informs the ICT that we have attached  $10\text{k}\Omega$  pure resistive impedance.
7. In the ICT toolbar, select the **Start reading from IED** button.
8. Once again, wait until the stability criteria is fulfilled, then select the **Submit** button.  
ICT automatically shifts to the third calibration tab, **Step3: Calibration step 3**.
9. Remove the known fault resistance attached earlier and apply a short circuit instead.
10. In the ICT toolbar, select the **Start reading from IED** button.
11. When the stability criteria are fulfilled, select the **Submit** button once again.  
ICT automatically shifts to the fourth calibration tab, **Step4: Save calibration factors**. Here the newly calculated  $k_1$ ,  $k_2$  and reference 1 are presented.
12. Check in the **Calibration result** field that all tests have been passed.
  - 12.1. If a failure is indicated during one or more check(s), follow the instructions/tips provided by the ICT in the **Calibration result** field.
  - 12.2. If these tips do not solve the issue, then contact ABB Support.

## Calibrating injection based sensitive rotor earth fault protection

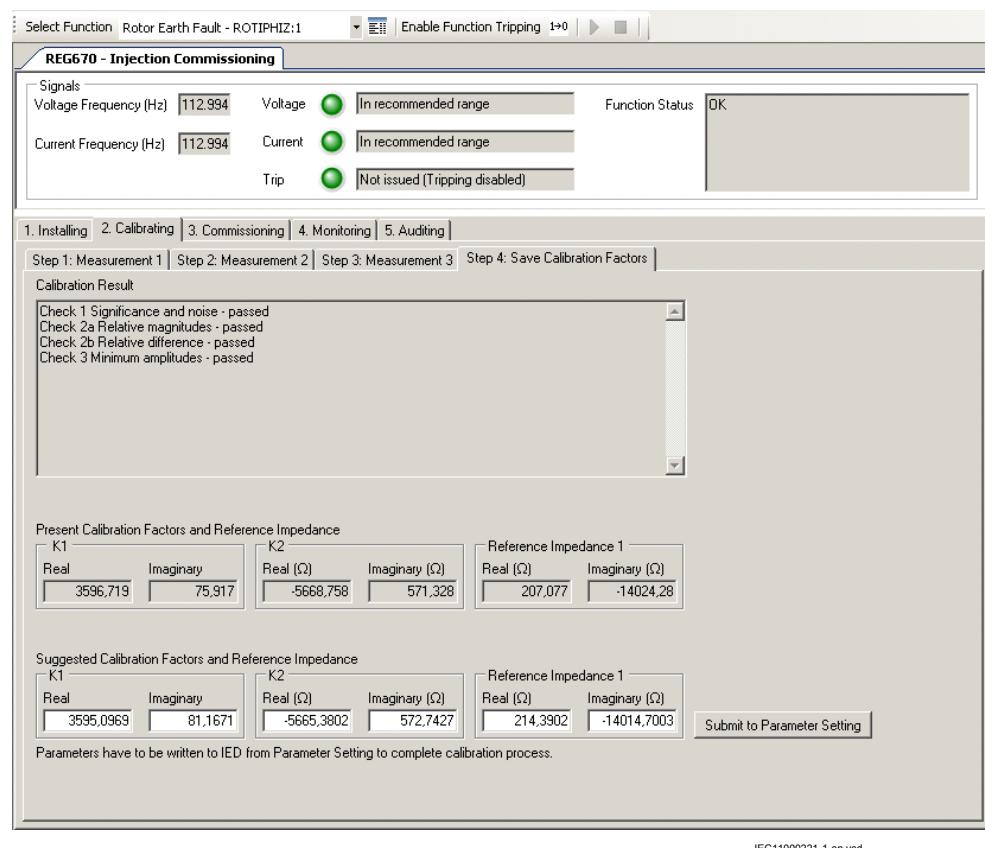


Figure 71: ICT calibration tab 4

13. Before proceeding any further make sure that you have removed the short-circuit that was applied during calibration step 3.
14. To finish the calibration process, select the **Submit to Parameter setting** button.
15. In Parameter setting, write the newly acquired parameters to IED.

## 10.5 Acquiring references

To detect different operation conditions of the generator and select proper impedance reference requires logic outside the injection function. Therefore changing/switching impedance reference is not described here but in a separate application note

*IMRG005030 Application example for injection based 100% Stator EF and Sensitive Rotor EF protection.*

The injection commissioning tool (ICT) helps the commissioning engineer to acquire additional references for different conditions of the generator. The below description

assumes that reference 1 was set during calibration and that a second reference must be set now.

1. Ensure that the generator is in a state where the reference must be set (for example normal operation).
2. To start, select the **Commissioning** tab.
3. In the **Reference impedance selection** drop-down menu, select **Reference 2**.
4. To start reading the measurements, click the **Start reading from IED** button in the ICT toolbar.

ICT starts to read the selected viewed quantity from IED and plots values on the X/Y graph.

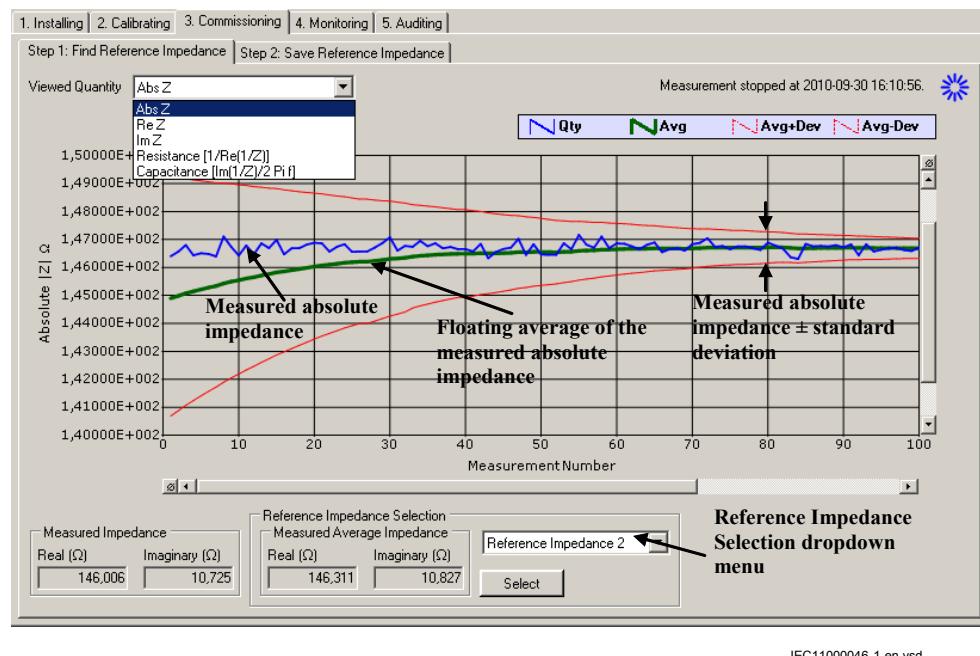


Figure 72: Commissioning tab

Normally continuous readings are performed and the read absolute impedance is viewed in the plot.

By observing the standard deviation of the measured impedance, the commissioning engineer can decide if the impedance of the generator is stable/settled, and also if the average impedance is based on enough values so that statistically the signal noise is “filtered out”. This results in a fairly accurate impedance measurement which can be used as an alternative reference.

5. Click the **Select** button when the standard deviation has converged so that its magnitude is within the noise level of the measured absolute impedance.

In the second commissioning sub tab, Step2 : Save Reference Impedance, the measured real and imaginary reference 2 impedance is presented.

6. Select the **Submit to Parameter setting** button.  
This forwards the newly acquired reference to Parameter setting.
7. Write the newly acquired real and imaginary parts of Reference 2 to IED.

## 10.6 Verifying calibration

After the calibration is performed, it is appropriate to verify that known faults are measured as expected and that the function is indicating trips and alarms when it should, in other words that the calibration was successful. For this purpose the monitoring feature can be used.

1. In the ICT toolbar, select the fourth tab, **Monitoring**.

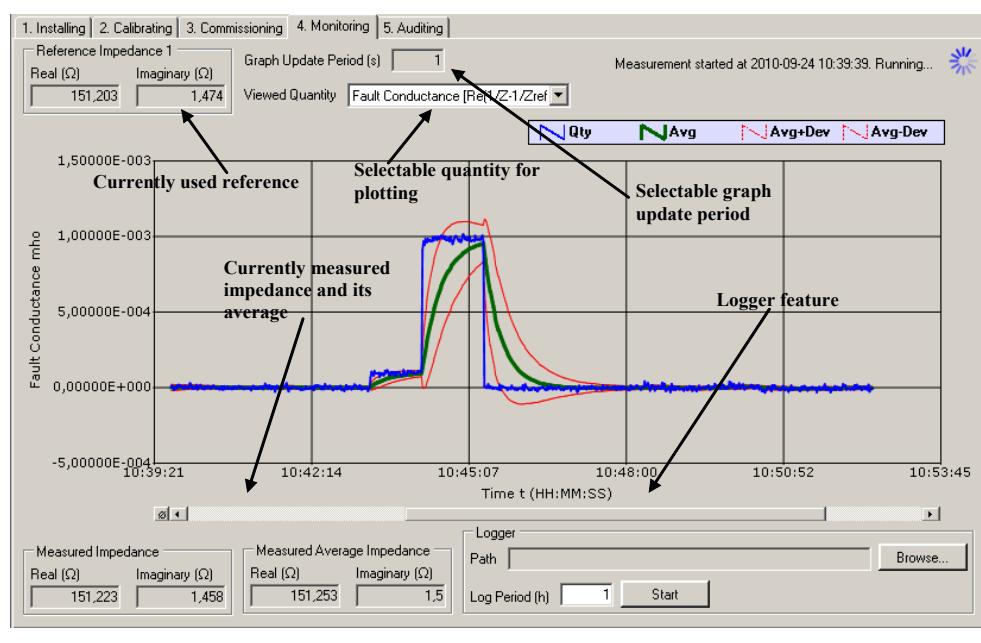


Figure 73: Monitoring tab

2. Set the graph update period to one second by typing 1 into the **Graph update period** field.
3. To start continuously plotting values on the graph with one second interval, select **Start readings from IED**.

By default the measured absolute impedance is plotted, however there are several items that can be viewed when monitoring. To see these, select the available quantities under the **Viewed quantity** drop-down menu under the **Monitoring** tab.

4. Observe the fault conductance while applying known faults.  
Both the calibration factors and the reference that is used can be verified this way. In some cases though, it is desired to be able to measure/view other quantities.
5. Select **Fault conductance** in the **Viewed quantity** drop-down menu.  
The fault conductance is equal to 1/fault resistance, and is more suitable to view when no faults or very small faults are applied/measured.  
Due to the fact that no fault theoretically equals infinite fault resistance and viewing this only plots unreliable values, it is better to view the fault conductance, which is zero in this case.  
As no fault is applied, the measured fault conductance must be close to zero. Confirm this by viewing the graph.  
It may be necessary to zoom in or out to properly view the measurements. For instructions on this, see [Editing features in graph](#).
6. Apply for example 10kΩ fault resistance.
  - 6.1. Make sure that it is correctly measured.
  - 6.2. Try to change the **Viewed quantity** to **Fault resistance** as 10kΩ is relatively small.  
You should be able to measure approximately 10kΩ here. If you choose to view fault conductance, the measurement corresponds to approximately  $1 \times 10^{-4}$  Mho.
7. Apply another known fault, say 1kΩ and verify that it is measured correctly.
8. When you are completely sure that the function measures correctly, stop the measurements and remove any applied faults.  
Previously it was verified that the function measures correctly by applying known faults and observing the graph during monitoring. Besides measuring the fault size a trip indication is required when a large fault is measured to prevent that a damage to the generator occurs. To allow the specific function to issue a trip indication, it must first be enabled:
  - 8.1. Select the **Enable Function Tripping** button in the ICT toolbar.
  - 8.2. Choose **Yes** in the pop-up message.  
ICT now writes this to IED.
  - 8.3. By default the trip level is set to 1kΩ. In other words, if the fault resistance is lower, then the function issue trips.
9. Verify the measurements by applying various faults.  
Trip indication shall be visible in the ICT toolbar.
10. Verify that TRIP and ALARM signals are connected to tripping/alarming/signaling/communication in accordance with the scheme design.



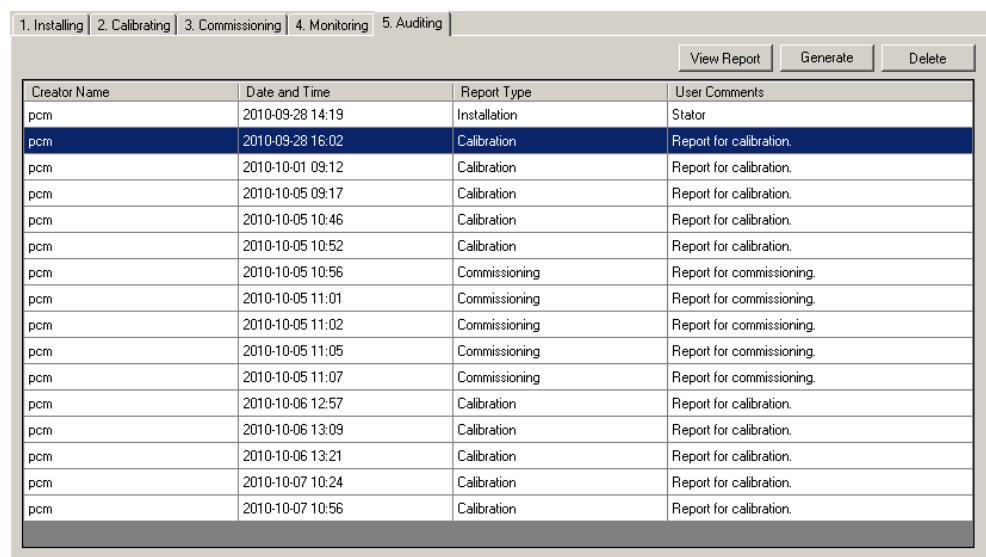
It is very important that the Function Tripping is Enabled under the following situations:

- After completion of the calibration step
- Before leaving the ICT Tool

## 10.7 Auditing

During installations, calibrations and commissions the ICT generates reports for each of the steps and collects them under the Auditing tab. See the procedures below on how to view and delete reports as well as generate logs from reports.

1. To view the reports, go to the **Auditing** tab.



The screenshot shows a software interface for managing reports. At the top, there is a navigation bar with tabs labeled 1. Installing, 2. Calibrating, 3. Commissioning, 4. Monitoring, and 5. Auditing. The 5. Auditing tab is currently active. Below the tabs is a toolbar with three buttons: 'View Report', 'Generate', and 'Delete'. The main area is a table with four columns: 'Creator Name', 'Date and Time', 'Report Type', and 'User Comments'. There are approximately 20 rows of data. The second row from the top is highlighted with a blue background, indicating it is selected. The data in the table is as follows:

Creator Name	Date and Time	Report Type	User Comments
pcm	2010-09-28 14:19	Installation	Stator
pcm	2010-09-28 16:02	Calibration	Report for calibration.
pcm	2010-10-01 09:12	Calibration	Report for calibration.
pcm	2010-10-05 09:17	Calibration	Report for calibration.
pcm	2010-10-05 10:46	Calibration	Report for calibration.
pcm	2010-10-05 10:52	Calibration	Report for calibration.
pcm	2010-10-05 10:56	Commissioning	Report for commissioning.
pcm	2010-10-05 11:01	Commissioning	Report for commissioning.
pcm	2010-10-05 11:02	Commissioning	Report for commissioning.
pcm	2010-10-05 11:05	Commissioning	Report for commissioning.
pcm	2010-10-05 11:07	Commissioning	Report for commissioning.
pcm	2010-10-06 12:57	Calibration	Report for calibration.
pcm	2010-10-06 13:09	Calibration	Report for calibration.
pcm	2010-10-06 13:21	Calibration	Report for calibration.
pcm	2010-10-07 10:24	Calibration	Report for calibration.
pcm	2010-10-07 10:56	Calibration	Report for calibration.

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*Figure 74: Auditing tab*

2. Open and view each report.
3. View reports in one of the following ways:
  - In the short cut menu, right click and select **View report**.
  - Click the **View report** button in the upper right corner of the auditing screen.
  - Double click a report record.
4. Delete reports in one of the following ways:

- In the short cut menu, right click and select **Delete report**.
  - Click the **Delete report** button in the upper right corner of the auditing screen.
  - Select a record with the mouse cursor then press the Delete key on the keyboard.
5. Generate logs in one of the following ways:
- In the short cut menu, right click and select **Generate log**.
  - Click the **Generate log** button.

Besides generating a report you can also generate a log file with the same information as for the report. Open and see the details of the file in Notepad or MS Excel.

After a successful generation of the log, the system confirms with a message along with the path of the log file.

## 10.8 Editing features in graph

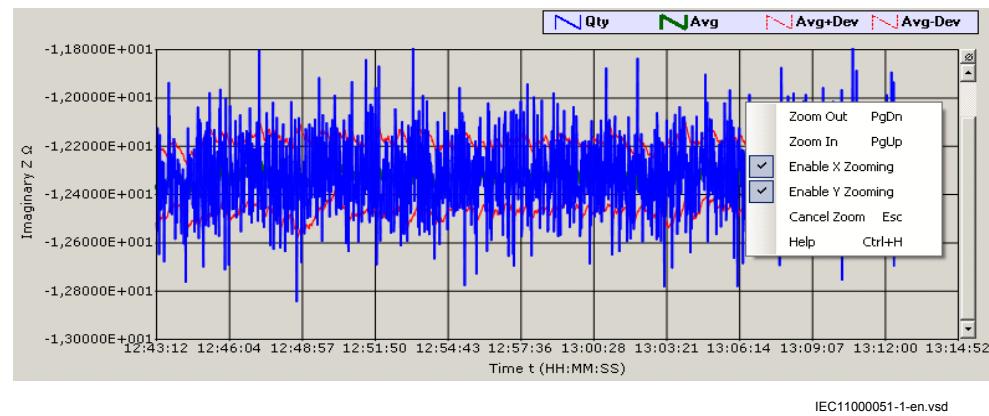
You can do the following operations on the graph during calibration, commissioning and monitoring:

- Zoom in
- Zoom out
- Cancel zoom
- Enable X-zooming
- Enable Y-zooming

1. Zoom in one of the following ways:
- Right click a graph and select **Zoom in** or **Zoom out** in the shortcut menu.

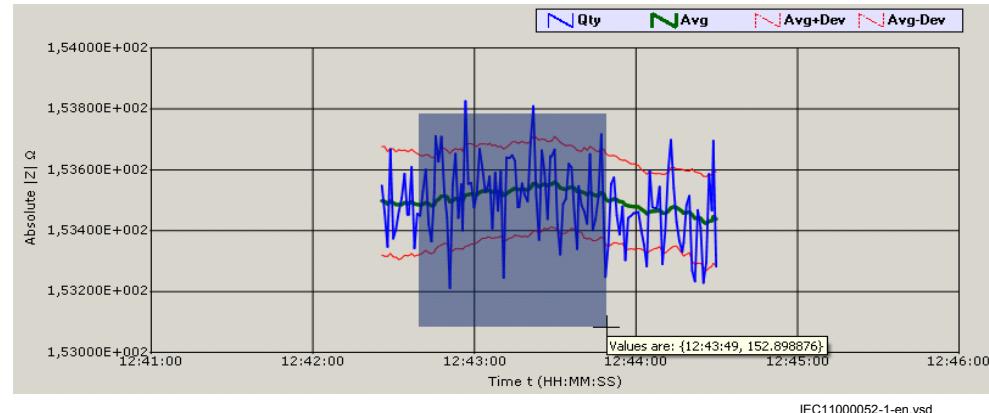
## Section 10

### Calibrating injection based sensitive rotor earth fault protection



*Figure 75: Zooming via the shortcut menu*

- Use the mouse to zoom in and select a part of the graph area.



*Figure 76: Zooming via area selection of a part of the graph*

- Press **PgUp** key on the keyboard to zoom in and **PgDn** to zoom out.
- 2. Cancel a zoom in the following ways:
  - Right click a graph and select **Cancel Zoom** in the shortcut menu. The graph area is squeezed to the original size.
  - Press **Esc**.
- 3. Enable X and Y zooming
  - To enable and disable X zooming, right click the graph and select or deselect **Enable X zooming** in the shortcut menu.
  - To enable and disable Y zooming, right click the graph and select or deselect **Enable Y zooming** in the shortcut menu.

## 10.9 Logging measurements to file

In addition to viewing online plotted data under the Monitoring tab, it is also possible to log quantities to a file (tabbed text file) that can be viewed in the graph. Besides this voltage levels measured by the function and also error codes are logged. This file can then be imported to other tools for deeper analysis when needed. The logger feature is available on the lower right corner of the Monitoring tab. Note that the logger is independent of graph plotting.

1. Select the **Browse** button.  
See figure [Monitoring tab](#).
2. Navigate to a desired folder.
3. Type a suitable file name for the .txt file and select **Save**.
4. To start logging to this file, select the **Start** button.  
ICT continuously logs data to this file with logging interval set under graph update period. Notice that there is a field named Log period and its default value is 1 hour. The period can be adjusted before the logging is started, if needed.
5. The logging can be stopped by selecting the **Stop** button.
6. You can open the file in notepad or MS Excel.

## Section 11    Calibrating injection based 100% stator earth fault protection

### 11.1    Commissioning process

The commissioning process utilizes the commissioning tool ICT. The instructions for the process cover installation, calibration, commissioning, monitoring and auditing for the 100% stator earth fault STTIPHIZ (64S) function.

### 11.2    Commissioning tool ICT

The 100% stator and rotor earth fault protection STTIPHIZ (64S) functions in IED require a number of settings. The settings  $k1$ ,  $k2$  and the reference impedance require measurements on the generator performed by the ICT (injection commissioning tool). The factors are derived in connection to the calibration measurements during commissioning. The ICT tool is an integrated part of the PCM600 tool.

Furthermore, ICT also assists the commissioning engineer to perform a successful installation because of its structure and validating capabilities. During installation, commissioning and calibration, ICT performs various tests to verify that the installation is acceptable and the calibration successful. Besides carrying out the actual tests, ICT also provides the commissioning engineer with tips if such are needed during the commissioning.

When ICT is started, 100% stator earth fault protection is chosen.

There are five different parts of the ICT tool to be performed during commissioning and operation:

1. Installing
2. Calibrating
3. Commissioning
4. Monitoring
5. Auditing

Before proceeding make sure that all necessary connections are in place.

## Installing

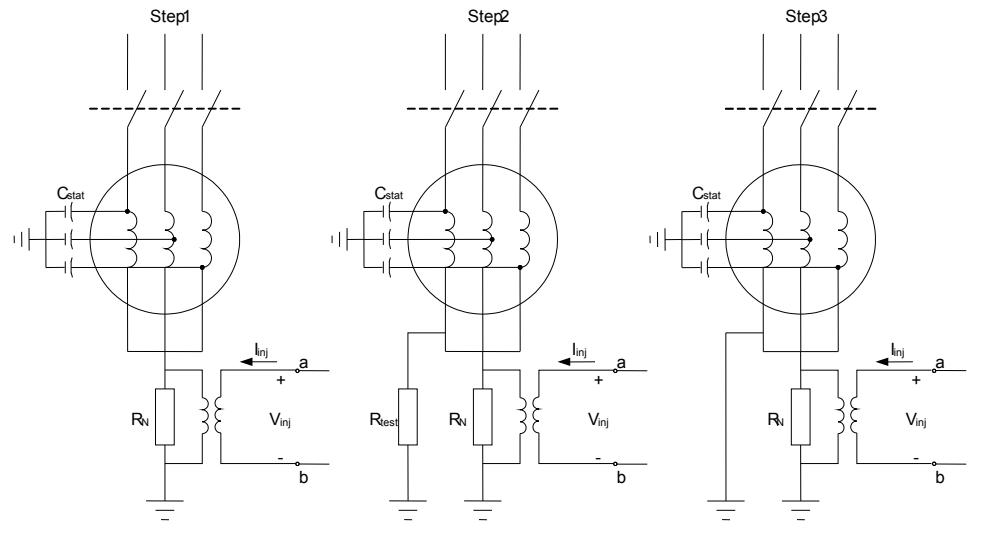
When the injection is started, check that the injected voltage and current are within the permissible limits. If not, adjust the settings of the injection unit REX060. The ICT tool will check automatically for slight differences between actual injected and set injection frequency (e.g. due to accuracy of the REX060 hardware). Set manually the actual frequency value measured by ICT in the IED via PST. Check that the selected injection frequency setting on REX060 is equal to the *FreqInjected* setting in parameter setting. Also verify that the measured injection frequency is reasonable and continue by submitting the frequency value to parameter setting, then finish by writing it to IED.

The high accuracy of this frequency is essential for proper operation of the protection under different operating conditions.

## Calibrating

The calibration is based on three measurement steps.

The sequence of the calibration measurements is shown in the figure below. The connection of the fault resistance and short circuit is here shown for the case with injection in the generator neutral point via the neutral point VT. The same principle is valid for any other principles of injection; with LV neutral point resistor connected via DT or injection via open delta connected VT group on the generator terminal, etc.



*Figure 77: Different steps at calibration measurements*

## Calibrating injection based 100% stator earth fault protection

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For other injection point alternatives the connection of the test resistance (step 2) and short circuit (step 3) are made to the same points as shown in the figure above.

The sequence of the calibration session follows a scheme shown in the tool.

- Calibration sequence 1: The injection must be activated and the stator neutral point must be left with no additional impedance connected in parallel with the neutral point resistor. ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.
- Calibration sequence 2: A known resistor is connected to the generator neutral point in parallel with the stator neutral point resistor. The value of the resistance is input to ICT. ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.
- Calibration sequence 3: The generator neutral point is now directly connected to the ground, that is, the neutral point resistor is short-circuited. ICT now makes consecutive measurements until the statistical error reaches an acceptable value. This is graphically shown in a diagram. The user stops the sequence by acceptance of the measurement. The result is stored for later calculations.

After the three measurements, ICT calculates the complex factors  $k1$  and  $k2$ . The reference impedance  $\text{RefR1} + j\text{RefX1}$  is also calculated. After this the values are downloaded to the parameter setting part of the PCM600 tool. From PCM600 the setting can be downloaded to IED.

During the three measurements described above a check is made that there are sufficient changes in the measured impedance in order to guarantee that there is no primary fault from the beginning or other problems due to the installation or calibration procedure.

Now the reference impedance is derived for one operational state. It might be necessary to make measurements to derive reference impedance for other operational cases. For information on this, see Commissioning below.

### Commissioning

There is a possibility to have up to five different reference impedances. The need to change the reference impedance is that there will be different operating conditions for the generator:

- Generator stand still
- Generator running up, not synchronized to the network (circuit breaker open)
- Generator normal operation (circuit breaker closed)

---

It might therefore be necessary to find reference impedances for different operation states. In the commissioning part of ICT this can be done. For each operation state of interest a measurement calibration as above is performed. If the reference impedance differs from the first one, calculated under the calibration session, the new reference impedance is stored by the command; *Submit to Parameter setting*. It is possible to store up to five different reference impedances to be used at different operation states of the generator.

ICT also performs verification between the newly acquired and existing reference impedance(s) and warn the user if the resulting estimated fault difference could cause alarm or trip when one reference is shifted from another during operation.

If more than one reference impedance is to be used there must be a logic configured to detect such changes in the operation states when the reference impedance must be changed, and when a change in the function block must be initiated. The following automatic choices can for example be made:

1. Generator voltage < set value and generator circuit breaker open: Reference impedance 1
2. Generator voltage > set value and generator circuit breaker open: Reference impedance 2
3. Generator voltage > set value and generator circuit breaker closed: Reference impedance 3

For more information see separate application note *IMRG005030 Application example for injection based 100% Stator EF and Sensitive Rotor EF protection*.

### Monitoring

In the monitoring part the calibration can be checked by applying the known fault resistance and compare it with the actual function measurement. It is also possible to identify operational states where change of reference impedance is required.

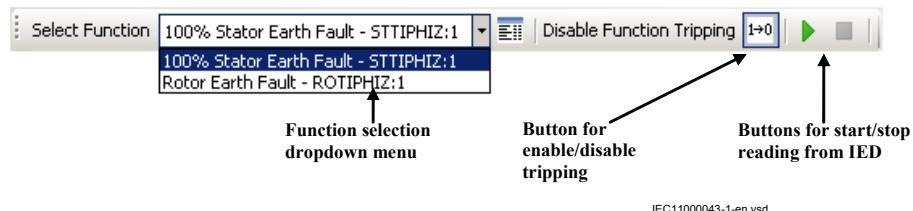
### Auditing

In the auditing part calibration and commissioning reports are made.

## 11.3

## Launching injection commissioning tool (ICT)

1. To launch the Injection commissioning tool (ICT), right-click **REG670** in the PCM plant structure and select the **Injection commissioning**.
2. In the ICT toolbar, select the **100% Stator Earth Fault** function.



*Figure 78: ICT toolbar*

3. Select the **Installing** tab if it was not already selected by default after the ICT was launched.  
The first thing that needs to be ensured prior to calibration is that the measured voltage and current signal on the injected frequency is present/found, and that the amplitude of these is within the permitted limits.
4. Make sure you have not attached any additional impedance in parallel with the stator circuit.
5. Activate the injection by turning the injection switch to on position on the injection unit REX060.
6. Select the **Start reading from IED** button from the ICT toolbar to start performing continuous measurements.
7. Verify that the bars/voltage levels for both the voltage and current on the injected frequency have acceptable level.  
The bars must be green and the function status field must also indicate OK.
8. Check that the actual injected frequency is close enough to the injection frequency set on the injection unit (REX060).  
If the voltage and/or current level(s)/frequencies are not reasonable, or the ICT indicates other warnings/abnormalities in the function status field, verify that the HW connections are proper (cables etc.), and selected gains and injection frequency on the REX060 is properly selected. Then repeat steps 3 to 6. Note that the *FreqInjected* setting in Parameter setting for the specific function must correspond with the chosen injection frequency on the REX060 HMI for that function.

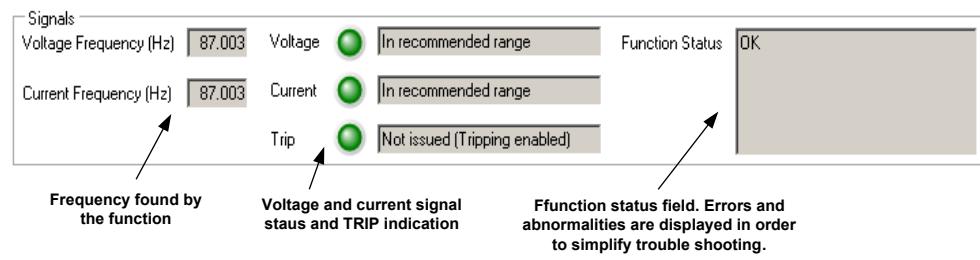


Figure 79: ICT signals and function indication panel

9. When you are ready to perform calibration, select the **Submit and save in report** button. ICT will now forward a more accurate frequency to *Parameter setting*. In *Parameter setting*, write the newly acquired parameter to IED.

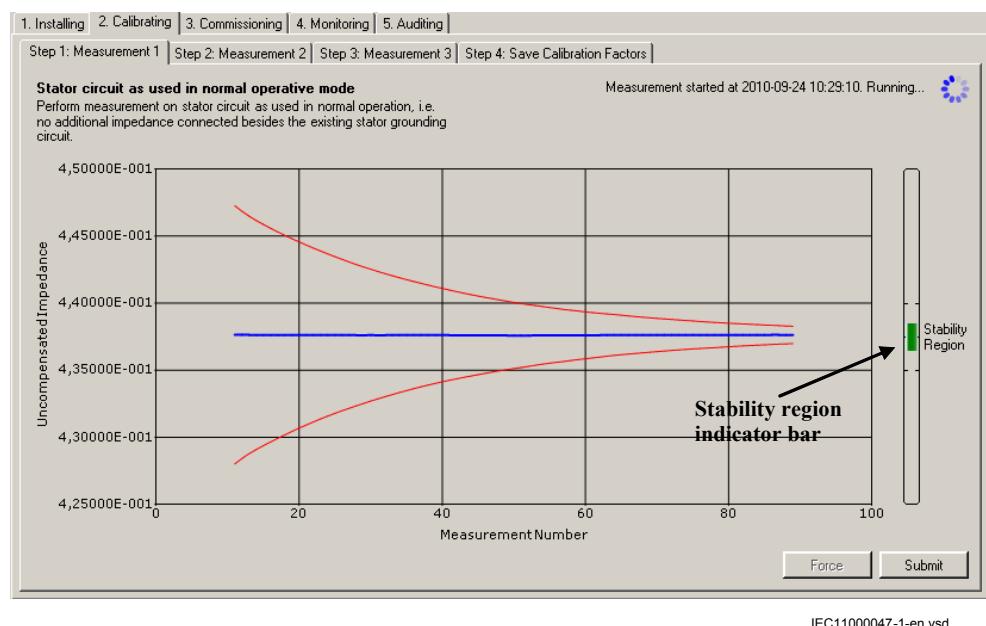
## 11.4 Performing calibration

1. From the **Calibration** tab, select the first sub tab, i.e. **Step1: Calibration step 1**.
2. Make sure you have not attached any additional impedance in parallel with the stator.
3. From the ICT toolbar, select the **Start reading from IED** button.  
ICT now performs continuous measurements and after the tenth measurement it starts to update the graph. Notice that the stability region indicator bar reduces in size.



It is very important that calibration steps 1 to 3 is performed in the proper order. If not, the calibration might fail.

4. When the bar has reached the stability region (turned green), select the **Submit** button.  
ICT automatically shifts to the second calibration sub tab, **Step2: Calibration step 2**.



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*Figure 80: ICT calibration tab 1 including the stability region indicator bar*

5. Attach an 10kΩ known fault (10kΩ resistance to ground).
6. Type 10000 in the real part of the **Connected impedance** field and leave the imaginary part field empty.  
This informs the ICT that we have attached 10kΩ pure resistive impedance.
7. In the ICT toolbar, select the **Start reading from IED** button.
8. Once again, wait until the stability criteria is fulfilled, then select the **Submit** button.  
ICT automatically shifts to the third calibration tab, **Step3: Calibration step 3**.
9. Remove the known fault resistance attached earlier and apply a short circuit instead.
10. In the ICT toolbar, select the **Start reading from IED** button.
11. When the stability criteria are fulfilled, select the **Submit** button once again.  
ICT automatically shifts to the fourth calibration tab, **Step4: Save calibration factors**. Here the newly calculated k1, k2 and reference 1 are presented.
12. Check in the **Calibration result** field that all tests have been passed.
  - 12.1. If a failure is indicated during one or more check(s), follow the instructions/tips provided by the ICT in the **Calibration result** field.
  - 12.2. If these tips do not solve the issue, then contact ABB Support.

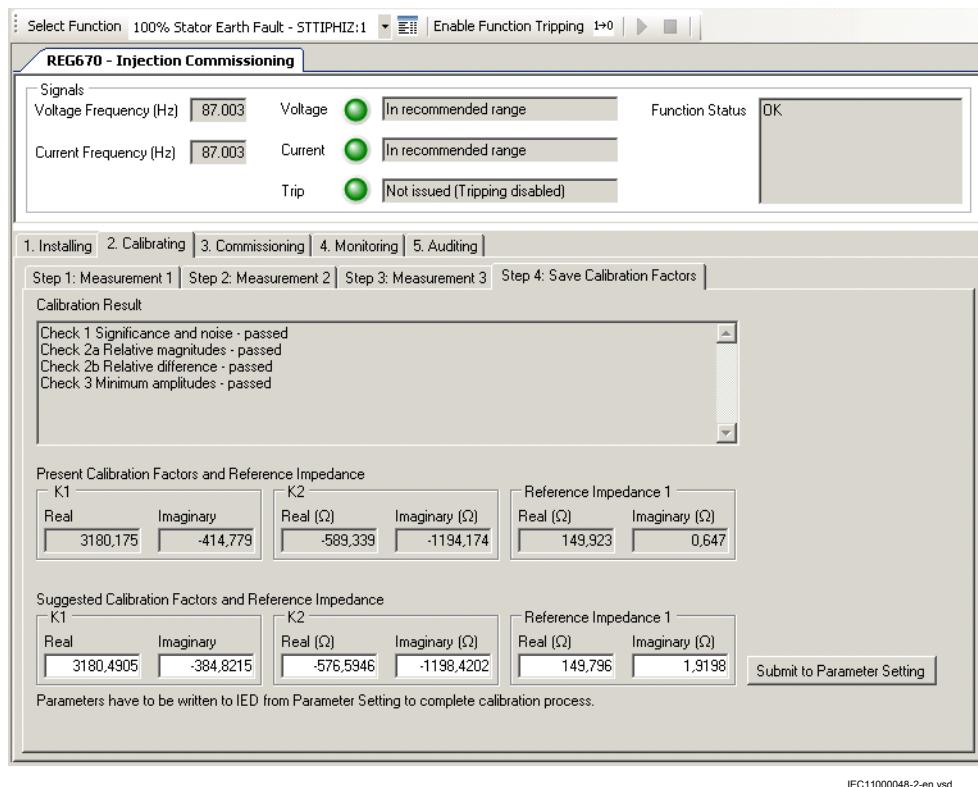


Figure 81: ICT calibration tab 4

13. Before proceeding any further make sure that you have removed the short-circuit that was applied during calibration step 3.
14. To finish the calibration process, select the **Submit to Parameter setting** button.
15. In Parameter setting, write the newly acquired parameters to IED.

## 11.5 Acquiring references

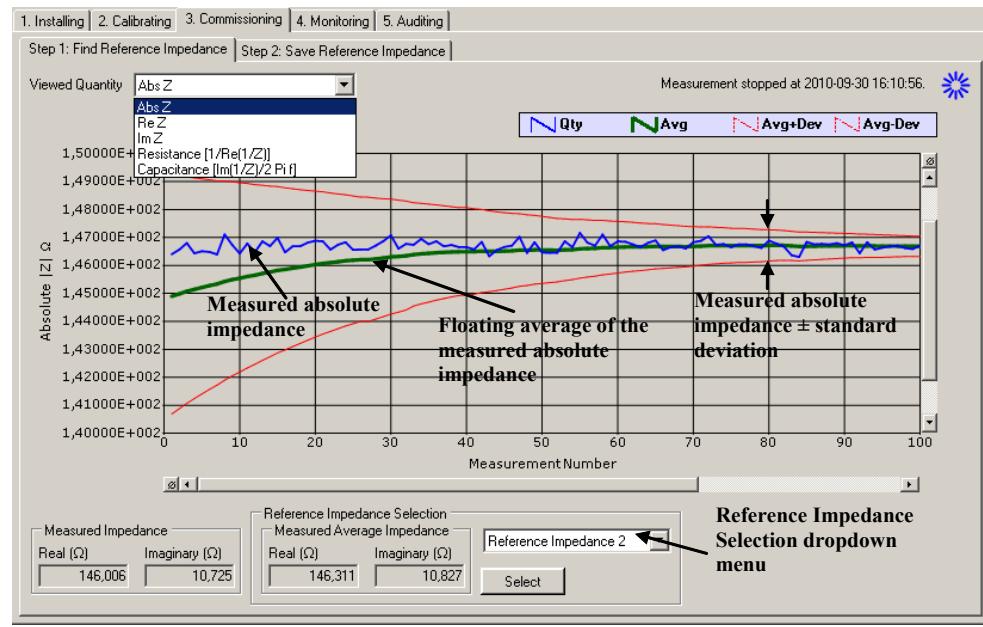
To detect different operation conditions of the generator and select proper impedance reference requires logic outside the injection function. Therefore changing/swapping impedance reference is not described here but in a separate application note

*IMRG005030 Application example for injection based 100% Stator EF and Sensitive Rotor EF protection.*

The injection commissioning tool (ICT) helps the commissioning engineer to acquire additional references for different conditions of the generator. The below description assumes that reference 1 was set during calibration and that a second reference must be set now.

## Calibrating injection based 100% stator earth fault protection

1. Ensure that the generator is in a state where the reference must be set (for example normal operation).
2. To start, select the **Commissioning** tab.
3. In the **Reference impedance selection** drop-down menu. select **Reference 2**.
4. To start reading the measurements, click the **Start reading from IED** button in the ICT toolbar.  
ICT starts to read the selected viewed quantity from IED and plots values on the X/Y graph.



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*Figure 82: Commissioning tab*

Normally continuous readings are performed and the read absolute impedance is viewed in the plot.

By observing the standard deviation of the measured impedance, the commissioning engineer can decide if the impedance of the generator is stable/settled, and also if the average impedance is based on enough values so that statistically the signal noise is “filtered out”. This results in a fairly accurate impedance measurement which can be used as an alternative reference.

5. Click the **Select** button when the standard deviation has converged so that its magnitude is within the noise level of the measured absolute impedance.
- In the second commissioning sub tab, Step2 : Save Reference Impedance, the measured real and imaginary reference 2 impedance is presented.
6. Select the **Submit to Parameter setting** button.
- This forwards the newly acquired reference to Parameter setting.
7. Write the newly acquired real and imaginary parts of Reference 2 to IED.

## 11.6 Verifying calibration

After the calibration is performed, it is appropriate to verify that known faults are measured as expected and that the function is indicating trips and alarms when it should, in other words that the calibration was successful. For this purpose the monitoring feature can be used.

- In the ICT toolbar, select the fourth tab, **Monitoring**.

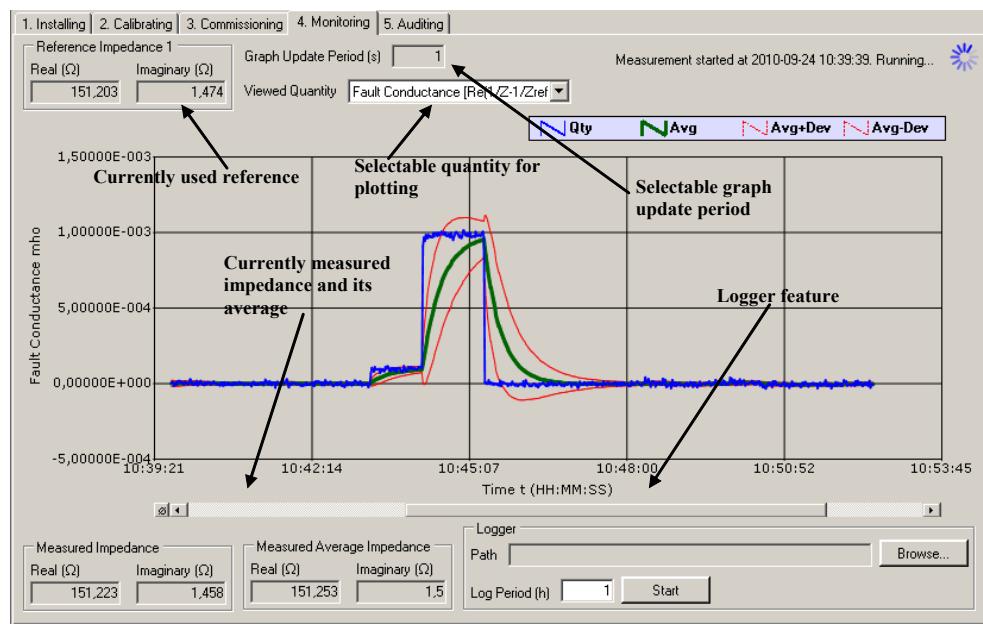


Figure 83: Monitoring tab

- Set the graph update period to one second by typing 1 into the **Graph update period** field.
- To start continuously plotting values on the graph with one second interval, select **Start readings from IED**. By default the measured absolute impedance is plotted, however there are several items that can be viewed when monitoring. To see these, select the available quantities under the **Viewed quantity** drop-down menu under the **Monitoring** tab.
- Observe the fault conductance while applying known faults. Both the calibration factors and the reference that is used can be verified this way. In some cases though, it is desired to be able to measure/view other quantities.
- Select **Fault conductance** in the **Viewed quantity** drop-down menu. The fault conductance is equal to 1/fault resistance, and is more suitable to view when no faults or very small faults are applied/measured.

Due to the fact that no fault theoretically equals infinite fault resistance and viewing this only plots unreliable values, it is better to view the fault conductance, which is zero in this case.

As no fault is applied, the measured fault conductance must be close to zero. Confirm this by viewing the graph.

It may be necessary to zoom in or out to properly view the measurements. For instructions on this, see [Editing features in graph](#).

6. Apply for example 10kΩ fault resistance.
  - 6.1. Make sure that it is correctly measured.
  - 6.2. Try to change the **Viewed quantity** to **Fault resistance** as 10kΩ is relatively small.  
You should be able to measure approximately 10kΩ here. If you choose to view fault conductance, the measurement corresponds to approximately  $1 \times 10^{-4}$  Mho.
7. Apply another known fault, say 1kΩ and verify that it is measured correctly.
8. When you are completely sure that the function measures correctly, stop the measurements and remove any applied faults.  
Previously it was verified that the function measures correctly by applying known faults and observing the graph during monitoring. Besides measuring the fault size a trip indication is required when a large fault is measured to prevent that a damage to the generator occurs. To allow the specific function to issue a trip indication, it must first be enabled:
  - 8.1. Select the **Enable Function Tripping** button in the ICT toolbar.
  - 8.2. Choose **Yes** in the pop-up message.  
ICT now writes this to IED.
  - 8.3. By default the trip level is set to 1kΩ. In other words, if the fault resistance is lower, then the function issue trips.
9. Verify the measurements by applying various faults.  
Trip indication shall be visible in the ICT toolbar.
10. Verify that TRIP and ALARM signals are connected to tripping/alarming/signaling/communication in accordance with the scheme design.



It is very important that the Function Tripping is Enabled under the following situations:

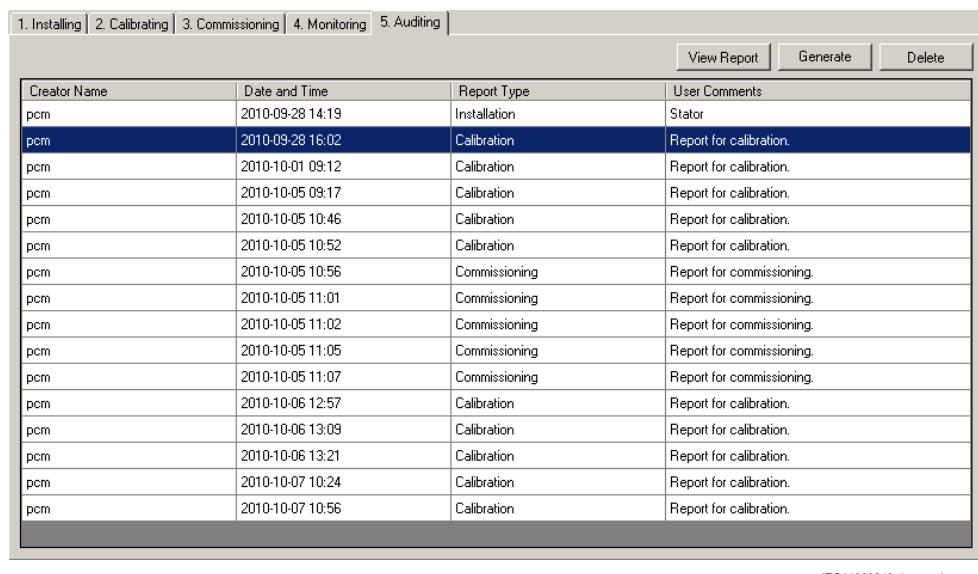
- After completion of the calibration step
- Before leaving the ICT Tool

## 11.7

## Auditing

During installations, calibrations and commissions the ICT generates reports for each of the steps and collects them under the Auditing tab. See the procedures below on how to view and delete reports as well as generate logs from reports.

1. To view the reports, go to the **Auditing** tab.



The screenshot shows a software interface titled "Auditing". At the top, there is a navigation bar with tabs: 1. Installing, 2. Calibrating, 3. Commissioning, 4. Monitoring, and 5. Auditing. The "5. Auditing" tab is selected. Below the navigation bar is a toolbar with three buttons: "View Report", "Generate", and "Delete". The main area is a table with four columns: "Creator Name", "Date and Time", "Report Type", and "User Comments". The table contains 16 rows, each representing a report entry. The second row, which corresponds to the date 2010-09-28 16:02, is highlighted with a blue background. The "User Comments" column for this row contains the text "Report for calibration.".

Creator Name	Date and Time	Report Type	User Comments
pcm	2010-09-28 14:19	Installation	Stator
pcm	2010-09-28 16:02	Calibration	Report for calibration.
pcm	2010-10-01 09:12	Calibration	Report for calibration.
pcm	2010-10-05 09:17	Calibration	Report for calibration.
pcm	2010-10-05 10:46	Calibration	Report for calibration.
pcm	2010-10-05 10:52	Calibration	Report for calibration.
pcm	2010-10-05 10:56	Commissioning	Report for commissioning.
pcm	2010-10-05 11:01	Commissioning	Report for commissioning.
pcm	2010-10-05 11:02	Commissioning	Report for commissioning.
pcm	2010-10-05 11:05	Commissioning	Report for commissioning.
pcm	2010-10-05 11:07	Commissioning	Report for commissioning.
pcm	2010-10-06 12:57	Calibration	Report for calibration.
pcm	2010-10-06 13:09	Calibration	Report for calibration.
pcm	2010-10-06 13:21	Calibration	Report for calibration.
pcm	2010-10-07 10:24	Calibration	Report for calibration.
pcm	2010-10-07 10:56	Calibration	Report for calibration.

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*Figure 84: Auditing tab*

2. Open and view each report.
3. View reports in one of the following ways:
  - In the short cut menu, right click and select **View report**.
  - Click the **View report** button in the upper right corner of the auditing screen.
  - Double click a report record.
4. Delete reports in one of the following ways:
  - In the short cut menu, right click and select **Delete report**.
  - Click the **Delete report** button in the upper right corner of the auditing screen.
  - Select a record with the mouse cursor then press the Delete key on the keyboard.
5. Generate logs in one of the following ways:
  - In the short cut menu, right click and select **Generate log**.
  - Click the **Generate log** button.

Besides generating a report you can also generate a log file with the same information as for the report. Open and see the details of the file in Notepad or MS Excel.

After a successful generation of the log, the system confirms with a message along with the path of the log file.

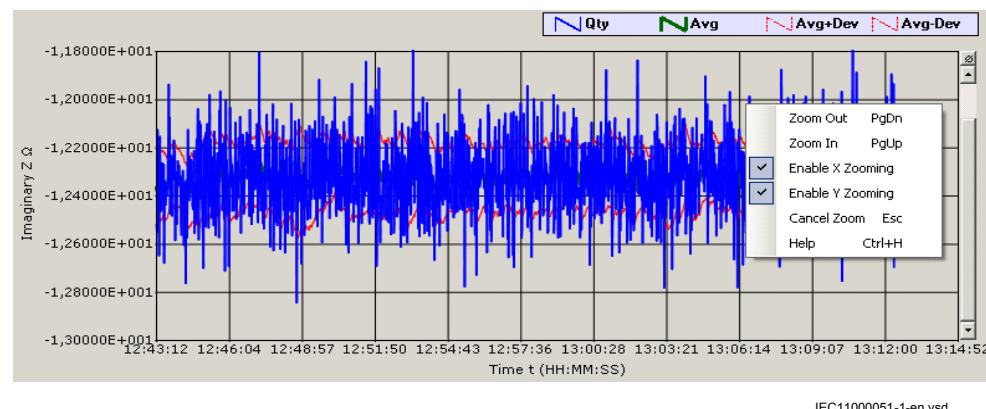
## 11.8 Editing features in graph

You can do the following operations on the graph during calibration, commissioning and monitoring:

- Zoom in
- Zoom out
- Cancel zoom
- Enable X-zooming
- Enable Y-zooming

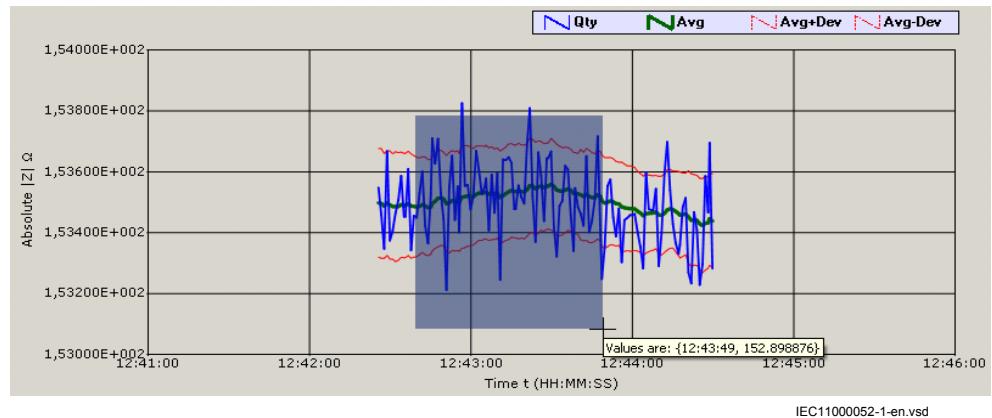
1. Zoom in one of the following ways:

- Right click a graph and select **Zoom in** or **Zoom out** in the shortcut menu.



*Figure 85: Zooming via the shortcut menu*

- Use the mouse to zoom in and select a part of the graph area.



*Figure 86: Zooming via area selection of a part of the graph*

- Press **PgUp** key on the keyboard to zoom in and **PgDn** to zoom out.
2. Cancel a zoom in the following ways:
    - Right click a graph and select **Cancel Zoom** in the shortcut menu.  
The graph area is squeezed to the original size.
    - Press **Esc**.
  3. Enable X and Y zooming
    - To enable and disable X zooming, right click the graph and select or deselect **Enable X zooming** in the shortcut menu.
    - To enable and disable Y zooming, right click the graph and select or deselect **Enable Y zooming** in the shortcut menu.

## 11.9 Logging measurements to file

In addition to viewing online plotted data under the Monitoring tab, it is also possible to log quantities to a file (tabbed text file) that can be viewed in the graph. Besides this voltage levels measured by the function and also error codes are logged. This file can then be imported to other tools for deeper analysis when needed. The logger feature is available on the lower right corner of the Monitoring tab. Note that the logger is independent of graph plotting.

1. Select the **Browse** button.  
See figure [Monitoring tab](#).
2. Navigate to a desired folder.
3. Type a suitable file name for the .txt file and select **Save**.
4. To start logging to this file, select the **Start** button.

## Calibrating injection based 100% stator earth fault protection

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ICT continuously logs data to this file with logging interval set under graph update period. Notice that there is a field named Log period and its default value is 1 hour. The period can be adjusted before the logging is started, if needed.

5. The logging can be stopped by selecting the **Stop** button.
6. You can open the file in notepad or MS Excel.



## Section 12

# Establishing connection and verifying the SPA/IEC- communication

### About this chapter

This chapter contains instructions on how to establish connection and verify that the SPA/IEC-communication operates as intended, when the IED is connected to a monitoring or control system via the rear SPA/IEC port.

## 12.1

### Entering settings

If the IED is connected to a monitoring or control system via the rear SPA/IEC port, the SPA/IEC port has to be set either for SPA or IEC use.

#### 12.1.1

### Entering SPA settings

The SPA/IEC port is located on the rear side of the IED. Two types of interfaces can be used:

- for plastic fibres with connector type HFBR
- for glass fibres with connectors type ST

When using the SPA protocol, the rear SPA/IEC port must be set for SPA use.

#### Procedure

1. Set the operation of the rear optical SPA/IEC port to “SPA”.

The operation of the rear SPA port can be found on the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical SPA-IEC-DNP port/Protocol selection**

When the setting is entered the IED restarts automatically. After the restart the SPA/IEC port operates as a SPA port.

2. Set the slave number and baud rate for the rear SPA port

The slave number and baud rate can be found on the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical SPA-IEC-DNP port/SPA**

Set the same slave number and baud rate as set in the SMS system for the IED.

## 12.1.2 Entering IEC settings

When using the IEC protocol, the rear SPA/IEC port must be set for IEC use.

Two types of interfaces can be used:

- for plastic fibres with connector type HFBR
- for glass fibres with connectors type ST

Procedure

1. Set the operation of the rear SPA/IEC port to “IEC”.

The operation of the rear SPA/IEC port can be found on the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical SPA-IEC-DNP port/Protocol selection**

When the setting is entered the IED restarts automatically After the restart the selected IEC port operates as an IEC port.

2. Set the slave number and baud rate for the rear IEC port

The slave number and baud rate can be found on the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical SPA-IEC-DNP port/IEC60870-5-103**

Set the same slave number and baud rate as set in the IEC master system for the IED.

## 12.2 Verifying the communication

To verify that the rear communication with the SMS/SCS system is working, there are some different methods. Choose one of the following.

### 12.2.1 Verifying SPA communication

Procedure

1. Use a SPA-emulator and send “RF” to the IED. The answer from the IED should be “”.
2. Generate one binary event by activating a function, which is configured to an event block where the used input is set to generate events on SPA. The configuration must be made with the PCM600 software. Verify that the event is presented in the SMS/SCS system.

During the following tests of the different functions in the IED, verify that the events and indications in the SMS/SCS system are as expected.

## 12.2.2

### Verifying IEC communication

To verify that the IEC communication with the IEC master system is working, there are some different methods. Choose one of the following.

#### Procedure

1. Check that the master system time-out for response from the IED, for example after a setting change, is  $> 40$  seconds.
2. Use a protocol analyzer and record the communication between the IED and the IEC master. Check in the protocol analyzer's log that the IED answers the master messages.
3. Generate one binary event by activating a function that is configured to an event block where the used input is set to generate events on IEC. The configuration must be made with the PCM600 software. Verify that the event is presented in the IEC master system.

During the following tests of the different functions in the IED, verify that the events and indications in the IEC master system are as expected.

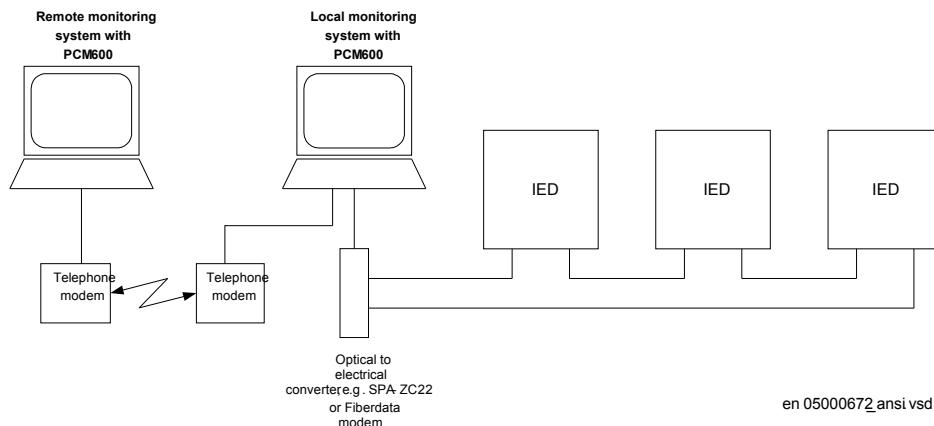
## 12.3

### Fibre optic loop

The SPA communication is mainly used for SMS. It can include different numerical IEDs with remote communication possibilities. The fibre optic loop can contain  $< 20\text{-}30$  IEDs depending on requirements on response time. Connection to a personal computer (PC) can be made directly (if the PC is located in the substation) or by telephone modem through a telephone network with ITU (CCITT) characteristics.

*Table 20: Max distances between IEDs/nodes*

glass	< 1000 m according to optical budget
plastic	< 25 m (inside cubicle) according to optical budget



*Figure 87: Example of SPA communication structure for a station monitoring system*

Where:

- 1 A separate minute pulse synchronization from station clock to obtain  $\pm 1$  ms accuracy for time tagging within the substation might be required.

## 12.4

### Optical budget calculation for serial communication with SPA/IEC

*Table 21: Example*

	Distance 1 km Glass	Distance 25 m Plastic
Maximum attenuation	- 11 dB	- 7 dB
4 dB/km multi mode: 820 nm - 62.5/125 um	4 dB	-
0.16 dB/m plastic: 620 nm - 1mm	-	4 dB
Margins for installation, aging, and so on	5 dB	1 dB
Losses in connection box, two contacts (0.5 dB/contact)	1 dB	-
Losses in connection box, two contacts (1 dB/contact)	-	2 dB
Margin for 2 repair splices (0.5 dB/splice)	1 dB	-
Maximum total attenuation	11 dB	7 dB

## Section 13

# Establishing connection and verifying the LON communication

### About this chapter

This chapter explains how to set up LON communication and how to verify that LON communication is up and running.

## 13.1

### Communication via the rear ports

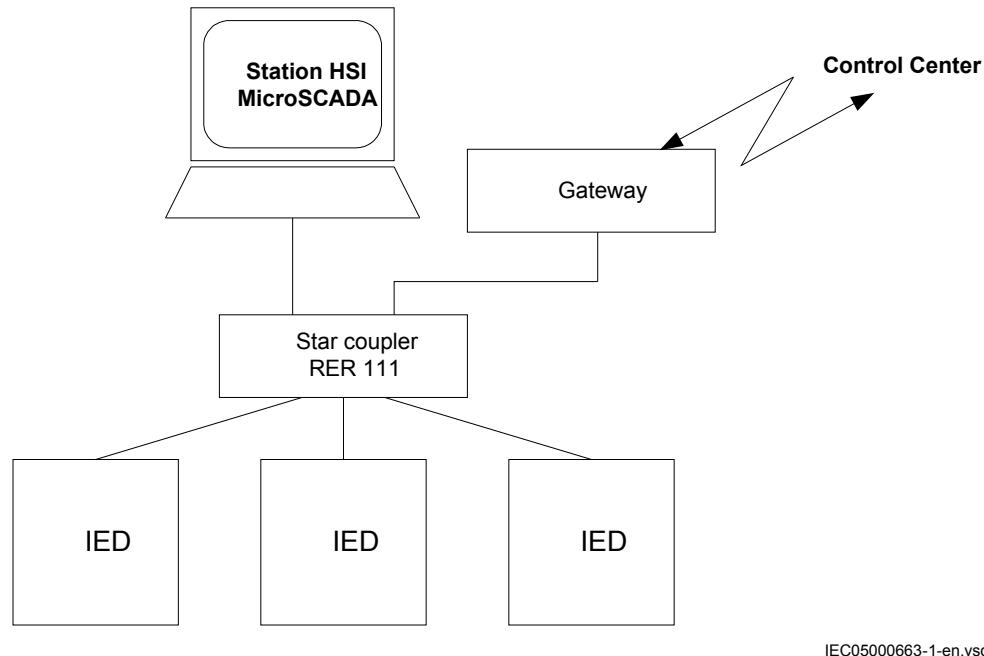
#### 13.1.1

#### LON communication

LON communication is normally used in substation automation systems. Optical fiber is used within the substation as the physical communication link.

The test can only be carried out when the whole communication system is installed. Thus, the test is a system test and is not dealt with here.

The communication protocol Local Optical Network (LON) is available for 670 IED series as an option.



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*Figure 88: Example of LON communication structure for a substation automation system*

An optical network can be used within the substation automation system. This enables communication with the IEDs in the 670 series through the LON bus from the operator's workplace, from the control center and also from other IEDs via bay-to-bay horizontal communication.

The fibre optic LON bus is implemented using either glass core or plastic core fibre optic cables.

*Table 22: Specification of the fibre optic connectors*

	Glass fibre	Plastic fibre
Cable connector	ST-connector	snap-in connector
Cable diameter	62.5/125 m	1 mm
Max. cable length	1000 m	10 m
Wavelength	820-900 nm	660 nm
Transmitted power	-13 dBm (HFBR-1414)	-13 dBm (HFBR-1521)
Receiver sensitivity	-24 dBm (HFBR-2412)	-20 dBm (HFBR-2521)

### 13.2.1

### The LON Protocol

The LON protocol is specified in the LonTalkProtocol Specification Version 3 from Echelon Corporation. This protocol is designed for communication in control networks and is a peer-to-peer protocol where all the devices connected to the network can communicate with each other directly. For more information of the bay-to-bay communication, refer to the section Multiple command function.

### 13.2.2

### Hardware and software modules

The hardware needed for applying LON communication depends on the application, but one very central unit needed is the LON Star Coupler and optical fibres connecting the star coupler to the IEDs. To interface the IEDs from MicroSCADA, the application library LIB670 is required.

The HV Control 670 software module is included in the LIB520 high-voltage process package, which is a part of the Application Software Library within MicroSCADA applications.

The HV Control 670 software module is used for control functions in IEDs in the 670 series. This module contains the process picture, dialogues and a tool to generate the process database for the control application in MicroSCADA.

Use the LON Network Tool (LNT) to set the LON communication. This is a software tool applied as one node on the LON bus. To communicate via LON, the IEDs need to know

- The node addresses of the other connected IEDs.
- The network variable selectors to be used.

This is organized by LNT.

The node address is transferred to LNT via the local HMI by setting the parameter *ServicePinMsg = Yes*. The node address is sent to LNT via the LON bus, or LNT can scan the network for new nodes.

The communication speed of the LON bus is set to the default of 1.25 Mbit/s. This can be changed by LNT.

The setting parameters for the LON communication are set via the local HMI. Refer to the technical reference manual for setting parameters specifications.

The path to LON settings in the local HMI is **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical LON port**

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If the LON communication from the IED stops, caused by setting of illegal communication parameters (outside the setting range) or by another disturbance, it is possible to reset the LON port of the IED.

By setting the parameter *LONDefault = Yes*, the LON communication is reset in the IED, and the addressing procedure can start from the beginning again.

Path in the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical LON port**

These parameters can only be set with the LON Network Tool (LNT).

**Table 23:** *Setting parameters for the LON communication*

Parameter	Range	Default	Unit	Parameter description
DomainID	0	0	-	Domain identification number
SubnetID*	0 - 255 Step: 1	0	-	Subnet identification number
NodeID*	0 - 127 Step: 1	0	-	Node identification number

\*Can be viewed in the local HMI

Path in the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical LON port**

These parameters can only be set with the LON Network Tool (LNT).

**Table 24:** *LON node information parameters*

Parameter	Range	Default	Unit	Parameter description
NeuronID*	0 - 12	Not loaded	-	Neuron hardware identification number in hexadecimal code
Location	0 - 6	No value	-	Location of the node

\*Can be viewed in the local HMI

Path in the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical LON port**

**Table 25:** *ADE Non group settings (basic)*

Name	Values (Range)	Unit	Step	Default	Description
Operation	Disabled Enabled	-	-	Disabled	Operation
TimerClass	Slow Normal Fast	-	-	Slow	Timer class

Path in the local HMI under **Main menu/Settings/General settings/Communication/SLM configuration/Rear optical LON port**

*Table 26: LON commands*

Command	Command description
ServicePinMsg	Command with confirmation. Transfers the node address to the LON Network Tool.

## 13.2

## Optical budget calculation for serial communication with LON

*Table 27: Example*

	Distance 1 km Glass	Distance 10 m Plastic
Maximum attenuation	-11 dB	- 7 dB
4 dB/km multi mode: 820 nm - 62.5/125 um	4 dB	-
0.3 dB/m plastic: 620 nm - 1mm	-	3 dB
Margins for installation, aging, and so on	5 dB	2 dB
Losses in connection box, two contacts (0.75 dB/contact)	1.5 dB	-
Losses in connection box, two contacts (1dB/contact)	-	2 dB
Margin for repair splices (0.5 dB/splice)	0.5 dB	-
Maximum total attenuation	11 dB	7 dB



## Section 14

# Establishing connection and verifying the IEC 61850 communication

## About this chapter

This chapter contains instructions on how to establish connection and verify that the IEC 61850 communication operates as intended, when the IED is connected to an Ethernet network via the optical ports of the OEM.

## 14.1

### Overview

The rear OEM ports are used for substation bus (IEC 61850-8-1) communication.

For IEC 61850-8-1 redundant communication, both rear OEM ports are utilized. In this case IEC 61850-9-2LE communication can not be used.



IEC 61850-9-2LE process bus communication is not supported in the IED.

## 14.2

### Setting the station communication

To enable IEC 61850 communication the corresponding OEM ports must be activated. The rear OEM port AB and CD is used for IEC 61850-8-1 communication. For IEC 61850-8-1 redundant communication, both OEM port AB and CD are used exclusively.

To enable IEC 61850 station communication:

1. Enable IEC 61850-8-1 (substation bus) communication for port AB.
  - 1.1. Set values for the rear port AB.  
Navigate to: **Main menu/Settings/general settings/Communication/Ethernet configuration/Rear OEM - port AB**  
Set values for *Mode*, *IPAddress* and *IPMask*. *Mode* must be set to *Normal*.  
Check that the correct IP address is assigned to the port.
  - 1.2. Enable IEC 61850-8-1 communication.

---

Navigate to: **Main menu/Settings/General settings/Communication/  
Station communication/IEC 61850-8-1**

Set *Operation* to *Enabled* and *GOOSE* to the port used (for example *OEM311\_AB*).

2. Enable redundant IEC 61850-8-1 communication for port AB and CD
  - 2.1. Enable redundant communication.  
Navigate to: **Main menu/Settings/general settings/Communication/  
Ethernet configuration/Rear OEM - redundant PRP**  
Set values for *Operation*, *IPAddress* and *IPMask*. *Operation* must be set to *Enabled*.  
The IED will restart after confirmation. Menu items **Rear OEM - port AB** and **Rear OEM - port CD** are hidden in local HMI after restart but are visible in PST where the values for parameter *Mode* is set to *Duo*.

## 14.3

## Verifying the communication

Connect your PC to the substation network and ping the connected IED and the Substation Master PC, to verify that the communication is working (up to the transport layer).

The best way to verify the communication up to the application layer is to use protocol analyzer ITT600 connected to the substation bus, and monitor the communication.

### Verifying redundant IEC 61850-8-1 communication

Ensure that the IED receives IEC 61850-8-1 data on both port AB and CD. Browse in the local HMI to **Main menu/Diagnostics/Communication/Redundant PRP** and check that both signals LAN-A-STATUS and LAN-B-STATUS are shown as *Ok*. Remove the optical connection to one of the ports AB or CD. Verify that either signal LAN-A-STATUS or LAN-B-STATUS (depending on which connection that was removed) are shown as *Error* and the other signal is shown as *Ok*. Be sure to re-connect the removed connection after completed verification.

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# Section 15    Verifying settings by secondary injection

## About this chapter

This chapter describes how to verify that protection functions operate correctly and according to their settings. It is preferable that only the tested function is in operation.

### 15.1    Overview

IED test requirements:

- Calculated settings
- Application configuration diagram
- Signal matrix (SMT) configuration
- Terminal diagram
- Technical reference manual
- Three-phase test equipment
- PCM600

The setting and configuration of the IED must be completed before the testing can start.

The terminal diagram, available in the technical reference manual, is a general diagram of the IED.



Note that the same diagram is not always applicable to each specific delivery (especially for the configuration of all the binary inputs and outputs).

Therefore, before testing, check that the available terminal diagram corresponds to the IED.

The technical reference manual contains application and functionality summaries, function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function.

The test equipment should be able to provide a three-phase supply of voltages and currents. The magnitude of voltage and current as well as the phase angle between voltage and current must be variable. The voltages and currents from the test equipment must be obtained from the same source and they must have minimal

harmonic content. If the test equipment cannot indicate the phase angle, a separate phase-angle measuring instrument is necessary.

Prepare the IED for test before testing a particular function. Consider the logic diagram of the tested protection function when performing the test. All included functions in the IED are tested according to the corresponding test instructions in this chapter. The functions can be tested in any order according to user preferences and the test instructions are therefore presented in alphabetical order. Only the functions that are used (*Operation* is set to *Enabled*) should be tested.

The response from a test can be viewed in different ways:

- Binary outputs signals
- Service values on the local HMI (logical signals or phasors)
- A PC with PCM600 application configuration software in debug mode

All setting groups that are used should be tested.



This IED is designed for a maximum continuous current of four times the rated current.



Please observe the measuring accuracy of the IED, the test equipment and the angular accuracy for both of them.



Please consider the configured logic from the function block to the output contacts when measuring the operate time.



After intense testing, it is important that the IED is not immediately restarted, which might cause a faulty trip due to flash memory restrictions. Some time must pass before the IED is restarted. For more information about the flash memory, refer to section “Configuring the IED and changing settings”.

## 15.2

# Preparing for test

### 15.2.1

## Preparing the IED to verify settings

If a test switch is included, start preparation by making the necessary connections to the test switch. This means connecting the test equipment according to a specific and designated IED terminal diagram.

Put the IED into the test mode to facilitate the test of individual functions and prevent unwanted operation caused by other functions. The busbar differential protection is not included in the test mode and is not prevented to operate during the test operations. The test switch should then be connected to the IED.

Verify that analog input signals from the analog input module are measured and recorded correctly by injecting currents and voltages required by the specific IED.

To make testing even more effective, use PCM600. PCM600 includes the Signal monitoring tool, which is useful in reading the individual currents and voltages, their amplitudes and phase angles. In addition, PCM600 contains the Disturbance handling tool. The content of reports generated by the Disturbance handling tool can be configured which makes the work more efficient. For example, the tool may be configured to only show time tagged events and to exclude analog information and so on.

Check the disturbance report settings to ensure that the indications are correct.

For test functions and test and signal parameter names, see the technical reference manual. The correct initiation of the disturbance recorder is made on pickup and/or release or trip from a function. Also check that the wanted recordings of analog (real and calculated) and binary signals are achieved.



Parameters can be entered into different setting groups. Make sure to test functions for the same parameter setting group. If needed, repeat the tests for all different setting groups used. The difference between testing the first parameter setting group and the remaining is that there is no need for testing the connections.

During testing, observe that the right testing method, that corresponds to the actual parameters set in the activated parameter setting group, is used.

Set and configure the function(s) before testing. Most functions are highly flexible and permit a choice of functional and tripping modes. The various modes are checked at the factory as part of the design verification. In certain cases, only modes with a high probability of coming into operation need to be checked when commissioned to verify the configuration and settings.

## 15.2.2

### Preparing the connection to the test equipment

The IED can be equipped with a test switch of type RTXP8, RTXP18 or RTXP24 or FT. The test switch and its associated test plug handles are a part of the COMBITEST or FT system of ABB, which provides secure and convenient testing of the IED.

When using the COMBITEST, preparations for testing are automatically carried out in the proper sequence, that is, for example, blocking of tripping circuits, short circuiting of CT's, opening of voltage circuits, making IED terminals available for secondary injection. Terminals 1 and 8, 1 and 18 as well as 1 and 12 of the test switches RTXP8, RTXP18 and RTXP24 respectively are not disconnected as they supply DC power to the protection IED. When FT switch is used for testing, care shall be exercised to open the tripping circuit, ahead of manipulating the CT fingers.

The RTXH test-plug handle leads may be connected to any type of test equipment or instrument. When a number of protection IEDs of the same type are tested, the test-plug handle only needs to be moved from the test switch of one protection IED to the test switch of the other, without altering the previous connections.

Use COMBITEST test system to prevent unwanted tripping when the handle is withdrawn, since latches on the handle secure it in the half withdrawn position. In this position, all voltages and currents are restored and any re-energizing transients are given a chance to decay before the trip circuits are restored. When the latches are released, the handle can be completely withdrawn from the test switch, restoring the trip circuits to the protection IED.

If a test switch is not used, perform measurement according to the provided circuit diagrams.



Never disconnect the secondary connection of a current transformer circuit without first short-circuiting the transformer's secondary winding. Operating a current transformer with the secondary winding open will cause a massive potential build up that may damage the transformer and cause personal injury.

## 15.2.3

### Activating the test mode

Put the IED into the test mode before testing. The test mode blocks all protection functions and some of the control functions in the IED, and the individual functions to be tested can be unblocked to prevent unwanted operation caused by other functions. In this way, it is possible to test slower back-up measuring functions without the interference from faster measuring functions. The busbar differential protection is not included in the test mode and is not prevented to operate during the test operations. The

---

test switch should then be connected to the IED. Test mode is indicated when the yellow PickupLED flashes.

1. Browse to the **TestMode** menu and press *E*.  
The **TestMode** menu is found on the local HMI under **Main menu/Test/IED test mode/TestMode**
2. Use the up and down arrows to choose *Enabled* and press *E*.
3. Press the left arrow to exit the menu.  
The dialog box *Save changes* appears.
4. Choose *Yes*, press *E* and exit the menu.  
The yellow pickupLED above the LCD will start flashing when the IED is in test mode.

## 15.2.4

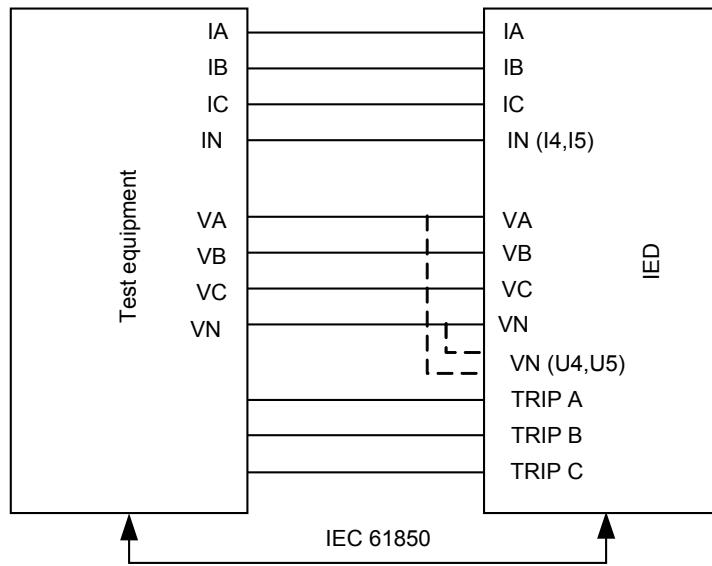
### Connecting the test equipment to the IED

Connect the test equipment according to the IED specific connection diagram and the needed input and output signals for the function under test. An example of a connection is shown in figure 89.

Connect the current and voltage terminals. Pay attention to the current polarity. Make sure that the connection of input and output current terminals and the connection of the residual current conductor is correct. Check that the input and output logical signals in the logic diagram for the function under test are connected to the corresponding binary inputs and outputs of the IED under test.



To ensure correct results, make sure that the IED as well as the test equipment are properly grounded before testing.



ANSI09000652-1-en.vsd

Figure 89: Connection example of the test equipment to the IED when test equipment is connected to the transformer input module

### 15.2.5 Verifying analog primary and secondary measurement

Verify that the connections are correct and that measuring and scaling is done correctly. This is done by injecting current and voltage to the IED.



Apply input signals as needed according to the actual hardware and the application configuration.

1. Inject a symmetrical three-phase voltage and current at rated value.
2. Compare the injected value with the measured values.  
The voltage and current phasor menu in the local HMI is located under **Main menu/Measurements/Analog primary values** and **Main menu/Measurements/Analog secondary values**.
3. Compare the frequency reading with the set frequency and the direction of the power.

The frequency and active power are located under **Main menu/Measurements/Monitoring/ServiceValues(MMXN)/CVMMXN:x**. Then navigate to the bottom of the list to find the frequency.

4. Inject an unsymmetrical three-phase voltage and current, to verify that phases are correctly connected.

If some setting deviates, check the analog input settings under

**Main menu/Settings/General settings/Analog modules**

#### 15.2.6 Releasing the function to be tested

Release or unblock the function to be tested. This is done to ensure that only the function or the chain of functions to be tested are in operation and that other functions are prevented from operating. Release the tested function(s) by setting the corresponding *Blocked* parameter under Function test modes to *No* in the local HMI.

When testing a function in this blocking feature, remember that not only the actual function must be activated, but the whole sequence of interconnected functions (from measuring inputs to binary output contacts), including logic must be activated. Before starting a new test mode session, scroll through every function to ensure that only the function to be tested (and the interconnected ones) have the parameters *Blocked* and eventually *EvDisable* set to *No* and *Yes* respectively. Remember that a function is also blocked if the BLOCK input signal on the corresponding function block is active, which depends on the configuration. Ensure that the logical status of the BLOCK input signal is equal to 0 for the function to be tested. Event function blocks can also be individually blocked to ensure that no events are reported to a remote station during the test. This is done by setting the parameter *EvDisable* to *Yes*.



Any function is blocked if the corresponding setting in the local HMI under **Main menu/Test/Function test modes** menu remains *Enabled*, that is, the parameter *Blocked* is set to *Yes* and the parameter *TestMode* under **Main menu/Test/IED test mode** remains active. All functions that were blocked or released in a previous test mode session, that is, the parameter *Test mode* is set to *Enabled*, are reset when a new test mode session is started.

#### Procedure

1. Click the **Function test modes** menu.  
The Function test modes menu is located in the local HMI under **Main menu/Test/Function test modes**.
2. Browse to the function instance that needs to be released.
3. Set parameter *Blocked* for the selected function to *No*.

---

## 15.2.7 Disturbance report

### 15.2.7.1 Introduction

The following sub-functions are included in the disturbance report function:

- Disturbance recorder
- Event list
- Event recorder
- Trip value recorder
- Indications

If the disturbance report is enabled, then its sub-functions are also set up and so it is not possible to only disable these sub-functions. The disturbance report function is disabled (parameter *Operation = Disabled*) in PCM600 or the local HMI under **Main menu/Settings/General settings/Monitoring/DisturbanceReport/DisturbanceReport(RDRE)**.

### 15.2.7.2 Disturbance report settings

When the IED is in test mode, the disturbance report can be made active or inactive. If the disturbance recorder is turned on during test mode, recordings will be made. When test mode is switched off all recordings made during the test session are cleared.

Setting *OpModeTest* for the control of the disturbance recorder during test mode are located on the local HMI under **Main menu/Settings/General settings/Monitoring/DisturbanceReport/DisturbanceReport(RDRE)**.

### 15.2.7.3 Disturbance recorder (DR)

A *Manual Trig* can be started at any time. This results in a recording of the actual values from all recorded channels.

The *Manual Trig* can be initiated in two ways:

1. From the local HMI under **Main menu/Disturbance records**.
  - 1.1. Enter on the row at the bottom of the HMI called **Manual trig**.  
The newly performed manual trig will result in a new row.
  - 1.2. Navigate to **General information** or to **Trip values** to obtain more detailed information.
2. Open the Disturbance handling tool for the IED in the plant structure in PCM600.

- 2.1. Right-click and select *Execute manual Trig* in the window *Available recordings in IED*.
- 2.2. Read the required recordings from the IED.
- 2.3. Refresh the window *Recordings* and select a recording.
- 2.4. Right-click and select *Create Report* or *Open With* to export the recordings to any disturbance analyzing tool that can handle Comtrade formatted files.

Evaluation of the results from the disturbance recording function requires access to a PC either permanently connected to the IED or temporarily connected to the Ethernet port (RJ-45) on the front. The PCM600 software package must be installed in the PC.

Disturbance upload can be performed by the use of PCM600 or by any third party tool with IEC 61850 protocol. Reports can automatically be generated from PCM600.

Disturbance files can be analyzed by any tool reading Comtrade formatted disturbance files.

It could be useful to have a printer for hard copies. The correct start criteria and behavior of the disturbance recording function can be checked when IED protective functions are tested.

When the IED is brought into normal service it is recommended to delete all recordings, made during commissioning to avoid confusion in future fault analysis.

All recordings in the IED can be deleted in two ways:

1. in the local HMI under **Main menu/Reset/Reset disturbances**, or
2. in the Disturbance handling tool in PCM600 by selecting *Delete all recordings in the IED...* in the window *Available Recordings in IED*.

#### 15.2.7.4

#### Event recorder (ER) and Event list (EL)

The result from the event recorder and event list can be viewed on the local HMI or, after upload, in PCM600 as follows:

1. on the local HMI under **Main menu/Events**, or in more details via
2. the *Event Viewer* in PCM600.  
The internal FIFO register of all events will appear when the event viewer is launched.

When the IED is brought into normal service it is recommended to delete all events resulting from commissioning tests to avoid confusion in future fault analysis. All event in the IED can be cleared in the local HMI under **Main Menu//Reset/Reset internal event list** or **Main menu/Reset/Reset process event list**. It is not possible to clear the event lists from PCM600.

When testing binary inputs, the event list (EL) might be used instead. No uploading or analyzing of registrations is then needed since the event list keeps running, independent of start of disturbance registration.

## 15.2.8

### Identifying the function to test in the technical reference manual

Use the technical reference manual (to identify function blocks, logic diagrams, input and output signals, setting parameters and technical data).

## 15.2.9

### Exit test mode

The following procedure is used to return to normal operation.

1. Navigate to the test mode folder.
2. Change the *Enable* setting to *Disable*. Press the 'E' key and the left arrow key.
3. Answer *YES*, press the 'E' key and exit the menus.

## 15.3

### Basic IED functions

#### 15.3.1

#### Parameter setting group handling SETGRPS

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.3.1.1

#### Verifying the settings

1. Check the configuration of binary inputs that control the selection of the active setting group.
2. Browse to the **ActiveGroup** menu to achieve information about the active setting group.  
The **ActiveGroup** menu is located on the local HMI under **Main menu/Test/Function status/Setting groups/ActiveGroup**
3. Connect the appropriate dc voltage to the corresponding binary input of the IED and observe the information presented on the local HMI.  
The displayed information must always correspond to the activated input.
4. Check that the corresponding output indicates the active group.  
Operating procedures for the PC aided methods of changing the active setting groups are described in the corresponding PCM600 documents and instructions for the operators within the SCS are included in the SCS documentation.

### 15.3.1.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

## 15.4

### Differential protection

#### 15.4.1

#### Generator differential protection GENPDIF (87G)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

##### 15.4.1.1

##### Verifying the settings

1. Go to **Main menu/Test/Function test modes/Differential protection** and make sure all other functions, configured to the same current transformer inputs as the generator differential protection, are set off. Make sure that the generator differential function is unblocked.
2. Connect the test set for injection of three-phase current to the current IEDs, which are connected to the CTs on the HV side of the generator.
3. Increase the current in phase A until the protection function operates and note the operating current.
4. Check that trip and alarm contacts operate according to the configuration logic.
5. Decrease the current slowly from operate value and note the reset value.
6. Check in the same way the function by injecting current in phases B and C.
7. Inject a symmetrical three-phase current and note the operate value.
8. Connect the timer and set the current to twice the operate value.
9. Switch on the current and note the operate time.
10. Check in the same way the functioning of the measuring circuits connected to the CTs on the neutral point side of the generator.
11. Finally check that trip information is stored in the event menu.



Information on how to use the event menu is found in the operator's manual.

12. If available on the test set a second-harmonic current of about 20% (assumes 15% setting on I1/I2 ratio parameter) can be added to the fundamental tone in phase A. Increase the current in phase A above the pickup value measured in step 3. Repeat test with current injection in phases B and C respectively.

Fifth-harmonic blocking can be tested in a similar way.

The balancing of currents flowing into and out of the differential zone is typically checked by primary testing.

#### 15.4.1.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.4.2

### Transformer differential protection T2WPDIF (87T) and T3WPDIF (87T)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

#### 15.4.2.1

#### Verifying the settings

1. Go to **Main menu/Test/Function test modes/Differential protection** and make sure that the restricted earth fault protection, low impedance function REFPDIF (87N) is set to *Disabled* and that the four step residual overcurrent function EF4PTOC (51N/67N) under **Main menu/Test/Function test modes/Current protection** is set to *Disabled*, since they are configured to the same current transformer inputs as the transformer differential protection. Make sure that the transformer differential functions T2WPDIF (87T) or T3WPDIF (87T) are unblocked.
2. Connect the test set for injection of three-phase currents to the current terminals of the IED, which are connected to the CTs on the HV side of the power transformer.
3. Increase the current in phase A until the protection function operates and note the operating current.
4. Check that the trip and alarm contacts operate according to the configuration logic.
5. Decrease the current slowly from operate value and note the reset value.  
Depending on the power transformer phase shift/vector group (Yd (Wye/Delta) and so on), the single-phase injection current may appear as differential current in one or two phases and the operating value of the injected single-phase current will be different.
6. Check in the same way the function by injecting current in phases B and C respectively.
7. Inject a symmetrical three-phase current and note the operate value.
8. Connect the timer and set the current to twice the operate value.
9. Switch on the current and note the operate time.

10. Check in the same way the measuring circuits connected to the CTs on the LV side and other current inputs to the transformer differential protection.
11. Finally check that trip information is stored in the event menu.



Information on how to use the event menu is found in the operator's manual.

12. If available on the test set, a second harmonic current of about 20% (assumes 15% setting on I1/I2 ratio parameter) can be added to the fundamental tone in phase A. Increase the current in phase A above the pickup value measured in step [6](#). Repeat test with current injection in phases B and C respectively. The balancing of currents flowing into and out of the differential zone is checked by primary injection testing, see section ["III"](#). Fifth harmonic blocking can be tested in a similar way.



For more detailed formulas please refer to the application manual.

#### 15.4.2.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.4.3

### Restricted earth-fault protection, low impedance REFPDIF (87N)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.4.3.1

#### Verifying the settings

1. Connect the test set for single-phase current injection to the protection terminals connected to the CT in the power transformer neutral-to-ground circuit.
2. Increase the injection current and note the operating value of the protection function.
3. Check that all trip and pickup contacts operate according to the configuration logic.
4. Decrease the current slowly from operate value and note the reset value.
5. Connect the timer and set the current to ten times the value of the IDMin setting.
6. Switch on the current and note the operate time.

7. Connect the test set to terminal A and neutral of the three-phase current input configured to REFPDIF (87N). Also inject a current higher than half the  $Idmin$  setting in the neutral-to-ground circuit with the same phase angle and with polarity corresponding to an internal fault.
8. Increase the current injected in A, and note the operate value. Decrease the current slowly and note the reset value.
9. Inject current into terminals B and C in the same way as in step 7 above and note the operate and reset values.
10. Inject a current equal to 10% of rated current into terminal A.
11. Inject a current in the neutral-to-ground circuit with the same phase angle and with polarity corresponding to an external fault.
12. Increase the current to five times the operating value and check that the protection does not operate.
13. Finally check that trip information is stored in the event and disturbance recorder.

#### 15.4.3.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.4.4

### High impedance differential protection HZPDIF (87)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

#### 15.4.4.1

#### Verifying the settings

1. Connect single-phase or three-phase test set to inject the operating voltage. The injection shall be on the primary side of the stabilizing resistor.



As the operating voltage is adjusted on the stabilizing resistor and with the setting of the resistor value in the function this is essential for the measurement of the expected value. Normally a slightly higher operating value is no problem as the sensitivity is not influenced much.

2. Connect the trip contact to the test set to stop the test set for measurement of trip times below.
3. Increase the voltage and make note of the operate value *Pickup*. This is done with manual test and without trip of the test set.

4. Reduce the voltage slowly and make note of the reset value. The reset value must be high for this function.
5. Check the operating time by injecting a voltage corresponding to  $1.2 \cdot Pickup$  level. Make note of the measured trip time.
6. If required, verify the trip time at another voltage. Normally  $2 \cdot Pickup$  is selected.
7. If used, measure the alarm level operating value. Increase the voltage and make note of the operate value *AlarmPickup*. This is done with manual test and without trip of the test set.
8. Measure the operating time on the alarm output by connecting the stop of the test set to an output from *tAlarm*. Inject a voltage  $1.2 \cdot AlarmPickup$  and measure the alarm time.
9. Check that trip and alarm outputs operate accordingly to the configuration logic.
10. Finally check that pickup and alarm information is stored in the event menu and if a serial connection to the SA is available verify that the correct and only the required signals are presented on the local HMI and on the SCADA system.



Information on how to use the event menu is found in the operator's manual.

#### 15.4.4.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.5

## Impedance protection

#### 15.5.1

### Full scheme distance protection, mho characteristic ZMHPDIS (21)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

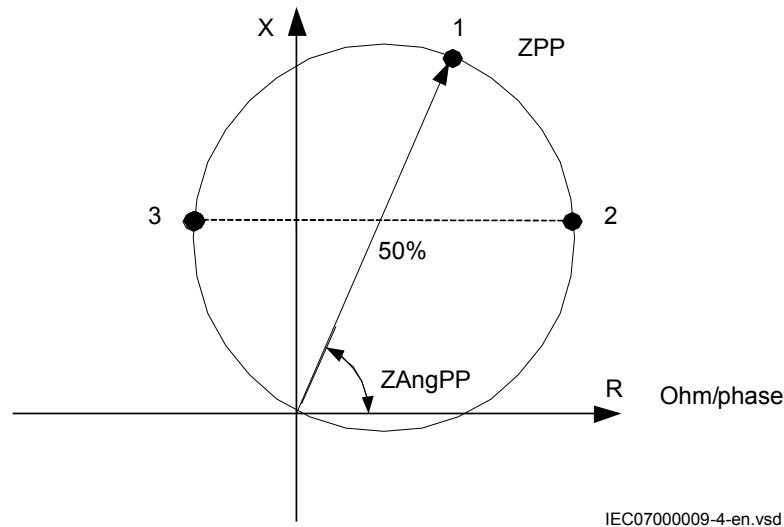
Keep the current constant when measuring operating characteristics. Keep the current as close as possible to its rated value or lower. But make sure it is higher than the set minimum operating current.

Ensure that the maximum continuous current in an IED does not exceed four times its rated value, if the measurement of the operating characteristics runs under constant voltage conditions.

To verify the mho characteristic, at least two points should be tested.

In the following, three test points are proposed. The mho characteristic always goes through the origin, which automatically gives a fourth point for the characteristic.

### 15.5.1.1 Phase-to-phase faults



*Figure 90: Proposed test points for phase-to-phase fault*

Label	Description
ZPP1	The measured impedance for phase-to-phase fault at point 1 (zone reach ZPP) ohm/phase.
ZAngPP	The characteristic angel for phase-to-phase fault in degrees.
ZPP2 and ZPP3	The fault impedance for phase-to-phase fault at the boundary for the zone reach at point 2 and 3.

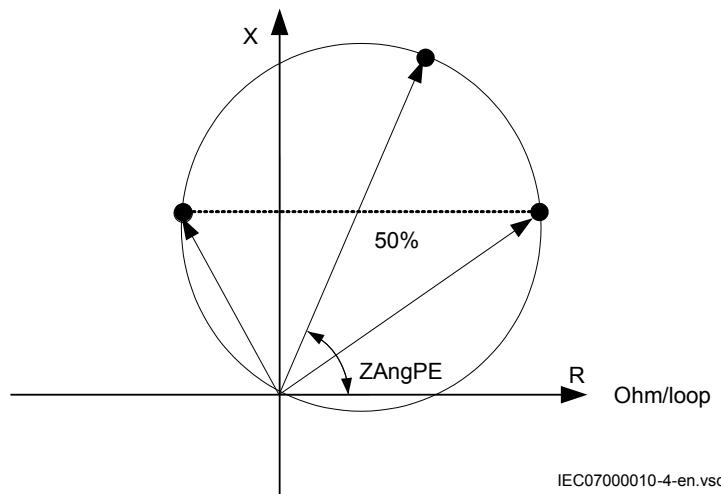
*Table 28: Test points for phase-to-phase*

Test points	R	X
1	$ZPP \cdot \cos(ZAngPP)$	$ZPP \cdot \sin(ZAngPP)$
2	$ZPP/2 + \Delta R = ZPP/2 \cdot (1 + \cos(ZAngPP))$	$ZPP/2 \cdot \sin(ZAngPP)$
3	$ZPP/2 - \Delta R = ZPP/2 \cdot (1 - \cos(ZAngPP))$	$ZPP/2 \cdot \sin(ZAngPP)$

Change the magnitude and angle of phase-to-phase voltage to achieve impedances at test points p1, p2 and p3. For each test point, observe that the output signals, START, STLx and STPP are activated where x refers to the actual phase to be tested. After the timer  $tPP$  for the actual zone has elapsed, also the signals TRIP, TRPP and TRx shall be activated.

### 15.5.1.2 Phase-to-ground faults

For simplicity, the same test points as for phase-to-phase faults are proposed, but considering new impedance values.



*Figure 91:*

Label	Description
ZPE1	The measured impedance for phase-to-ground fault at point 1 (zone reach ZPE) ohm/phase.
ZAngPE	The characteristic angel for phase-to-ground fault in degrees.
ZPE2 and ZPE3	The fault impedance for phase-to-ground fault at the boundary for the zone reach at point 2 and 3.

*Table 29: Test points for phase-to-phase loops A-B (Ohm/Loop)*

Test points	Set	Comments
1	$ZPE \cdot \cos(ZAngPE)$	$ZPE \cdot \sin(ZAngPE)$
2	$ZPE/2 + \Delta R = (ZPE/2) \cdot (1 - \cos(ZAngPE))$	$ZPE/2 \cdot \sin(ZAngPE)$
3	$ZPE/2 - \Delta R = ZPE/2 \cdot (1 - \cos(ZAngPE))$	$ZPE/2 \cdot \sin(ZAngPE)$

Check also in the same way as for phase-to-ground fault for each test point that the output signals STPE<sub>x</sub> are activated where x refers to the actual phase to be tested. After the timer  $tPE$  for the zone has elapsed, also the signals TRIP, TRPE and TRx shall be activated.

## 15.5.2 Pole slip protection PSPPPAM (78)

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

### 15.5.2.1 Verifying the settings

It is assumed that setting of the pole slip protection function PSPPPAM (78) is done according to impedances as seen in figure [92](#) and figure [93](#).

The test is done by means of injection of three-phase current and three-phase voltage from a modern test device. This test device shall be able to give voltage and current with the possibility to change voltage and current amplitude and the angle between the injected voltage and current. The parameter setting shall be according to the real application chosen values.

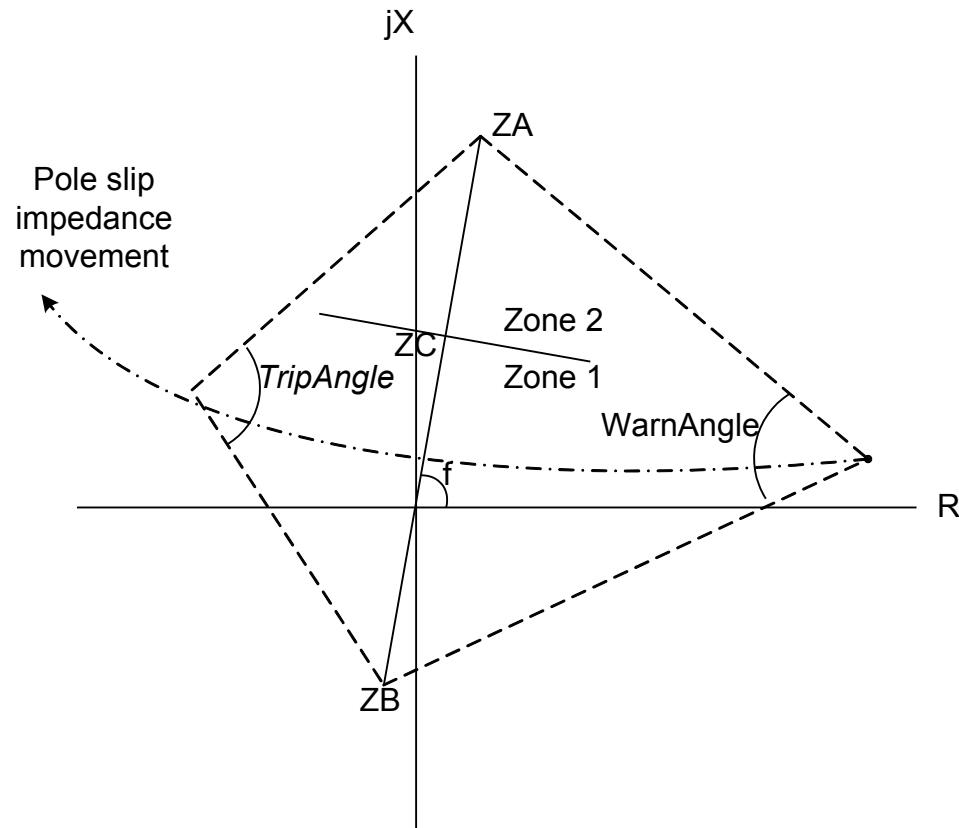
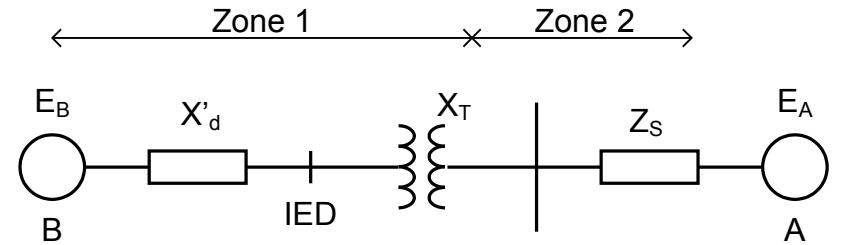
#### Procedure

1. Feed the IED with current and voltage corresponding to a normal operation point Injected voltage U equal to base voltage ( $V_{Base}$ ) and the injected current I equal to half the base current ( $I$ ). The angle between the voltage and current shall be  $0^\circ$ .  
This is done with a speed so that the final impedance is reached after 1 second.  
As the injected voltage is higher than 0.92  $V_{Base}$  no START signal should be activated.
2. With maintained amplitude of the injected voltage the current amplitude and angle is changed to a value  $ZC/2$ .  
This is done with a speed so that the final impedance is reached after 1 second.  
As the injected voltage is higher than 0.92  $V_{Base}$  the START signal should be activated.
3. With reduced amplitude of the injected voltage to 0.8  $V_{Base}$  the current amplitude and angle is changed to a value  $ZC/2$ .  
This is done with a speed so that the final impedance is reached after 1 second.  
As the injected voltage is lower than 0.92  $V_{Base}$  the START signal should be activated.
4. With reduced amplitude of the injected voltage to 0.8  $V_{Base}$  the current amplitude and angle is changed via  $ZC/2$  to a value corresponding to half  $I_{Base}$  and  $180^\circ$  between the injected current and voltage.  
This is done with a speed so that the final impedance is reached after 1 second.  
As the injected voltage is lower than 0.92  $V_{Base}$  the START signal should be activated. In addition to this the signal ZONE1 should be activated.
5. Set  $NILimit$  to 1 and repeat step 4.

Now the signals TRIP1 and TRIP should be activated.

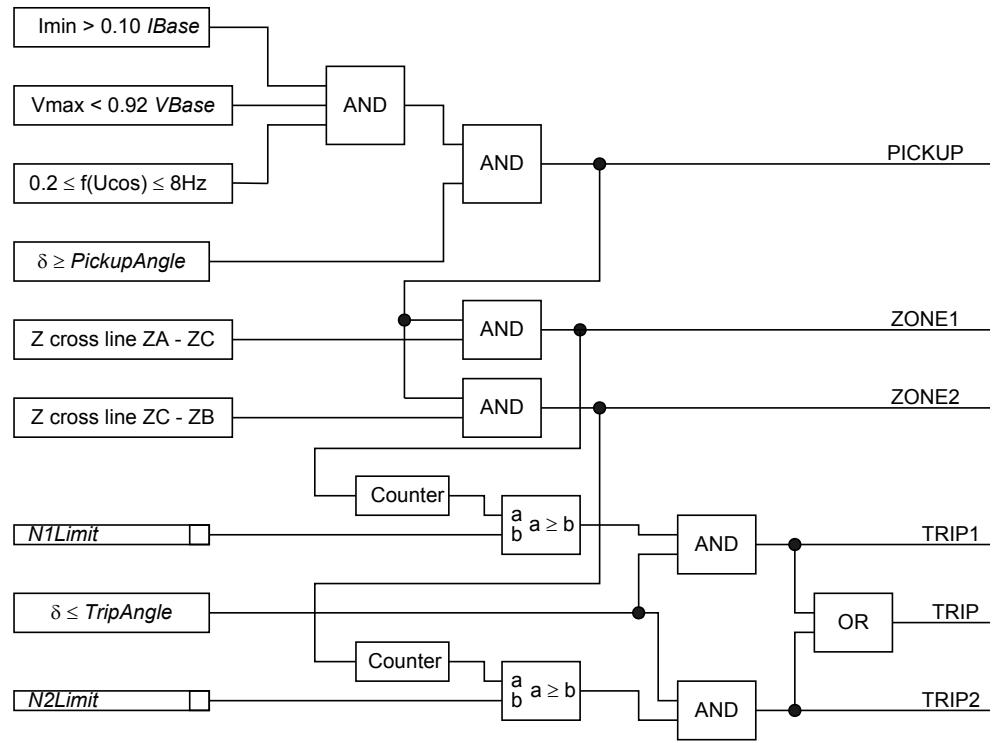
6. With reduced amplitude of the injected voltage to 0.8  $V_{Base}$  the current amplitude and angle is changed via  $ZC + (ZA - ZC)/2$  to a value corresponding to half  $I_{Base}$  and  $180^\circ$  between the injected current and voltage. This is done with a speed so that the final impedance is reached after 1s. As the injected voltage is lower than 0.92  $V_{Base}$  the START signal should be activated. In addition to this the signal ZONE2 should be activated.
7. Set  $N2Limit$  to 1 and repeat step 6.

Now the signals TRIP2 and TRIP should be activated.



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*Figure 92: Setting of the pole slip protection PSPPPAM (78)*



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Figure 93: Logic diagram of the pole slip protection PSPPPAM (78)

### 15.5.2.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

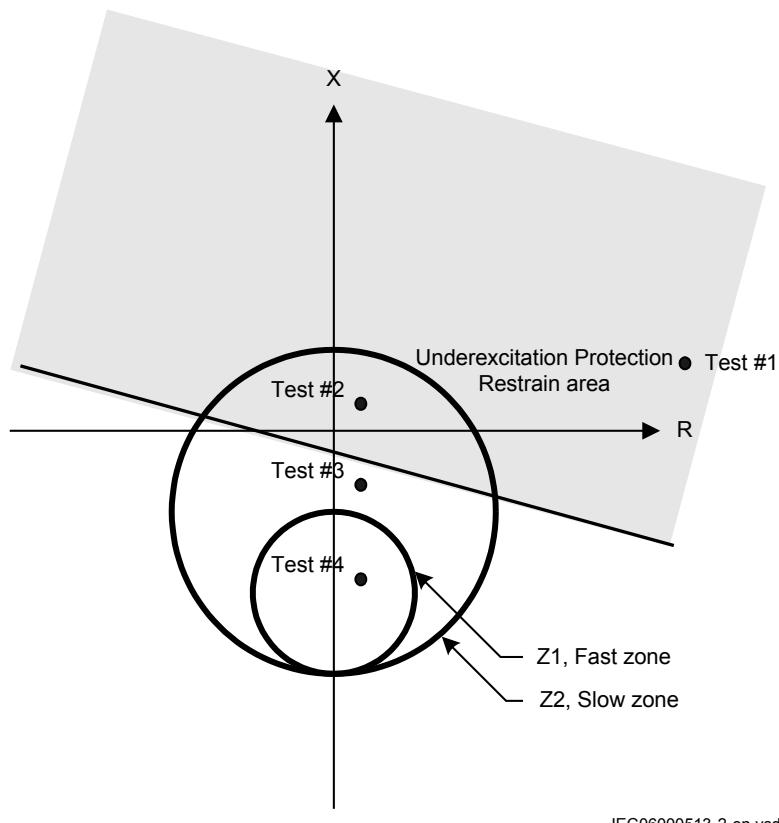
### 15.5.3 Loss of excitation LEXPDIS (40)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

#### 15.5.3.1 Verifying the settings

The test is done by means of injection of three phase current and three phase voltage from a modern test device. This test device shall be able to give voltage and current corresponding to the set apparent impedance.

1. Feed the IED with current and voltage corresponding to the apparent impedance: Test #1, as shown in figure [94](#). Read the analog outputs for R and X and check that this reading corresponds to the injected impedance. No pickup or trip signals shall be activated.
2. Feed the IED with current and voltage corresponding to the apparent impedance: Test #2, as shown in figure [94](#). Read the analog outputs for R and X and check that this reading corresponds to the injected impedance. No pickup or trip signals shall be activated.
3. Feed the IED with current and voltage corresponding to the apparent impedance: Test #3, as shown in figure [94](#). Read the analog outputs for R and X and check that this reading corresponds to the injected impedance. The signals PICKUP and PU\_Z2 shall be activated instantaneously and the signals TRIP and TRZ2 shall be activated after the set delay  $tZ2$ .
4. Switch the current infeed injection off. The function shall reset. Turn the current on with the values corresponding to Test #3 and measure the time to activation of signal TRZ2. This time shall be compared to  $tZ2$ .
5. Feed the IED with current and voltage corresponding to the apparent impedance: Test #4, as shown in figure [94](#). Read the analog outputs for R and X and check that this reading corresponds to the injected impedance. The signals PICkUP, PU\_Z2 and PU\_Z1 shall be activated instantaneously and the signals TRIP, TRZ2 and TRZ1 shall be activated after the different set time delays.
6. Switch the current infeed injection off. The function shall reset. Turn the current on with the values corresponding to Test #4 and measure the time to activation of signal TRZ1. This time shall be compared to  $tZ1$ .



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Figure 94: Testing current and voltage corresponding to the apparent impedance

#### 15.5.3.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6 Current protection

#### 15.6.1 Instantaneous phase overcurrent protection PHIOC (50)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

To verify the settings the following fault type should be tested:

- Phase-to-ground fault

Ensure that the maximum continuous current, supplied from the current source used for the test of the IED, does not exceed four times the rated current value of the IED.

### 15.6.1.1

#### Measuring the operate limit of set values

1. Inject a phase current into the IED with an initial value below that of the setting.
2. Set the operation mode to *1 out of 3*.
3. Increase the injected current in the Ln phase until the TR\_A (TR\_B or TR\_C) signal appears.
4. Switch the fault current off.



Observe: Do not exceed the maximum permitted overloading of the current circuits in the IED.

5. Compare the measured operating current with the set value.
6. Set the operation mode to *2 out of 3* and inject current into one of the phases. Check - no operation.

### 15.6.1.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6.2

#### Four step phase overcurrent protection OC4PTOC (51\_67)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.



When inverse time overcurrent characteristic is selected, the operate time of the stage will be the sum of the inverse time delay and the set definite time delay. Thus, if only the inverse time delay is required, it is of utmost importance to set the definite time delay for that stage to zero.

### 15.6.2.1

#### Verifying the settings

Verifying settings by secondary injection

---

1. Connect the test set for appropriate current injection to the appropriate IED phases. If there is any configuration logic that is used to enable or block any of the four available overcurrent steps, make sure that the step under test is enabled, for example end fault protection.  
If *1 out of 3* currents for operation is chosen: Connect the injection current to phases A and neutral.  
If *2 out of 3* currents for operation is chosen: Connect the injection current into phase A and out from phase B.  
If *3 out of 3* currents for operation is chosen: Connect the symmetrical three-phase injection current into phases A, B and C.
2. Connect the test set for the appropriate three-phase voltage injection to the IED phases A, B and C. The protection shall be fed with a symmetrical three-phase voltage.
3. Set the injected polarizing voltage slightly larger than the set minimum polarizing voltage (default is 5% of *VBase*) and set the injection current to lag the appropriate voltage by an angle of about 80° if forward directional function is selected.  
If *1 out of 3* currents for operation is chosen: The voltage angle of phase A is the reference.  
If *2 out of 3* currents for operation is chosen: The voltage angle of phase A – the voltage angle of B is the reference.  
If *3 out of 3* currents for operation is chosen: The voltage angle of phase A is the reference.  
If reverse directional function is selected, set the injection current to lag the polarizing voltage by an angle equal to 260° (equal to 80° + 180°).
4. Increase the injected current and note the operated value of the tested step of the function.
5. Decrease the current slowly and note the reset value.
6. If the test has been performed by injection of current in phase A, repeat the test when injecting current into phases B and C with polarizing voltage connected to phases B respectively C (*1 out of 3* currents for operation).
7. If the test has been performed by injection of current in phases A — B, repeat the test when injecting current into phases B — C and C — A with appropriate phase angle of injected currents.
8. Block higher set stages when testing lower set stages according to below.
9. Connect a trip output contact to a timer.
10. Set the injected current to 200% of the operate level of the tested stage, switch on the current and check the time delay.  
For inverse time curves, check the operate time at a current equal to 110% of the operate current for *txMin*.
11. Check that all trip and pickup contacts operate according to the configuration (signal matrixes)
12. Reverse the direction of the injected current and check that the protection does not operate.

13. If *2 out of 3* or *3 out of 3* currents for operation is chosen: Check that the function will not operate with current in one phase only.
14. Repeat the above described tests for the higher set stages.
15. Finally check that pickup and trip information is stored in the event menu.



Check of the non-directional phase overcurrent function. This is done in principle as instructed above, without applying any polarizing voltage.

#### 15.6.2.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.6.3

#### Instantaneous residual overcurrent protection EFPIOC (50N)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

To verify the settings the following fault type should be tested:

- Phase-to-ground fault

Ensure that the maximum continuous current, supplied from the current source used for the test of the IED, does not exceed four times the rated current value of the IED.

#### 15.6.3.1

#### Measuring the operate limit of set values

1. Inject a phase current into the IED with an initial value below that of the setting.
2. Increase the injected current in the *Ln* or in the neutral (summated current input) phase until the TRIP signal appears.
3. Disable the fault current  
Observe to not exceed the maximum permitted overloading of the current circuits in the IED
4. Compare the measured operating current with the set value.

### 15.6.3.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6.4

#### Four step residual overcurrent protection EF4PTOC (51N/67N)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.



When inverse time overcurrent characteristic is selected, the operate time of the stage will be the sum of the inverse time delay and the set definite time delay. Thus, if only the inverse time delay is required, it is of utmost importance to set the definite time delay for that stage to zero.

### 15.6.4.1

#### Four step directional ground fault protection

1. Connect the test set for single current injection to the appropriate IED terminals. Connect the injection current to terminals A and neutral.
2. Set the injected polarizing voltage slightly larger than the set minimum polarizing voltage (default 5% of Vn) and set the injection current to lag the voltage by an angle equal to the set reference characteristic angle (*AngleRCA*), if the forward directional function is selected.  
If reverse directional function is selected, set the injection current to lag the polarizing voltage by an angle equal to  $RCA + 180^\circ$ .
3. Increase the injected current and note the value at which the studied step of the function operates.
4. Decrease the current slowly and note the reset value.
5. If the test has been performed by injection of current in phase A, repeat the test, injecting current into terminals B and C with a polarizing voltage connected to terminals B, respectively C.
6. Block lower set steps when testing higher set steps according to the instructions that follow.
7. Connect a trip output contact to a timer.
8. Set the injected current to 200% of the operate level of the tested step, switch on the current and check the time delay.  
For inverse time curves, check the operate time at a current equal to 110% of the operate current for *txMin*.

9. Check that all trip and trip contacts operate according to the configuration (signal matrixes)
10. Reverse the direction of the injected current and check that the step does not operate.
11. Check that the protection does not operate when the polarizing voltage is zero.
12. Repeat the above described tests for the higher set steps.
13. Finally, check that pickup and trip information is stored in the event menu.

#### 15.6.4.2

#### Four step non-directional ground fault protection

1. Do as described in ["Four step directional ground fault protection"](#), but without applying any polarizing voltage.

#### 15.6.4.3

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.6.5

#### Four step negative sequence overcurrent protection NS4PTOC (46I2)

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.



When inverse time overcurrent characteristic is selected, the operate time of the stage will be the sum of the inverse time delay and the set definite time delay. Thus, if only the inverse time delay is required, it is of utmost importance to set the definite time delay for that stage to zero.

#### Procedure

1. Connect the test set for injection of three-phase currents and voltages to the appropriate CT and VT inputs of the IED.
2. Inject pure negative sequence current, that is, phase currents with exactly same magnitude, reversed sequence and exactly  $120^\circ$  phase displaced into the IED with an initial value below negative sequence current pickup level. No output signals should be activated. Check under NS4PTOC function Service Values that correct I<sub>2</sub> magnitude is measured by the function.
3. Set the injected negative sequence polarizing voltage slightly larger than the set minimum polarizing voltage (default 5 % of V<sub>n</sub>) and set the injection current to

lag the voltage by an angle equal to the set reference characteristic angle ( $180^\circ - AngleRCA$ ) if the forward directional function is selected.

If reverse directional function is selected, set the injection current to lag the polarizing voltage by an angle equal to RCA.

4. Increase the injected current and note the value at which the studied step of the function operates.
5. Decrease the current slowly and note the reset value.
6. Block lower set steps when testing higher set steps according to the instructions that follow.
7. Connect a trip output contact to a timer.
8. Set the injected current to 200 % of the operate level of the tested step, switch on the current and check the time delay.  
For inverse time curves, check the operate time at a current equal to 110 % of the operate current in order to test parameter  $t_{xmin}$ .
9. Check that all trip and pickup contacts operate according to the configuration (signal matrixes)
10. Reverse the direction of the injected current and check that the step does not operate.
11. Check that the protection does not operate when the polarizing voltage is zero.
12. Repeat the above-described tests for the higher set steps.
13. Finally, check that pickup and trip information is stored in the event menu.

#### 15.6.5.1

#### Completing the test

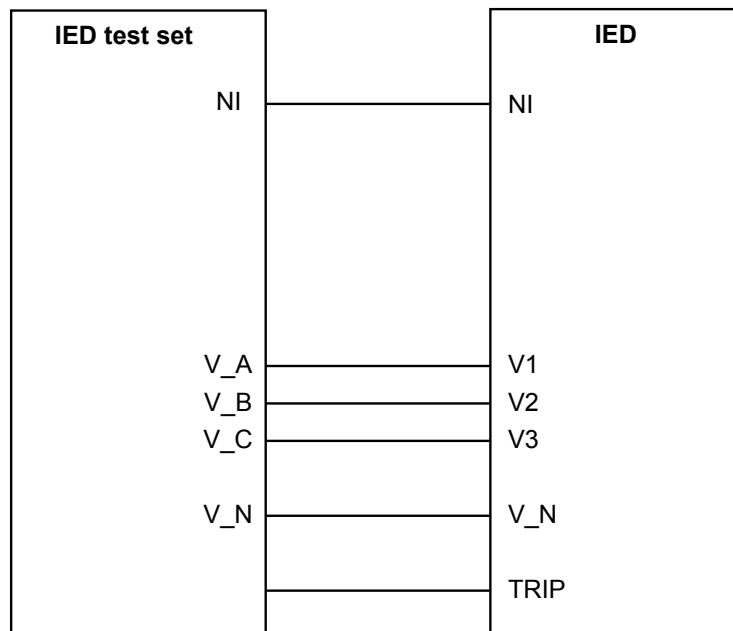
Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.6.6

#### Sensitive directional residual overcurrent and power protection SDEPSDE (67N)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

Figure 95 shows the principal connection of the test set during the test of the sensitive directional residual overcurrent protection. Observe that the polarizing voltage is equal to  $-3V_0$ .



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*Figure 95: Principle connection of the test set*

Values of the logical signals belonging to the sensitive directional residual overcurrent protection are available on the local HMI under **Main menu/Test/Function status/ Current protection/SensDirResOvCurr(PSDE,67N)/SDEPSDE:x**

#### 15.6.6.1 Measuring the operate and time limit for set values

##### Operation mode $3I_0 \cdot \cos\varphi$

###### Procedure

1. Set the polarizing voltage to  $1.2 \cdot VNRelPU$  and the phase angle between voltage and current to the set characteristic angle ( $RCADir$ ), the current lagging the voltage. Take setting  $RCAComp$  into consideration if not equal to 0.
2. Measure that the operate current of the set directional element is equal to the  $INcosPhiPU$  setting.  
The I Dir ( $I_0 \cos(\text{Angle})$ ) function activates the BFI\_3P and STDIRIN output.
3. Measure with angles  $\varphi = RCADir +/- 45^\circ$  that the measuring element operates when  $I_0 \cos (RCADir - \varphi) = I_0 \cos (+/-45) = INcosPhiPU$ .
4. Compare the result with the set value.  
Take the set characteristic into consideration, see figure 96 and figure 97.

5. Measure the operate time of the timer by injecting a current two times the set  $INcosPhiPU$  value and the polarizing voltage  $1.2 \cdot VNRelPU$ .

$$Tinv = kSN \cdot Sref / 3I_{0test} \cdot \cos(\phi)$$

(Equation 1)

6. Compare the result with the expected value.  
The expected value depends on whether definite or inverse time was selected.
7. Set the polarizing voltage to zero and increase until the boolean output signal VNREL is activated, which is visible in the Application Configuration in PCM600 when the IED is in online mode. Compare the voltage with the set value  $VNRelPU$ .
8. Continue to test another function or complete the test by setting the test mode to *Disabled*.

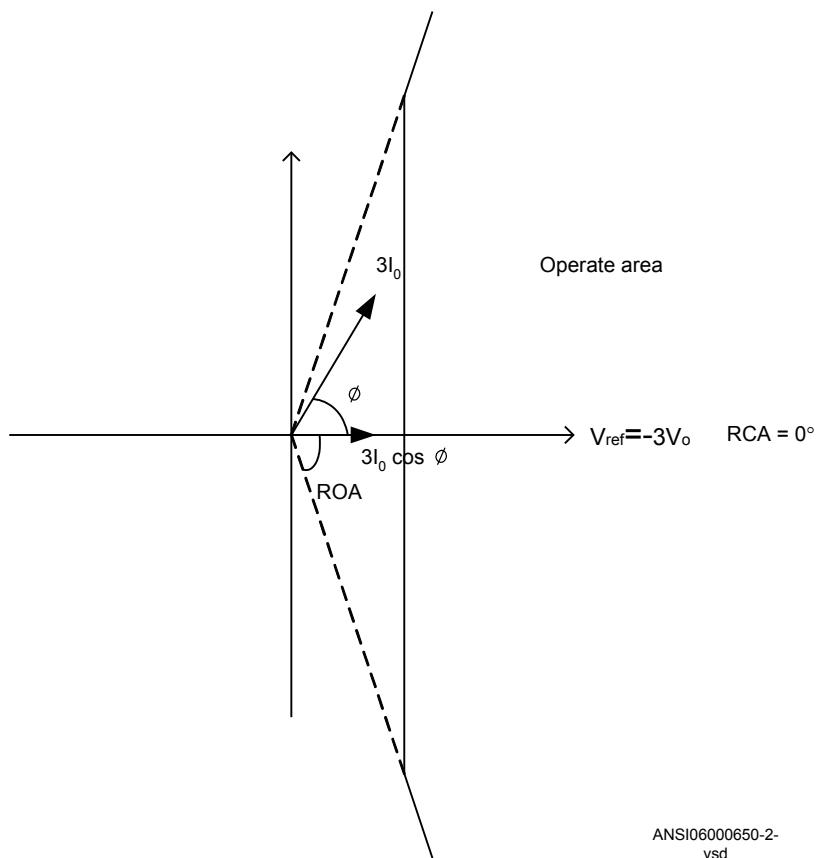
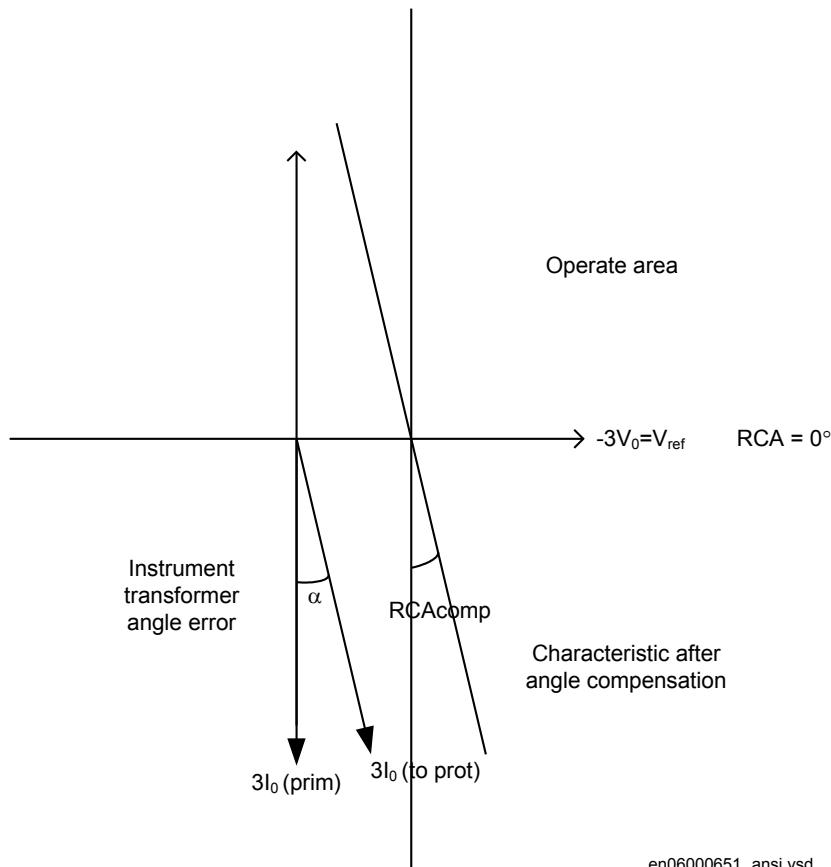


Figure 96: Characteristic with ROADir restriction



*Figure 97: Explanation of RCAComp*

#### Operation mode $3I_0 \cdot 3V_0 \cdot \cos\varphi$

1. Set the polarizing voltage to  $1.2 \cdot VNRelPU$  and the phase angle between voltage and current to the set characteristic angle ( $RCADir$ ), the current lagging the voltage.
2. Measure that the operate power is equal to the  $SN\_PU$  setting for the set directional element.  
Note that for pick-up, both the injected current and voltage must be greater than the set values  $INRelPU$  and  $VNRelPU$  respectively.  
The function activates the  $BFI\_3P$  and  $STDIRIN$  outputs.
3. Measure with angles  $\varphi = RCADir +/- 45^\circ$  that the measuring element operates when  $3I_0 \cdot 3V_0 \cdot \cos(RCADir - \varphi) = 3I_0 \cdot 3V_0 \cdot \cos(+/-45) = SN\_PU$ .
4. Compare the result with the set value. Take the set characteristic into consideration, see figure 96 and figure 97.

- 
5. Measure the operate time of the timer by injecting  $1.2 \cdot VNRelPU$  and a current to get two times the set  $SN\_PU$  operate value.

$$Tinv = kSN \cdot Sref / 3I_{0test} \cdot 3V_{0test} \cdot \cos(\varphi)$$

(Equation 2)

6. Compare the result with the expected value.  
The expected value depends on whether definite or inverse time was selected.
7. Continue to test another function or complete the test by setting the test mode to *Disabled*.

### Operation mode $3I_0$ and $\varphi$

1. Set the polarizing voltage to  $1.2 \cdot VNRelPU$  and the phase angle between voltage and current to the set characteristic angle ( $RCADir$ ), the current lagging the voltage.
2. Measure that the operate power is equal to the  $INRelPU$  setting for the set directional element.



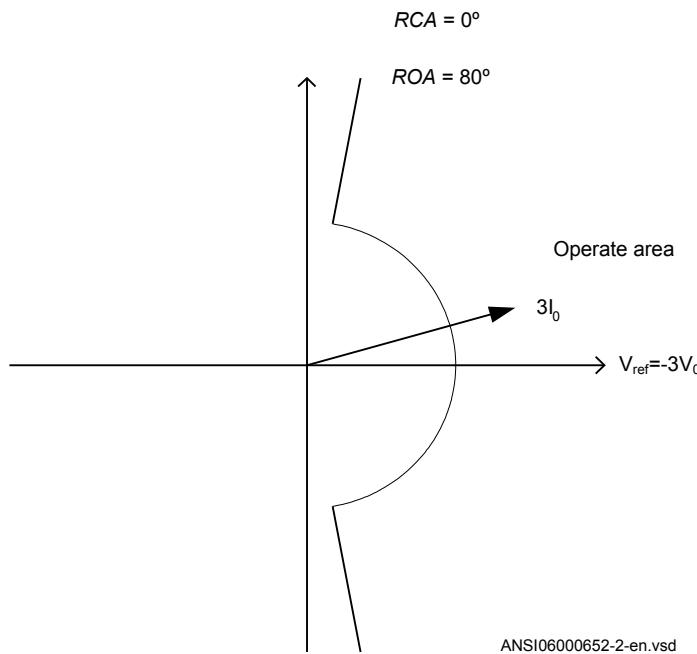
Note that for pickup, both the injected current and voltage must be greater than the set values  $INRelPU$  and  $VNRelPU$  respectively.

- The function activates the  $BFI\_3P$  and  $STDIRIN$  output.
3. Measure with angles  $\varphi$  around  $RCADir +/- ROADir$ .
  4. Compare the result with the set values, refer to figure 98 for example characteristic.
  5. Measure the operate time of the timer by injecting a current to get two times the set  $SN\_PU$  operate value.

$$Tinv = kSN \cdot Sref / 3I_{0test} \cdot 3V_{0test} \cdot \cos(\varphi)$$

(Equation 3)

6. Compare the result with the expected value.  
The expected value depends on whether definite or inverse time was selected.
7. Continue to test another function or complete the test by setting the test mode to *Disabled*.



*Figure 98: Example characteristic*

#### **Non-directional ground fault current protection**

Procedure

1. Measure that the operate current is equal to the *INNonDirPU* setting.  
The function activates the *BFI\_3P* and *STDIRIN* output.
2. Measure the operate time of the timer by injecting a current to get two times the set *INNonDirPU* operate value.
3. Compare the result with the expected value.  
The expected value depends on whether definite time *tINNonDir* or inverse time was selected.
4. Continue to test another function or complete the test by setting the test mode to *Disabled*.

#### **Residual overvoltage release and protection**

Procedure

1. Measure that the operate voltage is equal to the *VN\_PU* setting.  
The function activates the *BFI\_3P* and *STUN* signals.
2. Measure the operate time by injecting a voltage 1.2 timers set *VN\_PU* operate value.
3. Compare the result with the set *tVN* operate value.

- 
4. Inject a voltage  $0.8 \cdot VNRelPU$  and a current high enough to operate the directional function at the chosen angle.
  5. Increase the voltage until the directional function is released.
  6. Compare the measured value with the set  $VNRelPU$  operate value.

### 15.6.6.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6.7

#### Thermal overload protection, two time constants TRPTTR (49)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

### 15.6.7.1

#### Checking operate and reset values

1. Connect symmetrical three-phase currents to the appropriate current terminals of the IED.
2. Set the Time constant 1 (*Tau1*) and Time Constant 2 (*Tau2*) temporarily to 1 minute.
3. Set the three-phase injection currents slightly lower than the set operate value of stage *IBase1*, increase the current in phase A until stage *IBase1* operates and note the operate value.



Observe the maximum permitted overloading of the current circuits in the IED.

4. Decrease the current slowly and note the reset value.  
Check in the same way as the operate and reset values of *IBase1* for phases B and C.
5. Activate the digital input for cooling input signal to switch over to base current *IBase2*.
6. Check for all three phases the operate and reset values for *IBase2* in the same way as described above for stage *IBase1*
7. Deactivate the digital input signal for stage *IBase2*.
8. Set the time constant for *IBase1* in accordance with the setting plan.
9. Set the injection current for phase A to  $1.50 \cdot IBase1$ .
10. Connect a trip output contact to the timer and monitor the output of contacts ALARM1 and ALARM2 to digital inputs in test equipment.

Read the heat content in the thermal protection from the local HMI and wait until the content is zero.

11. Switch on the injection current and check that ALARM1 and ALARM2 contacts operate at the set percentage level and that the operate time for tripping is in accordance with the set Time Constant 1 ( $Tau1$ ).  
With setting  $Itr = 101\%IBasel$  and injection current  $1.50 \cdot IBasel$ , the trip time from zero content in the memory shall be  $0.60 \cdot \text{Time Constant 1 } (Tau1)$ .
12. Check that all trip and alarm contacts operate according to the configuration logic.
13. Switch off the injection current and check from the service menu readings of thermal status and LOCKOUT that the lockout resets at the set percentage of heat content.
14. Activate the digital input for cooling input signal to switch over to base current  $IBase2$ .  
Wait 5 minutes to empty the thermal memory and set Time Constant 2 ( $Tau2$ ) in accordance with the setting plan.
15. Test with injection current  $1.50 \cdot IBASE2$  the thermal alarm level, the operate time for tripping and the lockout reset in the same way as described for stage  $IBASE1$ .
16. Finally check that pickup and trip information is stored in the event menu.

#### 15.6.7.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6.8

### Breaker failure protection CCRBRF (50BF)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

The Breaker failure protection function CCRBRF (50BF) should normally be tested in conjunction with some other function that provides an initiate signal. An external INITIATE signal can also be used.

To verify the settings in the most common back-up trip mode *1 out of 3*, it is sufficient to test phase-to-ground faults.

At mode *2 out of 4* the phase current setting, *Pickup\_PH* can be checked by single-phase injection where the return current is connected to the summated current input. The value of residual (ground fault) current IN set lower than *Pickup\_PH* is easiest checked in back-up trip mode *1 out of 4*.

### 15.6.8.1

#### Checking the phase current operate value, *Pickup\_PH*

The check of the *Pickup\_PH* current level is best made in *FunctionMode = Current* and *BuTripMode = 1 out of 3 or 2 out of 4*.

1. Apply the fault condition, including INITIATION of CCRBRF (50BF), with a current below set *Pickup\_PH*.
2. Repeat the fault condition and increase the current in steps until a trip occurs.
3. Compare the result with the set *Pickup\_PH*.
4. Disconnect AC and INITIATE input signals.



Note! If *NoIPickupcheck* or *Retrip off* is set, only back-up trip can be used to check set *Pickup\_PH*.

### 15.6.8.2

#### Checking the residual (ground fault) current operate value *Pickup\_N* set below *Pickup\_PH*

Check the low set *Pickup\_N* current where setting *FunctionMode = Current* and setting *BuTripMode = 1 out of 4*

1. Apply the fault condition, including INITIATION of CCRBRF (50BF), with a current just below set *IN>Pickup\_N*.
2. Repeat the fault condition and increase the current in steps until trip appears.
3. Compare the result with the set *Pickup\_N*.
4. Disconnect AC and INITIATION input signals.

### 15.6.8.3

#### Checking the re-trip and back-up times

The check of the set times can be made in connection with the check of operate values above.

Choose the applicable function and trip mode, such as *FunctionMode = Current* and *RetripMode = Current check*.

1. Apply the fault condition, including initiation of CCRBRF (50BF), well above the set current value. Measure time from INITIATION of CCRBRF (50BF).
2. Check the re-trip *t1* and back-up trip times *t2* and *t3*.  
In applicable cases, the back-up trip for multi-phase start *t2MPh* and back-up trip 2, *t2* and *t3* can also be checked. To check *t2MPh*, a two-phase or three-phase initiation shall be applied.
3. Disconnect AC and INITIATE input signals.

### 15.6.8.4

#### **Verifying the re-trip mode**

Choose the mode below, which corresponds to the actual case.

In the cases below it is assumed that *FunctionMode = Current* is selected.

##### **Checking the case without re-trip, *RetripMode = Retrip Off***

1. Set *RetripMode = Retrip Off*.
2. Apply the fault condition, including initiation of CCRBRF (50BF), well above the set current value.
3. Verify that no re-trip, but back-up trip is achieved after set time.
4. Disconnect AC and INITIATE input signals.

##### **Checking the re-trip with current check, *RetripMode = CB Pos Check***

1. Set *RetripMode = CB Pos Check*.
2. Apply the fault condition, including initiation of CCRBRF (50BF), well above the set current value.
3. Verify that re-trip is achieved after set time *t1* and back-up trip after time *t2*.
4. Apply the fault condition, including initiation of CCRBRF (50BF), with current below set current value.
5. Verify that no re-trip, and no back-up trip is obtained.
6. Disconnect AC and INITIATE input signals.

##### **Checking re-trip without current check, *RetripMode = No CBPos Check***

1. Set *RetripMode = No CBPos Check*.
2. Apply the fault condition, including initiation of CCRBRF (50BF), well above the set current value.
3. Verify that re-trip is achieved after set time *t1*, and back-up trip after time *t2*.
4. Apply the fault condition, including initiation of CCRBRF (50BF), with current below set current value.
5. Verify that re-trip is achieved after set time *t1*, but no back-up trip is obtained.
6. Disconnect AC and INITIATE input signals.

### 15.6.8.5

#### **Verifying the back-up trip mode**

In the cases below it is assumed that *FunctionMode = Current* is selected.

##### **Checking that back-up tripping is not achieved at normal CB tripping**

Use the actual tripping modes. The case below applies to re-trip with current check.

## Verifying settings by secondary injection

1. Apply the fault condition, including initiation of CCRBRF (50BF), with phase current well above set value  $I_P$ .
2. Arrange switching the current off, with a margin before back-up trip time,  $t_2$ . It may be made at issue of re-trip command.
3. Check that re-trip is achieved, if selected, but no back-up trip.
4. Disconnect AC and INITIATE input signals.

The normal mode  $BuTripMode = 1 \text{ out of } 3$  should have been verified in the tests above. In applicable cases the modes  $1 \text{ out of } 4$  and  $2 \text{ out of } 4$  can be checked. Choose the mode below, which corresponds to the actual case.

#### **Checking the case $BuTripMode = 1 \text{ out of } 4$**

It is assumed that the ground-fault current setting  $Pickup_N$  is below phase current setting  $Pickup_PH$ .

1. Set  $BuTripMode = 1 \text{ out of } 4$ .
2. Apply the fault condition, including initiation of CCRBRF (50BF), with one-phase current below set  $Pickup_PH$  but above  $Pickup_N$ . The residual ground-fault should then be above set  $Pickup_N$ .
3. Verify that back-up trip is achieved after set time. If selected, re-trip should also appear.
4. Disconnect AC and INITIATE input signals.

#### **Checking the case $BuTripMode = 2 \text{ out of } 4$**

The ground-fault current setting  $Pickup_N$  may be equal to or below phase-current setting  $Pickup_PH$ .

1. Set  $BuTripMode = 2 \text{ out of } 4$ .
2. Apply the fault condition, including initiation of CCRBRF (50BF), with one-phase current above set  $Pickup_PH$  and residual (ground fault) above set  $Pickup_N$ . It can be obtained by applying a single-phase current.
3. Verify that back-up trip is achieved after set time. If selected, re-trip should also appear.
4. Apply the fault condition, including initiation of CCRBRF (50BF), with at least one-phase current below set  $Pickup_PH$  and residual (ground fault) above set  $Pickup_N$ . The current may be arranged by feeding three- (or two-) phase currents with equal phase angle ( $I_0$ -component) below  $Pickup_PH$ , but of such value that the residual (ground fault) current ( $3I_0$ ) will be above set value  $Pickup_N$ .
5. Verify that back-up trip is not achieved.
6. Disconnect AC and INITIATE input signals.

**15.6.8.6****Verifying instantaneous back-up trip at CB faulty condition**

Applies in a case where a signal from CB supervision function regarding CB being faulty and unable to trip is connected to input 52FAIL.

1. Repeat the check of back-up trip time. Disconnect current and INITIATE input signals.
2. Activate the input 52FAIL. The output CBALARM (CB faulty alarm) should appear after set time  $t_{CBAalarm}$ . Keep the input activated.
3. Apply the fault condition, including initiation of CCRBRF (50BF), with current above set current value.
4. Verify that back-up trip is obtained without intentional delay, for example within 20ms from application of initiation.
5. Disconnect injected AC and INITIATEinput signals.

**15.6.8.7****Verifying the case *RetripMode = Contact***

It is assumed that re-trip without current check is selected, *RetripMode = Contact*.

1. Set *FunctionMode = Contact*
2. Apply input signal for CB closed to relevant input or inputs 52a\_A (B or C)
3. Apply input signal, or signals for initiation of CCRBRF (50BF). The value of current could be low.
4. Verify that phase-selection re-trip and back-up trip are achieved after set times.
5. Disconnect the trip signal(s). Keep the CB closed signal(s).
6. Apply input signal(s), for initiation of CCRBRF (50BF). The value of current could be low.
7. Arrange disconnection of CB closed signal(s) well before set back-up trip time  $t_2$ .
8. Verify that back-up trip is not achieved.
9. Disconnect injected AC and INITIATE input signals.

**15.6.8.8****Verifying the function mode *Current&Contact***

To be made only when *FunctionMode = Current&Contact* is selected. It is suggested to make the tests in one phase only, or at three-pole trip applications for just three-pole tripping.

**Checking the case with fault current above set value *Pickup\_PH***

The operation shall be as in *FunctionMode = Current*.

1. Set *FunctionMode* = *Current&Contact*.
2. Leave the inputs for CB close inactivated. These signals should not influence.
3. Apply the fault condition, including initiation of CCRBRF (50BF), with current above the set *Pickup\_PH* value.
4. Check that the re-trip, if selected, and back-up trip commands are achieved.
5. Disconnect injected AC and INITIATE input signals.

**Checking the case with fault current below set value *Pickup\_BlkCont***

The case shall simulate a case where the fault current is very low and operation will depend on CB position signal from CB auxiliary contact. It is suggested that re-trip without current check is used, setting *RetripMode* = *No CBPos Check*.

1. Set *FunctionMode* = *Current&Contact*.
2. Apply input signal for CB closed to relevant input or inputs 52a\_A (B or C)
3. Apply the fault condition with input signal(s) for initiation of CCRBRF (50BF). The value of current should be below the set value *Pickup\_BlkCont*
4. Verify that phase selection re-trip (if selected) and back-up trip are achieved after set times. Failure to trip is simulated by keeping the signal(s) CB closed activated.
5. Disconnect the AC and the INITIATE signal(s). Keep the CB closed signal(s).
6. Apply the fault and the initiation again. The value of current should be below the set value *Pickup\_BlkCont*.
7. Arrange disconnection of BC closed signal(s) well before set back-up trip time *t2*. It simulates a correct CB tripping.
8. Verify that back-up trip is not achieved. Re-trip can appear for example, due to selection “Re-trip without current check”.
9. Disconnect injected AC and INITIATE input signals.

**15.6.8.9****Completing the test**

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

**15.6.9****Pole discrepancy protection CCRPLD (52PD)**

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

**15.6.9.1****Verifying the settings**

1. External detection logic, Contact function *selection* = *ContactSel* setting equals CCRPLD (52PD) signal from CB. Activate the EXTPDIND binary input, and measure the operating time of CCRPLD (52PD).  
Use the TRIP signal from the configured binary output to stop the timer.
2. Compare the measured time with the set value *tTrip*.
3. Reset the EXTPDIND input.
4. Activate the BLKDBYAR binary input.  
This test should be performed together with Autorecloser SMBRREC (79).
5. Activate the EXTPDIND binary input.  
No TRIP signal should appear.
6. Reset both BLKDBYAR and EXTPDIND binary inputs.
7. Activate the BLOCK binary input.
8. Activate EXTPDIND binary input.  
NO TRIP signal should appear.
9. Reset both BLOCK and EXTPDIND binary inputs.
10. If Internal detection logic Contact function *selection* = *ContactSel* setting equals Pole position from auxiliary contacts. Then set inputs 52b\_A...52a\_C in a status that activates the pole discordance logic and repeats step 2 to step 6.
11. Unsymmetrical current detection with CB monitoring: Set measured current in one phase to 110% of current release level. Activate CLOSECMD and measure the operating time of the CCRPLD (52PD) protection.  
Use the TRIP signal from the configured binary out put stop the timer.
12. 12. Deactivate the CLOSECMD: Set measured current in one phase to 90% of Current Release level. Activate CLOSECMD.  
NO TRIP signal should appear.
13. 13. Repeat step 14 and 15 using OPENCMD instead of CLOSECMD.  
Asymmetry current detection with CB monitoring: Set all three currents to 110% of Current Release level. Activate CLOSECMD.  
NO TRIP signal should appear due to symmetrical condition.
14. 14. Deactivate the CLOSECMD. Decrease one current with 120% of the current unsymmetrical level compared to the other two phases. Activate CLOSECMD and measure the operating time of the CCRPLD (52PD) protection.  
Use the TRIP signal from the configured binary out put stop the timer.
15. 15. Deactivate the CLOSECMD. Decrease one current with 80% of the current unsymmetrical level compared to the other two phases. Activate CLOSECMD.  
NO TRIP signal should appear.

#### 15.6.9.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

**15.6.10****Directional underpower protection GUPPDUP (37)**

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

**15.6.10.1****Verifying the settings**

The underpower protection shall be set to values according to the real set values to be used.

The test is made by means of injection of voltage and current where the amplitude of both current and voltage and the phase angle between the voltage and current can be controlled. During the test, the analog outputs of active and reactive power shall be monitored.

1. Connect the test set for injection of voltage and current corresponding to the mode to be used in the application. If a three-phase test set is available this could be used for all the modes. If a single-phase current/voltage test set is available the test set should be connected to a selected input for one-phase current and voltage.

*Table 30: Calculation modes*

Set value: Mode	Formula used for complex power calculation
A, B, C	$\bar{S} = \bar{V}_A \cdot \bar{I}_A^* + \bar{V}_B \cdot \bar{I}_B^* + \bar{V}_C \cdot \bar{I}_C^*$ (Equation 4)
Arone	$\bar{S} = \bar{V}_{AB} \cdot \bar{I}_A^* - \bar{V}_{BC} \cdot \bar{I}_C^*$ (Equation 5)
PosSeq	$\bar{S} = 3 \cdot \bar{V}_{PosSeq} \cdot \bar{I}_{PosSeq}^*$ (Equation 6)
AB	$\bar{S} = \bar{V}_{AB} \cdot (\bar{I}_A^* - \bar{I}_B^*)$ (Equation 7)
BC	$\bar{S} = \bar{V}_{BC} \cdot (\bar{I}_B^* - \bar{I}_C^*)$ (Equation 8)
Table continues on next page	

Set value: Mode	Formula used for complex power calculation
CA	$\bar{S} = \bar{V}_{CA} \cdot (\bar{I}_C^* - \bar{I}_A^*)$ (Equation 9)
A	$\bar{S} = 3 \cdot \bar{V}_A \cdot \bar{I}_A^*$ (Equation 10)
B	$\bar{S} = 3 \cdot \bar{V}_B \cdot \bar{I}_B^*$ (Equation 11)
C	$\bar{S} = 3 \cdot \bar{V}_C \cdot \bar{I}_C^*$ (Equation 12)

2. Adjust the injected current and voltage to the set values in % of  $I_{Base}$  and  $V_{Base}$  (converted to secondary current and voltage). The angle between the injected current and voltage shall be set equal to the set direction  $Angle1$ , angle for stage 1 (equal to  $0^\circ$  for low forward power protection and equal to  $180^\circ$  for reverse power protection). Check that the monitored active power is equal to 100% of rated power and that the reactive power is equal to 0% of rated power.
3. Change the angle between the injected current and voltage to  $Angle1 + 90^\circ$ . Check that the monitored active power is equal to 0% of rated power and that the reactive power is equal to 100% of rated power.
4. Change the angle between the injected current and voltage back to  $0^\circ$ . Decrease the current slowly until the PICKUP1 signal, pickup of stage 1, is activated.
5. Increase the current to 100% of  $I_{Base}$ .
6. Switch the current off and measure the time for activation of TRIP1, trip of stage 1.
7. If a second stage is used, repeat steps [2](#) to [6](#) for the second stage.

#### 15.6.10.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.6.11

#### Directional overpower protection GOPPDOP (32)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

### 15.6.11.1

#### Verifying the settings

The overpower protection shall be set to values according to the real set values to be used. The test is made by means of injection of voltage and current where the amplitude of both current and voltage and the phase angle between the voltage and current can be controlled. During the test the analog outputs of active and reactive power shall be monitored.

1. Connect the test set for injection of voltage and current corresponding to the mode to be used in the application. If a three phase test set is available this could be used for all the modes. If a single phase current/voltage test set is available the test set should be connected to a selected input for one phase current and voltage.
2. Adjust the injected current and voltage to the set rated values in % of  $I_{Base}$  and  $V_{Base}$  (converted to secondary current and voltage). The angle between the injected current and voltage shall be set equal to the set direction  $Angle1$ , angle for stage 1 (equal to  $0^\circ$  for low forward power protection and equal to  $180^\circ$  for reverse power protection). Check that the monitored active power is equal to 100% of rated power and that the reactive power is equal to 0% of rated power.
3. Change the angle between the injected current and voltage to  $Angle1 + 90^\circ$ . Check that the monitored active power is equal to 0% of rated power and that the reactive power is equal to 100% of rated power.
4. Change the angle between the injected current and voltage back to  $Angle1$  value. Increase the current slowly from 0 until the PICKUP1 signal, pickup of stage 1, is activated. Check the injected power and compare it to the set value  $Power1$ , power setting for stage 1 in % of  $S_{base}$ .
5. Increase the current to 100% of  $I_{Base}$  and switch the current off.
6. Switch the current on and measure the time for activation of TRIP1, trip of stage 1.
7. If a second stage is used, repeat steps [2](#) to [6](#) for the second stage.

### 15.6.11.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.6.12

#### Negative-sequence time overcurrent protection for machines NS2PTOC (46I2)



When inverse time overcurrent characteristic is selected, the operate time of the stage will be the sum of the inverse time delay and the set

definite time delay. Thus, if only the inverse time delay is required, it is of utmost importance to set the definite time delay for that stage to zero.

#### 15.6.12.1

#### Verifying settings by secondary injection

1. Connect the test set for injection of three-phase currents to the appropriate current terminals of the IED.
2. Go to **Main menu/Settings/Setting group n/Current protection/NegSeqOverCurr2Step/NSOn/General** and make sure that the function is enabled, that is *Operation* is set to *Enabled*.
3. Inject current into IEDs in such a way that negative sequence component is created and then verify that negative sequence component of the injected currents is calculated correctly by the function. See example below for 1 A rated current transformer.
4. Inject pure negative sequence current, that is, phase currents with exactly same magnitude, reversed sequence and exactly  $120^\circ$  phase displaced into the IED with an initial value below negative sequence current pickup level. No output signals should be activated.  
*Note:* If it is difficult to obtain pure negative sequence current for the secondary injection test, a current corresponding to the two phase short-circuit condition can be used. A two phase short-circuit gives a negative sequence current of a magnitude: magnitude =  $(1/\sqrt{3}) \cdot \text{fault current}$ .
5. Increase the injected current and note the value at which the step 1 of the function operates. Pickup signal PU\_ST1 must be activated when amplitude of the negative sequence current lies slightly above the pickup level  $I2-I>$ . Corresponding trip signals TRST1 and TRIP is activated after the pre-set time delay has expired.  
*Note:* Block or disable operation of step 2 when testing step 1 if the injected current activates the step 2.
6. Decrease the current slowly and note the reset value.
7. Connect a trip output contact to a timer.
8. Set the current to 200 % of the pickup level of the step 1, switch on the current and check the definite time delay for trip signals TRST1 and TRIP. Once the measured negative sequence current exceeds the set pickup level  $I2-I>$ , the settable definite timer  $t1$  starts to count and trip signals is released after the set time delay has elapsed. The same test must be carried out to check the accuracy of definite time delay for ALARM signal.  
*Note:* The output ALARM is operated by PICKUP signal.
9. If inverse time is selected the trip signals TRST1 and TRIP operates after a time corresponding to the formula:

$$t[s] = \left[ \frac{\frac{1}{\left( \frac{I2-1>}{100} \right)^2}}{\left( \text{Multiple of Pickup} \right)^2} \right] \cdot K$$

This means that if current jumps from 0 to 2 times pickup and negative sequence capability value of generator  $K1$  is set to 10 sec and current pickup level  $I2-1>$  is set to 10% of rated generator current, then TRST1 and TRIP signals operates at time equal to 250 sec  $\pm$  tolerance.

10. Repeat the above-described tests for the step 2 of the function excluding the inverse time testing.
11. Finally check that pickup and trip information is stored in the event menu.

### Example

$CT_{prim}$

The CT ratios  $CT$  sec for all three phases is 1000 A,  $IBase$  is 1000 A, and the following secondary currents are applied:

IA	Ampl = 1.1 A	Angl = 15 deg
IB	Ampl = 0.6 A	Angl = 97 deg
IC	Ampl = 1.3 A	Angl = -135 deg

The service value output NSCURN indicating amplitude of negative sequence current in primary amperes should be 962A approximative.

#### 15.6.12.2

### Completing the test

Continue to test another functions or end the test by changing the Test mode setting to Off. Restore connections and settings to their original values, if they were changed for testing purposes. Make sure that all built-in features for this function, which shall be in operation, are enabled and with correct settings.

#### 15.6.13

### Accidental energizing protection for synchronous generator AEGGAPC (50AE)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

### 15.6.13.1

#### Verifying the settings

1. Connect the test set for three-phase current injection and for three phase voltage injection to the appropriate IED terminals.
2. Inject zero voltage to the IED.
3. Increase the injected symmetric three phase current slowly and note the operated value (pickup value) of the studied step of the function.
4. Decrease the current slowly and note the reset value.
5. Connect a trip output contact to a timer.
6. Set the injected current to 200% of the operate level of the tested stage, switch on the current and check the time delay.
7. Check that all trip and pickup contacts operate according to the configuration (signal matrices).
8. Finally check that pickup and trip information is stored in the event menu.
9. Inject rated symmetric three phase voltage to the IED.
10. Set the injected current to 200% of the operate level of the tested stage, switch on the current. The function does not pickup and trip.
11. Inject 95% of the set *27\_pick\_up* value symmetric three-phase voltage to the IED.
12. Set the injected current to 200% of the operate level of the tested stage, switch on the current. The function does pickup and trip.

## 15.7

### Voltage protection

#### 15.7.1

##### Two step undervoltage protection UV2PTUV (27)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.7.1.1

##### Verifying the settings

###### Verification of PICKUP value and time delay to operate for Step1

1. Check that the IED settings are appropriate, especially the PICKUP value, the definite time delay and the *1 out of 3* operation mode.
2. Supply the IED with three-phase voltages at their rated values.
3. Slowly decrease the voltage in one of the phases, until the PICKUP signal appears.
4. Note the operate value and compare it with the set value.
5. Increase the measured voltage to rated load conditions.

6. Check that the PICKUP signal resets.
7. Instantaneously decrease the voltage in one phase to a value about 20% lower than the measured operate value.
8. Measure the time delay for the TRIP signal, and compare it with the set value.

### Extended testing

1. The test above can now be repeated for step [2](#).
2. The tests above can be repeated for *2 out of 3* and for *3 out of 3* operation mode.
3. The tests above can be repeated to check security, that is, the PICKUP and operate signals, that are not supposed to appear, - do not.
4. The tests above can be repeated to check the time to reset.
5. The tests above can be repeated to test the inverse time characteristic.

#### 15.7.1.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.7.2 Two step overvoltage protection OV2PTOV (59)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.7.2.1 Verifying the settings

1. Apply single-phase voltage below the set value *Pickup1*.
2. Slowly increase the voltage until the PU\_ST1 signal appears.
3. Note the operate value and compare it with the set value.
4. Switch the applied voltage off.
5. Set and apply about 20% higher voltage than the measured operate value for one phase.
6. Measure the time delay for the TRST1 signal and compare it with the set value.
7. Repeat the test for step [2](#).

#### 15.7.2.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.7.3

## Two step residual overvoltage protection ROV2PTOV (59N)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.7.3.1

### Verifying the settings

1. Apply the single-phase voltage either to a single phase voltage input or to a residual voltage input with the pickup value below the set value *Pickup1*.
2. Slowly increase the value until PU\_ST1 appears.
3. Note the operate value and compare it with the set value.
4. Switch the applied voltage off.
5. Set and apply about 20% higher voltage than the measured operate value for one phase.
6. Measure the time delay for the TRST1 signal and compare it with the set value.
7. Repeat the test for step [2](#).

#### 15.7.3.2

### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.7.4

## Overexcitation protection OEXPVPH (24)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.7.4.1

### Verifying the settings

1. Enable function.
2. Connect a symmetrical three-phase voltage input from the test set to the appropriate connection terminals of the overexcitation protection OEXPVPH (24) is configured for a three-phase voltage input.  
A single-phase injection voltage is applied if the function is configured for a phase-to-phase voltage input.  
OEXPVPH (24) is conveniently tested using rated frequency for the injection voltage and increasing the injection voltage to get the desired overexcitation level.
3. Connect the alarm contact to the timer and set the time delay *tAlarm* temporarily to zero.

- 
4. Increase the voltage and note the operate value *Pickup1*.
  5. Reduce the voltage slowly and note the reset value.
  6. Set the alarm time delay to the correct value according to the setting plan and check the time delay, injecting a voltage corresponding to  $1.2 \cdot \text{Pickup1}$ .
  7. Connect a trip output contact to the timer and temporarily set the time delay *t\_MinTripDelay* to 0.5s.
  8. Increase the voltage and note the *Pickup2* operate value
  9. Reduce the voltage slowly and note the reset value.
  10. Set the time delay to the correct value according to the setting plan and check the time delay *t\_MinTripDelay*, injecting a voltage corresponding to  $1.2 \cdot \text{Pickup2}$ .
  11. Check that trip and alarm contacts operate according to the configuration logic.
  12. Set the cooling time constant temporarily to min value (1min.) to quickly lower the thermal content.
  13. Wait for a period equal to 6 times *t\_CoolingK* switch 20 minutes on a voltage  $1.15 \cdot \text{Pickup1}$  and check the inverse operate time.  
Wait until the thermal memory is emptied, set the cooling time constant according to the setting plan and check another point on the inverse time curve injecting a voltage  $1.3 \cdot \text{Pickup1}$ .
  14. Finally check that PICKUP and TRIP information is stored in the event menu.

#### 15.7.4.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.7.5

### Voltage differential protection VDCPTOV (60)

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.7.5.1

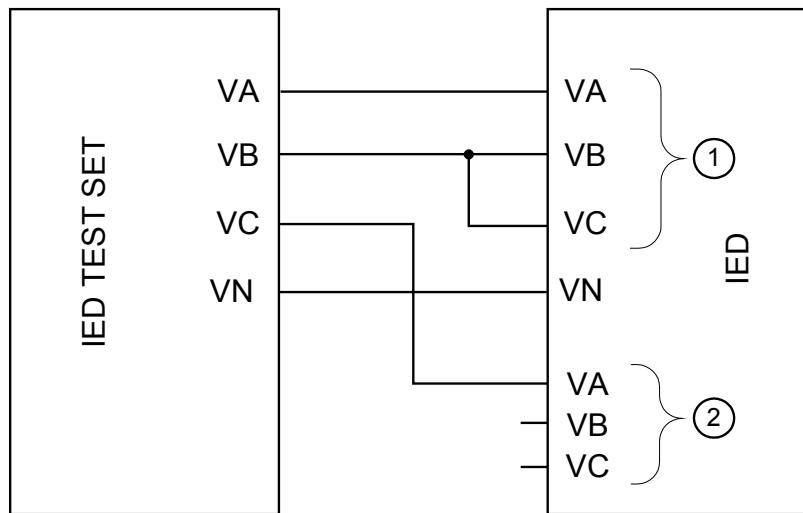
#### Check of undervoltage levels

This test is relevant if the setting *BlkDiffAtVLow* = Yes.

##### Check of *V1Low*

Procedure

1. Connect voltages to the IED according to valid connection diagram and figure 99.
  2. Apply voltage higher than the highest set value of *VDTrip*, *V1Low* and *V2Low* to the V1 three-phase inputs and to one phase of the V2 inputs according to figure 99.
- The voltage differential PICKUP signal is set.



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*Figure 99: Connection of the test set to the IED for test of V1 block level*

where:

- 1 is three-phase voltage group1 (V1)
- 2 is three-phase voltage group2 (V2)

3. Decrease slowly the voltage in phase VL1 of the test set until the PICKUP signal resets.
4. Check V1 blocking level by comparing the voltage level at reset with the set undervoltage blocking  $VILow$ .
5. Repeat steps [2](#) to [4](#) to check  $VILow$  for the other phases.

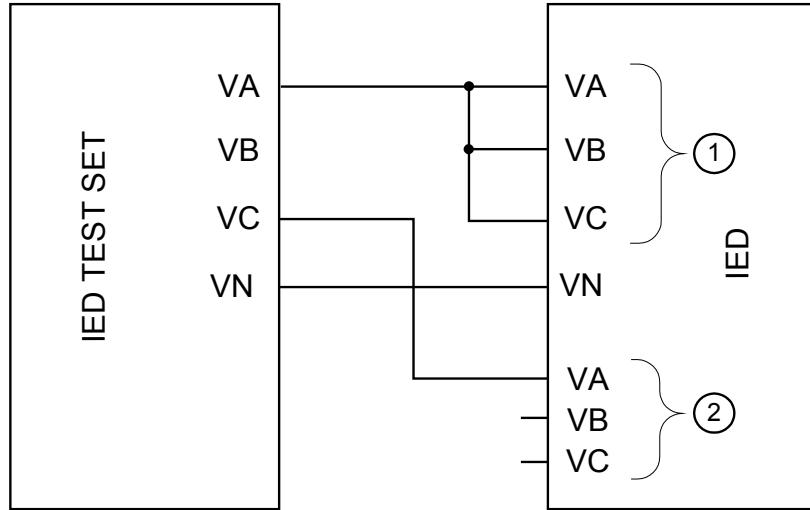


The connections to V1 must be shifted to test another phase. (VL1 to VL2, VL2 to VL3, VL3 to VL1)

### Check of $V2Low$

#### Procedure

1. Connect voltages to the IED according to valid connection diagram and figure [100](#).



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*Figure 100: Connection of the test set to the IED for test of V2 block level*

where:

- 1 is three-phase voltage group1 (V1)
  - 2 is three-phase voltage group2 (V2)

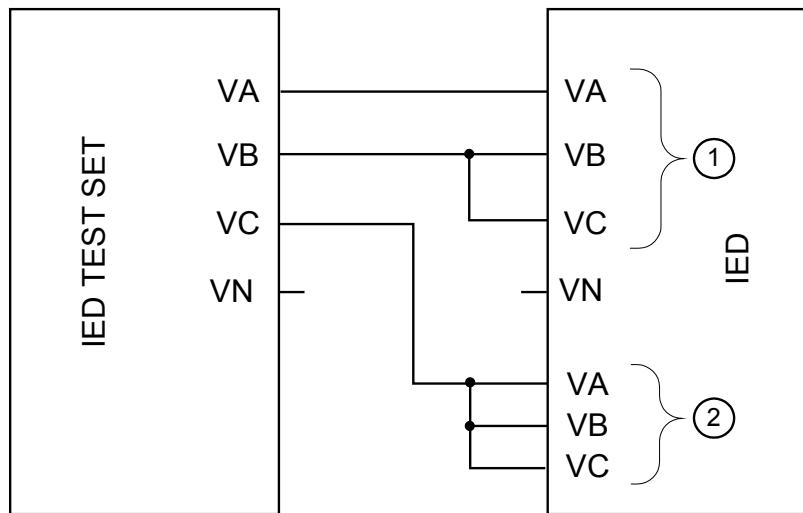
2. Apply voltage higher than the highest set value of  $VDTrip$ ,  $V1Low$  and  $V2Low$  to the V1 three-phase inputs and to one phase of the V2 inputs according to figure 100.  
The voltage differential PICKUP signal is set.
  3. Decrease slowly the voltage in phase VL3 of the test set until the PICKUP signal resets.
  4. Check V2 blocking level by comparing the voltage level at reset with the set undervoltage blocking  $V2Low$ .

## 15.7.5.2

### **Check of voltage differential trip and alarm levels**

## Procedure

1. Connect voltages to the IED according to valid connection diagram and figure [101](#).



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*Figure 101: Connection of the test set to the IED for test of alarm levels, trip levels and trip timer*

where:

- 1      is three-phase voltage group1 (V1)
- 2      is three-phase voltage group2 (V2)

2. Apply  $1.2 \cdot V_n$  (rated voltage) to the V1 and V2 inputs.
3. Decrease slowly the voltage of in phase VL1 of the test set until the ALARM signal is activated.



The ALARM signal is delayed with timer  $t_{Alarm}$

4. Check the alarm operation level by comparing the differential voltage level at ALARM with the set alarm level  $VDA_{alarm}$ .
5. Continue to slowly decrease the voltage until PICKUP signal is activated.
6. Check the differential voltage operation level by comparing the differential voltage level at PICKUP with the set trip level  $VD_{Trip}$ .
7. Repeat steps 1 to 2 to check the other phases.  
Observe that the connections to V1 must be shifted to test another phase. (VL1 to VL2, VL2 to VL3, VL3 to VL1)

### 15.7.5.3

#### Check of trip and trip reset timers

##### Procedure

1. Connect voltages to the IED according to valid connection diagram and figure [101](#).
2. Set  $V_n$  (rated voltage) to the V1 inputs and increase V2 voltage until differential voltage is  $1.5 \cdot$  operating level ( $VD_{Trip}$ ).
3. Switch on the test set. Measure the time from activation of the PICKUP signal until TRIP signal is activated.
4. Check the measured time by comparing it to the set trip time  $t_{Trip}$ .
5. Increase the voltage until PICKUP signal resets. Measure the time from reset of PICKUP signal to reset of TRIP signal.
6. Check the measured time by comparing it to the set trip reset time  $t_{Reset}$ .

### 15.7.5.4

#### Final adjustment of compensation for VT ratio differences

##### Procedure

1. With the protection in test mode, view the differential voltage service values in each phase on the local HMI under **Main menu/Test/Function status/Voltage protection/VoltageDiff(PTOV,60)/VDCPTOV:x**.



The IED voltage inputs should be connected to the VTs according to valid connection diagram.

2. Record the differential voltages.
3. Calculate the compensation factor  $RF\_x$  for each phase.  
For information about calculation of the compensation factor, see the application manual.
4. Set the compensation factors on the local HMI under **Main menu/Settings/Settings group N/Voltage protection/VoltageDiff(PTOV,60)/VDCPTOV:x**
5. Check that the differential voltages are close to zero.

### 15.7.5.5

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

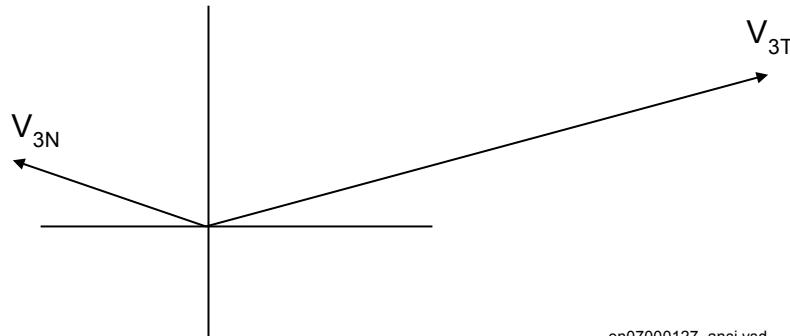
**15.7.6**
**100% Stator ground fault protection, 3rd harmonic based STEFPHIZ (59THD)**

Prepare the IED for verification of settings outlined in section "["Overview"](#)" and section "["Preparing for test"](#)" in this chapter.

**15.7.6.1**
**Testing**

The protection function uses measurement of the third-harmonic voltages in the neutral point of the generator and on the generator terminal (broken delta voltage transformer connection to the IED).

The test set shall be capable to generate third-harmonic voltages. One voltage ( $V_{N3}$ ) is connected to the residual voltage input related to the terminal side of the generator. The second voltage ( $V_{3T}$ ) is connected to the voltage input related to the neutral of the generator. The angle between the injected third-harmonic voltages shall be adjustable.



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*Figure 102: Typical phasor diagram for third harmonic voltages for healthy machine*

1. Inject the following voltages:  $V_{3T} = 15 \text{ V}$ ,  $V_{3N} = 5 \text{ V}$  and the angle between the voltages =  $180^\circ$ . Check the monitored values of the following analogue signals: E3 (the magnitude of the third-harmonic induced voltage in the stator),  $V_{3N}$ : 5 V (the magnitude of the third-harmonic voltage measured at the neutral side of the generator),  $V_{3T}$ : 15 V (the magnitude of the third-harmonic voltage measured at the terminal side of the generator) and ANGLE:  $180^\circ$  (the angle between the third harmonic voltage phasors  $V_{3N}$  and  $V_{3T}$ ). The value of E3 should be close to the following value:

$$E3 = \sqrt{(V_{3N} - V_{3T} \cdot \cos(\text{ANGLE}))^2 + (V_{3T} \cdot \sin(\text{ANGLE}))^2}$$

(Equation 13)

2. Read the value of DV (differential voltage). The value of DV should be close to the following value:

$$DU = \sqrt{(V_{3N} + V_{3T} \cdot \cos(\text{ANGLE}))^2 + (V_{3T} \cdot \sin(\text{ANGLE}))^2}$$

(Equation 14)

3. Decrease the value of the injected voltage  $V_{3N}$  until the signal PICKUP3H is activated. Check that

$$\frac{DV}{V_{3N}} = Beta$$

(Equation 15)

considering stated accuracy (*beta* is a setting parameter)

4. Increase the voltage  $V_{3N}$  so that the pickup signal falls. After that, switch the voltage  $V_{3N}$  to zero and measure the time delay for the activation of the signals TRIP and TRIP3H.

The 100% stator ground fault protection also has a fundamental frequency neutral point overvoltage function (95% stator ground fault protection). This part of the protection can be tested separately by means of fundamental frequency voltage injection from a test equipment.

## 15.7.6.2

### Verifying settings

1. With the generator rotating at rated speed but not connected: check the value of the following analogue signals: E3 (the magnitude of the 3<sup>rd</sup> harmonic induced voltage in the stator),  $V_{3N}$  (the magnitude of the third-harmonic voltage measured at the neutral side of the generator),  $V_{3T}$  (the magnitude of the third-harmonic voltage measured at the terminal side of the generator) and ANGLE (the angle between the third-harmonic voltage phasors  $V_{3N}$  and  $V_{3T}$ ). The value of E3 should be close to the following value:

$$E3 = \sqrt{(V_{3N} - V_{3T} \cdot \cos(\text{ANGLE}))^2 + (V_{3T} \cdot \sin(\text{ANGLE}))^2}$$

(Equation 16)

- Make sure that ANGLE has a value bigger than 125°
2. Read the value of DV (differential voltage). The value of DV should be close to the following value:

$$DV = \sqrt{(V_{3N} + V_{3T} \cdot \cos(ANGLE))^2 + (V_{3T} \cdot \sin(ANGLE))^2}$$

(Equation 17)

3. Read the value of BV (bias voltage:  $Beta \cdot V_{3N}$ ). The ratio DV/BV should be well below 1 for a non-faulted generator.
4. After synchronization of the generator the ratio DV/BV is checked for different load levels of the generator. These different monitoring of load levels should be the base for the setting of *beta*.  
If the function is used with the option of neutral point measurement only the test is performed by check of this voltage. The operate value should be above the measured residual third-harmonic voltage in the neutral point at normal operation (non-faulted generator).

#### 15.7.6.3

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.8

## Frequency protection

#### 15.8.1

### Underfrequency protection SAPTUF (81)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### 15.8.1.1

#### Verifying the settings

##### Verification of PICKUP value and time delay to operate

1. Check that the IED settings are appropriate, especially the PICKUP value and the definite time delay.
2. Supply the IED with three-phase voltages at their rated values.
3. Slowly decrease the frequency of the applied voltage, until the PICKUP signal appears.
4. Note the operate value and compare it with the set value.

5. Increase the frequency until rated operating levels are reached.
6. Check that the PICKUP signal resets.
7. Instantaneously decrease the frequency of the applied voltage to a value about 20% lower than the operate value.
8. Measure the time delay of the TRIP signal, and compare it with the set value.

### Extended testing

1. The test above can be repeated to check the time to reset.
2. The tests above can be repeated to test the frequency dependent inverse time characteristic.

### Verification of the low voltage magnitude blocking

1. Check that the IED settings are appropriate, especially the *PUFrequency*, *IntBlockLevel*, and the *TimeDlyOperate*.
2. Supply the IED with three-phase voltages at rated values.
3. Slowly decrease the magnitude of the applied voltage, until the BLKDMAGN signal appears.
4. Note the voltage magnitude value and compare it with the set value *IntBlockLevel*.
5. Slowly decrease the frequency of the applied voltage, to a value below *PUFrequency*.
6. Check that the PICKUP signal does not appear.
7. Wait for a time corresponding to *TimeDlyOperate*, and make sure that the TRIP signal not appears.

#### 15.8.1.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

### 15.8.2 Overfrequency protection SAPTOF (81)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

#### 15.8.2.1 Verifying the settings

##### Verification of PICKUP value and time delay to operate

1. Check that the settings in the IED are appropriate, especially the PICKUP value and the definite time delay.
2. Supply the IED with three-phase voltages at their rated values.
3. Slowly increase the frequency of the applied voltage, until the PICKUP signal appears.
4. Note the operate value and compare it with the set value.
5. Decrease the frequency to rated operating conditions.
6. Check that the PICKUP signal resets.
7. Instantaneously increase the frequency of the applied voltage to a value about 20% higher than the operate value.
8. Measure the time delay for the TRIP signal, and compare it with the set value.

#### **Extended testing**

1. The test above can be repeated to check the time to reset.

#### **Verification of the low voltage magnitude blocking**

1. Check that the settings in the IED are appropriate, especially the *PUFrequency*, *IntBlocklevel*, and the *TimeDlyOperate*.
2. Supply the IED with three-phase voltages at their rated values.
3. Slowly decrease the magnitude of the applied voltage, until the BLKDMAGN signal appears.
4. Note the voltage magnitude value and compare it with the set value, *IntBlocklevel*.
5. Slowly increase the frequency of the applied voltage, to a value above *PUFrequency*.
6. Check that the PICKUP signal does not appear.
7. Wait for a time corresponding to *TimeDlyOperate*, and make sure that the TRIP signal does not appear.

#### **15.8.2.2**

#### **Completing the test**

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### **15.8.3**

#### **Rate-of-change frequency protection SAPFRC (81)**

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

#### **15.8.3.1**

#### **Verifying the settings**

### PICKUP value and time delay to operate

1. Check that the settings in the IED are appropriate, especially the PICKUP value and the definite time delay. Set *PickupFreqgrad*, to a rather small negative value.
2. Supply the IED with three-phase voltages at their rated values.
3. Slowly decrease the frequency of the applied voltage, with an increasing rate-of-change that finally exceeds the setting of *PickupFreqgrad*, and check that the PICKUP signal appears.
4. Note the operate value and compare it with the set value.
5. Increase the frequency to rated operating conditions, and zero rate-of-change.
6. Check that the PICKUP signal resets.
7. Instantaneously decrease the frequency of the applied voltage to a value about 20% lower than the nominal value.
8. Measure the time delay for the TRIP signal, and compare it with the set value.

### Extended testing

1. The test above can be repeated to check a positive setting of *PickupFreqGrad*.
2. The tests above can be repeated to check the time to reset.
3. The tests above can be repeated to test the RESTORE signal, when the frequency recovers from a low value.

#### 15.8.3.2 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

## 15.9 Multipurpose protection

### 15.9.1 General current and voltage protection CVGAPC

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

One of the new facilities within the general current and voltage protection function CVGAPC is that the value, which is processed and used for evaluation in the function, can be chosen in many different ways by the setting parameters *CurrentInput* and *VoltageInput*.

These setting parameters decide what kind of preprocessing the connected three-phase CT and VT inputs shall be subjected to. That is, for example, single-phase quantities,

phase-to-phase quantities, positive sequence quantities, negative sequence quantities, maximum quantity from the three-phase group, minimum quantity from the three-phase group, difference between maximum and minimum quantities (unbalance) can be derived and then used in the function.

Due to the versatile possibilities of CVGAPC itself, but also the possibilities of logic combinations in the application configuration of outputs from more than one CVGAPC function block, it is hardly possible to define a fully covering general commissioning test.



When inverse time overcurrent characteristic is selected, the operate time of the stage will be the sum of the inverse time delay and the set definite time delay. Thus, if only the inverse time delay is required, it is of utmost importance to set the definite time delay for that stage to zero.

#### 15.9.1.1

#### Built-in overcurrent feature (non-directional)

##### Procedure

1. Go to **Main menu/Test/Function test modes/Multipurpose protection/GeneralCurrentVoltage(GAPC)/CVGAPC:x** and make sure that CVGAPC to be tested is unblocked and other functions that might disturb the evaluation of the test are blocked.
2. Connect the test set for injection of three-phase currents to the appropriate current terminals of the IED in the 670 series.
3. Inject current(s) in a way that relevant measured current (according to setting parameter *CurrentInput*) is created from the test set. Increase the current(s) until the low set stage operates and check against the set operate value.
4. Decrease the current slowly and check the reset value.
5. Block high set stage if the injection current will activate the high set stage when testing the low set stage according to below.
6. Connect a TRIP output contact to the timer.
7. Set the current to 200% of the operate value of low set stage, switch on the current and check the time delay.  
For inverse time curves, check the operate time at a current equal to 110% of the operate current at  $t_{MinTripDelay}$ .
8. Check that TRIP and PICKUP contacts operate according to the configuration logic.
9. Release the blocking of the high set stage and check the operate and reset value and the time delay for the high set stage in the same way as for the low set stage.
10. Finally check that PICKUP and TRIP information is stored in the event menu.



Information on how to use the event menu is found in the operator's manual.

#### 15.9.1.2

#### Overcurrent feature with current restraint

The current restraining value has also to be measured or calculated and the influence on the operation has to be calculated when the testing of the operate value is done.

##### Procedure

1. Operate value measurement

The current restraining value has also to be measured or calculated and the influence on the operation has to be calculated when the testing of the operate value is done.

#### 15.9.1.3

#### Overcurrent feature with voltage restraint

##### Procedure

1. Connect the test set for injection of three-phase currents and three-phase voltages to the appropriate current and voltage terminals of the IED.

2. Inject current(s) and voltage(s) in a way that relevant measured (according to setting parameter *CurrentInput* and *VoltageInput*) currents and voltages are created from the test set.

Overall check in principal as above (non-directional overcurrent feature)

3. Operate value measurement

The relevant voltage restraining value (according to setting parameter *VoltageInput*) has also to be injected from the test set and the influence on the operate value has to be calculated when the testing the operate value is done.

4. Operate time measurement

Definite times may be tested as above (non-directional overcurrent feature). For inverse time characteristics the PICKUP value (to which the overcurrent ratio has to be calculated) is the actual pickup value as got with actual restraining from the voltage restraining quantity.

#### 15.9.1.4

#### Overcurrent feature with directionality

Please note that the directional characteristic can be set in two different ways either just dependent on the angle between current and polarizing voltage (setting parameter *DirPrinc\_OC1* or *DirPrinc\_OC2* set to or in a way that the operate value also is dependent on the angle between current and polarizing voltage according to the I ·

$\cos(\Phi)$  law (setting parameter *DirPrincOC1* or *DirPrincOC2* set to  $I \cdot \cos(\Phi)$ ). This has to be known if a more detailed measurement of the directional characteristic is made, than the one described below.

#### Procedure

1. Connect the test set for injection of three-phase currents and three-phase voltages to the appropriate current and voltage terminals of the IED.
2. Inject current(s) and voltage(s) in a way that relevant measured (according to setting parameter *CurrentInput* and *VoltageInput*) currents and voltages are created from the test set.
3. Set the relevant measuring quantity current to lag or lead (lag for negative RCA angle and lead for positive RCA angle) the relevant polarizing quantity voltage by an angle equal to the set IED characteristic angle (*rca-dir*) when forward directional feature is selected and the *CTWYEpoint* configuration parameter is set to *ToObject*.  
If reverse directional feature is selected or *CTWYEpoint* configuration parameter is set to *FromObject*, the angle between current and polarizing voltage shall be set equal to *rca-dir*+180°.
4. Overall check in principal as above (non-directional overcurrent feature)
5. Reverse the direction of the injection current and check that the protection does not operate.
6. Check with low polarization voltage that the feature becomes non-directional, blocked or with memory according to the setting.

#### 15.9.1.5

#### Over/Undervoltage feature

#### Procedure

1. Connect the test set for injection three-phase voltages to the appropriate voltage terminals of the IED.
2. Inject voltage(s) in a way that relevant measured (according to setting parameter *VoltageInput*) voltages are created from the test set.
3. Overall check in principal as above (non-directional overcurrent feature) and correspondingly for the undervoltage feature.

#### 15.9.1.6

#### Completing the test

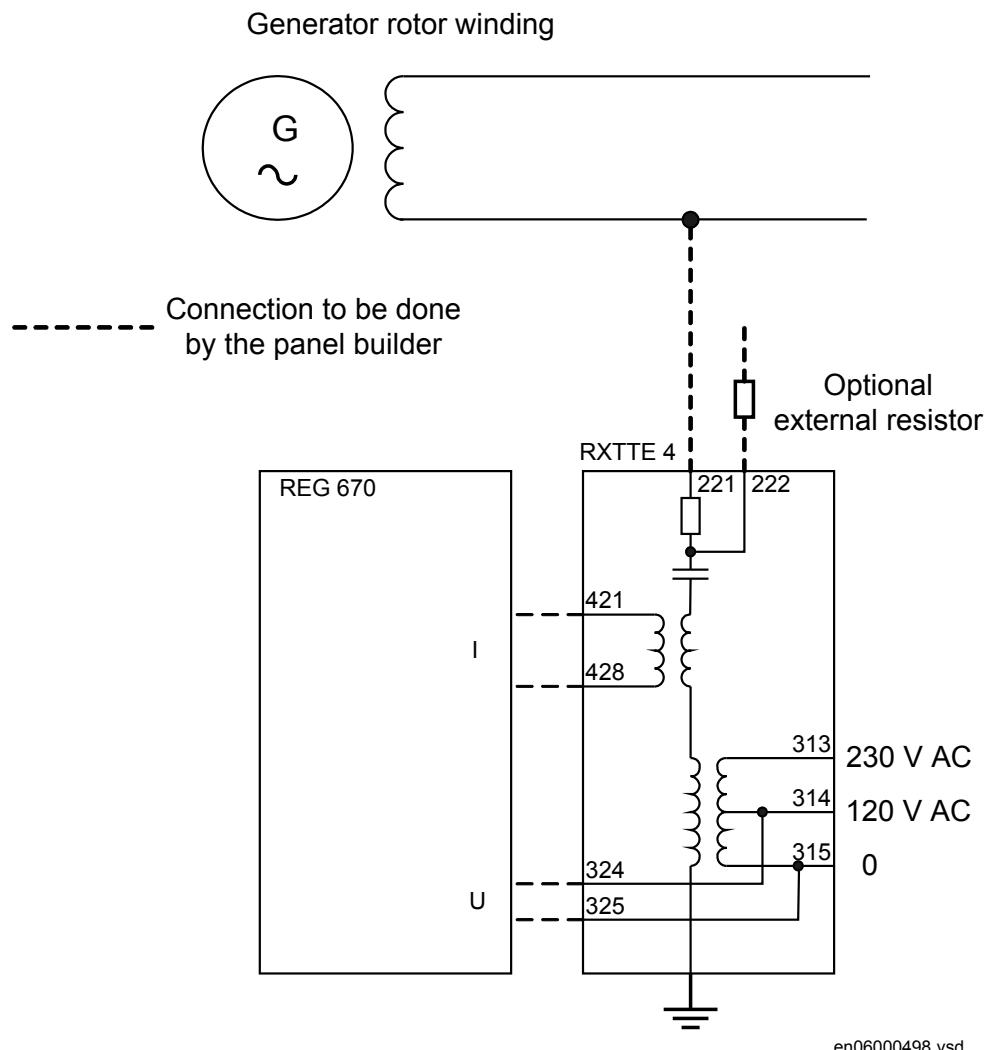
Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

**15.9.2****Rotor earth fault protection with RXTTE4 and general current and voltage protection CVGAPC**

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

**15.9.2.1****Testing**

The protection function uses injection of an ac voltage to the generator field circuit. The COMBIFLEX voltage injection unit RXTTE4, Part No 1MRK 002 108-AB contains a voltage transformer with a primary winding for connection to 120 or 230 V, 50 or 60 Hz supply voltage. From the secondary winding of this internal voltage transformer approximately 40 V AC is injected via series capacitors and resistors into the rotor circuit. The injected voltage is fed to a voltage input of the REG670 IED. The current caused by the injection is fed to a current input of the REG670 IED via a current transformer, which is amplifying the current ten times, as shown in figure [103](#).



*Figure 103: Ten times amplification of current via a current transformer*

The test described in steps 1 to 6 can be done with the generator at stand-still situations.

#### Procedure

1. The test should be prepared with a switch connected between the output of RXTTE4 (221) and the station earth. Initially this switch is open.
2. First the 120 (230) V input to RXTTE4 is disconnected. This should give a signal from REG670 that the injection voltage is low.
3. Reconnect the 120 (230) V input and check that the low injection voltage signal resets.

4. Close the switch to the station earth and check that the trip from the rotor earth fault will be given after the set delay time.
5. Open the switch to the station earth and check that the trip signal resets instantaneously.
6. Connect an adjustable resistor to the field circuit (221 on RXTTE4). Decrease this resistor from a large value until the function operates and check monitored value *ICOSFI*.

When the generator has been started the service value of injection voltage and injection current shall be checked so that there is no risk for unwanted trip due to large capacitive detected current.

### 15.9.2.2

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

## 15.10

### Secondary system supervision

#### 15.10.1

##### Current circuit supervision CCSRDIIF (87)

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

The Current circuit supervision function CCSRDIIF (87) is conveniently tested with the same three-phase test set as used when testing the measuring functions in the IED.

The condition for this procedure is that the setting of *IMinOp* is lower than the setting of *Pickup\_Block*.

#### 15.10.1.1

##### Verifying the settings

1. Check the input circuits and the operate value of the *IMinOp* current level detector by injecting current, one phase at a time.
2. Check the phase current blocking function for all three phases by injection current, one phase at a time. The output signals shall reset with a delay of 1 second when the current exceeds  $1.5 \cdot I_{Base}$ .
3. Inject a current  $0.9 \cdot I_{Base}$  to phase A and a current  $0.15 \cdot I_{Base}$  to the reference current input I5.
4. Decrease slowly the current to the reference current input and check that blocking is obtained when the current is about  $0.1 \cdot I_{Base}$ .

**15.10.1.2****Completing the test**

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

**15.10.2****Fuse failure supervision SDDRFUF**

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

The verification is divided in two main parts. The first part is common to all fuse failure supervision options, and checks that binary inputs and outputs operate as expected according to actual configuration. In the second part the relevant set operate values are measured.

**15.10.2.1****Checking that the binary inputs and outputs operate as expected**

1. Simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.
2. Connect the nominal dc voltage to the 89bS binary input.
  - The signal BLKV should appear with almost no time delay.
  - No signals BLKZ and 3PH should appear on the IED.
  - Only the distance protection function can operate.
  - Undervoltage-dependent functions must not operate.
3. Disconnect the dc voltage from the 89b binary input terminal.
4. Connect the nominal dc voltage to the MCBOP binary input.
  - The BLKV and BLKZ signals should appear without any time delay.
  - All undervoltage-dependent functions must be blocked.
5. Disconnect the dc voltage from the MCBOP binary input terminal.
6. Disconnect one of the phase voltages and observe the logical output signals on the binary outputs of the IED. BLKV and BLKZ signals should simultaneously appear.
7. After more than 5 seconds disconnect the remaining two-phase voltages and all three currents.
  - There should be no change in the high status of the output signals BLKV and BLKZ.
  - The signal 3PH will appear.
8. Establish normal voltage and current operating conditions simultaneously and observe the corresponding output signals.  
They should change to logical 0 as follows:

- Signal 3PH after about 25ms
- Signal BLKV after about 50ms
- Signal BLKZ after about 200ms

**15.10.2.2****Measuring the operate value for the negative sequence function**

Measure the operate value for the negative sequence function, if included in the IED.

1. Simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.
2. Slowly decrease the measured voltage in one phase until the BLKV signal appears.
3. Record the measured voltage and calculate the corresponding negative-sequence voltage according to the equation.

Observe that the voltages in the equation are phasors.

$$3 \cdot \overline{V_2} = \overline{V_A} + a^2 \cdot \overline{V_B} + a \cdot \overline{V_C}$$

(Equation 18)

Where:

$$\overline{V_A}, \overline{V_B} \text{ and } \overline{V_C} \quad = \text{the measured phase voltages}$$

$$a = 1 \cdot e^{j\frac{2 \cdot \pi}{3}} = -0,5 + j\frac{\sqrt{3}}{2}$$

4. Compare the result with the set value (consider that the set value  $3V2PU$  is in percentage of the base voltage  $V_{Base}$ ) of the negative-sequence operating voltage.

**15.10.2.3****Measuring the operate value for the zero-sequence function**

Measure the operate value for the zero-sequence function, if included in the IED.

1. Simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.
2. Slowly decrease the measured voltage in one phase until the BLKV signal appears.
3. Record the measured voltage and calculate the corresponding zero-sequence voltage according to the equation.

Observe that the voltages in the equation are phasors.

$$3 \cdot \overline{V_0} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

(Equation 21)

Where:

$$\overline{V_A}, \overline{V_B} \text{ and } \overline{V_C}$$

= the measured phase voltages.

4. Compare the result with the set value (consider that the set value *3V0Pickup* is in percentage of the base voltage of the zero-sequence operating voltage).

### 15.10.2.4

#### Checking the operation of the dv/dt and di/dt based function

Check the operation of the dv/dt and di/dt based function, if included in the IED.

1. Simulate normal operating conditions with the three-phase currents in phase with their corresponding phase voltages and with all of them equal to their rated values.
2. Connect the nominal dc voltage to the 52a binary input.
3. Change the voltages and currents in all three phases simultaneously.  
The voltage change should be greater than set *DVPU* and the current change should be less than the set *DIPU*.
  - The BLKV and BLKZ signals appear without any time delay. The BLKZ signal will be activated, only if the internal deadline detection is not activated at the same time.
  - 3PH should appear after 5 seconds, if the remaining voltage levels are lower than the set *VDLDPU* of the DLD function.
4. Apply normal conditions as in step 3.  
The BLKV, BLKZ and 3PH signals should reset, if activated, see step 1 and 3.
5. Change the voltages and currents in all three phases simultaneously.  
The voltage change should be greater than set *DVPU* and the current change should be greater than the set *DIPU*.  
The BLKV, BLKZ and 3PH signals should not appear.
6. Disconnect the dc voltage to the 52a binary input.
7. Apply normal conditions as in step 1.
8. Repeat step 3.
9. Connect the nominal voltages in all three phases and feed a current below the operate level in all three phases.
10. Keep the current constant. Disconnect the voltage in all three phases simultaneously.

### 15.10.2.5

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

## 15.11

### Control

#### 15.11.1

#### Synchrocheck, energizing check, and synchronizing SESRSYN (25)

This section contains instructions on how to test the synchrochecksynchronism check, energizing check, and synchronizing function SESRSYN (25) for single, double and breaker-and-a-half arrangements.

This section contains instructions on how to test the synchrochecksynchronism check and energizing check for single CB with or without the synchronizing function.

Prepare the IED for verification of settings outlined in section "[Overview](#)" and section "[Preparing for test](#)" in this chapter.

At commissioning and periodical checks, the functions shall be tested with the used settings. To test a specific function, it might be necessary to change some setting parameters, for example:

- *AutoEnerg = Disabled/DLLB/DBLL/Both*
- *ManEnerg = Disabled*
- *Operation = Disabled/Enabled*
- Activation of the voltage selection function if applicable

The tests explained in the test procedures below describe the settings, which can be used as references during testing before the final settings are specified. After testing, restore the equipment to the normal or desired settings.

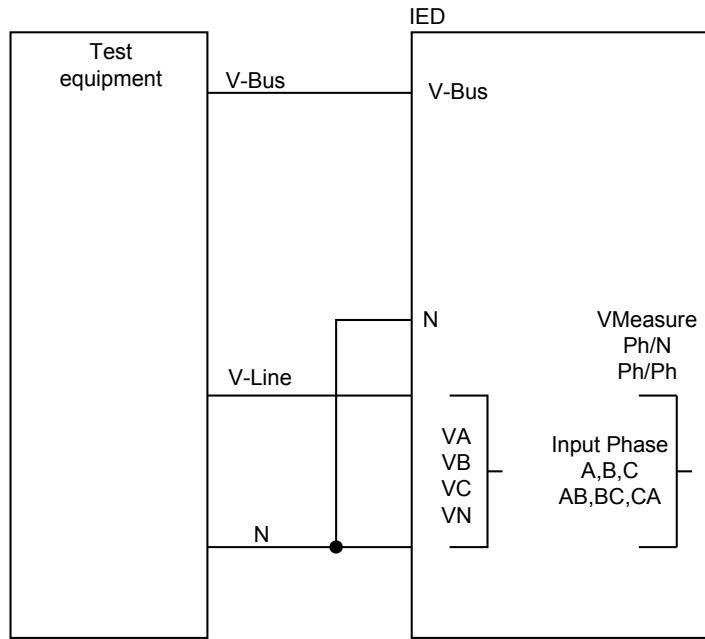
A secondary injection test set with the possibility to alter the phase angle and amplitude of the voltage is needed. The test set must also be able to generate different frequencies on different outputs.



The description below applies for a system with a nominal frequency of 60 Hz but can be directly applicable to 50 Hz. SESRSYN (25) can be set to use different phases, phase to ground or phase to phase. Use the set voltages instead of what is indicated below.

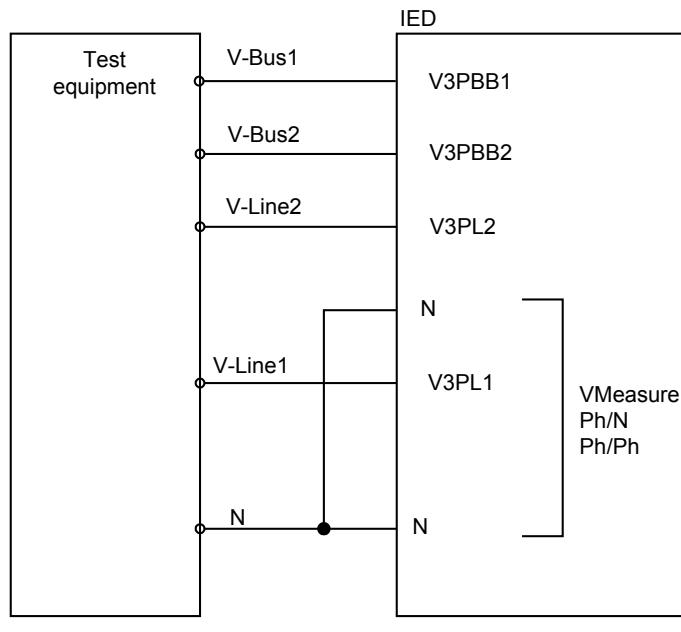
Figure 104 shows the general test connection principle, which can be used during testing. This description describes the test of the version intended for one bay.

Figure 105 shows the general test connection for a breaker-and-a-half diameter with one-phase voltage connected to the line side.



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*Figure 104: General test connection with three-phase voltage connected to the line side*



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Figure 105: General test connection for a breaker-and-a-half diameter with one-phase voltage connected to the line side

### 15.11.1.1 Testing the synchronizing function

This section is applicable only if the synchronizing function is included.

The voltage inputs used are:

V3PL1	VA, VB or VC line 1 voltage inputs on the IED
V3PBB1	Bus1 voltage input on the IED

### Testing the frequency difference

The frequency difference is in the example set at 0.20 Hz on the local HMI, and the test should verify that operation is achieved when the *FreqDiffMax* frequency difference is lower than 0.20 Hz. The test procedure below will depend on the settings used. Input STARTSYN must be activated during the test.

1. Apply voltages

- 1.1. V-Line = 100%  $VBaseLine$  and f-Line = 60.0 Hz
- 1.2. V-Bus = 100%  $VBaseBus$  and f-Bus = 60.2Hz
2. Check that a closing pulse is submitted and at closing angle less than 2 degrees from phase equality. Modern test sets will evaluate this automatically.
3. Repeat with
  - 3.1. V-Bus = 100%  $VBaseBus$  and f-bus = 60.25 Hz
  - 3.2. Verify that the function does not operate when frequency difference is above limit.
4. Repeat with different frequency differences for example, 100 mHz with f-Bus nominal and line leading and for example 20 mHz (or just above  $FreqDiffMin$ ) to verify that independent of frequency difference the closing pulse occurs within 2 degrees.
5. Verify that the closing command is not issued when the frequency difference is less than the set value  $FreqDiffMin$ .

#### 15.11.1.2

#### **Testing the synchrocheck check**

During the test of SESRSYN (25) for a single bay arrangement, these voltage inputs are used:

V-Line	VA, VB or VC line 1 voltage input on the IED
V-Bus	V5 voltage input on the IED

#### **Testing the voltage difference**

Set the voltage difference to 0.15 p.u. on the local HMI, and the test should check that operation is achieved when the voltage difference  $VDiffSC$  is lower than 0.15 p.u.

The settings used in the test shall be final settings. The test shall be adapted to site setting values instead of values in the example below.

Test with no voltage difference between the inputs.

Test with a voltage difference higher than the set  $VDiffSC$

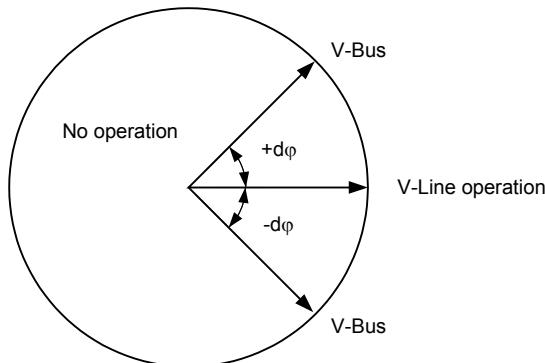
1. Apply voltages V-Line (for example) = 80%  $V_{BaseLine}$  and V-Bus = 80%  $V_{BaseBus}$  with the same phase-angle and frequency.
2. Check that the AUTOSYOK and MANSYOK outputs are activated.
3. The test can be repeated with different voltage values to verify that the function operates within the set  $VDiffSC$ . Check with both V-Line and V-Bus respectively lower than the other.
4. Increase the V-Bus to 110%  $V_{BaseBus}$ , and the V-Line = 90%  $V_{BaseLine}$  and also the opposite condition.
5. Check that the two outputs for manual and auto synchronism are not activated.

### Testing the phase angle difference

The phase angle differences  $PhaseDiffM$  and  $PhaseDiffA$  respectively are set to their final settings and the test should verify that operation is achieved when the phase angle difference is lower than this value both leading and lagging.

Test with no voltage difference.

1. Apply voltages V-Line (for example) = 100%  $V_{BaseLine}$  and V-Bus = 100%  $V_{BaseBus}$ , with a phase difference equal to 0 degrees and a frequency difference lower than  $FreqDiffA$  and  $FreqDiffM$ .
2. Check that the AUTOSYOK and MANSYOK outputs are activated.  
The test can be repeated with other phase difference values to verify that the function operates for values lower than the set ones,  $PhaseDiffM$  and  $PhaseDiffA$ . By changing the phase angle on the voltage connected to V-Bus, between  $\pm d\phi$  degrees, the user can check that the two outputs are activated for a phase difference lower than the set value. It should not operate for other values. See figure [106](#).



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*Figure 106: Test of phase difference*

3. Change the phase angle between  $+d\phi$  and  $-d\phi$  and verify that the two outputs are activated for phase differences between these values but not for phase differences outside, see figure [106](#).

### Testing the frequency difference

The frequency difference test should verify that operation is achieved when the *FreqDiffA* and *FreqDiffM* frequency difference is lower than the set value for manual and auto synchronizing check, *FreqDiffA* and *FreqDiffM* respectively and that operation is blocked when the frequency difference is greater.

Test with frequency difference = 0 mHz

Test with a frequency difference outside the set limits for manual and auto synchronizing check respectively.

1. Apply voltages V-Line equal to 100% *VBaseLine* and V-Bus equal to 100% *VBaseBus*, with a frequency difference equal to 0 mHz and a phase difference lower than the set value.
2. Check that the AUTOSYOK and MANSYOK outputs are activated.
3. Apply voltage to the V-Line equal to 100% *VBaseLine* with a frequency equal to 50 Hz and voltage V-Bus equal to 100% *VBaseBus*, with a frequency outside the set limit.
4. Check that the two outputs are not activated. The test can be repeated with different frequency values to verify that the function operates for values lower than the set ones. If a modern test set is used, the frequency can be changed continuously.

### Testing the reference voltage

1. Use the same basic test connection as in figure [104](#).

- The voltage difference between the voltage connected to V-Bus and V-Line should be 0%, so that the AUTOSYOK and MANSYOK outputs are activated first.
2. Change the V-Line voltage connection to V-Line2 without changing the setting on the local HMI. Check that the two outputs are not activated.

### 15.11.1.3

#### Testing the energizing check

During the test of the energizing check function for a single bay arrangement, these voltage inputs are used:

V-Line	VA, VB or VC line1 voltage inputs on the IED
V-Bus	Bus voltage input on the IED

#### General

When testing the energizing check function for the applicable bus, arrangement shall be done for the energizing check functions. The voltage is selected by activation of different inputs in the voltage selection logic.

The test shall be performed according to the settings for the station. Test the alternatives below that are applicable.

#### Testing the dead line live bus (DLLB)

The test should verify that the energizing check function operates for a low voltage on the V-Line and for a high voltage on the V-Bus. This corresponds to the energizing of a dead line to a live bus.

1. Apply a single-phase voltage 100%  $V_{BaseBus}$  to the V-Bus, and a single-phase voltage 30%  $V_{BaseLine}$  to the V-Line.
2. Check that the AUTOENOK and MANENOK outputs are activated after set  $tAutoEnerg$  respectively  $tManEnerg$ .
3. Increase the V-Line to 60%  $V_{BaseLine}$  and V-Bus to be equal to 100%  $V_{BaseBus}$ . The outputs should not be activated.
4. The test can be repeated with different values on the V-Bus and the V-Line.

#### Testing the dead bus live line (DBLL)

The test should verify that the energizing check function operates for a low voltage on the V-Bus and for a high voltage on the V-Line. This corresponds to an energizing of a dead bus to a live line.

1. Verify the settings *AutoEnerg* or *ManEnerg* to be *DBLL*.
2. Apply a single-phase voltage of 30% *VBaseBus* to the V-Bus and a single-phase voltage of 100% *VBaseLine* to the V-Line.
3. Check that the AUTOENOK and MANENOK outputs are activated after set *tAutoEnerg* respectively *tManEnerg*.
4. Decrease the V-Line to 60% *VBaseLine* and keep the V-Bus equal to 30% *VBaseBus*. The outputs should not be activated.
5. The test can be repeated with different values on the V-Bus and the V-Line.

#### **Testing both directions (DLLB or DBLL)**

1. Verify the local HMI settings *AutoEnerg* or *ManEnerg* to be *Both*.
2. Apply a single-phase voltage of 30% *VBaseLine* to the V-Line and a single-phase voltage of 100% *VBaseBus* to the V-Bus.
3. Check that the AUTOENOK and MANENOK outputs are activated after set *tAutoEnerg* respectively *tManEnerg*.
4. Change the connection so that the V-Line is equal to 100% *VBaseLine* and the V-Bus is equal to 30% *VBaseBus*. The outputs should still be activated.
5. The test can be repeated with different values on the V-Bus and the V-Line.

#### **Testing the dead bus dead line (DBDL)**

The test should verify that the energizing check function operates for a low voltage on both the V-Bus and the V-Line, that is, closing of the breaker in a non-energized system. Test is valid only when this function is used.

1. Verify the local HMI setting *AutoEnerg* to be *Disabled* and *ManEnerg* to be *DBLL*.
2. Set the parameter *ManEnergDBDL* to *Enabled*.
3. Apply a single-phase voltage of 30% *VBaseBus* to the V-Bus and a single-phase voltage of 30% *VBaseLine* to the V-Line.
4. Check that the MANENOK output is activated after set *tManEnerg*.
5. Increase the V-Bus to 80% and keep the V-Line equal to 30%. The outputs should not be activated.
6. Repeat the test with *ManEnerg* set to *DLLB* with different values on the V-Bus and the V-Line voltage.

#### **15.11.1.4**

#### **Testing the voltage selection**

### Testing the voltage selection for single CB arrangements

This test should verify that the correct voltage is selected for the measurement in the SESRSYN function used in a double-bus arrangement. Apply a single-phase voltage of 100% *VBaseLine* to the V-Line and a single-phase voltage of 100% *VBaseBus* to the V-Bus.

If the VB1/2OK inputs for the fuse failure are used, they must be activated, during tests below. Also verify that deactivation prevents operation and gives an alarm.

1. Connect the signals above to binary inputs and binary outputs.
2. Connect the voltage inputs to the analog inputs used for each bus or line depending of the type of busbar arrangement and verify that correct output signals are generated.

### Testing the voltage selection for double breaker or 1½ circuit breaker diameter when applicable

This test should verify that correct voltage is selected for the measurement in the energizing function used for a diameter in a Breaker-and-a-half arrangement. Apply single-phase voltages to the inputs. H means a voltage of 100% *VBaseBus* and L means a voltage of 30% *VBaseLine*. Verify that correct output signals are generated.

1. Connect the analog signals to the voltage inputs, in pair of two for V1 and V2. (Inputs U3P - BB1, BB2, L1, L2)
2. Activate the binary signals according to the used alternative. Verify the measuring voltage on the synchronizing check function SESRSYN (25). Normally it can be good to verify synchronizing check with the same voltages and phase angles on both voltages. The voltages should be verified to be available when selected and not available when another input is activated so connect only one voltage transformer reference at each time.
3. Record the voltage selection tests in a matrix table showing read values and AUTOSYOK/MANSYOK signals to document the test performed.

#### 15.11.1.5 Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

#### 15.11.2 Apparatus control APC

The apparatus control function consists of four types of function blocks, which are connected in a delivery-specific way between bays and to the station level. For that

reason, test the total function in a system, that is, either in a complete delivery system as an acceptance test (FAT/SAT) or as parts of that system.



If a block/unblock command is sent from remote to function, while the IED is shut down, this command will not be recognized after the start up, thus the command that was sent prior to the shut down is used. In such cases, where there is a mismatch, the user is advised to make a complete cycle of block/unblock operations to align the statuses.

#### 15.11.3

#### Interlocking

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

Values of the logical signals are available on the local HMI under **Main menu/Tests/Function status/Control/<Function>/<1:Function>**. The Signal Monitoring in PCM600 shows the same signals that are available on the local HMI.

The interlocking function consists of a bay-level part and a station-level part. The interlocking is delivery specific and is realized by bay-to-bay communication over the station bus. For that reason, test the function in a system, that is, either in a complete delivery system as an acceptance test (FAT/SAT) or as parts of that system.

#### 15.11.4

#### Single command SingleCommand16Signals

For the single command function block, it is necessary to configure the output signal to corresponding binary output of the IED. The operation of the single command function (SingleCommand16Signals) is then checked from the local HMI by applying the commands with *Mode* = *Off*, *Steady* or *Pulse*, and by observing the logic statuses of the corresponding binary output. Command control functions included in the operation of different built-in functions must be tested at the same time as their corresponding functions.

### 15.12

#### Logic

##### 15.12.1

##### Tripping logic SMPPTRC (94)

Prepare the IED for verification of settings outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

This function is functionality tested together with other protection functions (line differential protection, ground-fault overcurrent protection, and so on) within the IED. It is recommended that the function is tested together with the autorecloser function, when built into the IED or when a separate external unit is used for reclosing purposes. The instances of SMPPTRC (94) are identical except for the name of the function block SMPPTRC (94). The testing is preferably done in conjunction with the protection system and autoreclosing function.

### 15.12.1.1

#### Three phase operating mode

1. Check that *AutoLock* and *TripLockout* are both set to *Disable*.
2. Initiate a three-phase fault

An adequate time interval between the faults should be considered, to overcome a reset time caused by the possible activation of the Autorecloser function SMBRREC (79). The function must issue a three-pole trip in all cases, when trip is initiated by any protection or some other built-in or external function. The following functional output signals must always appear simultaneously: TRIP, TR\_A, TR\_B, TR\_C and TR3P.

### 15.12.1.2

#### 1ph/3ph operating mode

In addition to various other tests, the following tests should be performed. They depend on the complete configuration of an IED:

##### Procedure

1. Make sure that *TripLockout* and *AutoLock* are both set to *Disabled*.
2. Initiate different single-phase-to-ground faults one at a time.
3. Initiate different phase-to-phase and three-phase faults.  
Consider using an adequate time interval between faults, to overcome a reset time, which is activated by SMBRREC (79). A three-pole trip should occur for each separate fault and all of the trips. Functional outputs TRIP, all TR\_A, TR\_B, TR\_C and TR3P should be active at each fault.



No other outputs should be active.

4. Initiate a single phase-to-ground fault and switch it off immediately when the trip signal is issued for the corresponding phase. Initiate the same fault once again within the reset time of the used SMBRREC (79).
5. Initiate a single phase-to-ground fault and switch it off immediately when the trip signal is issued for the corresponding phase. Initiate the second single phase-to-

ground fault in one of the remaining phases within the time interval, shorter than *tEvolvingFault* (default setting 2.0s) and shorter than the dead-time of SMBRREC (79), when included in the protection scheme.

Check that the second trip is a three-pole trip and that a three-phase autoreclosing attempt is given after the three-phase dead time. Functional outputs TRIP, TR\_A, TR\_B, TR\_C and TR1P should be active during the first fault. No other outputs should be active. Functional outputs TRIP, all TR\_A, TR\_B, TR\_C and TR3P should be active during second fault.

#### 15.12.1.3

#### 1ph/2ph/3ph operating mode

In addition to other tests, the following tests, which depend on the complete configuration of an IED, should be carried out.

##### Procedure

1. Make sure that *AutoLock* and *TripLockout* are both set to *Disabled*.
2. Initiate different single-phase-to-ground faults one at a time.  
Take an adequate time interval between faults into consideration, to overcome a reset time, which is activated by the autorecloser function SMBRREC (79). Only a single-pole trip should occur for each separate fault and only one of the trip outputs (TR\_A, TR\_B, TR\_C) should be activated at a time. Functional outputs TRIP and TR1P should be active at each fault. No other outputs should be active.
3. Initiate different phase-to-phase faults one at a time.  
Take an adequate time interval between faults into consideration, to overcome a reset time which is activated by SMBRREC (79). Only a two-phase trip should occur for each separate fault and only corresponding two trip outputs (TR\_A, TR\_B, TR\_C) should be activated at a time. Functional outputs TRIP and TR2P should be active at each fault. No other outputs should be active.
4. Initiate a three-phase fault.
5. Initiate a single phase-to-ground fault and switch it off immediately when the trip signal is issued for the corresponding phase. Initiate the same fault once again within the reset time of the used SMBRREC (79).  
A single-phase fault shall be given at the first fault. A three-pole trip must be initiated for the second fault. Check that the corresponding trip signals appear after both faults. Functional outputs TRIP, TR\_A, TR\_B, TR\_C and TR1P should be active during first fault. No other outputs should be active. Functional outputs TRIP, all TR\_A, TR\_B, TR\_C and TR3P should be active during second fault.
6. Initiate a single phase-to-ground fault and switch it off immediately when the trip signal is generated for the corresponding phase. Initiate the second single-phase-to-ground fault in one of the remaining phases within the time interval, shorter than *tEvolvingFault* (default setting 2.0s) and shorter than the dead-time of SMBRREC (79), when included in the protection scheme.

7. Check, that the output signals, issued for the first fault, correspond to a two-phase trip for included phases. The output signals generated by the second fault must correspond to the three-phase tripping action.

#### 15.12.1.4

#### Circuit breaker lockout

The following tests should be carried out when the built-in lockout function is used in addition to possible other tests, which depends on the complete configuration of an IED.

1. Check that *AutoLock* and *TripLockout* are both set to *disable*.
2. Activate shortly the set lockout (SETLKOUT) signal in the IED.
3. Check that the circuit breaker lockout (CLLKOUT) signal is set.
4. Activate shortly thereafter, the reset lockout (RSTLKOUT) signal in the IED.
5. Check that the circuit breaker lockout (CLLKOUT) signal is reset.
6. Initiate a three-phase fault.  
A three- trip should occur and all trip outputs TR\_A, TR\_B, TR\_C should be activated. Functional outputs TRIP and TR3P should be active at each fault. The output CLLKOUT should not be set.
7. Activate the automatic lockout function, set *AutoLock = Enable* and repeat  
Beside the TRIP outputs, CLLKOUT should be set.
8. Reset the lockout signal by shortly thereafter activating the reset lockout (RSTLKOUT) signal.
9. Activate the trip signal lockout function, set *TripLockout = Enable* and repeat.  
All trip outputs (TR\_A, TR\_B, TR\_C) and functional outputs TRIP and TR3P must be active and stay active after each fault, CLLKOUT should be set.
10. Repeat.  
All functional outputs should reset.
11. Deactivate the TRIP signal lockout function, set *TripLockout = Disable* and the automatic lockout function, set *AutoLock = Disable*.

#### 15.12.1.5

#### Completing the test

Continue to test another function or end the test by changing the *TestMode* setting to *Disabled*. Restore connections and settings to their original values, if they were changed for testing purposes.

## 15.13 Monitoring

### 15.13.1 Event function EVENT

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

During testing, the IED can be set when in test mode from PST. The functionality of the event reporting during test mode is set in the Parameter Setting tool in PCM600.

- Use event masks
- Report no events
- Report all events

In test mode, individual event blocks can be blocked from PCM600.

Individually, event blocks can also be blocked from the local HMI under

**Main menu/Test/Function test modes/Monitoring/EventCounter(GGIO)/CNTGGIO:x**

## 15.14 Metering

### 15.14.1 Pulse counter PCGGIO

The test of the Pulse counter function PCGGIO requires the Parameter Setting tool in PCM600 or an appropriate connection to the local HMI with the necessary functionality. A known number of pulses with different frequencies are connected to the pulse counter input. The test should be performed with settings *Operation = Enable* or *Operation = Disable* and the function blocked or unblocked. The pulse counter value is then checked in PCM600 or on the local HMI.

## 15.15 Station communication

### 15.15.1 Multiple command and transmit MultiCmd/MultiTransm

The multiple command and transmit function (MultiCmd/MultiTransm) is only applicable for horizontal communication.

Test of the multiple command function block and multiple transmit is recommended to be performed in a system, that is, either in a complete delivery system as an acceptance test (FAT/SAT) or as parts of that system, because the command function blocks are connected in a delivery-specific way between bays and the station level and transmit.

Command and transmit function blocks included in the operation of different built-in functions must be tested at the same time as their corresponding functions.

## 15.16

## Remote communication

### 15.16.1

### Binary signal transfer BinSignReceive, BinSignTransm

Prepare the IED for verification of settings as outlined in section ["Overview"](#) and section ["Preparing for test"](#) in this chapter.

To perform a test of Binary signal transfer function (BinSignReceive/BinSignTransm), the hardware (LDCM) and binary input and output signals to transfer must be configured as required by the application.

There are two types of internal self supervision of BinSignReceive/BinSignTransm

- The I/O-circuit board is supervised as an I/O module. For example it generates FAIL if the board is not inserted. I/O-modules not configured are not supervised.
- The communication is supervised and the signal COMFAIL is generated if a communication error is detected.

Status for inputs and outputs as well as self-supervision status are available from the local HMI under

- Self-supervision status: **Main menu/Diagnostics/Internal events**
- Status for inputs and outputs: **Main menu/Test/Function status**, browse to the function group of interest.
- Remote communication related signals: **Main menu/Test/Function status/Communication/Remote communication**

Test the correct functionality by simulating different kind of faults. Also check that sent and received data is correctly transmitted and read.

A test connection is shown in figure [107](#). A binary input signal (BI) at End1 is configured to be transferred through the communication link to End2. At End2 the received signal is configured to control a binary output (BO). Check at End2 that the BI signal is received and the BO operates.

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Repeat the test for all the signals configured to be transmitted over the communication link.

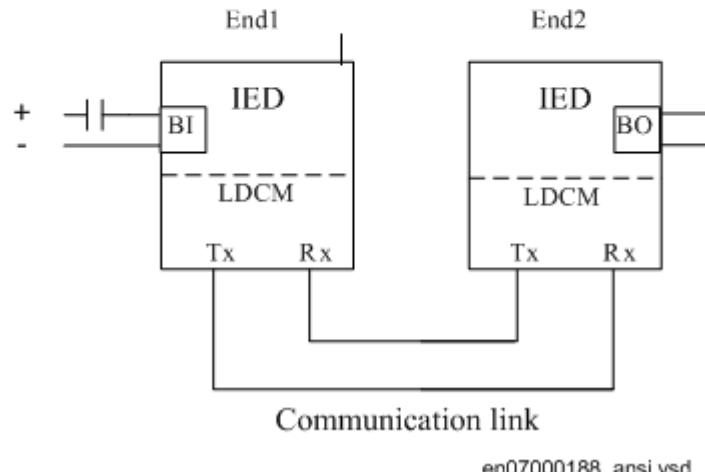


Figure 107: Test of RTC with I/O







## Section 17    Checking the directionality

### 16.1

#### About this chapter

This chapter describes how to check that the directionality is correct for each directional dependent function. The scope is also to verify that all analog values are correct. This must be done with the protection system in operation; the protected object must be energized and the primary load current must be higher than the minimum operating value set in the IED.

### 16.2

#### Overview

Before starting this process, all individual devices that are involved in the fault clearance process of the protected object must have been individually tested and must be set in operation. The circuit breaker must be ready for an open-close-open cycle.

The directional test is performed when the protected object is energized and a certain amount of load current is available. It is also necessary to know the flow of the load current (import or export, i.e. forward or reverse) by help of the indication from an external instrument (energy-meter, or SCADA information).

The design of the test procedure depends on the type of protection function to be tested. Some items that can be used as guidelines are following.

### 16.3

#### Testing the directionality of the distance protection

The test is performed by looking at the information given by the directional function ZDRDIR or ZDMRDIR.

Procedure:

1. Make sure that all control and protection functions that belong to the object that are going to be energized have been tested and are set to be in operation
2. Make sure that the primary load current fulfills the following conditions (by using an external equipment):

- The magnitude of the primary load current must be higher than the minimum operating current set for the directional elements in the IED. In case of default settings this means:
  - load current > 5% of base current
  - Otherwise the settings  $IMinOpPG$  and  $IMinOpPP$  for ZDRDIR or ZDMRDIR are available under the HMI menu: **Main menu/Settings/Setting group N/Impedance protection/DirectionalImpedance(RDIR)**

The primary load impedance must have an angle (PHI) between the setting angles for the directional lines. In case of default settings this means:

- for forward (exported) load:  $-15 \text{ deg} < \text{PHI} < 115 \text{ deg}$
- for reverse (imported) load:  $165 \text{ deg} < \text{PHI} < 295 \text{ deg}$

The settings for forward load:  $-ArgDir < \text{PHI} < ArgNegRes$  and the settings for reverse load:  $180 \text{ deg} - ArgDir < \text{PHI} < 180 \text{ deg} + ArgNegRes$  included in the directional functions ZDRDIR or ZDMRDIR are available under the HMI menu:

- **Main menu/Settings/Setting group N/Impedance protection/DirectionalImpedance(RDIR)**

3. The directionality of the load current is shown by the directional function ZDRDIR or ZDMRDIR and it is available under the HMI menu: **Main menu/Test/Function status/Impedance protection/DirectionalImpedance(RDIR)**

If the load current flows in forward (exporting) direction there will be shown:

- L1Dir = forward
- L2Dir = forward
- L3Dir = forward

If the load current flows in the reverse direction (importing) there will be shown:

- L1Dir = reverse
- L2Dir = reverse
- L3Dir = reverse

Compare this result with the information given by the external equipment, it must be the same. If the direction of the three phases is not the same, this is a sign of incorrect connection of the voltage or current transformers serving the distance protection function. It is also possible that there is a wrong setting for the earthing point for one or more of the CTs serving distance protection (the setting name is: *CTStarPoint*).

If the directional function shows forward when it should show reverse (or vice-versa) for all the three phases, this probably means a wrong connection of CTs and/or VTs serving the distance protection, or it can mean a wrong setting of earthing point (the setting name is : *CTStarPoint*) for all the three CTs, or it could mean a wrong setting for the pre-processing blocks (*3PhaseAnalogGroup*) connected to

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the CTs/VTs and serving the distance protection (verify that no wrong negation has been set; the setting name is: *Negation*).

If the directional function shows “No direction” for all the three phases it can mean that the load current is below the minimum operating current or that the load impedance has an angle which is outside the above given valid angles for determining forward or reverse direction.

If the directional function shows “No direction” for only some of the three phases, this probably means a wrong CTs/VTs connection.

4. The measured impedance information is available under the same menu. These values are not affected by the minimum operating current setting and the measured values are shown any time the load current is higher than 3% of the nominal current of the line:

- L1R
- L1X
- L2R
- L2X
- L3R
- L3X

The measured impedance information can still be used to determine the direction of the load. A positive resistance measured in all phases indicates a forward (exporting) resistive load (active power), while a negative sign indicates a reverse (importing) resistive load (active power). Usually it is enough to look at the resistive values to get information of the load direction, that must anyway be compared with the indication given by external equipment measuring the same power flow.



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## Section 18

# Commissioning and maintenance of the fault clearing system

### About this chapter

This chapter discusses maintenance tests and other periodic maintenance measures.

## 17.1

### Commissioning tests

During commissioning all protection functions shall be verified with the setting values used at each plant. The commissioning tests must include verification of all circuits by highlighting the circuit diagrams and the configuration diagrams for the used functions.

Further, the settings for protection functions are tested and recorded carefully as outlined for the future periodic maintenance tests.

The final testing includes primary verification of all directional functions where load currents is checked on the local HMI and in PCM600. The magnitudes and angles of all currents and voltages should be checked and the symmetry verified.

Directional functions have information about the measured direction and, for example, measured impedance. These values must be checked and verified as correct with the export or import of power available.

Finally, final trip tests must be performed. This involves activation of protection functions or tripping outputs with the circuit breaker closed and the tripping of the breaker verified. When several breakers are involved, each breaker must be checked individually and it must be verified that the other involved breakers are not tripped at the same time.

## 17.2

### Periodic maintenance tests

The periodicity of all tests depends on several factors, for example the importance of the installation, environmental conditions, simple or complex equipment, static or electromechanical IEDs, and so on.

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The normal maintenance practices of the user should be followed. However, ABB's recommendation is as follows:

Every second to third year

- Visual inspection of all equipment.
- Removal of dust on ventilation louvres and IEDs if necessary.
- Periodic maintenance test for protection IEDs of object where no redundant protections are provided.

Every four to six years

- Periodic maintenance test for protection IEDs of objects with redundant protection system.



First maintenance test should always be carried out after the first half year of service.



When protection IEDs are combined with built-in control, the test interval can be increased drastically, up to for instance 15 years, because the IED continuously reads service values, operates the breakers, and so on.

## 17.2.1

### Visual inspection

Prior to testing, the protection IEDs should be inspected to detect any visible damage that may have occurred (for example, dirt or moisture deposits, overheating). Should burned contacts be observed when inspecting the IEDs, a diamond file or an extremely fine file can be used to polish the contacts. Emery cloth or similar products must not be used as insulating grains of abrasive may be deposited on the contact surfaces and cause failure.

Make sure that all IEDs are equipped with covers.

## 17.2.2

### Maintenance tests

To be made after the first half year of service, then with the cycle as proposed above and after any suspected maloperation or change of the IED setting.

Testing of protection IEDs shall preferably be made with the primary circuit de-energized. The IED cannot protect the circuit during testing. Trained personnel may

test one IED at a time on live circuits where redundant protection is installed and de-energization of the primary circuit is not allowed.

ABB protection IEDs are preferably tested by aid of components from the COMBITEST testing system or FT test systems described in information B03-9510 E. Main components are RTXP 8/18/24 test switch located to the left in each protection IED and RTXH 8/18/24 test handle, which is inserted in test switch at secondary testing. All necessary operations such as opening of trip circuits, short-circuiting of current circuits and opening of voltage circuits are automatically performed in the right order to allow for simple and safe secondary testing even with the object in service.

Important components of FT test system are FT1, FTx, FT19, FT19RS, FR19RX switches and assemblies as well as FT-1 test plug.

### **17.2.2.1**

#### **Preparation**

Before starting maintenance testing, the test engineers should scrutinize applicable circuit diagrams and have the following documentation available:

- Test instructions for protection IEDs to be tested
- Test records from previous commissioning and maintenance tests
- List of valid settings
- Blank test records to fill in measured values

### **17.2.2.2**

#### **Recording**

It is of utmost importance to carefully record the test results. Special test sheets covering the frequency of test, date of test and achieved test values should be used. IED setting list and protocols from previous tests should be available and all results should be compared for differences. At component failures, spare equipment is used and set to the requested value. A note of the exchange is made and the new measured values are recorded. Test records for several years of testing should be stored in a common file for a station, or a part of a station, to give a simple overview of the period of testing and achieved test values. These test records are valuable when analysis of service disturbances shall be done.

### **17.2.2.3**

#### **Secondary injection**

The periodic maintenance test is done by secondary injection from a portable test set. Each protection shall be tested according to the secondary injection test information for the specific protection IED. Only the setting values adopted shall be checked for each protection function. If the discrepancy between obtained value and requested set value is too big the setting should be adjusted, the new value recorded and a note should be made in the test record.

#### 17.2.2.4

#### Alarm test

When inserting the test handle of RTXP or using FT plugs, the alarm and event signalling is normally blocked. This is done in the IED by setting the event reporting to *Disabled* during the test. This can be done when the test handle is inserted or the IED is set to test mode from the local HMI. At the end of the secondary injection test it should be checked that the event and alarm signalling is correct by activating the events and performing some selected tests.

#### 17.2.2.5

#### Self supervision check

Once secondary testing has been completed, it should be checked that no self-supervision signals are activated continuously or sporadically. Especially check the time synchronization system, GPS or other, and communication signals, both station communication and remote communication.

#### 17.2.2.6

#### Trip circuit check

When the protection IED undergoes an operational check, a tripping pulse is normally obtained on one or more of the output contacts and preferably on the test switch. The healthy circuit is of utmost importance for the protection operation. If the circuit is not provided with a continuous trip-circuit supervision, it is possible to check that circuit is really closed when the test-plug handle has been removed by using a high-ohmic voltmeter and measuring between the plus and the trip output on the panel. The measurement is then done through the tripping magnet of the circuit breaker and therefore the complete tripping circuit is checked.



Note that the breaker must be closed.



Please observe that the test system does not provide built-in security during this test. If the instrument should be set on Amp instead of Volts, the circuit breaker naturally is tripped, therefore, great care is necessary.

Trip circuit from trip IEDs to circuit breaker is often supervised by trip-circuit supervision. It can then be checked that a circuit is healthy by opening tripping output terminals in the cubicle. When the terminal is opened, an alarm shall be achieved on the signal system after a delay of some seconds.



Remember to close the circuit directly after the test and tighten the terminal carefully.

#### 17.2.2.7

#### Measurement of service currents

After a maintenance test it is recommended to measure the service currents and service voltages recorded by the protection IED. The service values are checked on the local HMI or in PCM600. Ensure that the correct values and angles between voltages and currents are recorded. Also check the direction of directional functions such as Distance and directional overcurrent functions.

For transformer differential protection, the achieved differential current value is dependent on the tap changer position and can vary between less than 1% up to perhaps 10% of rated current. For line differential functions, the capacitive charging currents can normally be recorded as a differential current.

The zero-sequence current to ground-fault protection IEDs should be measured. The current amounts normally very small but normally it is possible to see if the current circuit is "alive".

The neutral-point voltage to an ground-fault protection IED is checked. The voltage is normally 0.1 to 1V secondary. However, voltage can be considerably higher due to harmonics. Normally a CVT secondary can have around 2.5 - 3% third-harmonic voltage.

#### 17.2.2.8

#### Restoring

Maintenance is very important to improve the availability of the protection system by detecting failures before the protection is required to operate. There is however little point in testing healthy equipment and then putting it back into service with an open terminal, with a removed fuse or open miniature circuit breaker with an open connection, wrong setting, and so on.

Thus a list should be prepared of all items disturbed during test so that all can be put back into service quickly and without overlooking something. It should be put back into service item by item and signed by the responsible engineer.



# Section 19     Fault tracing and repair

## About this chapter

This chapter describes how to carry out fault tracing and if necessary, a change of circuit board.

## 18.1     Fault tracing

### 18.1.1     Information on the local HMI

If an internal fault has occurred, the local HMI displays information under **Main menu/Diagnostics/IED status/General**

Under the Diagnostics menus, indications of a possible internal failure (serious fault) or internal warning (minor problem) are listed.

Indications regarding the faulty unit are outlined in table [31](#).

*Table 31:     Self-supervision signals on the local HMI*

HMI Signal Name:	Status	Description
INT Fail	OFF / ON	This signal will be active if one or more of the following internal signals are active; INT--NUMFAIL, INT--LMDERROR, INT--WATCHDOG, INT--APPERROR, INT--RTEERROR, INT--FTFERROR, or any of the HW dependent signals
INT Warning	OFF / ON	This signal will be active if one or more of the following internal signals are active; INT--RTCERROR, INT--IEC61850ERROR, INT--TIMESYNCHERROR
NUM Fail	OFF / ON	This signal will be active if one or more of the following internal signals are active; INT--WATCHDOG, INT--APPERROR, INT--RTEERROR, INT--FTFERROR
NUM Warning	OFF / ON	This signal will be active if one or more of the following internal signals are active; INT--RTCERROR, INT--IEC61850ERROR
Table continues on next page		

HMI Signal Name:	Status	Description
ADMn	READY / FAIL	Analog input module n failed. Signal activation will reset the IED
BIMn	READY / FAIL	BIM error. Binary input module Error status. Signal activation will reset the IED
BOMn	READY / FAIL	BOM error. Binary output module Error status.
IOMn	READY / FAIL	IOM-error. Input/Output Module Error status.
MIMn	READY / FAIL	mA input module MIM1 failed. Signal activation will reset the IED
RTC	READY / FAIL	This signal will be active when there is a hardware error with the real time clock.
Time Sync	READY / FAIL	This signal will be active when the source of the time synchronization is lost, or when the time system has to make a time reset.
Application	READY / FAIL	This signal will be active if one or more of the application threads are not in the state that Runtime Engine expects. The states can be CREATED, INITIALIZED, RUNNING, etc.
RTE	READY / FAIL	This signal will be active if the Runtime Engine failed to do some actions with the application threads. The actions can be loading of settings or parameters for components, changing of setting groups, loading or unloading of application threads.
IEC61850	READY / FAIL	This signal will be active if the IEC61850 stack did not succeed in some actions like reading IEC61850 configuration, startup etc.
LMD	READY / FAIL	LON network interface, MIP/DPS, is in an unrecoverable error state.
LDCMxxx	READY / FAIL	Line Differential Communication Error status
OEM	READY / FAIL	Optical Ethernet Module error status.

Also the internal signals, such as INT--FAIL and INT--WARNING can be connected to binary output contacts for signalling to a control room.

In the IED Status - Information, the present information from the self-supervision function can be viewed. Indications of failure or warnings for each hardware module are provided, as well as information about the external time synchronization and the internal clock. All according to table 31. Loss of time synchronization can be considered as a warning only. The IED has full functionality without time synchronization.

## 18.1.2

## Using front-connected PC

Here, two summary signals appear, self-supervision summary and numerical module status summary. These signals can be compared to the internal signals as:

- Self-supervision summary = INT--FAIL and INT--WARNING
- CPU-module status summary = INT--NUMFAIL and INT--NUMWARN

When an internal fault has occurred, extensive information about the fault can be retrieved from the list of internal events available in the SMS part:

### TRM-STAT TermStatus - Internal Events

The list of internal events provides valuable information, which can be used during commissioning and fault tracing.

The internal events are time tagged with a resolution of 1ms and stored in a list. The list can store up to 40 events. The list is based on the FIFO principle, when it is full, the oldest event is overwritten. The list cannot be cleared and its content cannot be erased.

The internal events in this list not only refer to faults in the IED, but also to other activities, such as change of settings, clearing of disturbance reports, and loss of external time synchronization.

The information can only be retrieved from the Parameter Setting software package. The PC can be connected either to the port at the front or at the rear of the IED.

These events are logged as internal events.

*Table 32: Events available for the internal event list in the IED*

Event message:	Description	Generating signal:
INT--FAIL	Off	Internal fail status
INT--FAIL		INT--FAIL (reset event)
INT--WARNING	Off	Internal warning status
INT--WARNING		INT--WARNING (reset event)
INT--NUMFAIL	Off	Numerical module fatal error status
INT--NUMFAIL		INT--NUMFAIL (reset event)
INT--NUMWARN	Off	Numerical module non-fatal error status
INT--NUMWARN		INT--NUMWARN (reset event)
IOn--Error	Off	In/Out module No. n status
IOn--Error		IOn--Error (reset event)
Table continues on next page		

<b>Event message:</b>		<b>Description</b>	<b>Generating signal:</b>
ADMn-Error	Off	Analog/Digital module No. n status	ADMn-Error (reset event)
ADMn-Error			ADMn-Error (set event)
MIM1-Error	Off	mA-input module status	MIM1-Error (reset event)
MIM1-Error			MIM1-Error (set event)
INT--RTC	Off	Real Time Clock (RTC) status	INT--RTC (reset event)
INT--RTC			INT--RTC (set event)
INT--TSYNC	Off	External time synchronization status	INT--TSYNC (reset event)
INT--TSYNC			INT--TSYNC (set event)
INT--SETCHGD		Any settings in IED changed	
DRPC-CLEARED		All disturbances in Disturbance report cleared	

The events in the internal event list are time tagged with a resolution of 1ms.

This means that, when using the PC for fault tracing, it provides information on the:

- Module that should be changed.
- Sequence of faults, if more than one unit is faulty.
- Exact time when the fault occurred.

## 18.2 Repair instruction



Never disconnect the secondary connection of a current transformer circuit without short-circuiting the transformer's secondary winding. Operating a current transformer with the secondary winding open will cause a massive potential build up that may damage the transformer and may cause injuries to humans.



Never connect or disconnect a wire and/or a connector to or from a IED during normal service. Hazardous voltages and currents are present that may be lethal. Operation may be disrupted and IED and measuring circuitry may be damaged.

An alternative is to open the IED and send only the faulty circuit board to ABB for repair. When a printed circuit board is sent to ABB, it must always be placed in a

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metallic, ESD-proof, protection bag. The user can also purchase separate replacement modules.



Strictly follow the company and country safety regulations.

Most electronic components are sensitive to electrostatic discharge and latent damage may occur. Please observe usual procedures for handling electronics and also use an ESD wrist strap. A semi-conducting layer must be placed on the workbench and connected to ground.

Disassemble and reassemble the IED accordingly:

1. Switch off the dc supply.
2. Short-circuit the current transformers and disconnect all current and voltage connections from the IED.
3. Disconnect all signal wires by removing the female connectors.
4. Disconnect the optical fibers.
5. Unscrew the main back plate of the IED.
6. If the transformer module is to be changed:
  - Remove the IED from the panel if necessary.
  - Remove the rear plate of the IED.
  - Remove the front plate.
  - Remove the screws of the transformer input module, both front and rear.
7. Pull out the faulty module.
8. Check that the new module has a correct identity number.
9. Check that the springs on the card rail are connected to the corresponding metallic area on the circuit board when the new module is inserted.
10. Reassemble the IED.

If the IED has been calibrated with the system inputs, the calibration procedure must be performed again to maintain the total system accuracy.

## 18.3

## Repair support

If an IED needs to be repaired, the whole IED must be removed and sent to an ABB Logistic Center. Please contact the local ABB representative to get more details.

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## 18.4 Maintenance

The IED is self-supervised. No special maintenance is required.

Instructions from the power network company and other maintenance directives valid for maintenance of the power system must be followed.

# Section 20      Glossary

## About this chapter

This chapter contains a glossary with terms, acronyms and abbreviations used in ABB technical documentation.

<b>AC</b>	Alternating current
<b>ACT</b>	Application configuration tool within PCM600
<b>A/D converter</b>	Analog-to-digital converter
<b>ADBS</b>	Amplitude deadband supervision
<b>ADM</b>	Analog digital conversion module, with time synchronization
<b>AI</b>	Analog input
<b>ANSI</b>	American National Standards Institute
<b>AR</b>	Autoreclosing
<b>AngNegRes</b>	Setting parameter/ZD/
<b>ArgDirAngDir</b>	Setting parameter/ZD/
<b>ASCT</b>	Auxiliary summation current transformer
<b>ASD</b>	Adaptive signal detection
<b>AWG</b>	American Wire Gauge standard
<b>BBP</b>	Busbar protection
<b>BFP</b>	Breaker failure protection
<b>BI</b>	Binary input
<b>BIM</b>	Binary input module
<b>BOM</b>	Binary output module
<b>BOS</b>	Binary outputs status
<b>BR</b>	External bistable relay
<b>BS</b>	British Standards
<b>BSR</b>	Binary signal transfer function, receiver blocks
<b>BST</b>	Binary signal transfer function, transmit blocks
<b>C37.94</b>	IEEE/ANSI protocol used when sending binary signals between IEDs

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<b>CAN</b>	Controller Area Network. ISO standard (ISO 11898) for serial communication
<b>CB</b>	Circuit breaker
<b>CBM</b>	Combined backplane module
<b>CCITT</b>	Consultative Committee for International Telegraph and Telephony. A United Nations-sponsored standards body within the International Telecommunications Union.
<b>CCM</b>	CAN carrier module
<b>CCVT</b>	Capacitive Coupled Voltage Transformer
<b>Class C</b>	Protection Current Transformer class as per IEEE/ ANSI
<b>CMPPS</b>	Combined megapulses per second
<b>CMT</b>	Communication Management tool in PCM600
<b>CO cycle</b>	Close-open cycle
<b>Codirectional</b>	Way of transmitting G.703 over a balanced line. Involves two twisted pairs making it possible to transmit information in both directions
<b>COMTRADE</b>	Standard Common Format for Transient Data Exchange format for Disturbance recorder according to IEEE/ANSI C37.111, 1999 / IEC60255-24
<b>Contra-directional</b>	Way of transmitting G.703 over a balanced line. Involves four twisted pairs, two of which are used for transmitting data in both directions and two for transmitting clock signals
<b>CPU</b>	Central processor unit
<b>CR</b>	Carrier receive
<b>CRC</b>	Cyclic redundancy check
<b>CROB</b>	Control relay output block
<b>CS</b>	Carrier send
<b>CT</b>	Current transformer
<b>CVT or CCVT</b>	Capacitive voltage transformer
<b>DAR</b>	Delayed autoreclosing
<b>DARPA</b>	Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)
<b>DBDL</b>	Dead bus dead line
<b>DBLL</b>	Dead bus live line
<b>DC</b>	Direct current

<b>DFC</b>	Data flow control
<b>DFT</b>	Discrete Fourier transform
<b>DHCP</b>	Dynamic Host Configuration Protocol
<b>DIP-switch</b>	Small switch mounted on a printed circuit board
<b>DI</b>	Digital input
<b>DLLB</b>	Dead line live bus
<b>DNP</b>	Distributed Network Protocol as per IEEE Std 1815-2012
<b>DR</b>	Disturbance recorder
<b>DRAM</b>	Dynamic random access memory
<b>DRH</b>	Disturbance report handler
<b>DSP</b>	Digital signal processor
<b>DTT</b>	Direct transfer trip scheme
<b>EHV network</b>	Extra high voltage network
<b>EIA</b>	Electronic Industries Association
<b>EMC</b>	Electromagnetic compatibility
<b>EMF</b>	(Electromotive force)
<b>EMI</b>	Electromagnetic interference
<b>EnFP</b>	End fault protection
<b>EPA</b>	Enhanced performance architecture
<b>ESD</b>	Electrostatic discharge
<b>FCB</b>	Flow control bit; Frame count bit
<b>FOX 20</b>	Modular 20 channel telecommunication system for speech, data and protection signals
<b>FOX 512/515</b>	Access multiplexer
<b>FOX 6Plus</b>	Compact time-division multiplexer for the transmission of up to seven duplex channels of digital data over optical fibers
<b>G.703</b>	Electrical and functional description for digital lines used by local telephone companies. Can be transported over balanced and unbalanced lines
<b>GCM</b>	Communication interface module with carrier of GPS receiver module
<b>GDE</b>	Graphical display editor within PCM600
<b>GI</b>	General interrogation command

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<b>GIS</b>	Gas-insulated switchgear
<b>GOOSE</b>	Generic object-oriented substation event
<b>GPS</b>	Global positioning system
<b>GSAL</b>	Generic security application
<b>GTM</b>	GPS Time Module
<b>HDLC protocol</b>	High-level data link control, protocol based on the HDLC standard
<b>HFBR connector type</b>	Plastic fiber connector
<b>HMI</b>	Human-machine interface
<b>HSAR</b>	High speed autoreclosing
<b>HV</b>	High-voltage
<b>HVDC</b>	High-voltage direct current
<b>ICT</b>	Installation and Commissioning Tool for injection based protection in REG670
<b>IDBS</b>	Integrating deadband supervision
<b>IEC</b>	International Electrical Committee
<b>IEC 60044-6</b>	IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance
<b>IEC 60870-5-103</b>	Communication standard for protective equipment. A serial master/slave protocol for point-to-point communication
<b>IEC 61850</b>	Substation automation communication standard
<b>IEC 61850-8-1</b>	Communication protocol standard
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>IEEE 802.12</b>	A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable
<b>IEEE P1386.1</b>	PCI Mezzanine Card (PMC) standard for local bus modules. References the CMC (IEEE P1386, also known as Common Mezzanine Card) standard for the mechanics and the PCI specifications from the PCI SIG (Special Interest Group) for the electrical EMF (Electromotive force).
<b>IEEE 1686</b>	Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities
<b>IED</b>	Intelligent electronic device
<b>I-GIS</b>	Intelligent gas-insulated switchgear
<b>IOM</b>	Binary input/output module

<b>Instance</b>	When several occurrences of the same function are available in the IED, they are referred to as instances of that function. One instance of a function is identical to another of the same kind but has a different number in the IED user interfaces. The word "instance" is sometimes defined as an item of information that is representative of a type. In the same way an instance of a function in the IED is representative of a type of function.
<b>IP</b>	<p>1. Internet protocol. The network layer for the TCP/IP protocol suite widely used on Ethernet networks. IP is a connectionless, best-effort packet-switching protocol. It provides packet routing, fragmentation and reassembly through the data link layer.</p> <p>2. Ingression protection, according to IEC standard</p>
<b>IP 20</b>	Ingression protection, according to IEC standard, level IP20- Protected against solid foreign objects of 12.5mm diameter and greater.
<b>IP 40</b>	Ingression protection, according to IEC standard, level IP40- Protected against solid foreign objects of 1mm diameter and greater.
<b>IP 54</b>	Ingression protection, according to IEC standard, level IP54- Dust-protected, protected against splashing water.
<b>IRF</b>	Internal failure signal
<b>IRIG-B:</b>	InterRange Instrumentation Group Time code format B, standard 200
<b>ITU</b>	International Telecommunications Union
<b>LAN</b>	Local area network
<b>LIB 520</b>	High-voltage software module
<b>LCD</b>	Liquid crystal display
<b>LDCM</b>	Line differential communication module
<b>LDI</b>	Local detection device
<b>LED</b>	Light-emitting diode
<b>LNT</b>	LON network tool
<b>LON</b>	Local operating network
<b>MCB</b>	Miniature circuit breaker
<b>MCM</b>	Mezzanine carrier module

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<b>MIM</b>	Milli-ampere module
<b>MPM</b>	Main processing module
<b>MVB</b>	Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.
<b>NCC</b>	National Control Centre
<b>NUM</b>	Numerical module
<b>OCO cycle</b>	Open-close-open cycle
<b>OCP</b>	Overcurrent protection
<b>OEM</b>	Optical ethernet module
<b>OLTC</b>	On-load tap changer
<b>OV</b>	Over-voltage
<b>Overreach</b>	A term used to describe how the relay behaves during a fault condition. For example, a distance relay is overreaching when the impedance presented to it is smaller than the apparent impedance to the fault applied to the balance point, that is, the set reach. The relay “sees” the fault but perhaps it should not have seen it.
<b>PCI</b>	Peripheral component interconnect, a local data bus
<b>PCM</b>	Pulse code modulation
<b>PCM600</b>	Protection and control IED manager
<b>PC-MIP</b>	Mezzanine card standard
<b>PMC</b>	PCI Mezzanine card
<b>POR</b>	Permissive overreach
<b>POTT</b>	Permissive overreach transfer trip
<b>Process bus</b>	Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components
<b>PSM</b>	Power supply module
<b>PST</b>	Parameter setting tool within PCM600
<b>PT ratio</b>	Potential transformer or voltage transformer ratio
<b>PUTT</b>	Permissive underreach transfer trip
<b>RASC</b>	Synchrocheck relay, COMBIFLEX
<b>RCA</b>	Relay characteristic angle
<b>RFPP</b>	Resistance for phase-to-phase faults
	Resistance for phase-to-ground faults

<b>RISC</b>	Reduced instruction set computer
<b>RMS value</b>	Root mean square value
<b>RS422</b>	A balanced serial interface for the transmission of digital data in point-to-point connections
<b>RS485</b>	Serial link according to EIA standard RS485
<b>RTC</b>	Real-time clock
<b>RTU</b>	Remote terminal unit
<b>SA</b>	Substation Automation
<b>SBO</b>	Select-before-operate
<b>SC</b>	Switch or push button to close
<b>SCS</b>	Station control system
<b>SCADA</b>	Supervision, control and data acquisition
<b>SCT</b>	System configuration tool according to standard IEC 61850
<b>SDU</b>	Service data unit
<b>SLM</b>	Serial communication module. Used for SPA/LON/IEC/DNP3 communication.
<b>SMA connector</b>	Subminiature version A, A threaded connector with constant impedance.
<b>SMT</b>	Signal matrix tool within PCM600
<b>SMS</b>	Station monitoring system
<b>SNTP</b>	Simple network time protocol – is used to synchronize computer clocks on local area networks. This reduces the requirement to have accurate hardware clocks in every embedded system in a network. Each embedded node can instead synchronize with a remote clock, providing the required accuracy.
<b>SPA</b>	Strömberg protection acquisition, a serial master/slave protocol for point-to-point communication
<b>SRY</b>	Switch for CB ready condition
<b>ST</b>	Switch or push button to trip
<b>Starpoint</b>	Neutral/Wye point of transformer or generator
<b>SVC</b>	Static VAr compensation
<b>TC</b>	Trip coil
<b>TCS</b>	Trip circuit supervision

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<b>TCP</b>	Transmission control protocol. The most common transport layer protocol used on Ethernet and the Internet.
<b>TCP/IP</b>	Transmission control protocol over Internet Protocol. The de facto standard Ethernet protocols incorporated into 4.2BSD Unix. TCP/IP was developed by DARPA for Internet working and encompasses both network layer and transport layer protocols. While TCP and IP specify two protocols at specific protocol layers, TCP/IP is often used to refer to the entire US Department of Defense protocol suite based upon these, including Telnet, FTP, UDP and RDP.
<b>TEF</b>	Time delayed ground-fault protection function
<b>TNC connector</b>	Threaded Neill-Concelman, a threaded constant impedance version of a BNC connector
<b>TPZ, TPY, TPX, TPS</b>	Current transformer class according to IEC
<b>UMT</b>	User management tool
<b>Underreach</b>	A term used to describe how the relay behaves during a fault condition. For example, a distance relay is underreaching when the impedance presented to it is greater than the apparent impedance to the fault applied to the balance point, that is, the set reach. The relay does not "see" the fault but perhaps it should have seen it. See also Overreach.
<b>UTC</b>	Coordinated Universal Time. A coordinated time scale, maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated dissemination of standard frequencies and time signals. UTC is derived from International Atomic Time (TAI) by the addition of a whole number of "leap seconds" to synchronize it with Universal Time 1 (UT1), thus allowing for the eccentricity of the Earth's orbit, the rotational axis tilt (23.5 degrees), but still showing the Earth's irregular rotation, on which UT1 is based. The Coordinated Universal Time is expressed using a 24-hour clock, and uses the Gregorian calendar. It is used for aeroplane and ship navigation, where it is also sometimes known by the military name, "Zulu time." "Zulu" in the phonetic alphabet stands for "Z", which stands for longitude zero.
<b>UV</b>	Undervoltage
<b>WEI</b>	Weak end infeed logic
<b>VT</b>	Voltage transformer

<b>X.21</b>	A digital signalling interface primarily used for telecom equipment
<b>3I<sub>O</sub></b>	Three times zero-sequence current. Often referred to as the residual or the -fault current
<b>3V<sub>O</sub></b>	Three times the zero sequence voltage. Often referred to as the residual voltage or the neutral point voltage





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