Relion® 650 series

Transformer protection
RET650
Commissioning Manual

Power and productivity
for a better world™

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Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC).

This conformity is proved by tests conducted by ABB AB in accordance with the generic standard EN 50263 for the EMC directive, and with the standards EN 60255-5 and/or EN 50178 for the low voltage directive.

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Safety information

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

Non-observance can result in death, personal injury or substantial property damage.

Only a competent electrician is allowed to carry out the electrical installation.

National and local electrical safety regulations must always be followed.

The frame of the IED has to be carefully earthed.

The IED contains components which are sensitive to electrostatic discharge. Unnecessary touching of electronic components must therefore be avoided.

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

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Section 1 Introduction

1.1 This manual

The commissioning manual contains instructions on how to commission the IED. The manual can also be used by system engineers and maintenance personnel for assistance during the testing phase. The manual provides procedures for checking of external circuitry and energizing the IED, parameter setting and configuration as well as verifying settings by secondary injection. The manual describes the process of testing an IED in a substation which is not in service. The chapters are organized in chronological order in which the IED should be commissioned.

1.2 Intended audience

This manual addresses the personnel responsible for commissioning, maintenance and taking the IED in and out of normal service.

The commissioning personnel must have a basic knowledge of 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 IED.

1.3 Product documentation

1.3.1 Product documentation set

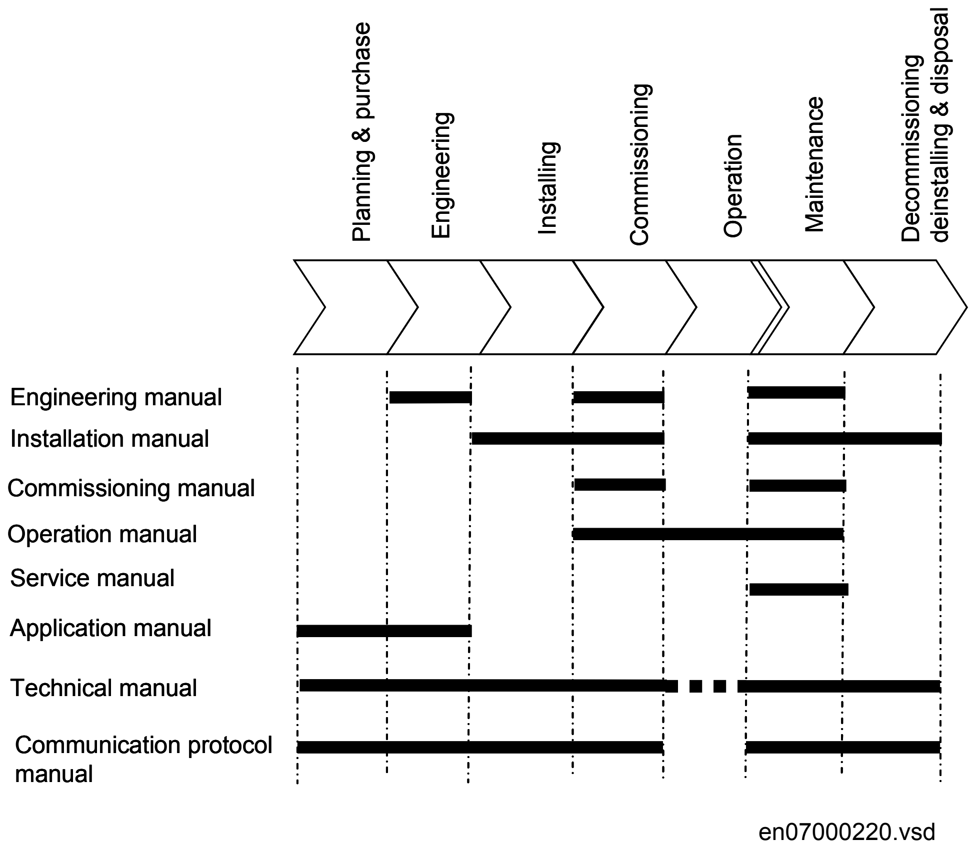

Figure 1: The intended use of manuals in different lifecycles

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

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

The commissioning manual contains instructions on how to commission the IED. The manual can also be used by system engineers and maintenance personnel for assistance during the testing phase. The manual provides procedures for checking of external circuitry and energizing the IED, parameter setting and configuration as well as verifying settings by secondary injection. The manual describes the process of testing an IED in a substation which is not in service. The chapters are organized in chronological order in which the IED should be commissioned.

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

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

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

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

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

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

The service manual is not available yet.

1.3.2 Document revision history

Document revision/date	Product series version	History
-/September 2009	1.0	First release

1.3.3 Related documents

Documents related to RET650	Identity number
Commissioning manual	1MRK 504 109-UEN
Technical manual	1MRK 504 106-UEN
Application manual	1MRK 504 107-UEN

Table continues on next page

Documents related to RET650	Identity number
Product Guide, configured	1MRK 504 110-BEN
Type test certificate	1MRK 504 110-TEN

650 series manuals	Identity number
Operation manual	1MRK 500 088-UEN
Communication protocol manual, DNP3	1MRK 511 224-UEN
Communication protocol manual, IEC 61850	1MRK 511 205-UEN
Engineering manual	1MRK 511 206-UEN
Installation manual	1MRK 514 013-UEN
Point list manual, DNP3	1MRK 511 225-UEN

1.4 Symbols and conventions

1.4.1 Safety indication symbols

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

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

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

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

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

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

1.4.2 Manual conventions

Conventions used in IED manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in Glossary. Glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, for example:
  To navigate between the options, use and .
- HMI menu paths are presented in bold, for example:
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press .
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- The ^ character in front of an input or output signal name in the function block symbol given for a function, indicates that the user can set an own signal name in PCM600.
- The * character after an input or output signal name in the function block symbol given for a function, indicates that the signal must be connected to another function block in the application configuration to achieve a valid application configuration.

1.4.3 Functions included in 650 series IEDs

Table 1: Main protection functions

IEC 61850	ANSI	Function description
Differential protection		
T2WPDIF	87T	Transformer differential protection, two winding
T3WPDIF	87T	Transformer differential protection, three winding
REFPDIF	87N	Restricted earth fault protection, low impedance

Table 2: Back-up protection functions

IEC 61850	ANSI	Function description
Current protection		
PHPIOC	50	Instantaneous phase overcurrent protection
OC4PTOC	51/67	Four step directional phase overcurrent protection
EFPIOC	50N	Instantaneous residual overcurrent protection
EF4PTOC	51N/67N	Four step directional residual overcurrent protection
TRPTTR	49	Thermal overload protection, two time constants
CCRBRF	50BF	Breaker failure protection

Table continues on next page

IEC 61850	ANSI	Function description
CCRPLD	52PD	Pole discordance protection
GUPPDUP	37	Directional underpower protection
GOPPDOP	32	Directional overpower protection
DNSPTOC	46	Negative sequence based overcurrent function
Voltage protection		
UV2PTUV	27	Two step undervoltage protection
OV2PTOV	59	Two step overvoltage protection
ROV2PTOV	59N	Two step residual overvoltage protection
OEXPVPH	24	Overexcitation protection
Frequency protection		
SAPTUF	81	Underfrequency function
SAPTOF	81	Overfrequency function
SAPFRC	81	Rate-of-change frequency protection

Table 3: Control and monitoring functions

IEC 61850	ANSI	Function description
Control		
QCBAY		Bay control
LOCREM		Handling of LR-switch positions
LOCREMCTRL		LHMI control of PSTO
TR1ATCC	90	Automatic voltage control for tapchanger, single control
TR8ATCC	90	Automatic voltage control for tapchanger, parallell control
TCMYLTC	84	Tap changer control and supervision, 6 binary inputs
SLGGIO		Logic Rotating Switch for function selection and LHMI presentation
VSGGIO		Selector mini switch extension
DPGGIO		IEC61850 generic communication I/O functions double point
SPC8GGIO		Single point generic control 8 signals
AUTOBITS		AutomationBits, command function for DNP3.0
Secondary system supervision		
TCSSCBR		Breaker close/trip circuit monitoring
Logic		
SMPPTRC	94	Tripping logic
TMAGGIO		Trip matrix logic
OR		Configurable logic blocks, OR
INVERTER		Configurable logic blocks, Inverter
PULSETIMER		Configurable logic blocks, PULSETIMER
GATE		Configurable logic blocks, Controllable gate
XOR		Configurable logic blocks, exclusive OR
Table continues on next page		

IEC 61850	ANSI	Function description
LOOPDELAY		Configurable logic blocks, loop delay
TimeSet		Configurable logic blocks, timer
AND		Configurable logic blocks, AND
SRMEMORY		Configurable logic blocks, set-reset memory
RSMEMORY		Configurable logic blocks, reset-set memory
FSDSIGN		Fixed signal function block
B16I		Boolean 16 to Integer conversion
B16IFCVI		Boolean 16 to integer conversion with logic node representation
IB16A		Integer to Boolean 16 conversion
IB16FCVB		Integer to boolean 16 conversion with logic node representation
Monitoring		
CVMMXN		Measurements
CMMXU		Phase current measurement
VMMXU		Phase-phase voltage measurement
CMSQI		Current sequence component measurement
VMSQI		Voltage sequence measurement
VNMMXU		Phase-neutral voltage measurement
CNTGGIO		Event counter
DRPRDRE		Disturbance report
AxRADR		Analog input signals
BxRBDR		Binary input signals
SPGGIO		IEC61850 generic communication I/O functions
SP16GGIO		IEC61850 generic communication I/O functions 16 inputs
MVGGIO		IEC61850 generic communication I/O functions
MVEXP		Measured value expander block
SPVNZBAT		Station battery supervision
SSIMG	63	Insulation gas monitoring function
SSIML	71	Insulation liquid monitoring function
SSCBR		Circuit breaker condition monitoring
Metering		
PCGGIO		Pulse counter logic
ETPMMTR		Function for energy calculation and demand handling

Table 4: Designed to communicate

IEC 61850	ANSI	Function description
Station communication		
		IEC61850 communication protocol
		DNP3.0 for TCP/IP communication protocol
GOOSEINTLKRCV		Horizontal communication via GOOSE for interlocking
GOOSEBINRCV		GOOSE binary receive

Table 5: Basic IED functions

IEC 61850	Function description
Basic functions included in all products	
INTERRSIG	Self supervision with internal event list
	Time synchronization
SETGRP	Setting group handling
ACTVGRP	Parameter setting groups
TESTMODE	Test mode functionality
CHNGLCK	Change lock function
ATHSTAT	Authority status
ATHCHCK	Authority check

Section 2 Starting up

2.1 Factory and site acceptance testing

Testing the proper IED operation is carried out at different occasions, for example:

- Acceptance testing
- Commissioning testing
- Maintenance testing

This manual describes the workflow and the steps to carry out the commissioning testing.

Factory acceptance testing (FAT) is typically done to verify that the IED and configuration meets the requirements by the utility or industry. This test is the most complex and in depth, as it is done to familiarize the user to a new protection or to verify a new configuration. The complexity of this testing depends on several factors.

- New IED type
- New configuration
- Pre-configured
- Modified existing configuration

Site acceptance testing (SAT or commissioning testing) is typically done to verify that the new installed IED is correctly set and connected to the power system. SAT requires that the acceptance testing has been performed and that the application configuration is verified.

Maintenance testing is a periodical verification that the IED is healthy and has correct settings depending on changes in the power system. There are also other types of maintenance testing.

2.2 Commissioning checklist

Before starting up commissioning at site, check that the following items are available.

- Single line diagram
- Protection block diagram
- Circuit diagram
- Setting list and configuration
- Crossed Ethernet cable (CAT 5)
- Three-phase test equipment

- PC with PCM600 installed along with the connectivity packages corresponding to the IED used
- Administration rights on the PC to set up IP addresses
- Product documentation (engineering manual, installation manual, commissioning manual, operation manual, technical manual and communication protocol manual)

2.3 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.

2.4 Energizing the IED

2.4.1 Check the IED operation

Check all connections to external circuitry to ensure that the installation was made correctly, before energizing the IED and carrying out the commissioning procedures.

Energize the power supply of the IED to start it up. This could be done in number of ways, from energizing a whole cubicle to energizing a single IED. The IED time must be set. The self-supervision function in the **Main menu/Diagnostics/Internal events**or**Main menu/Diagnostics/IED status/General** menu in LHMI should also be checked to verify that the IED operates properly.

2.4.2 IED start-up sequence

The following sequence is expected when the IED is energized.

- The green Ready LED starts instantly flashing and the ABB logo is shown on the LCD.
- After approximately 30 seconds "Starting" is shown on the LCD.
- Within 90 seconds the main menu is shown on the LCD and the green Ready LED shows a steady light, which indicates a successful start-up.

The start-up times depend on the size of the application configuration. Application configuration with less functionality means shorter start-up times.

If the green Ready LED continues to flash after start-up, the IED has detected an internal error. Navigate via **Main menu/Diagnostics/IED status/General** to investigate the fault.

2.5 Setting up communication between PCM600 and the IED

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

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

Each IED has an Ethernet interface connector on the front and on the rear side. The Ethernet connector can 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.

For the connection of PCM600 to the IED two basic variants have to be considered.

- Direct point to point link between PCM600 and the IED front 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 in both cases the same.

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 can be set via the LHMI for each available Ethernet interface in the IED. Each Ethernet interface has a default factory IP address when the complete 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 subnetwork mask is 255.255.255.0, which can be set via the LHMI path **Main menu/Configuration/Communication/TCP-IP configuration/1:ETHFRNT**
- The default IP address for the IED rear port is 192.168.1.10 and the corresponding subnetwork mask is 255.255.0.0, which can be set via the LHMI path **Main menu/Configuration/Communication/TCP-IP configuration/1:ETHLAN1**

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 requested 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 null-modem cable or cross-wired cable. The minimum length should be about 2 m. The connector type is RJ-45, see Figure 2.

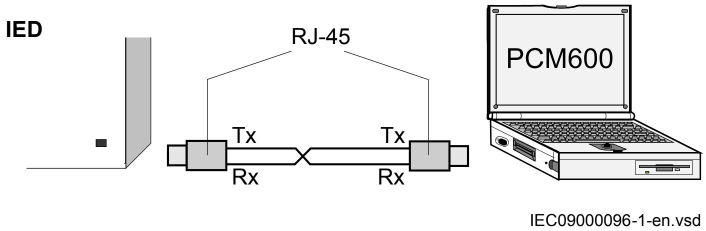

Figure 2: Point to point link between IED and PCM600 using a null-modem cable

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 requested 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 straight (standard) Ethernet cable can be used.

When a computer is connected to the IED and the setting *DHCPServer* is set to *On* via the LHMI path **Main menu/Configuration/Communication/TCP-IP configuration/1:ETHFRNT/DHCPServer**, the IEDs DHCP server for the front port assigns an IP address for the computer. The computer must be configured to obtain its IP address automatically as described in the following procedure.

1. Select *Network Connections* in the PC, see Figure 3.

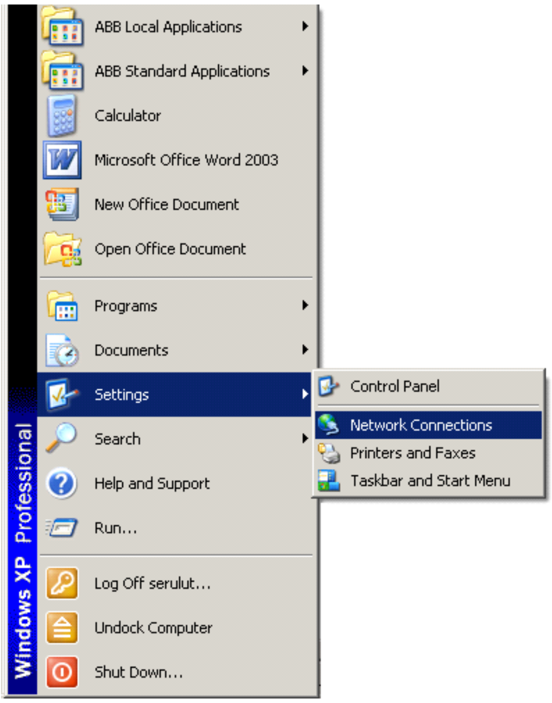

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Figure 3: Select: Network connections

2. Select *Properties* in the status window, see Figure 4.

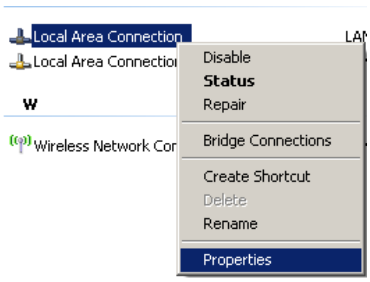

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Figure 4: Right-click Local Area Connection and select Properties

3. Select the TCP/IP protocol from the list of configured components using this connection and click *Properties*, see Figure 5.

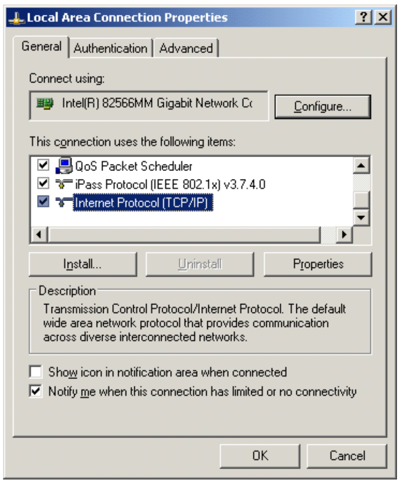

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Figure 5: Select the TCP/IP protocol and open Properties

4. Select *Obtain an IP address automatically*if the parameter *DHCPServer* is set to *On*, see Figure 6.

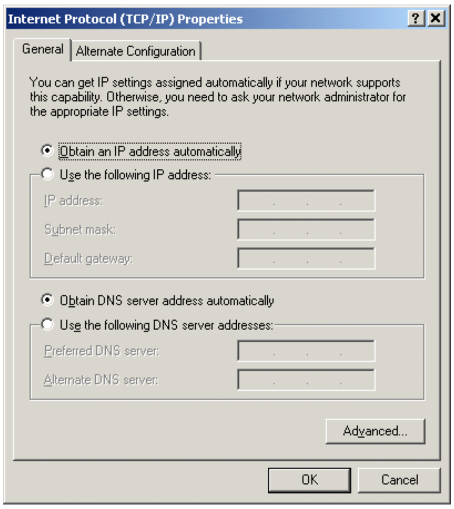

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Figure 6: Select: Obtain an IP address automatically

5. Select *Use the following IP address* and define *IP address* and *Subnet mask* if the parameter *DHCPServer* is set to *Off*, see Figure 7. The IP address must be different from the IP address chosen for the IED.

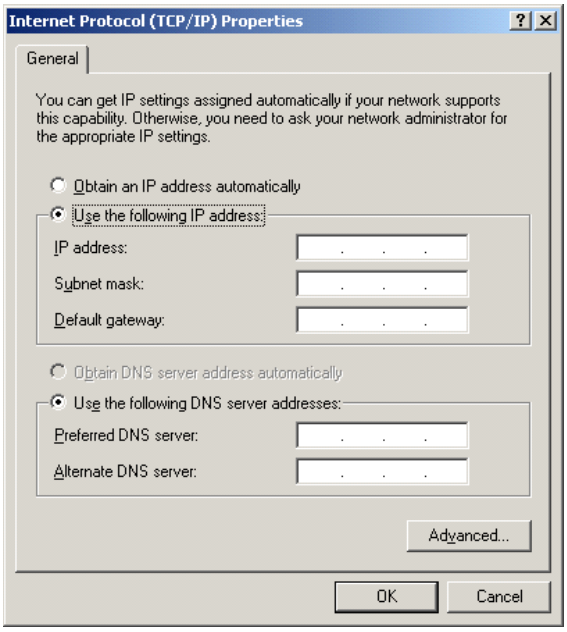

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Figure 7: Select: Use the following IP address

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. PC and IED must belong to the same subnetwork.

2.6 Writing an application configuration to the IED

Ensure that the IED includes the correct application configuration according to project specifications.

The application configuration is created using PCM600 and then written to the IED. Establish a connection between PCM600 and the IED when an application configuration must be written to IED.

When writing an application configuration to the IED, the IED is automatically set in configuration mode. When the IED is set in configuration mode, all functions are blocked. The red Trip LED on the IED flashes, and the green Ready LED is lit while the IED is in the configuration mode. When the writing procedure is completed, the IED is automatically set into normal mode.

Be sure to set the correct technical key in IED and PCM600 to prevent writing an application configuration to the wrong IED.

See the engineering manual for information on how to create or modify an application configuration and how to write to IED.

Set setting parameters through the LHMI. See the operation manual for information on how to change a setting from the LHMI.

2.7 Checking CT circuits

- 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 L1, L2, L3.)
- 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.
- Earthing check of the individual CT secondary circuits to verify that each three-phase set of main CTs is properly connected to the station earth and only at one electrical point.
- Insulation resistance check.

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

2.8 Checking VT circuits

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

Do not continue before any errors are corrected.

Test the circuitry.

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

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

The primary injection test verifies the VT ratio and the wiring all the way through from the primary system to the IED. Injection must be performed for each phase-to-neutral circuit and each phase-to-phase pair. In each case voltages in all phases and neutral are measured.

2.9 Checking the RTXP test switch

The RTXP test switch is designed to provide the means of safe testing of the IED. This is achieved by the electromechanical design of the test switch and test plug handle, when the test plug handle is inserted it first blocks the trip and alarm circuits then it short circuit CT secondary circuit and opens VT secondary circuits making the IED available for secondary injection.

When pulled out the test handle is mechanically stopped in half withdrawn position, in this position the current and voltage enter the protection, but the alarm and trip circuits are still isolated.

Not until the test handle is completely removed the trip and alarm circuits are restored for operation.

Verify by pulling in all cables that the contact sockets have been crimped correctly and that they are fully inserted. This should never be done with current circuits in service.

Current circuit

1. Verify that the contact are of current circuit type.
2. Verify that the short circuit jumpers are located in the correct slots.

Voltage circuit

1. Verify that the contact are of voltage circuit type.
2. Check that no short circuit jumpers are located in the slots dedicated for voltage.

Trip and alarm circuits

1. Check that the correct type of contacts are used.

2.10 Checking transducer circuits

Verify from the manufacturer that the total circuit resistance is under specified values from the instrument (transducer) manufacturer.

2.11 Checking binary input and output circuits

2.11.1 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 IEDs specifications.

2.11.2 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.

2.12 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 for plastic fiber cables and 275 mm for glass fiber cables. The allowed minimum bending radius has to be checked from the optical cable manufacturer.

Section 3 Establishing connection and verifying the IEC 61850 station communication

3.1 Setting the station communication

To enable IEC 61850 station communication:

- The IEC 61850-8-1 station communication functionality must be on in the LHMI. Navigate to **Main menu/Configuration/Communication/Station communication/1:IEC61850-8-1** and set parameter *Operation* to *On*.
- To enable GOOSE communication the *Operation* parameter for the corresponding GOOSE function blocks (GOOSEBINRCV and GOOSEINTLKRCV) must be set to *On* in the application configuration.
- To enable GOOSE communication via the front port the parameter *GOOSE* in **Main menu/Configuration/Communication/Station communication/IEC61850-8-1** must be set to *Front*. To enable GOOSE communication via rear port the parameter *GOOSE* must be set to *LAN1*.

3.2 Verifying the communication

Connect your PC to the nearby switch and ping the connected IED and the Substation Master PC to verify that the communication is working (up to the transport layer). If it is possible to see all of them, then they can see each other.

The best way to verify the communication up to the application layer is to

- use a protocol analyzer, for example an Ethereal that is connected to the substation bus, and
- monitor the communication

Section 4 Testing IED operation

4.1 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 test mode to facilitate the test of individual functions and prevent unwanted operation caused by other functions. 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 PCM600 should be used. PCM600 includes the Signal monitoring tool, which is useful to read of 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.

The disturbance report settings must be checked to ensure that indications are correct.

Functions to test, signal and parameter names can be found in the technical manual. The correct initiation of the disturbance recorder is made on start and/or release or trip from a function. Also check that the wanted recordings of analogue (real and calculated) and binary signals are achieved.

The 650 series products can have between 1 to 4 individual parameter setting groups prepared with full sets of different parameters for all functions. The purpose of these groups is to be able to handle different power system load conditions to optimize the parameters settings of the different functions for these different power systems conditions (for example summer/winter and day/night).

Parameters can be entered into different setting groups. Make sure to test functions for the same parameter setting group. If needed the tests must be repeated 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.

Observe during testing that the right method for testing must be used that corresponds to the actual parameters set in the activated parameter setting group.

Set and configure the function(s) before the testing can start. Most functions are highly flexible in that it permits 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.

Requirements for testing the function.

- Calculated settings
- Valid configuration diagram for the IED
- Valid terminal diagram for the IED
- Technical manual
- Three-phase test equipment

Content of the technical manual.

- Application and functionality summaries
- Function blocks
- Logic diagrams
- Input and output signals
- A list of setting parameters
- Technical data for the function

The test equipment should be able to provide a three-phase supply of currents (and for some START functions also voltage). The magnitude and angle of currents (and voltages) should be possible to vary. Check that the IED is prepared for test before starting the test session. Consider the logic diagram of the function when performing the test.

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

- Binary output signals
- Service values in LHMI (logical signal or phasors)
- A PC with PCM600 (configuration software) in debug mode

4.2 Activating test mode

The IED shall be put into test mode before testing. Test mode blocks all 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. Test mode is indicated when the yellow Start LED flashes.

Procedure

1. Browse to **Main menu/Tests/IED test mode/1:TESTMODE**
2. Set parameter *TestMode* to *On* and save the changes.
   As a consequence the yellow Start LED will start flashing as a reminder and remains flashing until the test mode is switched off.

4.3 Preparing the connection to the test equipment

The IED can be equipped with a test switch of type RTXP8, RTXP18 or RTXP24. The test switch and its associated test plug handle (RTXH8, RTXH18 or RTXH24) are a part of the COMBITEST system, which provide 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.

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 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 reenergizing 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, take measures according to provided circuit diagrams.

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 injure humans.

4.4 Connecting test equipment to the IED

Connect the test equipment according to the IED specific connection diagram.

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.

4.5 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. The user can release the tested function(s) by setting the corresponding *Blocked* parameter under Function test modes to *No* in LHMI.

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 and so on. Before starting a new test mode session the user should scroll through every function to ensure that only the function to be tested (and the interconnected ones) have the parameters *Blocked* and eventually *EvDisable* are 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 individually be 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 LHMI under **Main menu/Tests/Function test modes** menu remains *On*, that is the parameter *Blocked* is set to *Yes* and the parameter *TestMode* under the **Main menu/Tests/IED test mode** remains active. All functions that were blocked or released from a previous test mode session, that is the parameter *Test mode* is set to *On*, are reset when a new test mode session is started.

Procedure

1. Browse to the **Function test modes** menu.
   The Function test modes menu is located in LHMI under **Main menu/Tests/ Function test modes**.
2. Browse to the function instance that should be released.
3. Set parameter *Blocked* for the selected function to *Yes*.

4.6 Verifying analog primary and secondary measurement

Verify that the connections are correct and that measuring and scaling is 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 made in PCM600.

Procedure

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 LHMI 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/Tests/ Function status/Monitoring/CVMMXN/1:CVMMXN/Outputs**. Then navigate to the bottom of the list to find the frequency.

   Check both analog primary and secondary values, because then the CT and VT ratios entered into the IED are also checked.

   These checks shall be repeated for Analog primary values.
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/Configuration/Analog modules

Measured values such as current and voltages as well as active, reactive and apparent power, power factor phase angles as well as positive and negative and zero sequence currents and voltages are available in LHMI under **Main menu/ Tests/Function status/Monitoring**.

Navigate to the measurement function that contains the quantity to be checked.

Table 6: Measurement functions

Function	Quantity	Description
CMMXU	IL1 to IL3	amplitude, range and angle
CMSQI	$3I_0$; I1 and I2	amplitude, range and angle
CVMMXN	S; P; Q; PF; Ilag; Ilead; U; I and f	amplitude, range and angle
VMMXU	UL12 to UL31 i.e. phase-to-phase	amplitude, range and angle
VMSQI	$3U_0$; U1 and U2	amplitude, range and angle
VNMMXU	UL1 to UL3 i.e. phase-to-neutral	amplitude, range and angle

Also the Signal monitoring tool in PCM600 can be used to read measured values. In many cases it is more convenient to use PCM600 since, among many things, reports on measured values can be exported from the Signal monitoring tool to other tools (for example MS Excel) further analysis.

4.7 Testing protection functionality

Each protection function must be tested individually by secondary injection.

- Verify operating levels (trip) and timers.
- Verify alarm and blocking signals.
- Use the disturbance handling tool in PCM600 to evaluate that the protection function has received the correct data and responded correctly (signaling and timing).
- Use the event viewer tool in PCM600 to check that only expected events have occurred.

Section 5 Testing functionality

5.1 Testing disturbance report

5.1.1 Introduction

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

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

If the disturbance report is set on, then its sub-functions are also set up and so it is not possible to only switch these sub-functions off. The disturbance report function is switched off (parameter *Operation* = *Off*) in PCM600 or the local HMI under **Main menu/Settings/IED Settings/Monitoring/Disturbance Report/ 1:DRPRDRE**.

5.1.2 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 in the local HMI under:

Main menu/Settings/IED Settings/Monitoring/Disturbance Report/ 1:DRPRDRE

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5.1.3 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 local HMI under **Main menu/Clear/Clear 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*.

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

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

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/Clear/Clear internal event list** or **Main menu/Clear/Clear 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.

5.2 Identifying the function to test in the technical reference manual

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

5.3 Testing differential protection functions

5.3.1 Transformer differential protection

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.3.1.1 Verifying the settings

Procedure

1. Go to the **Main menu/Test/Function Test ModeDifferential protection** menu and make sure that the Restricted earth-fault protection, low impedance function (REFPDIF) is set to off and that the Four step residual overcurrent function (EF4PTOC) function under **Main menu/Test/Function Test Mode/Current protection** is set to off, since they are configured to the same current transformer inputs as the transformer differential protection, Make

sure that the transformer differential functions T3WPDIF and T2WPDIF 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 CT's on the HV side of the power transformer.
3. Increase the current in phase L1 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.
   Depending of the power transformer vector group (Yd etc.), 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 L2 and L3 respectively.
7. Inject a symmetrical three phase currents 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 CT's 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.
12. If available on the test set a second harmonic current of about 20% (assumes 15% setting on I1/I2ratio parameter) can be added to the fundamental tone in phase L1. Increase the current in phase L1 above the pickup value measured in point 3 above. Repeat test with current injection in phases L2 and L3 respectively.
    The balancing of currents flowing into and out of the differential zone is checked by primary injection testing.
    Fifth harmonic blocking can be tested in a similar way

5.3.1.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.3.2 Restricted earth-fault protection, low impedance REFPDIF

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.3.2.1 Verifying the settings

Procedure

1. Connect the test set for single-phase current injection to the protection terminals connected to the CT in the power transformer neutral-to-earth circuit.
2. Increase the injection current and note the operating value of the protection function.
3. Check that all trip and start 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 twice the operate value.
6. Switch on the current and note the operate time.
7. Connect the test set to terminal L1 and neutral of the three-phase current input configured to REFPDIF. Also inject a current higher than half the *Idmin* setting in the neutral-to-earth circuit with the same phase angle and with polarity corresponding to an internal fault.
8. Increase the current injected in L1, and note the operate value. Decrease the current slowly and note the reset value.
9. Inject current into terminals L2 and L3 in the same way as in point 7 above and note the operate and reset values.
10. Inject a current equal to 10% of rated current into terminal L1.
11. Inject a current in the neutral-to-earth 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 menu.

5.3.2.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4 Testing current protection functions

5.4.1 Instantaneous phase overcurrent protection PHPIOC

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

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

- Phase-to-earth 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.

5.4.1.1 Measuring the operate limit of set values

Procedure:

1. Inject a phase current into the IED with an initial value below that of the setting.
2. Increase the injected current until the TRIP signal appears.
3. Switch the fault current off.
   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.

5.4.1.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.2 Four step phase overcurrent protection OC4PTOC

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.2.1 Verifying the settings

Procedure:

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/block any of the four available overcurrent steps, make sure that the step under test is enabled, for example end fault protection.
Connect the symmetrical three-phase injection current into phases L1, L2 and L3.

2. Connect the test set for the appropriate three-phase voltage injection to the IED phases L1, L2 and L3. 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 *UBase*) and set the injection current to lag the appropriate voltage by an angle of about 80° if forward directional function is selected.
   If 1 of 3 currents for operation is chosen: The voltage angle of phase L1 is the reference.
   The voltage angle of phase L1 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 L1, repeat the test when injecting current into phases L2 and L3 with polarizing voltage connected to phases L2 respectively L3 (1 of 3 currents for operation).
7. If the test has been performed by injection of current in phases L1 – L2, repeat the test when injecting current into phases L2 – L3 and L3 – L1 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 start 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. Repeat the above-described tests for the higher set stages.
14. Finally check that start and trip information is stored in the event menu.

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

5.4.2.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.3 Instantaneous residual overcurrent protection EFPIOC

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

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

- Phase-to-earth 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.

5.4.3.1 Measuring the operate limit of set values

Procedure

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. Switch the fault current off.
   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.

5.4.3.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.4 Four step residual overcurrent protection EF4PTOC

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.4.1 Four step directional residual overcurrent protection

Procedure:

1. Connect the test set for single current injection to the appropriate IED terminals. Connect the injection current to terminals L1 and neutral, or to terminals N and neutral.
2. Set the injected polarizing voltage slightly larger than the set minimum polarizing voltage (default 1 % of Ur) 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°.
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 L1, repeat the test when injecting current into terminals L2 and L3 with a polarizing voltage connected to terminals L2 respectively L3.
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 *tnmin*.
9. Check that all trip and start 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 start and trip information is stored in the event menu.

5.4.4.2 Four step non-directional residual overcurrent protection

Procedure:

1. Do as described in "Four step directional residual overcurrent protection", but without applying any polarizing voltage.

5.4.4.3 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.5 Thermal overload protection, two time constants TRPTTR

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.5.1 Checking operate and reset values

Procedure:

1. Connect symmetrical 3-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 3-phase injection currents slightly lower than the set operate value of stage *IBase1*, increase the current in phase L1 until stage *IBase1* operates and note the operate value.
   Observe the maximum permitted overloading of the current circuits in the terminal.
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 L2 and L3.
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 L1 to 1.50 x *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 (*Tau 1*).

With setting Itr = 101% *IBase1* and injection current 1.50 x *IBase1*, the trip time from zero content in the memory shall be 0.60 x 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 x *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 start and trip information is stored in the **Event** menu.

5.4.5.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.6 Breaker failure protection CCRBRF

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

Breaker failure protection (CCRBRF) should normally be tested in conjunction with some other function that provides a start signal. An external START 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-earth -faults.

At mode *2 out of 4* the Phase current setting, *IP>* can be checked by single phase injection where the return current is connected to the summated current input. The value of residual (EF) current “IN” set lower than *IP>* is easiest checked in back-up trip mode *1 out of 4*.

5.4.6.1 Checking the phase current operate value, *IP>*

Check the current level *IP>* where setting *FunctionMode*=*Current* and setting *BuTripMode*=*1 out of 3 or 2 out of 4* as set under **Main menu/Settings/IED Settings/CCRBRF(50BF)/1:CCRBRF**.

Procedure:

1. Apply the fault condition, including START of CCRBRF, with a current below set *IP>*.
2. Repeat the fault condition and increase the current in steps until a trip occurs.
3. Compare the result with the set *IP>*.
4. Disconnect AC and START input signals.
   Note: If “No I> check” or “*Retrip off*” is set, only back-up trip can be used to check set *IP>*.

5.4.6.2 Checking the residual (EF) current operate value *IN>* set below *IP>*

Check the low set *IN>* current where setting *FunctionMode*=*Current* and setting *BuTripMode*=*1 out of 4* as set under **Main menu/Settings/IED Settings/CCRBRF(50BF)/1:CCRBRF**.

Procedure

1. Apply the fault condition, including *start* of CCRBRP, with a current just below set *IN>*.
2. Repeat the fault condition and increase the current in steps until trip appears.
3. Compare the result with the set *IN>*.
4. Disconnect AC and start input signals.

5.4.6.3 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 setting *RetripMode*=*No* CBPos. Check as set under **Main menu/Settings/IED Settings/CCRBRF(50BF)/1:CCRBRF**.

Procedure

1. Apply the fault condition, including start of CCRBRF, well above the set current value. Measure time from “Start" of CCRBRF.
2. Check the re-trip *t1* and back-up trip times *t2*
3. Disconnect AC and start input signals.

5.4.6.4 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* as set under **Main menu/Settings/IED Settings/CCRBRF(50BF)/1:CCRBRF**.

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

Procedure:

1. Set *RetripMode = Retrip Off*.
2. Apply the fault condition, including start of CCRBRF, 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 start input signals.

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

Procedure

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

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

Procedure:

1. Set *RetripMode = No CBPos Check*.
2. Apply the fault condition, including start of CCRBRF, 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 start of CCRBRF, 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 start input signals.

5.4.6.5 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.

Procedure:

1. Apply the fault condition, including start of CCRBRF, with phase current well above set value “IP”
2. Arrange switching the current off, with a margin before back-up trip time, *t2*. 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 start input signals.

The normal mode *BuTripMode = “1 out of 3*” should have been verified in the tests above. In applicable cases the modes “*1 out of 4*” and “*2 out of 4*” can be checked. Choose the mode below, which corresponds to the actual case.

Checking the case *BuTripMode = 1 out of 4*

It is assumed that EF current setting *IN*> is below phase current setting *IP*>.

Procedure:

1. Set *BuTripMode = 1 out of 4.*
2. Apply the fault condition, including start of CCRBRF, with one phase current below set *IP*> but above *IN*>. The residual (EF) should then be above set IN>.
3. Verify that back-up trip is achieved after set time. If selected, re-trip should also appear.
4. Disconnect AC and start input signals.

Checking the case *BuTripMode = 2 out of 4*

The EF current setting *IN*> may be equal to or below phase current setting *IP*>.

Procedure:

1. Set *BuTripMode = 2 out of 4*
2. Apply the fault condition, including start of CCRBRF, with one phase current above set *IP*> and residual (EF) above set *IN* 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 start of CCRBRF, with at least one phase current below set *IP*> and residual (EF) above set *IN*>. The current may be arranged by feeding three (or two) phase currents with equal phase angle (I0-component) below *IP*>, but of such value that the residual (EF) current ($3I_0$) will be above set value *IN*>.
5. Verify that back-up trip is not achieved.
6. Disconnect AC and start input signals.

5.4.6.6 Verifying the case *RetripMode* = *No CB Pos Check*

It is assumed that re-trip without current check is selected, *RetripMode = No CB Pos Check* check.

Procedure:

1. Set *FunctionMode = Contact*
2. Apply input signal for CB closed to input CBCLD
3. Apply input signal, for start of CCRBRF. The value of current could be low.
4. Verify that re-trip and back-up trip are achieved after set times.
5. Disconnect the start signal. Keep the CB closed signal.
6. Apply input signal, for start of CCRBRF. The value of current could be low.
7. Arrange disconnection of CB closed signal well before set back-up trip time *t2*.
8. Verify that back-up trip is not achieved.
9. Disconnect injected AC and start input signals.

5.4.6.7 Verifying the function mode *Current&Contact*

To be made only when *FunctionMode = Current&Contact* is selected.

Checking the case with fault current above set value *IP>*

The operation shall be as in *FunctionMode = Current.*

Procedure:

1. Set *FunctionMode = Current&Contact.*
2. Leave the inputs for CB close inactivated. These signals should not influence.
3. Apply the fault condition, including start of CCRBRF, with current above the set *IP>* value.
4. Check that the re-trip, if selected, and back-up trip commands are achieved.
5. Disconnect injected AC and start input signals.

Checking the case with fault current below set value *I>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*.

Procedure:

1. Set *FunctionMode = Current&Contact* check.
2. Apply input signal for CB closed to relevant input or inputs CBCLDL1 (2 or 3)
3. Apply the fault condition with input signal(s) for start of CCRBRF. The value of current should be below the set value *I>BlkCont*
4. Verify that 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 start signal(s). Keep the CB closed signal(s).

6. Apply the fault and the start again. The value of current should be below the set value *I>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 start input signals.

5.4.6.8 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.7 Pole discordance protection CCRPLD

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.7.1 Verifying the settings

Procedure:

1. When the CCRPLD function is set for external, set setting *ContSel* to *PD signal from CB* under: **Main menu/Settings/IED Settings/Current/ CCRPLD/1:CCRPLD** to activate the logic that detects pole discordance when external pole discordance signalling is used (input EXTPDIND) in the application configuration.
2. Activate the input EXTPDIND on the CCRPLD function block, and measure the operating time of the CCRPLD protection.
3. Compare the measured time with the set value *tTrip*.
4. Reset the EXTPDIND input.
5. When CCRPLD function is set for unsymmetry current detection with CB monitoring, set setting *CurrSel* under **Main menu/Settings/IED Settings/ Current/CCRPLD/1:CCRPLD** to *CB oper monitor*.
   Use the TRIP signal from the configured binary output to stop the timer.
6. Activate input CLOSECMD on CCRPLD function block and measure the operating time of the CCRPLD protection.
7. Set measured current in one phase to 110% of *CurrRelLevel*

8. Deactivate input CLOSECMD. Set measured current in one phase to 90% of *CurrRelLevel*. Activate CLOSECMD.
   NO TRIP signal should appear.
9. Repeat point 4 and 5 using OPENCMD instead of CLOSECMD. Set all three currents to 110% of *CurrRelLevel*. Activate CLOSECMD.
   NO TRIP signal should appear due to symmetrical condition.
10. Deactivate the CLOSECMD. Set measured current in one phase to 120% of the *CurrUnsymmLevel* compared to the other two phases.
11. Set the two other phase currents to 0.
12. Activate CLOSECMD and measure the operating time of the CCRPLD protection.
    Use the TRIP signal from the configured binary out put stop the timer.
13. Deactivate the CLOSECMD. Set measured current in one phase to 80% of the *CurrUnsymmLevel*.
14. Set the two other phase currents to 0.
15. Activate CLOSECMD.
    NO TRIP signal should appear.

5.4.7.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.8 Directional under-power protection GUPPDUP

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.8.1 Verifying the settings

The under-power 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.

Procedure

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.
   Use the formulas stated in Table 6 for the different calculation modes used. The set mode *Mode* can be found under **Main menu/Settings/IED Settings/ Current/GUPPDUP/1:GUPPDUP/General**.

Set value: *Mode*	Formula used for complex power calculation
L1, L2, L3	$$\bar{S} = \bar{U}_{L1} \cdot \bar{I}_{L1}^* + \bar{U}_{L2} \cdot \bar{I}_{L2}^* + \bar{U}_{L3} \cdot \bar{I}_{L3}^*$$ (Equation 1) $$\bar{S} = \bar{V}_A \cdot \bar{I}_A^* + \bar{V}_B \cdot \bar{I}_B^* + \bar{V}_C \cdot \bar{I}_C^*$$ (Equation 1)
Arone	$$\bar{S} = \bar{U}_{L1L2} \cdot \bar{I}_{L1}^* - \bar{U}_{L2L3} \cdot \bar{I}_{L3}^*$$ (Equation 2)
PosSeq	$$\bar{S} = 3 \cdot \bar{U}_{PosSeq} \cdot \bar{I}_{PosSeq}^*$$ (Equation 3)
L1L2	$$\bar{S} = \bar{U}_{L1L2} \cdot (\bar{I}_{L1}^* - \bar{I}_{L2}^*)$$ (Equation 4)
L2L3	$$\bar{S} = \bar{U}_{L2L3} \cdot (\bar{I}_{L2}^* - \bar{I}_{L3}^*)$$ (Equation 5)
L3L1	$$\bar{S} = \bar{U}_{L3L1} \cdot (\bar{I}_{L3}^* - \bar{I}_{L1}^*)$$ (Equation 6)
L1	$$\bar{S} = 3 \cdot \bar{U}_{L1} \cdot \bar{I}_{L1}^*$$ (Equation 7)
L2	$$\bar{S} = 3 \cdot \bar{U}_{L2} \cdot \bar{I}_{L2}^*$$ (Equation 8)
L3	$$\bar{S} = 3 \cdot \bar{U}_{L3} \cdot \bar{I}_{L3}^*$$ (Equation 9)

2. Adjust the injected current and voltage to the set values in % of *IBase* and *UBase* (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 step 1 (equal to 0° for low forward power protection and equal to 180° 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°. 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°. Decrease the current slowly until the START1 signal, start of stage 1, is activated.
5. Increase the current to 100 % of *IBase*.
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 points 2 - 6 for the second stage.

5.4.8.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.4.9 Directional over-power protection GOPPDOP

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.4.9.1 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.

Procedure

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.

Use the formulas stated in Table 6 for the different calculation modes used. The set mode *Mode* can be found under **Main menu/Settings/IED Settings/ CurrentGOPPDOP/1:GOPPDOP/General**.

2. Adjust the injected current and voltage to the set rated values in % of *IBase* and *UBase* (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 step 1 (equal to 0° for low forward power protection and equal to 180° 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°. 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 START1 signal, start of stage 1, is activated. Check the injected power and compare it to the set value *Power1*, power setting for stage 1 in % of *Sbase*.
5. Increase the current to 100 % of *IBase* 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 points 2 - 6 for the second stage.

5.4.9.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.5 Testing voltage protection functions

5.5.1 Two step undervoltage protection UV2PTUV

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.5.1.1 Verifying the setting

Verification of START-value and time delay to operate for Step1

Procedure

1. Check that the IED settings are appropriate, especially the START-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 START 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 START 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

Procedure

1. The test above can now be repeated for Step2.
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 START 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.

5.5.1.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.5.2 Two step overvoltage protection OV2PTOV

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.5.2.1 Verifying the settings

Procedure

1. Apply single phase voltage below the set value *U1>*.
2. Slowly increase the voltage until the 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 TR1 signal and compare it with the set value.
7. Repeat the test for step 2.

5.5.2.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.5.3 Two step residual overvoltage protection ROV2PTOV

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.5.3.1 Verifying the settings

Procedure

1. Apply the single phase voltage either to a single phase voltage input or to a residual voltage input with the start value below the set value *U1>*
2. Slowly increase the value until 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 TR1 signal and compare it with the set value.
7. Repeat the test for step 2.

5.5.3.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.5.4 Overexcitation protection OEXPVPH

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.5.4.1 Verifying the settings

Procedure

1. Enable frequency measuring (FRME function).
2. Connect a symmetrical three-phase voltage input from the test set to the appropriate connection terminals of the Overexcitation protection function (OEXPVPH).
   The function 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 V/Hz>.
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 x V/Hz>.
7. Connect a trip output contact to the timer and temporarily set the time delay *tMin* to 0.5 s.
8. Increase the voltage and note the V/Hz>> 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 *tMin*, injecting a voltage corresponding to 1.2 x V/Hz>>.
11. Check that trip and alarm contacts operate according to the configuration logic.
12. Finally check that start and trip information is stored in the Event menu.

5.5.4.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.6 Testing frequency protection functions

5.6.1 Under frequency protection SAPTUF

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.6.1.1 Verifying the settings

Verification of START-value and time delay to operate

Procedure:

1. Check that the IED settings are appropriate, especially the START 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 START 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 START 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

Procedure:

1. The test above can be repeated to check the time to reset.
2. The tests above can be repeated to test the voltage dependent inverse time characteristic.

Verification of the low voltage magnitude blocking

Procedure:

1.
2. Check that the IED settings are appropriate, especially the *StartFrequency*and the *tDelay* and the *MinValFreqMeas* in the SMAI preprocessing function.
3. Supply the IED with three-phase voltages at rated values.
4. Slowly decrease the magnitude of the applied voltage, until the BLKDMAGN signal appears.
5. Note the voltage magnitude value and compare it with the set value *MinValFreqMeas*.
6. Slowly decrease the frequency of the applied voltage, to a value below *StartFrequency*.
7. Check that the START signal not appears.
8. Wait for a time corresponding to *tDelay*, and check that the TRIP signal not appears.

5.6.1.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/ Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.6.2 Over frequency protection SAPTOF

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

5.6.2.1 Verifying the settings

Verification of START-value and time delay to operate

Procedure:

1. Check that you have appropriate settings in the IED, especially the START 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 START 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 START 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

Procedure:

1. The test above can be repeated to check the time to reset.

Verification of the low voltage magnitude blocking

Procedure:

1. Check that you have appropriate settings in the IED, especially the *StartFrequency*, *TtDelay* and the *MinValFreqMeas* in the SMAI preprocessing function
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, *MinValFreqMeas*.
5. Slowly increase the frequency of the applied voltage, to a value above *StartFrequency*.
6. Check that the START signal does not appear.
7. Wait for a time corresponding to *tDelay*, and make sure that the TRIP signal does not appear.

5.6.2.2 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.7 Testing control functions

The save of persistent parts of function block states/values to persistent memory uses an exponential back-off algorithm, which rapidly increases the time between save operations when there are frequent changes in such states/values. This means, that when e.g. a pulse counter is exercised periodically, the time between saves of its counter value to persistent memory will occur more and more seldom until there is one hour between save operations. If the IED is restarted by turning auxiliary power off and back on, then up to one hour of counter value increments will be lost. This back-off algorithm is necessary to avoid wearing out the FLASH memory that is used to save the states/values. When changing parameter values using LHMI or PST, there is a save of this type of memory before rebooting, so in this case normally no information is lost. When there are long periods of inactivity, the time between save operations decreases slowly again, until it reaches the minimum time between saves, which is approximately once per second. After commissioning is complete, the possible loss of information should not be an issue, since in normal operation an IED is switched off extremely seldom. But during certain tests, if the IED is rebooted, then data of this kind will sometimes revert back to old values.

5.7.1 Voltage control

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

Automatic voltage control for tap changer, single control (TR1ATCC) is based on a transformer configuration consists of one tap changer on a single two winding power transformer.

Automatic voltage control for tap changer, parallel control (TR8ATCC), if installed, may be set to operate in Master Follower (MF) mode, or Minimise Circulating Current (MCC) mode. The commissioning tests for each parallel control mode are addressed separately in the following procedure.

Secondary injection of load current (I_L) and secondary bus voltage (UB) equivalent quantities is required during installation and commissioning tests. The test consists mainly of:

1. Increasing or decreasing the injected voltage or current at the analogue inputs of the IED.
2. Checking that the corresponding command/s (Lower or Raise) are issued by the voltage control function.

Setting confirmation is an important step for voltage control in the installation and commissioning phase to ensure consistency of power systems base quantities, alarm/ blocking conditions and parallel control settings for each transformer control function.

Before starting any test, verify the following settings in PCM600 or local HMI for TR1ATCC, TR8ATCC and TCMYLTC.

- Confirm power system base quantities *IBase* (for winding 1 which is defined in a global base function, selected with setting *GlobalBaseSel1* for TR1ATCC and TR8ATCC), *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC), UBase.

Main menu/Settings/IED Settings/Control/TR8ATCC (90)/TR8ATCC/General

and

Main menu/Settings/IED Settings/Control/TCMYLTC (84)

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- Confirm that setting for short circuit impedance *Xr2* for TR1ATCC, TR8ATCC is in accordance with transformer data:
  - Short circuit impedance. **Main menu/Settings/IED Settings/Control/TR1ATCC (90)/TR1ATCC/Xr2**.
- Confirm that setting for TCMYLTC is in accordance with transformer data:
  - Tap change timeout duration - effectively the maximum transformer tap change time, *tTCTimeout*, available in local HMI under **Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/tTCTimeout**.
  - On-Load-Tap Changer pulse duration – required length of pulse from IED to On-Load-Tap-Changer, *tPulseDur*, available in local HMI under **Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/tPulseDur**.
  - Transformer tap range, *LowVoltTap* and *HighVoltTap*, available in local HMI under **Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/LowVoltTap and HighVoltTap**.
  - On-Load-Tap Changer code type – method for digital feedback of tap position, *CodeType*, available in local HMI under **Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/CodeType**.

During the installation and commissioning, the behaviour of the voltage control functions for different tests may be governed by a parameter group, available in local HMI under **Main menu/Settings/IED Settings/Control/TCMYLTC**. These parameter settings can cause a Total Block, Automatic Block or Alarm for a variety of system conditions including over and under voltage, over current and tap changer failure. It is important to review these settings and confirm the intended response of the voltage control function for different secondary injection tests.

Terminology

The busbar voltage UB is a shorter notation for the measured voltages Ua, Ub, Uc or Uij, where Uij is the phase-phase voltage, Uij = Ui -Uj, or Ui, where Ui is one single-phase to earth voltage.

I_L is a shorter notation for the measured load current; it is to be used instead of the three-phase quantities Ia, Ib, Ic or the two-phase quantities Ii and Ij, or single phase current Ii.

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TR1ATCC in menu structures designates Automatic voltage control for tap changer, single control, TR8ATCC designates Automatic voltage control for tap changer, parallel control and TCMYLTC designates Tap changer control and supervision, 6 binary inputs.

5.7.1.1 Secondary test

The voltage control function performs basic voltage regulation by comparing a calculated load voltage (U_L) against a voltage range defined by setting *Udeadband* (with upper and lower limits U2 and U1 respectively). The calculated load voltage U_L represents the secondary transformer bus voltage UB adjusted for Load drop compensation (LDC) where enabled in settings. Note that when LDC is disabled, UB equals U_L.

When the load voltage U_L stays within the interval between U1 and U2, no action will be taken.

If U_L < U1 or U_L > U2, a command timer will start which is constant time or inverse time defined by setting *t1* and *t1Use*. The command timer will operate while the measured voltage stays outside the inner deadband (defined by setting *UDeadbandInner*).

If U_L remains outside of the voltage range defined by *UDeadband* and the command timer expires, the voltage control will execute a Raise or Lower command to the transformer tap changer. This command sequence will be repeated until U_L is brought back within the inner deadband range.

5.7.1.2 Check the activation of the voltage control operation

Procedure

1. Confirm Transformer Tap Control = *On* & Transformer Voltage Control = *On*
   - Direct tap change control

   Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/ Operation

- Automatic transformer voltage control

Main menu/Settings/IED Settings/Control

- Enable Tap Command

Main menu/Settings/IED Settings/Control/TCMYLTC (84)/TCMYLTC/EnabTapCmd
While the test set is connected to the IED but no voltage is applied, the voltage control functions will detect an under voltage condition that may result in an alarm or blocking of the voltage control operation. These conditions will be shown on the local HMI.

2. Apply the corresponding voltage
Confirm the analogue measuring mode prior to undertaking secondary injection (positive sequence, phase-phase, or phase-earth). This measuring mode is defined in
Main menu/Settings/IED Settings/Control/TR8ATCC (90)/TR8ATCC/General/MeasMode
The application of nominal voltage *USet* according to set *MeasMode* to the IEDs should cause the alarm or blocking condition for undervoltage to reset.

5.7.1.3 Check the normal voltage regulation function

Procedure

1. Review the settings for *UDeadband* (based on percentage of nominal bus voltage) and calculate the upper (U2) and lower (U1) voltage regulation limits for which a tap change command will be issued.
2. Review the expected time for first (*t1*) and subsequent (*t2*) tap change commands from the voltage control function
Main menu/Settings/IED Settings/Control/TR1ATCC (90)/TR1ATCC/t1 and t2
3. Lower the voltage 1% below U1 and wait for the issue of a Raise command from the voltage control after the expiry of a constant or inverse time delay set by *t1*. Detection of this command will involve locating the allocated binary output for a Raise pulse command in the PCM600 Signal Matrix (SMT) and monitoring a positive from this output.
4. After the issue of the Raise command, return the applied voltage to *USet* (nominal value).
5. Raise the voltage 1% above the upper deadband limit U2 and wait for the issue of a Lower command from the voltage control after the expiry of a constant or inverse time delay set by *t1*. Detection of this command will involve locating the allocated binary output for a Low pulse command in the PCM600 Signal Matrix (SMT) and monitoring a positive from this output.
6. Return the applied voltage to *USet*.

5.7.1.4 Check the undervoltage block function

Procedure

1. Confirm the setting for *Ublock*, nominally at 80% of rated voltage.
2. Confirm the voltage control function response to an applied voltage below *Ublock*, by reviewing setting **Main menu/Settings/IED Settings/Control/** that may cause an alarm, total or automatic block of the voltage control function to be displayed on the local HMI.
3. Apply a voltage slightly below *Ublock* and confirm the response of the voltage control function.

5.7.1.5 Check the upper and lower busbar voltage limit

Procedure

1. Confirm the settings for *Umin* and *Umax*.
   Main menu/Settings/IED Settings/Control/
2. Confirm the voltage control function response to an applied voltage below *Umin* and above *Umax*, by reviewing settings **Main menu/Settings/IED Settings/Control/** and **Main menu/Settings/IED Settings/Control/**. These conditions may cause an alarm, total or automatic block of the voltage control function to be displayed on the local HMI.
3. Decrease the injected voltage slightly below the *Umin* value and check for the corresponding blocking or alarm condition on the local HMI. For an alarm condition, the voltage regulation function is not blocked and a Raise command should be issued from the IED.
4. Increase the applied voltage slightly above the *Umax* value and check for the corresponding blocking or alarm condition on the local HMI. For an alarm condition, the voltage regulation function is not blocked and a Lower command should be issued from the IED.

5.7.1.6 Check the overcurrent block function

Procedure

1. Confirm the setting for *Iblock*.
   Main menu/Settings/IED Settings/Control/
2. Confirm the voltage control function response to an applied current above *Iblock*, by reviewing settings **Main menu/Settings/IED Settings/Control/**. This condition may cause an alarm, total or automatic block of the voltage control function to be displayed on the local HMI.
3. Inject a current higher than the *Iblock* setting and confirm the alarm or blocking condition is present on the local HMI. If an automatic or total blocking condition occurs, change the applied secondary voltage and confirm that no tap change commands are issued from the associated binary outputs.

This situation can also be confirmed through reviewing the Disturbance and Service reports on the local HMI.

5.7.1.7 Automatic voltage control for tap changer, single control TR1ATCC

Load drop compensation

Procedure

1. Confirm that *OperationLDC* is set to *On*
2. Confirm settings for *Rline* and *Xline*
3. Calculate the expected Load Voltage U_L (displayed as a measured value on the local HMI) based on secondary injection of transformer secondary voltage (*U*B = *USet*) and rated load current (I_L = *IBase* (for winding 1, which is defined in a global base function, selected with setting *GlobalBaseSel1* for TR1ATCC and TR8ATCC)), in accordance with equation 10.

$$U_L = UB - (Rline + jXline) \cdot I_L$$

(Equation 10)

where:

U_L, I_L = $Re(I_L) + jIm(I_L)$ are complex phase quantities

When all secondary phase-to-earth voltages are available, use the positive sequence components of voltage and current. By separation of real and imaginary parts:

$$ul,re = ub,re - rline \cdot il,re + xline \cdot il,im$$

(Equation 11)

$$ul,im = ub,im - xline \cdot il,re - rline \cdot il,im$$

(Equation 12)

where:

ub	is the complex value of the busbar voltage
il	is the complex value of the line current (secondary side)
rline	is the value of the line resistance
xline	is the value of the line reactance

For comparison with the set point value, the modulus of U_L are according to equation 13.

$$|U_L| = \sqrt{(ul, re)^2 + (ul, im)^2}$$

(Equation 13)

4. Inject voltage for UB equal to setting *USet*.
5. Inject current equal to rated current *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC).
6. Confirm on the local HMI that service values for bus voltage and load current are equal to injected quantities.
7. Confirm that the calculated value for load voltage, displayed on the local HMI, is equal to that derived through hand calculations.
8. When setting *OperationLDC* set to *On*, the voltage regulation algorithm uses the calculated value for load voltage as the regulating quantity to compare against *USet* and the voltage deadband limits *UDeadband* and *UDeadbandInner*.
9. While injecting rated current *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC) into the IED, inject a quantity for UB that is slightly higher then *USet*+$|(\text{Rline}+\text{jXLine})\cdot I_L|$. This will ensure that the regulating voltage U_L is higher than *USet*, and hence no tap change command should be issued from the IED.
10. Reduce the injected voltage for UB slightly below *USet*+$|(\text{Rline}+\text{jXLine})\cdot I_L|$ and confirm that the calculated value for load voltage is below *USet* and a tap change command is issued from the IED.

5.7.1.8 Automatic voltage control for tap changer, parallel control TR8ATCC

Master follower voltage regulation

Procedure

1. For the transformers connected in the parallel group, confirm that *OperationPAR* is set to *MF*.
2. For parallel operation, it is also recommended to confirm for parallel group membership, defined by setting *TnRXOP*.
   Main menu/Settings/IED Settings/Control/TR8ATCC(90)/TR8ATCC/ParCtrl
   the general parallel arrangement of transformers are defined by setting *TnRXOP* to *On* or *Off*. The following rules are applicable on the function inputs *T1RXOP* – *T4RXOP*. If IED*T1* and *T2* are connected, *T1RXOP* shall be set to *On* in ATC2 and *T2RXOP* shall be set to *On* in ATC3, *T2RXOP* and *T3RXOP* to *On* in ATC1 and so on.

The parameter corresponding to the own IED **must not** be set. *T1RXOP* should thus not be set in IED *T1*, *T2RXOP***not** in IED *T2*, and so on.

3. The lowest transformer number in the parallel group is by default set as the Master – confirm that this is the case by reviewing the setting in local HMI.
4. Review the settings for *UDeadband* (based on percentage of nominal bus voltage) and calculate the upper (U2) and lower (U1) voltage regulation limits for which a tap change command will be issued from the Master transformer in the group.
5. Review the expected time for first (*t1*) and subsequent (*t2*) tap change commands from the Master transformer
Main menu/Settings/IED Settings/Control/
6. Apply a voltage 1% below U1 and wait for the issue of a Raise command from the voltage control after the expiry of a constant or inverse time delay set by *t1*. Detection of this command will involve locating the allocated binary output for a Raise command in the PCM600 Signal Matrix (SMT) and monitoring a positive from this output. Confirm the timing of this command correlates with the setting *t1*.
7. After the issue of the Raise command, confirm that all Follower transformers in the group change tap in accordance with the command issued from the Master transformer.
8. Inject a voltage UB for the Master transformer that is 1% above the upper deadband limit U2 and wait for the issue of a Lower command from the voltage control after the expiry of a constant or inverse time delay set by *t2*.
9. Confirm that all Follower Transformers in the group change tap in accordance with this command.

Circulating current voltage regulation

This instruction for confirmation of circulating current voltage regulation assumes two transformers in the parallel group. Setting confirmation through secondary injection requires calculation of circulating currents for each transformer based on impedance values and respective compensating factors, and is therefore more complex for greater than two transformers.

Procedure

1. Confirm that *OperationPAR* is set to *CC* for the transformers in the parallel group.
2. For parallel operation, it is also recommended that settings be confirmed for parallel group membership, governed by setting *TnRXOP*
Main menu/Setting/IED Setting/Control
The general parallel arrangement of transformers are defined by setting *TnRXOP* to *On* or *Off*. The following rules are applicable on the function inputs *T1RXOP* - *T4RXOP*. If IED *T1* and *T2* are connected, *T1RXOP* shall be set to *On* in ATC2 and *T2RXOP* shall be set to *On* in ATC1. If *T1* - *T3* are available *T1RXOP* and *T2RXOP* shall be set to *On* in ATC3, *T2RXOP* and *T3RXOP* to *On* in ATC1 and so on.

The parameter corresponding to the own terminal **must not** be set. *T1RXOP* should thus **not** be set in IED *T1*, *T2RXOP* not in IED *T2* and so on.

3. Review the settings for *UDeadband* (based on percentage of nominal bus voltage) and calculate the upper (U2) and lower (U1) voltage regulation limits for which a tap change command will be issued from the Master transformer in the group.
4. Review the expected time for first (*t1*) and subsequent (*t2*) tap change commands from the Master transformer
Main menu/Setting/IED Setting/Control
5. Inject a voltage UB equal to *USet* for each transformer.
6. Inject a load current for Transformer 1 that is equal to rated load current *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC) and a load current for Transformer 2 that is equal to 95% of rated load current *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC). This will have the effect of producing a calculated circulating current that flows from HV to LV side for Transformer 1 and LV to HV side for Transformer 2.
7. Confirm that a circulating current is measured on the local HMI that is equal in magnitude to 5% of *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC), with polarity as discussed in step 6.
8. Confirm the settings for C*i* (Compensation Factor) and X*i* (Transformer Short Circuit Impedance). Using these setting values and the measured quantity of circulating current from the local HMI (I*cc_i*), calculate the value for circulating current voltage adjustment U*ci*.

$$Udi = Ci \cdot Icc\_i \cdot Xi$$

(Equation 14)

The voltage regulation algorithm then increases (for transformer *T2*) or decreases (for transformer *T1*) the measured voltage by Udi and compares Ui against the voltage deadband limits U1 and U2 for the purposes of voltage regulation.

$$Ui = UB + Udi$$

(Equation 15)

9. To cause a tap change, the calculated value for circulating current voltage adjustment must offset the injected quantity for bus voltage UB so that Ui is outside the voltage deadband created by setting *UDeadband*. Expressed by equation 16 and equation 17.

$$Udi > U2 - UB$$

(Equation 16)

$$UB = Uset$$ (for the purposes of this test procedure)

(Equation 17)

Therfore:

$$Ci \cdot Icc\_i \cdot Xi > U2 - Uset$$

(Equation 18)

$$\left| Icc\_i \right| > \left(U2 - Uset \right) / \left(Ci \cdot Xi \right)$$

(Equation 19)

10. Using the settings for *USet*, *UDeadband*, C (Compensating factor) and *Xr2* (transformer short circuit impedance) calculate the magnitude of Icc_*i* necessary to cause a tap change command.
11. Inject current equal to *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC) for Transformer 1 and (*IBase* - |Icc_*i*|) for Transformer 2 so that the magnitude of calculated circulating current will cause a Raise command to be issued for Transformer 2 and a Lower command for Transformer 1. Magnitude and direction of circulating currents measured for each transformer can be observed as service values on the local HMI and Raise/ Lower commands detected from the binary output mapped within SMT.

   The voltage injection equal to *USet* is required for both transformers during this test.

12. Confirm that a tap change command is issued from the voltage control function to compensate for the circulating current.
13. Injected currents can be reversed such that the direction of calculated circulating currents change polarity, which will cause a Lower command for Transformer 2 and a Raise command for Transformer 1.

Circulating current limit

Procedure

1. Confirm that *OperationPAR* is set to *CC* for each transformer in the parallel group.
2. Confirm that *OperCCBlock* is set to *On* for each transformer in the parallel group.
3. Review the setting for *CircCurrLimit*.
4. Review the setting for *CircCurrBk* to confirm whether a circulating current limit will result in an *Alarm* state, *Auto Block* or *Auto&Man Block* of the Automatic voltage control for tap changer, for parallel control TR8ATCC function.
5. Inject a voltage UB equal to *USet* for each transformer.
6. Inject a load current for Transformer 1 that is equal to rated load current *IBase* (for winding 2 which is defined in a global base function, selected with setting *GlobalBaseSel2* for TR1ATCC and TR8ATCC) and a load current for Transformer 2 that is 1% less than [*IBase* – (*IBase* · CircCurrLimit)]
7. Confirm that the Automatic voltage control for tap changer, for parallel control TR8ATCC function responds in accordance with the setting for *CircCurrBk*. Alarm and blocking conditions can be confirmed through interrogation of the Event or Control menus on the local HMI.

VTMismatch during parallel operation

Procedure

1. Confirm that *OperationPAR* is set to *MF* for each transformer in the parallel group.
2. Review the setting for *VTMismatch* and *tVTMismatch*.
3. Inject a voltage UB equal to *USet* for Transformer 1 and a voltage less than [*USet* – (*VTMismatch* · *USet*)] for Transformer 2.
4. This condition should result in a *VTMismatch* which will mutually block the operation of Automatic voltage control for tap changer, parallel control (TR8ATCC) for all transformers connected in the parallel group, which can be confirmed through interrogation of the local HMI.
5. Confirm that the Automatic voltage control for tap changer, parallel control (TR8ATCC) function responds in accordance with the setting for *CircCurrBk*.

5.7.1.9 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.8 Testing logic functions

5.8.1 Tripping logic SMPPTRC

Prepare the IED for verification of settings as outlined in 4.1 "Preparing the IED to verify settings".

Values of the logical signals are available on the local HMI under: **Main menu/ Tests/Function status/<Function group>/<Function>/<1:Function>**. The Signal monitoring tool in PCM600 shows the same signals that are available on the LHMI.

This function is functionality tested together with other protection functions (earth-fault overcurrent protection, etc.) within the IED. It is recommended that the function is tested together with the autoreclosing function, or when a separate external unit is used for reclosing purposes. The testing is preferable done in conjunction with the protection system and autoreclosing function.

5.8.1.1 Three phase operating mode

Procedure:

1. Check that *AutoLock* and *TripLockout* are both set to *Off*.
2. Initiate a three-phase fault
   An adequate time interval between the faults should be considered, to overcome a reclaim time caused by the possible activation of the autorecloser (SMBRREC) function. The function must issue a three-phase trip in all cases, when trip is initiated by any protection or some other built-in or external function. The functional TRIP output signal must always appear.

5.8.1.2 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 a IED.

Procedure:

1. Check that *AutoLock* and *TripLockout* are both set to *Off*.
2. Initiate a three-phase fault
   The functional output TRIP should be active at each fault. The output CLLKOUT must not be set.
3. Activate the automatic lockout function, set *AutoLock* = *On* and repeat
   Beside the TRIP outputs, CLLKOUT should be set.
4. Reset the lockout signal by shortly thereafter activating the reset lockout (RSTLKOUT) signal.
5. Activate the TRIP signal lockout function, set *TripLockout* = *On* and repeat.

The output TRIP must be active and stay active after each fault, CLLKOUT must be set.

6. Repeat.
   All functional outputs should reset.
7. Deactivate the TRIP signal lockout function, set *TripLockout = Off* and the automatic lockout function, set *AutoLock = Off*.

5.8.1.3 Completing the test

Continue to test another function or end the testing by setting the parameter *TestMode* to *Off* under **Main menu/Tests/IED test mode/1:TESTMODE**. If another function is tested, then set the parameter *Blocked* to *No*, under **Main menu/Tests/Function test modes/<Function group>/<Function>/<1:Function>** for the function, or for each individual function in a chain, to be tested next. Remember to set the parameter *Blocked* to *Yes*, for each individual function that has been tested.

5.9 Testing monitoring functions

5.9.1 Event counter CNTGGIO

The function can be tested by connecting a binary input to the counter under test and from outside apply pulses to the counter. The speed of pulses must not exceed 10 per second. Normally the counter will be tested in connection with tests on the function that the counter is connected to, such as trip logic. When configured, test it together with the function which operates it. Trig the function and check that the counter result is the same the number of operations.

5.10 Testing metering functions

5.10.1 Pulse counter PCGGIO

The test of Pulse counter PCGGIO function requires the Parameter Setting Tool (PST) in PCM600 or an appropriate connection to a 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 = Off/On* and the function blocked/deblocked. The pulse counter value is then checked in PCM600 or local HMI.

5.11 Exit test mode

The following procedure is used to return to normal operation.

Procedure

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

Section 6 Troubleshooting

6.1 Fault tracing

6.1.1 Identifying hardware errors

1. Check the module with an error.
   - Check the general IED status in **Main menu/Diagnostics/IED status/General** for a faulty hardware module.
   - Check the history of changes in internal event list in **Main menu/Events**.
2. Inspect the IED visually.
   - Inspect the IED visually to find any physical error causes.
   - If you can find some obvious physical damage, contact ABB for repair or replacement actions.
3. Check whether the error is external or internal.
   - Check that the error is not caused by external origins.
   - Remove the wiring from the IED and test the input and output operation with an external test device.
   - If the problem remains, contact ABB for repair or replacement actions.

6.1.2 Identifying runtime errors

1. Check the error origin from IED's internal event list **Main menu/Diagnostics/IED status/General**.
2. Reboot the IED and recheck the supervision events to see if the fault has cleared.
3. In case of persistent faults, contact ABB for corrective actions.

6.1.3 Identifying communication errors

Communication errors are normally communication interruptions or synchronization message errors due to communication link breakdown.

- Check the IEC61850 and DNP3 communication status in internal event list in **Main menu/Diagnostics/IED Status/General**.
- In case of persistent faults originating from IED's internal faults such as component breakdown, contact ABB for repair or replacement actions.

6.1.3.1 Checking the communication link operation

There are several different communication links on the product. First check that all communication ports that are used for communication are turned on.

1. Check the front communication port RJ-45.
   1.1. Check that the uplink LED is lit with a steady green light.
   The uplink LED is located on the LHMI above the RJ-45 communication port on the left. The port is used for direct electrical communication to a PC connected via a crossed-over Ethernet cable.
   1.2. Check the communication status of the front port via the LHMI in **Main menu/Test/Function status/Communication/1:DOSFRNT/Outputs**.
   Check that the *LINKUP* value is 1, that is, the communication is working. When the value is 0, there is no communication link.

> The rear port connector X0 is used for connecting an external HMI to the IED. If the *LINKUP* value is 0 for front port, there is no communication link via port X0. Do not use rear port connector X0 if the IED is equipped with an LHMI.

2. Check the communication status of the rear port X1 via the LHMI in **Main menu/Test/Function status/Communication/1:DOSLAN1/Outputs**.
   The X1 communication port on the rear side of the IED is for optical Ethernet via LC connector or electrical via RJ-45 connector of the IEC 61850-8-1 station bus communication.
   - Check that the *LINKUP* value is 1, that is, the communication is working. When the value is 0, there is no communication link.

6.1.3.2 Checking the time synchronization

- Select **Main menu/Diagnostics/IED status/General** and check the status of the time synchronization on **Time Synch**.
  The *Time synch* value is *Ready* when the synchronization is in order. Note that the time synchronization source has to be activated. Otherwise the value is always *Ready*.

6.1.4 Running the display test

To run the display test, either use the push buttons or start the test via the menu.

- Select **Main menu/Tests/LED test**.
- Press or simultaneously ESC and .

All the LEDs are tested by turning them on simultaneously. The LCD shows a set of patterns so that all the pixels are activated. After the test, the display returns to normal state.

6.2 Indication messages

6.2.1 Internal faults

When the Ready LED indicates an internal fault by flashing, the message associated with the fault is found in the internal event list in the LHMI menu **Main menu/Diagnostics/Internal events**. The message includes the date, time, description and signal state for the fault. The internal event list is not updated dynamically. The list is updated by leaving the **Internal events** menu and then selecting it again. The current status of the internal fault signals can also be checked via the LHMI in **Main menu/Diagnostics/IED status**.

Different actions are taken depending on the severity of the fault. After the fault is found to be permanent, the IED stays in internal fault mode. The IED continues to perform internal tests during the fault situation.

When a fault appears, the fault indication message is to be recorded and stated when ordering service.

Table 7: Internal fault indications

Fault indication	Additional information
Internal Fault Real Time Clock Error	Hardware error with the real time clock.
Internal Fault Runtime Exec. Error	One or more of the application threads are not working properly.
Internal Fault SW Watchdog Error	This signal will be activated when the terminal has been under too heavy load for at least 5 minutes.
Internal Fault Runtime App Error	One or more of the application threads are not in an expected state.
Internal Fault File System Error	A file system error has occurred.
Internal Fault TRM-Error	A TRM card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault BIO-Error	A BIO card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault COM-Error	A COM card error has occurred. The instance number is displayed at the end of the fault indication.
Internal Fault PSM-Error	A PSM card error has occurred. The instance number is displayed at the end of the fault indication.

6.2.2 Warnings

The warning message associated with the fault is found in the internal event list in the LHMI menu **Main menu/Diagnostics/Internal events**. The message includes the date, time, description and signal state for the fault. The current status of the internal fault signals can also be checked via the LHMI in **Main menu/Diagnostics/IED status/General**.

When a fault appears, the fault indication message is to be recorded and stated when ordering service.

Table 8: Warning indications

Warning indication	Additional information
Warning IEC 61850 Error	IEC 61850 has not succeeded in some actions such as reading the configuration file, startup etc.
Warning DNP3 Error	Error in DNP3 communication.

6.2.3 Additional indications

The additional indication messages do not activate internal fault or warning.

The messages are listed in the LHMI menu under the event list. The signal status data is found under the IED status and in the internal event list.

Table 9: Additional indications

Warning indication	Additional information
Time Synch Error	Source of the time synchronization is lost or time system has made a time reset.
BATTERY1 Error	BATTERY1 Error status.
Settings Changed	Settings have been changed.
Setting Groups Changed	Setting group has been changed.

6.3 Correction procedures

6.3.1 Resetting the configuration

The configuration is reset with PCM600.

For more information, see PCM600 documentation.

6.3.2 Changing and setting the password

The password can only be set with PCM600.

For more information, see PCM600 documentation.

6.3.3 Identifying IED application problems

Navigate to the appropriate menu in the LHMI to identify possible problems.

- Check that the function is on.
- Check that the correct setting group (1 to 4) is activated.
- Check the blocking.
- Check the mode.
- Check the measurement value.
- Check the connection to trip and disturbance recorder functions.
- Check the channel settings.

6.3.3.1 Inspecting the wiring

The physical inspection of wiring connections often reveals the wrong connection for phase currents or voltages. However, even though the phase current or voltage connections to IED terminals might be correct, wrong polarity of one or more measurement transformers can cause problems.

- Check the current or voltage measurements and their phase information from **Main menu/Measurements/Analog primary values** or **Analog secondary voltages**.
- Check that the phase information and phase shift between phases is correct.
- Correct the wiring if needed.
    - Change the parameter *Negation* in **Configuration/Analog modules/ 3PhaseAnalogGroup/1:SMAI_20_n** (n= the number of the SMAI used).

      Changing the *Negation* parameter is not recommended without special skills.

    - In PCM600, change the parameter *CTStarPointn* (n= the number on the current input) under the parameter settings for each current input.
- Check the actual state of the connected binary inputs.

- In LHMI, select **Main menu/Tests/Binary input values/Binary input modules**. Then navigate to the board with the actual binary input to be checked.
- With PCM600, right-click the product and select **Signal Monitoring**. Then navigate to the actual I/O board and to the binary input in question. The activated input signal is indicated with a yellow-lit diode.

- Measure output contacts using the voltage drop method of applying at least the minimum contact load given for the output relays in the technical data, for example 100 mA at 24 V AC/DC.

Output relays, especially power output relays, are designed for breaking high currents. Due to this, layers of high resistance may appear on the surface of the contacts. Do not determine proper functionality of connectivity or contact resistance by measuring with a regular hand-held ohm meter.

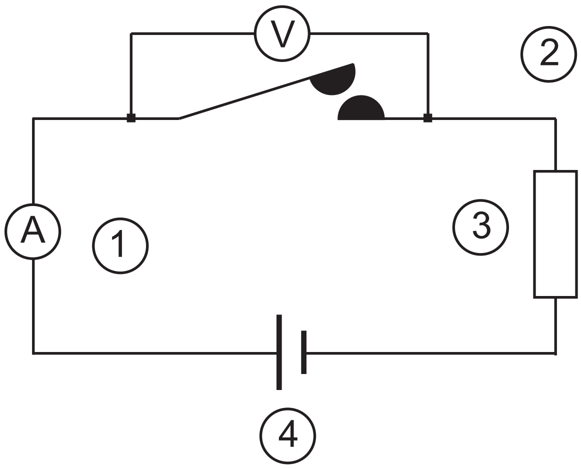

Figure 8: Testing output contacts using the voltage drop method

1 Contact current

2 Contact voltage drop

3 Load

4 Supply voltage

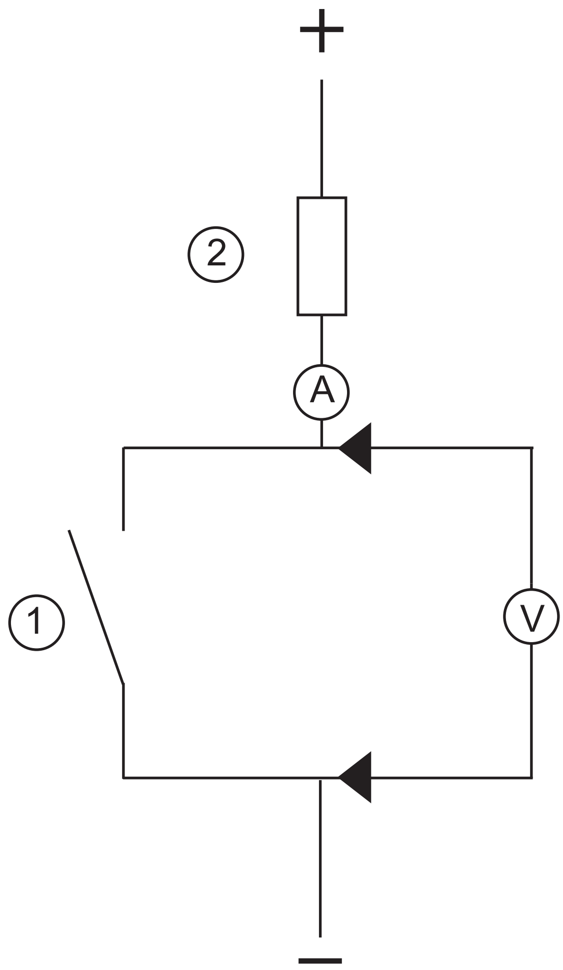

Figure 9: Testing a trip contact

1 Trip contact under test

2 Current limiting resistor

- To check the status of the output circuits driving the output relay via the LHMI, select **Main menu/Tests/Binary output values/Binary output modules** and then navigate to the board with the actual binary output to be checked.
- Test and change the relay state manually.
  1. To set the IED to test mode, select **Main menu/Tests/IED testmode1:TESTMODE/TestMode** and set the parameter to *On*.
  2. To operate or force the output relay to operate, select **Main menu/Tests/Forcing/Binary output values** and then navigate to the board with the actual binary output relay to be operated/forced.
  3. Select the BOn_PO to be operated/forced and use and or to operate the actual output relay.

In PCM600, only the result of these operations can be checked by right-clicking the product and selecting Signal Monitoring tool and then navigating to the actual I/O-board and the binary input in question. The activated output signal is indicated with a yellow-lit diode. Each BOn_PO is represented by two signals. The first signal in LHMI is the actual value 1 or 0 of the output, and in PCM600 a lit or dimmed diode. The second signal is the status Normal or Forced. Forced status is only achieved when the BO is set to *Forced* or operated on the LHMI.

Set the parameter *TestMode* to *Off* after completing these tests. The Start LED will stop flashing when the relay is no longer in test mode.

An initially high contact resistance will not cause problems as it will be reduced quickly by the electrical cleaning effect of fritting and thermal destruction of layers, bringing the contact resistance back to the mOhm range. As a result, practically the full voltage is available at the load.

Section 7 Glossary

AC	Alternating current
ACT	Application configuration tool within PCM600
A/D converter	Analog to digital converter
ADBS	Amplitude dead-band supervision
ANSI	American National Standards Institute
AR	Autoreclosing
ASCT	Auxiliary summation current transformer
ASD	Adaptive signal detection
AWG	American Wire Gauge standard
BR	External bi-stable relay
BS	British standard
CAN	Controller Area Network. ISO standard (ISO 11898) for serial communication
CB	Circuit breaker
CCITT	Consultative Committee for International Telegraph and Telephony. A United Nations sponsored standards body within the International Telecommunications Union.
CCVT	Capacitive Coupled Voltage Transformer
Class C	Protection Current Transformer class as per IEEE/ ANSI
CMPPS	Combined mega pulses per second
CO cycle	Close-open cycle
Co-directional	Way of transmitting G.703 over a balanced line. Involves two twisted pairs making it possible to transmit information in both directions
COMTRADE	Standard format according to IEC 60255-24
Contra-directional	Way of transmitting G.703 over a balanced line. Involves four twisted pairs of with two are used for transmitting data in both directions, and two pairs for transmitting clock signals
CPU	Central processor unit
CR	Carrier receive
CRC	Cyclic redundancy check
CS	Carrier send

CT	Current transformer
CVT	Capacitive voltage transformer
DAR	Delayed auto-reclosing
DARPA	Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)
DBDL	Dead bus dead line
DBLL	Dead bus live line
DC	Direct current
DFT	Discrete Fourier transform
DIP-switch	Small switch mounted on a printed circuit board
DLLB	Dead line live bus
DNP	Distributed Network Protocol as per IEEE/ANSI Std. 1379-2000
DR	Disturbance recorder
DRAM	Dynamic random access memory
DRH	Disturbance report handler
DSP	Digital signal processor
DTT	Direct transfer trip scheme
EHV network	Extra high voltage network
EIA	Electronic Industries Association
EMC	Electro magnetic compatibility
EMF	Electro motive force
EMI	Electro magnetic interference
EnFP	End fault protection
ESD	Electrostatic discharge
FOX 20	Modular 20 channel telecommunication system for speech, data and protection signals
FOX 512/515	Access multiplexer
FOX 6Plus	Compact, time-division multiplexer for the transmission of up to seven duplex channels of digital data over optical fibers
G.703	Electrical and functional description for digital lines used by local telephone companies. Can be transported over balanced and unbalanced lines
GCM	Communication interface module with carrier of GPS receiver module
GDE	Graphical display editor within PCM600

GI	General interrogation command
GIS	Gas insulated switchgear
GOOSE	Generic object oriented substation event
GPS	Global positioning system
HDLC protocol	High level data link control, protocol based on the HDLC standard
HFBR connector type	Plastic fiber connector
HMI	Human machine interface
HSAR	High speed auto reclosing
HV	High voltage
HVDC	High voltage direct current
IDBS	Integrating dead band supervision
IEC	International Electrical Committee
IEC 60044-6	IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance
IEC 61850	Substation Automation communication standard
IEEE	Institute of Electrical and Electronics Engineers
IEEE 802.12	A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable
IEEE P1386.1	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 Electro Motive Force.
IED	Intelligent electronic device
I-GIS	Intelligent gas insulated switchgear
Instance	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 will have 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.
IP	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 re-assembly through the data link layer.
	2. Ingression protection according to IEC standard
IP 20	Ingression protection, according to IEC standard, level 20
IP 40	Ingression protection, according to IEC standard, level 40
IP 54	Ingression protection, according to IEC standard, level 54
IRF	Internal fail signal
IRIG-B:	InterRange Instrumentation Group Time code format B, standard 200
ITU	International Telecommunications Union
LAN	Local area network
LIB 520	High voltage software module
LCD	Liquid crystal display
LDD	Local detection device
LED	Light emitting diode
MCB	Miniature circuit breaker
MCM	Mezzanine carrier module
MVB	Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.
NCC	National Control Centre
OCO cycle	Open-close-open cycle
OCP	Overcurrent protection
OLTC	On load tap changer
OV	Over voltage
Overreach	A term used to describe how the relay behaves during a fault condition. For example a distance relay is over-reaching when the impedance presented to it is smaller than the apparent impedance to the fault applied to the balance point, i.e. the set reach. The relay “sees” the fault but perhaps it should not have seen it.
PCI	Peripheral component interconnect, a local data bus
PCM	Pulse code modulation
PCM600	Protection and control IED manager
PC-MIP	Mezzanine card standard
PISA	Process interface for sensors & actuators
PMC	PCI Mezzanine card
POTT	Permissive overreach transfer trip

Process bus	Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components
PSM	Power supply module
PST	Parameter setting tool within PCM600
PT ratio	Potential transformer or voltage transformer ratio
PUTT	Permissive underreach transfer trip
RASC	Synchrocheck relay, COMBIFLEX
RCA	Relay characteristic angle
REVAL	Evaluation software
RFPP	Resistance for phase-to-phase faults
RFPE	Resistance for phase-to-earth faults
RISC	Reduced instruction set computer
RMS value	Root mean square value
RS422	A balanced serial interface for the transmission of digital data in point-to-point connections
RS485	Serial link according to EIA standard RS485
RTC	Real time clock
RTU	Remote terminal unit
SA	Substation Automation
SC	Switch or push-button to close
SCS	Station control system
SCT	System configuration tool according to standard IEC 61850
SMA connector	Subminiature version A, A threaded connector with constant impedance.
SMT	Signal matrix tool within PCM600
SMS	Station monitoring system
SNTP	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.
SRY	Switch for CB ready condition
ST	Switch or push-button to trip
Starpoint	Neutral point of transformer or generator
SVC	Static VAr compensation
TC	Trip coil

TCS	Trip circuit supervision
TCP	Transmission control protocol. The most common transport layer protocol used on Ethernet and the Internet.
TCP/IP	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.
TNC connector	Threaded Neill Concelman, A threaded constant impedance version of a BNC connector
TPZ, TPY, TPX, TPS	Current transformer class according to IEC
Underreach	A term used to describe how the relay behaves during a fault condition. For example a distance relay is under-reaching when the impedance presented to it is greater than the apparent impedance to the fault applied to the balance point, i.e. the set reach. The relay does not “see” the fault but perhaps it should have seen it. See also Overreach.
U/I-PISA	Process interface components that deliver measured voltage and current values
UTC	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 also sometimes known by the military name, "Zulu time". "Zulu" in the phonetic alphabet stands for "Z" which stands for longitude zero.
UV	Undervoltage
WEI	Weak end infeed logic
VT	Voltage transformer
X.21	A digital signalling interface primarily used for telecom equipment

$3I_O$	Three times zero-sequence current. Often referred to as the residual or the earth-fault current
$3U_O$	Three times the zero sequence voltage. Often referred to as the residual voltage or the neutral point voltage

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