Relion® 650 SERIES

Breaker protection REQ650
Version 1.1 ANSI
Application manual
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Section 17 Glossary
Section 1  Introduction

1.1  This manual

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

1.2  Intended audience

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

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as communication and protocols.
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 60870-5-103, 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

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### 1.3.3 Related documents

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<td>Communication protocol manual, DNP3</td>
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<tr>
<td>Communication protocol manual, IEC 61850</td>
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<tr>
<td>Communication protocol manual, IEC 60870-5-103</td>
</tr>
<tr>
<td>Point list manual, DNP3</td>
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</tbody>
</table>

Table continues on next page
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 of important facts and conditions.

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

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

1.4.2 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 the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, 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.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned then the dimension is in mm.
Section 2  Application

2.1  REQ650 application

Breaker protection REQ650 provides a standalone solution for applications, where synchronism check controlled closing of the circuit breaker is required, but the integration of the automatic reclosing function into the main line protection IED is not preferred or suitable. The advanced automatic reclosing, synchronizing, synchrocheck and energizing check functions of REQ650 provides an optimized stand alone product. This IED also enables well-structured and reliable protection and control systems especially in systems where complete bay control functionality including interlocking is not required.

REQ650 provides backup to the main protection with redundant protection and control functions.

Three pre-configured packages have been defined for following applications:

- Backup protection functions in a breaker bay giving three-phase trip (A01A). The connection of the bay is to a single or double busbar section.
- A breaker bay connecting a transmission line, with back-up protection functions enabling single phase trip (A11A). The connection of the bay is only to a single busbar section.
- A breaker bay connecting a transmission line, with back-up protection functions enabling single phase trip (B11A). The connection of the bay can be made to the double busbar sections.

The backup protection is mainly based on current and voltage based functions. In line protection applications, autoreclosing with or without synchronism check is available.

The package is delivered pre-configured and ready for use in the power system. Analogue inputs and binary inputs/outputs circuits are pre-defined.

The pre-configured IED can be modified and adapted to suit specific applications with the graphical configuration tool, using the glue logic and adjusting the parameter settings.
Figure 2: A typical backup protection functions in a breaker bay giving three-phase trip
Figure 3: A typical breaker bay connecting a transmission line, with back-up protection functions enabling single phase trip. The connection of the bay is only to a single busbar section.
Figure 4: A typical breaker bay connecting a transmission line, with back-up protection functions enabling single phase trip. The connection of the bay can be made to one of the double busbar sections.
### 2.2 Available functions

#### 2.2.1 Back-up protection functions

<table>
<thead>
<tr>
<th>IEC 61850/Function block name</th>
<th>ANSI</th>
<th>Function description</th>
<th>Breaker</th>
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<tr>
<td></td>
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<td>REQ650 (A01A) 3Ph/1CB/1BB</td>
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<tr>
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<td>Instantaneous phase overcurrent protection</td>
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</tr>
<tr>
<td>OC4PTOC 51/67</td>
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<td>Four step directional phase overcurrent protection</td>
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<tr>
<td>OC4SPTOC 51/67</td>
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<td>Four step phase overcurrent protection</td>
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<tr>
<td>EFPIOC 50N</td>
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<td>Instantaneous residual overcurrent protection</td>
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<tr>
<td>EF4PTOC 51N/67 N</td>
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<td>Four step directional residual overcurrent protection</td>
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<tr>
<td>SDEPSDE 67N</td>
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<td>Sensitive directional residual overcurrent and power protection</td>
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<td>LPTTR 26</td>
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<td>Thermal overload protection, one time constant</td>
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<tr>
<td>CCRBRF 50BF</td>
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<td>Breaker failure protection</td>
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<td>GUPPDUP 37</td>
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<td>Negative sequence based overcurrent function</td>
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<td><strong>Voltage protection</strong></td>
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<td><strong>Frequency protection</strong></td>
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<td>SAPTOF 81</td>
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<td>SAPFRC 81</td>
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## 2.2.2 Control and monitoring functions

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<td>3Ph/1CB/1BB</td>
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<tr>
<td>Control</td>
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<td>SESRSYN 25</td>
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<td>Autorecloser</td>
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<td>Selector mini switch extension</td>
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<td>Trip matrix logic</td>
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<td>OR</td>
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<td>Configurable logic blocks, set-reset memory flip-flop gate</td>
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<td>RSMMemory</td>
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<td>Configurable logic blocks, reset-set memory flip-flop gate</td>
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<td>Fixed signal function block</td>
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<td>Boolean 16 to Integer conversion</td>
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<td>B16IFCVI</td>
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<td>Boolean 16 to Integer conversion with logic node representation</td>
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<td>IB16A</td>
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<td>Integer to Boolean 16 conversion</td>
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<td>Phase-neutral voltage measurement</td>
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<td>Event counter</td>
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<td>SSILM</td>
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<td>Insulation liquid monitoring function</td>
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Table continues on next page
### 2.2.3 Designed to communicate

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<td>I103SUPERV</td>
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<td>Supervision status for IEC60870-5-103</td>
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#### Metering

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<th>Function</th>
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<td>Function for energy calculation and demand handling</td>
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### 2.2.4 Basic IED functions

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<tr>
<td>Basic functions included in all products</td>
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<tr>
<td>INTERRSIG</td>
<td>Self supervision with internal event list</td>
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<tr>
<td>SELF_SUPEVLST</td>
<td>Self supervision with internal event list</td>
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### IEC 61850/Function block name

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<td>TIMESYNCHGEN</td>
<td>Time synchronization</td>
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</tr>
<tr>
<td>DTSSBEGIN, DTSEND, TIMEZONE</td>
<td>Time synchronization, daylight saving</td>
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<tr>
<td>IRIG-B</td>
<td>Time synchronization</td>
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<td>Setting group handling</td>
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<td>Denial of service, socket flow control</td>
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#### 2.3 REQ650 application examples

#### 2.3.1 Adaptation to different applications

REQ650 is an IED with pre-defined configuration to be used as a backup for the main protection giving redundant protection and simple control functions. It is possible to use the IED in a wide range of applications. This is done by selecting a functionality from the comprehensive function library in the IED.

A selection of applications is described below.

The following application examples, describe line bay alternatives:

- Application 1: Line bay in a solidly grounded network, connected to single busbar switchyard
- Application 2: Line bay in a high impedance grounded network, connected to single busbar switchyard
- Application 3: Line bay in a solidly grounded network, connected to double busbar switchyard
- Application 4: Line bay in a high impedance grounded network, connected to double busbar switchyard
The following application examples, describe transformer bay alternatives:

- Application 5: Transformer bay in a solidly grounded network, connected to single busbar switchyard
- Application 6: Transformer bay in a solidly grounded network, connected to double busbar switchyard
- Application 7: Transformer bay in a high impedance grounded network, connected to single busbar switchyard

### 2.3.2 Line bay in a solidly grounded network, connected to single busbar switchyard

![Diagram of line bay in a solidly grounded network](ANSI11000150-1-en.vsd)

Figure 5: Line bay in a solidly grounded network

REQ650 has a number of back-up protection functions. In addition to this, three-phase trip and autoreclosing is available for REQ650 (A01A) and single-phase trip and autoreclosing is available for REQ650 (A11A).
2.3.3 Line bay in a high impedance grounded network, connected to single busbar switchyard

![Diagram of line bay in a high impedance grounded network]

Figure 6: Line bay in a high impedance grounded network

REQ650 has a number of back-up protection functions. In addition to this, three-phase trip and autoreclosing is available for REQ650 A01A and single-phase trip and autoreclosing is available for REQ650 A11A.
2.3.4 Line bay in a solidly grounded network, connected to double busbar switchyard

Figure 7: Line bay in a solidly grounded network

REQ650 has a number of back-up protection functions. In addition to this, three-phase trip and autoreclosing is available for REQ650 A01A and single-phase trip and autoreclosing is available for REQ650 B11A.
2.3.5 Line bay in a high impedance grounded network, connected to
double busbar switchyard

![Diagram of line bay in a high impedance grounded network]

Figure 8: Line bay in a high impedance grounded network

REQ650 has a number of back-up protection functions. In addition to this, three-phase trip and
autoreclosing is available for REQ650 A01A and single-phase trip and autoreclosing is available for
REQ650 B11A.

2.3.6 Functionality table

The proposal for functionality choice for the different application cases are shown in table 5.

The recommendations have the following meaning:

- Enabled: It is recommended to have the function activated in the application.
- Disabled: It is recommended to have the function deactivated in the application.
- Application dependent: The decision to have the function activated or not is dependent on the
  specific conditions in each case.

Applications 1 — 4 in table 5 are according to application examples given in
previous sections.
Table 5: Recommended functions in the different application examples

<table>
<thead>
<tr>
<th>Function</th>
<th>Application 1</th>
<th>Application 2</th>
<th>Application 3</th>
<th>Application 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous phase overcurrent protection PHPIOC (50), three-phase trip (A01)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Four step phase overcurrent protection OC4PTOC (51_67), three-phase trip (A01)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Instantaneous residual overcurrent protection EFPIOC (50N)</td>
<td>Enabled</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Four step residual overcurrent protection EF4PTOC (51N_67N)</td>
<td>Enabled</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Sensitive directional residual overcurrent and power protection SDEPSDE (67N)</td>
<td>Disabled</td>
<td>Enabled</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Thermal overload protection, one time constant LPTTR (26)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Breaker failure protection CCRBRF (50BF), three-phase trip (A01)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Stub protection STBPTOC (50STB)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Disabled</td>
</tr>
<tr>
<td>Pole discordance protection CCRPLD (52PD)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Broken conductor check BRCPTOC (46)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Directional underpower protection GUPPDUP (37)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Directional overpower protection GOPPDOP (32)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Negative sequence based overcurrent function DNSPTOC (46)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Two step undervoltage protection UV2PTUV (27)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Two step overvoltage protection OV2PTOV (59)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Two step residual overvoltage protection ROV2PTOV (59N)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Loss of voltage check LOVPTUV (27)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Underfrequency protection SAPTUF (81) (instance 1)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Underfrequency protection SAPTUF (81) (instance 2)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Overfrequency protection SAPTOF (81) (instance 1)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
</tbody>
</table>

Table continues on next page
<table>
<thead>
<tr>
<th>Function</th>
<th>Application 1</th>
<th>Application 2</th>
<th>Application 3</th>
<th>Application 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overfrequency protection SAPTOF (81) (instance 2)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Rate of change of frequency SAPFRC (81) (instance 1)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Rate of change of frequency SAPFRC (81) (instance 2)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Current circuit supervision CCSRDIF (87)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Fuse failure supervision SDDRFUF</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Breaker close/trip circuit monitoring TCSSCBR</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Synchrocheck, energizing check, and synchronizing SESRSYN (25)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Autorecloser SMBREC (79), three-phase trip (A01)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Autorecloser STBRREC (79), three-phase/single-phase trip (A11/B11)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Tripping logic SMPPTRC (94), three-phase trip (A01)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Station battery supervision SPVNZBAT</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Insulation gas monitoring function SSIMG (63)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Insulation liquid monitoring function SSIML (71)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Circuit breaker condition monitoring SSCBR</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
</tbody>
</table>
2.3.7 Transformer bay in a solidly grounded network, connected to single busbar switchyard

Figure 9: Transformer bay in a solidly grounded system
2.3.8 Transformer bay in a solidly grounded network, connected to double busbar switchyard

Figure 10: Transformer bay in a solidly grounded system
2.3.9 Transformer bay in a high impedance grounded network, connected to single busbar switchyard

![Transformer bay diagram]

Figure 11: Transformer bay in a high impedance grounded system

2.3.10 Functionality table

The proposal for functionality choice for the different application cases are shown in table 9.

The recommendations have the following meaning:

- Enabled: It is recommended to have the function activated in the application.
- Disabled: It is recommended to have the function deactivated in the application.
- Application dependent: The decision to have the function activated or not is dependent on the specific conditions in each case.

Applications 5 — 7 in table 9 are according to application examples given in previous sections.
<table>
<thead>
<tr>
<th>Function</th>
<th>Application 5</th>
<th>Application 6</th>
<th>Application 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous phase overcurrent protection PHPIOC (50), three-pole</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Four step phase overcurrent protection OC4PTOC (51_67), three-pole</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Instantaneous residual overcurrent protection EFPIOC (50N)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Four step residual overcurrent protection EF4PTOC (51N_67N)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Sensitive directional residual overcurrent and power protection SDEPSDE (67N)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Thermal overload protection, one time constant LPTTR (26)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Breaker failure protection CCRBRF (50BF), three-pole</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Stub protection STBPTOC (50STB)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Pole discordance protection CCRPLD (52PD)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Broken conductor check BRCPTOC (46)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Directional underpower protection GUPPDUP (37)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Directional overpower protection GOPPDOP (32)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Negative sequence based overcurrent function DNPTOC (46)</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Two step undervoltage protection UV2PTUV (27)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Two step overvoltage protection OV2PTOV (59)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Two step residual overvoltage protection ROV2PTOV (59N)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Loss of voltage check LOVPTUV (27)</td>
<td>Enabled</td>
<td>Enabled</td>
<td>Enabled</td>
</tr>
<tr>
<td>Underfrequency protection SAPTUF (81), instance 1</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Underfrequency protection SAPTUF (81), instance 2</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Overfrequency protection SAPTOF (81), instance 1</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Overfrequency protection SAPTOF (81), instance 2</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Rate-of-change of frequency SAPFRC (81), instance 1</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Rate-of-change of frequency SAPFRC (81), instance 2</td>
<td>Application dependent</td>
<td>Application dependent</td>
<td>Application dependent</td>
</tr>
<tr>
<td>Synchrocheck, energizing check, and synchronizing SESRSYN (25)</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
<tr>
<td>Autorecloser SMBRECR (79), three-pole</td>
<td>Disabled</td>
<td>Disabled</td>
<td>Disabled</td>
</tr>
</tbody>
</table>
Section 3  
REQ650 setting examples

3.1 Setting example for a line bay with backup protection unit REQ650 A01A

The application example has a 145 kV line bay with backup protection unit REQ650 A01A. The main protection of the line is a distance protection unit, not covered in this setting example.

Solidly Grounded System

Figure 12: Line bay backup protection application

The following data is assumed:

Table 10: Typical data for the line bay

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line length</td>
<td>50 km</td>
</tr>
<tr>
<td>Positive sequence impedance</td>
<td>$0.05 + j 0.35 \text{ ohm/km} \Rightarrow 2.5 + j17.5 \text{ ohm}$</td>
</tr>
<tr>
<td>Zero sequence impedance</td>
<td>$0.15 + j 1.00 \text{ ohm/km} \Rightarrow 7.5 + j50 \text{ ohm}$</td>
</tr>
<tr>
<td>High positive sequence source impedance</td>
<td>j10 ohm (about 1900 MVA)</td>
</tr>
<tr>
<td>Low positive sequence source impedance</td>
<td>j3.2 ohm (about 6000 MVA)</td>
</tr>
<tr>
<td>High zero sequence source impedance</td>
<td>j8 ohm</td>
</tr>
<tr>
<td>Low zero sequence source impedance</td>
<td>j5 ohm</td>
</tr>
<tr>
<td>High positive sequence source impedance at the remote line end</td>
<td>j10 ohm (about 1900 MVA)</td>
</tr>
</tbody>
</table>

Table continues on next page
### Item Data

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low positive sequence source impedance at the remote line end</td>
<td>j3.2 ohm (about 6000 MVA)</td>
</tr>
<tr>
<td>High zero sequence source impedance at the remote line end</td>
<td>j8 ohm</td>
</tr>
<tr>
<td>Low zero sequence source impedance at the remote line end</td>
<td>j5 ohm</td>
</tr>
<tr>
<td>CT ratio</td>
<td>1000/1 A</td>
</tr>
<tr>
<td>VT ratio at A and B</td>
<td>$\frac{143}{\sqrt{3}}$ kV</td>
</tr>
<tr>
<td></td>
<td>$\frac{0.11}{\sqrt{3}}$</td>
</tr>
<tr>
<td>Maximum power transfer on the line</td>
<td>180 MVA</td>
</tr>
</tbody>
</table>

Only settings that need adjustment due to the specific application are described in setting examples. It is recommended to keep the default values for all settings that are not described. Refer to Technical manual for setting tables for each protection and control function.

Refer to setting guideline section in Application manual for guidelines on how to set functions that are not presented in setting examples.

Use parameter setting tool in PCM600 to set the IED according to calculations for the particular application.

The following protection functions are used:

- Instantaneous phase overcurrent protection
- Four step delayed phase overcurrent protection
- Instantaneous residual overcurrent protection
- Four step delayed residual overcurrent protection
- Breaker failure protection
- Pole discordance protection

All fault clearance is done by means of three-phase tripping of the circuit breaker.

#### 3.1.1 Calculating settings for analogue TRM inputs 4I 1I 5U

The transformer module (TRM) has the capability of 4 current inputs (tapped to 1 or 5 A), 1 current input (tapped 0.1 or 0.5 A) and 5 voltage inputs.

The line phase CTs (three-pole current transformer group) are connected to inputs 1–3 (A, B and C).
Current inputs 4 and 5 are not used.

The line phase VTs (three-pole voltage transformer group) are connected to inputs 6 - 8 (A, B and C).

The 145 kV busbar 1 phase VT is connected to input 9 (A).

Voltage input 10 is not used.

1. Set the current transformer inputs.
   1.1. Set $CTStarPoint1$ to "To Object".
       The CT secondary is grounded from the line.
   1.2. Set $CTSec1$ to $1 A$.
   1.3. Set $CTPrim1$ to $1000 A$.
   1.4. Set the same values for current inputs 2 and 3.

2. Set the voltage transformer inputs.
   2.1. Set $VTSec7$ to $110 V$.
       (The rated secondary voltage of the VT, given as phase-to-phase voltage)
   2.2. Set $VTPrim6$ to $143 kV$.
       (The rated secondary voltage of the VT, given as phase-to-phase voltage)
   2.3. Set the same values for current inputs 7 and 8.
   2.4. Set $VTSec9$ to $110 V$.
       (The rated secondary voltage of the VT, given as phase-to-phase voltage)
   2.5. Set $VTPrim9$ to $143 kV$.
       (The rated secondary voltage of the VT, given as phase-to-phase voltage)

3.1.2 Preprocessing blocks (SMAI)

It is possible to use frequency adapted fourier filtering in the preprocessing blocks. In this application, the frequency is close to nominal. Therefore, $InternalDftRef$ is used.

3.1.3 Calculating settings for global base values for setting function GBSVAL

Each function uses primary base values for reference of settings. The base values are defined in Global base values for settings function. It is possible to include six Global base values for settings GBASVAL functions: Global base 1 – Global base 6. In this application, only Global base 1 is needed for defining the base for all inputs.

For transformer protection, set the parameters for the Global base values for settings functions according to the power transformer primary rated values:

1. Set $IBase$ to $1000 A$.
2. Set $VBase$ to $145 kV$.
3. Set $SBase$ to $251 MVA$.
3.1.4 **Calculating settings for instantaneous phase overcurrent protection PHPIOC (50)**

Instantaneous phase overcurrent protection (PHPIOC, 50) shall give very fast fault clearance of line short circuits close to the substation.

1. **Set GlobalBaseSel to 1**
   - The settings are made in primary values. These values are given in the base settings in Global base 1.

2. **Set I>> to 600 % of IBase.**
   - The protection shall not overreach the line and it shall not trip for short circuits in the reverse direction.
   - A three-phase short circuit at the remote line end and low source impedance gives the following fault current to the protection:

   \[
   I_{sc} = \frac{V_{ph}}{Z_{sc} + Z_{line}} = \frac{145/\sqrt{3}}{3.2 + 2.5 + j17.5} = 4.0\angle83^\circ\ kA
   \]

   \(Z_{sc}\) is the positive sequence source impedance “behind” the line and \(Z_{line}\) is the positive sequence impedance of the line.
   - A three-phase short circuit at the own busbar (reverse fault) gives the following fault current to the protection:

   \[
   I_{sc} = \frac{V_{ph}}{Z_{sc} + Z_{line}} = \frac{145/\sqrt{3}}{3.2 + 2.5 + j17.5} = 4.0\angle83^\circ\ kA
   \]

   \(Z_{sc}\) is the positive sequence source impedance of the remote substation and \(Z_{line}\) is the positive sequence impedance of the line.

3. **Set Pickup to 600 % of IBase (6000 A primary).**

3.1.5 **Calculating settings for four step phase overcurrent protection I> OC4PTOC (51_67)**

The purpose of the delayed phase overcurrent protection is:

- Backup protection for short circuits on the whole line length
- Backup protection for short circuits in the remote busbar
- Backup protection for short circuits in other lines from the remote substation or the own substation, when possible

The reach of the phase overcurrent line protection is dependent of the operation state and the fault type. Therefore, the setting must be based on fault calculations made for different faults, fault points and switching states in the network. Although it is possible to make hand calculations of the different faults, it is recommended to use computer based fault calculations. Due to different practices, different time delay principles can be used.

The following principle for the phase overcurrent protection is recommended:
• One delayed step used as line backup protection. It should be set to assure selectivity to line protections. Directional function forward is used.
• One delayed step used as backup protection for the own busbar. It should be set to assure selectivity to line protections. Directional function reverse is used.
• A long time delayed step covering further parts of the system. This step should have a time delay longer than 1.0 s. Non-directional function is used.

3.1.5.1 Calculating general settings

1. Set GlobalBaseSel to 1.
   The settings are made in primary values. These values are given in the base settings in Global base 1.

3.1.5.2 Calculating settings for step 1

The protection shall be able to detect all short circuits within the defined protected zone. In this case, it is required that the protection shall detect phase-to-phase short circuit at the most remote point of the protected line. A two-phase short circuit at the remote line end and high source impedance, as shown in figure 13, results in the following fault current for the protection:

\[ I_{sc} = \frac{\sqrt{3}}{2} \frac{V_{ph}}{Z_{sc} + Z_{line}} = \frac{\sqrt{3}}{2} \frac{145/\sqrt{3}}{j10 + 2.5 + j17.5} = 2.6 \angle 85^\circ \text{ kA} \]
In case of a three-phase short circuit in zone 1 reach in the shortest line from the remote busbar as shown in figure 14, the current to the protection is $I = 1.5 \text{kA}$. 

Figure 13: Fault for step 1 setting
3.1.5.3 Calculating settings for step 2

The protection shall be able to detect all short circuits in the own busbar. A two-phase short circuit in the busbar and high source impedance from the remote line end, as shown in figure 15, results in the following fault current for the protection:

\[
I_{sc} = \frac{\sqrt{3}}{2} \cdot \frac{V_{ph}}{Z_{sc} + Z_{line}} = \frac{\sqrt{3}}{2} \cdot \frac{145/\sqrt{3}}{j10 + 2.5 + j17.5} = 2.6 \angle 85^\circ \text{ kA}
\]

Figure 14: Fault for step 1 setting

Recommended current setting is therefore 2000 A.

1. Set DirModeSel1 to Forward.
2. Set Characterist1 to IEC Def. Time.
   For the time delay characteristic, definite time is used in this network.
3. Set Pickup1 to 200% of IBase (2000 A primary current).
4. Set t1 to 0.4 s.
In case of a three-phase short circuit in zone 1 reach in the shortest line from the busbar as shown in figure 16, the current to the protection is \( I = 1.8 \text{ kA} \).

**Figure 15:  Fault for step 2 setting**

**Figure 16:  Fault for step 2 setting**
Recommended current setting is therefore 2000 A.

1. Set DirModeSel2 to Reverse.
2. Set Characterist1 is set to IEC Def. Time.
   For the time delay characteristic, definite time is used in this network.
3. Set Pickup2 to 200% of iBase (2000 A primary current).
4. Set t2 to 0.4 s.

3.1.5.4 Calculating settings for step 3

The phase overcurrent protection shall never trip for load current in extreme high load situations. The maximum load current through the coupler bay is 750 A (the same as the CT-rated current), corresponding to about 190 MVA. The resetting ratio is 0.95. The minimum setting can be calculated:

\[
\text{Pickup}_3 \geq \frac{1}{0.95} \times 750 = 790 \, \text{A}
\]

1. Set DirModeSel3 to Non-directional.
2. Set Characterist1 is set to IEC Def. Time.
   For the time delay characteristic, definite time is used in this network.
3. Set Pickup3 to 80% of iBase (800 A primary current).
4. Set t3 to 1.2 s.
   The time delay is set longer than zone 3 (0.8 s) of the distance protection in the system.

3.1.6 Calculating settings for instantaneous residual overcurrent protection EFPIOC (50N)

The instantaneous residual overcurrent protection shall give very fast fault clearance of line short circuits close to the substation.

1. Set GlobalBaseSel to 1
   The settings are made in primary values. These values are given in the base settings in Global base 1.
2. Set IN>> to 250% of iBase.
   The protection shall not overreach the line and it shall not trip for short circuits in the reverse direction.
   A three-phase short circuit at the remote line end and low source impedance results in the following fault current to the protection:

\[
3I_{o,\text{prot}} = 3I_{o,\text{fault}} \times \frac{Z_{sc0,\text{Rem}}}{Z_{sc0,\text{Rem}} + Z_{0,\text{Line}} + Z_{sc0,\text{Home}}} = \frac{3 \cdot V_{ph}}{2 \cdot Z_{1} + Z_{0}} \times \frac{Z_{sc0,\text{Rem}}}{Z_{sc0,\text{Rem}} + Z_{0,\text{Line}} + Z_{sc0,\text{Home}}}
\]

\(Z_{sc0,\text{Rem}}\) is the zero sequence source impedance at the remote line end, \(Z_{0,\text{Line}}\) is the line zero sequence impedance and \(Z_{sc0,\text{Home}}\) is the zero sequence source impedance at the local line end.
A single-phase in the remote busbar (forward fault) results in the following fault current to
the protection:

\[ I_{sc} = 2.1 \angle -87^\circ \text{ kA} \]

A single-pole in the local busbar (reverse fault) results in the following fault current to the
protection:

\[ I_{sc} = 2.1 \angle -87^\circ \text{ kA} \]

\( Z_{sc} \) is the positive sequence source impedance of the remote substation and \( Z_{line} \) is the
positive sequence impedance of the line.

3. Set \( I_{III} \) to 2.5 kA.
4. Set to 250 \% of \( I_{Base} \) (2500 A primary).

### 3.1.7 Calculating settings for four step residual overcurrent protection

310> EF4PTOC (51N_67N)

The purpose of the delayed phase overcurrent protection is:

- Backup protection for ground faults on the whole line length
- Backup protection for ground faults in the remote busbar
- Backup protection for ground faults in other lines from the remote substation or own
  substation, when possible

The reach of residual overcurrent line protection is dependent on the operation state and the fault
type. Therefore, the setting must be based on fault calculations made for different faults, fault
points and switching states in the network. Although it is possible to make hand calculations of
the different faults, it is recommended to use computer based fault calculations. Due to different
practices, different time delay principles can be used.

The following principle for the phase residual overcurrent protection is proposed:

- One delayed step used as line backup protection. It should be set to assure selectivity to line
  protection. Directional function forward is used.
- One delayed step used as backup protection of the own busbar. It should be set to assure
  selectivity to line protection. Directional function reverse is used.
- A long time delayed step covering further parts of the system and detecting high resistive
  faults. This step should have a time delay longer than 1.2 s. Non-directional function is used.

### 3.1.7.1 Calculating general settings

1. Set \( GlobalBaseSel \) to 1.

   The settings are made in primary values. These values are given in the base settings in Global
   base 1.
3.1.7.2 Calculating settings for step 1

The protection shall be able to detect all ground faults within the defined protected zone. In this case, it is required, that the protection shall detect single-phase ground at the most remote point of the protected line. A single-phase ground, as shown in figure 17, at the remote line end and high source impedance results in the following fault current to the protection:

\[ I_0 = 1.6 \angle -87^\circ \text{kA} \]

![Diagram](image)

**Figure 17: Fault for step 1 setting**

In case of a single phase ground-fault in zone 1 reach in the shortest line from the remote busbar, as shown in figure 18, the current to the protection is \( I = 1.1 \text{kA} \).
3.1.7.3 Calculating settings for step 2

The protection shall be able to detect all short circuits in the own busbar. A single phase-to-ground fault, as shown in figure 19, at the busbar and high source impedance from the remote line end results in the following fault current to the protection:

\[ 3I_0 = 1.3 \angle -87^\circ \, kA \]
In case of a single-phase ground-fault in zone 1 reach in the shortest line from the remote busbar, as shown in figure 20, the current to the protection is $I = 1.0 \text{ kA}$.

**Figure 19: Fault for step 2 setting**

**Figure 20: Fault for step 2 setting**
Proposed current setting is therefore 1200 A.

1. Set DirModeSel2 to Reverse.
2. Set Characterist2 to IEC Def. Time.
   For the time delay characteristic, definite time is used in this network.
3. Set Pickup2 to 120% of IBase (1200 A primary current).
4. Set t2 to 0.4 s.

3.1.7.4 Calculating settings for step 3

The current setting should be chosen in line with normal setting principles in the system. To detect high resistive faults, a current setting of about 100 A will detect ground-faults with a fault resistance up to about 800 Ω. Proposed current setting is therefore 100 A.

1. Set DirModeSel3 to Non-directional.
2. Set Characterist3 is set to IEC Def. Time.
   For the time delay characteristic, definite time is used in this network.
3. Set Pickup3 to 10% of IBase (100 A primary current).
4. Set t3 to 1.5 s.

3.1.8 Calculating settings for breaker failure protection CCRBRF (50BF)

Breaker failure protection can use either contact function in the circuit breaker or current measurement to detect correct breaker function. Current measurement breaker check seems to be the most suitable function for line protection.

1. Set GlobalBaseSel to 1
   The settings are made in primary values. These values are given in the base settings in Global base 1.
2. Set FunctionMode to Current
3. Set BuTripMode to 1 out of 4
   In the current measurement, three-phase current on the line is used. It is also possible to measure the residual current (analogue input 4). The logic to detect circuit breaker failure can be chosen:
   1 out of 3: at least one of the three-phase currents shall be higher than the set level to detect failure to break
   1 out of 4: at least one of the three-phase currents and the residual current shall be higher than the set level to detect failure to break
   2 out of 4: at least two of the three-phase currents and the residual current shall be higher than the set level to detect failure to break
   As the residual current protection is one of the protection functions to initiate the breaker failure protection, the setting 1 out of 4 is chosen.
4. Set Pickup_PH to 50 % of the base current.
   Pickup_PH should be set lower than the lowest current to be detected by the phase overcurrent protection which is about 800 A.
5. Set Pickup_N to 10 % of the base current.
**Pickup\_N** should be set lower than the lowest current to be detected by the busbar protection which is about 100 A.

6. Set the re-tip time delay $t_1$ to 0

The delay time of the breaker failure protection (BuTrip) is chosen according to figure 21.

- The maximum open time of the circuit breaker is considered to be 100 ms.
- The CCRBRF (50BF) reset time is max 15 ms.
- The margin should be chosen to about 2 cycles.

This results in about 155 ms minimum setting of backup trip delay $t_2$.

![Diagram](ANSI10000170_1_en.vsd)

**Figure 21:** Time sequences for breaker failure protection setting

7. Set $t_2$ to 0.17 s

### 3.1.9 Calculating settings for pole discordance protection CCRPLD (52PD)

Pole discordance protection (CCRPLD ,52PD) detects situations where the bus coupler breaker has different switching states in the phases (one open and two closed or two open and one closed). Pole discrepancy can be detected either from auxiliary breaker contract status or by current measurement.

1. Set *GlobalBaseSel* to 1
   The settings are made in primary values. These values are given in the base settings in Global base 1.
2. Set *Operation* to *Enabled*
3. Set *tTrip* to 3 s.
   When asymmetry is detected, a trip signal is activated. The delay must be so long that asymmetrical faults will not cause an unwanted trip.
4. Set ContactSel to Enabled if the primary auxiliary contact circuits are connected.
5. Set CurrentSel to Continuous monitor.
   The detection by means of current measurement can be constantly activated or activated in
   connection of breaker actions only.
6. Set CurrRelPU to 10 % of IBase.
   The current detected shall be active if all phase currents are higher than the setting.
7. Set CurrUnsymPU to 80%.
   Pole discrepancy is detected if the magnitude of the lowest phase current is lower than the
   fraction CurrUnsymPU(%) of the highest phase current.
Section 4  Analog inputs

4.1  Introduction

Analog input channels are already configured inside the IED. However the IED has to be set properly to get correct measurement results and correct protection operations. For power measuring and all directional and differential functions the directions of the input currents must be defined properly. Measuring and protection algorithms in the IED use primary system quantities. Set values are done in primary quantities as well and it is important to set the data about the connected current and voltage transformers properly.

The availability of CT and VT inputs, as well as setting parameters depends on the ordered IED.

A reference PhaseAngleRef must be defined to facilitate service values reading. This analog channels phase angle will always be fixed to zero degree and all other angle information will be shown in relation to this analog input. During testing and commissioning of the IED the reference channel can be changed to facilitate testing and service values reading.

4.2  Setting guidelines

4.2.1  Setting of the phase reference channel

All phase angles are calculated in relation to a defined reference. An appropriate analog input channel is selected and used as phase reference. The parameter PhaseAngleRef defines the analog channel that is used as phase angle reference.

4.2.1.1  Example

The setting shall be used if a phase-to-ground voltage (usually the A phase-to-ground voltage connected to VT channel number of the analog card) is selected to be the phase reference.

4.2.1.2  Setting of current channels

The direction of a current to the IED is depending on the connection of the CT. Unless indicated otherwise, the main CTs are supposed to be Wye (star) connected and can be connected with the grounding point to the object or from the object. This information must be set in the IED. The convention of the directionality is defined as follows: A positive value of current, power, and so on means that the quantity has the direction into the object and a negative value means direction out from the object. For directional functions the direction into the object is defined as Forward and the direction out from the object is defined as Reverse. See figure 22.
Definition of direction for directional functions

Reverse  Forward

- e.g. P, Q, I
- Measured quantity is positive when flowing towards the object

Set parameter CT_WyePoint
Correct Setting is "ToObject"

Set parameter CT_WyePoint
Correct Setting is "FromObject"

Figure 22: Internal convention of the directionality in the IED

With correct setting of the primary CT direction, CT_WyePoint set to FromObject or ToObject, a positive quantities always flowing towards the object and a direction defined as Forward always is looking towards the object. The following examples show the principle.

4.2.1.3 Example 1

Two IEDs used for protection of two objects.

Figure 23: Example how to set CT_WyePoint parameters in the IED
The figure 23 shows the most normal case where the objects have their own CTs. The settings for CT direction shall be done according to the figure. To protect the line the direction of the directional functions of the line protection shall be set to *Forward*. This means that the protection is looking towards the line.

### 4.2.1.4 Example 2

Two IEDs used for protection of two objects and sharing a CT.
Figure 24: Example how to set CT_WyePoint parameters in the IED
This example is similar to example 1 but the transformer is feeding just one line and the line protection uses the same CT as the transformer protection does. The CT direction is set with different reference objects for the two IEDs though it is the same current from the same CT that is feeding two IEDs. With these settings the directional functions of the line protection shall be set to *Forward* to look towards the line.

### 4.2.1.5 Examples how to connect, configure and set CT inputs for most commonly used CT connections

Figure 25 defines the marking of current transformers terminals commonly used around the world:

![Diagram of CT terminals](en06000641.vsd)

**Figure 25:** Commonly used markings of CT terminals

Where:

- **a)** is symbol and terminal marking used in this document. Terminals marked with a dot indicates the primary and secondary winding terminals with the same (that is, positive) polarity.
- **b)** and **c)** are equivalent symbols and terminal marking used by IEC (ANSI) standard for CTs. Note that for this two cases the CT polarity marking is correct!

It shall be noted that depending on national standard and utility practices rated secondary current of a CT has typically one of the following values:

- 1A
- 5A

However in some cases the following rated secondary currents are as well used:

- 2A
- 10A

The IED fully supports all of these rated secondary values.
4.2.1.6 Example how to connect wye connected three-phase CT set to the IED

Figure 26 gives an example how to connect the wye connected three-phase CT set to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED.

For correct connections, see the connection diagrams valid for the delivered IED.

Figure 26: Wye connected three-phase CT set with wye point towards the protected object
Where:

1) shows how to connect three individual phase currents from wye connected three-phase CT set to three CT inputs in the IED.

2) is TRM or AIM where these current inputs are located. It shall be noted that for all these current inputs the following setting values shall be entered.
   - $\text{CT}_{\text{prim}}=600\text{A}$
   - $\text{CT}_{\text{sec}}=5\text{A}$
   - $\text{CTStarPoint}=$ToObject

Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will have no influence on the measured currents (that is, currents are already measured towards the protected object).

3) are three connections, which connects these three current inputs to three input channels of the preprocessing function block 6). Depending on the type of functions, which need this current information, more than one preprocessing block might be connected in parallel to these three CT inputs.

4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:
   - fundamental frequency phasors for all four input channels
   - harmonic content for all four input channels
   - positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values.

If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters DFTReference shall be set accordingly.

Another alternative is to have the star point of the three-phase CT set as shown in figure 27:
Please note that in this case everything is done in a similar way as in the above described example, except that for all used current inputs on the TRM the following setting parameters shall be entered:

- CT<sub>prim</sub>=800A
- CT<sub>sec</sub>=1A
- CT<sub>WyePoint</sub>=FromObject

Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will reverse the measured currents (that is, turn the currents by 180°) in order to ensure that the currents within the IED are measured towards the protected object.

### 4.2.1.7 Example how to connect single-phase CT to the IED

Figure 28 gives an example how to connect the single-phase CT to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED.

For correct connections, see the connection diagrams valid for the delivered IED.
Figure 28: Connections for single-phase CT input
Where:

1) shows how to connect single-phase CT input in the IED.
2) is TRM or AIM where these current inputs are located. It shall be noted that for all these current inputs the following setting values shall be entered.
   - For connection a) shown in figure 28:
     - CTprim=1000A
     - CTsec=1A
     - CTWyePoint=ToObject

   Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will have no influence on the measured currents (that is, currents are already measured towards the protected object).

   - For connection b) shown in figure 28:
     - CTprim=1000A
     - CTsec=1A
     - CTWyePoint=FromObject

   Inside the IED only the ratio of the first two parameters is used. The third parameter as set in this example will invert the measured currents (that is, turn the currents by 180°) in order to ensure that the currents within the IED are measured towards the protected object.

3) shows the connection, which connect this CT input to the input channel of the preprocessing function block 5).
4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:
   - fundamental frequency phasors for all four input channels
   - harmonic content for all four input channels
   - positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

   These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values.

   If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters DFTReference shall be set accordingly.

4.2.1.8 Setting of voltage channels

As the IED uses primary system quantities the main VT ratios must be known. This is done by setting the two parameters VTsec and VTprim for each voltage channel. The phase-to-phase value can be used even if each channel is connected to a phase-to-ground voltage from the VT.

4.2.1.9 Example

Consider a VT with the following data:

\[
\frac{132kV}{\sqrt{3}} \quad \frac{120V}{\sqrt{3}}
\]

(Equation 1)
The following setting should be used: \(VT_{prim}=132\) (value in kV) \(VT_{sec}=120\) (value in V)

### 4.2.1.10 Examples how to connect, configure and set VT inputs for most commonly used VT connections

Figure 29 defines the marking of voltage transformers terminals commonly used around the world.

![Diagram of voltage transformer terminals](ANSI11000175_1_en.vsd)

**Figure 29: Commonly used markings of VT terminals**

Where:

- **a)** is symbol and terminal marking used in this document. Terminals marked with a dot indicates the primary and secondary winding terminals with the same (that is, positive) polarity
- **b)** is equivalent symbol and terminal marking used by IEC (ANSI) standard for phase-to-ground connected VT
- **c)** is equivalent symbol and terminal marking used by IEC (ANSI) standard for open delta connected VT
- **d)** is equivalent symbol and terminal marking used by IEC (ANSI) standard for phase-to-phase connected VT

It shall be noted that depending on national standard and utility practices rated secondary voltage of a VT has typically one of the following values:

- 100 V
- 110 V
- 115 V
- 120 V

The IED fully supports all of these values and most of them will be shown in the following examples.

### 4.2.1.11 Examples how to connect three phase-to-ground connected VTs to the IED

Figure 30 gives an example how to connect the three phase-to-ground connected VTs to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED.

For correct connections, see the connection diagrams valid for the delivered IED.
Figure 30: Three phase-to-ground connected VTs
Where:

1) is TRM or AIM where these three voltage inputs are located. It shall be noted that for these three voltage inputs the following setting values shall be entered:
   \[ VT_{prim} = 66 \text{ kV} \]
   \[ VT_{sec} = 110 \text{ V} \]
   Inside the IED, only the ratio of these two parameters is used. It shall be noted that the ratio of the entered values exactly corresponds to ratio of one individual VT.

\[
\frac{66}{110} = \frac{66}{\sqrt{3}} = \frac{110}{\sqrt{3}}
\]

(Equation 2)

2) are three connections, which connect these three voltage inputs to three input channels of the preprocessing function block 5). Depending on type of functions which need this voltage information, more than one preprocessing block might be connected in parallel to these three VT inputs

3) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:
   - fundamental frequency phasors for all four input channels
   - harmonic content for all four input channels
   - positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values. However the following settings shall be set as shown here:

\[ V_{Base} = 66 \text{ kV} \] (that is, rated Ph-Ph voltage)

If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters \( DFTReference \) shall be set accordingly.

4.2.1.12 Example how to connect two phase-to-phase connected VTs to the IED

Figure 31 gives an example how to connect the two phase-to-phase connected VTs to the IED. It as well gives overview of required actions by the user in order to make this measurement available to the built-in protection and control functions within the IED. It shall be noted that this VT connection is only used on lower voltage levels (that is, rated primary voltage below 40 kV).

For correct connections, see the connection diagrams valid for the delivered IED.
Figure 31: Phase-to-phase connected VTs

Where:

1) shows how to connect secondary side of two phase-to-phase VTs to three VT inputs in the IED
2) is the TRM or AIM where these three voltage inputs are located. It shall be noted that for these three voltage inputs the following setting values shall be entered:
   - \( VT_{prim} = 13.8 \text{ kV} \)
   - \( VT_{sec} = 120 \text{ V} \)
   Please note that inside the IED only ratio of these two parameters is used.
3) are three connections, which connects these three voltage inputs to three input channels of the preprocessing function block 5). Depending on the type of functions, which need this voltage information, more than one preprocessing block might be connected in parallel to these three VT inputs
4) Preprocessing block has a task to digitally filter the connected analog inputs and calculate:
   - fundamental frequency phasors for all four input channels
   - harmonic content for all four input channels
   - positive, negative and zero sequence quantities by using the fundamental frequency phasors for the first three input channels (channel one taken as reference for sequence quantities)

These calculated values are then available for all built-in protection and control functions within the IED, which are connected to this preprocessing function block. For this application most of the preprocessing settings can be left to the default values. However the following settings shall be set as shown here:
   - \( ConnectionType=Ph-Ph \)
   - \( VBase=13.8 \text{ kV} \)
   If frequency tracking and compensation is required (this feature is typically required only for IEDs installed in the generating stations) then the setting parameters \( DFT\text{Reference} \) shall be set accordingly.
Section 5  Local human-machine interface

5.1  Local HMI

The LHMI of the IED contains the following elements:

- Display (LCD)
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

5.1.1  Display

The LHMI includes a graphical monochrome display with a resolution of 320 x 240 pixels. The character size can vary.
The display view is divided into four basic areas.

1. Path
2. Content
3. Status
4. Scroll bar (appears when needed)

The function button panel shows on request what actions are possible with the function buttons. Each function button has a LED indication that can be used as a feedback signal for the function button control action. The LED is connected to the required signal with PCM600.
The alarm LED panel shows on request the alarm text labels for the alarm LEDs.

<table>
<thead>
<tr>
<th>Main menu</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Events</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disturbance records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Settings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Languages</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 35: Alarm LED panel

The function button and alarm LED panels are not visible at the same time. Each panel is shown by pressing one of the function buttons or the Multipage button. Pressing the ESC button clears the panel from the display. Both the panels have dynamic width that depends on the label string length that the panel contains.

5.1.2 LEDs

The LHMI includes three protection indicators above the display: Normal, Pickup and Trip.

There are also 15 matrix programmable alarm LEDs on front of the LHMI. Each LED can indicate three states with the colors: green, yellow and red. The alarm texts related to each three-color LED are divided into three pages. The 15 physical three-color LEDs in one LED group can indicate 45 different signals. Altogether, 135 signals can be indicated since there are three LED groups. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI or PCM600.

There are two additional LEDs which are embedded into the control buttons 🔄 and 🔄. They represent the status of the circuit breaker.

5.1.3 Keypad

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

The keypad also contains programmable push-buttons that can be configured either as menu shortcut or control buttons.
5.1.4 Local HMI functionality

5.1.4.1 Protection and alarm indication

Protection indicators

The protection indicator LEDs are Normal, Pickup and Trip.

Table 11: Normal LED (green)

<table>
<thead>
<tr>
<th>LED state</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Auxiliary supply voltage is disconnected.</td>
</tr>
<tr>
<td>On</td>
<td>Normal operation.</td>
</tr>
<tr>
<td>Flashing</td>
<td>Internal fault has occurred.</td>
</tr>
</tbody>
</table>
### Table 12: PickUp LED (yellow)

<table>
<thead>
<tr>
<th>LED state</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Normal operation.</td>
</tr>
</tbody>
</table>
| On        | A protection function has picked up and an indication message is displayed.  
  • If several protection functions Pick up within a short time, the last Pick up is indicated on the display. |
| Flashing  | A flashing yellow LED has a higher priority than a steady yellow LED.  
  The IED is in test mode and protection functions are blocked.  
  • The indication disappears when the IED is no longer in test mode and blocking is removed. |

### Table 13: Trip LED (red)

<table>
<thead>
<tr>
<th>LED state</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Normal operation.</td>
</tr>
</tbody>
</table>
| On        | A protection function has tripped and an indication message is displayed.  
  • The trip indication is latching and must be reset via communication or by pressing CLEAR. |

### Alarm indicators

The 15 programmable three-color LEDs are used for alarm indication. An individual alarm/status signal, connected to any of the LED function blocks, can be assigned to one of the three LED colors when configuring the IED.

### Table 14: Alarm indications

<table>
<thead>
<tr>
<th>LED state</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Normal operation. All activation signals are off.</td>
</tr>
<tr>
<td>On</td>
<td></td>
</tr>
</tbody>
</table>
  • Follow-S sequence: The activation signal is on.  
  • LatchedColl-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged.  
  • LatchedAck-F-S sequence: The indication has been acknowledged, but the activation signal is still on.  
  • LatchedAck-S-F sequence: The activation signal is on, or it is off but the indication has not been acknowledged.  
  • LatchedReset-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged.  
  • Follow-F sequence: The activation signal is on.  
  • LatchedAck-F-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged.  
  • LatchedAck-S-F sequence: The indication has been acknowledged, but the activation signal is still on. |
| Flashing  |  
  • Follow-F sequence: The activation signal is on.  
  • LatchedAck-F-S sequence: The activation signal is on, or it is off but the indication has not been acknowledged.  
  • LatchedAck-S-F sequence: The indication has been acknowledged, but the activation signal is still on. |
## Alarm indications for REQ650

### Table 15: Alarm group 1 indications in REQ650 (B11A) configuration

<table>
<thead>
<tr>
<th>Alarm group 1 LEDs</th>
<th>LED color</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRP1_LED1</td>
<td>Red LED</td>
<td>GENERAL TRIP A</td>
</tr>
<tr>
<td>GRP1_LED2</td>
<td>Red LED</td>
<td>GENERAL TRIP B</td>
</tr>
<tr>
<td>GRP1_LED3</td>
<td>Red LED</td>
<td>GENERAL TRIP C</td>
</tr>
<tr>
<td>GRP1_LED4</td>
<td>Red LED</td>
<td>50BF TRIP</td>
</tr>
<tr>
<td>GRP1_LED5</td>
<td>Red LED</td>
<td>50/51 TRIP</td>
</tr>
<tr>
<td>GRP1_LED6</td>
<td>Red LED</td>
<td>51N/67N TRIP</td>
</tr>
<tr>
<td>GRP1_LED7</td>
<td>Red LED</td>
<td>59 TRIP</td>
</tr>
<tr>
<td>GRP1_LED8</td>
<td>Red LED</td>
<td>52PD TRIP</td>
</tr>
<tr>
<td>GRP1_LED9</td>
<td>Red LED</td>
<td>46 TRIP</td>
</tr>
<tr>
<td>GRP1_LED10</td>
<td>Red LED</td>
<td>EXTERNAL TRIP</td>
</tr>
<tr>
<td>GRP1_LED11</td>
<td>Red LED</td>
<td>TRIP LOCKOUT</td>
</tr>
<tr>
<td>GRP1_LED12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP1_LED13</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP1_LED14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP1_LED15</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 16: Alarm group 2 indications in REQ650 (B11A) configuration

<table>
<thead>
<tr>
<th>Alarm group 2 LEDs</th>
<th>LED color</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRP2_LED1</td>
<td>Red LED</td>
<td>GENERAL PICKUP A</td>
</tr>
<tr>
<td>GRP2_LED2</td>
<td>Yellow LED</td>
<td>GENERAL PICKUP B</td>
</tr>
<tr>
<td>GRP2_LED3</td>
<td>Yellow LED</td>
<td>GENERAL PICKUP C</td>
</tr>
<tr>
<td>GRP2_LED4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP2_LED5</td>
<td>Yellow LED</td>
<td>51 PICKUP</td>
</tr>
<tr>
<td>GRP2_LED6</td>
<td>Yellow LED</td>
<td>51N/67N PICKUP</td>
</tr>
<tr>
<td>GRP2_LED7</td>
<td>Yellow LED</td>
<td>59 PICKUP</td>
</tr>
<tr>
<td>GRP2_LED8</td>
<td>Yellow LED</td>
<td>52PD PICKUP</td>
</tr>
<tr>
<td>GRP2_LED9</td>
<td>Yellow LED</td>
<td>46 PICKUP</td>
</tr>
<tr>
<td>GRP2_LED10</td>
<td>Yellow LED</td>
<td>26 PICKUP</td>
</tr>
<tr>
<td>GRP2_LED11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP2_LED12</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP2_LED13</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP2_LED14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP2_LED15</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 17: Alarm group 3 indications in REQ650 (B11A) configuration

<table>
<thead>
<tr>
<th>Alarm group 2 LEDs</th>
<th>LED color</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRP3_LED1 – GRP3_LED9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GRP3_LED10</td>
<td>Yellow LED</td>
<td>26 THOL ALARM</td>
</tr>
<tr>
<td>GRP3_LED12</td>
<td>Yellow LED</td>
<td>25 INPROG</td>
</tr>
<tr>
<td>GRP3_LED13</td>
<td>Yellow LED</td>
<td>CB SUPV ALARM</td>
</tr>
<tr>
<td>GRP3_LED14</td>
<td>Yellow LED</td>
<td>TRIP CCT ALARM</td>
</tr>
<tr>
<td>GRP3_LED15</td>
<td>Red LED</td>
<td>STAT BATT ALARM</td>
</tr>
<tr>
<td></td>
<td>Yellow LED</td>
<td>STAT BATT START</td>
</tr>
</tbody>
</table>

5.1.4.2 Parameter management

The LHMI is used to access the IED parameters. Three types of parameters can be read and written.

- Numerical values
- String values
- Enumerated values

Numerical values are presented either in integer or in decimal format with minimum and maximum values. Character strings can be edited character by character. Enumerated values have a predefined set of selectable values.

5.1.4.3 Front communication

The RJ-45 port in the LHMI enables front communication.

- The green uplink LED on the left is lit when the cable is successfully connected to the port.
When a computer is connected to the IED front port with a crossed-over cable, the IED’s DHCP server for the front interface assigns an IP address to the computer if `DHCPServer` = *Enabled*. The default IP address for the front port is 10.1.150.3.

Do not connect the IED front port to LAN. Connect only a single local PC with PCM600 to front port.

### 5.1.4.4 Single-line diagram

**Single-line diagram for REQ650**

<table>
<thead>
<tr>
<th>BKRI Voltage</th>
<th>0.0 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BKRI Current</td>
<td>0.0 A</td>
</tr>
<tr>
<td>Active Power</td>
<td>0.0 MW</td>
</tr>
<tr>
<td>Reactive Power</td>
<td>0.0 MVAR</td>
</tr>
<tr>
<td>Power Factor</td>
<td>0.00</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00 Hz</td>
</tr>
</tbody>
</table>

*Figure 38: Single-line diagram for REQ650 (A11A)*
Section 6  Current protection

6.1  Instantaneous phase overcurrent protection PHPIOC (50)

6.1.1  Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous phase overcurrent</td>
<td>PHPIOC</td>
<td>3I&gt;&gt;</td>
<td>50</td>
</tr>
</tbody>
</table>

6.1.2  Application

Long transmission lines often transfer great quantities of electric power from production to consumption areas. The unbalance of the produced and consumed electric power at each end of the transmission line is very large. This means that a fault on the line can easily endanger the stability of a complete system.

The transient stability of a power system depends mostly on three parameters (at constant amount of transmitted electric power):

- The type of the fault. Three-phase faults are the most dangerous, because no power can be transmitted through the fault point during fault conditions.
- The magnitude of the fault current. A high fault current indicates that the decrease of transmitted power is high.
- The total fault clearing time. The phase angles between the EMFs of the generators on both sides of the transmission line increase over the permitted stability limits if the total fault clearing time, which consists of the protection operating time and the breaker opening time, is too long.

The fault current on long transmission lines depends mostly on the fault position and decreases with the distance from the generation point. For this reason the protection must operate very quickly for faults very close to the generation (and relay) point, for which very high fault currents are characteristic.

The instantaneous phase overcurrent protection PHPIOC (50) can operate in 10 ms for faults characterized by very high currents.

6.1.3  Setting guidelines

The parameters for instantaneous phase overcurrent protection PHPIOC (50) are set via the local HMI or PCM600.
This protection function must operate only in a selective way. So check all system and transient conditions that could cause its unwanted operation.

Only detailed network studies can determine the operating conditions under which the highest possible fault current is expected on the line. In most cases, this current appears during three-phase fault conditions. But also examine single-phase-to-ground and two-phase-to-ground conditions.

Also study transients that could cause a high increase of the line current for short times. A typical example is a transmission line with a power transformer at the remote end, which can cause high inrush current when connected to the network and can thus also cause the operation of the built-in, instantaneous, overcurrent protection.

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

**Pickup:** Set operate current in % of IBase.

### 6.1.3.1 Meshed network without parallel line

The following fault calculations have to be done for three-phase, single-phase-to-ground and two-phase-to-ground faults. With reference to figure 39, apply a fault in B and then calculate the current through-fault phase current $I_{fB}$. The calculation should be done using the minimum source impedance values for $Z_A$ and the maximum source impedance values for $Z_B$ in order to get the maximum through fault current from A to B.

![Figure 39: Through fault current from A to B: $I_{fB}$](image)

Then a fault in A has to be applied and the through fault current $I_{fA}$ has to be calculated, figure 40. In order to get the maximum through fault current, the minimum value for $Z_B$ and the maximum value for $Z_A$ have to be considered.
Figure 40: Through fault current from B to A: $I_{fA}$

The IED must not trip for any of the two through-fault currents. Hence the minimum theoretical current setting ($I_{min}$) will be:

$$I_{min} \geq \text{MAX}(I_{fA}, I_{fB})$$

(Equation 3)

A safety margin of 5% for the maximum protection static inaccuracy and a safety margin of 5% for the maximum possible transient overreach have to be introduced. An additional 20% is suggested due to the inaccuracy of the instrument transformers under transient conditions and inaccuracy in the system data.

The minimum primary setting ($I_s$) for the instantaneous phase overcurrent protection is then:

$$I_s \geq 1,3 \cdot I_{min}$$

(Equation 4)

The protection function can be used for the specific application only if this setting value is equal to or less than the maximum fault current that the IED has to clear, $I_F$ in figure 41.

Figure 41: Fault current: $I_F$

The IED setting value *Pickup* is given in percentage of the primary base current value, $I_{Base}$. The value for *Pickup* is given from this formula:
\[ Pickup = \frac{I_s}{I_{Base}} \cdot 100 \]

(Equation 5)

### 6.1.3.2 Meshed network with parallel line

In case of parallel lines, the influence of the induced current from the parallel line to the protected line has to be considered. One example is given in figure 42 where the two lines are connected to the same busbars. In this case the influence of the induced fault current from the faulty line (line 1) to the healthy line (line 2) is considered together with the two through fault currents \( I_{fA} \) and \( I_{fB} \) mentioned previously. The maximal influence from the parallel line for the IED in figure 42 will be with a fault at the C point with the C breaker open.

A fault in C has to be applied, and then the maximum current seen from the IED (\( I_M \)) on the healthy line (this applies for single-phase-to-ground and two-phase-to-ground faults) is calculated.

\[ Z_A \]
\[ Z_B \]
\[ Z_{L1} \]
\[ Z_{L2} \]

**Figure 42:** Two parallel lines. Influence from parallel line to the through fault current: \( I_M \)

The minimum theoretical current setting for the overcurrent protection function (\( I_{min} \)) will be:

\[ I_{min} \geq \text{MAX}(I_{fA}, I_{fB}, I_M) \]

(Equation 6)

Where \( I_{fA} \) and \( I_{fB} \) have been described in the previous paragraph. Considering the safety margins mentioned previously, the minimum setting (\( I_s \)) for the instantaneous phase overcurrent protection is then:

\[ I_s \geq 1.3 \cdot I_{min} \]

(Equation 7)

The protection function can be used for the specific application only if this setting value is equal or less than the maximum phase fault current that the IED has to clear.
The IED setting value *Pickup* is given in percentage of the primary base current value, *IBase*. The value for *Pickup* is given from this formula:

\[
\text{Pickup} = \frac{I_s}{I_{Base}} \times 100
\]

(Equation 8)

### 6.2 Instantaneous phase overcurrent protection SPTPIOC (50)

#### 6.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous phase overcurrent protection</td>
<td>SPTPIOC</td>
<td>3I&gt;&gt;</td>
<td>50</td>
</tr>
</tbody>
</table>

#### 6.2.2 Application

Long transmission lines often transfer great quantities of electric power from production to consumption areas. The unbalance of the produced and consumed electric power at each end of the transmission line is very large. This means that a fault on the line can easily endanger the stability of a complete system. The transient stability of a power system depends mostly on three parameters (at constant amount of transmitted electric power):

- The type of the fault. Three-phase faults are the most dangerous, because no power can be transmitted through the fault point during fault conditions.
- The magnitude of the fault current. A high fault current indicates that the decrease of transmitted power is high.
- The total fault clearing time. The phase angles between the Electro motive forces (EMFs) of the generators on both sides of the transmission line increase over the permitted stability limits if the total fault clearing time, which consists of the protection operating time and the breaker opening time, is too long.

The fault current on long transmission lines depends mostly on the fault position and decreases with the distance from the generation point. For this reason the protection must operate very quickly for faults very close to the generation (and relay) point, for which very high fault currents are characteristic.

The instantaneous phase overcurrent protection SPTPIOC (50) can operate in 10 ms for faults characterized by very high currents.
6.2.3 Setting guidelines

The parameters for Instantaneous phase overcurrent protection SPTPIOC (50) are set via the local HMI or Protection and Control Manager (PCM600). This protection function must operate only in a selective way. So check all system and transient conditions that could cause its unwanted operation.

Detailed network studies can determine the operating conditions under which the highest possible fault current is expected on the line. In most cases, this current appears during three-phase fault conditions. But also examine single-phase-to-ground and two-phase-to-ground conditions.

Also, study transients that could cause a high increase of the line current for short times. A typical example is a transmission line with a power transformer at the remote end, which can cause high inrush current when connected to the network and can thus also cause the operation of the built-in, instantaneous, overcurrent protection.

Common base IED values for primary current (IBase), primary voltage (setting VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

**Pickup:** Set operate current in % of IBase.

6.2.3.1 Meshed network without parallel line

The following fault calculations have to be done for three-phase, single-phase-to-ground and two-phase-to-ground faults. With reference to figure 43, apply a fault in B and then calculate the current through fault phase current $I_{fB}$. The calculation should be done using the minimum source impedance values for $Z_A$ and the maximum source impedance values for $Z_B$ in order to get the maximum through fault current from A to B.

\[ I_{fB} = \frac{V}{Z_A + Z_L + Z_B} \]

*Figure 43: Through fault current from A to B: $I_{fB}$*

Then a fault in A has to be applied and the through fault current $I_{fA}$ has to be calculated, figure 44. In order to get the maximum through fault current, the minimum value for $Z_B$ and the maximum value for $Z_A$ have to be considered.
Figure 44: Through fault current from B to A: $I_{fA}$

The IED must not trip for any of the two through fault currents. Hence the minimum theoretical current setting ($I_{imin}$) will be:

$$I_{imin} \geq \text{MAX}(I_{fA}, I_{fB})$$

(Equation 9)

A safety margin of 5% for the maximum protection static inaccuracy and a safety margin of 5% for the maximum possible transient overreach have to be introduced. An additional 20% is suggested due to the inaccuracy of the instrument transformers under transient conditions and inaccuracy in the system data. The minimum primary setting ($I_s$) for SPTPIOC (50) is then:

$$I_s \geq 1.3 \cdot I_{imin}$$

(Equation 10)

The protection function can be used for the specific application only if this setting value is equal to or less than the maximum fault current that the IED has to clear, fault current ($I_F$) in figure 45.

Figure 45: Fault current: $I_F$

The IED setting value $Pickup$ is given in percentage of the primary base current value, $I_{Base}$. The value for $Pickup$ is given from this formula:
6.2.3.2 Meshed network with parallel line

In case of parallel lines, the influence of the induced current from the parallel line to the protected line has to be considered. One example is given in figure 46 where the two lines are connected to the same busbars. In this case the influence of the induced fault current from the faulty line (line 1) to the healthy line (line 2) is considered together with the two through fault currents \(I_{fA}\) and \(I_{fB}\) mentioned previously. The maximal influence from the parallel line for the IED in figure 46 will be with a fault at the C point with the C breaker open.

A fault in C has to be applied, and then the maximum current \((I_M)\) seen from the IED on the healthy line (this applies for single-phase-to-ground and two-phase-to-ground faults) is calculated.

\[
\text{Pickup} = \frac{I_s}{I_{Base}} \cdot 100
\]

(Equation 11)

\[
I_{min} \geq \text{MAX}(I_{fA}, I_{fB}, I_M)
\]

(Equation 12)

Where \(I_{fA}\) and \(I_{fB}\) have been described in the previous paragraph. Considering the safety margins mentioned previously, the minimum setting \(I_s\) as given in equation below:

\[
I_s \geq 1.3 \cdot I_{min}
\]

(Equation 13)

The protection function can be used for the specific application only if this setting value is equal or less than the maximum phase fault current that the IED has to clear. The IED setting value \(\text{Pickup}\) is given in percentage of the primary base current value, \(I_{Base}\). The value for \(\text{Pickup}\) is given from this formula:
\[ \text{Pickup} = \frac{I_s}{I_{\text{Base}}} \cdot 100 \]  

(Equation 14)

6.3 Four step phase overcurrent protection OC4PTOC (51/67)

6.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four step phase overcurrent protection</td>
<td>OC4PTOC</td>
<td></td>
<td>51/67</td>
</tr>
</tbody>
</table>

6.3.2 Application

The Four step phase overcurrent protection OC4PTOC (51/67) is used in several applications in the power system. Some applications are:

- Short circuit protection of feeders in distribution and subtransmission systems. Normally these feeders have radial structure.
- Back-up short circuit protection of transmission lines.
- Back-up short circuit protection of power transformers.
- Short circuit protection of different kinds of equipment connected to the power system such as; shunt capacitor banks, shunt reactors, motors and others.
- Back-up short circuit protection of power generators.

If VT inputs are not available or not connected, setting parameter \text{DirModeSelx} (x = step 1, 2, 3 or 4) shall be left to default value \text{Non-directional} or set to \text{Disabled}.

In many applications several steps with different current pick up levels and time delays are needed. OC4PTOC (51/67) can have up to four different, individual settable, steps. The flexibility of each step of OC4PTOC (51/67) is great. The following options are possible:

Non-directional / Directional function: In most applications the non-directional functionality is used. This is mostly the case when no fault current can be fed from the protected object itself. In order to achieve both selectivity and fast fault clearance, the directional function can be necessary.

Choice of delay time characteristics: There are several types of delay time characteristics available such as definite time delay and different types of inverse time delay characteristics. The selectivity between different overcurrent protections is normally enabled by co-ordination between the...
function time delays of the different protections. To enable optimal co-ordination between all
overcurrent protections, they should have the same time delay characteristic. Therefore a wide
range of standardized inverse time characteristics are available: IEC and ANSI.

The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time
characteristic. Step 2 and 3 are always definite time delayed and are used in system where IDMT is
not needed.

6.3.3 Setting guidelines

The parameters for Four step phase overcurrent protection OC4PTOC (51/67) are set via the local
HMI or PCM600.

The following settings can be done for OC4PTOC (51/67).

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power
(SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is
used to select a GBASVAL function for reference of base values.

MeasType: Selection of discrete Fourier filtered (DFT) or true RMS filtered (RMS) signals. RMS is
used when the harmonic contents are to be considered, for example in applications with shunt
capacitors.

Operation: The protection can be set to Disabled or Enabled
Figure 47: Directional function characteristic

1. RCA = Relay characteristic angle 55°
2. ROA = Relay operating angle 80°
3. Reverse
4. Forward

6.3.3.1 Settings for steps 1 to 4

\[ n \text{ means step 1 and 4. } x \text{ means step 1, 2, 3 and 4.} \]

\textit{DirModeSel}x: The directional mode of step \( x \). Possible settings are \textit{Disabled/ Non-directional/ Forward/ Reverse}. 

\textit{Characteristn}: Selection of time characteristic for step \( n \). Definite time delay and different types of inverse time characteristics are available according to table 18. Step 2 and 3 are always definite time delayed.
Table 18:  Inverse time characteristics

<table>
<thead>
<tr>
<th>Curve name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Very Inverse</td>
</tr>
<tr>
<td>ANSI Normal Inverse</td>
</tr>
<tr>
<td>ANSI Moderately Inverse</td>
</tr>
<tr>
<td>ANSI/IEEE Definite time</td>
</tr>
<tr>
<td>ANSI Long Time Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Very Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Inverse</td>
</tr>
<tr>
<td>IEC Normal Inverse</td>
</tr>
<tr>
<td>IEC Very Inverse</td>
</tr>
<tr>
<td>IEC Inverse</td>
</tr>
<tr>
<td>IEC Extremely Inverse</td>
</tr>
<tr>
<td>IEC Short Time Inverse</td>
</tr>
<tr>
<td>IEC Long Time Inverse</td>
</tr>
<tr>
<td>IEC Definite Time</td>
</tr>
<tr>
<td>ASEA RI</td>
</tr>
<tr>
<td>RXIDG (logarithmic)</td>
</tr>
</tbody>
</table>

The different characteristics are described in Technical manual.

*Pickupx:* Operation phase current level for step x given in % of IBase.

*tx:* Definite time delay for step x. Used if definite time characteristic is chosen.

*TDn:* Time multiplier for inverse time delay for step n.

*IMinn:* Minimum operate current for step n in % of IBase. Set IMinn below Pickupx for every step to achieve ANSI reset characteristic according to standard. If IMinn is set above Pickupx for any step the ANSI reset works as if current is zero when current drops below IMinn.

*tnMin:* Minimum operation time for all inverse time characteristics. At high currents the inverse time characteristic might give a very short operation time. By setting this parameter the operation time of the step can never be shorter than the setting. Setting range: 0.000 - 60.000s in steps of 0.001s.
In order to fully comply with curves definition setting parameter $tnMin$ shall be set to the value, which is equal to the operating time of the selected inverse curve for measured current of twenty times the set current pickup value. Note that the operating time value is dependent on the selected setting value for time multiplier $TDn$.

### 6.3.3.2 Current applications

The four step phase overcurrent protection can be used in different ways, depending on the application where the protection is used. A general description is given below.

The pickup current setting inverse time protection or the lowest current step constant inverse time protection must be given a current setting so that the highest possible load current does not cause protection operation. Here consideration also has to be taken to the protection reset current, so that a short peak of overcurrent does not cause operation of the protection even when the overcurrent has ceased. This phenomenon is described in figure 49.
Figure 49: Pickup and reset current for an overcurrent protection

The lowest setting value can be written according to equation 15.

\[ I_{pu} \geq 1.2 \cdot \frac{I_{max}}{k} \]  

(Equation 15)

where:
- 1.2 is a safety factor,
- k is the resetting ratio of the protection, and
- \( I_{max} \) is the maximum load current.

The maximum load current on the line has to be estimated. There is also a demand that all faults, within the zone that the protection shall cover, must be detected by the phase overcurrent protection. The minimum fault current \( I_{scmin} \), to be detected by the protection, must be calculated. Taking this value as a base, the highest pick up current setting can be written according to equation 16.

\[ I_{pu} \leq 0.7 \cdot I_{scmin} \]  

(Equation 16)

where:
- 0.7 is a safety factor and
- \( I_{scmin} \) is the smallest fault current to be detected by the overcurrent protection.
As a summary the pickup current shall be chosen within the interval stated in equation 17.

\[
1.2 \cdot \frac{I_{\text{max}}}{k} \leq I_{\text{pu}} \leq 0.7 \cdot I_{\text{sc min}}
\]

(Equation 17)

The high current function of the overcurrent protection, which only has a short delay of the operation, must be given a current setting so that the protection is selective to other protection in the power system. It is desirable to have a rapid tripping of faults within as large portion as possible of the part of the power system to be protected by the protection (primary protected zone). A fault current calculation gives the largest current of faults, Iscmax, at the most remote part of the primary protected zone. Considerations have to be made to the risk of transient overreach, due to a possible DC component of the short circuit current. The lowest current setting of the most rapid stage, of the phase overcurrent protection, can be written according to

\[
I_{\text{high}} \geq 1.2 \cdot k_t \cdot I_{\text{sc max}}
\]

(Equation 18)

where:

- 1.2 is a safety factor,
- \( k_t \) is a factor that takes care of the transient overreach due to the DC component of the fault current and can be considered to be less than 1.1
- Iscmax is the largest fault current at a fault at the most remote point of the primary protection zone.

The operate times of the phase overcurrent protection has to be chosen so that the fault time is so short that protected equipment will not be destroyed due to thermal overload, at the same time as selectivity is assured. For overcurrent protection, in a radial fed network, the time setting can be chosen in a graphical way. This is mostly used in the case of inverse time overcurrent protection. Figure 50 shows how the time-versus-current curves are plotted in a diagram. The time setting is chosen to get the shortest fault time with maintained selectivity. Selectivity is assured if the time difference between the curves is larger than a critical time difference.
To assure selectivity between different protections, in the radial network, there have to be a minimum time difference $D_t$ between the time delays of two protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference, the operation time of protections, breaker opening time and protection resetting time must be known. These time delays can vary significantly between different protective equipment. The following time delays can be estimated:

- Protection operation time: 15-60 ms
- Protection resetting time: 15-60 ms
- Breaker opening time: 20-120 ms

**Example**

Assume two substations A and B directly connected to each other via one line, as shown in the figure 51. Consider a fault located at another line from the station B. The fault current to the overcurrent protection of IED B1 has a magnitude so that the protection will have instantaneous function. The overcurrent protection of IED A1 must have a delayed function. The sequence of events during the fault can be described using a time axis, see figure 51.
The fault occurs
Protection B1 trips
Breaker at B1 opens
Protection A1 resets

**Figure 51:** Sequence of events during fault

where:
\( t=0 \) is when the fault occurs,
\( t=t_1 \) is when the trip signal from the overcurrent protection at IED B1 is sent to the circuit breaker. The operation time of this protection is \( t_1 \),
\( t=t_2 \) is when the circuit breaker at IED B1 opens. The circuit breaker opening time is \( t_2 - t_1 \) and
\( t=t_3 \) is when the overcurrent protection at IED A1 resets. The protection resetting time is \( t_3 - t_2 \).

To ensure that the overcurrent protection at IED A1, is selective to the overcurrent protection at IED B1, the minimum time difference must be larger than the time \( t_3 \). There are uncertainties in the values of protection operation time, breaker opening time and protection resetting time. Therefore a safety margin has to be included. With normal values the needed time difference can be calculated according to equation 19.

\[
\Delta t \geq 40 \text{ ms} + 100 \text{ ms} + 40 \text{ ms} + 40 \text{ ms} = 220 \text{ ms}
\] (Equation 19)

where it is considered that:
the operation time of overcurrent protection B1 is 40 ms
the breaker open time is 100 ms
the resetting time of protection A1 is 40 ms and
the additional margin is 40 ms
6.4 Four step phase overcurrent protection OC4SPTOC 51_67

6.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four step phase overcurrent protection</td>
<td>OC4SPTOC</td>
<td></td>
<td>51/67</td>
</tr>
</tbody>
</table>

6.4.2 Application

The four step phase overcurrent protection OC4SPTOC (51_67) is used in several applications in the power system. Some applications are:

- Short circuit protection of feeders in distribution and subtransmission systems.
- Normally these feeders have radial structure.
- Back-up short circuit protection of transmission lines.
- Back-up short circuit protection of power transformers.
- Short circuit protection of different kinds of equipment connected to the power system such as; shunt capacitor banks, shunt reactors, motors and others.
- Back-up short circuit protection of power generators.

If VT inputs are not available or not connected, setting parameter DirModeSelx (x=step 1, 2, 3 or 4) shall be left to default value, Nondirectional, or set to Disabled.

In many applications several steps with different current pick up levels and time delays are needed. OC4SPTOC (51_67) can have up to four different, individual settable, steps. The flexibility of each step of the OC4SPTOC (51_67) function is great. The following options are possible:

Non-directional/Directional function: In most applications the non-directional functionality is used. This is mostly the case when no fault current can be fed from the protected object itself. In order to achieve both selectivity and fast fault clearance, the directional function can be necessary.

Choice of delay time characteristics: There are several types of delay time characteristics available such as definite time delay and different types of inverse time delay characteristics. The selectivity between different overcurrent functions is normally enabled by co-ordination between the function time delays of the different functions. To enable optimal co-ordination between all overcurrent functions, they should have the same time delay characteristic. Therefore a wide range of standardized inverse time characteristics are available: IEC and ANSI.
The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time characteristic. Step 2 and 3 are always definite time delayed and are used in system where IDMT is not needed.

### 6.4.3 Setting guidelines

The parameters for four step phase overcurrent protection OC4SPTOC (51_67) are set via the local HMI or Protection and Control IED Manager (PCM600).

The following settings can be done for the four step phase overcurrent protection.

- **Common base IED values for primary current (setting IBase), primary voltage (VBase) and primary power (SBase)** are set in a Global base values for settings function GBASVAL.
- **Setting GlobalBaseSel**: Used to select a GBASVAL function for reference of base values.
- **MeasType**: Selection of discrete Fourier filtered (DFT) or true RMS filtered (RMS) signals. RMS is used when the harmonic contents are to be considered, for example in applications with shunt capacitors.
- **Operation**: The protection can be set to **Disabled** or **Enabled**.
Figure 52: Directional function characteristic

1. RCA = Relay characteristic angle 55°
2. ROA = Relay operating angle 80°
3. Reverse
4. Forward

6.4.3.1 Settings for steps 1 to 4

- \( n \): means
  step 1 and 4. \( x \) means step 1, 2, 3 and 4.
- DirModeSelx:
  The directional mode of step \( x \). Possible settings are Disabled/Non-directional/ Forward/ Reverse
- Characteristn:
  Selection of time characteristic for step \( n \). Definite time delay and different types of inverse time characteristics are available according to table 14. Step 2 and 3 are always definite time delayed.
Table 19: Inverse time characteristics

<table>
<thead>
<tr>
<th>Curve name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Very Inverse</td>
</tr>
<tr>
<td>ANSI Normal Inverse</td>
</tr>
<tr>
<td>ANSI Moderately Inverse</td>
</tr>
<tr>
<td>ANSI/IEEE Definite time</td>
</tr>
<tr>
<td>ANSI Long Time Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Very Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Inverse</td>
</tr>
<tr>
<td>IEC Normal Inverse</td>
</tr>
<tr>
<td>IEC Very Inverse</td>
</tr>
<tr>
<td>IEC Inverse</td>
</tr>
<tr>
<td>IEC Extremely Inverse</td>
</tr>
<tr>
<td>IEC Short Time Inverse</td>
</tr>
<tr>
<td>IEC Long Time Inverse</td>
</tr>
<tr>
<td>IEC Definite Time</td>
</tr>
<tr>
<td>ASEA RI</td>
</tr>
<tr>
<td>RXIDG (logarithmic)</td>
</tr>
</tbody>
</table>

The different characteristics are described in the Technical manual.

- **Pickupx**: Operation phase current level for step x given in % of $I_{Base}$.
- **tx**: Definite time delay for step x. Used if definite time characteristic is chosen.
- **TDn**: Time multiplier for inverse time delay for step n.
- **IMinn**: Minimum operate current for step n in % of $I_{Base}$. Set **IMinn** below **Pickupx** for every step to achieve ANSI reset characteristic according to standard. If **IMinn** is set above **Pickupx** for any step the ANSI reset works as if current is zero when current drops below **IMinn**.
- **tnMin**: Minimum operation time for all inverse time characteristics. At high currents the inverse time characteristic might give a very short operation time. By setting this parameter the operation time of the step can never be shorter than the setting.
In order to fully comply with curves definition setting parameter $tnMin$ shall be set to the value which is equal to the operating time of the selected inverse curve for measured current of twenty times the set current pickup value. Note that the operating time value is dependent on the selected setting value for time multiplier $TDn$.

6.4.3.2 Current application

OC4SPTOC (51_67) function can be used in different ways, depending on the application where the protection is used. A general description is given below.

The pickup current setting inverse time protection or the lowest current step constant inverse time protection must be given a current setting so that the highest possible load current does not cause protection operation. Here consideration also has to be taken to the protection reset current, so that a short peak of overcurrent does not cause operation of the protection even when the overcurrent has ceased. This phenomenon is described in figure 54.
The IED does not reset

\[ \text{ANSI10000274-1-en.vsd} \]

**Figure 54:** Pickup and reset current for an overcurrent protection

The lowest setting value can be written according to equation 20.

\[ I_{pu} \geq 1.2 \frac{I_{max}}{k} \]

(Equation 20)

where:

- \( 1.2 \) is a safety factor,
- \( k \) is the resetting ratio of the protection, and
- \( I_{max} \) is the maximum load current.

The maximum load current on the line has to be estimated. There is also a demand that all faults, within the zone that the protection shall cover, must be detected by the phase overcurrent protection. The minimum fault current \( I_{scmin} \), to be detected by the protection, must be calculated. Taking this value as a base, the highest pick up current setting can be written according to equation 21.

\[ I_{pu} \leq 0.7 \cdot I_{scmin} \]

(Equation 21)

where:

- \( 0.7 \) is a safety factor
- \( I_{scmin} \) is the smallest fault current to be detected by the overcurrent protection
The high current function of the overcurrent protection, which only has a short delay of the operation, must be given a current setting so that the protection is selective to other protection in the power system. It is desirable to have a rapid tripping of faults within as large portion as possible of the part of the power system to be protected by the protection (primary protected zone). A fault current calculation gives the largest current of faults, \( I_{\text{sc max}} \), at the most remote part of the primary protected zone. Considerations have to be made to the risk of transient overreach, due to a possible DC component of the short circuit current. The lowest current setting of the most rapid stage, of the phase overcurrent protection, can be written according to

\[
I_{\text{high}} \geq 1.2 \cdot k_t \cdot I_{\text{sc max}}
\]

(Equation 23)

where:

- 1.2 is a safety factor
- \( k_t \) is a factor that takes care of the transient overreach due to the DC component of the fault current and can be considered to be less than 1.1
- \( I_{\text{sc max}} \) is the largest fault current at a fault at the most remote point of the primary protection zone

The operate times of the phase overcurrent protection has to be chosen so that the fault time is so short that protected equipment will not be destroyed due to thermal overload, at the same time as selectivity is assured. For overcurrent protection, in a radial fed network, the time setting can be chosen in a graphical way. This is mostly used in the case of inverse time overcurrent protection. Figure 55 shows how the time-versus-current curves are plotted in a diagram. The time setting is chosen to get the shortest fault time with maintained selectivity. Selectivity is assured if the time difference between the curves is larger than a critical time difference.
To assure selectivity between different protections, in the radial network, there have to be a minimum time difference $\Delta t$ between the time delays of two protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference, the operation time of protections, breaker opening time and protection resetting time must be known. These time delays can vary significantly between different protective equipment. The following time delays can be estimated:

- Protection operation time: 15-60 ms
- Protection resetting time: 15-60 ms
- Breaker opening time: 20-120 ms

### Example

Assume two substations A and B directly connected to each other via one line, as shown in the figure [56]. Consider a fault located at another line from the station B. The fault current to the overcurrent protection of IED B1 has a magnitude so that the protection will have instantaneous function. The overcurrent protection of IED A1 must have a delayed function. The sequence of events during the fault can be described using a time axis, see figure [56].

![Figure 55: Fault time with maintained selectivity](IEC10000273-1-en.vsd)
The fault occurs
Protection B1 trips
Breaker at B1 opens
Protection A1 resets

Figure 56: Sequence of events during fault
where:
- $t=0$ is when the fault occurs.
- $t=t_1$ is when the trip signal from the overcurrent protection at IED B1 is sent to the circuit breaker. The operation time of this protection is $t_1$.
- $t=t_2$ is when the circuit breaker at IED B1 opens. The circuit breaker opening time is $t_2 - t_1$.
- $t=t_3$ is when the overcurrent protection at IED A1 resets. The protection resetting time is $t_3 - t_2$.

To ensure that the overcurrent protection at IED A1 is selective to the overcurrent protection at IED B1, the minimum time difference must be larger than the time $t_3$. There are uncertainties in the values of protection operation time, breaker opening time and protection resetting time. Therefore a safety margin has to be included. With normal values the needed time difference can be calculated according to equation 24.

$$\Delta t \geq 40\, ms + 100\, ms + 40\, ms + 40\, ms = 220\, ms$$

(Equation 24)

where it is considered that:
- the operation time of overcurrent protection B1 is 40 ms
- the breaker open time is 100 ms
- the resetting time of protection A1 is 40 ms
- the additional margin is 40 ms

6.5 Instantaneous residual overcurrent protection EFPIOC (50N)
6.5.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instantaneous residual overcurrent protection</td>
<td>EFPIOC</td>
<td>IN&gt;&gt;</td>
<td>50N</td>
</tr>
</tbody>
</table>

6.5.2 Application

In many applications, when fault current is limited to a defined value by the object impedance, an instantaneous ground-fault protection can provide fast and selective tripping.

The Instantaneous residual overcurrent EFPIOC (50N), which can operate in 15 ms (50 Hz nominal system frequency) for faults characterized by very high currents, is included in the IED.

6.5.3 Setting guidelines

The parameters for the Instantaneous residual overcurrent protection EFPIOC (50N) are set via the local HMI or PCM600.

Some guidelines for the choice of setting parameter for EFPIOC (50N) is given.

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

The setting of the function is limited to the operation residual current to the protection (Pickup).

The basic requirement is to assure selectivity, that is EFPIOC (50N) shall not be allowed to operate for faults at other objects than the protected object (line).

For a normal line in a meshed system single phase-to-ground faults and phase-to-phase-to-ground faults shall be calculated as shown in figure 57 and figure 58. The residual currents (3I₀) to the protection are calculated. For a fault at the remote line end this fault current is Iᵦ. In this calculation the operational state with high source impedance Z_A and low source impedance Z_B should be used. For the fault at the home busbar this fault current is Iᵦ. In this calculation the operational state with low source impedance Z_A and high source impedance Z_B should be used.
The function shall not operate for any of the calculated currents to the protection. The minimum theoretical current setting ($I_{\text{min}}$) will be:

$$I_{\text{min}} \geq \text{MAX}(I_{fA}, I_{fB})$$

(Equation 25)

A safety margin of 5% for the maximum static inaccuracy and a safety margin of 5% for maximum possible transient overreach have to be introduced. An additional 20% is suggested due to inaccuracy of instrument transformers under transient conditions and inaccuracy in the system data.

The minimum primary current setting ($I_s$) is:

$$I_s \geq 1,3 \cdot I_{\text{min}}$$

(Equation 26)

In case of parallel lines with zero sequence mutual coupling a fault on the parallel line, as shown in figure 59, should be calculated.
Figure 59: Two parallel lines. Influence from parallel line to the through fault current: $I_M$

The minimum theoretical current setting ($I_{\text{min}}$) will in this case be:

$$I_{\text{min}} \geq \text{MAX}(I_{A}, I_{B}, I_{M})$$

(Equation 27)

Where:

$I_A$ and $I_B$ have been described for the single line case.

Considering the safety margins mentioned previously, the minimum setting ($I_s$) is:

$$I_s \geq 1, 3 \cdot I_{\text{min}}$$

(Equation 28)

Transformer inrush current shall be considered.

The setting of the protection is set as a percentage of the base current ($I_{\text{Base}}$).

Operation: set the protection to Enabled or Disabled.

Pickup: Set operate current in % of $I_{\text{Base}}$. $I_{\text{Base}}$ is a global parameter valid for all functions in the IED.

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

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four step residual overcurrent protection</td>
<td>EF4PTOC</td>
<td></td>
<td>51N/67N</td>
</tr>
</tbody>
</table>

### 6.6.2 Application

The four step residual overcurrent protection EF4PTOC (51N_67N) is used in several applications in the power system. Some applications are:

- Ground-fault protection of feeders in effectively grounded distribution and subtransmission systems. Normally these feeders have radial structure.
- Back-up ground-fault protection of transmission lines.
- Sensitive ground-fault protection of transmission lines. EF4PTOC (51N_67N) can have better sensitivity to detect resistive phase-to-ground-faults compared to distance protection.
- Back-up ground-fault protection of power transformers.
- Ground-fault protection of different kinds of equipment connected to the power system such as shunt capacitor banks, shunt reactors and others.

In many applications several steps with different current pickup levels and time delays are needed. EF4PTOC (51N_67N) can have up to four, individual settable steps. The flexibility of each step of EF4PTOC (51N_67N) is great. The following options are possible:

Non-directional/Directional function: In some applications the non-directional functionality is used. This is mostly the case when no fault current can be fed from the protected object itself. In order to achieve both selectivity and fast fault clearance, the directional function can be necessary. This can be the case for ground-fault protection in meshed and effectively grounded transmission systems. The directional residual overcurrent protection is also well suited to operate in teleprotection communication schemes, which enables fast clearance of ground faults on transmission lines. The directional function uses the polarizing quantity as decided by setting. Voltage polarizing (-3V₀) is most commonly used but alternatively current polarizing where currents in transformer neutrals providing the neutral (zero sequence) source (ZN) is used to polarize (IN · ZN) the function. Dual polarizing where the sum of both voltage and current components is allowed to polarize can also be selected.

Choice of time characteristics: There are several types of time characteristics available such as definite time delay and different types of inverse time characteristics. The selectivity between different overcurrent protections is normally enabled by co-ordination between the operating time of the different protections. To enable optimal co-ordination all overcurrent protections, to be co-ordinated against each other, should have the same time characteristic. Therefore a wide range of standardized inverse time characteristics are available: IEC and ANSI. The time characteristic for step 1 and 4 can be chosen as definite time delay or inverse time characteristic. Step 2 and 3 are always definite time delayed and are used in system where IDMT is not needed.
### Table 20: Time characteristics

<table>
<thead>
<tr>
<th>Curve name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Very Inverse</td>
</tr>
<tr>
<td>ANSI Normal Inverse</td>
</tr>
<tr>
<td>ANSI Moderately Inverse</td>
</tr>
<tr>
<td>ANSI/IEEE Definite time</td>
</tr>
<tr>
<td>ANSI Long Time Extremely Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Very Inverse</td>
</tr>
<tr>
<td>ANSI Long Time Inverse</td>
</tr>
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</tr>
<tr>
<td>IEC Very Inverse</td>
</tr>
<tr>
<td>IEC Inverse</td>
</tr>
<tr>
<td>IEC Extremely Inverse</td>
</tr>
<tr>
<td>IEC Short Time Inverse</td>
</tr>
<tr>
<td>IEC Long Time Inverse</td>
</tr>
<tr>
<td>IEC Definite Time</td>
</tr>
<tr>
<td>ASEA RI</td>
</tr>
<tr>
<td>RXIDG (logarithmic)</td>
</tr>
</tbody>
</table>

Power transformers can have a large inrush current, when being energized. This inrush current can have residual current components. The phenomenon is due to saturation of the transformer magnetic core during parts of the cycle. There is a risk that inrush current will give a residual current that reaches level above the pickup current of the residual overcurrent protection. The inrush current has a large second harmonic content. This can be used to avoid unwanted operation of the protection. Therefore, EF4PTOC (51N/67N) has a possibility of second harmonic restrain \(2nd\text{HarmStab}\) if the level of this harmonic current reaches a value above a set percentage of the fundamental current.

#### 6.6.3 Setting guidelines

The parameters for the four step residual overcurrent protection EF4PTOC (51N/67N) are set via the local HMI or PCM600.

The following settings can be done for the four step residual overcurrent protection.

Common base IED values for primary current \((iBase)\), primary voltage \((VBase)\) and primary power \((SBase)\) are set in a global base values for settings function GBASVAL. Setting \(GlobalBaseSel\) is used to select a GBASVAL function for reference of base values.

**Operation:** Sets the protection to *Enabled* or *Disabled*. 
**6.6.3.1 Settings for steps 1 and 4**

$n$ means step 1 and 4.

**DirModeSelx**: The directional mode of step $x$. Possible settings are Disabled/ Non-directional/ Forward/ Reverse.

**Characteristic**: Selection of time characteristic for step $x$. Definite time delay and different types of inverse time characteristics are available.

Inverse time characteristic enables fast fault clearance of high current faults at the same time as selectivity to other inverse time phase overcurrent protections can be assured. This is mainly used in radial fed networks but can also be used in meshed networks. In meshed networks the settings must be based on network fault calculations.

To assure selectivity between different protections, in the radial network, there have to be a minimum time difference $\Delta t$ between the time delays of two protections. The minimum time difference can be determined for different cases. To determine the shortest possible time difference, the operation time of protections, breaker opening time and protection resetting time must be known. These time delays can vary significantly between different protective equipment. The following time delays can be estimated:

- Protection operation time: 15-60 ms
- Protection resetting time: 15-60 ms
- Breaker opening time: 20-120 ms

The different characteristics are described in the Technical Manual (TM).

**Pickup**$^x$**: Operation residual current level for step $x$ given in % of $I_{Base}$.

**TDn**: Time multiplier for the dependent (inverse) characteristic for step $n$.

**IMinn**: Minimum operate current for step $n$ in % of $I_{Base}$. Set $IMinn$ below Pickup$^x$ for every step to achieve ANSI reset characteristic according to standard. If $IMinn$ is set above Pickup$^x$ for any step the ANSI reset works as if current is zero when current drops below $IMinn$.

**tnMin**: Minimum operating time for inverse time characteristics. At high currents the inverse time characteristic might give a very short operation time. By setting this parameter the operation time of the step $n$ can never be shorter than the setting.
6.6.3.2 Common settings for all steps

\( tx \): Definite time delay for step \( x \). Used if definite time characteristic is chosen.

\textit{AngleRCA}: Relay characteristic angle given in degree. This angle is defined as shown in figure 61. The angle is defined positive when the residual current lags the reference voltage (\( V_{pol} = -3V_0 \)).
In a normal transmission network a normal value of RCA is about 65°. The setting range is -180° to +180°.

**polMethod** Defines if the directional polarization is from

- **Voltage (-3V₀)**
- **Current (3I₀ · ZNpol where ZNpol is RNpol + jXNpol), or**
- **both currents and voltage, Dual (dual polarizing, -3U₀ + 3I₀ · ZNpol).**

Normally voltage polarizing from the residual sum or an external open delta is used. Current polarizing is useful when the local source is strong and a high sensitivity is required. In such cases the polarizing voltage (-3V₀) can be below 1% and it is then necessary to use current polarizing or dual polarizing. Multiply the required set current (primary) with the minimum impedance (ZNpol) and check that the percentage of the phase-to-ground voltage is definitely higher than 1% (minimum 3V₀> VPolMin setting) as a verification.

**RNPol, XNPol:** The zero-sequence source is set in primary ohms as base for the current polarizing. The polarizing voltage is then achieved as 3I₀ · ZNpol. The ZNpol can be defined as (ZS₁-ZS₀)/3, that is the ground return impedance of the source behind the protection. The maximum ground-fault current at the local source can be used to calculate the value of ZN as V/(√3 · 3I₀) Typically, the minimum ZNPol (3 · zero sequence source) is set. Setting is in primary ohms.

When the dual polarizing method is used it is important that the setting Pickupx or the product 3I₀ · ZNpol is not greater than 3U₀. If so, there is a risk for incorrect operation for faults in the reverse direction.

**IPolMin:** is the minimum ground-fault current accepted for directional evaluation. For smaller currents than this value the operation will be blocked. Typical setting is 5-10% of IBase.

**VPolMin:** Minimum polarization (reference) residual voltage for the directional function, given in % of VBase/√3.
INDirPU: Operating residual current release level in % of /Base for directional comparison scheme. The setting is given in % of /Base. The output signals, PUFW and PUREV can be used in a teleprotection scheme. The appropriate signal should be configured to the communication scheme block.

6.6.3.3 2nd harmonic restrain

If a power transformer is energized there is a risk that the current transformer core will saturate during part of the period, resulting in an inrush transformer current. This will give a declining residual current in the network, as the inrush current is deviating between the phases. There is a risk that the residual overcurrent function will give an unwanted trip. The inrush current has a relatively large ratio of 2nd harmonic component. This component can be used to create a restrain signal to prevent this unwanted function.

At current transformer saturation a false residual current can be measured by the protection. Also here the 2nd harmonic restrain can prevent unwanted operation.

2ndHarmStab: The rate of 2nd harmonic current content for activation of the 2nd harmonic restrain signal. The setting is given in % of the fundamental frequency residual current.

HarmRestrainx: Enable block of step x from the harmonic restrain function.

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

6.7.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitive directional residual over current and power protection</td>
<td>SDEPSDE</td>
<td>-</td>
<td>67N</td>
</tr>
</tbody>
</table>

6.7.2 Application

In networks with high impedance grounding, the phase-to-ground fault current is significantly smaller than the short circuit currents. Another difficulty for ground-fault protection is that the magnitude of the phase-to-ground fault current is almost independent of the fault location in the network.

Directional residual current can be used to detect and give selective trip of phase-to-ground faults in high impedance grounded networks. The protection uses the residual current component $3I_0 \cdot \cos \phi$, where $\phi$ is the angle between the residual current and the residual voltage (-3U0), compensated with a characteristic angle. Alternatively, the function can be set to strict $3I_0$ level with an check of angle $3I_0$ and $\cos \phi$.

Directional residual power can also be used to detect and give selective trip of phase-to-ground faults in high impedance grounded networks. The protection uses the residual power component.
3I_0 \cdot 3V_0 \cdot \cos \phi$, where $\phi$ is the angle between the residual current and the reference residual voltage, compensated with a characteristic angle.

A normal non-directional residual current function can also be used with definite or inverse time delay.

A back-up neutral point voltage function is also available for non-directional sensitive back-up protection.

In an isolated network, that is, the network is only coupled to ground via the capacitances between the phase conductors and ground, the residual current always has -90° phase shift compared to the reference residual voltage. The characteristic angle is chosen to -90° in such a network.

In resistance grounded networks or in Petersen coil grounded, with a parallel resistor, the active residual current component (in phase with the residual voltage) should be used for the ground-fault detection. In such networks the characteristic angle is chosen to 0°.

As the magnitude of the residual current is independent of the fault location the selectivity of the ground-fault protection is achieved by time selectivity.

When should the sensitive directional residual overcurrent protection be used and when should the sensitive directional residual power protection be used? Consider the following facts:

- Sensitive directional residual overcurrent protection gives possibility for better sensitivity
- Sensitive directional residual power protection gives possibility to use inverse time characteristics. This is applicable in large high impedance grounded networks, with large capacitive ground-fault current
- In some power systems a medium size neutral point resistor is used, for example, in low impedance grounded system. Such a resistor will give a resistive ground-fault current component of about 200 - 400 A at a zero resistive phase-to-ground fault. In such a system the directional residual power protection gives better possibilities for selectivity enabled by inverse time power characteristics.

### 6.7.3 Setting guidelines

The sensitive ground-fault protection is intended to be used in high impedance grounded systems, or in systems with resistive grounding where the neutral point resistor gives an ground-fault current larger than what normal high impedance gives but smaller than the phase to phase short circuit current.

In a high impedance system the fault current is assumed to be limited by the system zero sequence shunt impedance to ground and the fault resistance only. All the series impedances in the system are assumed to be zero.

In the setting of ground-fault protection, in a high impedance grounded system, the neutral point voltage (zero sequence voltage) and the ground-fault current will be calculated at the desired sensitivity (fault resistance). The complex neutral point voltage (zero sequence) can be calculated as:
\[ V_0 = \frac{V_{\text{phase}}}{1 + \frac{3 \cdot R_f}{Z_0}} \]  

(Equation 29)

Where

- \( V_{\text{phase}} \) is the phase voltage in the fault point before the fault,
- \( R_f \) is the resistance to ground in the fault point and
- \( Z_0 \) is the system zero sequence impedance to ground

The fault current, in the fault point, can be calculated as:

\[ I_j = 3I_0 = \frac{3 \cdot V_{\text{phase}}}{Z_0 + 3 \cdot R_f} \]  

(Equation 30)

The impedance \( Z_0 \) is dependent on the system grounding. In an isolated system (without neutral point apparatus) the impedance is equal to the capacitive coupling between the phase conductors and ground:

\[ Z_0 = -jX_c = -j \frac{3 \cdot V_{\text{phase}}}{I_j} \]  

(Equation 31)

Where

- \( I_j \) is the capacitive ground-fault current at a non-resistive phase to ground-fault
- \( X_c \) is the capacitive reactance to ground

In a system with a neutral point resistor (resistance grounded system) the impedance \( Z_0 \) can be calculated as:

\[ Z_0 = \frac{-jX_c \cdot 3R_n}{-jX_c + 3R_n} \]  

(Equation 32)

Where

- \( R_n \) is the resistance of the neutral point resistor
In many systems there is also a neutral point reactor (Petersen coil) connected to one or more transformer neutral points. In such a system the impedance $Z_0$ can be calculated as:

$$Z_n = -jX_n / 3R_n / j3X_n = \frac{9R_n X_n X_c}{3X_n X_c + j3R_n \cdot (3X_n - X_c)}$$

(Equation 33)

Where

$X_n$ is the reactance of the Petersen coil. If the Petersen coil is well tuned we have $3X_n = X_c$ in this case the impedance $Z_0$ will be: $Z_0 = 3R_n$

Now consider a system with an grounding via a resistor giving higher ground-fault current than the high impedance grounding. The series impedances in the system can no longer be neglected. The system with a single phase to ground-fault can be described as in figure 62.

![Figure 62: Equivalent of power system for calculation of setting](en06000654_ansii.vsd)

The residual fault current can be written:
\[3I_0 = \frac{3V_{\text{phase}}}{2 \cdot Z_1 + Z_0 + 3 \cdot R_f}\]

(Equation 34)

Where

- \(V_{\text{phase}}\) is the phase voltage in the fault point before the fault
- \(Z_1\) is the total positive sequence impedance to the fault point. \(Z_1 = Z_{sc} + Z_{T,1} + Z_{\text{lineAB},1} + Z_{\text{lineBC},1}\)
- \(Z_0\) is the total zero sequence impedance to the fault point. \(Z_0 = Z_{T,0} + 3R_N + Z_{\text{lineAB},0} + Z_{\text{lineBC},0}\)
- \(R_f\) is the fault resistance.

The residual voltages in stations A and B can be written:

- \(V_{0A} = 3I_0 \cdot (Z_{T,0} + 3R_N)\)  
  (Equation 35)

- \(V_{0B} = 3I_0 \cdot (Z_{T,0} + 3R_N + Z_{\text{lineAB},0})\)  
  (Equation 36)

The residual power, measured by the sensitive ground-fault protections in A and B will be:

- \(S_{0A} = 3V_{0A} \cdot 3I_0\)  
  (Equation 37)

- \(S_{0B} = 3V_{0B} \cdot 3I_0\)  
  (Equation 38)

The residual power is a complex quantity. The protection will have a maximum sensitivity in the characteristic angle RCA. The apparent residual power component in the characteristic angle, measured by the protection, can be written:

- \(S_{0A,\text{prot}} = 3V_{0A} \cdot 3I_0 \cdot \cos \phi_A\)  
  (Equation 39)

- \(S_{0B,\text{prot}} = 3V_{0B} \cdot 3I_0 \cdot \cos \phi_B\)  
  (Equation 40)

The angles \(\phi_A\) and \(\phi_B\) are the phase angles between the residual current and the residual voltage in the station compensated with the characteristic angle RCA.
The protection will use the power components in the characteristic angle direction for measurement, and as base for the inverse time delay.

The inverse time delay is defined as:

\[ t_{inv} = \frac{TDSN \cdot (3I_0 \cdot 3V_0 \cdot \cos \phi(\text{reference}))}{3I_0 \cdot 3V_0 \cos \phi(\text{measured})} \]

(Equation 41)

Common base IED values for primary current (I_Base), primary voltage (V_Base) and primary power (S_Base) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

The function can be set *Enabled/Disabled* with the setting of *Operation*.

With the setting *OpModeSel* the principle of directional function is chosen.

With *OpModeSel* set to 3I0cosfi the current component in the direction equal to the characteristic angle RCADir is measured. The characteristic for RCADir is equal to 0° is shown in figure 63.

![Diagram showing characteristic for RCADir equal to 0°](en06000648_ansi.vsd)

**Figure 63:** Characteristic for RCADir equal to 0°

The characteristic is for RCADir equal to -90° is shown in figure 64.
When OpModeSel is set to 3I03V0Cosf, the apparent residual power component in the direction is measured.

When OpModeSel is set to 3I0 and f, the function will operate if the residual current is larger than the setting INDirPU and the residual current angle is within the sector RCADir ± ROAdir.

The characteristic for RCADir = 0° and ROAdir = 80° is shown in figure 65.
DirMode is set Forward or Reverse to set the direction of the trip function from the directional residual current function.

All the directional protection modes have a residual current release level setting INRelPU which is set in % of IBase. This setting should be chosen smaller than or equal to the lowest fault current to be detected.

All the directional protection modes have a residual voltage release level setting VNRelPU which is set in % of VBase. This setting should be chosen smaller than or equal to the lowest fault residual voltage to be detected.

tDef is the definite time delay, given in s, for the directional residual current protection if definite time delay is chosen.

The characteristic angle of the directional functions RCADir is set in degrees. RCADir is normally set equal to 0° in a high impedance grounded network with a neutral point resistor as the active current component is appearing out on the faulted feeder only. RCADir is set equal to -90° in an isolated network as all currents are mainly capacitive.

The relay open angle ROADir is set in degrees. For angles differing more than ROADir from RCADir the function from the protection is blocked. The setting can be used to prevent unwanted function for non-faulted feeders, with large capacitive ground-fault current contributions, due to CT phase angle error.

INCosPhiPU is the operate current level for the directional function when OpModeSel is set 3I0Cosfi. The setting is given in % of IBase. The setting should be based on calculation of the active or capacitive ground-fault current at required sensitivity of the protection.

SN_PU is the operate power level for the directional function when OpModeSel is set 3I03V0Cosfi. The setting is given in % of IBase. The setting should be based on calculation of the active or capacitive ground-fault residual power at required sensitivity of the protection.

The input transformer for the Sensitive directional residual over current and power protection function has the same short circuit capacity as the phase current transformers.

If the time delay for residual power is chosen the delay time is dependent on two setting parameters. SRef is the reference residual power, given in % of SBase. TDSN is the time multiplier. The time delay will follow the following expression:

\[
\frac{TDSN \cdot Sref}{3I_0 \cdot 3V_0 \cdot \cos \phi(\text{measured})}
\]

(Equation 42)

INDirPU is the operate current level for the directional function when OpModeSel is set 3I0 and fi. The setting is given in % of IBase. The setting should be based on calculation of the ground-fault current at required sensitivity of the protection.

OpINNonDir is set Enabled to activate the non-directional residual current protection.

INNonDirPU is the operate current level for the non-directional function. The setting is given in % of IBase. This function can be used for detection and clearance of cross-country faults in a shorter time than for the directional function. The current setting should be larger than the maximum single-phase residual current out on the protected line.
*TimeChar* is the selection of time delay characteristic for the non-directional residual current protection. Definite time delay and different types of inverse time characteristics are available:

<table>
<thead>
<tr>
<th>ANSI Extremely Inverse</th>
<th>ANSI Very Inverse</th>
<th>ANSI Normal Inverse</th>
<th>ANSI Moderately Inverse</th>
<th>ANSI/IEEE Definite time</th>
<th>ANSI Long Time Extremely Inverse</th>
<th>ANSI Long Time Very Inverse</th>
<th>ANSI Long Time Inverse</th>
<th>IEC Normal Inverse</th>
<th>IEC Very Inverse</th>
<th>IEC Inverse</th>
<th>IEC Extremely Inverse</th>
<th>IEC Short Time Inverse</th>
<th>IEC Long Time Inverse</th>
<th>IEC Definite time</th>
<th>ASEA RI</th>
<th>RXIDG (logarithmic)</th>
</tr>
</thead>
</table>

The different characteristics are described in Technical Manual.

\(tINonDir\) is the definite time delay for the non directional ground-fault current protection, given in s.

*OpVN* is set *Enabled* to activate the trip function of the residual voltage protection.

\(tVN\) is the definite time delay for the trip function of the residual voltage protection, given in s.

### 6.8 Thermal overload protection, one time constant LPTTR (26)

#### 6.8.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal overload protection, one time constant</td>
<td>LPTTR</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>
6.8.2 Application

Lines and cables in the power system are designed for a certain maximum load current level. If the current exceeds this level the losses will be higher than expected. As a consequence the temperature of the conductors will increase. If the temperature of the lines and cables reaches too high values the equipment might be damaged:

- The sag of overhead lines can reach unacceptable value.
- If the temperature of conductors, for example aluminium conductors, get too high the material will be destroyed.
- In cables the insulation can be damaged as a consequence of the overtemperature. As a consequence of this phase to phase or phase to ground faults can occur.

In stressed situations in the power system it can be required to overload lines and cables for a limited time. This should be done without risks.

The thermal overload protection provides information that makes a temporary overloading of cables and lines possible. The thermal overload protection estimates the conductor temperature continuously. This estimation is made by using a thermal model of the line/cable based on the current measurement.

If the temperature of the protected object reaches a set warning level $\text{AlarmTemp}$, a signal ALARM can be given to the operator. This enables actions in the power system to be taken before dangerous temperatures are reached. If the temperature continues to increase to the trip value $\text{TripTemp}$, the protection initiates trip of the protected line.

6.8.3 Setting guidelines

The parameters for the Thermal overload protection LPTTR (26) are set via the local HMI or PCM600.

The following settings can be done for the thermal overload protection.

Common base IED values for primary current ($I_{\text{Base}}$), primary voltage ($V_{\text{Base}}$) and primary power ($S_{\text{Base}}$) are set in a Global base values for settings function GBASVAL. Setting $\text{GlobalBaseSel}$ is used to select a GBASVAL function for reference of base values.

$\text{Operation: Disabled/ Enabled}$

$I_{\text{Ref}}$: Reference, steady state current, given in % of $I_{\text{Base}}$ that will give a steady state (end) temperature $T_{\text{Ref}}$. It is suggested to set this current to the maximum steady state current allowed for the line/cable under emergency operation (a few hours per year).

$T_{\text{Ref}}$: Reference temperature (end temperature) corresponding to the steady state current $I_{\text{Ref}}$. From cable manuals current values with corresponding conductor temperature are often given. These values are given for conditions such as ground temperature, ambient air temperature, way of laying of cable and ground thermal resistivity. From manuals for overhead conductor temperatures and corresponding current is given.

$\text{Tau}$: The thermal time constant of the protected circuit given in minutes. Please refer to manufacturers manuals for details.

$\text{TripTemp}$: Temperature value for trip of the protected circuit. For cables a maximum allowed conductor temperature is often stated to be 90°C. For overhead lines the critical temperature for aluminium conductor is about 90 - 100°C. For a copper conductor a normal figure is 70°C.
**AlarmTemp**: Temperature level for alarm of the protected circuit. ALARM signal can be used as a warning before the circuit is tripped. Therefore the setting shall be lower than the trip level. It shall at the same time be higher than the maximum conductor temperature at normal operation. For cables this level is often given to 65°C. Similar values are stated for overhead lines. A suitable setting can be about 15°C below the trip value.

**RecITemp**: Temperature where lockout signal LOCKOUT from the protection is released. When the thermal overload protection trips a lock-out signal is activated. This signal is intended to block switch in of the protected circuit as long as the conductor temperature is high. The signal is released when the estimated temperature is below the set value. This temperature value should be chosen below the alarm temperature.

### 6.9 Breaker failure protection CCRBRF (50BF)

#### 6.9.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaker failure protection</td>
<td>CCRBRF</td>
<td>3l&gt;BF</td>
<td>50BF</td>
</tr>
</tbody>
</table>

#### 6.9.2 Application

In the design of the fault clearance system the N-1 criterion is often used. This means that a fault needs to be cleared even if any component in the fault clearance system is faulty. One necessary component in the fault clearance system is the circuit breaker. It is from practical and economical reason not feasible to duplicate the circuit breaker for the protected component. Instead a breaker failure protection is used.

Breaker failure protection (CCRBRF, 50BF) will issue a back-up trip command to adjacent circuit breakers in case of failure to trip of the “normal” circuit breaker for the protected component. The detection of failure to break the current through the breaker is made by means of current measurement or as detection of remaining trip signal (unconditional).

CCRBRF (50BF) can also give a re-trip. This means that a second trip signal is sent to the protected circuit breaker. The re-trip function can be used to increase the probability of operation of the breaker, or it can be used to avoid back-up trip of many breakers in case of mistakes during relay maintenance and test.

#### 6.9.3 Setting guidelines

The parameters for Breaker failure protection CCRBRF (50BF) are set via the local HMI or PCM600.

The following settings can be done for the breaker failure protection.
Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

**Operation:** Disabled/Enabled

*FunctionMode* This parameter can be set Current or Contact. This states the way the detection of failure of the breaker is performed. In the mode current the current measurement is used for the detection. In the mode Contact the long duration of breaker position signal is used as indicator of failure of the breaker. The mode Current&Contact means that both ways of detections are activated. Contact mode can be usable in applications where the fault current through the circuit breaker is small. This can be the case for some generator protection application (for example reverse power protection) or in case of line ends with weak end infeed.

*RetripMode:* This setting states how the re-trip function shall operate. Retrip Off means that the re-trip function is not activated. CB Pos Check (circuit breaker position check) and Current means that a phase current must be larger than the operate level to allow re-trip. CB Pos Check (circuit breaker position check) and Contact means re-trip is done when circuit breaker is closed (breaker position is used). No CBPos Check means re-trip is done without check of breaker position.

**Table 21: Dependencies between parameters RetripMode and FunctionMode**

<table>
<thead>
<tr>
<th>RetripMode</th>
<th>FunctionMode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrip Off</td>
<td>N/A</td>
<td>the re-trip function is not activated</td>
</tr>
<tr>
<td>CB Pos Check</td>
<td>Current</td>
<td>a phase current must be larger than the operate level to allow re-trip</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>re-trip is done when breaker position indicates that breaker is still closed after re-trip time has elapsed</td>
</tr>
<tr>
<td></td>
<td>Current&amp;Contact</td>
<td>both methods are used</td>
</tr>
<tr>
<td>No CBPos Check</td>
<td>Current</td>
<td>re-trip is done without check of breaker position</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>re-trip is done without check of breaker position</td>
</tr>
<tr>
<td></td>
<td>Current&amp;Contact</td>
<td>both methods are used</td>
</tr>
</tbody>
</table>

*BuTripMode:* Back-up trip mode is given to state sufficient current criteria to detect failure to break. For Current operation 2 out of 4 means that at least two currents, of the three-phase currents and the residual current, shall be high to indicate breaker failure. 1 out of 3 means that at least one current of the three-phase currents shall be high to indicate breaker failure. 1 out of 4 means that at least one current of the three-phase currents or the residual current shall be high to indicate breaker failure. In most applications 1 out of 3 is sufficient. For Contact operation means back-up trip is done when circuit breaker is closed (breaker position is used).

*Pickup PH:* Current level for detection of breaker failure, set in % of IBase. This parameter should be set so that faults with small fault current can be detected. The setting can be chosen in accordance with the most sensitive protection function to start the breaker failure protection. Typical setting is 10% of IBase.

*Pickup BlkCont:* If any contact based detection of breaker failure is used this function can be blocked if any phase current is larger than this setting level. If the FunctionMode is set Current&Contact breaker failure for high current faults are safely detected by the current...
measurement function. To increase security the contact based function should be disabled for high currents. The setting can be given within the range 5 – 200% of \( I_{Base} \).

\textit{Pickup\_N}: Residual current level for detection of breaker failure set in % of \( I_{Base} \). In high impedance grounded systems the residual current at phase- to-ground faults are normally much smaller than the short circuit currents. In order to detect breaker failure at single-phase-ground faults in these systems it is necessary to measure the residual current separately. Also in effectively grounded systems the setting of the ground-fault current protection can be chosen to relatively low current level. The \textit{BuTripMode} is set \textit{1 out of 4}. The current setting should be chosen in accordance to the setting of the sensitive ground-fault protection. The setting can be given within the range 2 – 200% of \( I_{Base} \).

\textit{t1}: Time delay of the re-trip. The setting can be given within the range 0 – 60s in steps of 0.001 s. Typical setting is 0 – 50ms.

\textit{t2}: Time delay of the back-up trip. The choice of this setting is made as short as possible at the same time as unwanted operation must be avoided. Typical setting is 90 – 200ms (also dependent of re-trip timer).

The minimum time delay for the re-trip can be estimated as:

\[ t_2 \geq t_1 + t_{c\text{bopen}} + t_{BFP\_\text{reset}} + t_{\text{margin}} \]  

(Equation 43)

where:
- \( t_{c\text{bopen}} \) is the maximum opening time for the circuit breaker
- \( t_{BFP\_\text{reset}} \) is the maximum time for breaker failure protection to detect correct breaker function (the current criteria reset)
- \( t_{\text{margin}} \) is a safety margin

It is often required that the total fault clearance time shall be less than a given critical time. This time is often dependent of the ability to maintain transient stability in case of a fault close to a power plant.
### 6.10 Breaker failure protection CSPRBRF (50BF)

#### 6.10.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 Identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaker failure protection</td>
<td>CSPRBRF</td>
<td></td>
<td>50BF</td>
</tr>
</tbody>
</table>

#### 6.10.2 Application

In the design of the fault clearance system the N-1 criterion is often used. This means that a fault needs to be cleared even if any component in the fault clearance system is faulty. One necessary component in the fault clearance system is the circuit breaker. It is from practical and economical reason not feasible to duplicate the circuit breaker for the protected component. Instead a breaker failure protection is used.

The Breaker failure protection (CSPRBRF, 50BF) issues a back-up trip command to adjacent circuit breakers in case of failure to trip of the “normal” circuit breaker for the protected component. The detection of failure to break the current through the breaker is made by means of current measurement or as detection of remaining trip signal (unconditional).
CSPRBRF (50BF) can also give a re-trip. This means that a second trip signal is sent to the protected circuit breaker. The re-trip function can be used to increase the probability of operation of the breaker, or it can be used to avoid back-up trip of many breakers in case of mistakes during relay maintenance and test.

### 6.10.3 Setting guidelines

The parameters for Breaker failure protection CSPRBRF (50BF) are set via the local HMI or PCM600.

The following settings can be done for the breaker failure protection. Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power (setting $S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting $GlobalBaseSel$ is used to select a GBASVAL function for reference of base values.

**Operation:** Disabled/Enabled

**FunctionMode**. This parameter can be set Current/Contact. This states the way the detection of failure of the breaker is performed. In the mode current the current measurement is used for the detection. In the mode Contact the long duration of breaker position signal is used as indicator of failure of the breaker. The mode Current&Contact means that both ways of detections are activated. Contact mode can be usable in applications where the fault current through the circuit breaker is small. This can be the case for some generator protection application (for example reverse power protection) or in case of line ends with weak end infeed.

**RetripMode**: This setting states how the re-trip function shall operate. Retrip Off means that the re-trip function is not activated. CB Pos Check (circuit breaker position check) and Current means that a phase current must be larger than the operate level to allow re-trip. CB Pos Check (circuit breaker position check) and Contact means re-trip is done when circuit breaker is closed (breaker position is used). No CB Pos Check means re-trip is done without check of breaker position.

**BuTripMode**: Back-up trip mode is given to state sufficient current criteria to detect failure to break. For Current operation 2 out of 4 means that at least two currents, of the three phase-currents and the residual current, shall be high to indicate breaker failure. 1 out of 3 means that at least one current of the three phase-currents shall be high to indicate breaker failure. 1 out of 4

<table>
<thead>
<tr>
<th>RetripMode</th>
<th>FunctionMode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrip Off</td>
<td>N/A</td>
<td>The re-trip function is not activated</td>
</tr>
<tr>
<td>CB Pos Check</td>
<td>Current</td>
<td>A phase current must be larger than the operate level to allow re-trip</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>Re-trip is done when circuit breaker is closed (breaker position is used) and a long duration of a trip signal indicates breaker failure</td>
</tr>
<tr>
<td></td>
<td>Current&amp;Contact</td>
<td>Both methods are used</td>
</tr>
<tr>
<td>No CB Pos Check</td>
<td>Current</td>
<td>Re-trip is done without check of breaker position</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>Re-trip is done without check of breaker position</td>
</tr>
<tr>
<td></td>
<td>Current&amp;Contact</td>
<td>Both methods are used</td>
</tr>
</tbody>
</table>
means that at least one current of the three phase currents or the residual current shall be high to indicate breaker failure. In most applications 1 out of 3 is sufficient. For "Contact" operation means back-up trip is done when circuit breaker is closed (breaker position is used).

**Pickup_PH:** Current level for detection of breaker failure, set in % of \( IBase \). This parameter should be set so that faults with small fault current can be detected. The setting can be chosen in accordance with the most sensitive protection function to start the breaker failure protection. Typical setting is 10% of \( IBase \).

**Pickup_BlkCont:** If any contact based detection of breaker failure is used this function can be blocked if any phase current is larger than this setting level. If the FunctionMode is set "Current and Contact" breaker failure for high current faults are safely detected by the current measurement function. To increase security the contact based function should be disabled for high currents. The setting can be given within the range 5 – 200% of \( IBase \).

**Pickup_N:** Residual current level for detection of breaker failure set in % of \( IBase \). In high impedance grounded systems the residual current at phase to ground faults are normally much smaller than the short circuit currents. In order to detect breaker failure at single-phase ground faults in these systems it is necessary to measure the residual current separately. Also in effectively grounded systems the setting of the ground-fault current protection can be chosen to relatively low current level. The BuTripMode is set 1 out of 4. The current setting should be chosen in accordance to the setting of the sensitive ground fault protection. The setting can be given within the range 2 – 200 % of \( IBase \).

**t1:** Time delay of the re-trip. The setting can be given within the range 0 – 60 s in steps of 0.001 s. Typical setting is 0 – 50 ms.

**t2:** Time delay of the back-up trip. The choice of this setting is made as short as possible at the same time as unwanted operation must be avoided. Typical setting is 90 – 200 ms (also dependent of re-trip timer).

The minimum time delay for the re-trip can be estimated as:

\[
 t_2 \geq t_1 + t_{cbopen} + t_{BFP\_reset} + t_{margin}
\]

(Equation 44)

where:

- \( t_{cbopen} \) is the maximum opening time for the circuit breaker
- \( t_{BFP\_reset} \) is the maximum time for breaker failure protection to detect correct breaker function (the current criteria reset)
- \( t_{margin} \) is the safety margin

It is often required that the total fault clearance time shall be less than a given critical time. This time is often dependent of the ability to maintain transient stability in case of a fault close to a power plant.
Time

Protection operate time

The fault occurs

Normal $t_{\text{cbopen}}$

Retrip delay $t_1$

$t_{\text{cbopen}}$ after re-trip

$t_{\text{cbopen}}$

Retrip delay $t_1$

Margin

Minimum back-up trip delay $t_2$

Critical fault clearance time for stability

Trip and Pickup CSPRBRF

Figure 67: Time Sequence

6.11 Stub protection STBPTOC (50STB)

6.11.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stub protection</td>
<td>STBPTOC</td>
<td>$3I&gt;STUB$</td>
<td>50STB</td>
</tr>
</tbody>
</table>

6.11.2 Application

Stub protection STBPTOC (50STB) is a simple phase overcurrent protection, fed from the two current transformer groups feeding the object taken out of service. The stub protection is only activated when the disconnector of the object is open. STBPTOC (50STB) enables fast fault clearance of faults at the section between the CTs and the open disconnector.
6.11.3 Setting guidelines

The parameters for Stub protection STBPTOC (50STB) are set via the local HMI or PCM600.

The following settings can be done for the stub protection.

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

Operation: Disabled/Enabled

IPickup: Current level for the Stub protection, set in % of IBase. This parameter should be set so that all faults on the stub can be detected. The setting should thus be based on fault calculations.
6.12 Pole discrepancy protection CCRPLD (52PD)

6.12.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pole discrepancy protection</td>
<td>CCRPLD</td>
<td></td>
<td>52PD</td>
</tr>
</tbody>
</table>

6.12.2 Application

There is a risk that a circuit breaker will get discrepancy between the poles at circuit breaker operation: closing or opening. One pole can be open and the other two closed, or two poles can be open and one closed. Pole discrepancy of a circuit breaker will cause unsymmetrical currents in the power system. The consequence of this can be:

- Negative sequence currents that will give stress on rotating machines
- Zero sequence currents that might give unwanted operation of sensitive ground-fault protections in the power system.

It is therefore important to detect situations with pole discrepancy of circuit breakers. When this is detected the breaker should be tripped directly.

Pole discordance protection CCRPLD (52PD) will detect situation with deviating positions of the poles of the protected circuit breaker. The protection has two different options to make this detection:

- By connecting the auxiliary contacts in the circuit breaker so that logic is created and a signal can be sent to the pole discrepancy protection, indicating pole discrepancy.
- Each phase current through the circuit breaker is measured. If the difference between the phase currents is larger than a $\text{CurrUnsymPU}$ this is an indication of pole discrepancy, and the protection will operate.

6.12.3 Setting guidelines

The parameters for the Pole discrepancy protection CCRPLD (52PD) are set via the local HMI or PCM600.

The following settings can be done for the pole discrepancy protection.

Common base IED values for primary current ($\text{IBase}$), primary voltage ($\text{VBase}$) and primary power ($\text{SBase}$) are set in a Global base values for settings function GBASVAL. Setting $\text{GlobalBaseSel}$ is used to select a GBASVAL function for reference of base values.

*Operation: Disabled or Enabled*
**tTrip**: Time delay of the operation.

**ContactSel**: Operation of the contact based pole discrepancy protection. Can be set: *Disabled/PD signal from CB*. If *PD signal from CB* is chosen the logic to detect pole discrepancy is made in the vicinity to the breaker auxiliary contacts and only one signal is connected to the pole discrepancy function.

**CurrentSel**: Operation of the current based pole discrepancy protection. Can be set: *Disabled/CB oper monitor/Continuous monitor*. In the alternative *CB oper monitor* the function is activated only directly in connection to breaker open or close command (during 200 ms). In the alternative *Continuous monitor* function is continuously activated.

**CurrUnsymPU**: Unsymmetrical magnitude of lowest phase current compared to the highest, set in % of the highest phase current.

**CurrRelPU**: Current magnitude for release of the function in % of *IBase*.

---

### 6.13 Broken conductor check BRCPTOC (46)

#### 6.13.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken conductor check</td>
<td>BRCPTOC</td>
<td>-</td>
<td>46</td>
</tr>
</tbody>
</table>

#### 6.13.2 Application

Conventional protection functions cannot detect the broken conductor condition. Broken conductor check (BRCPTOC, 46) function, consisting of continuous current unsymmetrical check on the line where the IED connected will give alarm or trip at detecting broken conductors.

#### 6.13.3 Setting guidelines

Common base IED values for primary current (*IBase*), primary voltage (*VBase*) and primary power (*SBase*) are set in a Global base values for settings function GBASVAL. Setting *GlobalBaseSel* is used to select a GBASVAL function for reference of base values.

Broken conductor check BRCPTOC (46) must be set to detect open phase/s (series faults) with different loads on the line. BRCPTOC (46) must at the same time be set to not operate for maximum asymmetry which can exist due to, for example, not transposed power lines.

All settings are in primary values or percentage.

Set minimum operating level per phase *Pickup_PPH* to typically 10-20% of rated current.

Set the unsymmetrical current, which is relation between the difference of the minimum and maximum phase currents to the maximum phase current to typical *Pickup_ub = 50%*.
Note that it must be set to avoid problem with asymmetry under minimum operating conditions.

Set the time delay $t_{\text{Oper}} = 5 - 60$ seconds and reset time $t_{\text{Reset}} = 0.010 - 60.000$ seconds.

### 6.14 Directional over-/under-power protection GOPPDOP/GUPPDUP (32/37)

#### 6.14.1 Application

The task of a generator in a power plant is to convert mechanical energy available as a torque on a rotating shaft to electric energy.

Sometimes, the mechanical power from a prime mover may decrease so much that it does not cover bearing losses and ventilation losses. Then, the synchronous generator becomes a synchronous motor and starts to take electric power from the rest of the power system. This operating state, where individual synchronous machines operate as motors, implies no risk for the machine itself. If the generator under consideration is very large and if it consumes lots of electric power, it may be desirable to disconnect it to ease the task for the rest of the power system.

Often, the motoring condition may imply that the turbine is in a very dangerous state. The task of the reverse power protection is to protect the turbine and not to protect the generator itself.

Steam turbines easily become overheated if the steam flow becomes too low or if the steam ceases to flow through the turbine. Therefore, turbo-generators should have reverse power protection. There are several contingencies that may cause reverse power: break of a main steam pipe, damage to one or more blades in the steam turbine or inadvertent closing of the main stop valves. In the last case, it is highly desirable to have a reliable reverse power protection. It may prevent damage to an otherwise undamaged plant.

During the routine shutdown of many thermal power units, the reverse power protection gives the tripping impulse to the generator breaker (the unit breaker). By doing so, one prevents the disconnection of the unit before the mechanical power has become zero. Earlier disconnection would cause an acceleration of the turbine generator at all routine shutdowns. This should have caused overspeed and high centrifugal stresses.

When the steam ceases to flow through a turbine, the cooling of the turbine blades will disappear. Now, it is not possible to remove all heat generated by the windage losses. Instead, the heat will increase the temperature in the steam turbine and especially of the blades. When a steam turbine rotates without steam supply, the electric power consumption will be about 2% of rated power. Even if the turbine rotates in vacuum, it will soon become overheated and damaged. The turbine overheats within minutes if the turbine loses the vacuum.

The critical time to overheating of a steam turbine varies from about 0.5 to 30 minutes depending on the type of turbine. A high-pressure turbine with small and thin blades will become overheated more easily than a low-pressure turbine with long and heavy blades. The conditions vary from turbine to turbine and it is necessary to ask the turbine manufacturer in each case.

Power to the power plant auxiliaries may come from a station service transformer connected to the primary side of the step-up transformer. Power may also come from a start-up service transformer connected to the external network. One has to design the reverse power protection...
so that it can detect reverse power independent of the flow of power to the power plant auxiliaries.

Hydro turbines tolerate reverse power much better than steam turbines do. Only Kaplan turbine and bulb turbines may suffer from reverse power. There is a risk that the turbine runner moves axially and touches stationary parts. They are not always strong enough to withstand the associated stresses.

Ice and snow may block the intake when the outdoor temperature falls far below zero. Branches and leaves may also block the trash gates. A complete blockage of the intake may cause cavitations. The risk for damages to hydro turbines can justify reverse power protection in unattended plants.

A hydro turbine that rotates in water with closed wicket gates will draw electric power from the rest of the power system. This power will be about 10% of the rated power. If there is only air in the hydro turbine, the power demand will fall to about 3%.

Diesel engines should have reverse power protection. The generator will take about 15% of its rated power or more from the system. A stiff engine may require perhaps 25% of the rated power to motor it. An engine that is well run in might need no more than 5%. It is necessary to obtain information from the engine manufacturer and to measure the reverse power during commissioning.

Gas turbines usually do not require reverse power protection.

Figure 69 illustrates the reverse power protection with underpower protection and with overpower protection. The underpower protection gives a higher margin and should provide better dependability. On the other hand, the risk for unwanted operation immediately after synchronization may be higher. One should set the underpower protection to trip if the active power from the generator is less than about 2%. One should set the overpower protection to trip if the power flow from the network to the generator is higher than 1%.

Figure 69: Reverse power protection with underpower or overpower protection

6.14.2 Directional overpower protection GOPPDOP (32)
6.14.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional overpower protection</td>
<td>GOPPDOP</td>
<td></td>
<td>32</td>
</tr>
</tbody>
</table>

6.14.2.2 Setting guidelines

Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

**Operation:** With the parameter Operation the function can be set Enabled/ Disabled.

**Mode:** The voltage and current used for the power measurement. The setting possibilities are shown in table 23.

For reverse power applications PosSeq or Arone modes are strongly recommended.

Table 23: Complex power calculation

<table>
<thead>
<tr>
<th>Set value Mode</th>
<th>Formula used for complex power calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A,B,C$</td>
<td>$\bar{S} = \bar{V}_A \cdot \bar{I}_A^* + \bar{V}_B \cdot \bar{I}_B^* + \bar{V}_C \cdot \bar{I}_C^*$ (Equation 45)</td>
</tr>
<tr>
<td>Arone</td>
<td>$\bar{S} = \bar{V}_{AB} \cdot \bar{I}<em>A^* - \bar{V}</em>{BC} \cdot \bar{I}_C^*$ (Equation 46)</td>
</tr>
<tr>
<td>PosSeq</td>
<td>$\bar{S} = 3 \cdot \bar{V}<em>{PosSeq} \cdot \bar{I}</em>{PosSeq}^*$ (Equation 47)</td>
</tr>
<tr>
<td>$A,B$</td>
<td>$\bar{S} = \bar{V}_{AB} \cdot (\bar{I}_A^* - \bar{I}_B^*)$ (Equation 48)</td>
</tr>
<tr>
<td>$B,C$</td>
<td>$\bar{S} = \bar{V}_{BC} \cdot (\bar{I}_B^* - \bar{I}_C^*)$ (Equation 49)</td>
</tr>
<tr>
<td>$C,A$</td>
<td>$\bar{S} = \bar{V}_{CA} \cdot (\bar{I}_C^* - \bar{I}_A^*)$ (Equation 50)</td>
</tr>
</tbody>
</table>

Table continues on next page
### Set value Mode | Formula used for complex power calculation
--- | ---
A | $S = 3 \cdot V_A^* I_A^*$
(B) | $S = 3 \cdot V_B^* I_B^*$
(C) | $S = 3 \cdot V_C^* I_C^*$

(Equation 51)

(Equation 52)

(Equation 53)

The function has two stages with the same setting parameters.

**OpMode1(2)** is set to define the function of the stage. Possible settings are:

*Enabled:* the stage is activated

*Disabled:* the stage is disabled

The function gives trip if the power component in the direction defined by the setting **Angle1(2)** is larger than the set pick up power value **Power1(2)**

![Figure 70: Overpower mode](en06000440.vsd)

*Figure 70: Overpower mode*

The setting **Power1(2)** gives the power component pick up value in the **Angle1(2)** direction. The setting is given in p.u. of the generator rated power, see equation 54.
Minimum recommended setting is 1.0% of $S_N$. Note also that at the same time the minimum IED pickup current shall be bigger than 9mA secondary.

$$S_N = \sqrt{3} \cdot V_{\text{Base}} \cdot I_{\text{Base}}$$

(Equation 54)

The setting $\text{Angle1}(2)$ gives the characteristic angle giving maximum sensitivity of the power protection function. The setting is given in degrees. For active power the set angle should be 0° or 180°. 180° should be used for generator reverse power protection in 50Hz network while -179.5° should be used for generator reverse power protection in 60Hz network. This angle adjustment in 60Hz networks will improve accuracy of the power function.

Figure 71: For reverse power the set angle should be 180° in the overpower function $\text{TripDelay1}(2)$ is set in seconds to give the time delay for trip of the stage after pick up.

The possibility to have low pass filtering of the measured power can be made as shown in the formula:
\[ S = TD \cdot S_{\text{old}} + (1 - TD) \cdot S_{\text{Calculated}} \]

(Equation 55)

Where

- \( S \) is a new measured value to be used for the protection function
- \( S_{\text{old}} \) is the measured value given from the function in previous execution cycle
- \( S_{\text{Calculated}} \) is the new calculated value in the present execution cycle
- \( TD \) is settable parameter

The value of \( TD = 0.98 \) or even \( TD = 0.99 \) is recommended in generator reverse power applications as the trip delay is normally quite long. This filtering will improve accuracy of the power function.

### 6.14.3 Directional underpower protection GUPPDUP (37)

#### 6.14.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional underpower protection</td>
<td>GUPPDUP</td>
<td></td>
<td>37</td>
</tr>
</tbody>
</table>

#### 6.14.3.2 Setting guidelines

Common base IED values for primary current (\( I_{\text{Base}} \)), primary voltage (\( V_{\text{Base}} \)) and primary power (\( S_{\text{Base}} \)) are set in a Global base values for settings function GBASVAL. Setting \( \text{GlobalBaseSel} \) is used to select a GBASVAL function for reference of base values.

**Operation**: With the parameter *Operation* the function can be set *Enabled/Disabled*.

**Mode**: The voltage and current used for the power measurement. The setting possibilities are shown in table 24.

For reverse power applications *PosSeq* or *Arone* modes are strongly recommended.
### Table 24: Complex power calculation

<table>
<thead>
<tr>
<th>Set value Mode</th>
<th>Formula used for complex power calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, C</td>
<td>$\vec{S} = \vec{V}_A \cdot \vec{I}_A^* + \vec{V}_B \cdot \vec{I}_B^* + \vec{V}_C \cdot \vec{I}_C^*$ (Equation 56)</td>
</tr>
<tr>
<td>Arone</td>
<td>$\vec{S} = \vec{V}_{AB} \cdot \vec{I}<em>A^* - \vec{V}</em>{BC} \cdot \vec{I}_C^*$ (Equation 57)</td>
</tr>
<tr>
<td>PosSeq</td>
<td>$\vec{S} = 3 \cdot \vec{I}<em>{PosSeq} \cdot \vec{I}</em>{PosSeq}^*$ (Equation 58)</td>
</tr>
<tr>
<td>AB</td>
<td>$\vec{S} = \vec{V}_{AB} \cdot (\vec{I}_A^* - \vec{I}_B^*)$ (Equation 59)</td>
</tr>
<tr>
<td>BC</td>
<td>$\vec{S} = \vec{V}_{BC} \cdot (\vec{I}_B^* - \vec{I}_C^*)$ (Equation 60)</td>
</tr>
<tr>
<td>CA</td>
<td>$\vec{S} = \vec{V}_{CA} \cdot (\vec{I}_C^* - \vec{I}_A^*)$ (Equation 61)</td>
</tr>
<tr>
<td>A</td>
<td>$\vec{S} = 3 \cdot \vec{V}_A \cdot \vec{I}_A^*$ (Equation 62)</td>
</tr>
<tr>
<td>B</td>
<td>$\vec{S} = 3 \cdot \vec{V}_B \cdot \vec{I}_B^*$ (Equation 63)</td>
</tr>
<tr>
<td>C</td>
<td>$\vec{S} = 3 \cdot \vec{V}_C \cdot \vec{I}_C^*$ (Equation 64)</td>
</tr>
</tbody>
</table>

The function has two stages with the same setting parameters.

**OpMode(2)** is set to define the function of the stage. Possible settings are:

- **Enabled**: the stage is activated. **Disabled**: the stage is disabled

The function gives trip if the power component in the direction defined by the setting **Angle(2)** is smaller than the set pick up power value **Power(2)**
**Figure 72: Underpower mode**

The setting \( \text{Power1(2)} \) gives the power component pick up value in the \( \text{Angle1(2)} \) direction. The setting is given in p.u. of the generator rated power, see equation 65.

Minimum recommended setting is 1.0% of \( S_N \). At the same time the minimum IED pickup current shall be bigger than 9mA secondary.

\[
S_N = \sqrt{3} \cdot V_{\text{Base}} \cdot I_{\text{Base}}
\]  

(Equation 65)

The setting \( \text{Angle1(2)} \) gives the characteristic angle giving maximum sensitivity of the power protection function. The setting is given in degrees. For active power the set angle should be 0° or 180°. 0° should be used for generator low forward active power protection.
Figure 73: For low forward power the set angle should be \( 0^\circ \) in the underpower function. 

TripDelay1(2) is set in seconds to give the time delay for trip of the stage after pick up.

The possibility to have low pass filtering of the measured power can be made as shown in the formula:

\[
S = TD \cdot S_{old} + (1 - TD) \cdot S_{calculated}
\]

(Equation 66)

Where

- \( S \) is a new measured value to be used for the protection function
- \( S_{old} \) is the measured value given from the function in previous execution cycle
- \( S_{calculated} \) is the new calculated value in the present execution cycle
- \( TD \) is settable parameter

The value of \( TD=0.98 \) or even \( TD=0.99 \) is recommended in generator low forward power applications as the trip delay is normally quite long. This filtering will improve accuracy of the power function.
6.15 Negative sequence based overcurrent function DNSPTOC (46)

6.15.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative sequence based overcurrent function</td>
<td>DNSPTOC</td>
<td></td>
<td>46</td>
</tr>
</tbody>
</table>

6.15.2 Application

Negative sequence based overcurrent function (DNSPTOC, 46) may be used in power line applications where the reverse zero sequence source is weak or open, the forward source impedance is strong and it is desired to detect forward ground faults.

Additionally, it is applied in applications on underground cables, where zero sequence impedance depends on the fault current return paths, but the cable negative sequence impedance is practically constant.

The directional function is current and voltage polarized. The function can be set to forward, reverse or non-directional independently for each step.

DNSPTOC (46) protects against all unbalanced faults including phase-to-phase faults. The minimum pickup current of the function must be set to above the normal system unbalance level in order to avoid unintentional tripping.

6.15.3 Setting guidelines

Below is an example of Negative sequence based overcurrent function (DNSPTOC, 46) used as a sensitive ground-fault protection for power lines. The following settings must be done in order to ensure proper operation of the protection:

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

- setting RCADir to value +65 degrees, that is, the negative sequence current typically lags the inverted negative sequence voltage for this angle during the fault
- setting ROADir to value 90 degrees
- setting LowVolt_VM to value 2%, that is, the negative sequence voltage level above which the directional element will be enabled
- setting Operation_OC1 to Enabled
- setting PickupCurr_OC1 to value between 3-10%, (typical values)
- setting tDef_OC1 to insure proper time coordination with other ground-fault protections installed in the vicinity of this power line
• setting DirMode_OC1 to Forward
• setting DirPrinc_OC1 to IcosPhi&V
• setting ActLowVolt1_VM to Block

DNSPTOC (46) is used in directional comparison protection scheme for the power line protection, when communication channels to the remote end of this power line are available. In that case, two negative sequence overcurrent steps are required - one in forward and another in reverse direction. The OC1 stage is used to detect faults in forward direction and the OC2 stage is used to detect faults in reverse direction.

However, the following must be noted for such application:

• setting RCADir and ROADir are applicable for both steps OC1 and OC2
• setting DirMode_OC1 must be set to Forward
• setting DirMode_OC2 must be set to Reverse
• setting PickupCurr_OC2 must be made more sensitive than pickup value of the forward OC1 element, that is, typically 60% of PickupCurr_OC1 set pickup level in order to insure proper operation of the directional comparison scheme during current reversal situations
• the start signals PU_OC1 and PU_OC2 from OC1 and OC2 elements is used to send forward and reverse signals to the remote end of the power line
• the available scheme communications function block within IED is used between the protection function and the teleprotection communication equipment, in order to insure proper conditioning of the above two start signals.
Section 7 Voltage protection

7.1 Two step undervoltage protection UV2PTUV (27)

7.1.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two step undervoltage protection</td>
<td>UV2PTUV</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>2U&lt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.1.2 Application

Two-step undervoltage protection function (UV2PTUV, 27) is applicable in all situations, where reliable detection of low phase voltages is necessary. It is used also as a supervision and fault detection function for other protection functions, to increase the security of a complete protection system.

UV2PTUV (27) is applied to power system elements, such as generators, transformers, motors and power lines in order to detect low voltage conditions. Low voltage conditions are caused by abnormal operation or fault in the power system. UV2PTUV (27) is used in combination with overcurrent protections, either as restraint or in logic “and gates” of the trip signals issued by the two functions. Other applications are the detection of “no voltage” condition, for example, before the energization of a HV line or for automatic breaker trip in case of a blackout. UV2PTUV (27) is also used to initiate voltage correction measures, like insertion of shunt capacitor banks to compensate for reactive load and thereby increasing the voltage. The function has a high measuring accuracy to allow applications to control reactive load.

UV2PTUV (27) is used to disconnect from the network apparatuses, like electric motors, which will be damaged when subject to service under low voltage conditions. UV2PTUV (27) deals with low voltage conditions at power system frequency, which can be caused by the following reasons:

1. Malfunctioning of a voltage regulator or wrong settings under manual control (symmetrical voltage decrease).
2. Overload (symmetrical voltage decrease).
3. Short circuits, often as phase-to-ground faults (unsymmetrical voltage decrease).

UV2PTUV (27) prevents sensitive equipment from running under conditions that could cause their overheating and thus shorten their life time expectancy. In many cases, it is a useful function in circuits for local or remote automation processes in the power system.
7.1.3 Setting guidelines

The parameters for Two step undervoltage protection UV2PTUV (27) are set via the local HMI or PCM600.

All the voltage conditions in the system where UV2PTUV (27) performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general undervoltage functions are used. All voltage related settings are made as a percentage of the global settings base voltage $V_{Base}$, which normally is set to the primary nominal voltage level (phase-to-phase) of the power system or the high voltage equipment under consideration.

The setting for UV2PTUV (27) is normally not critical, since there must be enough time available for the main protection to clear short circuits and ground faults.

Some applications and related setting guidelines for the voltage level are described in the following sections.

7.1.3.1 Equipment protection, such as for motors and generators

The setting must be below the lowest occurring "normal" voltage and above the lowest acceptable voltage for the equipment.

7.1.3.2 Disconnected equipment detection

The setting must be below the lowest occurring "normal" voltage and above the highest occurring voltage, caused by inductive or capacitive coupling, when the equipment is disconnected.

7.1.3.3 Power supply quality

The setting must be below the lowest occurring "normal" voltage and above the lowest acceptable voltage, due to regulation, good practice or other agreements.

7.1.3.4 Voltage instability mitigation

This setting is very much dependent on the power system characteristics, and thorough studies have to be made to find the suitable levels.

7.1.3.5 Backup protection for power system faults

The setting must be below the lowest occurring "normal" voltage and above the highest occurring voltage during the fault conditions under consideration.

7.1.3.6 Settings for Two step undervoltage protection

The following settings can be done for two step undervoltage protection (UV2PTUV,27).
Common base IED values for primary current ($i_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function $GBASVAL$. Setting $GlobalBaseSel$ is used to select a $GBASVAL$ function for reference of base values.

$ConnType$: Sets whether the measurement shall be phase-to-ground fundamental value, phase-to-phase fundamental value, phase-to-ground RMS value or phase-to-phase RMS value.

$Operation$: $Disabled/Enabled$.

$UV2PTUV$ (27) measures selectively phase-to-ground voltages, or phase-to-phase voltage chosen by the setting $ConnType$.

This means operation for phase-to-ground voltage if:

$$V < (\% \cdot V_{Base}(kV))/\sqrt{3}$$

(Equation 67)

and operation for phase-to-phase voltage if:

$$V_{pickup} < (\% \cdot V_{Base}(kV))$$

(Equation 68)

$Characteristic1$: This parameter gives the type of time delay to be used for step 1. The setting can be $Definite time/Inverse Curve A/Inverse Curve B$. The choice is highly dependent of the protection application.

$OpModen$: This parameter describes how many of the three measured voltages that should be below the set level to give operation for step $n$ ($n=step \ 1 \ and \ 2$). The setting can be $1 \ out \ of \ 3, \ 2 \ out \ of \ 3 \ or \ 3 \ out \ of \ 3$. In most applications it is sufficient that one phase voltage is low to give operation. If the function shall be insensitive for single phase-to-ground faults $2 \ out \ of \ 3$ can be chosen.

$Pickupn$: Set operate undervoltage operation value for step $n$ ($n=step \ 1 \ and \ 2$), given as % of the global parameter $V_{Base}$. The setting is highly dependent of the protection application. Here it is essential to consider the minimum voltage at non-faulted situations. Normally this voltage is larger than 90% of nominal voltage.

$tn$: time delay for step $n$ ($n=step \ 1 \ and \ 2$), given in s. The setting is highly dependent of the protection application. In many applications the protection function shall not directly trip in case of short circuits or ground faults in the system. The time delay must be coordinated to the short circuit protections.

$t1Min$: Minimum operation time for inverse time characteristic for step 1, given in s. For very low voltages the undervoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting $t1Min$ longer than the operation time for other protections such unselective tripping can be avoided.

$TD1$: Time multiplier for inverse time characteristic. This parameter is used for coordination between different inverse time delayed undervoltage protections.

The function must be externally blocked when the protected object is disconnected.
7.2 Two step overvoltage protection OV2PTOV (59)

7.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two step overvoltage protection</td>
<td>OV2PTOV</td>
<td></td>
<td>2U&gt; 59</td>
</tr>
</tbody>
</table>

7.2.2 Application

Two step overvoltage protection OV2PTOV (59) is applicable in all situations, where reliable detection of high voltage is necessary. OV2PTOV (59) is used for supervision and detection of abnormal conditions, which, in combination with other protection functions, increase the security of a complete protection system.

High voltage conditions are caused by abnormal situations in the power system. OV2PTOV (59) is applied to power system elements, such as generators, transformers, motors and power lines in order to detect high voltage conditions. OV2PTOV (59) is used in combination with low current signals, to identify a transmission line, open in the remote end. In addition to that, OV2PTOV (59) is also used to initiate voltage correction measures, like insertion of shunt reactors, to compensate for low load, and thereby decreasing the voltage. The function has a high measuring accuracy and setting hysteresis to allow applications to control reactive load.

OV2PTOV (59) is used to disconnect, from the network, apparatuses, like electric motors, which will be damaged when subject to service under high voltage conditions. It deals with high voltage conditions at power system frequency, which can be caused by:

1. Different kinds of faults, where a too high voltage appears in a certain power system, like metallic connection to a higher voltage level (broken conductor falling down to a crossing overhead line, transformer flash over fault from the high voltage winding to the low voltage winding and so on).
2. Malfunctioning of a voltage regulator or wrong settings under manual control (symmetrical voltage decrease).
3. Low load compared to the reactive power generation (symmetrical voltage decrease).
4. Ground-faults in high impedance grounded systems causes, beside the high voltage in the neutral, high voltages in the two non-faulted phases, (unsymmetrical voltage increase).

OV2PTOV (59) prevents sensitive equipment from running under conditions that could cause their overheating or stress of insulation material, and, thus, shorten their life time expectancy. In many cases, it is a useful function in circuits for local or remote automation processes in the power system.
7.2.3 Setting guidelines

The parameters for Two step overvoltage protection (OV2PTOV, 59) are set via the local HMI or PCM600.

All the voltage conditions in the system where OV2PTOV (59) performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general overvoltage functions are used. All voltage related settings are made as a percentage of a settable base primary voltage, which normally is set to the nominal voltage level (phase-to-phase) of the power system or the high voltage equipment under consideration.

The time delay for the OV2PTOV (59) can sometimes be critical and related to the size of the overvoltage - a power system or a high voltage component can withstand smaller overvoltages for some time, but in case of large overvoltages the related equipment should be disconnected more rapidly.

Some applications and related setting guidelines for the voltage level are given below:

**Equipment protection, such as for motors, generators, reactors and transformers**

High voltage can cause overexcitation of the core and deteriorate the winding insulation. The setting must be above the highest occurring "normal" voltage and below the highest acceptable voltage for the equipment.

**Equipment protection, capacitors**

High voltage can deteriorate the dielectricum and the insulation. The setting must be above the highest occurring "normal" voltage and below the highest acceptable voltage for the capacitor.

**High impedance grounded systems**

In high impedance grounded systems, ground-faults cause a voltage increase in the non-faulty phases. OV2PTOV (59) can be used to detect such faults. The setting must be above the highest occurring "normal" voltage and below the lowest occurring voltage during faults. A metallic single-phase ground-fault causes the non-faulted phase voltages to increase a factor of $\sqrt{3}$.

**The following settings can be done for Two step overvoltage protection**

Common base IED values for primary current ($I_{\text{Base}}$), primary voltage ($V_{\text{Base}}$) and primary power ($S_{\text{Base}}$) are set in a Global base values for settings function GBASVAL. Setting $\text{GlobalBaseSel}$ is used to select a GBASVAL function for reference of base values.

- **ConnType**: Sets whether the measurement shall be phase-to-ground fundamental value, phase-to-phase fundamental value, phase-to-ground RMS value or phase-to-phase RMS value.

- **Operation**: Disabled/Enabled.

OV2PTOV (59) measures the phase-to-ground voltages, or phase-to-phase voltages as selected. The function will operate if the voltage gets higher than the set percentage of the global set base voltage $V_{\text{Base}}$. This means operation for phase-to-ground voltage over:
\[ V < \left( \% \right) \cdot V_{\text{Base}}(kV) / \sqrt{3} \]

(Equation 69)

and operation for phase-to-phase voltage over:

\[ V_{\text{pickup}} > \left( \% \right) \cdot V_{\text{Base}}(kV) \]

(Equation 70)

**Characteristic**: This parameter gives the type of time delay to be used. The setting can be *Definite time/Inverse Curve A/Inverse Curve B/Inverse Curve C*. The choice is highly dependent of the protection application.

**OpModen**: This parameter describes how many of the three measured voltages that should be above the set level to give operation for step n (n=step 1 and 2). The setting can be *1 out of 3, 2 out of 3 or 3 out of 3*. In most applications it is sufficient that one phase voltage is high to give operation. If the function shall be insensitive for single phase-to-ground faults *3 out of 3* can be chosen, because the voltage will normally rise in the non-faulted phases at single phase-to-ground faults.

**Pickupn**: Set operate overvoltage operation value for step n (n=step 1 and 2), given as % of the global parameter *VBase*. The setting is highly dependent of the protection application. Here it is essential to consider the Maximum voltage at non-faulted situations. Normally this voltage is less than 110% of nominal voltage.

\[ t_n: \text{time delay for step } n \ (n=\text{step } 1 \text{ and } 2), \text{given in s.} \]

The setting is highly dependent of the protection application. In many applications the protection function has the task to prevent damages to the protected object. The speed might be important for example in case of protection of transformer that might be overexcited. The time delay must be co-ordinated with other automated actions in the system.

\[ t1_{\text{Min}}: \text{Minimum operation time for inverse time characteristic for step } 1, \text{given in s.} \]

For very high voltages the overvoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting *t1_{\text{Min}}* longer than the operation time for other protections such unselective tripping can be avoided.

**TD1**: Time multiplier for inverse time characteristic. This parameter is used for co-ordination between different inverse time delayed undervoltage protections.

### 7.3 Two step residual overvoltage protection ROV2PTOV (59N)

#### 7.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<tr>
<td>Two step residual overvoltage protection</td>
<td>ROV2PTOV</td>
<td>3U0&gt;</td>
<td>59N</td>
</tr>
</tbody>
</table>
7.3.2 Application

Two step residual overvoltage protection ROV2PTOV (59N) is primarily used in high impedance grounded distribution networks, mainly as a backup for the primary ground-fault protection of the feeders and the transformer. To increase the security for different ground-fault related functions, the residual overvoltage signal can be used as a release signal. The residual voltage can be measured either at the transformer neutral or from a voltage transformer open delta connection. The residual voltage can also be calculated internally, based on measurement of the three-phase voltages.

In high impedance grounded systems the system neutral voltage, that is, the residual voltage, will increase in case of any fault connected to ground. Depending on the type of fault and fault resistance the residual voltage will reach different values. The highest residual voltage, equal to three times the phase-to-ground voltage, is achieved for a single phase-to-ground fault. The residual voltage increases approximately the same amount in the whole system and does not provide any guidance in finding the faulted component. Therefore, ROV2PTOV (59N) is often used as a backup protection or as a release signal for the feeder ground-fault protection.

7.3.3 Setting guidelines

The parameters for Two step residual overvoltage protection ROV2PTOV (59N) are set via the local HMI or PCM600.

All the voltage conditions in the system where ROV2PTOV (59N) performs its functions should be considered. The same also applies to the associated equipment, its voltage and time characteristic.

There is a very wide application area where general single input or residual overvoltage functions are used. All voltage related settings are made as a percentage of a settable base voltage, which can be set to the primary nominal voltage (phase-phase) level of the power system or the high voltage equipment under consideration.

The time delay for ROV2PTOV (59N) are seldom critical, since residual voltage is related to ground-faults in a high impedance grounded system, and enough time must normally be given for the primary protection to clear the fault. In some more specific situations, where the single overvoltage protection is used to protect some specific equipment, the time delay is shorter.

Some applications and related setting guidelines for the residual voltage level are given below.

7.3.3.1 Power supply quality

The setting must be above the highest occurring “normal” residual voltage and below the highest acceptable residual voltage, due to regulation, good practice or other agreements.

7.3.3.2 High impedance grounded systems

In high impedance grounded systems, ground faults cause a neutral voltage in the feeding transformer neutral. Two step residual overvoltage protection ROV2PTOV (59N) is used to trip the transformer, as a backup protection for the feeder ground-fault protection, and as a backup for the transformer primary ground-fault protection. The setting must be above the highest occurring “normal” residual voltage, and below the lowest occurring residual voltage during the faults under consideration. A metallic single-phase ground fault causes a transformer neutral to reach a voltage equal to the normal phase-to-ground voltage.
The voltage transformers measuring the phase-to-ground voltages measure zero voltage in the faulty phase. The two healthy phases will measure full phase-to-phase voltage, as the ground is available on the faulty phase and the neutral has a full phase-to-ground voltage. The residual overvoltage will be three times the phase-to-ground voltage. See Figure 74.

Figure 74: Non-effectively grounded systems

7.3.3.3 Direct grounded system

In direct grounded systems, an ground-fault on one phase indicates a voltage collapse in that phase. The two healthy phases will have normal phase-to-ground voltages. The residual sum will have the same value as phase-to-ground voltage. See Figure 75.
7.3.3.4 Settings for Two step residual overvoltage protection

Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting $GlobalBaseSel$ is used to select a GBASVAL function for reference of base values.

**Operation: Disabled or Enabled**

$V_{Base}$ is used as voltage reference for the voltage. The voltage can be fed to the IED in different ways:

1. The IED is fed from a normal voltage transformer group where the residual voltage is created from the phase-to-ground voltages within the protection software.
2. The IED is fed from a broken delta connection normal voltage transformer group. In an open delta connection the protection is fed by the voltage 3V0 (single input). The setting chapter in the application manual explains how the analog input needs to be set.
3. The IED is fed from a single voltage transformer connected to the neutral point of a power transformer in the power system. In this connection the protection is fed by the voltage VN=V0 (single input). The setting chapter in the application manual explains how the analog input needs to be set. $ROV2PTOV$ (59N) will measure the residual voltage corresponding nominal phase-to-ground voltage for high impedance grounded system. The measurement will be based on the neutral voltage displacement.

**Characteristic1:** This parameter gives the type of time delay to be used. The setting can be, *Definite time or Inverse curve A or Inverse curve B or Inverse curve C*. The choice is highly dependent of the protection application.
**Pickup**: Set operate overvoltage operation value for step \( n \) (\( n = \) step 1 and 2), given as \( \% \) of residual voltage corresponding to global set parameter \( V_{\text{Base}} \):

\[
V > \left( \% \right) \cdot V_{\text{Base}} \left( kV \right) / \sqrt{3}
\]

The setting is dependent of the required sensitivity of the protection and the system grounding. In non-effectively grounded systems the residual voltage can be maximum the rated phase-to-ground voltage, which should correspond to 100%.

In effectively grounded systems this value is dependent of the ratio \( Z_0/Z_1 \). The required setting to detect high resistive ground-faults must be based on network calculations.

\( t_n \): time delay of step \( n \) (\( n = \) step 1 and 2), given in s. The setting is highly dependent of the protection application. In many applications, the protection function has the task to prevent damages to the protected object. The speed might be important for example in case of protection of transformer that might be overexcited. The time delay must be co-ordinated with other automated actions in the system.

\( t_{1\text{Min}} \): Minimum operation time for inverse time characteristic for step 1, given in s. For very high voltages the overvoltage function, using inverse time characteristic, can give very short operation time. This might lead to unselective trip. By setting \( t_{1\text{Min}} \) longer than the operation time for other protections such unselective tripping can be avoided.

\( TD_1 \): Time multiplier for inverse time characteristic. This parameter is used for co-ordination between different inverse time delayed undervoltage protections.

## 7.4 Loss of voltage check LOVPTUV (27)

### 7.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of voltage check</td>
<td>LOVPTUV</td>
<td>-</td>
<td>27</td>
</tr>
</tbody>
</table>

### 7.4.2 Application

The trip of the circuit breaker at a prolonged loss of voltage at all the three phases is normally used in automatic restoration systems to facilitate the system restoration after a major blackout. Loss of voltage check (LOVPTUV, 27) generates a TRIP signal only if the voltage in all the three phases is low for more than the set time. If the trip to the circuit breaker is not required, LOVPTUV (27) is used for signallization only through an output contact or through the event recording function.

### 7.4.3 Setting guidelines

Loss of voltage check (LOVPTUV, 27) is in principle independent of the protection functions. It requires to be set to open the circuit breaker in order to allow a simple system restoration following a main voltage loss of a big part of the network and only when the voltage is lost with breakers still closed.
Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting $Global\text{BaseSel}$ is used to select a GBASVAL function for reference of base values.

All settings are in primary values or per unit. Set operating level per phase to typically 70% of the global parameter $V_{Base}$ level. Set the time delay $t_{Trip}$=5-20 seconds.

7.4.4 **Advanced users settings**

For advanced users the following parameters need also to be set. Set the length of the trip pulse to typical $t_{Pulse}$=0.15 sec. Set the blocking time $t_{Block}$ to block Loss of voltage check (LOVPTUV, 27), if some but not all voltage are low, to typical 5.0 seconds and set the time delay for enabling the function after restoration $t_{Restore}$ to 3 - 40 seconds.
Section 8 Frequency protection

8.1 Underfrequency protection SAPTUF (81)

8.1.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<tbody>
<tr>
<td>Underfrequency protection</td>
<td>SAPTUF</td>
<td></td>
<td>81</td>
</tr>
</tbody>
</table>

8.1.2 Application

Underfrequency protection SAPTUF (81) is applicable in all situations, where reliable detection of low fundamental power system voltage frequency is needed. The power system frequency, and rate of change of frequency, is a measure of the unbalance between the actual generation and the load demand. Low fundamental frequency in a power system indicates that the available generation is too low to fully supply the power demanded by the load connected to the power grid. SAPTUF (81) detects such situations and provides an output signal, suitable for load shedding, generator boosting, HVDC-set-point change, gas turbine start up and so on. Sometimes shunt reactors are automatically switched in due to low frequency, in order to reduce the power system voltage and hence also reduce the voltage dependent part of the load. SAPTUF (81) is very sensitive and accurate and is used to alert operators that frequency has slightly deviated from the set-point, and that manual actions might be enough. The underfrequency signal is also used for overexcitation detection. This is especially important for generator step-up transformers, which might be connected to the generator but disconnected from the grid, during a roll-out sequence. If the generator is still energized, the system will experience overexcitation, due to the low frequency.

8.1.3 Setting guidelines

The parameters for underfrequency protection SAPTUF (81) are set via the local HMI or Protection and Control IED Manager (PCM600).

All the frequency and voltage magnitude conditions in the system where SAPTUF (81) performs its functions should be considered. The same also applies to the associated equipment, its frequency and time characteristic.

There are especially two application areas for SAPTUF (81):

1. to protect equipment against damage due to low frequency, such as generators, transformers, and motors. Overexcitation is also related to low frequency
2. to protect a power system, or a part of a power system, against breakdown, by shedding load, in generation deficit situations.
The under frequency PICKUP value is set in Hz. All voltage magnitude related settings are made as a percentage of a global base voltage parameter.

SAPTUF (81) is not instantaneous, since the frequency is related to movements of the system inertia, but the time and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Some applications and related setting guidelines for the frequency level are given below:

**Equipment protection, such as for motors and generators**

The setting has to be well below the lowest occurring “normal” frequency and well above the lowest acceptable frequency for the equipment.

**Power system protection, by load shedding**

The setting has to be below the lowest occurring “normal” frequency and well above the lowest acceptable frequency for power stations, or sensitive loads. The setting level, the number of levels and the distance between two levels (in time and/or in frequency) depends very much on the characteristics of the power system under consideration. The size of the “largest loss of production” compared to “the size of the power system” is a critical parameter. In large systems, the load shedding can be set at a fairly high frequency level, and the time delay is normally not critical. In smaller systems the frequency PICKUP level has to be set at a lower value, and the time delay must be rather short.

### 8.2 Overfrequency protection SAPTOF (81)

#### 8.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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</thead>
<tbody>
<tr>
<td>Overfrequency protection</td>
<td>SAPTOF</td>
<td></td>
<td>81</td>
</tr>
</tbody>
</table>

#### 8.2.2 Application

Overfrequency protection function SAPTOF (81) is applicable in all situations, where reliable detection of high fundamental power system voltage frequency is needed. The power system frequency, and rate of change of frequency, is a measure of the unbalance between the actual generation and the load demand. High fundamental frequency in a power system indicates that the available generation is too large compared to the power demanded by the load connected to the power grid. SAPTOF (81) detects such situations and provides an output signal, suitable for generator shedding, HVDC-set-point change and so on. SAPTOF (81) is very sensitive and accurate and can also be used to alert operators that frequency has slightly deviated from the set-point, and that manual actions might be enough.
8.2.3 Setting guidelines

The parameters for Overfrequency protection (SAPTOF, 81) are set via local HMI or PCM600.

All the frequency and voltage magnitude conditions in the system where SAPTOF (81) performs its functions must be considered. The same also applies to the associated equipment, its frequency and time characteristic.

There are especially two application areas for SAPTOF (81):

1. to protect equipment against damage due to high frequency, such as generators, and motors
2. to protect a power system, or a part of a power system, against breakdown, by shedding generation, in generation surplus situations.

The overfrequency pickup value is set in Hz. All voltage magnitude related settings are made as a percentage of a settable global base voltage parameter \( V_{\text{Base}} \).

SAPTOF (81) is not instantaneous, since the frequency is related to movements of the system inertia, but the time and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Some applications and related setting guidelines for the frequency level are given below:

**Equipment protection, such as for motors and generators**

The setting has to be well above the highest occurring "normal" frequency and well below the highest acceptable frequency for the equipment.

**Power system protection, by generator shedding**

The setting must be above the highest occurring "normal" frequency and below the highest acceptable frequency for power stations, or sensitive loads. The setting level, the number of levels and the distance between two levels (in time and/or in frequency) depend very much on the characteristics of the power system under consideration. The size of the "largest loss of load" compared to "the size of the power system" is a critical parameter. In large systems, the generator shedding can be set at a fairly low frequency level, and the time delay is normally not critical. In smaller systems the frequency PICKUP level has to be set at a higher value, and the time delay must be rather short.

8.3 Rate-of-change frequency protection SAPFRC (81)

8.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
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<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<tr>
<td>Rate-of-change frequency protection</td>
<td>SAPFRC</td>
<td></td>
<td>81</td>
</tr>
</tbody>
</table>

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8.3.2 Application

Rate-of-change frequency protection (SAPFRC, 81), is applicable in all situations, where reliable detection of change of the fundamental power system voltage frequency is needed. SAPFRC (81) can be used both for increasing frequency and for decreasing frequency. SAPFRC (81) provides an output signal, suitable for load shedding or generator shedding, generator boosting, HVDC-set-point change, gas turbine start up. Very often SAPFRC (81) is used in combination with a low frequency signal, especially in smaller power systems, where loss of a fairly large generator will require quick remedial actions to secure the power system integrity. In such situations load shedding actions are required at a rather high frequency level, but in combination with a large negative rate-of-change of frequency the underfrequency protection can be used at a rather high setting.

8.3.3 Setting guidelines

The parameters for Rate-of-change frequency protection SAPFRC (81) are set via the local HMI or PCM600.

All the frequency and voltage magnitude conditions in the system where SAPFRC (81) performs its functions should be considered. The same also applies to the associated equipment, its frequency and time characteristic.

There are especially two application areas for SAPFRC (81):

1. to protect equipment against damage due to high or to low frequency, such as generators, transformers, and motors
2. to protect a power system, or a part of a power system, against breakdown, by shedding load or generation, in situations where load and generation are not in balance.

SAPFRC (81) is normally used together with an overfrequency or underfrequency function, in small power systems, where a single event can cause a large imbalance between load and generation. In such situations load or generation shedding has to take place very quickly, and there might not be enough time to wait until the frequency signal has reached an abnormal value. Actions are therefore taken at a frequency level closer to the primary nominal level, if the rate-of-change frequency is large (with respect to sign).

SAPFRC (81)PICKUP value is set in Hz/s. All voltage magnitude related settings are made as a percentage of a settable base voltage, which normally is set to the primary nominal voltage level (phase-phase) of the power system or the high voltage equipment under consideration.

SAPFRC (81) is not instantaneous, since the function needs some time to supply a stable value. It is recommended to have a time delay long enough to take care of signal noise. However, the time, rate-of-change frequency and frequency steps between different actions might be critical, and sometimes a rather short operation time is required, for example, down to 70 ms.

Smaller industrial systems might experience rate-of-change frequency as large as 5 Hz/s, due to a single event. Even large power systems may form small islands with a large imbalance between load and generation, when severe faults (or combinations of faults) are cleared - up to 3 Hz/s has been experienced when a small island was isolated from a large system. For more “normal” severe disturbances in large power systems, rate-of-change of frequency is much less, most often just a fraction of 1.0 Hz/s.
Section 9  Secondary system supervision

9.1  Current circuit supervision CCSRDIF (87)

9.1.1  Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<tr>
<td>Current circuit supervision</td>
<td>CCSRDIF</td>
<td>-</td>
<td>87</td>
</tr>
</tbody>
</table>

9.1.2  Application

Open or short circuited current transformer cores can cause unwanted operation of many protection functions such as differential, ground-fault current and negative-sequence current functions. When currents from two independent three-phase sets of CTs, or CT cores, measuring the same primary currents are available, reliable current circuit supervision can be arranged by comparing the currents from the two sets. If an error in any CT circuit is detected, the protection functions concerned can be blocked and an alarm given.

In case of large currents, unequal transient saturation of CT cores with different remanence or different saturation factor may result in differences in the secondary currents from the two CT sets. Unwanted blocking of protection functions during the transient stage must then be avoided.

Current circuit supervision CCSRDIF (87) must be sensitive and have short operate time in order to prevent unwanted tripping from fast-acting, sensitive numerical protections in case of faulty CT secondary circuits.

Open CT circuits creates extremely high voltages in the circuits, which may damage the insulation and cause new problems. The application shall, thus, be done with this in consideration, especially if protection functions are blocked.

9.1.3  Setting guidelines

Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

Current circuit supervision CCSRDIF (87) compares the residual current from a three-phase set of current transformer cores with the neutral point current on a separate input taken from another set of cores on the same current transformer.

The minimum operate current, $I_{MinOp}$, must be set as a minimum to twice the residual current in the supervised CT circuits under normal service conditions and rated primary current.
The parameter *Pickup Block* is normally set at 150% to block the function during transient conditions.

The FAIL output is connected in the PCM configuration to the blocking input of the protection function to be blocked at faulty CT secondary circuits.

## 9.2 Fuse failure supervision SDDRFUF

### 9.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuse failure supervision</td>
<td>SDDRFUF</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### 9.2.2 Application

Different protection functions within the protection IED, operates on the basis of the measured voltage in the relay point. Examples are:

- distance protection function
- under/over-voltage function
- synchronism check function and voltage check for the weak infeed logic.

These functions can operate unintentionally if a fault occurs in the secondary circuits between the voltage instrument transformers and the IED.

It is possible to use different measures to prevent such unwanted operations. Miniature circuit breakers in the voltage measuring circuits, located as close as possible to the voltage instrument transformers, are one of them. Separate fuse-failure monitoring IEDs or elements within the protection and monitoring devices are another possibilities. These solutions are combined to get the best possible effect in the fuse failure supervision function (SDDRFUF).

SDDRFUF function built into the IED products can operate on the basis of external binary signals from the miniature circuit breaker or from the line disconnector. The first case influences the operation of all voltage-dependent functions while the second one does not affect the impedance measuring functions.

The negative sequence detection algorithm, based on the negative-sequence measuring quantities, a high value of voltage $3V_2$ without the presence of the negative-sequence current $3I_2$, is recommended for use in isolated or high-impedance grounded networks.

The zero sequence detection algorithm, based on the zero sequence measuring quantities, a high value of voltage $3V_0$ without the presence of the residual current $3I_0$, is recommended for use in directly or low impedance grounded networks. In cases where the line can have a weak-infeed of zero sequence current this function shall be avoided.

A criterion based on delta current and delta voltage measurements can be added to the fuse failure supervision function in order to detect a three phase fuse failure, which in practice is more associated with voltage transformer switching during station operations.
9.2.3 Setting guidelines

9.2.3.1 General

The negative and zero sequence voltages and currents always exist due to different non-symmetries in the primary system and differences in the current and voltage instrument transformers. The minimum value for the operation of the current and voltage measuring elements must always be set with a safety margin of 10 to 20%, depending on the system operating conditions.

Pay special attention to the dissymmetry of the measuring quantities when the function is used on longer untransposed lines, on multicircuit lines and so on.

The settings of negative sequence, zero sequence and delta algorithm are in percent of the base voltage and base current for the function, \( V_{\text{Base}} \) and \( I_{\text{Base}} \) respectively. Set \( V_{\text{Base}} \) to the primary rated phase-phase voltage of the potential voltage transformer and \( I_{\text{Base}} \) to the primary rated current of the current transformer.

9.2.3.2 Setting of common parameters

Common base IED values for primary current (\( I_{\text{Base}} \)), primary voltage (\( V_{\text{Base}} \)) and primary power (\( S_{\text{Base}} \)) are set in a Global base values for settings function GBASVAL. Setting \( \text{GlobalBaseSel} \) is used to select a GBASVAL function for reference of base values.

The settings of negative sequence, zero sequence and delta algorithm are in percent of the global base voltage and global base current for the function, \( V_{\text{Base}} \) and \( I_{\text{Base}} \) respectively.

The voltage threshold \( V_{\text{SealInPU}} \) is used to identify low voltage condition in the system. Set \( V_{\text{SealInPU}} \) below the minimum operating voltage that might occur during emergency conditions. We propose a setting of approximately 70% of the global parameter \( V_{\text{Base}} \).

The drop off time of 200 ms for dead phase detection makes it recommended to always set \( \text{SealIn} \) to \( \text{Enabled} \) since this will secure a fuse failure indication at persistent fuse fail when closing the local breaker when the line is already energized from the other end. When the remote breaker closes the voltage will return except in the phase that has a persistent fuse fail. Since the local breaker is open there is no current and the dead phase indication will persist in the phase with the blown fuse. When the local breaker closes the current will start to flow and the function detects the fuse failure situation. But due to the 200 ms drop off timer the output BLKZ will not be activated until after 200 ms. This means that distance functions are not blocked and due to the “no voltage but current” situation might issue a trip.

The operation mode selector \( \text{OpModeSel} \) has been introduced for better adaptation to system requirements. The mode selector makes it possible to select interactions between the negative sequence and zero sequence algorithm. In normal applications the \( \text{OpModeSel} \) is set to either \( V_{12}I_{2} \) for selecting negative sequence algorithm or \( V_{0}I_{0} \) for zero sequence based algorithm. If system studies or field experiences shows that there is a risk that the fuse failure function will not be activated due to the system conditions, the dependability of the fuse failure function can be increased if the \( \text{OpModeSel} \) is set to \( V_{0}I_{0} \) OR \( V_{12}I_{2} \) or \( \text{OptimZsNs} \). In mode \( V_{0}I_{0} \) OR \( V_{12}I_{2} \) both the negative and zero sequence based algorithm is activated and working in an OR-condition. Also in mode \( \text{OptimZsNs} \) both the negative and zero sequence algorithm are activated and the one that has the highest magnitude of measured negative sequence current will operate. If there is a requirement to increase the security of the fuse failure function \( \text{OpModeSel} \) can be selected to \( V_{0}I_{0} \) AND \( V_{12}I_{2} \) which gives that both negative and zero sequence algorithm is activated working in...
an AND-condition, that is, both algorithm must give condition for block in order to activate the output signals BLKV or BLKZ.

9.2.3.3 **Negative sequence based**

The relay setting value $3V2PU$ is given in percentage of the base voltage $VBase$ and should not be set lower than according to equation 71.

$$3V2PU = \frac{3V2}{VBase} \cdot 100$$

(Equation 71)

where:

$3V2PU$ is maximal negative sequence voltage during normal operation condition
$VBase$ is setting of the global base voltage for all functions in the IED.

The setting of the current limit $3I2PU$ is in percentage of global parameter $IBase$. The setting of $3I2PU$ must be higher than the normal unbalance current that might exist in the system and can be calculated according to equation 72.

$$3I2PU = \frac{3I2}{IBase} \cdot 100$$

(Equation 72)

where:

$3I2$ is maximal negative sequence current during normal operating condition
$IBase$ is setting of base current for the function

9.2.3.4 **Zero sequence based**

The relay setting value $3V0PU$ is given in percentage of the global parameter $VBase$. The setting of $3V0PU$ should not be set lower than according to equation 73.

$$3V0PU = \frac{3V0}{VBase} \cdot 100$$

(Equation 73)

where:

$3V0$ is maximal zero sequence voltage during normal operation condition
$VBase$ is setting of global base voltage all functions in the IED.
The setting of the current limit $3I_{0P}$U is done in percentage of the global parameter $I_{Base}$. The setting of $3I_{0P}$U must be higher than the normal unbalance current that might exist in the system. The setting can be calculated according to equation 74.

$$3I\_0P \_U = \frac{3I_0}{I_{Base}} \cdot 100$$

(Equation 74)

where:

$3I_{0P}$U is maximal zero sequence current during normal operating condition

$I_{Base}$ is setting of global base current all functions in the IED.

### 9.2.3.5 Delta V and delta I

Set the operation mode selector OpDVDI to Enabled if the delta function shall be in operation.

The setting of $DV_{PU}$ should be set high (approximately 60% of $V_{Base}$) and the current threshold $DI_{PU}$ low (approximately 10% of $I_{Base}$) to avoid unwanted operation due to normal switching conditions in the network. The delta current and delta voltage function shall always be used together with either the negative or zero sequence algorithm. If $V_{Setprim}$ is the primary voltage for operation of $dU/dt$ and $I_{Setprim}$ the primary current for operation of $dI/dt$, the setting of $DV_{PU}$ and $DI_{PU}$ will be given according to equation 75 and equation 76.

$$DV_{PU} = \frac{V_{Setprim}}{V_{Base}} \cdot 100$$

(Equation 75)

$$DI_{PU} = \frac{I_{Setprim}}{I_{Base}} \cdot 100$$

(Equation 76)

The voltage thresholds $VPP_{U}$ is used to identify low voltage condition in the system. Set $VPP_{U}$ below the minimum operating voltage that might occur during emergency conditions. We propose a setting of approximately 70% of $V_B$.

The current threshold $SOP$ shall be set lower than the $I_{MinOp}$ for the distance protection function. A 5-10% lower value is recommended.

### 9.2.3.6 Dead line detection

The condition for operation of the dead line detection is set by the parameters $IDL_{DPU}$ for the current threshold and $VDL_{DPU}$ for the voltage threshold.

Set the $IDL_{DPU}$ with a sufficient margin below the minimum expected load current. A safety margin of at least 15-20% is recommended. The operate value must however exceed the maximum charging current of an overhead line, when only one phase is disconnected (mutual coupling to the other phases).
Set the $VDLPU$ with a sufficient margin below the minimum expected operating voltage. A safety margin of at least 15% is recommended.

### 9.3 Breaker close/trip circuit monitoring TCSSCBR

#### 9.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaker close/trip circuit monitoring</td>
<td>TCSSCBR</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 9.3.2 Application

TCSSCBR detects faults in the electrical control circuit of the circuit breaker. The function can supervise both open and closed coil circuits. This kind of monitoring is necessary to find out the vitality of the control circuits continuously.

- **Trip circuit supervision** generates a current of approximately 1.0 mA through the supervised circuit. It must be ensured that this current will not cause a latch up of the controlled object.

- **To protect the trip circuit supervision circuits in the IED**, the output contacts are provided with parallel transient voltage suppressors. The breakdown voltage of these suppressors is 400 $\pm$ 20 V DC.

The following figure shows an application of the trip-circuit monitoring function usage. The best solution is to connect an external $R_{ext}$ shunt resistor in parallel with the circuit breaker internal contact. Although the circuit breaker internal contact is open, TCSSCBR can see the trip circuit through $R_{ext}$. The $R_{ext}$ resistor should have such a resistance that the current through the resistance remains small, that is, it does not harm or overload the circuit breaker's trip coil.
Figure 76: Operating principle of the trip-circuit supervision with an external resistor. The TCSSCBR blocking switch is not required since the external resistor is used.

If the TCSSCBR is required only in a closed position, the external shunt resistance may be omitted. When the circuit breaker is in the open position, the TCSSCBR sees the situation as a faulty circuit. One way to avoid TCSSCBR operation in this situation would be to block the monitoring function whenever the circuit breaker is open.

Figure 77: Operating principle of the trip-circuit supervision without an external resistor. The circuit breaker open indication is set to block TCSSCBR when the circuit breaker is open.
Trip-circuit monitoring and other trip contacts

It is typical that the trip circuit contains more than one trip contact in parallel, for example in transformer feeders where the trip of a Buchholz relay is connected in parallel with the feeder terminal and other relays involved.

Figure 78: Constant test current flow in parallel trip contacts and trip-circuit supervision

Several trip-circuit monitoring functions parallel in circuit

Not only the trip circuit often have parallel trip contacts, it is also possible that the circuit has multiple TCSSCBR circuits in parallel. Each TCSSCBR circuit causes its own supervising current to flow through the monitored coil and the actual coil current is a sum of all TCSSCBR currents. This must be taken into consideration when determining the resistance of $R_{ext}$.

Setting the TCSSCBR function in a protection IED not-in-use does not typically affect the supervising current injection.

Trip-circuit monitoring with auxiliary relays

Many retrofit projects are carried out partially, that is, the old electromechanical relays are replaced with new ones but the circuit breaker is not replaced. This creates a problem that the coil current of an old type circuit breaker can be too high for the protection IED trip contact to break.

The circuit breaker coil current is normally cut by an internal contact of the circuit breaker. In case of a circuit breaker failure, there is a risk that the protection IED trip contact is destroyed since the contact is obliged to disconnect high level of electromagnetic energy accumulated in the trip coil.

An auxiliary relay can be used between the protection IED trip contact and the circuit breaker coil. This way the breaking capacity question is solved, but the TCSSCBR circuit in the protection IED monitors the healthy auxiliary relay coil, not the circuit breaker coil. The separate trip circuit monitoring relay is applicable for this to supervise the trip coil of the circuit breaker.
Dimensioning of the external resistor

Under normal operating conditions, the applied external voltage is divided between the relay’s internal circuit and the external trip circuit so that at the minimum 20 V (3...20 V) remains over the relay’s internal circuit. Should the external circuit’s resistance be too high or the internal circuit’s too low, for example due to welded relay contacts, the fault is detected.

Mathematically, the operation condition can be expressed as:

\[ V_c - \left( R_{\text{ext}} + R_s \right) \times I_c \geq 20V \ DC \]

(Equation 77)

- \( V_c \): Operating voltage over the supervised trip circuit
- \( I_c \): Measuring current through the trip circuit, appr. 1.0 mA (0.85...1.20 mA)
- \( R_{\text{ext}} \): External shunt resistance
- \( R_s \): Trip coil resistance

If the external shunt resistance is used, it has to be calculated not to interfere with the functionality of the supervision or the trip coil. Too high a resistance causes too high a voltage drop, jeopardizing the requirement of at least 20 V over the internal circuit, while a resistance too low can enable false operations of the trip coil.

<table>
<thead>
<tr>
<th>Operating voltage ( U_c )</th>
<th>Shunt resistor ( R_{\text{ext}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 V DC</td>
<td>10 kΩ, 5 W</td>
</tr>
<tr>
<td>60 V DC</td>
<td>22 kΩ, 5 W</td>
</tr>
<tr>
<td>110 V DC</td>
<td>33 kΩ, 5 W</td>
</tr>
<tr>
<td>220 V DC</td>
<td>68 kΩ, 5 W</td>
</tr>
</tbody>
</table>

Due to the requirement that the voltage over the TCSSCBR contact must be 20V or higher, the correct operation is not guaranteed with auxiliary operating voltages lower than 48V DC because of the voltage drop in the \( R_{\text{ext}} \) and operating coil or even voltage drop of the feeding auxiliary voltage system which can cause too low voltage values over the TCSSCBR contact. In this case, erroneous alarming can occur.

At lower (<48V DC) auxiliary circuit operating voltages, it is recommended to use the circuit breaker position to block unintentional operation of TCSSCBR. The use of the position indication is described earlier in this chapter.
Section 10    Control

10.1 Synchronism check, energizing check, and synchronizing SESRSYN (25)

10.1.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchrocheck, energizing check, and synchronizing</td>
<td>SESRSYN</td>
<td>sc/vc</td>
<td>25</td>
</tr>
</tbody>
</table>

10.1.2 Application

10.1.2.1 Synchronizing

To allow closing of breakers between asynchronous networks a synchronizing function is provided. The breaker close command is issued at the optimum time when conditions across the breaker are satisfied in order to avoid stress on the network and its components.

The systems are defined to be asynchronous when the frequency difference between bus and line is larger than an adjustable parameter. If the frequency difference is less than this threshold value the system is defined to have a parallel circuit and the synchronism check function is used.

The synchronizing function measures the difference between the V-Line and the V-Bus. It operates and enables a closing command to the circuit breaker when the calculated closing angle is equal to the measured phase angle and the following conditions are simultaneously fulfilled:

- The measured voltage V-Line is higher than 80% of GblBaseSelLine and the measured voltage V-Bus is higher than 80% of GblBaseSelBus.
- The voltage difference is smaller than 0.10 p.u, that is (V-Bus/GblBaseSelBus) - (V-Line/GblBaseSelLine) < 0.10.
- The difference in frequency is less than the set value of FreqDiffMax and larger than the set value of FreqDiffMin. If the frequency is less than FreqDiffMin the synchronism check is used and the value of FreqDiffMin must thus be identical to the value FreqDiffM resp FreqDiffA for synchronism check function. The bus and line frequencies must also be within a range of +/- 5 Hz from the rated frequency. When the synchronizing option is included also for autoreclose there is no reason to have different frequency setting for the manual and automatic reclosing and the frequency difference values for synchronism check should be kept low.
- The frequency rate of change is less than set value for both V-Bus and V-Line.
- The closing angle is decided by the calculation of slip frequency and required pre-closing time.
The synchronizing function compensates for measured slip frequency as well as the circuit breaker closing delay. The phase angle advance is calculated continuously. Closing angle is the change in angle during the set breaker closing operate time \( t_{Breaker} \).

The reference voltage can be phase-neutral A, B, C or phase-phase A-B, B-C, C-A or positive sequence. The bus voltage must then be connected to the same phase or phases as are chosen for the line. If different phases voltages are used for the reference voltage, the phase shift has to be compensated with the parameter \( \text{PhaseShift} \), and the voltage amplitude has to be compensated by the factor \( \text{URatio} \). Positive sequence selection setting requires that both reference voltages are three phase voltages.

### 10.1.2.2 Synchronism check

The main purpose of the synchronism check function is to provide control over the closing of circuit breakers in power networks in order to prevent closing if conditions for synchronism are not detected. It is also used to prevent the re-connection of two systems, which are divided after islanding and after a three pole reclosing.

Single pole auto-reclosing does not require any synchronism check since the system is tied together by two phases.

SESRSYN (25) function block includes both the synchronism check function and the energizing function to allow closing when one side of the breaker is dead. SESRSYN (25) function also includes a built in voltage selection scheme which allows simple application in busbar arrangements.

**Figure 79: Two interconnected power systems**

Figure 79 shows two interconnected power systems. The cloud means that the interconnection can be further away, that is, a weak connection through other stations. The need for a check of synchronization increases as the meshed system decreases since the risk of the two networks being out of synchronization at manual or automatic closing is greater.

The synchronism check function measures the conditions across the circuit breaker and compares them to set limits. Output is generated only when all measured conditions are within their set limits simultaneously. The check consists of:

- Live line and live bus.
- Voltage level difference.
- Frequency difference (slip). The bus and line frequency must also be within a range of \( \pm 5 \) Hz from rated frequency.
- Phase angle difference.

A time delay is available to ensure that the conditions are fulfilled for a minimum period of time.
In very stable power systems the frequency difference is insignificant or zero for manually initiated closing or closing by automatic restoration. In steady conditions a bigger phase angle difference can be allowed as this is sometimes the case in a long and loaded parallel power line. For this application we accept a synchronism check with a long operation time and high sensitivity regarding the frequency difference. The phase angle difference setting can be set for steady state conditions.

Another example, is when the operation of the power net is disturbed and high-speed auto-reclosing after fault clearance takes place. This can cause a power swing in the net and the phase angle difference may begin to oscillate. Generally, the frequency difference is the time derivative of the phase angle difference and will, typically oscillate between positive and negative values. When the circuit breaker needs to be closed by auto-reclosing after fault-clearance some frequency difference should be tolerated, to a greater extent than in the steady condition mentioned in the case above. But if a big phase angle difference is allowed at the same time, there is some risk that auto-reclosing will take place when the phase angle difference is big and increasing. In this case it should be safer to close when the phase angle difference is smaller.

To fulfill the above requirements the synchronism check function is provided with duplicate settings, one for steady (Manual) conditions and one for operation under disturbed conditions (Auto).

![Figure 80: Principle for the synchronism check function](ANSI10000195_1_en.vsd)

### 10.1.2.3 Energizing check

The main purpose of the energizing check function is to facilitate the controlled re-connection of disconnected lines and buses to energized lines and buses.

The energizing check function measures the bus and line voltages and compares them to both high and low threshold values. The output is given only when the actual measured conditions match the set conditions. Figure 81 shows two power systems, where one (1) is energized and the
other (2) is not energized. Power system 2 is energized (DLLB) from system 1 via the circuit breaker A.

1 A

Figure 81: Principle for the energizing check function

The energizing operation can operate in the dead line live bus (DLLB) direction, dead bus live line (DBLL) direction, or in both directions over the circuit breaker. Energizing from different directions can be different for automatic reclosing and manual closing of the circuit breaker. For manual closing it is also possible to allow closing when both sides of the breaker are dead, Dead Bus Dead Line (DBDL).

The equipment is considered energized if the voltage is above a set value, for example, 80% of the base voltage, and non-energized if it is below a set value, for example, 30% of the base voltage. A disconnected line can have a considerable potential because of factors such as induction from a line running in parallel, or feeding via extinguishing capacitors in the circuit breakers. This voltage can be as high as 50% or more of the base voltage of the line. Normally, for breakers with single breaking elements (<330kV) the level is well below 30%.

When the energizing direction corresponds to the settings, the situation has to remain constant for a certain period of time before the close signal is permitted. The purpose of the delayed operate time is to ensure that the dead side remains de-energized and that the condition is not due to temporary interference.

10.1.2.4 Voltage selection

The voltage selection function is used for the connection of appropriate voltages to the synchronism check and energizing check functions. For example, when the IED is used in a double bus arrangement, the voltage that should be selected depends on the status of the breakers and/or disconnectors. By checking the status of the disconnectors auxiliary contacts, the right voltages for the synchronism check and energizing check functions can be selected.

The voltages from busbars and lines must be physically connected to the voltage inputs in the IED and connected, using the control software, to each of the maximum two SESRSYN(25) functions available in the IED.
10.1.2.5 External fuse failure

External fuse-failure signals or signals from a tripped fuse switch/MCB are connected to binary inputs that are configured to inputs of SESRSYN(25) function in the IED. The internal fuse failure supervision function can also be used, for at least the line voltage supply. The signal VTSU is then used and connected to the blocking input of the energizing check function block. In case of a fuse failure, SESRSYN(25) and energizing check functions are blocked.

The VB1OK/VB2OK and VB1FF inputs are related to the busbar voltage and the ULNOK and ULNFF inputs are related to the line voltage.

External selection of energizing direction

The energizing can be selected by use of the available logic function blocks. Below is an example where the choice of mode is done from a symbol on the local HMI through selector switch function block, but alternatively there can for example, be a physical selector switch on the front of the panel which is connected to a binary to integer function block (B16I).

If the PSTO input is used, connected to the Local-Remote switch on the local HMI, the choice can also be from the station HMI system, typically ABB Microscada through IEC 61850 communication.

The connection example for selection of the manual energizing mode is shown in figure 82. Selected names are just examples but note that the symbol on the local HMI can only show three signs.

![Figure 82: Selection of the energizing direction from a local HMI symbol through a selector switch function block.](ANSI11000163_1_en.vsd)

10.1.3 Application examples

SESRSYN (25) function block can also be used in some switchyard arrangements, but with different parameter settings. Below are some examples of how different arrangements are connected to the IED analog inputs and to the function block SESRSYN(25). One function block is used per circuit breaker.

The input used below in example are typical and can be changed by use of configuration and signal matrix tools.

The SESRSYN and connected SMAI function block instances must have the same cycle time in the application configuration.
10.1.3.1 Single circuit breaker with single busbar

Figure 83: Connection of SESRSYN (25) function block in a single busbar arrangement

Figure 83 illustrates connection principles. For the SESRSYN (25) function there is one voltage transformer on each side of the circuit breaker. The voltage transformer circuit connections are straightforward; no special voltage selection is necessary. For SESRSYN (25), the voltage from the busbar VT is connected to analog input VREF1 on the analog input module. The line voltage is connected as a three-phase voltage to the analog inputs VA, VB and VC.
10.1.3.2 Single circuit breaker with double busbar, external voltage selection

Figure 84: Connection of SESRSYN (25) function block in a single breaker, double busbar arrangement with external voltage selection.

In this type of arrangement no internal voltage selection is required. The voltage selection is made by external relays typically connected according to figure 84. Suitable voltage and VT fuse failure supervision from the two busbars are selected based on the position of the busbar disconnectors. That means that the connections to the function block will be the same as for the single busbar arrangement.
**10.1.3.3 Single circuit breaker with double busbar, internal voltage selection**

![Diagram showing connection of the Synchrocheck function block in a single breaker, double busbar arrangement with internal selection.](ANSI1000166_1_en.vsd)

**Figure 85:** Connection of the Synchrocheck function block in a single breaker, double busbar arrangement with internal selection.

With the configuration according to figure 85, the voltage selection is made internally based on the signals from 189 and 289.

**10.1.4 Setting guidelines**

The setting parameters for the synchronizing, synchronism check and energizing check function (SESRSYN) are set via the local HMI, or Protection and Control IED Manager (PCM600).

Common base IED value for primary voltage ($V_{Base}$) is set in a Global base value function GBASVAL. Setting $GlobalBaseSel$ is used to select a GBASVAL function for reference of base values.

**Operation:** The operation mode can be set Enabled or Disabled from PST. The setting Disabled disables the whole function.

**MeasVoltBus1 and MeasVoltBus2**

Configuration parameters for selection of measuring phase of the voltage for the busbar 1 and 2 respectively, which can be single-phase ($UL1$), two-phase ($UL1L2$) or positive sequence voltage.
MeasVoltBus1 and MeasVoltBus2 must always be set to measure the same type of voltage, either single-phase (UL1), two-phase (UL1L2) or positive sequence voltage.

MeasVoltLine1
Configuration parameters for selection of measuring phase of the voltage for the line, which can be a single-phase (UL1), two-phase (UL1L2) or positive sequence voltage.

MeasVoltLine1 must always be set to measure the same type of voltage as MeasVoltBus1 and MeasVoltBus2, either single-phase (UL1), two-phase (UL1L2) or positive sequence voltage.

PhaseShift
This setting is used to compensate for a phase shift caused by a line transformer between the two measurement points for bus voltage and line voltage, or one voltage is measured phase-phase and the other phase-neutral. The set value is added to the measured line phase angle. The bus voltage is reference voltage.

VRatio
The VRatio is defined as $VRatio = \text{bus voltage}/\text{line voltage}$. A typical use of the setting is to compensate for the voltage difference caused if one wishes to connect the bus voltage phase-phase and line voltage phase-neutral. The MeasVoltBus1 setting should then be set to phase-phase and the VRatio setting to $\sqrt{3} = 1.73$. This setting scales up the line voltage to equal level with the bus voltage.

OperationSynch
The setting Disabled disables the Synchronizing function. With the setting Enabled, the function is in service and the output signal depends on the input conditions.

FreqDiffMax
The setting FreqDiffMax is the maximum slip frequency at which synchronizing is accepted. $1/FreqDiffMax$ shows the time for the vector to move 360 degrees, one turn on the synchronoscope and is called the Beat time. A typical value for the FreqDiffMax is 200-250 mHz which gives beat times on 4-5 seconds. Higher values should be avoided as the two networks normally are regulated to nominal frequency independent of each other so the frequency difference shall be small.

FreqDiffMin
The setting FreqDiffMin is the minimum frequency difference where the system are defined to be asynchronous. For frequency difference lower than this value the systems are considered to be in parallel. A typical value for the FreqDiffMin is 10 mHz. Generally the value should be low if both synchronizing and synchronism check function is provided as it is better to let synchronizing function close as it will close at the exact right instance if the networks runs with a frequency difference. The synchronism check function will at such a case close to the set phase angle difference value which can be 35 degrees from the correct angle.
The $FreqDiffMin$ shall be set to the same value as $FreqDiffM$ resp $FreqDiffA$ for the synchronism check function dependent of whether the functions are used for manual operation, auto-reclosing or both.

$FreqRateChange$

The maximum allowed rate of change for the frequency.

$tBreaker$

The $tBreaker$ shall be set to match the closing time for the circuit breaker and should also include the possible auxiliary relays in the closing circuit. It is important to check that no slow logic components are used in the configuration of the IED as there then can be big variations in closing time due to those components. Typical setting is 80-150 ms depending on the breaker closing time.

$tClosePulse$

Setting for the duration of the breaker close pulse.

$tMinSynch$

The $tMinSynch$ is set to limit the minimum time at which synchronizing closing attempt is given. The setting will not give a closing should a condition fulfilled occur within this time from the synchronizing function is started. Typical setting is 200 ms.

$tMaxSynch$

The $tMaxSynch$ is set to reset the operation of the synchronizing function if the operation does not take place within this time. The setting must allow for the setting of $FreqDiffMin$ which will decide how long it will take maximum to reach phase equality. At a setting of 10 ms the beat time is 100 seconds and the setting would thus need to be at least $tMinSynch$ plus 100 seconds. If the network frequencies are expected to be outside the limits from start a margin needs to be added. Typical setting 300 seconds.

$OperationSC$

The $OperationSC$ setting $Disabled$ disables the synchronism check function and sets the outputs AUTOSYOK, MANSYOK, TSTAUTSY and TSTMANSY to low.

With the setting $Enabled$, the function is in service and the output signal depends on the input conditions.

$VDiffSC$

Setting for voltage difference between line and bus.

$FreqDiffM$ and $FreqDiffA$

The frequency difference level settings, $FreqDiffM$ and $FreqDiffA$, shall be chosen depending on the condition in the network. At steady conditions a low frequency difference setting is needed, where the $FreqDiffM$ setting is used. For auto-reclosing a bigger frequency difference setting is preferable, where the $FreqDiffA$ setting is used. A typical value for the $FreqDiffM$ can be 10 mHz and a typical value for the $FreqDiffA$ can be 100-200 mHz.

$PhaseDiffM$ and $PhaseDiffA$
The phase angle difference level settings, \textit{PhaseDiffM} and \textit{PhaseDiffA}, shall also be chosen depending on conditions in the network. The phase angle setting must be chosen to allow closing under maximum load condition. A typical maximum value in heavy loaded networks can be 45 degrees whereas in most networks the maximum occurring angle is below 25 degrees.

\textit{tSCM} and \textit{tSCA}

The purpose of the timer delay settings, \textit{tSCM} and \textit{tSCA}, is to ensure that the synchronism check conditions remains constant and that the situation is not due to a temporary interference. Should the conditions not persist for the specified time, the delay timer is reset and the procedure is restarted when the conditions are fulfilled again. Circuit breaker closing is thus not permitted until the synchronism check situation has remained constant throughout the set delay setting time. Under stable conditions a longer operation time delay setting is needed, where the \textit{tSCM} setting is used. During auto-reclosing a shorter operation time delay setting is preferable, where the \textit{tSCA} setting is used. A typical value for the \textit{tSCM} may be 1 second and a typical value for the \textit{tSCA} may be 0.1 second.

\textit{AutoEnerg} and \textit{ManEnerg}

Two different settings can be used for automatic and manual closing of the circuit breaker. The settings for each of them are:

- \textit{Disabled}, the energizing function is disabled.
- \textit{DLLB}, Dead Line Live Bus, the line voltage is below a standard value.
- \textit{DBLL}, Dead Bus Live Line, the bus voltage is below a standard value.
- \textit{Both}, energizing can be done in both directions, \textit{DLLB} or \textit{DBLL}.

\textit{tAutoEnerg} and \textit{tManEnerg}

The purpose of the timer delay settings, \textit{tAutoEnerg} and \textit{tManEnerg}, is to ensure that the dead side remains de-energized and that the condition is not due to a temporary interference. Should the conditions not persist for the specified time, the delay timer is reset and the procedure is restarted when the conditions are fulfilled again. Circuit breaker closing is thus not permitted until the energizing condition has remained constant throughout the set delay setting time.

\textit{ManEnergDBDL}

If the parameter is set to \textit{Enabled}, manual energizing is enabled.

\section*{10.2 Autorecloser SMBRREC (79)}

\subsection*{10.2.1 Identification}

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10.2.2 Application

Automatic reclosing is a well-established method for the restoration of service in a power system after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by the operation of line protection and line breakers, the arc de-ionizes and recovers its ability to withstand voltage at a somewhat variable rate. Thus, a certain dead time with a de-energized line is necessary. Line service can then be resumed by automatic reclosing of the line breakers. The dead time selected should be long enough to ensure a high probability of arc de-ionization and successful reclosing.

For individual line breakers, auto-reclosing equipment or functions, the auto-reclosing open time is used to determine line “dead time”. When simultaneous tripping and reclosing at the two line ends occurs, auto-reclosing open time is approximately equal to the line “dead time”. If the open time and dead time differ then, the line will be energized until the breakers at both ends have opened.

Figure 86: Single-shot automatic reclosing at a permanent fault

Three-phase automatic reclosing can be performed with or without the use of a synchronism check, and an energizing check, such as dead line or dead busbar check.

For the individual line breakers and auto-reclosing equipment, the "auto-reclosing open time" expression is used. This is the dead time setting for the Auto-Recloser. During simultaneous tripping and reclosing at the two line ends, auto-reclosing open time is approximately equal to the
line dead time. Otherwise these two times may differ as one line end might have a slower trip than
the other end which means that the line will not be dead until both ends have opened.

If the fault is permanent, the line protection will trip again when reclosing is attempted in order to
clear the fault.

It is common to use one automatic reclosing function per line circuit-breaker (CB). When one CB
per line end is used, then there is one auto-reclosing function per line end. If auto-reclosing
functions are included in duplicated line protection, which means two auto-reclosing functions per
CB, one should take measures to avoid uncoordinated reclosing commands. In breaker-and-a-half,
double-breaker and ring bus arrangements, two CBs per line end are operated. One auto-reclosing
function per CB is recommended. Arranged in such a way, sequential reclosing of the two CBs can
be arranged with a priority circuit available in the auto-reclose function. In case of a permanent
fault and unsuccessful reclosing of the first CB, reclosing of the second CB is cancelled and thus
the stress on the power system is limited. Another advantage with the breaker connected auto-
recloser is that checking that the breaker closed before the sequence, breaker prepared for an
auto-reclose sequence and so on. is much simpler.

The auto-reclosing function performs three-phase automatic-reclosing with single-shot or
multiple-shots.

In power transmission systems it is common practise to apply single and/or three phase, single-
shot Auto-Reclosing. In Sub-transmission and Distribution systems tripping and auto-reclosing
are usually three-phase. The mode of automatic-reclosing varies however. Single-shot and multi-
shot are in use. The first shot can have a short delay, HSAR, or a longer delay, DAR. The second and
following reclosing shots have a rather long delay. When multiple shots are used the dead time
must harmonize with the breaker duty-cycle capacity.

Automatic-reclosing is usually started by the line protection and in particular by instantaneous
tripping of such protection. The auto-reclosing function can be inhibited (blocked) when certain
protection functions detecting permanent faults, such as shunt reactor, cable or busbar
protection are in operation. Back-up protection zones indicating faults outside the own line are
also connected to inhibit the Auto-Reclose.

Automatic-reclosing should not be attempted when closing a CB and energizing a line onto a fault
(SOTF), except when multiple-shots are used where shots 2 etc. will be started at SOTF. Likewise a
CB in a multi-breaker busbar arrangement which was not closed when a fault occurred should not
be closed by operation of the Auto-Reclosing function. Auto-Reclosing is often combined with a
release condition from synchronism check and dead line or dead busbar check. In order to limit the
stress on turbo-generator sets from Auto-Reclosing onto a permanent fault, one can arrange to
combine Auto-Reclosing with a synchronism check on line terminals close to such power stations
and attempt energizing from the side furthest away from the power station and perform the
synchronism check at the local end if the energizing was successful.

Transmission protection systems are usually sub-divided and provided with two redundant
protection IEDs. In such systems it is common to provide auto-reclosing in only one of the sub-
systems as the requirement is for fault clearance and a failure to reclose because of the auto-
recloser being out of service is not considered a major disturbance. If two auto-reclosers are
provided on the same breaker, the application must be carefully checked and normally one must
be the master and be connected to inhibit the other auto-recloser if it has started. This inhibit can
for example be done from Autorecloser (SMBRREC ,79) In progress.

A permanent fault will cause the line protection to trip again when it recloses in an attempt to
clear the fault.

The auto-reclosing function allows a number of parameters to be adjusted.
Examples:

- number of auto-reclosing shots
- auto-reclosing open times (dead time) for each shot

10.2.2.1 Auto-reclosing operation OFF and ON

Operation of the automatic reclosing can be set OFF and ON by a setting parameter and by external control. Parameter Operation= Disabled, or Enabled sets the function OFF and ON. In setting Operation=ExternalCtrl, OFF and ON control is made by input signal pulses, for example, from the control system or from the binary input (and other systems).

When the function is set ON and operative (other conditions such as CB closed and CB Ready are also fulfilled), the output SETON is activated (high). When the function is ready to accept a reclosing start.

10.2.2.2 Initiate auto-reclosing and conditions for initiation of a reclosing cycle

The usual way to start a reclosing cycle, or sequence, is to start it at tripping by line protection by applying a signal to the input RI. Starting signals can be either, General Trip signals or, only the conditions for Differential, Distance protection Zone 1 and Distance protection Aided trip. In some cases also Directional Ground fault function Aided trip can be connected to start an Auto-Reclose attempt.

A number of conditions need to be fulfilled for the start to be accepted and a new auto-reclosing cycle to be started. They are linked to dedicated inputs. The inputs are:

- CBREADY, CB ready for a reclosing cycle, for example, charged operating gear.
- 52a to ensure that the CB was closed when the line fault occurred and start was applied.
- No signal at input INHIBIT that is, no blocking or inhibit signal present. After the start has been accepted, it is latched in and an internal signal “Started” is set. It can be interrupted by certain events, like an “Inhibit” signal.

10.2.2.3 Initiate auto-reclosing from CB open information

If a user wants to initiate auto-reclosing from the “CB open” position instead of from protection trip signals, the function offers such a possibility. This starting mode is selected with the setting parameter StartByCBOpen=Enabled. It is then necessary to block reclosing for all manual trip operations. Typically CBAuxContType=NormClosed is also set and a CB auxiliary contact of type NC (normally closed, 52b) is connected to inputs 52a and RI. When the signal changes from “CB closed” to “CB open” an auto-reclosing start pulse is generated and latched in the function, subject to the usual checks. Then the reclosing sequence continues as usual. One needs to connect signals from manual tripping and other functions, which shall prevent reclosing, to the input INHIBIT.

10.2.2.4 Blocking of the autorecloser

Auto-Reclose attempts are expected to take place only in the event of transient faults on the own line. The Auto-Recloser must be blocked for the following conditions:
• Tripping from Delayed Distance protection zones
• Tripping from Back-up protection functions
• Tripping from Breaker failure function
• Intertrip received from remote end Breaker failure function
• Busbar protection tripping

Depending of the starting principle (General Trip or only Instantaneous trip) adopted above the delayed and back-up zones might not be required. Breaker failure local and remote must however always be connected.

10.2.2.5 Control of the auto-reclosing open time

There are settings for the three-phase auto-reclosing open time, \( t1 \ 3Ph \) to \( t5 \ 3Ph \).

10.2.2.6 Long trip signal

In normal circumstances the trip command resets quickly because of fault clearance. The user can set a maximum trip pulse duration \( t_{Trip} \). A long trip signal interrupts the reclosing sequence in the same way as a signal to input INHIBIT.

10.2.2.7 Maximum number of reclosing shots

The maximum number of reclosing shots in an auto-reclosing cycle is selected by the setting parameter \( NoOfShots \).

10.2.2.8 3-phase reclosing, one to five shots according to setting NoOfShots.

A trip operation is made as a three-phase trip at all types of fault. The reclosing is as a three-phase. Here, the auto-reclosing function is assumed to be "On" and "Ready". The breaker is closed and the operation gear ready (operating energy stored). Input RI is received and sealed-in. The output READY is reset (set to false). Output ACTIVE is set. The timer for 3-phase auto-reclosing open time is started.

While any of the auto-reclosing open time timers are running, the output INPROGR is activated. When the "open reset" timer runs out, the respective internal signal is transmitted to the output module for further checks and to issue a closing command to the circuit breaker.

When issuing a CB closing command a “reset” timer \( t_{Reset} \) is started. If no tripping takes place during that time the auto-reclosing function resets to the “Ready” state and the signal ACTIVE resets. If the first reclosing shot fails, 2nd to 5th reclosing shots will follow, if selected.

10.2.2.9 Reclosing reset timer

The reset timer \( t_{Reset} \) defines the time it takes from issue of the reclosing command, until the reclosing function resets. Should a new trip occur during this time, it is treated as a continuation of the first fault. The reclaim timer is started when the CB closing command is given.
10.2.2.10 Transient fault

After the Reclosing command the reset timer keeps running for the set time. If no tripping occurs within this time, \( t_{Reset} \), the Auto-Reclosing will reset. The CB remains closed and the operating gear recharges. The input signals 52a and CBREADY will be set.

10.2.2.11 Permanent fault and reclosing unsuccessful signal

If a new trip occurs, and a new input signal RI or TRSOTF appears, after the CB closing command, the output UNSUCCCL (unsuccessful closing) is set high. The timer for the first shot can no longer be started. Depending on the set number of Reclosing shots further shots may be made or the Reclosing sequence is ended. After reset timer time-out the Auto-Reclosing function resets, but the CB remains open. The “CB closed” information through the input 52a is missing. Thus, the reclosing function is not ready for a new reclosing cycle.

Normally, the signal UNSUCCCL appears when a new trip and start is received after the last reclosing shot has been made and the auto-reclosing function is blocked. The signal resets after reset time. The “unsuccessful” signal can also be made to depend on CB position input. The parameter \( \text{UnsucClByCBChk} \) should then be set to \( \text{CBCheck} \), and a timer \( t_{UnsucCl} \) should be set too. If the CB does not respond to the closing command and does not close, but remains open, the output UNSUCCCL is set high after time \( t_{UnsucCl} \). The Unsuccessful output can for example, be used in Multi-Breaker arrangement to cancel the auto-reclosing function for the second breaker, if the first breaker closed onto a persistent fault. It can also be used to generate a Lock-out of manual closing until the operator has reset the Lock-out, see separate section.

10.2.2.12 Lock-out initiation

In many cases there is a requirement that a Lock-out is generated when the auto-reclosing attempt fails. This is done with logic connected to the in- and outputs of the Autoreclose function and connected to Binary IO as required. Many alternative ways of performing the logic exist depending on whether manual closing is interlocked in the IED, whether an external physical Lock-out relay exists and whether the reset is hardwired, or carried out by means of communication. There are also different alternatives regarding what shall generate Lock-out. Examples of questions are:

- Shall back-up time delayed trip give Lock-out (normally yes)
- Shall Lock-out be generated when closing onto a fault (mostly)
- Shall Lock-out be generated when the Auto-Recloser was OFF at the fault
- Shall Lock-out be generated if the Breaker did not have sufficient operating power for an auto-reclosing sequence (normally not as no closing attempt has been given)

In figures 87 and 88 the logic shows how a closing Lock-out logic can be designed with the Lock-out relay as an external relay alternatively with the Lock-out created internally with the manual closing going through the Synchro-check function. An example of Lock-out logic.
10.2.2.13 Automatic continuation of the reclosing sequence

SMBRREC (79) function can be programmed to proceed to the following reclosing shots (if multiple shots are selected) even if start signals are not received from the protection functions, but the breaker is still not closed. This is done by setting parameter AutoCont = Enabled and tAutoContWait to the required delay for the function to proceed without a new start.

10.2.2.14 Thermal overload protection holding the auto-reclosing function back

If the input THOLHOLD (thermal overload protection holding reclosing back) is activated, it will keep the reclosing function on a hold until it is reset. There may thus be a considerable delay between start of Auto-Reclosing and reclosing command to the circuit-breaker. An external logic limiting the time and sending an inhibit to the INHIBIT input can be used. The input can also be used to set the Auto-Reclosing on hold for a longer or shorter period.
10.2.3 Setting guidelines

10.2.3.1 Configuration

Use the PCM600 configuration tool to configure signals.

Autorecloser function parameters are set via the local HMI or Parameter Setting Tool (PST). Parameter Setting Tool is a part of PCM600.

Recommendations for input signals
Please see examples in figure 89.

ON and OFF

These inputs can be connected to binary inputs or to a communication interface block for external control.

RI

It should be connected to the trip output protection function, which starts the autorecloser (SMBRREC, 79) function. It can also be connected to a binary input for start from an external contact. A logical OR-gate can be used to combine the number of start sources.

If StartByCBOpen is used, the CB Open condition shall also be connected to the input RI.

INHIBIT

To this input shall be connected signals that interrupt a reclosing cycle or prevent a start from being accepted. Such signals can come from protection for a line connected shunt reactor, from transfer trip receive, from back-up protection functions, busbar protection trip or from breaker failure protection. When the CB open position is set to start SMBRREC(79), then manual opening must also be connected here. The inhibit is often a combination of signals from external IEDs via the IO and internal functions. An OR gate is then used for the combination.

52a and CBREADY

These should be connected to binary inputs to pick-up information from the CB. The 52a input is interpreted as CB Closed, if parameter CBAuxContType is set NormOpen, which is the default setting. At three operating gears in the breaker (single pole operated breakers) the connection should be “All poles closed” (series connection of the NO contacts) or “At least one pole open” (parallel connection of NC contacts) if the CBAuxContType is set to NormClosed. The “CB Ready” is a signal meaning that the CB is ready for a reclosing operation, either Close-Open (CO), or Open-Close-Open (OCO). If the available signal is of type “CB not charged” or “not ready”, an inverter can be inserted in front of the CBREADY input.

SYNC

This is connected to the internal synchronism check function when required. It can also be connected to a binary input for synchronization from an external device. If neither internal nor external synchronism or energizing check is required, it can be connected to a permanently high source, TRUE. The signal is required for three phase shots 1-5 to proceed.
**TRSOTF**

This is the signal “Trip by Switch Onto Fault”. It is usually connected to the “switch onto fault” output of line protection if multi-shot Auto-Reclose attempts are used. The input will start the shots 2-5. For single shot applications the input is set to FALSE.

**THOLHOLD**

Signal “Thermal overload protection holding back Auto-Reclosing”. It is normally set to FALSE. It can be connected to a thermal overload protection trip signal which resets only when the thermal content has gone down to an acceptable level, for example, 70%. As long as the signal is high, indicating that the line is hot, the Auto-Reclosing is held back. When the signal resets, a reclosing cycle will continue. Please observe that this have a considerable delay. Input can also be used for other purposes if for some reason the Auto-Reclose shot is halted.

**WAIT**

Used to hold back reclosing of the “low priority unit” during sequential reclosing. See “Recommendation for multi-breaker arrangement” below. The signal is activated from output WFMASTER on the second breaker Auto-Recloser in multi-breaker arrangements.

**BLKON**

Used to block the autorecloser (SMBRREC ,79) function for example, when certain special service conditions arise. Input is normally set to FALSE. When used, blocking must be reset with BLOCKOFF.

**BLOCKOFF**

Used to Unblock SMBRREC (79) function when it has gone to Block due to activating input BLKON or by an unsuccessful Auto-Reclose attempt if the setting BlockByUnsuccCl is set to Enabled. Input is normally set to FALSE.

**RESET**

Used to Reset SMBRREC (79) to start condition. Possible Thermal overload Hold will be reset. Positions, setting On-Off. will be started and checked with set times. Input is normally set to FALSE.

**Recommendations for output signals**

Please see figure 89.

**SETON**

Indicates that Autorecloser (SMBRREC ,79) function is switched on and operative.

**BLOCKED**

Indicates that SMRREC (79) function is temporarily or permanently blocked.

**ACTIVE**

Indicates that SMBRREC (79) is active, from start until end of Reset time.

**INPROGR**

Indicates that a sequence is in progress, from start until reclosing command.
UNSUCCL
Indicates unsuccessful reclosing.

CLOSECMD
Connect to a binary output for circuit-breaker closing command.

READY
Indicates that SMBRREC (79) function is ready for a new and complete reclosing sequence. It can be connected to the zone extension of a line protection should extended zone reach before automatic reclosing be necessary.

3PT1,-3PT2,-3PT3,-3PT4 and -3PT5
Indicates that three-phase automatic reclosing shots 1-5 are in progress. The signals can be used as an indication of progress or for own logic.

WFMASTER
Wait from master is used in high priority units to hold back reclosing of the low priority unit during sequential reclosing.

Other outputs
The other outputs can be connected for indication, disturbance recording, as required.

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Figure 89: Example of I/O-signal connections at a three-phase reclosing function
10.2.3.2  Auto-recloser parameter settings

The operation of the Autorecloser (SMBRREC,79) function can be switched *Enabled* and *Disabled*. The setting makes it possible to switch it *Enabled* or *Disabled* using an external switch via IO or communication ports.

**Number of reclosing shots**

In sub-transmission 1 shot is mostly used. In most cases one reclosing shot is sufficient as the majority of arcing faults will cease after the first reclosing shot. In power systems with many other types of faults caused by other phenomena, for example wind, a greater number of reclose attempts (shots) can be motivated.

**Auto-reclosing open times, dead times**

Three-phase shot 1 delay: For three-phase High-Speed Auto-Reclosing (HSAR) a typical open time is 400ms. Different local phenomena, such as moisture, salt, pollution etc. can influence the required dead time. Some users apply Delayed Auto-Reclosing (DAR) with delays of 10s or more. The delay of reclosing shot 2 and possible later shots are usually set at 30s or more. A check that the CB duty cycle can manage the selected setting must be done. The setting can in some cases be restricted by national regulations. For multiple shots the setting of shots 2-5 must be longer than the circuit breaker duty cycle time.

**tSync, Maximum wait time for synchronismcheck**

The time window should be coordinated with the operate time and other settings of the synchronism check function. Attention should also be paid to the possibility of a power swing when reclosing after a line fault. Too short a time may prevent a potentially successful reclosing. A typical setting may be 2.0 s.

**tTrip, Long trip pulse**

Usually the trip command and initiate auto-reclosing signal reset quickly as the fault is cleared. A prolonged trip command may depend on a CB failing to clear the fault. A trip signal present when the CB is reclosed will result in a new trip. At a setting somewhat longer than the auto-reclosing open time, this facility will not influence the reclosing. A typical setting of \(t_{\text{Trip}}\) could be close to the auto-reclosing open time.

**tInhibit, Inhibit resetting delay**

A typical setting is \(t_{\text{Inhibit}} = 5.0\) s to ensure reliable interruption and temporary blocking of the function. Function will be blocked during this time after the \(t_{\text{Inhibit}}\) has been activated.

**tReset, Reset time**

The Reset time sets the time for resetting the function to its original state, after which a line fault and tripping will be treated as an independent new case with a new reclosing cycle. One may consider a nominal CB duty cycle of for instance, O-0.3sec CO- 3 min. – CO. However the 3 minute (180 s) recovery time is usually not critical as fault levels are mostly lower than rated value and the risk of a new fault within a short time is negligible. A typical time may be \(t_{\text{Reset}} = 60\) or 180 s dependent of the fault level and breaker duty cycle.

**StartByCBOpen**

The normal setting is *Disabled*. It is used when the function is started by protection trip signals.
**FollowCB**

The usual setting is *Follow CB = Disabled*. The setting *Enabled* can be used for delayed reclosing with long delay, to cover the case when a CB is being manually closed during the "auto-reclosing open time" before the auto-reclosing function has issued its CB closing command.

**tCBClosedMin**

A typical setting is 5.0 s. If the CB has not been closed for at least this minimum time, a reclosing start will not be accepted.

**CBAuxContType, CB auxiliary contact type**

It shall be set to correspond to the CB auxiliary contact used. A *NormOpen* contact is recommended in order to generate a positive signal when the CB is in the closed position.

**CBReadyType, Type of CB ready signal connected**

The selection depends on the type of performance available from the CB operating gear. At setting *OCO* (CB ready for an Open – Close – Open cycle), the condition is checked only at the start of the reclosing cycle. The signal will disappear after tripping, but the CB will still be able to perform the C-O sequence. For the selection *CO* (CB ready for a Close – Open cycle) the condition is also checked after the set auto-reclosing dead time. This selection has a value first of all at multi-shot reclosing to ensure that the CB is ready for a C-O sequence at shot 2 and further shots. During single-shot reclosing, the *OCO* selection can be used. A breaker shall according to its duty cycle always have storing energy for a CO operation after the first trip. (IEC 56 duty cycle is O-0.3sec CO-3minCO).

**tPulse, Breaker closing command pulse duration**

The pulse should be long enough to ensure reliable operation of the CB. A typical setting may be *tPulse=200 ms*. A longer pulse setting may facilitate dynamic indication at testing, for example in “Debug” mode of PCM600 Application Configuration Tool (ACT).

**BlockByUnsucCl**

Setting of whether an unsuccessful auto-reclose attempt shall set the Auto-Reclose in block. If used the inputs BLKOFF must be configured to unblock the function after an unsuccessful Reclosing attempt. Normal setting is *Disabled*.

**UnsuccClByCBCheck, Unsuccessful closing by CB check**

The normal setting is *NoCBCheck*. The “auto-reclosing unsuccessful” event is then decided by a new trip within the reset time after the last reclosing shot. If one wants to get the UNSUCCL (Unsuccessful closing) signal in the case the CB does not respond to the closing command, CLOSECMD, one can set *UnsuccClByCBCheck= CB Check* and set *tUnsucCl* for instance to 1.0 s.

**Priority and time tWaitForMaster**

In single CB applications, one sets *Priority = None*. At sequential reclosing the function of the first CB, e.g. near the busbar, is set *Priority = High* and for the second CB *Priority = Low*. The maximum waiting time, *tWaitForMaster* of the second CB is set longer than the “auto-reclosing open time” and a margin for synchronism check at the first CB. Typical setting is *tWaitForMaster=2sec*. 
**AutoCont** and **tAutoContWait**, Automatic continuation to the next shot if the CB is not closed within the set time

The normal setting is **AutoCont = Disabled**. The **tAutoContWait** is the length of time SMBRREC (79) waits to see if the breaker is closed when **AutoCont** is set to **Enabled**. Normally, the setting can be **tAutoContWait = 2 sec.**

10.3 **Autorecloser STBRREC (79)**

10.3.1 **Identification**

<table>
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<th>ANSI/IEEE C37.2 Device Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autorecloser</td>
<td>STBRREC</td>
<td></td>
<td>O→I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>79</td>
</tr>
</tbody>
</table>

10.3.2 **Application**

Automatic reclosing is a well-established method for the restoration of service in a power system after a transient line fault. The majority of line faults are flashover arcs, which are transient by nature. When the power line is switched off by the operation of line protection and line breakers, the arc de-ionizes and recovers its ability to withstand voltage at a somewhat variable rate. Thus, a certain dead time with a de-energized line is necessary. Line service can then be resumed by automatic reclosing of the line breakers. The dead time selected should be long enough to ensure a high probability of arc de-ionization and successful reclosing.

For individual line breakers, auto-reclosing equipment or functions, the autoreclosing open time is used to determine line “dead time”. When simultaneous tripping and reclosing at the two line ends occurs, auto-reclosing open time is approximately equal to the line “dead time”. If the open time and dead time differ then, the line will be energized until the breakers at both ends have opened.
Single-pole tripping and single-pole automatic reclosing is a way of limiting the effect of a single-phase line fault on power system operation. Especially at higher voltage levels, the majority of faults are of single-phase type (around 90%). To maintain system stability in power systems with limited meshing or parallel routing single phase auto reclosing is of particular value. During the single phase dead time the system is still capable of transmitting load on the two healthy phases and the system is still synchronized. It requires that each phase breaker operates individually, which is usually the case for higher transmission voltages.

A somewhat longer dead time may be required for single-phase reclosing compared to high-speed three-phase reclosing. This is due to the influence on the fault arc from the voltage and the current in the non-tripped phases.

To maximize the availability of the power system it is possible to choose single pole tripping and automatic reclosing during single-phase faults and three pole tripping and automatic reclosing during multi-phase faults. Three-phase automatic reclosing can be performed with or without the use of a synchronism check, and an energizing check, such as dead line or dead busbar check.

During the single-pole open time there is an equivalent "series"-fault in the system resulting in a flow of zero sequence current. It is therefore necessary to coordinate the residual current protections (ground fault protection) with the single pole tripping and the auto-reclosing function. Attention shall also be paid to “pole discordance” (pole discordance) that arises when circuit breakers are provided with single pole operating devices. These breakers need pole discordance protection. They must also be coordinated with the single pole auto-recloser and
blocked during the dead time when a normal discordance occurs. Alternatively they should use a trip time longer than the set single phase dead time.

For the individual line breakers and auto-reclosing equipment, the “auto-reclosing open time” expression is used. This is the dead time setting for the Auto-Recloser. During simultaneous tripping and reclosing at the two line ends, auto-reclosing open time is approximately equal to the line dead time. Otherwise these two times may differ as one line end might have a slower trip than the other end which means that the line will not be dead until both ends have opened.

If the fault is permanent, the line protection will trip again when reclosing is attempted in order to clear the fault.

It is common to use one automatic reclosing function per line circuit-breaker (CB). When one CB per line end is used, then there is one auto-reclosing function per line end. If auto-reclosing functions are included in duplicated line protection, which means two auto-reclosing functions per CB, one should take measures to avoid uncoordinated reclosing commands. In breaker-and-a-half, double-breaker and ring bus arrangements, two CBs per line end are operated. One auto-reclosing function per CB is recommended. Arranged in such a way, sequential reclosing of the two CBs can be arranged with a priority circuit available in the auto-reclose function. In case of a permanent fault and unsuccessful reclosing of the first CB, reclosing of the second CB is cancelled and thus the stress on the power system is limited. Another advantage with the breaker connected auto-recloser is that checking that the breaker closed before the sequence, breaker prepared for an autoreclose sequence and so on is much simpler.

The auto-reclosing function can be selected to perform single-phase and/or three phase automatic-reclosing from several single-shot to multiple-shot reclosing programs.

In power transmission systems it is common practice to apply single and/or three phase, single-shot Auto-Reclosing. In Sub-transmission and Distribution systems tripping and auto-reclosing are usually three-phase. The mode of automatic reclosing varies however. Single-shot and multi-shot are in use. The first shot can have a short delay, HSAR, or a longer delay, DAR. The second and following reclosing shots have a rather long delay. When multiple shots are used the dead time must harmonize with the breaker duty-cycle capacity.

Automatic-reclosing is usually started by the line protection and in particular by instantaneous tripping of such protection. The auto-reclosing function can be inhibited (blocked) when certain protection functions detecting permanent faults, such as shunt reactor, cable or bus bar protection are in operation. Back-up protection zones indicating faults outside the own line are also connected to inhibit the Auto-Reclose.

Automatic-reclosing should not be attempted when closing a CB and energizing a line onto a fault (SOTF), except when multiple-shots are used where shots 2 etc. will be started at SOTF. Likewise a CB in a multi-breaker bus bar arrangement which was not closed when a fault occurred should not be closed by operation of the Auto-Reclosing function. Auto-Reclosing is often combined with a release condition from synchronism check and dead line or dead bus bar check. In order to limit the stress on turbo-generator sets from Auto-Reclosing onto a permanent fault, one can arrange to combine Auto-Reclosing with a synchronism check on line terminals close to such power stations and attempt energizing from the side furthest away from the power station and perform the synchronism check at the local end if the energizing was successful.

Transmission protection systems are usually sub-divided and provided with two redundant protection IEDs. In such systems it is common to provide auto-reclosing in only one of the sub-systems as the requirement is for fault clearance and a failure to reclose because of the auto-recloser being out of service is not considered a major disturbance. If two auto-reclosers are provided on the same breaker, the application must be carefully checked and normally one must
be the master and be connected to inhibit the other auto-recloser if it has started. This inhibit can, for example, be done from STBRREC (79) In progress.

When Single and/or three phase auto-reclosing is used there are a number of cases where the tripping shall be three phase anyway. Some examples are:

When Single and/or three phase auto-reclosing is used there are a number of cases where the tripping shall be three phase anyway. Some examples are:

• Evolving fault where the fault during the dead-time spreads to another phase. The other two phases must then be tripped and a three phase dead-time and autoreclose initiated
• Permanent fault
• Fault during three phase dead-time
• Auto-reclose out of service or CB not ready for an auto-reclosing cycle

*Prepare three phase tripping* is then used to switch the tripping to three phase. This signal is generated by the auto-recloser and connected to the trip function block and also connected outside the IED through IO when a common auto-recloser is provided for two sub-systems. An alternative signal *Prepare 1 Phase tripping* is also provided and can be used as an alternative when the autorecloser is shared with another subsystem. This provides a fail safe connection so that even a failure in the IED with the auto-recloser will mean that the other sub-system will start a three-phase trip.

A permanent fault will cause the line protection to trip again when it recloses in an attempt to clear the fault.

The auto-reclosing function allows a number of parameters to be adjusted.

Examples:

• number of auto-reclosing shots
• auto-reclosing program
• auto-reclosing open times (dead time) for each shot.

10.3.2.1 Auto-reclosing operation Disabled and Enabled

Operation of the automatic reclosing can be set OFF and ON by a setting parameter and by external control. Parameter *Operation* = *Disabled*, or *Enabled* sets the function OFF and ON. In setting *Operation=ExternalCtrl* Disabled and Enabled control is made by input signal pulses, for example, from the control system or from the binary input (and other systems).

When the function is set *Enabled* and operative (other conditions such as CB closed and CB Ready are also fulfilled), the output SETON is activated (high) when the function is ready to accept a reclosing start.

10.3.2.2 Initiate auto-reclosing and conditions for initiation of a reclosing cycle

The usual way to start a reclosing cycle, or sequence, is to start it at tripping by line protection by applying a signal to the input PICKUP. Starting signals can be either, General Trip signals or, only the conditions for Differential, Distance protection Zone 1 and Distance protection Aided trip. In
some cases also Directional Ground fault function Aided trip can be connected to start an Auto-
Reclose attempt.

A number of conditions need to be fulfilled for the start to be accepted and a new auto-reclosing
cycle to be started. They are linked to dedicated inputs. The inputs are:

- CBREADY, CB ready for a reclosing cycle, for example, charged operating gear
- 52a to ensure that the CB was closed when the line fault occurred and start was applied.
- No signal at input INHIBIT that is, no blocking or inhibit signal present. After the start has
  been accepted, it is latched in and an internal signal Started is set. It can be interrupted by
certain events, like an Inhibit signal.

10.3.2.3 Initiate auto-reclosing from CB open information

If a user wants to initiate auto-reclosing from the “CB open” position instead of from protection
trip signals, the function offers such a possibility. This starting mode is selected with the setting
parameter StartByCBOpen=Enabled. It is then necessary to block reclosing for all manual trip
operations. Typically CBAuxContType=NormClosed is also set and a CB auxiliary contact of type
NC (normally closed, 52b) is connected to inputs 52a and PICKUP. When the signal changes from
“CB closed” to “CB open” an auto-reclosing start pulse is generated and latched in the function,
subject to the usual checks. Then the reclosing sequence continues as usual. One needs to connect
signals from manual tripping and other functions, which shall prevent reclosing, to the input
INHIBIT.

10.3.2.4 Blocking of the autorecloser

Auto-Reclose attempts are expected to take place only in the event of transient faults on the own
line. The Auto-Recloser must be blocked for the following conditions:

- Tripping from Delayed Distance protection zones
- Tripping from Back-up protection functions
- Tripping from Breaker failure function
- Intertrip received from remote end Breaker failure function
- Busbar protection tripping

Depending of the starting principle (General Trip or only Instantaneous trip) adopted above the
delayed and back-up zones might not be required. Breaker failure local and remote must however
always be connected.

10.3.2.5 Control of the auto-reclosing open time for shot 1

Up to four different time settings can be used for the first shot, and one extension time. There are
separate settings for single- and three-phase auto-reclosing open time, \( t_{1\text{Ph}}, t_{1\text{3Ph}} \). If no
particular input signal is applied, and an autoreclosing program with single-phase reclosing is
selected, the auto-reclosing open time \( t_{1\text{Ph}} \) will be used. If input signal TR3P is activated in
connection with start, the auto-reclosing open time for three-phase reclosing is used.

An auto-reclosing open time extension delay, \( t_{\text{Extended} t1} \), can be added to the normal shot 1
delay. It is intended to come into use if the communication channel for permissive line protection
is lost. In such a case there can be a significant time difference in fault clearance at the two ends
of the line. A longer “auto-reclosing open time” can then be useful. This extension time is
controlled by setting parameter Extended t1 = Disabled and the input PLCLOST.
10.3.2.6 Long trip signal

In normal circumstances the trip command resets quickly due to fault clearing. The user can set a maximum trip pulse duration $t_{Trip}$. When trip signals are longer, the auto-reclosing open time is extended by $t_{Extended}$. If $t_{Extended} = \text{Disabled}$, a long trip signal interrupts the reclosing sequence in the same way as a signal to input INHIBIT.

10.3.2.7 Reclosing programs

The maximum number of reclosing shots in an auto-reclosing cycle is selected by the setting parameter $NoOfShots$. The type of reclosing used at the first reclosing shot is set by parameter $FirstShot$. The first alternative is three-phase reclosing. The other alternatives include some single-phase or two-phase reclosing. Usually there is no two-phase tripping arranged, and then there will be no two-phase reclosing.

The decision is also made in the tripping function block (TR) where the setting $3Ph,1/3Ph$ is selected.

10.3.2.8 FirstShot=3ph (normal setting for a single 3 phase shot)

3-phase reclosing, one to five shots according to setting $NoOfShots$. The output three-phase trip PREP3P is always set (high). A trip operation is made as a three-phase trip at all types of fault. The reclosing is as a three-phase Reclosing as in mode 1/3ph described below. All signals, blockings, inhibits, timers, requirements etc. are the same as for FirstShot=1/3ph.

10.3.2.9 3-phase reclosing, one to five shots according to setting $NoOfShots$

1-phase or 3-phase reclosing first shot, followed by 3-phase reclosing shots, if selected. Here, the auto-reclosing function is assumed to be "On" and "Ready". The breaker is closed and the operation gear ready (operating energy stored). Input START is received and sealed-in. The output READY is reset (set to false). Output ACTIVE is set.

- If TR3P is low (1-phase trip): The timer for 1-phase reclosing open time is started and the output 1PT1 (1-phase reclosing in progress) is activated. It can be used to suppress pole disagreement trip and ground-fault protection during the 1-phase open interval.
- If TR3P is high (3-phase trip): The timer for 3-phase auto-reclosing open time, $t_{13Ph}$ or $t_{13PhHS}$ is started and output 3PT1 (3-phase auto-reclosing shot 1 in progress) is set.

While any of the auto-reclosing open time timers are running, the output INPROGR is activated. When the "open time" timer runs out, the respective internal signal is transmitted to the output module for further checks and to issue a closing command to the circuit breaker.

When a CB closing command is issued the output prepare 3-phase trip is set. When issuing a CB closing command a resettimer $t_{Reset}$ is started. If no tripping takes place during that time the auto-reclosing function resets to the "Ready" state and the signal ACTIVE resets. If the first reclosing shot fails, a 3-phase trip will be initiated and 3-phase reclosing can follow, if selected.
10.3.2.10 FirstShot=1ph 1-phase reclosing in the first shot

The 1-phase reclosing attempt can be followed by 3-phase reclosing, if selected. If the first trip is a 3-phase trip the auto-reclosing will be blocked. In the event of a 1-phase trip, the operation is as in the example described above, program mode 1/3ph. If the first reclosing shot fails, a 3-phase trip will be initiated and 3-phase reclosing can follow, if selected. A maximum of four additional shots can be done (according to the NoOfShots parameter). During 3-phase trip (TR2P low and TR3P high) the auto-reclosing will be blocked and no reclosing takes place.

10.3.2.11 FirstShot=1ph + 1*3ph 1-phase or 3-phase reclosing in the first shot

At 1-phase trip, the operation is as described above. If the first reclosing shot fails, a 3-phase trip will be issued and 3-phase reclosing will follow, if selected. At 3-phase trip, the operation is similar to the above. But, if the first reclosing shot fails, a 3-phase trip command will be issued and the auto-reclosing will be blocked. No more shots take place! 1*3ph should be understood as “Just one shot at 3-phase reclosing”.

10.3.2.12 FirstShot=1ph + 1*2/3ph 1-phase, 2-phase or 3-phase reclosing in the first shot

At 1-phase trip, the operation is as described above. If the first reclosing shot fails, a 3-phase trip will be issued and 3-phase reclosing will follow, if selected. At 3-phase trip, the operation is similar as above. But, if the first reclosing shot fails, a 3-phase trip will be issued and the auto-reclosing will be blocked. No more shots take place! “1*3ph” should be understood as “Just one shot at 3-phase reclosing”.

A start of a new reclosing cycle is blocked during the set “reclaim time” after the selected number of reclosing shots have been made.

10.3.2.13 Evolving fault

An evolving fault starts as a single-phase fault which leads to single-pole tripping and then the fault spreads to another pole. The second fault is then cleared by three-pole tripping.

The Auto-Reclosing function will first receive a trip and start signal (START) without any three-phase signal (TR3P). The Auto-Reclosing function will start a single-phase reclosing, if programmed to do so. At the evolving fault clearance there will be a new signal PICKUP and three-pole trip information, TR3P. The single-phase reclosing sequence will then be stopped, and instead the timer, t1 3Ph, for three-phase reclosing will be started from zero. The sequence will continue as a three-phase reclosing sequence, if it is a selected alternative reclosing mode.

The second fault which can be single phase is tripped three phase because trip module (TR) in the IED has an evolving fault timer which ensures that second fault is always tripped three phase. For other types of relays where the relays do not include this function the output PREP3PH is used to prepare the other sub-system for three pole tripping. This signal will, for evolving fault situations be activated a short time after the first trip has reset and will thus ensure that new trips will be three phase.
10.3.2.14 **Reclosing reset timer**

The reset timer $t_{Reset}$ defines the time it takes from issue of the reclosing command, until the reclosing function resets. Should a new trip occur during this time, it is treated as a continuation of the first fault. The reclaim timer is started when the CB closing command is given.

10.3.2.15 **Transient fault**

After the Reclosing command the reset timer keeps running for the set time. If no tripping occurs within this time, $t_{Reset}$, the Auto-Reclosing will reset. The CB remains closed and the operating gear recharges. The input signals 52A and CBREADY will be set.

10.3.2.16 **Permanent fault and reclosing unsuccessful signal**

If a new trip occurs, and a new input signal PICKUP or TRSOTF appears, after the CB closing command, the output UNSUCCL (unsuccessful closing) is set high. The timer for the first shot can no longer be started. Depending on the set number of Reclosing shots further shots may be made or the Reclosing sequence is ended. After reset timer time-out the Auto-Reclosing function resets, but the CB remains open. The “CB closed” information through the input 52A is missing. Thus, the reclosing function is not ready for a new reclosing cycle.

Normally, the signal UNSUCCL appears when a new trip and start is received after the last reclosing shot has been made and the auto-reclosing function is blocked. The signal resets after reclaim reset time. The “unsuccessful” signal can also be made to depend on CB position input. The parameter $UnsuccClByCBChk$ should then be set to $CB$ Check, and a timer $t_{UnsucCl}$ should be set too. If the CB does not respond to the closing command and does not close, but remains open, the output UNSUCCL is set high after time $t_{UnsucCl}$. The Unsuccessful output can for example, be used in Multi-Breaker arrangement to cancel the auto-reclosing function for the second breaker, if the first breaker closed onto a persistent fault. It can also be used to generate a Lock-out of manual closing until the operator has reset the Lock-out, see separate section.

10.3.2.17 **Lock-out initiation**

In many cases there is a requirement that a Lock-out is generated when the Auto- Reclosing attempt fails. This is done with logic connected to the in- and outputs of the Auto-Reclose function and connected to Binary IO as required. Many alternative ways of performing the logic exist depending on whether manual closing is interlocked in the IED, whether an external physical Lock-out relay exists and whether the reset is hardwired, or carried out by means of communication.

There are also different alternatives regarding what shall generate Lock-out. Examples of questions are:

- Shall back-up time delayed trip give Lock-out (normally yes)
- Shall Lock-out be generated when closing onto a fault (mostly)
- Shall Lock-out generated when the Auto-Recloser was OFF at the fault
- Shall Lock-out be generated if the Breaker did not have sufficient operating power for an Auto-Reclosing sequence (normally not as no closing attempt has been given)

In figure 91 and figure 92 the logic shows how a closing Lock-out logic can be designed with the Lock-out relay as an external relay alternatively with the Lock-out created internally with the Manual closing going through the Synchro-check function. Lock-out arranged with an external Lock-out relay.
10.3.2.18 Automatic continuation of the reclosing sequence

The auto-reclosing function can be programmed to proceed to the following reclosing shots (if selected) even if the start signals are not received from the protection functions, but the breaker is still not closed. This is done by setting parameter AutoCont = Enabled and tAutoContWait to the required delay for the function to proceed without a new start.

10.3.2.19 Thermal overload protection holding the auto-reclosing function back

If the input THOLHOLD (thermal overload protection holding reclosing back) is activated, it will keep the reclosing function on a hold until it is reset. There may thus be a considerable delay between start of Auto-Reclosing and reclosing command to the circuit-breaker. An external logic limiting the time and sending an inhibit to the INHIBIT input can be used. The input can also be used to set the Auto- Reclosing on hold for a longer or shorter period.
10.3.3 Setting guidelines

10.3.3.1 Configuration

Use the PCM600 configuration tool to configure signals.

Autorecloser function parameters are set via the local HMI or Parameter Setting Tool (PST). Parameter Setting Tool is a part of PCM600.

10.3.3.2 Recommendations for input signals

Please see examples in figure 93. The figure is also valid for output signals.

![Connection diagram](image-url)

**Figure 93**: Connection diagram Example of I/O-signal connections at a three-phase reclosing function

**ON and OFF**

These inputs can be connected to binary inputs or to a communication interface block for external control.

**PICKUP**

It should be connected to the trip output protection function, which starts the auto-reclosing function. It can also be connected to a binary input for start from an external contact. A logical OR-gate can be used to combine the number of start sources.
If `StartByCBOpen` is used, the CB Open condition shall also be connected to the input PICKUP.

**INHIBIT**

Signals that interpret a reclosing cycle or prevent start from being accepted are connected to this input. Such signals can come from protection for a line connected shunt reactor, from transfer trip receive, from back-up protection functions, busbar protection trip or from breaker failure protection. When the CB open position is set to start the Auto-Recloser, then manual opening must also be connected here. The inhibit is often a combination of signals from external IEDs via the IO and internal functions. An OR gate is then used for the combination.

**52A and CBREADY**

These should be connected to binary inputs to pick-up information from the CB. The CBREADY input is interpreted as CB Closed, if parameter `CBAuxContType` is set `NormOpen`, which is the default setting. At three operating gears in the breaker (single pole operated breakers) the connection should be “All poles closed” (series connection of the NO contacts) or “At least one pole open” (parallel connection of NC contacts) if the `CBAuxContType` is set to `NormClosed`. The “CB Ready” is a signal meaning that the CB is ready for a reclosing operation, either Close-Open (CO), or Open-Close-Open (OCO). If the available signal is of type “CB not charged” or “not ready”, an inverter can be inserted in front of the CBREADY input.

**SYNC**

This is connected to the internal synchronism check function when required. It can also be connected to a binary input for synchronization from an external device. If neither internal nor external synchronism or energizing check is required, it can be connected to a permanently high source, TRUE. The signal is required for three phase shots 1-5 to proceed.

**TRSOVT**

This is the signal “Trip by Switch Onto Fault”. It is usually connected to the “switch onto fault” output of line protection if multi-shot Auto-Reclose attempts are used. The input will start the shots 2-5. For single shot applications the input is set to FALSE.

**THOLHOLD**

Signal “Thermal overload protection holding back Auto-Reclosing”. It is normally set to FALSE. It can be connected to a thermal overload protection trip signal which resets only when the thermal content has gone down to an acceptable level, for example, 70%. As long as the signal is high, indicating that the line is hot, the Auto-Reclosing is held back. When the signal resets, a reclosing cycle will continue. Please observe that this have a considerable delay. Input can also be used for other purposes if for some reason the Auto-Reclose shot is halted.

**WAIT**

Used to hold back reclosing of the “low priority unit” during sequential reclosing. See “Recommendation for multi-breaker arrangement” below. The signal is activated from output `WFMASTER` on the second breaker Auto-Recloser in multi-breaker arrangements.

**BLKON**

Used to block the Auto-Reclosing function for example, when certain special service conditions arise. Input is normally set to FALSE. When used, blocking must be reset with BLOCKOFF.
**BLOCKOFF**

Used to Unblock the Auto-Reclosing function when it has gone to Block due to activating input BLKON or by an unsuccessful Auto-Reclose attempt if the setting BlockByUnsuccCl is set to Enabled. Input is normally set to FALSE.

**RESET**

Used to Reset the Auto-Recloser to start condition. Possible Thermal overload Hold and so on will be reset. Positions, setting Enabled-Disabled and so on will be started and checked with set times. Input is normally set to FALSE.

**Recommendations for output signals**

**SETON**

Indicates that the auto-reclose function is switched ON and operative.

**BLOCKED**

Indicates that the auto-reclose function is temporarily or permanently blocked.

**ACTIVE**

Indicates that STBRREC (79) is active, from start until end of reset time.

**INPROGR**

Indicates that a sequence is in progress, from start until reclosing command.

**UNSUCCCL**

Indicates unsuccessful reclosing.

**CLOSEDCMD**

Connect to a binary output for circuit-breaker closing command.

**READY**

Indicates that the Auto-reclosing function is ready for a new and complete reclosing sequence. It can be connected to the zone extension of a line protection should extended zone reach before automatic reclosing be necessary.

**1PT1**

Indicates that 1-phase automatic reclosing is in progress. It is used to temporarily block an ground-fault and/or pole disagreement function during the 1-phase open interval

**3PT1, 3PT2, 3PT3, 3PT4 and 3PT5**

Indicates that three-pole automatic reclosing shots 1-5 are in progress. The signals can be used as an indication of progress or for own logic.

**PREP3P**

Prepare three-pole trip is usually connected to the trip block to force a coming trip to be a three-pole one. If the function cannot make a single- or two-pole reclosing, the tripping should be three-pole.
WFMASTER
Wait from master is used in high priority units to hold back reclosing of the low priority unit during sequential reclosing.

Other outputs
The other outputs can be connected for indication, disturbance recording and so on as required.

10.3.3.3 STBRREC- Auto-recloser parameter settings

Auto-recloser parameter settings

Operation
The operation of the Autorecloser (STBRREC, 79) function can be switched Enabled and Disabled. The setting makes it possible to switch it Enabled or Disabled using an external switch via IO or communication ports.

NoOfShots, Number of reclosing shots
In power transmission 1 shot is mostly used. In most cases one reclosing shot is sufficient as the majority of arcing faults will cease after the first reclosing shot. In power systems with many other types of faults caused by other phenomena, for example wind, a greater number of reclose attempts (shots) can be motivated.

First shot and reclosing program
There are six different possibilities in the selection of reclosing programs. What type of reclosing to use for the different kinds of faults depends on the power system configuration and on the users practices and preferences. When the circuit-breakers only have three-pole operation, then three-pole reclosing has to be chosen. This is usually the case in subtransmission and distribution lines. Three-phase tripping and reclosing for all types of faults is also widely accepted in completely meshed power systems. In transmission systems with few parallel circuits, single-phase reclosing for single-phase faults is an attractive alternative for maintaining service and system stability.

Auto-reclosing open times, dead times
Three-phase shot 1 delay: For three-phase High-Speed Auto-Reclosing (HSAR) a typical open time is 400 ms. Different local phenomena, such as moisture, salt, pollution etc. can influence the required dead time. Some users apply Delayed Auto-Reclosing (DAR) with delays of 10 s or more. The delay of reclosing shot 2 and possible later shots are usually set at 30 s or more. A check that the CB duty cycle can manage the selected setting must be done. The setting can in some cases be restricted by national regulations. For multiple shots the setting of shots 2-5 must be longer than the circuit breaker duty cycle time.

Extended t1 and tExtended t1
Extended auto-reclosing open time for shot 1.

The communication link in a permissive (not strict) line protection scheme, for instance a power line carrier (PLC) link, may not always be available. If lost, it can result in delayed tripping at one end of a line. There is a possibility to extend the autoreclosing open time in such a case by use of an input to PLCLOST, and the setting parameters. Typical setting in such a case: Extended t1 = Enabled and tExtended t1 = 0.5 s.
**tTrip, Long trip pulse**

Usually the trip command and initiate auto-reclosing signal reset quickly as the fault is cleared. A prolonged trip command may depend on a CB failing to clear the fault. A trip signal present when the CB is reclosed will result in a new trip. Depending on the setting Extended \( t_1 = \text{Disabled or Enabled} \) a trip/ initiate pulse longer than the set time \( t_{Trip} \) will either block the reclosing or extend the auto-reclosing open time. At a setting somewhat longer than the auto-reclosing open time, this facility will not influence the reclosing. A typical setting of \( t_{Trip} \) could be close to the autoreclosing open time.

**tInhibit, Inhibit resetting delay**

A typical setting is \( t_{Inhibit} = 5.0 \, s \) to ensure reliable interruption and temporary blocking of the function. Function will be blocked during this time after the \( t_{Inhibit} \) has been activated.

**timetReset, Reset time**

The Reset time sets the time for resetting the function to its original state, after which a line fault and tripping will be treated as an independent new case with a new reclosing cycle. One may consider a nominal CB duty cycle of for instance, O-0.3 s CO- 3 min. – CO. However the 3 minute (180 s) recovery time is usually not critical as fault levels are mostly lower than rated value and the risk of a new fault within a short time is negligible. A typical time may be \( t_{Reset} = 60 \) or \( 180 \, s \) dependent of the fault level and breaker duty cycle.

**StartByCBOpen**

The normal setting is \( \text{Disabled} \). It is used when the function is started by protection trip signals \( \text{Follow CB} = \text{Disabled} \). \( \text{Follow CB} = \text{Enabled} \).

**Follow CB**

The usual setting is \( \text{Follow CB} = \text{Disabled} \). The setting \( \text{Enabled} \) can be used for delayed reclosing with long delay, to cover the case when a CB is being manually closed during the “auto-reclosing open time” before the auto-reclosing function has issued its CB closing command.

**tCBClosedMin**

A typical setting is 5.0 s. If the CB has not been closed for at least this minimum time, a reclosing start will not be accepted.

**CBAuxContType, CB auxiliary contact type**

It shall be set to correspond to the CB auxiliary contact used. A \( \text{NormOpen} \) contact is recommended in order to generate a positive signal when the CB is in the closed position.

**CBReadyType, Type of CB ready signal connected**

The selection depends on the type of performance available from the CB operating gear. At setting \( \text{OCO} \) (CB ready for an Open – Close – Open cycle), the condition is checked only at the start of the reclosing cycle. The signal will disappear after tripping, but the CB will still be able to perform the C-O sequence. For the selection \( \text{CO} \) (CB ready for a Close – Open cycle) the condition is also checked after the set auto-reclosing dead time. This selection has a value first of all at multi-shot reclosing to ensure that the CB is ready for a C-O sequence at shot 2 and further shots. During single-shot reclosing, the \( \text{OCO} \) selection can be used. A breaker shall according to its duty cycle always have storing energy for a CO operation after the first trip. (IEC 56 duty cycle is O-0.3 secCO-3minCO).
**tPulse**, Breaker closing command pulse duration

The pulse should be long enough to ensure reliable operation of the CB. A typical setting may be \( tPulse = 200 \text{ ms} \). A longer pulse setting may facilitate dynamic indication at testing, for example in “Debug” mode of PCM600 Application Configuration Tool (ACT).

**BlockByUnsucCl**

Setting of whether an Unsuccessful Auto-Reclose attempt shall set the Auto-Reclose in Block. If used the inputs BLKOFF must be configured to unblock the function after an unsuccessful Reclosing attempt. Normal setting is *Disabled*.

**UnsucClByCBChk**, Unsuccessful closing by CB check

The normal setting is *NoCBCheck*. The “auto-reclosing unsuccessful” event is then decided by a new trip within the reclaim reclaimreset time after the last reclosing shot. If one wants to get the UNSUCCL (Unsuccessful closing) signal in the case the CB does not respond to the closing command, CLOSECMD, one can set *UnsucClByCBChk = CB check* and set *tUnsucCl* for instance to 1.0 s.

**Priority and time tWaitForMaster**

In single CB applications, one sets *Priority = None*. At sequential reclosing the function of the first CB, for example near the busbar, is set *Priority = High* and for the second CB *Priority = Low*. The maximum waiting time, *tWaitForMaster* of the second CB is set longer than the “auto-reclosing open time” and a margin for synchronism check at the first CB. Typical setting is *tWaitForMaster = 2s*.

**AutoCont** and **tAutoContWait**, Automatic continuation to the next shot if the CB is not closed within the set time

The normal setting is *AutoCont = Disabled*. The *tAutoContWait* is the length of time STBRREC (79) waits to see if the breaker is closed when AutoCont is set to *Enabled*. Normally the setting can be *tAutoContWait = 2 s*.

### 10.4 Apparatus control

#### 10.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay control</td>
<td>QCBAY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Local remote</td>
<td>LOCREM</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Local remote control</td>
<td>LOCREMCTRL</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 10.4.2 Application

The apparatus control is a function for control and supervising of circuit breakers, disconnectors, and grounding switches within a bay. Permission to operate is given after evaluation of conditions from other functions such as interlocking, synchronism check, operator place selection and external or internal blockings.
The complete apparatus control function is not included in this product, and the information below is included for understanding of the principle for the use of QCBAY, LOCREM, and LOCREMCTRL for the selection of the operator place.

Figure 94 gives an overview from what places the apparatus control function receive commands. Commands to an apparatus can be initiated from the Control Centre (CC), the station HMI or the local HMI on the IED front.

Features in the apparatus control function:

- Operation of primary apparatuses
- Select-Execute principle to give high security
- Selection function to prevent simultaneous operation
- Selection and supervision of operator place
- Command supervision
- Block/deblock of operation
- Block/deblock of updating of position indications
- Substitution of position indications
- Overriding of interlocking functions
- Overriding of synchronism check
- Operation counter
- Suppression of Mid position

The apparatus control function is realized by means of a number of function blocks designated:

- Switch controller SCSWI
- Circuit breaker SXCBR
- Circuit switch SXSWI
- Position evaluation POS_EVAL
- Select release SELGGIO
SCSWI, SXCBR, QCBAY, SXSWI and SELGGIO are logical nodes according to IEC 61850. The signal flow between these function blocks appears in figure 95. The function Logical node Interlocking (SCILO) in the figure 95 is the logical node for interlocking.

Control operation can be performed from the local HMI. If the administrator has defined users with the UM tool, then the local/remote switch is under authority control. If not, the default (factory) user is the SuperUser that can perform control operations from the local HMI without LogOn. The default position of the local/remote switch is on remote.

**Figure 95: Signal flow between apparatus control function blocks**

**Bay control (QCBAY)**
The Bay control (QCBAY) is used to handle the selection of the operator place for the bay. The function gives permission to operate from two types of locations either from Remote (for example, control centre or station HMI) or from Local (local HMI on the IED) or from all (Local and Remote). The Local/Remote switch position can also be set to Off, which means no operator place selected that is, operation is not possible neither from local nor from remote.

QCBAY also provides blocking functions that can be distributed to different apparatuses within the bay. There are two different blocking alternatives:
• Blocking of update of positions
• Blocking of commands

The function does not have a corresponding functionality defined in the IEC 61850 standard, which means that this function is included as a vendor specific logical node.

10.4.3 Interaction between modules

A typical bay with apparatus control function consists of a combination of logical nodes or functions that are described here:

• The Switch controller (SCSWI) initializes all operations for one apparatus and performs the actual switching and is more or less the interface to the drive of one apparatus. It includes the position handling as well as the control of the position.
• The Circuit breaker (SXCBR) is the process interface to the circuit breaker for the apparatus control function.
• The Circuit switch (SXSWI) is the process interface to the disconnector or the grounding switch for the apparatus control function.
• The Bay control (QCBAY) fulfils the bay-level functions for the apparatuses, such as operator place selection and blockings for the complete bay.
• The function (SELGGIO), deals with reservation of the bay.
• The Four step overcurrent protection (OC4PTOC, 51/67) trips the breaker.
• The Protection trip logic (SMPPTRC, 94) connects the “trip” outputs of one or more protection functions to a common “trip” to be transmitted to SXCBR.
• The Autorecloser (SMBRREC, 79) consists of the facilities to automatically close a tripped breaker with respect to a number of configurable conditions.
• The logical node Interlocking (SCILO, 3) provides the information to SCSWI whether it is permitted to operate due to the switchyard topology. The interlocking conditions are evaluated with separate logic and connected to SCILO (3).
• The Synchronism, energizing check, and synchronizing (SESRSYN, 25) calculates and compares the voltage phasor difference from both sides of an open breaker with predefined switching conditions (synchronism check). Also the case that one side is dead (energizing-check) is included.
• The logical node Generic Automatic Process Control, GAPC, is an automatic function that reduces the interaction between the operator and the system. With one command, the operator can start a sequence that will end with a connection of a process object (for example a line) to one of the possible busbars.

The overview of the interaction between these functions is shown in figure 96 below.
Figure 96: Example overview of the interactions between functions in a typical bay

10.4.4 Setting guidelines

The setting parameters for the apparatus control function are set via the local HMI or PCM600.
10.4.4.1 Bay control (QCBAY)

If the parameter \textit{AllPSTOValid} is set to \textit{No priority}, all originators from local and remote are accepted without any priority.

10.5 Logic rotating switch for function selection and LHMI presentation SLGGIO

10.5.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic rotating switch for function selection and LHMI presentation</td>
<td>SLGGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

10.5.2 Application

The logic rotating switch for function selection and LHMI presentation function (SLGGIO) (or the selector switch function block, as it is also known) is used to get a selector switch functionality similar with the one provided by a hardware selector switch. Hardware selector switches are used extensively by utilities, in order to have different functions operating on pre-set values. Hardware switches are however sources for maintenance issues, lower system reliability and extended purchase portfolio. The virtual selector switches eliminate all these problems.

SLGGIO function block has two operating inputs (UP and DOWN), one blocking input (BLOCK) and one operator position input (PSTO).

SLGGIO can be activated both from the local HMI and from external sources (switches), via the IED binary inputs. It also allows the operation from remote (like the station computer). SWPOSN is an integer value output, giving the actual output number. Since the number of positions of the switch can be established by settings (see below), one must be careful in coordinating the settings with the configuration (if one sets the number of positions to $x$ in settings – for example, there will be only the first $x$ outputs available from the block in the configuration). Also the frequency of the (UP or DOWN) pulses should be lower than the setting $t_{\text{Pulse}}$.

From the local HMI, there are two modes of operating the switch: from the menu and from the Single-line diagram (SLD).

10.5.3 Setting guidelines

The following settings are available for the Logic rotating switch for function selection and LHMI presentation (SLGGIO) function:

\textit{Operation:} Sets the operation of the function \textit{Enabled} or \textit{Disabled}.

\textit{NrPos:} Sets the number of positions in the switch (max. 32). This setting influence the behavior of the switch when changes from the last to the first position.

\textit{OutType:} \textit{Steady} or \textit{Pulsed}.
**tPulse**: In case of a pulsed output, it gives the length of the pulse (in seconds).

**tDelay**: The delay between the UP or DOWN activation signal positive front and the output activation.

**StopAtExtremes**: Sets the behavior of the switch at the end positions – if set to *Disabled*, when pressing UP while on first position, the switch will jump to the last position; when pressing DOWN at the last position, the switch will jump to the first position; when set to *Enabled*, no jump will be allowed.

### 10.6 Selector mini switch VSGGIO

#### 10.6.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selector mini switch</td>
<td>VSGGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 10.6.2 Application

Selector mini switch (VSGGIO) function is a multipurpose function used in the configuration tool in PCM600 for a variety of applications, as a general purpose switch. VSGGIO can be used for both acquiring an external switch position (through the IPOS1 and the IPOS2 inputs) and represent it through the single line diagram symbols (or use it in the configuration through the outputs POS1 and POS2) as well as, a command function (controlled by the PSTO input), giving switching commands through the CMDPOS12 and CMDPOS21 outputs.

The output POSITION is an integer output, showing the actual position as an integer number 0 – 3.

An example where VSGGIO is configured to switch Autorecloser enabled–disabled from a button symbol on the local HMI is shown in Figure 97. The Close and Open buttons on the local HMI are normally used for enable–disable operations of the circuit breaker.

![Figure 97: Control of Autorecloser from local HMI through Selector mini switch](IEC07000112-2-en_ansi.vsd)
10.6.3 Setting guidelines

Selector mini switch (VSGGO) function can generate pulsed or steady commands (by setting the Mode parameter). When pulsed commands are generated, the length of the pulse can be set using the tPulse parameter. Also, being accessible on the single line diagram (SLD), this function block has two control modes (settable through CtlModel): Dir Norm and SBO Enh.

10.7 IEC61850 generic communication I/O functions DPPGIO

10.7.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850 generic communication I/O functions</td>
<td>DPPGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

10.7.2 Application

The IEC61850 generic communication I/O functions (DPPGIO) function block is used to send three logical outputs to other systems or equipment in the substation. The three inputs are named OPEN, CLOSE and VALID, since this function block is intended to be used as a position indicator block in interlocking and reservation station-wide logics.

10.7.3 Setting guidelines

The function does not have any parameters available in the local HMI or PCM600.

10.8 Single point generic control 8 signals SPC8GGIO

10.8.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single point generic control 8 signals SPC8GGIO</td>
<td>SPC8GGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

10.8.2 Application

The Single point generic control 8 signals (SPC8GGIO) function block is a collection of 8 single point commands, designed to bring in commands from REMOTE (SCADA) to those parts of the logic configuration that do not need complicated function blocks that have the capability to receive commands (for example SCSWI). In this way, simple commands can be sent directly to the IED outputs, without confirmation. Confirmation (status) of the result of the commands is supposed to be achieved by other means, such as binary inputs and SPGGIO function blocks.
PSTO is the universal operator place selector for all control functions. Even if PSTO can be configured to allow LOCAL or ALL operator positions, the only functional position usable with the SPC8GGIO function block is REMOTE.

10.8.3 Setting guidelines

The parameters for the single point generic control 8 signals (SPC8GGIO) function are set via the local HMI or PCM600.

*Operation:* turning the function operation *Enabled/Disabled.*

There are two settings for every command output (totally 8):

- **Latchedx:** decides if the command signal for output \( x \) is *Latched* (steady) or *Pulsed*.
- **tPulsex:** if *Latchedx* is set to *Pulsed*, then *tPulsex* will set the length of the pulse (in seconds).

10.9 Automation bits AUTOBITS

10.9.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutomationBits, command function for DNP3</td>
<td>AUTOBITS</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

10.9.2 Application

The AUTOBITS function block (or the automation bits function block) is used within PCM600 in order to get into the configuration the commands coming through the DNP3 protocol. AUTOBITS function block have 32 individual outputs which each can be mapped as a Binary Output point in DNP3. The output is operated by a "Object 12" in DNP3. This object contains parameters for control-code, count, on-time and off-time. To operate an AUTOBITS output point, send a control-code of latch-On, latch-Off, pulse-On, pulse-Off, Trip or Close. The remaining parameters are regarded as appropriate. For example, pulse-On, on-time=100, off-time=300, count=5 would give 5 positive 100 ms pulses, 300 ms apart.

See the communication protocol manual for a detailed description of the DNP3 protocol.

10.9.3 Setting guidelines

AUTOBITS function block has one setting, *(Operation: Enabled/Disabled)* enabling or disabling the function. These names will be seen in the DNP communication configuration tool in PCM600.
Section 11  Logic

11.1  Tripping logic SMPPTRC (94)

11.1.1  Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tripping logic</td>
<td>SMPPTRC</td>
<td>I-&gt;O</td>
<td>94</td>
</tr>
</tbody>
</table>

11.1.2  Application

All trip signals from the different protection functions shall be routed through the trip logic. In its simplest alternative the logic will only link the TRIP signal and make sure that it is long enough.

Tripping logic (SMPPTRC,94) in the IED for protection, control and monitoring offers three-pole tripping.

The three-pole trip for all faults offers a simple solution and is often sufficient in well meshed transmission systems and in High Voltage (HV) systems.

One SMPPTRC (94) function block should be used for each breaker, if the line is connected to the substation via more than one breaker.

To prevent closing of a circuit breaker after a trip the function can block the closing.

11.1.2.1  Three-pole tripping

A simple application with three-pole tripping from the logic block utilizes a part of the function block. Connect the inputs from the protection function blocks to the input TRINP_3P. If necessary (normally the case) use a logic OR block to combine the different function outputs to this input. Connect the output TRIP to the digital Output/s on the IO board.

For special applications such as Lock-out refer to the separate section below. The typical connection is shown below in figure 98. Signals that are not used are dimmed.
11.1.2.2 Lock-out

This function block is provided with possibilities to initiate lock-out. The lock-out can be set to only activate the block closing output CLLKOUT or initiate the block closing output and also maintain the trip signal (latched trip).

The lock-out can then be manually reset after checking the primary fault by activating the input reset Lock-Out RSTLKOUT.

If external conditions are required to initiate Lock-out but not initiate trip this can be achieved by activating input SETLKOUT. The setting AutoLock = Disabled means that the internal trip will not activate lock-out so only initiation of the input SETLKOUT will result in lock-out. This is normally the case for overhead line protection where most faults are transient. Unsuccessful autoreclose and back-up zone tripping can in such cases be connected to initiate Lock-out by activating the input SETLKOUT.

11.1.2.3 Blocking of the function block

Blocking can be initiated internally by logic, or by the operator using a communication channel. Total blockage of Tripping logic (SMPPTRC,94) function is done by activating the input BLOCK and can be used to block the output of SMPPTRC (94) in the event of internal failures.

11.1.3 Setting guidelines

The parameters for Tripping logic SMPPTRC (94) are set via the local HMI or PCM600.

The following trip parameters can be set to regulate tripping.

*Operation:* Sets the mode of operation. *Disabled* switches the tripping off. The normal selection is *Enabled*.

*TripLockout:* Sets the scheme for lock-out. *Disabled* only activates lock-out output. *Enabled* activates the lock-out output and latching output contacts. The normal selection is *Disabled.*
**AutoLock**: Sets the scheme for lock-out. *Disabled* only activates lock-out through the input SETLKOUT. *Enabled* also allows activation from trip function itself and activates the lockout output. The normal selection is *Disabled*.

**tTripMin**: Sets the required minimum duration of the trip pulse. It should be set to ensure that the breaker is tripped and if a signal is used to initiate Breaker failure protection CCRBRF (50BF) longer than the back-up trip timer in CCRBRF (50BF). Normal setting is 0.150s.

### 11.2 Tripping logic SPTPTRC 94

#### 11.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 Identification</th>
<th>IEC 60617 Identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tripping logic</td>
<td>SPTPTRC</td>
<td>I→O</td>
<td>94</td>
</tr>
</tbody>
</table>

#### 11.2.2 Application

All trip signals from the different protection functions shall be routed through the trip logic. In its simplest alternative the logic will only link the TRIP signal and make sure that it is long enough.

Tripping logic (SPTPTRC, 94) in the IED for protection, control and monitoring offers three-phase tripping. two different operating modes:

- Three-pole tripping for all fault types (3ph operating mode)
- Single-pole tripping for single-pole faults and three-pole tripping for multiphase and evolving faults (1ph/3ph operating mode). The logic also issues a three-pole tripping command when phase selection within the operating protection functions is not possible, or when external conditions request three-pole tripping.

The three-pole trip for all faults offers a simple solution and is often sufficient in well meshed transmission systems and in High Voltage (HV) systems. Since most faults, especially at the highest voltage levels, are single pole to ground faults, single pole tripping can be of great value. If only the faulty pole is tripped, power can still be transferred on the line during the dead time that arises before reclosing. Single pole tripping during single phase faults must be combined with single pole reclosing.

#### 11.2.2.1 Single- and/or three-pole tripping

The single-/three-pole tripping will give single-pole tripping for single-phase faults and three-pole tripping for multi-phase fault. The operating mode is always used together with a single-phase autoreclosing scheme.

The single-pole tripping can include different options and the use of the different inputs in the function block.
The inputs 1PTRZ and 1PTREF are used for single-pole tripping for distance protection and directional ground fault protection as required.

The inputs are combined with the phase selection logic and the pickup signals from the phase selector must be connected to the inputs PS_A, PS_B and PS_C to achieve the tripping on the respective single-pole trip outputs TR_A, TR_B and TR_C. The Output TRIP is a general trip and activated independent of which phase is involved. Depending on which phases are involved the outputs TR1P, TR2P and TR3P will be activated as well.

When single-pole tripping schemes are used a single-phase autoreclosing attempt is expected to follow. For cases where the autoreclosing is not in service or will not follow for some reason, the input Prepare Three-pole Trip P3PTR must be activated. This is normally connected to the respective output on the Auto-Recloser but can also be connected to other signals, for example an external logic signal. If two breakers are involved, one TR block instance and one Auto-Recloser instance is used for each breaker. This will ensure correct operation and behavior of each breaker.

The output Trip 3 Phase TR3P must be connected to the respective input in SESRSYN (25) to switch SESRSYN (25) to three-phase reclosing. If this signal is not activated SESRSYN (25) will use single-phase reclosing dead time.

Note also that if a second line protection is utilizing the same SESRSYN (25) the three-pole trip signal must be generated, for example by using the three-trip relays contacts in series and connecting them in parallel to the TR3P output from the trip block.

The trip logic also has inputs TRIN_A, TRIN_B and TRIN_C where phase-selected trip signals can be connected. Examples can be individual phase inter-trips from remote end or internal/external phase selected trip signals, which are routed through the IED to achieve, for example SESRSYN (25), Breaker failure, and so on. Other back-up functions are connected to the input TRIN as described above. A typical connection for a single-pole tripping scheme is shown in figure 99.

Figure 99: The trip logic function SPTPTRC (94) used for single-pole tripping application

11.2.2.2 Lock out

This function block is provided with possibilities to initiate lock-out. The lock-out can be set to only activate the block closing output CLLKOUT or initiate the block closing output and also maintain the trip signal (latched trip).

The lock-out can then be manually reset after checking the primary fault by activating the input reset lock-out RSTLKOUT.

If external conditions are required to initiate Lock-out but not initiate trip this can be achieved by activating input SETLKOUT. The setting AutoLock = Disabled will mean that the internal trip will not activate lock-out so only initiation of the input SETLKOUT will result in lock-out. This is normally the case for overhead line protection where most faults are transient. Unsuccessful auto-reclose and back-up zone tripping can in such cases be connected to initiate Lock-out by activating the input SETLKOUT.
11.2.3 Blocking of the function block

Blocking can be initiated internally by logic, or by the operator using a communication channel. Total blockage of the Tripping logic SPTPTRC (94) function is done by activating the input BLOCK and can be used to block the output of SPTPTRC (94) in the event of internal failures.

11.2.3 Setting guidelines

The parameters for Tripping logic SPTPTRC (94) function are set via the local HMI or PCM600.

The following trip parameters can be set to regulate tripping.

Program

Set the required tripping scheme depending on value selected 3 phase or 1p/3p.

Operation

Sets the mode of operation. Disabled switches the tripping off. The normal selection is Enabled.

TripLockout

Sets the scheme for lock-out. Disabled only activates lock-out output. Enabled activates the lock-out output and latching output contacts. The normal selection is Disabled.

AutoLock

Sets the scheme for lock-out. Disabled only activates lock-out through the input SETLKOUT. Enabled also allows activation from trip function itself and activates the lockout output. The normal selection is Disabled.

tTripMin

Sets the required minimum duration of the trip pulse. It should be set to ensure that the breaker is tripped and if a signal is used to initiate the Breaker failure protection CSPRBRF (50BF) function longer than the back-up trip timer in CSPRBRF (50BF). Normal setting is 0.150s.

11.3 Trip matrix logic TMAGGIO

11.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<tbody>
<tr>
<td>Trip matrix logic</td>
<td>TMAGGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

11.3.2 Application

Trip matrix logic TMAGGIO function is used to route trip signals and other logical output signals to different output contacts on the IED.
TMAGGIO output signals and the physical outputs allows the user to adapt the signals to the physical tripping outputs according to the specific application needs.

### 11.3.3 Setting guidelines

**Operation:** Operation of function *Enabled/Disabled.*

**PulseTime:** Defines the pulse time delay. When used for direct tripping of circuit breaker(s) the pulse time delay shall be set to approximately 0.150 seconds in order to obtain satisfactory minimum duration of the trip pulse to the circuit breaker trip coils.

**OnDelay:** Used to prevent output signals to be given for spurious inputs. Normally set to 0 or a low value.

**OffDelay:** Defines a minimum on time for the outputs. When used for direct tripping of circuit breaker(s) the off delay time shall be set to approximately 0.150 seconds in order to obtain satisfactory minimum duration of the trip pulse to the circuit breaker trip coils.

**ModeOutputx:** Defines if output signal OUTPUTx (where x=1-3) is *Steady* or *Pulsed.*

### 11.4 Configurable logic blocks

#### 11.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Function block</td>
<td>OR</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inverter function block</td>
<td>INVERTER</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PULSETIMER function block</td>
<td>PULSETIMER</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Controllable gate function block</td>
<td>GATE</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Exclusive OR function block</td>
<td>XOR</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### Function description

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic loop delay function block</td>
<td>LOOPDELAY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Timer function block</td>
<td>TIMERSET</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AND function block</td>
<td>AND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Set-reset memory function block</td>
<td>SRMEMORY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reset-set with memory function block</td>
<td>RSMEMORY</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Application

A set of standard logic blocks, like AND, OR etc, and timers are available for adapting the IED configuration to the specific application needs.

There are no settings for AND gates, OR gates, inverters or XOR gates.

For normal On/Off delay and pulse timers the time delays and pulse lengths are set from the local HMI or via the PST tool.

Both timers in the same logic block (the one delayed on pick-up and the one delayed on drop-out) always have a common setting value.

For controllable gates, settable timers and SR flip-flops with memory, the setting parameters are accessible via the local HMI or via the PST tool.

### Configuration

Logic is configured using the ACT configuration tool.
Execution of functions as defined by the configurable logic blocks runs according to a fixed sequence with different cycle times.

For each cycle time, the function block is given an serial execution number. This is shown when using the ACT configuration tool with the designation of the function block and the cycle time, see example below.

![Function Block Instance](image)

**Figure 100: Example designation, serial execution number and cycle time for logic function**

The execution of different function blocks within the same cycle is determined by the order of their serial execution numbers. Always remember this when connecting two or more logical function blocks in series.

Always be careful when connecting function blocks with a fast cycle time to function blocks with a slow cycle time.

Remember to design the logic circuits carefully and always check the execution sequence for different functions. In other cases, additional time delays must be introduced into the logic schemes to prevent errors, for example, race between functions.

Default value on all four inputs of the AND gate are logical 1 which makes it possible for the user to just use the required number of inputs and leave the rest un-connected. The output OUT has a default value 0 initially, which will suppress one cycle pulse if the function has been put in the wrong execution order.

### 11.5 Fixed signals FXDSIGN

#### 11.5.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed signals</td>
<td>FXDSIGN</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
11.5.2 Application

The Fixed signals function (FXDSIGN) generates a number of pre-set (fixed) signals that can be used in the configuration of an IED, either for forcing the unused inputs in other function blocks to a certain level/value, or for creating certain logic.

Example for use of GRP_OFF signal in FXDSIGN

The Restricted earth fault function REFPDIF (87N) can be used both for auto-transformers and normal transformers.

When used for auto-transformers, information from both windings parts, together with the neutral point current, needs to be available to the function. This means that three inputs are needed.

![Figure 101: REFPDIF (87N) function inputs for autotransformer application](ANSI11000083_1_en.vsd)

For normal transformers only one winding and the neutral point is available. This means that only two inputs are used. Since all group connections are mandatory to be connected, the third input needs to be connected to something, which is the GRP_OFF signal in FXDSIGN function block.

![Figure 102: REFPDIF (87N) function inputs for normal transformer application](ANSI11000084_1_en.vsd)
11.6 Boolean 16 to integer conversion B16I

11.6.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean 16 to integer conversion</td>
<td>B16I</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

11.6.2 Application

Boolean 16 to integer conversion function B16I is used to transform a set of 16 binary (logical) signals into an integer. It can be used – for example, to connect logical output signals from a function (like distance protection) to integer inputs from another function (like line differential protection). B16I does not have a logical node mapping.

11.6.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

11.7 Boolean 16 to integer conversion with logic node representation B16IFCVI

11.7.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean 16 to integer conversion with logic node representation</td>
<td>B16IFCVI</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

11.7.2 Application

Boolean 16 to integer conversion with logic node representation function B16IFCVI is used to transform a set of 16 binary (logical) signals into an integer. B16IFCVI can receive an integer from a station computer – for example, over IEC 61850. These functions are very useful when you want to generate logical commands (for selector switches or voltage controllers) by inputting an integer number. B16IFCVI has a logical node mapping in IEC 61850.

11.7.3 Setting guidelines

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600).
11.8 Integer to boolean 16 conversion IB16A

11.8.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer to boolean 16 conversion IB16A</td>
<td>IB16A</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

11.8.2 Application

Integer to boolean 16 conversion function (IB16A) is used to transform an integer into a set of 16 binary (logical) signals. It can be used – for example, to connect integer output signals from a function (like distance protection) to binary (logical) inputs in another function (like line differential protection). IB16A function does not have a logical node mapping.

11.8.3 Setting guidelines

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600).

11.9 Integer to boolean 16 conversion with logic node representation IB16FCVB

11.9.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer to boolean 16 conversion with logic node representation IB16FCVB</td>
<td>IB16FCVB</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

11.9.2 Application

Integer to boolean 16 conversion with logic node representation function (IB16FCVB) is used to transform an integer into a set of 16 binary (logical) signals. IB16FCVB function can receive an integer from a station computer – for example, over IEC 61850. These functions are very useful when the user wants to generate logical commands (for selector switches or voltage controllers) by inputting an integer number. IB16FCVB function has a logical node mapping in IEC 61850.

11.9.3 Settings

The function does not have any parameters available in the local HMI or Protection and Control IED Manager (PCM600)
Section 12 Monitoring

12.1 IEC61850 generic communication I/O functions SPGGIO

12.1.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850 generic communication I/O functions</td>
<td>SPGGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

12.1.2 Application

IEC 61850 generic communication I/O functions (SPGGIO) function is used to send one single logical output to other systems or equipment in the substation. It has one visible input, that should be connected in ACT tool.

12.1.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

12.2 IEC61850 generic communication I/O functions 16 inputs SP16GGIO

12.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850 generic communication I/O functions 16 inputs</td>
<td>SP16GGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

12.2.2 Application

SP16GGIO function block is used to send up to 16 logical signals to other systems or equipment in the substation. Inputs should be connected in ACT tool.

12.2.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).
12.3 IEC61850 generic communication I/O functions MVGGIO

12.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC61850 generic communication I/O functions</td>
<td>MVGGIO</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

12.3.2 Application

IEC61850 generic communication I/O functions (MVGGIO) function is used to send the instantaneous value of an analog output to other systems or equipment in the substation. It can also be used inside the same IED, to attach a RANGE aspect to an analog value and to permit measurement supervision on that value.

12.3.3 Setting guidelines

The settings available for IEC61850 generic communication I/O functions (MVGGIO) function allows the user to choose a deadband and a zero deadband for the monitored signal. Values within the zero deadband are considered as zero.

The high and low limit settings provides limits for the high-high-, high, normal, low and low-low ranges of the measured value. The actual range of the measured value is shown on the range output of MVGGIO function block. When a Measured value expander block (MVEXP) is connected to the range output, the logical outputs of the MVEXP are changed accordingly.

12.4 Measurements

12.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements</td>
<td>CVMMXN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phase current measurement</td>
<td>CMMXU</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Phase-phase voltage measurement</td>
<td>VMMXU</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table continues on next page
### Function description

| Current sequence component measurement | CMSQI | I1, I2, I0 |
| Voltage sequence measurement          | VMSQI | U1, U2, U0 |
| Phase-neutral voltage measurement     | VNMMXU| U |

### 12.4.2 Application

Measurement functions is used for power system measurement, supervision and reporting to the local HMI, monitoring tool within PCM600 or to station level for example, via IEC 61850. The possibility to continuously monitor measured values of active power, reactive power, currents, voltages, frequency, power factor etc. is vital for efficient production, transmission and distribution of electrical energy. It provides to the system operator fast and easy overview of the present status of the power system. Additionally, it can be used during testing and commissioning of protection and control IEDs in order to verify proper operation and connection of instrument transformers (CTs and VTs). During normal service by periodic comparison of the measured value from the IED with other independent meters the proper operation of the IED analog measurement chain can be verified. Finally, it can be used to verify proper direction orientation for distance or directional overcurrent protection function.

The available measured values of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

All measured values can be supervised with four settable limits that is, low-low limit, low limit, high limit and high-high limit. A zero clamping reduction is also supported, that is, the measured value below a settable limit is forced to zero which reduces the impact of noise in the inputs. There are no interconnections regarding any settings or parameters, neither between functions nor between signals within each function.

Zero clampings are handled by ZeroDb for each signal separately for each of the functions. For example, the zero clamping of U12 is handled by VLZeroDB in VMMXU, zero clamping of I1 is handled by ILZeroDb in CMMXU.

Dead-band supervision can be used to report measured signal value to station level when change in measured value is above set threshold limit or time integral of all changes since the last time value updating exceeds the threshold limit. Measure value can also be based on periodic reporting.

The measurement function, CVMMXN, provides the following power system quantities:
• P, Q and S: three phase active, reactive and apparent power
• PF: power factor
• V: phase-to-phase voltage magnitude
• I: phase current magnitude
• F: power system frequency

The output values are displayed in the local HMI under Main menu/Tests/Function status/Monitoring/CVMMXN/Outputs

The measuring functions CMMXU, VNMMXU and VMMXU provide physical quantities:

• I: phase currents (magnitude and angle) (CMMXU)
• V: voltages (phase-to-ground and phase-to-phase voltage, magnitude and angle) (VMMXU, VNMMXU)

It is possible to calibrate the measuring function above to get better then class 0.5 presentation. This is accomplished by angle and magnitude compensation at 5, 30 and 100% of rated current and at 100% of rated voltage.

The power system quantities provided, depends on the actual hardware, (TRM) and the logic configuration made in PCM600.

The measuring functions CMSQI and VMSQI provide sequential quantities:

• I: sequence currents (positive, zero, negative sequence, magnitude and angle)
• V: sequence voltages (positive, zero and negative sequence, magnitude and angle).

The CVMMXN function calculates three-phase power quantities by using fundamental frequency phasors (DFT values) of the measured current respectively voltage signals. The measured power quantities are available either, as instantaneously calculated quantities or, averaged values over a period of time (low pass filtered) depending on the selected settings.

12.4.3 Setting guidelines

The available setting parameters of the measurement function CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

The parameters for the Measurement functions CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU are set via the local HMI or PCM600.

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

Operation: Disabled/Enabled. Every function instance (CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU) can be taken in operation (Enabled) or out of operation (Disabled).

The following general settings can be set for the Measurement function (CVMMXN).

PowMagFact: Magnitude factor to scale power calculations.
PowAngComp: Angle compensation for phase shift between measured I & V.
Mode: Selection of measured current and voltage. There are 9 different ways of calculating monitored three-phase values depending on the available VT inputs connected to the IED. See parameter group setting table.

\( k \): Low pass filter coefficient for power measurement, \( V \) and \( I \).

\( V_{\text{MagCompY}} \): Magnitude compensation to calibrate voltage measurements at \( Y\% \) of \( V_n \), where \( Y \) is equal to 5, 30 or 100.

\( I_{\text{MagCompY}} \): Magnitude compensation to calibrate current measurements at \( Y\% \) of \( I_n \), where \( Y \) is equal to 5, 30 or 100.

\( I_{\text{AngCompY}} \): Angle compensation to calibrate angle measurements at \( Y\% \) of \( I_n \), where \( Y \) is equal to 5, 30 or 100.

The following general settings can be set for the **Phase-phase current measurement** (CMMXU).

\( I_{\text{MagCompY}} \): Magnitude compensation to calibrate current measurements at \( Y\% \) of \( I_n \), where \( Y \) is equal to 5, 30 or 100.

\( I_{\text{AngCompY}} \): Angle compensation to calibrate angle measurements at \( Y\% \) of \( I_n \), where \( Y \) is equal to 5, 30 or 100.

The following general settings can be set for the **Phase-phase voltage measurement** (VMMXU).

\( V_{\text{MagCompY}} \): Amplitude compensation to calibrate voltage measurements at \( Y\% \) of \( V_n \), where \( Y \) is equal to 5, 30 or 100.

\( V_{\text{AngCompY}} \): Angle compensation to calibrate angle measurements at \( Y\% \) of \( V_n \), where \( Y \) is equal to 5, 30 or 100.

The following general settings can be set for all monitored quantities included in the functions (CVMMXN, CMMXU, VMMXU, CMSQI, VMSQI, VNMMXU) \( X \) in setting names below equals \( S, P, Q, PF, V, I, F, IA, IB, IC, VA, VB, VCVAB, VBC, VCA, I1, I2, 3I0, V1, V2 \) or \( 3V0 \).

\( X_{\text{min}} \): Minimum value for analog signal \( X \).

\( X_{\text{max}} \): Maximum value for analog signal \( X \).

\( X_{\text{min}} \) and \( X_{\text{max}} \) values are directly set in applicable measuring unit, \( V, A \), and so on, for all measurement functions, except CVMMXN where \( X_{\text{min}} \) and \( X_{\text{max}} \) values are set in \( \% \) of \( S_{\text{Base}} \).

\( X_{\text{ZeroDb}} \): Zero point clamping. A signal value less than \( X_{\text{ZeroDb}} \) is forced to zero.

\( X_{\text{RepTyp}} \): Reporting type. Cyclic (Cyclic), magnitude deadband (Dead band) or integral deadband (Int deadband). The reporting interval is controlled by the parameter \( X_{\text{DbRepInt}} \).

\( X_{\text{DbRepInt}} \): Reporting deadband setting. Cyclic reporting is the setting value and is reporting interval in seconds. Magnitude deadband is the setting value in \( \% \) of measuring range. Integral deadband setting is the integral area, that is, measured value in \( \% \) of measuring range multiplied by the time between two measured values.

Limits are directly set in applicable measuring unit, \( V, A \), and so on, for all measurement functions, except CVMMXN where limits are set in \( \% \) of \( S_{\text{Base}} \).
**XHiHiLim**: High-high limit.

**XHiLim**: High limit.

**XLowLim**: Low limit.

**XLowLowLim**: Low-low limit.

**XLimHyst**: Hysteresis value in % of range and is common for all limits.

All phase angles are presented in relation to defined reference channel. The parameter *PhaseAngleRef* defines the reference.

### Calibration curves

It is possible to calibrate the functions (*CVMMXN, CMMXU, VNMMXU and VMMXU*) to get class 0.5 presentations of currents, voltages and powers. This is accomplished by magnitude and angle compensation at 5, 30 and 100% of rated current and voltage. The compensation curve will have the characteristic for magnitude and angle compensation of currents as shown in figure 103 (example). The first phase will be used as reference channel and compared with the curve for calculation of factors. The factors will then be used for all related channels.

![Calibration curves](ANSl05000652_3_en.vsd)

*Figure 103: Calibration curves*

### 12.4.4 Setting examples

Three setting examples, in connection to Measurement function (*CVMMXN*), are provided:
• Measurement function (CVMMXN) application for a 400 kV OHL
• Measurement function (CVMMXN) application on the secondary side of a transformer
• Measurement function (CVMMXN) application for a generator

For each of them detail explanation and final list of selected setting parameters values will be provided.

The available measured values of an IED are depending on the actual hardware (TRM) and the logic configuration made in PCM600.

12.4.4.1 Measurement function application for a 380 kV OHL

Single line diagram for this application is given in figure 104:

![Single line diagram for 380 kV OHL application](ANSI09000039-1-en.vsd)

Figure 104: Single line diagram for 380 kV OHL application

In order to monitor, supervise and calibrate the active and reactive power as indicated in figure 104 it is necessary to do the following:

1. Set correctly CT and VT data and phase angle reference channel PhaseAngleRef using PCM600 for analog input channels
2. Connect, in PCM600, measurement function to three-phase CT and VT inputs
3. Set under General settings parameters for the Measurement function:
   • general settings as shown in table 26.
   • level supervision of active power as shown in table 27.
   • calibration parameters as shown in table 28.
### Table 26: General settings parameters for the Measurement function

<table>
<thead>
<tr>
<th>Setting</th>
<th>Short Description</th>
<th>Selected value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>Operation Disabled/Enabled</td>
<td>Enabled</td>
<td>Function must be Enabled</td>
</tr>
<tr>
<td>PowMagFact</td>
<td>Magnitude factor to scale power calculations</td>
<td>1.000</td>
<td>It can be used during commissioning to achieve higher measurement accuracy. Typically no scaling is required</td>
</tr>
<tr>
<td>PowAngComp</td>
<td>Angle compensation for phase shift between measured I &amp; V</td>
<td>0.0</td>
<td>It can be used during commissioning to achieve higher measurement accuracy. Typically no angle compensation is required. As well here required direction of P &amp; Q measurement is towards protected object (as per IED internal default direction)</td>
</tr>
<tr>
<td>Mode</td>
<td>Selection of measured current and voltage</td>
<td>A, B, C</td>
<td>All three phase-to-ground VT inputs are available</td>
</tr>
<tr>
<td>k</td>
<td>Low pass filter coefficient for power measurement, V and I</td>
<td>0.00</td>
<td>Typically no additional filtering is required</td>
</tr>
</tbody>
</table>

### Table 27: Settings parameters for level supervision

<table>
<thead>
<tr>
<th>Setting</th>
<th>Short Description</th>
<th>Selected value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMin</td>
<td>Minimum value</td>
<td>-750</td>
<td>Minimum expected load</td>
</tr>
<tr>
<td>PMax</td>
<td>Minimum value</td>
<td>750</td>
<td>Maximum expected load</td>
</tr>
<tr>
<td>PZeroDb</td>
<td>Zero point clamping in 0.001% of range</td>
<td>3000</td>
<td>Set zero point clamping to 45 MW that is, 3% of 1500 MW</td>
</tr>
<tr>
<td>PRepTyp</td>
<td>Reporting type</td>
<td>db</td>
<td>Select magnitude deadband supervision</td>
</tr>
<tr>
<td>PDbRepInt</td>
<td>Cycl: Report interval (s), Db: In % of range, Int Db: In %</td>
<td>2</td>
<td>Set ±Δdb=30 MW that is, 2% (larger changes than 30 MW will be reported)</td>
</tr>
<tr>
<td>PHPiHiLim</td>
<td>High limit (physical value)</td>
<td>600</td>
<td>High alarm limit that is, extreme overload alarm</td>
</tr>
<tr>
<td>PHPiLim</td>
<td>High limit (physical value)</td>
<td>500</td>
<td>High warning limit that is, overload warning</td>
</tr>
<tr>
<td>PLowLim</td>
<td>Low limit (physical value)</td>
<td>-800</td>
<td>Low warning limit. Not active</td>
</tr>
<tr>
<td>PLowLowLim</td>
<td>Low limit (physical value)</td>
<td>-800</td>
<td>Low alarm limit. Not active</td>
</tr>
<tr>
<td>PLimHyst</td>
<td>Hysteresis value in % of range (common for all limits)</td>
<td>2</td>
<td>Set ±Δ Hysteresis MW that is, 2%</td>
</tr>
</tbody>
</table>

### Table 28: Settings for calibration parameters

<table>
<thead>
<tr>
<th>Setting</th>
<th>Short Description</th>
<th>Selected value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMagComp5</td>
<td>Magnitude factor to calibrate current at 5% of In</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>IMagComp30</td>
<td>Magnitude factor to calibrate current at 30% of In</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>IMagComp100</td>
<td>Magnitude factor to calibrate current at 100% of In</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>VAmpComp5</td>
<td>Magnitude factor to calibrate voltage at 5% of Vn</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Setting</td>
<td>Short Description</td>
<td>Selected value</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------------------------------</td>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>VMagComp30</td>
<td>Magnitude factor to calibrate voltage at 30% of Vn</td>
<td>0.00</td>
<td></td>
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<tr>
<td>VMagComp100</td>
<td>Magnitude factor to calibrate voltage at 100% of Vn</td>
<td>0.00</td>
<td></td>
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<tr>
<td>IAngComp5</td>
<td>Angle calibration for current at 5% of In</td>
<td>0.00</td>
<td></td>
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<tr>
<td>IAngComp30</td>
<td>Angle pre-calibration for current at 30% of In</td>
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</tr>
<tr>
<td>IAngComp100</td>
<td>Angle pre-calibration for current at 100% of In</td>
<td>0.00</td>
<td></td>
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</table>

12.5 Event counter CNTGGIO

12.5.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event counter</td>
<td>CNTGGIO</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12.5.2 Application

Event counter (CNTGGIO) has six counters which are used for storing the number of times each counter has been activated. CNTGGIO can be used to count how many times a specific function, for example the tripping logic, has issued a trip signal. All six counters have a common blocking and resetting feature.

12.5.3 Setting guidelines

*Operation:* Sets the operation of Event counter (CNTGGIO) *Enabled* or *Disabled.*

12.6 Disturbance report

12.6.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbance report</td>
<td>DRPRDRE</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Analog input signals</td>
<td>A1RADR</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Analog input signals</td>
<td>A2RADR</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Analog input signals</td>
<td>A3RADR</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table continues on next page
12.6.2 Application

To get fast, complete and reliable information about disturbances in the primary and/or in the secondary system it is very important to gather information on fault currents, voltages and events. It is also important having a continuous event-logging to be able to monitor in an overview perspective. These tasks are accomplished by the disturbance report function DRPRDRE and facilitate a better understanding of the power system behavior and related primary and secondary equipment during and after a disturbance. An analysis of the recorded data provides valuable information that can be used to explain a disturbance, basis for change of IED setting plan, improve existing equipment, and so on. This information can also be used in a longer perspective when planning for and designing new installations, that is, a disturbance recording could be a part of Functional Analysis (FA).

Disturbance report DRPRDRE, always included in the IED, acquires sampled data of all selected analog and binary signals connected to the function blocks that is,

- maximum 30 external analog signals,
- 10 internal derived analog signals, and
- 96 binary signals.

Disturbance report function is a common name for several functions that is, Indications, Event recorder, Sequential of events, Trip value recorder, Disturbance recorder.

Disturbance report function is characterized by great flexibility as far as configuration, starting conditions, recording times, and large storage capacity are concerned. Thus, disturbance report is not dependent on the operation of protective functions, and it can record disturbances that were not discovered by protective functions for one reason or another. Disturbance report can be used as an advanced stand-alone disturbance recorder.

Every disturbance report recording is saved in the IED. The same applies to all events, which are continuously saved in a ring-buffer. Local HMI can be used to get information about the recordings, and the disturbance report files may be uploaded in the PCM600 using the Disturbance handling tool, for report reading or further analysis (using WaveWin, that can be found on the PCM600 installation CD). The user can also upload disturbance report files using FTP or MMS (over 61850) clients.

If the IED is connected to a station bus (IEC 61850-8-1), the disturbance recorder (record made and fault number) and the fault locator information are available as GOOSE or Report Control data.
12.6.3 **Setting guidelines**

The setting parameters for the Disturbance report function DRPRDRE are set via the local HMI or PCM600.

It is possible to handle up to 40 analog and 96 binary signals, either internal signals or signals coming from external inputs. The binary signals are identical in all functions that is, Disturbance recorder, Event recorder, Indication, Trip value recorder and Sequential of events function.

User-defined names of binary and analog input signals is set using PCM600. The analog and binary signals appear with their user-defined names. The name is used in all related functions (Disturbance recorder, Event recorder, Indication, Trip value recorder and Sequential of events).

Figure 105 shows the relations between Disturbance report, included functions and function blocks. Sequential of events, Event recorder and Indication uses information from the binary input function blocks (BxRBDR). Trip value recorder uses analog information from the analog input function blocks (AxRADR). Disturbance report function acquires information from both AxRADR and BxRBDR.

*Figure 105: Disturbance report functions and related function blocks*

For Disturbance report function there are a number of settings which also influences the sub-functions.

Three LED indications placed above the LCD screen makes it possible to get quick status information about the IED.

<table>
<thead>
<tr>
<th>Green LED:</th>
<th>Steady light</th>
<th>In Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashing light</td>
<td>Internal failure</td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>No power supply</td>
<td></td>
</tr>
</tbody>
</table>

Table continues on next page
Yellow LED: Function controlled by SetLEDn setting in Disturbance report function.

Red LED: Function controlled by SetLEDn setting in Disturbance report function.

**Operation**
The operation of Disturbance report function DRPRDRE has to be set *Enabled* or *Disabled*. If *Disabled* is selected, note that no disturbance report is registered, and none sub-function will operate (the only general parameter that influences Sequential of events).

*Operation = Disabled:*
- Disturbance reports are not stored.
- LED information (yellow - pickup, red - trip) is not stored or changed.

*Operation = Enabled:*
- Disturbance reports are stored, disturbance data can be read from the local HMI and from a PC using PCM600.
- LED information (yellow - pickup, red - trip) is stored.

Every recording will get a number (0 to 999) which is used as identifier (local HMI, disturbance handling tool and IEC 61850). An alternative recording identification is date, time and sequence number. The sequence number is automatically increased by one for each new recording and is reset to zero at midnight. The maximum number of recordings stored in the IED is 100. The oldest recording will be overwritten when a new recording arrives (FIFO).

To be able to delete disturbance records, *Operation* parameter has to be *Enabled*.

The maximum number of recordings depend on each recordings total recording time. Long recording time will reduce the number of recordings to less than 100.

The IED flash disk should NOT be used to store any user files. This might cause disturbance recordings to be deleted due to lack of disk space.

**Recording times**
Prefault recording time (*PreFaultRecT*) is the recording time before the starting point of the disturbance. The setting should be at least $0.1 \text{s}$ to ensure enough samples for the estimation of pre-fault values in the Trip value recorder function.
Postfault recording time (*PostFaultRecT*) is the maximum recording time after the disappearance of the trig-signal (does not influence the Trip value recorder function).

Recording time limit (*TimeLimit*) is the maximum recording time after trig. The parameter limits the recording time if some triggering condition (fault-time) is very long or permanently set (does not influence the Trip value recorder function).

Post retrigger (*PostRetrig*) can be set to *Enabled* or *Disabled*. Makes it possible to choose performance of Disturbance report function if a new trig signal appears in the post-fault window.

*PostRetrig = Disabled*

The function is insensitive for new trig signals during post fault time.

*PostRetrig = Enabled*

The function completes current report and starts a new complete report that is, the latter will include:

- new pre-fault- and fault-time (which will overlap previous report)
- events and indications might be saved in the previous report too, due to overlap
- new trip value calculations if installed, in operation and started

**Operation in test mode**
If the IED is in test mode and *OpModeTest = Disabled*. Disturbance report function does not save any recordings and no LED information is displayed.

If the IED is in test mode and *OpModeTest = Enabled*. Disturbance report function works in normal mode and the status is indicated in the saved recording.

### 12.6.3.1 Binary input signals

Up to 96 binary signals can be selected among internal logical and binary input signals. The configuration tool is used to configure the signals.

For each of the 96 signals, it is also possible to select if the signal is to be used as a trigger for the start of Disturbance report and if the trigger should be activated on positive (1) or negative (0) slope.

*TrigDRN*: Disturbance report may trig for binary input N (*Enabled*) or not (*Disabled*).

*TrigLevelN*: Trig on positive (*Trig on 1*) or negative (*Trig on 0*) slope for binary input N.

### 12.6.3.2 Analog input signals

Up to 40 analog signals can be selected among internal analog and analog input signals. PCM600 is used to configure the signals.

The analog trigger of Disturbance report is not affected if analog input M is to be included in the disturbance recording or not (*OperationM = Enabled/Disabled*).

If *OperationM = Disabled*, no waveform (samples) will be recorded and reported in graph. However, Trip value, pre-fault and fault value will be recorded and reported. The input channel can still be used to trig the disturbance recorder.
If $OperationM = Enabled$, waveform (samples) will also be recorded and reported in graph.

$NomValueM$: Nominal value for input M.

$OverTrigOpM$, $UnderTrigOpM$: Over or Under trig operation, Disturbance report may trig for high/low level of analog input M ($Enabled$) or not ($Disabled$).

$OverTrigLeM$, $UnderTrigLeM$: Over or under trig level, Trig high/low level relative nominal value for analog input M in percent of nominal value.

### 12.6.3.3 Sub-function parameters

All functions are in operation as long as Disturbance report is in operation.

**Indications**

$IndicationMaN$: Indication mask for binary input N. If set ($Show$), a status change of that particular input, will be fetched and shown in the disturbance summary on local HMI. If not set ($Hide$), status change will not be indicated.

$SetLEDN$: Set yellow $Pick$ up and red $Trip$ LED on local HMI in front of the IED if binary input N changes status.

**Disturbance recorder**

$OperationM$: Analog channel M is to be recorded by the disturbance recorder ($Enabled$) or not ($Disabled$).

If $OperationM = Disabled$, no waveform (samples) will be recorded and reported in graph. However, Trip value, pre-fault and fault value will be recorded and reported. The input channel can still be used to trig the disturbance recorder.

If $OperationM = Enabled$, waveform (samples) will also be recorded and reported in graph.

**Event recorder**

Event recorder function has no dedicated parameters.

**Trip value recorder**

$ZeroAngleRef$: The parameter defines which analog signal that will be used as phase angle reference for all other analog input signals. This signal will also be used for frequency measurement and the measured frequency is used when calculating trip values. It is suggested to point out a sampled voltage input signal, for example, a line or busbar phase voltage (channel 1-30).

**Sequential of events**

function has no dedicated parameters.

### 12.6.3.4 Consideration

The density of recording equipment in power systems is increasing, since the number of modern IEDs, where recorders are included, is increasing. This leads to a vast number of recordings at every single disturbance and a lot of information has to be handled if the recording functions do not have proper settings. The goal is to optimize the settings in each IED to be able to capture just valuable disturbances and to maximize the number that is possible to save in the IED.

The recording time should not be longer than necessary ($PostFaultrecT$ and $TimeLimit$).
• Should the function record faults only for the protected object or cover more?
• How long is the longest expected fault clearing time?
• Is it necessary to include reclosure in the recording or should a persistent fault generate a second recording (PostRetrig)?

Minimize the number of recordings:

• Binary signals: Use only relevant signals to start the recording that is, protection trip, carrier receive and/or pickup signals.
• Analog signals: The level triggering should be used with great care, since unfortunate settings will cause enormously number of recordings. If nevertheless analog input triggering is used, chose settings by a sufficient margin from normal operation values. Phase voltages are not recommended for trigging.

Remember that values of parameters set elsewhere are linked to the information on a report. Such parameters are, for example, station and object identifiers, CT and VT ratios.

12.7 Measured value expander block MVEXP

12.7.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured value expander block</td>
<td>MVEXP</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

12.7.2 Application

The current and voltage measurements functions (CVMMXN, CMMXU, VMMXU and VNMMXU), current and voltage sequence measurement functions (CMSQI and VMSQI) and IEC 61850 generic communication I/O functions (MVGGIO) are provided with measurement supervision functionality. All measured values can be supervised with four settable limits, that is low-low limit, low limit, high limit and high-high limit. The measure value expander block (MVEXP) has been introduced to be able to translate the integer output signal from the measuring functions to 5 binary signals, that is below low-low limit, below low limit, normal, above high-high limit or above high limit. The output signals can be used as conditions in the configurable logic.

12.7.3 Setting guidelines

The function does not have any parameters available in Local HMI or Protection and Control IED Manager (PCM600).

Common base IED values for primary current (I_Base), primary voltage (V_Base) and primary power (S_Base) are set in a Global base values for settings function GBASVAL. Setting Global_BaseSel is used to select a GBASVAL function for reference of base values.
12.8 Station battery supervision SPVNZBAT

12.8.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station battery supervision function</td>
<td>SPVNZBAT</td>
<td>U&lt;-&gt;</td>
<td>-</td>
</tr>
</tbody>
</table>

12.8.2 Application

Usually, the load on the DC system is a constant resistance load, for example, lamps, LEDs, electronic instruments and electromagnetic contactors in a steady state condition. A transient RL load exists when breakers are tripped or closed.

The battery voltage has to be continuously monitored as the batteries can withstand moderate overvoltage and undervoltage only for a short period of time.

- If the battery is subjected to a prolonged or frequent overvoltage, it leads to the ageing of the battery, which may lead to the earlier failure of the battery. The other occurrences may be the thermal runaway, generation of heat or increased amount of hydrogen gas and the depletion of fluid in case of valve regulated batteries.

- If the value of the charging voltage drops below the minimum recommended float voltage of the battery, the battery does not receive sufficient charging current to offset internal losses, resulting in a gradual loss of capacity.
  - If a lead acid battery is subjected to a continuous undervoltage, heavy sulfation occurs on the plates, which leads to the loss of the battery capacity.

12.9 Insulation gas monitoring function SSIMG (63)

12.9.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
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<td>Insulation gas monitoring function</td>
<td>SSIMG</td>
<td>-</td>
<td>63</td>
</tr>
</tbody>
</table>

12.9.2 Application

Insulation gas monitoring function (SSIMG, 63) is used for monitoring the circuit breaker condition. Proper arc extinction by the compressed gas in the circuit breaker is very important. When the pressure becomes too low compared to the required value, the circuit breaker operation gets blocked to avoid disaster. Binary information based on the gas pressure in the circuit breaker...
is used as input signals to the function. In addition to that, the function generates alarms based on received information.

### 12.10 Insulation liquid monitoring function SSIML (71)

#### 12.10.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
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<tbody>
<tr>
<td>Insulation liquid monitoring function</td>
<td>SSIML</td>
<td>-</td>
<td>71</td>
</tr>
</tbody>
</table>

#### 12.10.2 Application

Insulation liquid monitoring function (SSIML, 71) is used for monitoring the circuit breaker condition. Proper arc extinction by the compressed oil in the circuit breaker is very important. When the level becomes too low, compared to the required value, the circuit breaker operation is blocked to avoid disaster. Binary information based on the oil level in the circuit breaker is used as input signals to the function. In addition to that, the function generates alarms based on received information.

### 12.11 Circuit breaker condition monitoring SSCBR

#### 12.11.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit breaker condition monitoring</td>
<td>SSCBR</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 12.11.2 Application

SSCBR includes different metering and monitoring subfunctions.

**Circuit breaker status**

Circuit breaker status monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position.

**Circuit breaker operation monitoring**

The purpose of the circuit breaker operation monitoring is to indicate that the circuit breaker has not been operated for a long time. The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.
Breaker contact travel time

High travelling times indicate the need for maintenance of the circuit breaker mechanism. Therefore, detecting excessive travelling time is needed. During the opening cycle operation, the main contact starts opening. The auxiliary contact A opens, the auxiliary contact B closes, and the main contact reaches its opening position. During the closing cycle, the first main contact starts closing. The auxiliary contact B opens, the auxiliary contact A closes, and the main contact reaches its close position. The travel times are calculated based on the state changes of the auxiliary contacts and the adding correction factor to consider the time difference of the main contact’s and the auxiliary contact’s position change.

Operation counter

Routine maintenance of the breaker, such as lubricating breaker mechanism, is generally based on a number of operations. A suitable threshold setting, to raise an alarm when the number of operation cycle exceeds the set limit, helps preventive maintenance. This can also be used to indicate the requirement for oil sampling for dielectric testing in case of an oil circuit breaker.

The change of state can be detected from the binary input of the auxiliary contact. There is a possibility to set an initial value for the counter which can be used to initialize this functionality after a period of operation or in case of refurbished primary equipment.

Accumulation of $I^yt$

Accumulation of $I^yt$ calculates the accumulated energy $\Sigma I^yt$ where the factor $y$ is known as the current exponent. The factor $y$ depends on the type of the circuit breaker. For oil circuit breakers the factor $y$ is normally 2. In case of a high-voltage system, the factor $y$ can be 1.4...1.5.

Remaining life of the breaker

Every time the breaker operates, the life of the circuit breaker reduces due to wearing. The wearing in the breaker depends on the tripping current, and the remaining life of the breaker is estimated from the circuit breaker trip curve provided by the manufacturer.

Example for estimating the remaining life of a circuit breaker
Figure 106: Trip Curves for a typical 12 kV, 630 A, 16 kA vacuum interrupter

$N_r$ the number of closing-opening operations allowed for the circuit breaker

$I_a$ the current at the time of tripping of the circuit breaker

**Calculation of Directional Coefficient**

The directional coefficient is calculated according to the formula:
\[ Directional \ Coef = \frac{\log\left(\frac{B}{A}\right)}{\log\left(\frac{I_f}{I_r}\right)} = -2.2609 \]

(Equation 78)

- \( I_r \): Rated operating current = 630 A
- \( I_f \): Rated fault current = 16 kA
- \( A \): Op number rated = 30000
- \( B \): Op number fault = 20

**Calculation for estimating the remaining life**

The trip curve shows that there are 30,000 possible operations at the rated operating current of 630 A and 20 operations at the rated fault current 16 kA. Therefore, if the tripping current is 10 kA, one operation at 10 kA is equivalent to \( \frac{30,000}{58} = 517 \) operations at the rated current. It is also assumed that prior to this tripping, the remaining life of the circuit breaker is 15,000 operations. Therefore, after one operation of 10 kA, the remaining life of the circuit breaker is 15,000 - 517 = 14,483 at the rated operating current.

**Spring charged indication**

For normal operation of the circuit breaker, the circuit breaker spring should be charged within a specified time. Therefore, detecting long spring charging time indicates that it is time for the circuit breaker maintenance. The last value of the spring charging time can be used as a service value.

**Gas pressure supervision**

The gas pressure supervision monitors the gas pressure inside the arc chamber. When the pressure becomes too low compared to the required value, the circuit breaker operations are locked. A binary input is available based on the pressure levels in the function, and alarms are generated based on these inputs.
Section 13 Metering

13.1 Pulse counter PCGGIO

13.1.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse counter</td>
<td>PCGGIO</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

13.1.2 Application

Pulse counter (PCGGIO) function counts externally generated binary pulses, for instance pulses coming from an external energy meter, for calculation of energy consumption values. The pulses are captured by the binary input module (BIO), and read by the PCGGIO function. The number of pulses in the counter is then reported via the station bus to the substation automation system or read via the station monitoring system as a service value. When using IEC 61850, a scaled service value is available over the station bus.

The normal use for this function is the counting of energy pulses from external energy meters. An optional number of inputs from the binary input module in IED can be used for this purpose with a frequency of up to 10 Hz. PCGGIO can also be used as a general purpose counter.

13.1.3 Setting guidelines

From PCM600, these parameters can be set individually for each pulse counter:

- Operation: Disabled/Enabled
- tReporting: 0-3600s
- EventMask: NoEvents/ReportEvents

The configuration of the inputs and outputs of PCGGIO function block is made with PCM600.

On the binary input output module (BIO), the debounce filter default time is set to 5 ms, that is, the counter suppresses pulses with a pulse length less than 5 ms. The binary input channels on the binary input output module (BIO) have individual settings for debounce time, oscillation count and oscillation time. The values can be changed in the local HMI and PCM600 under Main menu/Configuration/I/O modules.

The setting is individual for all input channels on the binary input output module (BIO), that is, if changes of the limits are made for inputs not connected to the pulse counter, it will not influence the inputs used for pulse counting.
13.2 Energy calculation and demand handling ETPMMTR

13.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy calculation and demand handling</td>
<td>ETPMMTR</td>
<td>Wh</td>
<td>-</td>
</tr>
</tbody>
</table>

13.2.2 Application

Energy calculation and demand handling function ETPMMTR is intended for statistics of the forward and reverse active and reactive energy. It has a high accuracy basically given by the measurements function (CVMMXN). This function has a site calibration possibility to further increase the total accuracy.

The function is connected to the instantaneous outputs of (CVMMXN) as shown in figure 107.

Figure 107: Connection of energy calculation and demand handling function ETPMMTR to the measurements function (CVMMXN)

The energy values can be read through communication in MWh and MVarh in monitoring tool of PCM600 and/or alternatively the values can be presented on the local HMI. The local HMI graphical display is configured with PCM600 Graphical display editor tool (GDE) with a measuring value which is selected to the active and reactive component as preferred. All four values can also be presented.

Maximum demand values are presented in MWh or MVarh in the same way.

Alternatively, the values can be presented with use of the pulse counters function (PCGGIO). The output values are scaled with the pulse output setting values $EAFAccPlsQty$, $EARAccPlsQty$, $ERFAccPlsQty$ and $ERRAccPlsQty$ of the energy metering function and then the pulse counter can be set-up to present the correct values by scaling in this function. Pulse counter values can then be presented on the local HMI in the same way and/or sent to the SA system through communication where the total energy then is calculated by summation of the energy pulses. This principle is good for very high values of energy as the saturation of numbers else will limit energy integration to about one year with 50 kV and 3000 A. After that the accumulation will start on zero again.
13.2.3 Setting guidelines

The parameters are set via the local HMI or PCM600.

The following settings can be done for the energy calculation and demand handling function ETPMMTR:

Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting $GlobalBaseSel$ is used to select a GBASVAL function for reference of base values.

*Operation: Disabled/Enabled*

$tEnergy$: Time interval when energy is measured.

$StartAcc$. Disabled/Enabled is used to switch the accumulation of energy on and off.

The input signal STACC is used to start accumulation. Input signal STACC cannot be used to halt accumulation. The energy content is reset every time STACC is activated. STACC can for example, be used when an external clock is used to switch two active energy measuring function blocks on and off to have indication of two tariffs.

$tEnergyOnPls$: gives the pulse length ON time of the pulse. It should be at least 100 ms when connected to the Pulse counter function block. Typical value can be 100 ms.

$tEnergyOffPls$: gives the OFF time between pulses. Typical value can be 100 ms.

$EAFAccPlsQty$ and $EARAccPlsQty$: gives the MWh value in each pulse. It should be selected together with the setting of the Pulse counter (PCGGIO) settings to give the correct total pulse value.

$ERFAccPlsQty$ and $ERRAccPlsQty$: gives the MVarh value in each pulse. It should be selected together with the setting of the Pulse counter (PCGGIO) settings to give the correct total pulse value.

For the advanced user there are a number of settings for direction, zero clamping, max limit, and so on. Normally, the default values are suitable for these parameters.
Section 14  Station communication

14.1  IEC61850-8-1 communication protocol

14.1.1  Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61850-8-1 communication protocol</td>
<td>IEC 61850-8-1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

14.1.2  Application

IEC 61850-8-1 communication protocol allows vertical communication to HSI clients and allows horizontal communication between two or more intelligent electronic devices (IEDs) from one or several vendors to exchange information and to use it in the performance of their functions and for correct co-operation.

GOOSE (Generic Object Oriented Substation Event), which is a part of IEC 61850–8–1 standard, allows the IEDs to communicate state and control information amongst themselves, using a publish-subscribe mechanism. That is, upon detecting an event, the IED(s) use a multi-cast transmission to notify those devices that have registered to receive the data. An IED can, by publishing a GOOSE message, report its status. It can also request a control action to be directed at any device in the network.

Figure 108 shows the topology of an IEC 61850–8–1 configuration. IEC 61850–8–1 specifies only the interface to the substation LAN. The LAN itself is left to the system integrator.
Figure 108: Example of a communication system with IEC 61850

Figure 109 shows the GOOSE peer-to-peer communication.

Figure 109: Example of a broadcasted GOOSE message
14.1.2.1 Horizontal communication via GOOSE

GOOSE messages are sent in horizontal communication between the IEDs. The information, which is exchanged, is used for station wide interlocking, breaker failure protection, busbar voltage selection and so on.

The simplified principle is shown in Figure 110 and can be described as follows. When IED1 has decided to transmit the data set it forces a transmission via the station bus. All other IEDs will receive the data set, but only those who have this data set in their address list will take it and keeps it in a input container. It is defined, that the receiving IED will take the content of the received data set and makes it available for the application configuration.

Special function blocks take the data set and present it via the function block as output signals for application functions in the application configuration. Different GOOSE receive function blocks are available for the specific tasks.

SMT links the different data object attributes (for example stVal or magnitude) to the output signal to make it available for functions in the application configuration. When a matrix cell array is marked red the IEC 61850 data attribute type does not fit together, even if the GOOSE receive function block is the partner. SMT checks this on the content of the received data set. See Figure 111.
**Figure 111: SMT: GOOSE marshalling with SMT**

GOOSE receive function blocks extract process information, received by the data set, into single attribute information that can be used within the application configuration. Crosses in the SMT matrix connect received values to the respective function block signal in SMT, see [Figure 112](#).

The corresponding quality attribute is automatically connected by SMT. This quality attribute is available in ACT, through the outputs of the available GOOSE function blocks.
14.1.3 Setting guidelines

There are two settings related to the IEC 61850–8–1 protocol:

Operation User can set IEC 61850 communication to Enabled or Disabled.

GOOSE has to be set to the Ethernet link where GOOSE traffic shall be send and received.

IEC 61850–8–1 specific data (logical nodes etc.) per included function in an IED can be found in the communication protocol manual for IEC 61850.

14.2 DNP3 protocol

DNP3 (Distributed Network Protocol) is a set of communications protocols used to communicate data between components in process automation systems. For a detailed description of the DNP3 protocol, see the DNP3 Communication protocol manual.
14.3 IEC 60870-5-103 communication protocol

IEC 60870-5-103 is an unbalanced (master-slave) protocol for coded-bit serial communication exchanging information with a control system, and with a data transfer rate up to 38400 bit/s. In IEC terminology, a primary station is a master and a secondary station is a slave. The communication is based on a point-to-point principle. The master must have software that can interpret IEC 60870-5-103 communication messages.

The Communication protocol manual for IEC 60870-5-103 includes the 650 series vendor specific IEC 60870-5-103 implementation.
Section 15  Basic IED functions

15.1  Self supervision with internal event list

15.1.1  Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal error signal</td>
<td>INTERRSIG</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Internal event list</td>
<td>SELFSUPEVLST</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.1.2  Application

The protection and control IEDs have many functions included. Self supervision with internal event list (SELFSUPEVLST) and internal error signals (INTERRSIG) function provide supervision of the IED. The fault signals make it easier to analyze and locate a fault.

Both hardware and software supervision is included and it is also possible to indicate possible faults through a hardware contact on the power supply module and/or through the software communication.

Internal events are generated by the built-in supervisory functions. The supervisory functions supervise the status of the various modules in the IED and, in case of failure, a corresponding event is generated. Similarly, when the failure is corrected, a corresponding event is generated.

Apart from the built-in supervision of the various modules, events are also generated when the status changes for the:

- built-in real time clock (in operation/out of order).
- external time synchronization (in operation/out of order).
- Change lock (on/off)

Events are also generated:

- whenever any setting in the IED is changed.

The internal events are time tagged with a resolution of 1 ms and stored in a list. The list can store up to 40 events. The list is based on the FIFO principle, that is, when it is full, the oldest event is overwritten. The list can be cleared via the local HMI.

The list of internal events provides valuable information, which can be used during commissioning and fault tracing.

The list of internal events can be found in the LHMI or viewed in PCM600 using the Event viewer tool.
15.2 Time synchronization

15.2.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time synchronization</td>
<td>TIMESYNCHGEN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time system, summer time begins</td>
<td>DSTBEGIN</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time system, summer time ends</td>
<td>DSTEND</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time synchronization via IRIG-B</td>
<td>IRIG-B</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time synchronization via SNTP</td>
<td>SNTP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time zone from UTC</td>
<td>TIMEZONE</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.2.2 Application

Use time synchronization to achieve a common time base for the IEDs in a protection and control system. This makes comparison of events and disturbance data between all IEDs in the system possible.

Time-tagging of internal events and disturbances are an excellent help when evaluating faults. Without time synchronization, only the events within the IED can be compared to one another. With time synchronization, events and disturbances within the entire station, and even between line ends, can be compared during evaluation.
In the IED, the internal time can be synchronized from a number of sources:

- SNTP
- IRIG-B
- DNP
- IEC60870-5-103

Micro SCADA OPC server should not be used as a time synchronization source.

### 15.2.3 Setting guidelines

#### System time
The time is set with years, month, day, hour, minute and second.

#### Synchronization
The setting parameters for the real-time clock with external time synchronization (TIME) are set via local HMI or PCM600.

#### TimeSynch
When the source of the time synchronization is selected on the local HMI, the parameter is called `TimeSynch`. The time synchronization source can also be set from PCM600. The setting alternatives are:

- **FineSyncSource** which can have the following values:
  - `Disabled`
  - `SNTP`
  - `IRIG-B`

- **CoarseSyncSrc** which can have the following values:
  - `Disabled`
  - `SNTP`
  - `DNP`
  - `IEC60870-5-103`

The system time can be set manually, either via the local HMI or via any of the communication ports. The time synchronization fine tunes the clock.

#### IEC 60870-5-103 time synchronization
An IED with IEC 60870-5-103 protocol can be used for time synchronization, but for accuracy reasons, it is not recommended. In some cases, however, this kind of synchronization is needed, for example, when no other synchronization is available.

First, set the IED to be synchronized via IEC 60870-5-103 either from **IED Configuration/Time/Synchronization/TIMESYNCHGEN:1** in PST or from the local HMI.
**Figure 113: Settings under TIMESYNCHGEN:1 in PST**

Only CoarseSyncSrc can be set to IEC 60870-5-103, not FineSyncSource.

After setting up the time synchronization source, the user must check and modify the IEC 60870-5-103 time synchronization specific settings, under: IED Configuration/Communication/Station communication/IEC60870-5-103:1.

- **MasterTimeDomain** specifies the format of the time sent by the master. Format can be:
  - Coordinated Universal Time (UTC)
  - Local time set in the master (Local)
  - Local time set in the master adjusted according to daylight saving time (Local with DST)
- **TimeSyncMode** specifies the time sent by the IED. The time synchronisation is done using the following ways:
  - **IEDTime**: The IED sends the messages with its own time.
  - **LinMasTime**: The IED measures the offset between its own time and the master time, and applies the same offset for the messages sent as in the IEDTimeSkew. But in LinMasTime it applies the time changes occurred between two synchronised messages.
  - **IEDTimeSkew**: The IED measures the offset in between its own time and the master time and applies the same offset for the messages sent.
- **EvalTimeAccuracy** evaluates time accuracy for invalid time. Specifies the accuracy of the synchronization (5, 10, 20 or 40 ms). If the accuracy is worse than the specified value, the “Bad Time” flag is raised. To accommodate those masters that are really bad in time sync, the EvalTimeAccuracy can be set to *Disabled*.

According to the standard, the “Bad Time” flag is reported when synchronization has been omitted in the protection for >23 h.

### 15.3 Parameter setting group handling

#### 15.3.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting group handling</td>
<td>SETGRPS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Parameter setting groups</td>
<td>ACTVGRP</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 15.3.2 Application

Four sets of settings are available to optimize IED operation for different system conditions. By creating and switching between fine tuned setting sets, either from the local HMI or configurable binary inputs, results in a highly adaptable IED that can cope with a variety of system scenarios.
Different conditions in networks with different voltage levels require highly adaptable protection and control units to best provide for dependability, security and selectivity requirements. Protection units operate with a higher degree of availability, especially, if the setting values of their parameters are continuously optimized according to the conditions in the power system.

Operational departments can plan for different operating conditions in the primary equipment. The protection engineer can prepare the necessary optimized and pre-tested settings in advance for different protection functions. Four different groups of setting parameters are available in the IED. Any of them can be activated through the different programmable binary inputs by means of external or internal control signals.

15.3.3 Setting guidelines

The setting ActiveSetGrp, is used to select which parameter group to be active. The active group can also be selected with configured input to the function block ACTVGRP.

The parameter MaxNoSetGrp defines the maximum number of setting groups in use to switch between. Only the selected number of setting groups will be available in the Parameter Setting tool (PST) for activation with the ACTVGRP function block.

15.4 Test mode functionality TESTMODE

15.4.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test mode functionality</td>
<td>TESTMODE</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.4.2 Application

The protection and control IEDs may have a complex configuration with many included functions. To make the testing procedure easier, the IEDs include the feature that allows individual blocking of a single-, several-, or all functions.

This means that it is possible to see when a function is activated or trips. It also enables the user to follow the operation of several related functions to check correct functionality and to check parts of the configuration, and so on.

15.4.3 Setting guidelines

Remember always that there are two possible ways to place the IED in the TestMode= Enabled state. If, the IED is set to normal operation (TestMode = Disabled), but the functions are still shown being in the test mode, the input signal INPUT on the TESTMODE function block might be activated in the configuration.

Forcing of binary output signals is only possible when the IED is in test mode.
15.5 Change lock CHNGLCK

15.5.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change lock function</td>
<td>CHNGLCK</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.5.2 Application

Change lock function CHNGLCK is used to block further changes to the IED configuration once the commissioning is complete. The purpose is to make it impossible to perform inadvertent IED configuration and setting changes.

However, when activated, CHNGLCK will still allow the following actions that does not involve reconfiguring of the IED:

- Monitoring
- Reading events
- Resetting events
- Reading disturbance data
- Clear disturbances
- Reset LEDs
- Reset counters and other runtime component states
- Control operations
- Set system time
- Enter and exit from test mode
- Change of active setting group

The binary input controlling the function is defined in ACT or SMT. The CHNGLCK function is configured using ACT.

<table>
<thead>
<tr>
<th>LOCK</th>
<th>Binary input signal that will activate/deactivate the function, defined in ACT or SMT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTIVE</td>
<td>Output status signal</td>
</tr>
<tr>
<td>OVERRIDE</td>
<td>Set if function is overridden</td>
</tr>
</tbody>
</table>

When CHNGLCK has a logical one on its input, then all attempts to modify the IED configuration and setting will be denied and the message "Error: Changes blocked" will be displayed on the local HMI; in PCM600 the message will be “Operation denied by active ChangeLock”. The CHNGLCK function should be configured so that it is controlled by a signal from a binary input card. This guarantees that by setting that signal to a logical zero, CHNGLCK is deactivated. If any logic is included in the signal path to the CHNGLCK input, that logic must be designed so that it cannot permanently issue a logical one on the CHNGLCK input. If such a situation would occur in spite of these precautions, then please contact the local ABB representative for remedial action.
15.5.3 Setting guidelines

The Change lock function CHNGLCCK does not have any parameters available in the local HMI or PCM600.

15.6 IED identifiers TERMINALID

15.6.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED identifiers</td>
<td>TERMINALID</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.6.2 Application

15.6.2.1 Customer specific settings

The customer specific settings are used to give the IED a unique name and address. The settings are used by a central control system to communicate with the IED. The customer specific identifiers are found in the local HMI under Configuration/Power system/Identifiers/TERMINALID

The settings can also be made from PCM600. For more information about the available identifiers, see the technical manual.

Use only characters A - Z, a - z and 0 - 9 in station, unit and object names.

15.7 Product information PRODINF

15.7.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product information</td>
<td>PRODINF</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
15.7.2 Application

15.7.2.1 Factory defined settings

The factory defined settings are very useful for identifying a specific version and very helpful in the case of maintenance, repair, interchanging IEDs between different Substation Automation Systems and upgrading. The factory made settings can not be changed by the customer. They can only be viewed. The settings are found in the local HMI under Main menu/Diagnostics/IED status/ Product identifiers

The following identifiers are available:

- IEDProdType
  - Describes the type of the IED (like REL, REC or RET. Example: REL650
- ProductDef
  - Describes the release number, from the production. Example: 1.1.0.A1
- ProductVer
  - Describes the product version. Example: 1.1.0
- SerialNo
- OrderingNo
- ProductionDate

15.8 Primary system values PRIMVAL

15.8.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary system values</td>
<td>PRIMVAL</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.8.2 Application

The rated system frequency and phasor rotation are set under Main menu/Configuration/ Power system/ Primary values/PRIMVAL in the local HMI and PCM600 parameter setting tree.

15.9 Signal matrix for analog inputs SMAI

15.9.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal matrix for analog inputs</td>
<td>SMAI_20_1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
15.9.2 Application

Signal matrix for analog inputs function SMAI (or the pre-processing function) is used within PCM600 in direct relation with the Signal Matrix tool or the Application Configuration tool. Signal Matrix tool represents the way analog inputs are brought in for one IED configuration.

15.9.3 Setting guidelines

The parameters for the signal matrix for analog inputs (SMAI) functions are set via the local HMI, PCM600.

Every SMAI function block can receive four analog signals (three phases and one neutral value), either voltage or current. SMAI outputs give information about every aspect of the 3ph analog signals acquired (phase angle, RMS value, frequency and frequency derivates, and so on – 244 values in total). Besides the block “group name”, the analog inputs type (voltage or current) and the analog input names that can be set directly in ACT.

Common base IED values for primary current (IBase), primary voltage (VBase) and primary power (SBase) are set in a Global base values for settings function GBASVAL. Setting GlobalBaseSel is used to select a GBASVAL function for reference of base values.

DFTRefExtOut: Parameter valid for function block SMAI_20_1:1, SMAI_20_1:2 and SMAI_80_1 only. Reference block for external output (SPFCOUT function output).

DFTReference: Reference DFT for the block.

These DFT reference block settings decide DFT reference for DFT calculations (InternalDFTRef will use fixed DFT reference based on set system frequency. DFTRefGrpn will use DFT reference from the selected group block, when own group selected adaptive DFT reference will be used based on calculated signal frequency from own group. ExternalDFTRef will use reference based on input DFTSPFC.

ConnectionType: Connection type for that specific instance (n) of the SMAI (if it is Ph-N or Ph-Ph). Depending on connection type setting the not connected Ph-N or Ph-Ph outputs will be calculated.

Negation: If the user wants to negate the 3ph signal, it is possible to choose to negate only the phase signals Negate3Ph, only the neutral signal NegateN or both Negate3Ph+N; negation means rotation with 180° of the vectors.

MinValFreqMeas: The minimum value of the voltage for which the frequency is calculated, expressed as percent of GlobeBasVaGrp(n) (for each instance n).

Settings DFTRefExtOut and DFTReference shall be set to default value InternalDFTRef if no VT inputs are available.

Example of adaptive frequency tracking
Figure 114: SMAI instances as organized in different task time groups and the corresponding parameter numbers

The example shows a situation with adaptive frequency tracking with one reference selected for all instances. In practice each instance can be adapted to the needs of the actual application.

Example 1

Assume instance SMAI_20_7:1 in task time group 1 has been selected in the configuration to control the frequency tracking (For the SMAI_20_x task time groups). Observe that the selected reference instance (i.e. frequency tracking master) must be a voltage type. Observe that positive sequence voltage is used for the frequency tracking feature.

For task time group 1 this gives the following settings (see Figure 114 for numbering):
SMAI_20_7:1: $DFTRef_{ExtOut} = DFTRef_{Grp7}$ to route SMAI_20_7:1 reference to the SPFCOUT output. $DFTReference = DFTRef_{Grp7}$ for SMAI_20_7:1 to use SMAI_20_7:1 as reference (see Figure 115).


For task time group 2 this gives the following settings:

SMAI_20_1:2 - SMAI_20_12:2 $DFTReference = ExternalDFTRef$ to use DFTSPFC input as reference (SMAI_20_7:1)

### 15.10 Summation block 3 phase 3PHSUM

#### 15.10.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summation block 3 phase</td>
<td>3PHSUM</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 15.10.2 Application

Summation block 3 phase function 3PHSUM is used to get the sum of two sets of three-phase analog signals (of the same type) for those IED functions that might need it.

#### 15.10.3 Setting guidelines

The summation block receives the three-phase signals from SMAI blocks. The summation block has several settings.

Common base IED values for primary current ($I_{Base}$), primary voltage ($V_{Base}$) and primary power ($S_{Base}$) are set in a Global base values for settings function GBASVAL. Setting $GlobalBaseSet$ is used to select a GBASVAL function for reference of base values.

- **$SummationType$:** Summation type ($Group\ 1 + Group\ 2$, $Group\ 1 - Group\ 2$, $Group\ 2 - Group\ 1$ or – ($Group\ 1 + Group\ 2$)).

- **$DFTReference$:** The reference DFT block ($InternalDFT\ Ref, DFTRef_{Grp1}$ or $External\ DFT\ ref$).

- **$FreqMeasMinVal$:** The minimum value of the voltage for which the frequency is calculated, expressed as percent of $V_{Base}$ (for each instance $x$).

### 15.11 Global base values GBASVAL
15.11 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global base values</td>
<td>GBASVAL</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.11.2 Application

Global base values function (GBASVAL) is used to provide global values, common for all applicable functions within the IED. One set of global values consists of values for current, voltage and apparent power and it is possible to have six different sets.

This is an advantage since all applicable functions in the IED use a single source of base values. This facilitates consistency throughout the IED and also facilitates a single point for updating values when necessary.

Each applicable function in the IED has a parameter, GlobalBaseSel, defining one out of the six sets of GBASVAL functions.

15.11.3 Setting guidelines

**VBase**: Phase-to-phase voltage value to be used as a base value for applicable functions throughout the IED.

**IBase**: Phase current value to be used as a base value for applicable functions throughout the IED.

**SBase**: Standard apparent power value to be used as a base value for applicable functions throughout the IED, typically $S_{Base} = \sqrt{3} \cdot V_{Base} \cdot I_{Base}$.

15.12 Authority check ATHCHCK

15.12.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority check</td>
<td>ATHCHCK</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.12.2 Application

To safeguard the interests of our customers, both the IED and the tools that are accessing the IED are protected, by means of authorization handling. The authorization handling of the IED and the PCM600 is implemented at both access points to the IED:

- local, through the local HMI
- remote, through the communication ports
15.12.2.1 Authorization handling in the IED

At delivery the default user is the SuperUser. No Log on is required to operate the IED until a user has been created with the User Management Tool.

Once a user is created and written to the IED, that user can perform a Log on, using the password assigned in the tool. Then the default user will be Guest.

If there is no user created, an attempt to log on will display a message box: “No user defined!”

If one user leaves the IED without logging off, then after the timeout (set in Main menu/Configuration/HMI/Screen/1:SCREEN) elapses, the IED returns to Guest state, when only reading is possible. By factory default, the display timeout is set to 60 minutes.

If one or more users are created with the User Management Tool and written to the IED, then, when a user attempts a Log on by pressing the → key or when the user attempts to perform an operation that is password protected, the Log on window opens.

The cursor is focused on the User identity field, so upon pressing the → key, one can change the user name, by browsing the list of users, with the "up" and "down" arrows. After choosing the right user name, the user must press the → key again. When it comes to password, upon pressing the → key, the following characters will show up: “**********”. The user must scroll for every letter in the password. After all the letters are introduced (passwords are case sensitive) choose OK and press the → key again.

At successful Log on, the local HMI shows the new user name in the status bar at the bottom of the LCD. If the Log on is OK, when required to change for example a password protected setting, the local HMI returns to the actual setting folder. If the Log on has failed, an "Error Access Denied" message opens. If a user enters an incorrect password three times, that user will be blocked for ten minutes before a new attempt to log in can be performed. The user will be blocked from logging in, both from the local HMI and PCM600. However, other users are to log in during this period.

15.13 Authority status ATHSTAT

15.13.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority status</td>
<td>ATHSTAT</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

15.13.2 Application

Authority status (ATHSTAT) function is an indication function block, which informs about two events related to the IED and the user authorization:
• the fact that at least one user has tried to log on wrongly into the IED and it was blocked (the output USRBLKED)
• the fact that at least one user is logged on (the output LOGGEDON)

The two outputs of ATHSTAT function can be used in the configuration for different indication and alarming reasons, or can be sent to the station control for the same purpose.

## 15.14 Denial of service

### 15.14.1 Identification

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denial of service, frame rate control for front port</td>
<td>DOSFRNT</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function description</th>
<th>IEC 61850 identification</th>
<th>IEC 60617 identification</th>
<th>ANSI/IEEE C37.2 device number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denial of service, frame rate control for LAN1 port</td>
<td>DOSLAN1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### 15.14.2 Application

The denial of service functions (DOSFRNT, DOSLAN1 and DOSSCKT) are designed to limit the CPU load that can be produced by Ethernet network traffic on the IED. The communication facilities must not be allowed to compromise the primary functionality of the device. All inbound network traffic will be quota controlled so that too heavy network loads can be controlled. Heavy network load might for instance be the result of malfunctioning equipment connected to the network.

DOSFRNT, DOSLAN1 and DOSSCKT measures the IED load from communication and, if necessary, limit it for not jeopardizing the IEDs control and protection functionality due to high CPU load. The function has the following outputs:

• LINKUP indicates the Ethernet link status
• WARNING indicates that communication (frame rate) is higher than normal
• ALARM indicates that the IED limits communication

### 15.14.3 Setting guidelines

The function does not have any parameters available in the local HMI or PCM600.
Section 16   Requirements

16.1   Current transformer requirements

The performance of a protection function will depend on the quality of the measured current signal. Saturation of the current transformer (CT) will cause distortion of the current signal and can result in a failure to operate or cause unwanted operations of some functions. Consequently CT saturation can have an influence on both the dependability and the security of the protection. This protection IED has been designed to permit heavy CT saturation with maintained correct operation.

16.1.1   Current transformer classification

To guarantee correct operation, the current transformers (CTs) must be able to correctly reproduce the current for a minimum time before the CT will begin to saturate. To fulfill the requirement on a specified time to saturation the CTs must fulfill the requirements of a minimum secondary e.m.f. that is specified below.

There are several different ways to specify CTs. Conventional magnetic core CTs are usually specified and manufactured according to some international or national standards, which specify different protection classes as well. There are many different standards and a lot of classes but fundamentally there are three different types of CTs:

- High remanence type CT
- Low remanence type CT
- Non remanence type CT

The high remanence type has no limit for the remanent flux. This CT has a magnetic core without any airgap and a remanent flux might remain almost infinite time. In this type of transformers the remanence can be up to around 80% of the saturation flux. Typical examples of high remanence type CT are class P, PX, TPS, TPX according to IEC, class P, X according to BS (old British Standard) and non gapped class C, K according to ANSI/IEEE.

The low remanence type has a specified limit for the remanent flux. This CT is made with a small air gap to reduce the remanence to a level that does not exceed 10% of the saturation flux. The small air gap has only very limited influences on the other properties of the CT. Class PR, TPY according to IEC are low remanence type CTs.

The non remanence type CT has practically negligible level of remanent flux. This type of CT has relatively big air gaps in order to reduce the remanence to practically zero level. In the same time, these air gaps reduce the influence of the DC-component from the primary fault current. The air gaps will also decrease the measuring accuracy in the non-saturated region of operation. Class TPZ according to IEC is a non remanence type CT.

Different standards and classes specify the saturation e.m.f. in different ways but it is possible to approximately compare values from different classes. The rated equivalent limiting secondary e.m.f. $E_{al}$ according to the IEC 60044 – 6 standard is used to specify the CT requirements for the IED. The requirements are also specified according to other standards.
16.1.2 Conditions

The requirements are a result of investigations performed in our network simulator. The current transformer models are representative for current transformers of high remanence and low remanence type. The results may not always be valid for non remanence type CTs (TPZ).

The performances of the protection functions have been checked in the range from symmetrical to fully asymmetrical fault currents. Primary time constants of at least 120 ms have been considered at the tests. The current requirements below are thus applicable both for symmetrical and asymmetrical fault currents.

Depending on the protection function phase-to-ground, phase-to-phase and three-phase faults have been tested for different relevant fault positions for example, close in forward and reverse faults, zone 1 reach faults, internal and external faults. The dependability and security of the protection was verified by checking for example, time delays, unwanted operations, directionality, overreach and stability.

The remanence in the current transformer core can cause unwanted operations or minor additional time delays for some protection functions. As unwanted operations are not acceptable at all maximum remanance has been considered for fault cases critical for the security, for example, faults in reverse direction and external faults. Because of the almost negligible risk of additional time delays and the non-existent risk of failure to operate the remanence have not been considered for the dependability cases. The requirements below are therefore fully valid for all normal applications.

It is difficult to give general recommendations for additional margins for remanence to avoid the minor risk of an additional time delay. They depend on the performance and economy requirements. When current transformers of low remanence type (for example, TPY, PR) are used, normally no additional margin is needed. For current transformers of high remanence type (for example, P, PX, TPS, TPX) the small probability of fully asymmetrical faults, together with high remanence in the same direction as the flux generated by the fault, has to be kept in mind at the decision of an additional margin. Fully asymmetrical fault current will be achieved when the fault occurs at approximately zero voltage (0°). Investigations have shown that 95% of the faults in the network will occur when the voltage is between 40° and 90°. In addition fully asymmetrical fault current will not exist in all phases at the same time.

16.1.3 Fault current

The current transformer requirements are based on the maximum fault current for faults in different positions. Maximum fault current will occur for three-phase faults or single phase-to-ground faults. The current for a single phase-to-ground fault will exceed the current for a three-phase fault when the zero sequence impedance in the total fault loop is less than the positive sequence impedance.

When calculating the current transformer requirements, maximum fault current for the relevant fault position should be used and therefore both fault types have to be considered.

16.1.4 Secondary wire resistance and additional load

The voltage at the current transformer secondary terminals directly affects the current transformer saturation. This voltage is developed in a loop containing the secondary wires and the burden of all relays in the circuit. For ground faults the loop includes the phase and neutral wire, normally twice the resistance of the single secondary wire. For three-phase faults the neutral current is zero and it is just necessary to consider the resistance up to the point where the phase
wires are connected to the common neutral wire. The most common practice is to use four wires secondary cables so it normally is sufficient to consider just a single secondary wire for the three-phase case.

The conclusion is that the loop resistance, twice the resistance of the single secondary wire, must be used in the calculation for phase-to-ground faults and the phase resistance, the resistance of a single secondary wire, may normally be used in the calculation for three-phase faults.

As the burden can be considerable different for three-phase faults and phase-to-ground faults it is important to consider both cases. Even in a case where the phase-to-ground fault current is smaller than the three-phase fault current the phase-to-ground fault can be dimensioning for the CT depending on the higher burden.

In isolated or high impedance grounded systems the phase-to-ground fault is not the dimensioning case and therefore the resistance of the single secondary wire always can be used in the calculation, for this case.

### 16.1.5 General current transformer requirements

The current transformer ratio is mainly selected based on power system data for example, maximum load. However, it should be verified that the current to the protection is higher than the minimum operating value for all faults that are to be detected with the selected CT ratio. The minimum operating current is different for different functions and normally settable so each function should be checked.

The current error of the current transformer can limit the possibility to use a very sensitive setting of a sensitive residual overcurrent protection. If a very sensitive setting of this function will be used it is recommended that the current transformer should have an accuracy class which have an current error at rated primary current that is less than ±1% (for example, 5P). If current transformers with less accuracy are used it is advisable to check the actual unwanted residual current during the commissioning.

### 16.1.6 Rated equivalent secondary e.m.f. requirements

With regard to saturation of the current transformer all current transformers of high remanence and low remanence type that fulfill the requirements on the rated equivalent secondary e.m.f. \( E_{al} \) below can be used. The characteristic of the non remanence type CT (TPZ) is not well defined as far as the phase angle error is concerned. If no explicit recommendation is given for a specific function we therefore recommend contacting ABB to confirm that the non remanence type can be used.

The CT requirements for the different functions below are specified as a rated equivalent limiting secondary e.m.f. \( E_{al} \) according to the IEC 60044-6 standard. Requirements for CTs specified in different ways are given at the end of this section.

#### 16.1.6.1 Breaker failure protection

The CTs must have a rated equivalent secondary e.m.f. \( E_{al} \) that is larger than or equal to the required secondary e.m.f. \( E_{alreq} \) below:
\[ E_{ai} \geq E_{a\text{req}} = 5 \cdot I_{op} \cdot \frac{I_n}{I_{pn}} \left( R_{CT} + R_L + \frac{S_R}{I_n^2} \right) \]

(Equation 79)

where:
- \( I_{op} \): The primary operate value (A)
- \( I_{pn} \): The rated primary CT current (A)
- \( I_{sn} \): The rated secondary CT current (A)
- \( I_n \): The nominal current of the protection IED (A)
- \( R_{CT} \): The secondary resistance of the CT (Ω)
- \( R_L \): The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly grounded systems. The resistance of a single secondary wire should be used for faults in high impedance grounded systems.
- \( S_R \): The burden of an IED current input channel (VA). \( S_R = 0.010 \text{ VA/channel for } I_r = 1 \text{ A} \) and \( S_R = 0.250 \text{ VA/channel for } I_r = 5 \text{ A} \)

### 16.1.6.2 Non-directional instantaneous and definitive time, phase and residual overcurrent protection

The CTs must have a rated equivalent secondary e.m.f. \( E_{al} \) that is larger than or equal to the required secondary e.m.f. \( E_{a\text{req}} \) below:

\[ E_{ai} \geq E_{a\text{req}} = 1.5 \cdot I_{op} \cdot \frac{I_n}{I_{pn}} \left( R_{CT} + R_L + \frac{S_R}{I_n^2} \right) \]

(Equation 80)

where:
- \( I_{op} \): The primary operate value (A)
- \( I_{pn} \): The rated primary CT current (A)
- \( I_{sn} \): The rated secondary CT current (A)
- \( I_n \): The nominal current of the protection IED (A)
- \( R_{CT} \): The secondary resistance of the CT (Ω)
- \( R_L \): The resistance of the secondary cable and additional load (Ω). The loop resistance containing the phase and neutral wires, must be used for faults in solidly grounded systems. The resistance of a single secondary wire should be used for faults in high impedance grounded systems.
- \( S_R \): The burden of an IED current input channel (VA). \( S_R = 0.010 \text{ VA/channel for } I_r = 1 \text{ A} \) and \( S_R = 0.250 \text{ VA/channel for } I_r = 5 \text{ A} \)
16.1.6.3 Non-directional inverse time delayed phase and residual overcurrent protection

The requirement according to Equation 81 and Equation 82 does not need to be fulfilled if the high set instantaneous or definitive time stage is used. In this case Equation is the only necessary requirement.

If the inverse time delayed function is the only used overcurrent protection function the CTs must have a rated equivalent secondary e.m.f. \( E_{al} \) that is larger than or equal to the required secondary e.m.f. \( E_{alreq} \) below:

\[
E_{al} \geq E_{alreq} = 20 \cdot I_{op} \cdot \frac{I_{sn}}{I_{pn}} \left( R_{CT} + R_{L} + \frac{S_R}{I_n^2} \right)
\]

(Equation 81)

where

- \( I_{op} \) The primary current set value of the inverse time function (A)
- \( I_{pn} \) The rated primary CT current (A)
- \( I_{sn} \) The rated secondary CT current (A)
- \( I_n \) The nominal current of the protection IED (A)
- \( R_{CT} \) The secondary resistance of the CT (\( \Omega \))
- \( R_{L} \) The resistance of the secondary cable and additional load (\( \Omega \)). The loop resistance containing the phase and neutral wires, must be used for faults in solidly grounded systems. The resistance of a single secondary wire should be used for faults in high impedance grounded systems.
- \( S_R \) The burden of an IED current input channel (VA). \( S_R = 0.010 \text{ VA/channel for } I_r = 1 \text{ A and } S_R = 0.250 \text{ VA/channel for } I_r = 5 \text{ A} \)

Independent of the value of \( I_{op} \) the maximum required \( E_{al} \) is specified according to the following:

\[
E_{al} \geq E_{alreq, max} = I_{k,max} \cdot \frac{I_{sn}}{I_{pn}} \left( R_{CT} + R_{L} + \frac{S_R}{I_n^2} \right)
\]

(Equation 82)

where

- \( I_{k,max} \) Maximum primary fundamental frequency current for close-in faults (A)

16.1.6.4 Directional phase and residual overcurrent protection

If the directional overcurrent function is used the CTs must have a rated equivalent secondary e.m.f. \( E_{al} \) that is larger than or equal to the required equivalent secondary e.m.f. \( E_{alreq} \) below:
\[ E_{al} \geq E_{alreq} = I_{kmax} \cdot \frac{I_{sn}}{I_{pn}} \cdot \left( R_{CT} + R_{L} + \frac{S_R}{I_n} \right) \]

(Equation 83)

where:
- \( I_{kmax} \) Maximum primary fundamental frequency current for close-in forward and reverse faults (A)
- \( I_{pn} \) The rated primary CT current (A)
- \( I_{sn} \) The rated secondary CT current (A)
- \( I_n \) The rated current of the protection IED (A)
- \( R_{CT} \) The secondary resistance of the CT (\( \Omega \))
- \( R_L \) The resistance of the secondary cable and additional load (\( \Omega \)). The loop resistance containing the phase and neutral wires, must be used for faults in solidly grounded systems. The resistance of a single secondary wire should be used for faults in high impedance grounded systems.
- \( S_R \) The burden of an IED current input channel (VA). \( S_R = 0.010 \text{ VA/channel for } I_R = 1 \text{ A and } S_R = 0.250 \text{ VA/channel for } I_R = 5 \text{ A} \)

### 16.1.7 Current transformer requirements for CTs according to other standards

All kinds of conventional magnetic core CTs are possible to use with the IEDs if they fulfill the requirements corresponding to the above specified expressed as the rated equivalent secondary e.m.f. \( E_{al} \) according to the IEC 60044-6 standard. From different standards and available data for relaying applications it is possible to approximately calculate a secondary e.m.f. of the CT comparable with \( E_{al} \). By comparing this with the required secondary e.m.f. \( E_{alreq} \) it is possible to judge if the CT fulfills the requirements. The requirements according to some other standards are specified below.

#### 16.1.7.1 Current transformers according to IEC 60044-1, class P, PR

A CT according to IEC 60044-1 is specified by the secondary limiting e.m.f. \( E_{2\text{max}} \). The value of the \( E_{2\text{max}} \) is approximately equal to the corresponding \( E_{al} \) according to IEC 60044-6. Therefore, the CTs according to class P and PR must have a secondary limiting e.m.f. \( E_{2\text{max}} \) that fulfills the following:

\[ E_{2\text{max}} > \text{max inum of } E_{alreq} \]

(Equation 84)

#### 16.1.7.2 Current transformers according to IEC 60044-1, class PX, IEC 60044-6, class TPS (and old British Standard, class X)

CTs according to these classes are specified approximately in the same way by a rated knee-point e.m.f. \( E_{knee} \) (\( E_k \) for class PX, \( E_{kneeBS} \) for class X and the limiting secondary voltage \( V_{al} \) for TPS). The value of the \( E_{knee} \) is lower than the corresponding \( E_{al} \) according to IEC 60044-6. It is not possible...
to give a general relation between the $E_{\text{knee}}$ and the $E_{\text{al}}$ but normally the $E_{\text{knee}}$ is approximately 80 \% of the $E_{\text{al}}$. Therefore, the CTs according to class PX, X and TPS must have a rated knee-point e.m.f. $E_{\text{knee}}$ that fulfills the following:

$$ S = TD \cdot S_{\text{old}} + (1 - TD) \cdot S_{\text{calculated}} $$

(Equation 85)

### 16.1.7.3 Current transformers according to ANSI/IEEE

Current transformers according to ANSI/IEEE are partly specified in different ways. A rated secondary terminal voltage $V_{\text{ANSI}}$ is specified for a CT of class C. $V_{\text{ANSI}}$ is the secondary terminal voltage the CT will deliver to a standard burden at 20 times rated secondary current without exceeding 10 \% ratio correction. There are a number of standardized $U_{\text{ANSI}}$ values for example, $V_{\text{ANSI}}$ is 400 V for a C400 CT. A corresponding rated equivalent limiting secondary e.m.f. $E_{\text{alANSI}}$ can be estimated as follows:

$$ E_{\text{alANSI}} = \left| 20 \cdot I_{\text{SN}} \cdot R_{\text{CT}} + V_{\text{ANSI}} \right| = \left| 20 \cdot I_{\text{SN}} \cdot R_{\text{CT}} + 20 \cdot I_{\text{SN}} \cdot Z_{\text{bANSI}} \right| $$

(Equation 86)

where:

- $Z_{\text{bANSI}}$ The impedance (that is, complex quantity) of the standard ANSI burden for the specific C class ($\Omega$)
- $V_{\text{ANSI}}$ The secondary terminal voltage for the specific C class (V)

The CTs according to class C must have a calculated rated equivalent limiting secondary e.m.f. $E_{\text{alANSI}}$ that fulfills the following:

$$ E_{\text{alANSI}} > \text{max imum of } E_{\text{alreq}} $$

(Equation 87)

A CT according to ANSI/IEEE is also specified by the knee-point voltage $V_{\text{kneeANSI}}$ that is graphically defined from an excitation curve. The knee-point voltage $V_{\text{kneeANSI}}$ normally has a lower value than the knee-point e.m.f. according to IEC and BS. $V_{\text{kneeANSI}}$ can approximately be estimated to 75 \% of the corresponding $E_{\text{al}}$ according to IEC 60044 6. Therefore, the CTs according to ANSI/IEEE must have a knee-point voltage $V_{\text{kneeANSI}}$ that fulfills the following:

### 16.2 Voltage transformer requirements

The performance of a protection function will depend on the quality of the measured input signal. Transients caused by capacitive Coupled voltage transformers (CCVTs) can affect some protection functions.

Magnetic or capacitive voltage transformers can be used.
The capacitive voltage transformers (CCVTs) should fulfill the requirements according to the IEC 60044–5 standard regarding ferro-resonance and transients. The ferro-resonance requirements of the CCVTs are specified in chapter 7.4 of the standard.

The transient responses for three different standard transient response classes, T1, T2 and T3 are specified in chapter 15.5 of the standard. CCVTs according to all classes can be used.

The protection IED has effective filters for these transients, which gives secure and correct operation with CCVTs.

16.3 SNTP server requirements

16.3.1 SNTP server requirements

The SNTP server to be used is connected to the local network, that is not more than 4-5 switches or routers away from the IED. The SNTP server is dedicated for its task, or at least equipped with a real-time operating system, that is not a PC with SNTP server software. The SNTP server should be stable, that is, either synchronized from a stable source like GPS, or local without synchronization. Using a local SNTP server without synchronization as primary or secondary server in a redundant configuration is not recommended.
### Section 17  Glossary

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<td>AC</td>
<td>Alternating current</td>
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<tr>
<td>ACT</td>
<td>Application configuration tool within PCM600</td>
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<tr>
<td>A/D converter</td>
<td>Analog-to-digital converter</td>
</tr>
<tr>
<td>ADBS</td>
<td>Amplitude deadband supervision</td>
</tr>
<tr>
<td>AI</td>
<td>Analog input</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>AR</td>
<td>Autoreclosing</td>
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<tr>
<td>ASCT</td>
<td>Auxiliary summation current transformer</td>
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<tr>
<td>ASD</td>
<td>Adaptive signal detection</td>
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<tr>
<td>AWG</td>
<td>American Wire Gauge standard</td>
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<tr>
<td>BI</td>
<td>Binary input</td>
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<tr>
<td>BOS</td>
<td>Binary outputs status</td>
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<tr>
<td>BR</td>
<td>External bistable relay</td>
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<tr>
<td>BS</td>
<td>British Standards</td>
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<tr>
<td>CAN</td>
<td>Controller Area Network. ISO standard (ISO 11898) for serial communication</td>
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<tr>
<td>CB</td>
<td>Circuit breaker</td>
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<tr>
<td>CCVT</td>
<td>Capacitive Coupled Voltage Transformer</td>
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<tr>
<td>Class C</td>
<td>Protection Current Transformer class as per IEEE/ ANSI</td>
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<tr>
<td>CMPPS</td>
<td>Combined megapulses per second</td>
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<td>CMT</td>
<td>Communication Management tool in PCM600</td>
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<tr>
<td>CO cycle</td>
<td>Close-open cycle</td>
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<tr>
<td>Codirectional</td>
<td>Way of transmitting G.703 over a balanced line. Involves two twisted pairs making it possible to transmit information in both directions</td>
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<tr>
<td>COMTRADE</td>
<td>Standard Common Format for Transient Data Exchange format for Disturbance recorder according to IEEE/ANSI C37.111, 1999 / IEC60255-24</td>
</tr>
<tr>
<td>Contra-directional</td>
<td>Way of transmitting G.703 over a balanced line. Involves four twisted pairs, two of which are used for transmitting data in both directions and two for transmitting clock signals</td>
</tr>
<tr>
<td>CPU</td>
<td>Central processor unit</td>
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<tr>
<td>CR</td>
<td>Carrier receive</td>
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<tr>
<td>CRC</td>
<td>Cyclic redundancy check</td>
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<td>CROB</td>
<td>Control relay output block</td>
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<td>CS</td>
<td>Carrier send</td>
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<td>Abbreviation</td>
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<tr>
<td>CT</td>
<td>Current transformer</td>
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<tr>
<td>CVT or CCVT</td>
<td>Capacitive voltage transformer</td>
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<tr>
<td>DAR</td>
<td>Delayed autoreclosing</td>
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<tr>
<td>DARPA</td>
<td>Defense Advanced Research Projects Agency (The US developer of the TCP/IP protocol etc.)</td>
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<tr>
<td>DBDL</td>
<td>Dead bus dead line</td>
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<tr>
<td>DBLL</td>
<td>Dead bus live line</td>
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<tr>
<td>DC</td>
<td>Direct current</td>
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<tr>
<td>DFC</td>
<td>Data flow control</td>
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<tr>
<td>DFT</td>
<td>Discrete Fourier transform</td>
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<tr>
<td>DHCP</td>
<td>Dynamic Host Configuration Protocol</td>
</tr>
<tr>
<td>DIP-switch</td>
<td>Small switch mounted on a printed circuit board</td>
</tr>
<tr>
<td>DI</td>
<td>Digital input</td>
</tr>
<tr>
<td>DLLB</td>
<td>Dead line live bus</td>
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<tr>
<td>DNP</td>
<td>Distributed Network Protocol as per IEEE/ANSI Std. 1379-2000</td>
</tr>
<tr>
<td>DR</td>
<td>Disturbance recorder</td>
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<tr>
<td>DRAM</td>
<td>Dynamic random access memory</td>
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<tr>
<td>DRH</td>
<td>Disturbance report handler</td>
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<tr>
<td>DSP</td>
<td>Digital signal processor</td>
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<td>DTT</td>
<td>Direct transfer trip scheme</td>
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<tr>
<td>EHV network</td>
<td>Extra high voltage network</td>
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<tr>
<td>EIA</td>
<td>Electronic Industries Association</td>
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<tr>
<td>EMC</td>
<td>Electromagnetic compatibility</td>
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<tr>
<td>EMF</td>
<td>(Electric Motive Force)</td>
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<td>EMI</td>
<td>Electromagnetic interference</td>
</tr>
<tr>
<td>EnFP</td>
<td>End fault protection</td>
</tr>
<tr>
<td>EPA</td>
<td>Enhanced performance architecture</td>
</tr>
<tr>
<td>ESD</td>
<td>Electrostatic discharge</td>
</tr>
<tr>
<td>FCB</td>
<td>Flow control bit; Frame count bit</td>
</tr>
<tr>
<td>FOX 20</td>
<td>Modular 20 channel telecommunication system for speech, data and protection signals</td>
</tr>
<tr>
<td>FOX 512/515</td>
<td>Access multiplexer</td>
</tr>
<tr>
<td>FOX 6Plus</td>
<td>Compact time-division multiplexer for the transmission of up to seven duplex channels of digital data over optical fibers</td>
</tr>
<tr>
<td>G.703</td>
<td>Electrical and functional description for digital lines used by local telephone companies. Can be transported over balanced and unbalanced lines</td>
</tr>
<tr>
<td>GCM</td>
<td>Communication interface module with carrier of GPS receiver module</td>
</tr>
<tr>
<td>GDE</td>
<td>Graphical display editor within PCM600</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>GI</td>
<td>General interrogation command</td>
</tr>
<tr>
<td>GIS</td>
<td>Gas-insulated switchgear</td>
</tr>
<tr>
<td>GOOSE</td>
<td>Generic object-oriented substation event</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>HDLC protocol</td>
<td>High-level data link control, protocol based on the HDLC standard</td>
</tr>
<tr>
<td>HFBR connector type</td>
<td>Plastic fiber connector</td>
</tr>
<tr>
<td>HMI</td>
<td>Human-machine interface</td>
</tr>
<tr>
<td>HSAR</td>
<td>High speed autoreclosening</td>
</tr>
<tr>
<td>HV</td>
<td>High-voltage</td>
</tr>
<tr>
<td>HVDC</td>
<td>High-voltage direct current</td>
</tr>
<tr>
<td>IDBS</td>
<td>Integrating deadband supervision</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrical Committee</td>
</tr>
<tr>
<td>IEC 60044-6</td>
<td>IEC Standard, Instrument transformers – Part 6: Requirements for protective current transformers for transient performance</td>
</tr>
<tr>
<td>IEC 61850</td>
<td>Substation automation communication standard</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IEEE 802.12</td>
<td>A network technology standard that provides 100 Mbits/s on twisted-pair or optical fiber cable</td>
</tr>
<tr>
<td>IEEE P1386.1</td>
<td>PCI Mezzanine Card (PMC) standard for local bus modules. References the CMC (IEEE P1386, also known as Common Mezzanine Card) standard for the mechanics and the PCI specifications from the PCI SIG (Special Interest Group) for the electrical EMF (Electromotive force).</td>
</tr>
<tr>
<td>IED</td>
<td>Intelligent electronic device</td>
</tr>
<tr>
<td>I-GIS</td>
<td>Intelligent gas-insulated switchgear</td>
</tr>
<tr>
<td>Instance</td>
<td>When several occurrences of the same function are available in the IED, they are referred to as instances of that function. One instance of a function is identical to another of the same kind but has a different number in the IED user interfaces. The word “instance” is sometimes defined as an item of information that is representative of a type. In the same way an instance of a function in the IED is representative of a type of function.</td>
</tr>
</tbody>
</table>
| 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 reassembly through the data link layer.  
2. Ingression protection, according to IEC standard |
<p>| IP 20         | Ingression protection, according to IEC standard, level IP20- Protected against solid foreign objects of 12.5 mm diameter and greater. |
| IP 40         | Ingression protection, according to IEC standard, level IP40- Protected against solid foreign objects of 1 mm diameter and greater. |
| IP 54         | Ingression protection, according to IEC standard, level IP54- Dust-protected, protected against splashing water. |</p>
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>IRF</td>
<td>Internal failure signal</td>
</tr>
<tr>
<td>IRIG-B</td>
<td>InterRange Instrumentation Group Time code format B, standard 200</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunications Union</td>
</tr>
<tr>
<td>LAN</td>
<td>Local area network</td>
</tr>
<tr>
<td>LIB 520</td>
<td>High-voltage software module</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid crystal display</td>
</tr>
<tr>
<td>LDD</td>
<td>Local detection device</td>
</tr>
<tr>
<td>LED</td>
<td>Light-emitting diode</td>
</tr>
<tr>
<td>MCB</td>
<td>Miniature circuit breaker</td>
</tr>
<tr>
<td>MCM</td>
<td>Mezzanine carrier module</td>
</tr>
<tr>
<td>MVB</td>
<td>Multifunction vehicle bus. Standardized serial bus originally developed for use in trains.</td>
</tr>
<tr>
<td>NCC</td>
<td>National Control Centre</td>
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<tr>
<td>OCO cycle</td>
<td>Open-close-open cycle</td>
</tr>
<tr>
<td>OCP</td>
<td>Overcurrent protection</td>
</tr>
<tr>
<td>OLTC</td>
<td>On-load tap changer</td>
</tr>
<tr>
<td>OV</td>
<td>Over-voltage</td>
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<tr>
<td>Overreach</td>
<td>A term used to describe how the relay behaves during a fault condition. For example, a distance relay is overreaching when the impedance presented to it is smaller than the apparent impedance to the fault applied to the balance point, that is, the set reach. The relay “sees” the fault but perhaps it should not have seen it.</td>
</tr>
<tr>
<td>PCI</td>
<td>Peripheral component interconnect, a local data bus</td>
</tr>
<tr>
<td>PCM</td>
<td>Pulse code modulation</td>
</tr>
<tr>
<td>PCM600</td>
<td>Protection and control IED manager</td>
</tr>
<tr>
<td>PC-MIP</td>
<td>Mezzanine card standard</td>
</tr>
<tr>
<td>PISA</td>
<td>Process interface for sensors &amp; actuators</td>
</tr>
<tr>
<td>PMC</td>
<td>PCI Mezzanine card</td>
</tr>
<tr>
<td>POR</td>
<td>Permissive overreach</td>
</tr>
<tr>
<td>POTT</td>
<td>Permissive overreach transfer trip</td>
</tr>
<tr>
<td>Process bus</td>
<td>Bus or LAN used at the process level, that is, in near proximity to the measured and/or controlled components</td>
</tr>
<tr>
<td>PSM</td>
<td>Power supply module</td>
</tr>
<tr>
<td>PST</td>
<td>Parameter setting tool within PCM600</td>
</tr>
<tr>
<td>PT ratio</td>
<td>Potential transformer or voltage transformer ratio</td>
</tr>
<tr>
<td>PUTT</td>
<td>Permissive underreach transfer trip</td>
</tr>
<tr>
<td>RASC</td>
<td>Synchrocheck relay, COMBIFLEX</td>
</tr>
<tr>
<td>RCA</td>
<td>Relay characteristic angle</td>
</tr>
<tr>
<td>RFPP</td>
<td>Resistance for phase-to-phase faults</td>
</tr>
</tbody>
</table>
Resistance for phase-to-ground 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
SBO  Select-before-operate
SC  Switch or push button to close
SCS  Station control system
SCADA  Supervision, control and data acquisition
SCT  System configuration tool according to standard IEC 61850
SDU  Service data unit
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/Wye 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
UMT  User management tool
| **Underreach** | A term used to describe how the relay behaves during a fault condition. For example, a distance relay is underreaching when the impedance presented to it is greater than the apparent impedance to the fault applied to the balance point, that is, the set reach. The relay does not “see” the fault but perhaps it should have seen it. See also Overreach. |
|**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 is 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 |
|**3I₀** | Three times zero-sequence current. Often referred to as the residual or the fault current. Three times the zero sequence voltage. Often referred to as the residual voltage or the neutral point voltage |