NOTICE

This document contains information about one or more ABB products and may include a description of or a reference to one or more standards that may be generally relevant to the ABB products. The presence of any such description of a standard or reference to a standard is not a representation that all the ABB products referenced in this document support all the features of the described or referenced standard. To determine the specific features supported by ABB product, the reader should consult the product specifications for the ABB product.

ABB may have one or more patents or pending patent applications protecting the intellectual property in the ABB products described in this document.

The information in this document is subject to change without notice and should not be construed as a commitment by ABB. ABB assumes no responsibility for any errors that may appear in this document.

Products described or referenced in this document are designed to be connected and to communicate information and data through network interfaces, which should be connected to a secure network. It is the sole responsibility of the system/product owner to provide and continuously ensure a secure connection between the product and the system network and/or any other networks that may be connected.

The system/product owners must establish and maintain appropriate measures, including, but not limited to, the installation of firewalls, application of authentication measures, encryption of data, installation of antivirus programs, and so on, to protect these products, the network, its system, and interfaces against security breaches, unauthorized access, interference, intrusion, leakage, and/or theft of data or information.

ABB performs functionality testing on the products and updates that we release. However, system/product owners are ultimately responsible for ensuring that any product updates or other major system updates (to include but not limited to code changes, configuration file changes, third-party software updates or patches, hardware change out, and so on) are compatible with the security measures implemented. The system/product owners must verify that the system and associated products function as expected in the environment in which they are deployed.

In no event shall ABB be liable for direct, indirect, special, incidental or consequential damages of any nature or kind arising from the use of this document, nor shall ABB be liable for incidental or consequential damages arising from use of any software or hardware described in this document.

This document and parts thereof must not be reproduced or copied without written permission from ABB, and the contents thereof must not be imparted to a third party nor used for any unauthorized purpose.

The software or hardware described in this document is furnished under a license and may be used, copied, or disclosed only in accordance with the terms of such license. This product meets the requirements specified in EMC Directive 2014/30/EU and in Low Voltage Directive 2014/35/EU.

TRADEMARKS

All rights to copyrights, registered trademarks, and trademarks reside with their respective owners.

Copyright © 2020 ABB.

All rights reserved.

Release: June 2020

Document Number: 1VLG500007

Revision: F
# Table of Contents

## 1 Introduction .............................................................................................................. 1
  1.1 This manual ........................................................................................................... 1
  1.2 Intended users ....................................................................................................... 1

## 2 UniGear Digital ........................................................................................................ 2
  2.1 Sensors .................................................................................................................. 3
    2.1.1 Current sensors ............................................................................................. 4
    2.1.2 Voltage sensors ............................................................................................ 7
  2.2 Protection relays .................................................................................................... 11
  2.3 IEC 61850 ............................................................................................................ 22
  2.4 Switchgear type overview .................................................................................... 24

## 3 Engineering ............................................................................................................. 27
  3.1 Sensors .................................................................................................................. 27
    3.1.1 Current sensors ............................................................................................. 27
    3.1.2 Voltage sensors ............................................................................................ 32
  3.2 Documentation ....................................................................................................... 34
  3.3 Station bus (GOOSE) ......................................................................................... 36
  3.4 Process bus (SMV) ............................................................................................... 43
  3.5 Ethernet ................................................................................................................ 54
    3.5.1 Requirements ............................................................................................... 54
    3.5.2 Technology .................................................................................................... 55
    3.5.3 Topologies ..................................................................................................... 62
    3.5.4 Ethernet traffic estimation ............................................................................ 68
    3.5.5 Naming convention to identify protection relays ........................................... 69
    3.5.6 IP address allocation .................................................................................... 69
    3.5.7 Time synchronization .................................................................................. 70
    3.5.8 Traffic segregation ....................................................................................... 73
    3.5.9 Protection relays ............................................................................................. 75
    3.5.10 Managed Ethernet switches ......................................................................... 78
    3.5.11 Satellite controlled clock ............................................................................ 91
  3.6 Statistical energy meters ....................................................................................... 96
    3.6.1 ESM-ET statistical energy meter .................................................................... 96
List of Figures

Figure 1: UniGear Digital and its key components .......................................................... 2
Figure 2: Current sensor KECA 80 C104 / KECA 80 C165 ............................................. 4
Figure 3: Current sensor KECA 80 C184 / KECA 80 C216 ............................................ 5
Figure 4: Current sensor KECA 250 B1 ........................................................................... 6
Figure 5: Voltage sensor KEVA 17.5 B20 ................................................................. 7
Figure 6: Voltage sensor KEVA 24 B20 ................................................................. 8
Figure 7: Coupler adapter AR5 utilized with Relion® 615, 620 and 640 series protection relays ................................................................. 9
Figure 8: Connector pins assignment of a current sensor plug ...................................... 10
Figure 9: Connector pins assignment of a voltage sensor plug ...................................... 10
Figure 10: Functionality overview of REF615 standard configuration G ...................... 12
Figure 11: Functionality overview of REF615 standard configuration L ....................... 13
Figure 12: Functionality overview of REM615 standard configuration D ..................... 14
Figure 13: Functionality overview of RED615 standard configuration E ..................... 15
Figure 14: Functionality overview of REF620 standard configuration B ...................... 16
Figure 15: Functionality overview of REM620 standard configuration B ..................... 17
Figure 16: Protection and control REX640 .................................................................. 18
Figure 17: Overview of RIO600 connection ............................................................... 19
Figure 18: RIO600 communicating analog signals for the panel meters ....................... 19
Figure 19: ESSAILEC RJ45 test block ........................................................................... 20
Figure 20: Low Voltage Compartment door with ESSAILEC RJ45 test blocks .......... 20
Figure 21: The testing (only one phase is shown) .......................................................... 20
Figure 22: ESM-ET connectivity to I/U sensors ............................................................. 21
Figure 23: Examples of ESM and ENMI assembly ....................................................... 21
Figure 24: Switchgear with sensor measurement ............................................................ 22
Figure 25: Switchgear with sensor measurement and process bus application of voltage sharing and synchrocheck ................................................................. 23
Figure 26: UniGear ZS1 Digital (17.5 kV, 4 000 A, 50 kA) ............................................. 24
Figure 27: UniGear ZS1 Digital (24 kV, 3 150 A, 31.5 kA) ............................................. 25
Figure 28: UniGear S50 Digital (12 kV, 1 250 A, 31.5 kA) .......................................... 25
Figure 29: UniGear 500R Digital (17.5 kV, 2 000 A, 31.5 kA) ........................................ 26
Figure 30: UniGear MCC Digital (12 kV, 400 A, 50 kA) ................................................ 26
Figure 31: Example of a current sensor label ................................................................... 27
Figure 32: Example of setting the correction factors for the current sensors in PCM600 .... 27
Figure 33: Single line diagram .................................................................................... 28
Figure 34: Example of setting values for current sensor in PCM600 ............................. 29
Figure 35: Example of parameter setting for PHIPTOC1 Start value in PCM600 .......... 29
Figure 36: Current sensor with unique physical polarity ................................................ 30
Figure 37: Polarity setting for current sensors in incoming feeder ................................... 31
Figure 38: Example of polarity setting for current sensor in PCM600 ........................... 31
Figure 39: Example of a voltage sensor label ............................................................... 32
Figure 40: Example of setting the correction factors for the voltage sensors in PCM600 ... 32
Figure 41: Single line diagram .................................................................................... 33
Figure 42: Example of setting values for Voltage sensor in PCM600 ............................ 33
Figure 43: Example of a Network Overview Diagram .................................................. 34
Figure 44: Example of a logic diagram for interconnection between panels .................. 34
Figure 45: Example of a Sampled measured value diagram ........................................... 35
Figure 46: Creating a new GOOSE data set and its entries .......................................... 37
Figure 47: GOOSE control block properties ............................................................... 38
Figure 48: GOOSE control block editor (1- receiver #1, 2- receiver #2, 3 – sender) .......... 39
Figure 49: Selecting Show IED Capabilities Tab .......................................................... 39
Figure 50: Editing 615 series capabilities ................................................................. 40
Figure 51: Creating a new GOOSE data set and its entries ........................................ 40
Figure 52: Naming a GOOSE control block ............................................................. 41
Figure 53: GCB client ............................................................................................. 41
Figure 54: Adding a GOOSERCV function block in the Application Configuration Tool 42
Figure 55: Creating GOOSERCV block connection to a new variable ...................... 42
Figure 56: Signal Matrix ....................................................................................... 42
Figure 57: Example of Process bus application of voltage sharing and synchro-check ... 43
Figure 58: Example of Process bus application of voltage sharing redundancy and synchro check ............................................................... 43
Figure 59: Example of Process bus application of voltage sharing (Double busbar system) and synchro check ................................................................. 44
Figure 60: Example of Process bus application of voltage sharing redundancy (Double busbar system) and synchro check ................................................................. 44
Figure 61: Example of VMSWI voltage switch function block implementation in the Application Configuration Tool ................................................................. 44
Figure 62: Adding a SMSENDER voltage switch function block implementation in the Application Configuration Tool ................................................................. 45
Figure 63: Adding a ULTVTR1 block in the Application Configuration Tool .............. 45
Figure 64: Time parameter setting dialog in PCM600 .............................................. 46
Figure 65: Configuring the SMV senders and receivers .......................................... 47
Figure 66: Changing the Sampled Measured Value Control Block attributes ............ 48
Figure 67: Selecting Show IED Capabilities Tab ...................................................... 49
Figure 68: Editing 615 series capabilities .................................................................. 50
Figure 69: Sampled value control block ................................................................. 50
Figure 70: Connecting the SMV senders and receivers .......................................... 50
Figure 71: Receiving all phase voltages and residual voltage using SMV ................. 51
Figure 72: Receiving line voltage for synchrocheck functionality using SMV ........... 51
Figure 73: Application Configuration tool logic examples for the SMV fail save operation ............................................................... 52
Figure 74: SMV Max delay setting in PCM600 ....................................................... 53
Figure 75: FTP patch cable terminated with RJ-45 connectors ............................... 55
Figure 76: Fiber optic patch cable terminated with LC connectors .......................... 55
Figure 77: LC connectors ..................................................................................... 56
Figure 78: Communication module with single Ethernet connector (615 and 620 series) ... 56
Figure 79: Communication modules with multiple Ethernet connectors (615 and 620 series) . 57
Figure 80: Communication modules with multiple Ethernet connectors (640 series) .... 57
Figure 81: Example of Managed Ethernet Switches from AFS family .................... 59
Figure 82: 1 - Fast Ethernet fiber optic SFP module, 2 - Gigabit Ethernet fiber optic SFP module ............................................................... 59
Figure 83: Installed SFP module in managed Ethernet switch AFS677 ..................... 59
Figure 84: Example of satellite-controlled clock from Tekron with optional accessories ... 60
Figure 85: Example of satellite-controlled clock from Meinberg ............................ 61
Figure 86: Low Voltage Compartment of UniGear panel ........................................ 61
Figure 87: RSTP ring redundant structure ............................................................... 62
Figure 88: MRP / E-MRP ring redundant structure ............................................... 63
Figure 89: Single network using RSTP / E-MRP ..................................................... 63
Figure 90: PRP networks using RSTP / E-MRP ..................................................... 64
Figure 91: HSR network ....................................................................................... 65
Figure 92: HSR network with redboxes .................................................................. 65
Figure 93: Combined PRP and HSR networks ...................................................... 66
Figure 94: Example of an allocation of device IP addresses ................................... 70
Figure 95: Example of IEEE 1588-time synchronization via the Ethernet network .... 70
Figure 96: IEEE 1588 Time synchronization scheme for HSR-PRP networks .......... 72
Figure 97: IEEE 1588 Time synchronization scheme for PRP networks ................ 72
Figure 98: Example of traffic segregation via building virtual LANs ..................... 73
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>99</td>
<td>Virtual LANs allocation in PRP-RSTP networks</td>
<td>73</td>
</tr>
<tr>
<td>100</td>
<td>Virtual LANs allocation in HSR-PRP networks</td>
<td>74</td>
</tr>
<tr>
<td>101</td>
<td>Network parameters dialog</td>
<td>75</td>
</tr>
<tr>
<td>102</td>
<td>Adding RCHLCCH and SCHLCCH blocks in the Application Configuration Tool</td>
<td>76</td>
</tr>
<tr>
<td>103</td>
<td>Status of Ethernet rear port displayed via ITT SA Explorer (on top and on bottom)</td>
<td>77</td>
</tr>
<tr>
<td>104</td>
<td>AFS switch screen</td>
<td>78</td>
</tr>
<tr>
<td>105</td>
<td>Login window</td>
<td>78</td>
</tr>
<tr>
<td>106</td>
<td>Port Configuration dialog</td>
<td>79</td>
</tr>
<tr>
<td>107</td>
<td>Load / Save dialog</td>
<td>80</td>
</tr>
<tr>
<td>108</td>
<td>PTP Global dialog</td>
<td>81</td>
</tr>
<tr>
<td>109</td>
<td>PTP Version 2 (Transparent Clock) Global dialog</td>
<td>81</td>
</tr>
<tr>
<td>110</td>
<td>PTP Version 2 (Transparent Clock) Port dialog</td>
<td>82</td>
</tr>
<tr>
<td>111</td>
<td>Switching Global dialog in AFS67x (top) and AFS66x (bottom)</td>
<td>83</td>
</tr>
<tr>
<td>112</td>
<td>VLAN Global dialog in AFS67x</td>
<td>84</td>
</tr>
<tr>
<td>113</td>
<td>VLAN Static dialog</td>
<td>84</td>
</tr>
<tr>
<td>114</td>
<td>VLAN Port dialog</td>
<td>85</td>
</tr>
<tr>
<td>115</td>
<td>VLAN Global dialog in AFS67x</td>
<td>86</td>
</tr>
<tr>
<td>116</td>
<td>Spanning Tree Global dialog</td>
<td>86</td>
</tr>
<tr>
<td>117</td>
<td>Spanning Tree Ports dialog</td>
<td>87</td>
</tr>
<tr>
<td>118</td>
<td>E-MRP Ring Redundancy dialog</td>
<td>87</td>
</tr>
<tr>
<td>119</td>
<td>Example of AFS660 Front view</td>
<td>88</td>
</tr>
<tr>
<td>120</td>
<td>Switching Global dialog</td>
<td>88</td>
</tr>
<tr>
<td>121</td>
<td>PRP Configuration dialog</td>
<td>89</td>
</tr>
<tr>
<td>122</td>
<td>HSR Configuration dialog</td>
<td>90</td>
</tr>
<tr>
<td>123</td>
<td>IEC61850-MMS Configuration dialog</td>
<td>90</td>
</tr>
<tr>
<td>124</td>
<td>Tekron clock configuration Tool</td>
<td>91</td>
</tr>
<tr>
<td>125</td>
<td>Basic setting dialog</td>
<td>92</td>
</tr>
<tr>
<td>126</td>
<td>PTP setting dialog</td>
<td>92</td>
</tr>
<tr>
<td>127</td>
<td>Port Configuration dialog</td>
<td>93</td>
</tr>
<tr>
<td>128</td>
<td>PTP setting dialog</td>
<td>93</td>
</tr>
<tr>
<td>129</td>
<td>PTP Global settings dialog</td>
<td>94</td>
</tr>
<tr>
<td>130</td>
<td>PTP Network settings dialog</td>
<td>95</td>
</tr>
<tr>
<td>131</td>
<td>Network configuration dialog</td>
<td>96</td>
</tr>
<tr>
<td>132</td>
<td>Measurements configuration dialog</td>
<td>97</td>
</tr>
<tr>
<td>133</td>
<td>Clock configuration dialog</td>
<td>98</td>
</tr>
<tr>
<td>134</td>
<td>Example of setting the correction factors for the current and the voltage sensors in ESM Test tool</td>
<td>99</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: Sensor product portfolio for UniGear Digital ........................................3
Table 2: Protection relay key functionality overview for UniGear Digital .................11
Table 3: Overview of UniGear Digital in UniGear switchgear family ..........................24
Table 4: Maximum current Start and protection setting values ................................30
Table 5: Topology-dependent SMV max delay setting ...........................................53
Table 6: Recommended Managed Ethernet switches overview for UniGear Digital .........58
Table 7: Comparison of network topologies .........................................................67
Table 8: C37.238 Power Profile key parameters ..................................................71
1 Introduction

1.1 This manual
The engineering guide provides information for the UniGear Digital solution by providing details about its main components. This guide focuses especially on the IEC 61850 digital communication and it can be used as a technical reference during the engineering phase.

1.2 Intended users
This manual is intended for to be used by design, protection relay, test and service engineers. The protection relay engineer needs to have a thorough knowledge of protection systems, protection equipment, protection functions, configured functional logic in the Protection relays and their IEC 61850 engineering. The test and service engineers are expected to be familiar with handling of the electronic equipment.
2 UniGear Digital

UniGear Digital is a new solution implemented to the traditional UniGear switchgear. It is accomplished by using state-of-the-art, well-proven components: current and voltage sensors, Relion® protection relays and IEC 61850 digital communication.

The design of the current sensors is very compact, and it is optimized for the use in UniGear. Each panel can accommodate two sets of current sensors. The voltage sensors are very compact as well. They are integrated as part of support insulators housed in the cable compartment or directly in the busbar compartment.

The current and voltage sensors are very accurate (accuracy class 0.5), however revenue metering might require higher accuracy classes or separate instrument current and voltage transformer. Such transformers can optionally be added to sensor-equipped panels.

Capacitive voltage detection is enabled by capacitive dividers that are either integrated into the support insulators or into the conventional current transformers, which is used case by case.

Fast horizontal GOOSE communication for inter-panel (bay-to-bay) signals exchange is a mandatory part of this solution, while the Process bus is optional.

Figure 1: UniGear Digital and its key components
2.1 Sensors

Sensors, for current and voltage measurement, are an important part of UniGear Digital. Each switchgear type offering UniGear Digital solution uses sensors as shown in the table below.

Table 1: Sensor product portfolio for UniGear Digital

<table>
<thead>
<tr>
<th>Measurement type</th>
<th>Sensor type</th>
<th>Maximum app. parameter</th>
<th>Panel width [mm]</th>
<th>UniGear ZS1 Digital up to 17.5 kV</th>
<th>UniGear ZS1 Digital up to 24 kV</th>
<th>UniGear 550 Digital</th>
<th>UniGear 500R Digital</th>
<th>UniGear MCC Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>KECA 80 C104</td>
<td>Up to 1 250 A</td>
<td>650</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>KECA 80 C165</td>
<td>Up to 4 000 A / 1000</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>KECA 80 C184</td>
<td>Up to 1 250 A</td>
<td>800</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>KECA 80 C216</td>
<td>Up to 3 150 A</td>
<td>1000</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>KECA 250 B1</td>
<td>Up to 2 000 A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Voltage</td>
<td>KEVA 17.5 B20</td>
<td>Up to 17.5 kV</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>KEVA 24 B20</td>
<td>Up to 24 kV</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
2.1.1 Current sensors

Current measurement in KECA sensors is based on the Rogowski coil principle.

KECA 80 C104 / KECA 80 C165

For dynamic current measurement (protection purposes) the ABB sensors KECA 80 C104, and KECA 80 C165, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current $I_{th}$ (31.5 kA or 50 kA). With KECA 80 C104 and KECA 80 C165 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy ranges from 5 % of the rated primary current $I_{pr}$ not only up to 120 % of $I_{pr}$ (as being common for conventional current transformers), but even up to the rated continuous thermal current $I_{cth}$ (1 250 A or 4 000 A). That provides the possibility to designate the corresponding accuracy class as 5P400 and 5P630, proving excellent linearity and accuracy measurements.

Figure 2: Current sensor KECA 80 C104 / KECA 80 C165

Technical parameters

- Continuous thermal current: 1 250 / 4 000 A
- Rated primary current: 80 A / 150 mV at 50 Hz or 80 A / 180 mV at 60 Hz
- Accuracy class: 0.5 / 5P400; 5P630
**KECA 80 C184 / KECA 80 C216**

For dynamic current measurement (protection purposes) the ABB sensors KECA 80 C184, and KECA 80 C216, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current $I_{th}$ (31.5 kA). With KECA 80 C184 and KECA 80 C216 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy range from 5 % of the rated primary current $I_{pr}$ not only up to 120 % of $I_{pr}$ (as being common for conventional current transformers), but even up to the rated continuous thermal current $I_{cth}$ (1 250 A or 3 150 A). That provides the possibility to designate the corresponding accuracy class as 5P400, proving excellent linearity and accuracy measurements.

![Current sensor KECA 80 C184 / KECA 80 C216](image)

**Technical parameters**

- **Continuous thermal current**
  
  1 250 / 3 150 A

- **Rated primary current**
  
  80 A / 150 mV at 50 Hz or 80 A / 180 mV at 60 Hz

- **Accuracy class**
  
  0.5 / 5P400
**KECA 250 B1**

For dynamic current measurement (protection purposes) the ABB sensors KECA 250 B1, fulfil requirements of protection class 5P up to an impressive value reaching the rated short-time thermal current $I_{th}$ (31.5 kA). With KECA 250 B1 sensors, measuring class 0.5 is reached for continuous current measurement in the extended accuracy range from 5 % of the rated primary current $I_{pr}$, not only up to 120 % of $I_{pr}$ (as being common for conventional current transformers), but even up to the rated continuous thermal current $I_{cTh}$ (2 000 A). That provides the possibility to designate the corresponding accuracy class as 5P125, proving excellent linearity and accuracy measurements.

![Current sensor KECA 250 B1](image)

**Figure 4: Current sensor KECA 250 B1**

**Technical parameters**

- Continuous thermal current 2 000 A
- Rated primary current 250 A / 150 mV at 50 Hz or 250 A / 180 mV at 60 Hz
- Accuracy class 0.5 / 5P125
2.1.2 Voltage sensors

Voltage measurement in the KEVA sensor is based on the resistive divider principle. Voltage sensors are designed to be compact and shaped as support insulators. They can be installed in the switchgear’s cable compartment or directly in the busbar compartment.

**KEVA 17.5 B20**

KEVA B sensor can be used in all applications up to the voltage level 17.5 kV. The sensor fulfils requirements of accuracy class 0.5 for measurement purposes and accuracy class 3P for protection purposes.

![Voltage sensor KEVA 17.5 B20](image)

**Figure 5: Voltage sensor KEVA 17.5 B20**

**Technical parameters**

- Rated primary voltage: 15 / $\sqrt{3}$ kV
- Rated power frequency withstand voltage: 38 (42) kV
- Rated lightning impulse withstand voltage: 95 kV
- Transformation ratio: 10 000: 1
- Accuracy class: 0.5 / 3P
KEVA 24 B20

KEVA B sensor can be used in all applications up to the voltage level 24 kV. The sensor fulfils requirements of accuracy class 0.5 for measurement purposes and accuracy class 3P for protection purposes.

Figure 6: Voltage sensor KEVA 24 B20

Technical parameters

- Rated primary voltage: 22 / √3 kV
- Rated power frequency withstand voltage: 50 kV
- Rated lightning impulse withstand voltage: 125 kV
- Transformation ratio: 10 000:1
- Accuracy class: 0.5 / 3P
Sensor accessories

Sensors are connected to protection relay via cable with RJ-45 connector. In case both current and voltage sensors are connected to a protection relay, a coupler adapter AR5 is used. The coupler adapter AR5 is three phases adapter. Protection relays used in UniGear Digital have combined sensor inputs. Each current and voltage sensor has separate cable with one RJ-45 connector. The cable is a separable part of each sensor and it can be replaced by cable of the same length because of the guaranteed accuracy and performance of the sensor. The cable is to be connected directly (or via the coupler adapter AR5 if needed) to the protection relay. The coupler adapter AR5 is used to combine two RJ-45 connectors from current and voltage sensors into a combined sensor input for each phase on a protection relay.

Figure 7: Coupler adapter AR5 utilized with Relion™ 615, 620 and 640 series protection relays
Current sensor wires are connected according to the following assignment:
PIN 4 – S1, PIN 5 – S2, other PINs remain unused.

Figure 8: Connector pins assignment of a current sensor plug

Voltage sensor wires are connected according to the following assignment: PIN 7 – a,
PIN 8 - V, other PINs remain unused.

Figure 9: Connector pins assignment of a voltage sensor plug
2.2 Protection relays

UniGear Digital is supported by the following types of protection relays, shown in table below.

Table 2: Protection relay key functionality overview for UniGear Digital

<table>
<thead>
<tr>
<th>Relion®</th>
<th>Product type</th>
<th>Standard configuration</th>
<th>I/U sensor input</th>
<th>Arc protection</th>
<th>IEC 61850-9-2LE</th>
<th>Synchro-check / Synchronizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>615 series</td>
<td>REF615</td>
<td>G</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes* / No</td>
</tr>
<tr>
<td>REM615</td>
<td>D</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No / No</td>
</tr>
<tr>
<td>RED615</td>
<td>E</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes* / No</td>
<td></td>
</tr>
<tr>
<td>620 series</td>
<td>REF620</td>
<td>B</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes* / No</td>
</tr>
<tr>
<td>REM620</td>
<td>B</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No / No</td>
</tr>
<tr>
<td>640 series</td>
<td>REX640</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes / Yes</td>
</tr>
</tbody>
</table>

* Only available with IEC 61850-9-2LE

The above-mentioned protection relays support IEC 61850 Ed.2 and Ed.1 communication with GOOSE messaging (performance class P1 / 1A) and 9-2LE stream (sample rate 4 kHz in case of 50 Hz, 80 samples per cycle, 1 ASDU per frame). The IEC 61850-9-2LE interface is supported by the Relion® 615, 620 and 640 series, including the PRP1 / HSR redundancy (RED615 only via fiber optic interfaces). The 615, 620 and 640 series work as a redundancy box (Redbox) between the HSR / PRP1 networks and single attached devices or networks not aware of PRP1 / HSR.

The 615, 620 and 640 series support the IEEE 1588 (PTPv2) and Power profile as defined in IEEE C37.238 standard to reach the required timing accuracy over an Ethernet network. The 615, 620 and 640 series work as an ordinary clock (capable of acting as either a Master or a Slave clock). There is no need to design a substation with two Grandmaster clocks to reach redundancy because the 615, 620 and 640 series can work as Master clock. For more details see 615, 620 and 640 series manuals.
Feeder protection and control REF615

The REF615 is a dedicated feeder protection relay perfectly aligned for protection, control, measurement and supervision of utilities and industrial power distribution systems including radial, looped and meshed networks, and involving a potential distributed power generation. The REF615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

Figure 10: Functionality overview of REF615 standard configuration G
Figure 11: Functionality overview of REF615 standard configuration L
Motor protection and control REM615

The REM615 is a dedicated motor protection relay perfectly aligned for protection, control, measurement and supervision of asynchronous motors in manufacturing and process industry. The REM615 offers all the functionality needed to manage motor starts and normal operation, including also protection and fault clearance in drive and network disturbance situations. The REM615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE.

Figure 12: Functionality overview of REM615 standard configuration D
Line differential protection and control RED615

RED615 is a phase-segregated, two-end, line differential protection and control relay. With in-zone transformer support, perfectly harmonized for utility and industrial power distribution networks. The RED615 relays communicate between substations over a fiber optic link or a galvanic pilot wire connection. Protection of ring-type and meshed distribution networks generally requires unit protection solutions, also applied in radial networks containing distributed power generation. With relation to UniGear Digital this protection relay is used for more dedicated applications only. The RED615 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

Figure 13: Functionality overview of RED615 standard configuration E
Feeder protection and control REF620

The REF620 is a dedicated feeder management relay perfectly aligned for the protection, control, measurement and supervision of utility and industrial power distribution systems, including radial, looped and meshed networks, with or without distributed power generation. REF620 can also be used to protect feeders including motors or capacitor banks. Additionally, REF620 offers functionality for interconnection protection used with distributed generation like wind or solar power connection to utility grid. The REF620 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

Figure 14: Functionality overview of REF620 standard configuration B
Motor protection and control REM620

The REM620 is a dedicated motor management relay perfectly aligned for the protection, control, measurement and supervision of medium-sized and large asynchronous and synchronous motors requiring also differential protection in the manufacturing and process industry. The REF620 can send (1 instance) and / or receive (1 instance) voltage over the IEC 61850-9-2LE and to synchrocheck with IEC 61850-9-2 LE.

Figure 15: Functionality overview of REM620 standard configuration B
Protection and control REX640

REX640 is a powerful all-in-one protection and control relay for use in advanced power distributions and generation applications with unmatched flexibility available during the complete life cycle of the device. The modular design of both hardware and software elements facilitates the coverage of any comprehensive protection application requirement that may arise during the complete life cycle of the relay and substation. One full IEC 61850-9-2 LE stream containing both voltages and currents can be sent. Receiving of up to four Sampled Measured Value (SMV) streams is supported with a total of maximum 16 channels. The channels are freely configurable with the possibility to engineer SMV stream redundancy using the voltage and current switch functions with either another SMV stream or local measurements.

Figure 16: Protection and control REX640
Remote IO unit RIO600

The remote inputs / outputs unit RIO600 is designed to expand the digital and analog inputs / outputs of ABB’s Relion® protection relays and to provide inputs / outputs for the ABB ZEE600 using the IEC 61850 Ed.2 communication. The RIO600 communicates with the protection relays over the Ethernet cable via fast horizontal GOOSE communication.

![Figure 17: Overview of RIO600 connection](image)

The RIO600 AOM4 analog output module has four mA outputs providing mA output signal in range 0–20 mA. These outputs can be used for connection to the analog / digital panel meters. Operation accuracy of mA output is 0.1 % or 0.2 mA. There is an option to use a selector switch to display more than one phase on one panel meter.

![Figure 18: RIO600 communicating analog signals for the panel meters](image)
**TE Connectivity’s ESSAILEC RJ45 test block**

The test block is used for efficient testing of protection and control relay with sensor inputs during regular maintenance. The test block is flush mounting type on the low voltage compartment door and its vertical layout is recommended. The testing of protection and control relay’s sensor inputs is possible without opening the low voltage compartment door. One test block is intended for one phase and it consists of a socket, a lid and a plug.

![Figure 19: ESSAILEC RJ45 test block](image1)

![Figure 20: Low Voltage Compartment door with ESSAILEC RJ45 test blocks](image2)

The socket is covered during Normal operation by the lid. For testing, the lid is removed and replaced by the test plug.

![Figure 21: The testing (only one phase is shown)](image3)

**ESSAILEC Trip or Polarity range test block**

A test block allows the testing without circuit breaker tripping.
Statistical Energy meter

ESM-ET statistical energy meter (Order code: ESM-ET97-220-A2E2-05S) is manufactured by EnergoService (https://enip2.ru/en/). The meter is compatible and has been tested with ABB’s current and voltage sensors. New sets of dedicated I/U sensors are required. The energy meter can be used for current measurement up to 4 200 A and voltage measurement up to 40 kV. The amplitude correction and the phase error correction factors of the current and voltage sensors must be entered in the energy meter. ESM-ET counts four-quadrant active and reactive energy, it uses its built-in memory to store power demands and energy readings by time of use tariffs. ENMI-5 and 7 display panels connected with single patch cord serves as a Human Machine Interface (HMI) for the energy meter. The display panel can be mounted separately or attached to the back of the meter.

Figure 22: ESM-ET connectivity to I/U sensors

Figure 23: Examples of ESM and ENMI assembly
2.3 IEC 61850

The IEC 61850 standard was released in 2004 as a global international standard representing the architecture for communication networks and systems for power utility automation. It is updated with new version, Edition 2, which extends to new application areas in transmission and distribution power systems and defines a new functionality to Edition 1 functionality. IEC 61850 Edition 2 adds new functionality which is not supported by the Edition 1. Therefore, it is recommended to always use the same standard version in all devices and not to mix different versions in the same project.

The IEC 61850 standard defines the Ethernet technology for substation automation communication. It also includes the related system requirements and the data model of the protection and control functions. The standardized data modelling of substation functions including the communication interfaces pave the way to openness and interoperability of devices.

The IEC 61850 standard distinguishes Station bus IEC 61850-8-1 with vertical and horizontal GOOSE communication (real time communication between protection relays) and Process bus IEC 61850-9-2 for transmission of Sampled Measured Values (SMV) gathered by measurements. The UCA International Users Group created a guideline (commonly referred to as IEC 61850-9-2LE where “LE” stays for “Lite Edition”) that defines an application profile of IEC 61850-9-2 to facilitate implementation and enable interoperability.

The Station and Process busses can be physically separated, or they can coexist on the same Ethernet network. The GOOSE and SMV profiles enable designing substation communication for MV switchgear in a novel and flexible way to make the protection relay process data available to all other protection relays in the local network in a real-time manner.

Protection relays publish signals for interlocking, blocking, tripping between panels via horizontal GOOSE communication in UniGear Digital. Nowadays, GOOSE communication is used increasingly in substations and it offers new additional values like simplicity, functional flexibility, easy scalability and improved diagnostic, faster performance compared to conventional hard wired interpanel wires.

![Diagram of Switchgear with sensor measurement](image-url)
Process interfaces to MV apparatus (for example voltage sensors) are on the process level. Besides the conventional signal wiring between the process interface and protection relays, IEC 61850 introduces a concept where process signals can be exchanged in process bus, under IEC 61850-9-2. In MV switchgear application the station and the process bus can be combined to one common bus. When using conventional voltage instrument transformers (VTs) in MV switchgear they are usually located in the incoming feeders on the cable side and the busbar voltage is measured in any of the outgoing feeders or in dedicated metering panel. The sharing of the busbar voltage is done by interconnection wires between busbar VTs and protection relays in all outgoing feeders. Usage of sensors and IEC 61850-9-2 has significant effect on the design of the switchgear. The signal from the voltage sensor measuring the busbar voltage in one of the protection relays is digitized into sampled values stream shared over Ethernet network. The interconnection wiring in switchgear becomes simplified as less regular galvanic signal wires are needed. Transmitting voltage signal over process bus enable also higher error detection because the signal transmission is supervised.

Figure 25: Switchgear with sensor measurement and process bus application of voltage sharing and synchrocheck
### 2.4 Switchgear type overview

UniGear Digital is available for the following switchgear types:

- UniGear ZS1
- UniGear 550
- UniGear 500R
- UniGear MCC

#### Table 3: Overview of UniGear Digital in UniGear switchgear family

<table>
<thead>
<tr>
<th>Switchgear type</th>
<th>Busbar arrangement</th>
<th>UniGear Digital</th>
<th>Voltage level</th>
<th>Rated feeder current</th>
<th>Rated short-circuit current</th>
</tr>
</thead>
<tbody>
<tr>
<td>UniGear ZS1</td>
<td>Single busbar</td>
<td>Yes</td>
<td>Up to 24 kV</td>
<td>Up to 4 000 A</td>
<td>Up to 63 kA / 1 s (50 kA / 3 s)</td>
</tr>
<tr>
<td></td>
<td>Double busbar</td>
<td>Yes (Up to 17.5 kV)</td>
<td>Up to 24 kV</td>
<td>Up to 4 000 A</td>
<td>Up to 31.5 kA / 3 s</td>
</tr>
<tr>
<td></td>
<td>Back to back</td>
<td>No</td>
<td>Up to 24 kV</td>
<td>Up to 4 000 A</td>
<td>Up to 50 kA / 3 s</td>
</tr>
<tr>
<td>UniGear 550</td>
<td>Single busbar</td>
<td>Yes</td>
<td>Up to 12 kV</td>
<td>Up to 1 250 A</td>
<td>Up to 31.5 kA / 3 s</td>
</tr>
<tr>
<td>UniGear 500R (IEC)</td>
<td>Single busbar</td>
<td>Yes</td>
<td>Up to 17.5 kV</td>
<td>Up to 2 000 A</td>
<td>Up to 31.5 kA / 3 s</td>
</tr>
<tr>
<td>UniGear MCC</td>
<td>Single busbar</td>
<td>Yes</td>
<td>Up to 12 kV</td>
<td>Up to 400 A</td>
<td>Up to 50 kA / 3 s</td>
</tr>
</tbody>
</table>

Figure 26: UniGear ZS1 Digital (17.5 kV, 4 000 A, 50 kA)
Figure 27: UniGear ZS1 Digital (24 kV, 3150 A, 31.5 kA)

Figure 28: UniGear 550 Digital (12 kV, 1250 A, 31.5 kA)
Figure 29: UniGear 500R Digital (17.5 kV, 2 000 A, 31.5 kA)

Figure 30: UniGear MCC Digital (12 kV, 400 A, 50 kA)
3 Engineering

3.1 Sensors

3.1.1 Current sensors

Correlation factors

The amplitude and phase error of a current sensor is, in practice, constant and independent on the primary current. This means it is an inherent and constant property of each sensor and it is not considered to be unpredictable and bound to influences. Hence, it can be easily rectified in the protection relay by using appropriate correction factors, specified separately for every sensor. Values of correction factors for the amplitude and phase error of a current sensor are entered on the sensor label and as well as in the sensor’s routine test report. To achieve the required accuracy classes, it is recommended to use both correction factors (Cfs), that is, the amplitude correction factor (aI) and the phase error correction factor (pI) of the current sensor.

Figure 31: Example of a current sensor label

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the protection relay. The correction factors are entered via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Current (3I, CT))

Figure 32: Example of setting the correction factors for the current sensors in PCM600
Primary current

Setting example

In this example, an 80 A / 0.150 V at 50 Hz sensor is used and the application has a 1 000 A nominal current ($I_n$).

![Single line diagram](image)

**Figure 33: Single line diagram**

When defining another primary value for the sensor, also the nominal voltage should be redefined to maintain the same transformation ratio. However, the setting in the protection relay (**Rated Secondary Value**) is not in V but in mV / Hz, which makes the same setting value valid for both 50 Hz and 60 Hz nominal frequency.

$$RSV = \frac{I_n / I_{pr} \times K_r}{f_n}$$

- $RSV$: Rated secondary value in mV / Hz
- $I_n$: Application nominal current
- $I_{pr}$: Sensor-rated nominal current
- $K_r$: Sensor-rated voltage at the rated current in mV
- $f_n$: Network nominal frequency

In this example, the value is as calculated using the equation.

$$RSV = \frac{1000 A / 80 A \times 150 mV}{50 Hz} = 37.5 \frac{mV}{Hz}$$
Primary, Nominal current and Rated secondary values are entered via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Current (3I, CT))

Figure 34: Example of setting values for current sensor in PCM600

Unless otherwise specified, the Nominal Current setting should always be the same as the Primary Current setting which is a reference value for protection functions.

Each setting parameter of current protection functions is divided by application nominal current $I_n$.

Threshold for PHIPTOC1 Start value tripping at 2 000 A is:

$$\frac{I_{n\text{TRIP}}}{I_n} = \frac{2000 \text{ A}}{1000 \text{ A}} = 2$$

Figure 35: Example of parameter setting for PHIPTOC1 Start value in PCM600
Maximum current Start and protection setting values

If the ratio of the application nominal current $I_n$ and sensor-rated primary current $I_p$ becomes higher, and the rated secondary value needs to be set higher than 46.875 mV / Hz, the highest value that the relay can measure before the current sensor input is saturated is smaller than the maximum setting value of the current protection.

Table 4: Maximum current Start and protection setting values

<table>
<thead>
<tr>
<th>Application Nominal current ($I_n$)</th>
<th>Rated Secondary Value with 80 A / 0.150 V at 50 Hz</th>
<th>Maximum current Start and protection setting values</th>
</tr>
</thead>
<tbody>
<tr>
<td>... 1 250 A</td>
<td>1.000 ... 46.875 mV / Hz</td>
<td>40 x $I_n$</td>
</tr>
<tr>
<td>1 250 ... 2 500 A</td>
<td>46.875 ... 93.750 mV / Hz</td>
<td>20 x $I_n$</td>
</tr>
<tr>
<td>2 500 ... 4 000 A</td>
<td>93.750 ... 150.000 mV / Hz</td>
<td>12.5 x $I_n$</td>
</tr>
</tbody>
</table>

Priority

Each current sensor has unique physical polarity defined by sensor hardware.

Figure 36: Current sensor with unique physical polarity
Figure 37: Polarity setting for current sensors in incoming feeder

Sensor polarity is changed via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Current (3I, CT))

![Diagram showing polarity settings for current sensors](image)

**Reverse polarity (P2→P1)**
Reversed polarity: true

**Normal polarity (P1→P2)**
Reversed polarity: false

Figure 38: Example of polarity setting for current sensor in PCM600
3.1.2 Voltage sensors

Correction factors

The amplitude and phase error of a voltage sensor is, in practice, constant and independent on the primary voltage. This means it is an inherent and constant property of each sensor and it is not considered to be unpredictable and bound to influences. Hence, it can be easily rectified in the protection relay by using appropriate correction factors, specified separately for every sensor. Values of correction factors for the amplitude and phase error of a voltage sensor are entered on the sensor label and as well as in the sensor’s routine test report. To achieve the required accuracy classes, it is recommended to use both correction factors (Cfs), that is, the amplitude correction factor (aU) and the phase error correction factor (pU) of the voltage sensor.

Figure 39: Example of a voltage sensor label

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the protection relay. The correction factors are entered via parameter setting in PCM600 (IED Configuration / Configuration / Analog inputs / Voltage (3U, VT))

Figure 40: Example of setting the correction factors for the voltage sensors in PCM600

Amplitude correction factors of sensors also affect the scaling of SMV frames. Thus, it is enough to configure these correction factors in the sender only. On the other hand, phase error correction factors affect only the phasor of fundamental frequency and need to be set both in the SMV senders and the receivers.
Other parameters

The voltage sensor is based on the resistive divider principle. Therefore, the voltage is linear throughout the whole measuring range. The output signal is a voltage, directly proportional to the primary voltage. For the voltage sensor all parameters are readable directly from its rating plate and conversions are not needed.

In this example the system phase-to-phase voltage rating is 10 kV.

Figure 41: Single line diagram

*Primary voltage* parameter is set to 10 kV. For protection relays with sensor measurement support the *Voltage input type* is always set to “CVD sensor” and it cannot be changed. The same applies for the *VT connection* parameter which is always set to “WYE” type. The division ratio is 10 000: 1. Thus, the *Division ratio* parameter is set to “10 000”. The primary voltage is proportionally divided by this division ratio.

Figure 42: Example of setting values for Voltage sensor in PCM600
3.2 Documentation

Network overview diagram

The diagram provides an overview of the substation network (interconnections between the protection relay and Ethernet switch, network architectures, and device location – Panel No. …)

Figure 43: Example of a Network Overview Diagram

Logic diagrams for interconnection between panels

The GOOSE Logic diagrams show the principle of the application used and are project oriented.

Figure 44: Example of a logic diagram for interconnection between panels
**Sampled measured value diagram**

The diagram gives overview about measurement sharing when using the IEC 61850-9-2LE (Process Bus).

![Sampled measured value diagram](image)

Figure 45: Example of a Sampled measured value diagram
3.3 Station bus (GOOSE)

Protection and control relay manager (PCM600)

The protection relay configuration process is carried out via a protection relay configuration tool. The PCM600 provides versatile functionalities for the entire lifecycle of all Relion® protection and control relay applications, on all voltage levels. The IEC 61850 configuration tool of PCM600 makes it possible to view or engineer a data set and dataflow configuration for a vertical, GOOSE and SMV IEC 61850 communication. The IEC 61850 configuration tool is recommended to be used for simple applications.

- PCM600 v.2.5 or later / IEC 61850 Configuration / GOOSE Communication

Always use the latest version of PCM600 and the latest relevant connectivity package for protection relays.

Integrated Engineering Tool (IET600)

The IET600 is a System Configuration Tool which contains various modules to complete the system engineering of an IEC 61850 based substation, including:

- Configuration of the substation topology
- Configuration of the communication network
- Configuration of the IEC 61850 dataflow (Data sets, Control blocks)
- Engineering of typical bays for efficient engineering
- Import and export of IEC-61850-SCL data for exchange with other tools
- Export of project data for documentation

The IET600 tool is recommended for use in advanced applications. Always use the latest version of IET600 and the latest relevant connectivity package for protection relays.

Detailed information on the specific protection relay and its network configuration can be found in the Technical Manual or in the IEC 61850 Engineering Guide of dedicated protection relay.
Configuration procedure in PCM600

A maximum of allowed GOOSE control blocks, data sets and data attributes of the protection relay must not be exceeded. To minimize the message-handling load in receiving and sending protection relays, it is recommended to limit data attributes amount to 20 per data set.

Only three simple steps are needed to get GOOSE engineered in PCM600.

Step 1 / 3
Creating a GOOSE data set and its entries with the IEC 61850 Configuration tool

If quality data attributes are added to the data set, they must be located after the status value of the corresponding data object.

[Image: Creating a new GOOSE data set and its entries]

A maximum of 20 data attributes can be added to a single GOOSE data set. If a data set has quality attributes, the attributes must be located after the status value of the same data object.
Step 2 / 3

Configuring a GOOSE control block with the IEC 61850 Configuration tool

Figure 47: GOOSE control block properties

The data set defines what protection relay data is used in GOOSE service and sent to local Ethernet subnetwork in a GOOSE message. The GOOSE control block links the data set and its attributes to actual data.

GOOSE Control Block Attributes

- APPID – unique GoID in network
  - Reserved value is ranging from 0x0000 to 0x3FFF (Ed.1)
- MAC address
  - Unique Multicast address per GoCB is recommended
  - The allowed multicast address ranges from 01-0C-CD-01-00-00 to 01-0C-CD-01-01-FF
- GOOSE Control block name
- Data set definition
- VLAN ID
  - The default value is 0x000; it should be configured to > 0
  - Recommended values (as per IEC 61850-90-4) are ranging from 0x3E8 (1 000) to 0x5E7 (1 511)
- VLAN priority
  - The default value is 4 as per IEC 61850-8-1 (value range 0 …7)
- $T_{\text{min}}$ [ms]
  - Maximum response time to data change
- $T_{\text{max}}$ [ms]
  - Heartbeat cycle time in (the default value is 10 000 ms)
- ConfRev
  - Its value increases when referenced data set becomes modified
Step 3 / 3
Configuring GOOSE receivers with the IEC 61850 Configuration tool

Figure 48: GOOSE control block editor (1- receiver #1, 2- receiver #2, 3 – sender)

Configuration procedure in IET600

Step 1 / 6
After the common configuration items have been completed, the SCD file has been exported from PCM600 and the SCD file has been imported to IET600.

Step 2 / 6
In the Options dialog box in IET600, click Show IED Capabilities Tab.

Figure 49: Selecting Show IED Capabilities Tab
In the IED Capabilities tab, check the *Override for Client Service for Client Service Conf Dataset Modify* box to adjust the IED615 / IED620 option to support GOOSE dataset modification.

![Figure 50: Editing 615 series capabilities](image)

**Step 3 / 6**

Creating a GOOSE data set and its entries with the IET600

If quality data attributes are added to the data set, they must be located after the status value of the corresponding data object.

![Figure 51: Creating a new GOOSE data set and its entries](image)
Step 4 / 6
Configuring a GOOSE control block with the IET600

Figure 52: Naming a GOOSE control block

Step 5 / 6
Configuring GOOSE receivers with the IET600

Figure 53: GCB client

Step 6 / 6
Save and export the SCD file and import it to PCM600
Connecting GOOSE sender data to a protection relay application in PCM600

Step 1 / 3
Adding GOOSERCV function block with Application Configuration Tool. Give the GOOSERCV block application-specific user-defined names to distinguish between different blocks when making GOOSE connections in the Signal Matrix tool.

Step 2 / 3
Creating GOOSERCV block connection into the application

Step 3 / 3
Mapping of GOOSE sender data into the corresponding GOOSERCV function block in Signal Matrix
3.4  **Process bus (SMV)**

**Supported applications**

Power measurement, directional protections, voltage-based protections and synchro-check work when voltage is shared over the Process bus. 640 series support redundant SMV streams by using the voltage (VMSWI) and current (CMSWI) function blocks. Automatic switching to the backup SMV stream can be configured in Application Configuration using SMV quality and / or other logic.

**Figure 57**: Example of Process bus application of voltage sharing and synchro-check  

**Figure 58**: Example of Process bus application of voltage sharing redundancy and synchro check
Figure 59: Example of Process bus application of voltage sharing (Double busbar system) and synchro check

Figure 60: Example of Process bus application of voltage sharing redundancy (Double busbar system) and synchro check

Figure 61: Example of VMSWI voltage switch function block implementation in the Application Configuration Tool
SMV Engineering tools
- PCM600 v.2.6 or later / IEC 61850 Configuration / Process bus Communication
- IET600 v.5.2 or later

Always use the latest version of tools and the latest relevant connectivity package for protection relays.

Detailed information on the specific protection relay and its network configuration can be found in Technical Manual of dedicated protection relay or in the IEC 61850 Engineering Guide, ABB Oy, Distribution Automation.

Configuration procedure in PCM600

Only four simple steps are needed to get Process Bus engineered in PCM600.

Step 1 / 4

Activation of transmission of Sampled Measured Value needs to have the SMVSENDER function block added to the Application Configuration Tool (ACT) in a voltage sender protection relay. By adding the SMVSENDER function block new data set is automatically added to the protection relay configuration and a control block for SMV is created.

![Adding a SMSENDE](image)

Supervision of Sampled Measured Value receiving status needs to have the ULTTR1 function block added to the ACT in all voltage receiver protection relays.

![Adding a ULTTR1](image)
Step 2 / 4

Since the SMV needs to obtain accurate time synchronization, the synchronization method is to correspond to IEEE 1588, with the PTP priority to be set to correct values. Lower value means highest priority. Identical time synchronization method is to be used in all SMV sending and receiving protection relays.

Figure 64: Time parameter setting dialog in PCM600

IED Configuration / Configuration / Time / Parameter Setting / Synchronization

- Synch source = IEEE 1588
- PTP domain ID = 0, only clocks with the same domain are synchronized
- PTP priority 1 = 127...128, the clock with the lowest priority 1 becomes reference clock (Grandmaster)
- PTP priority 2 = 128...255, if all the relevant values for selecting the reference clock for multiple devices are the same, the clock with the lowest priority 2 is selected as the reference clock
- PTP announce mode: Power Profile

It is recommended to set Priority 1 and Priority 2 to be equal to 128 for all protection relays, except the voltage sender protection relays (Priority 1 = 127, Priority 2 = 128...255 to be different for each protection relay). Voltage sender protection relay provides the synchronization of network time in case Grandmaster clock is not available.
Step 3 / 4

The connection between SMV sender and receiver is handled using the IEC 61850 Configuration tool. Protection relay can receive voltage only from one another relay via IEC 61850-9-2LE.

Figure 65: Configuring the SMV senders and receivers
Step 4 / 4

Setting the Sampled Measured Value Control Block attributes

Figure 66: Changing the Sampled Measured Value Control Block attributes
Sampled Measured Value Control Block Attributes

- **App ID** – unique SvID in network
  - It shall always be **0x4000** based on 9-2LE
  - Reserved value range is from **0x4000** to **0x7FFF** (if no APPID is configured, the default value shall be 0x4000 based on IEC 61850-9-2)

- **MAC address**
  - Unique Multicast address per Control Block is recommended
  - The allowed multicast address range is from **01-0C-CD-04-00-00** to **01-0C-CD-04-01-FF**

- **VLAN ID**
  - The default value is 0x000, should be configured > 0
  - Recommended value range (as per IEC 61850-90-4) is from **0xBB8 (3 000)** to **0xDB7 (3 511)**

- **VLAN priority**
  - The default value is **4** as per IEC 61850-9-2 (value range 0 ... 7)

- **Config Revision**
  - It increases in case of modification of attributes
  - Recommended value is **1**

- **Data Set Definition**
- **Control block name (Sampled value ID)**

If configuration is updated in a manner that affects the **Config Revision** value of Sampled Measured Value Control Block, update all SMV sender and receiver protection relays using the PCM600 tool.

**Configuration procedure in IET600**

**Step 1 / 5**

After the common configuration items have been completed, the SCD file has been exported from PCM600 and the SCD file has been imported to IET600, the SMV sender and receiver connections can be handled using the IET600 tool.

**Step 2 / 5**

In the Options dialog box in IET600, click **Show IED Capabilities Tab**.

![Figure 67: Selecting Show IED Capabilities Tab](image)
In the IED Capabilities tab, check the *Override for Client Service SampledValues* box to adjust the IED615 / IED620 option to support sampled values services.

Figure 68: Editing 615 series capabilities

**Step 3 / 5**

Configuring sampled value control block in the IET600

Figure 69: Sampled value control block

**Step 4 / 5**

Connecting the SMV senders and receivers in the IET600

Figure 70: Connecting the SMV senders and receivers

**Step 5 / 5**

Save and export the SCD file and import it to PCM600
Application configuration of the SMV receiver

TVTR function blocks are used in receiver application to perform the supervision for the sampled values and to connect the received analog voltage inputs to the application. When SMVRCV is connected to the TVTR inputs, the connected TVTR does not physically measure its analog inputs if they are available in the protection relay. SMVRCV function block outputs need to be connected according to the SMV application requirements, typically all three analog phase voltages connected either to ULTVTR1 or alternatively only a single analog phase voltage UL1 connected to the ULTVTR2 input. RESTVTR1 input is typically connected only in case there is measured neutral voltage needed and then available from the sender.

Figure 71: Receiving all phase voltages and residual voltage using SMV

Synchrocheck function requires and uses only single analog phase voltage (UL1) connected to ULTVTR2.

Figure 72: Receiving line voltage for synchrocheck functionality using SMV
The ALARM output of UL1TVTR1 function block should be connected to ensure failsafe operation in all circumstances. The WARNING output is always internally active whenever the ALARM output is active. The WARNING in the receiver is activated if the synchronization accuracy of the sender or the receiver is less than 4 μs. The output is held on for 10 s after the synchronization accuracy returns within limits. The ALARM in the receiver is activated if the synchronization accuracy of the sender or the receiver is unknown, less than 100 ms or more than one consecutive frame is lost. The output is held on for 10 s after the synchronization accuracy returns within limits.

Figure 73: Application Configuration tool logic examples for the SMV fail save operation
SMV delay

The SMV Max Delay parameter, found via menu path Configuration / System, defines how long the receiver waits for the SMV frames before activating the ALARM output. This setting also delays the local measurements of the receiver to keep them correctly time aligned. The SMV Max Delay values include sampling, processing and network delay.

ALARM activates when two or more consecutive SMV frames are lost or late. A single loss of frame is corrected with a zero-order hold scheme, the effect on protection is considered negligible in this case and it does not activate the WARNING or ALARM outputs.

Table 5: Topology-dependent SMV max delay setting

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1 746</td>
<td>20</td>
<td>24</td>
<td>240</td>
<td>80</td>
<td>2 112</td>
<td>3 150</td>
</tr>
<tr>
<td>5</td>
<td>1 746</td>
<td>50</td>
<td>60</td>
<td>600</td>
<td>200</td>
<td>2 656</td>
<td>3 150</td>
</tr>
<tr>
<td>10</td>
<td>1 746</td>
<td>100</td>
<td>120</td>
<td>1 200</td>
<td>250</td>
<td>3 416</td>
<td>3 150</td>
</tr>
<tr>
<td>15</td>
<td>1 746</td>
<td>150</td>
<td>180</td>
<td>1 800</td>
<td>300</td>
<td>4 176</td>
<td>3 150</td>
</tr>
<tr>
<td>20</td>
<td>1 746</td>
<td>200</td>
<td>240</td>
<td>2 400</td>
<td>350</td>
<td>4 936</td>
<td>4 400</td>
</tr>
<tr>
<td>25</td>
<td>1 746</td>
<td>250</td>
<td>300</td>
<td>3 000</td>
<td>400</td>
<td>5 696</td>
<td>5 650</td>
</tr>
<tr>
<td>30</td>
<td>1 746</td>
<td>300</td>
<td>360</td>
<td>3 600</td>
<td>450</td>
<td>6 456</td>
<td>5 650</td>
</tr>
</tbody>
</table>

1) Queue latency calculated when the port has started to send a full-sized frame (1500 bytes) before the SMV frame and the switch has been configured to prioritize SMV

2) Additional tolerance in case of long wires or disturbance in network

Default max delay setting (3 150 µs) can be set for most of the communication topologies. Special attention must be focused on HSR topology when number of hops in network should be calculated for the worst situation (HSR ring is open).
3.5 **Ethernet**

3.5.1 **Requirements**

**Electro Magnetic Immunity (EMI)**

The IEC 61850-3 standard outlines the EMI immunity requirements for communication equipment installed in substations. EMI phenomena include inductive load switching, lightning strikes, electrostatic discharges from human contact, radio frequency interference due to personnel using portable radio handsets, ground potential rise resulting from high current fault conditions within the substation and a variety of other events commonly encountered in the substation.

**Environmental Robustness**

Both the IEC 61850-3 standard and the IEEE P1613 standard define the atmospheric environmental requirements for network communication devices such as the Ethernet switches in substations. Devices connected to the substation network must be specifically toughened for the substation environment.

**Real-Time Operation**

Modern managed Ethernet switches offer advanced Layer 2 and Layer 3 features that are critical for real-time control and substation automation. These include:

- IEEE 802.3x **Full-Duplex** operation on all ports, which ensures that no collisions occur and thereby makes Ethernet much more deterministic. There are absolutely zero collisions in connections that both support IEEE 802.3x Full-Duplex operation.

- IEEE 802.1p **Priority Queuing**, which allows frames to be tagged with different priority levels to ensure that real-time critical traffic always makes it through the network even during periods of high congestion.

- IEEE 802.1Q **VLAN** which allows the segregation and grouping of protection relays into virtual LANs to isolate real-time protection relays from data collection or less critical protection relays.

- IEEE 802.1w **Rapid Spanning Tree Protocol**, which allows the creation of fault tolerant ring network architectures that will reconfigure in milliseconds as opposed to tens of seconds, as was the case for the original Spanning Tree Protocol 802.1D.

It is important to note that the above features are based on standards, thereby ensuring interoperability amongst different vendors.
3.5.2 Technology

Metal cabling

Metal cabling consists of four twisted pairs terminated with RJ-45 (not ruggedized) connectors. The cabling should be shielded CAT6 S / FTP or better. In general, metal cabling is susceptible to electromagnetic interference, therefore should be only used inside the panels / switchgear.

Figure 75: FTP patch cable terminated with RJ-45 connectors

Fiber Optic

The ABB standard for fiber optic in substations is the multi-mode fiber cable 50 / 125 µm, 1 300 nm. Multi-mode communication links are generally the most common due to the low cost of fiber cabling and transceivers. When forming a multi-mode link, multi-mode transceivers must be used as well as multi-mode cabling. Multi-mode fiber cable 50 / 125 µm embodies a core size of 50 µm in diameter and a cladding size of 125 µm. 62.5 / 125 µm cabling is generally the most popular one. The name "Multi-mode" comes from the fact that the light used to transmit the data travels multiple paths within the core.

Patch cords

A patch cord or patch cable is an electrical or optical cable used to connect (“patch-in”) one device to another one for signal routing. The patch cord is terminated by connectors on both ends. Interconnections between protection relays and the Ethernet switch and between Ethernet switches inside the substation are made with the help of patch cables. Patch cables should be duplex; they have two fiber optics, one used for data transmission and the other for data reception.

Figure 76: Fiber optic patch cable terminated with LC connectors
**Fiber Optics Connector**

Relion® protection relays are equipped with Small Form Factor connectors, type LC. The innovative LC design offers a form factor one-half the size of current industry standards.

![Image of LC connectors](image)

Figure 77: LC connectors

**Ethernet rear connections of protection relays**

The Ethernet communication module is provided with either galvanic RJ-45 connection or optical multimode LC type connection, depending on the product variant and the selected communication interface option.

![Image of Ethernet connectors](image)

Figure 78: Communication module with single Ethernet connector (615 and 620 series)
Communication modules with multiple Ethernet connectors enable the forwarding of Ethernet traffic. These variants include an internal Ethernet switch that handles the Ethernet traffic. All Ethernet ports share this one common MAC table. Ethernet ports marked with LAN A and LAN B are used with redundant Ethernet protocols HSR and PRP. The third port without the LAN A or LAN B label is an interlink port which is used as a redundancy box connector with redundant Ethernet protocols.

Figure 79: Communication modules with multiple Ethernet connectors (615 and 620 series)

640 series modules allow the use of a secondary IP address. This secondary IP network is assigned to a single Ethernet port and can be used to make separate networks for different communication protocols or, for example, a service network for configuration purposes. Multicast communication, such as IEC 61850-9-2LE and GOOSE, is only supported on the Network 1 interface. The IP address for Network 2 is disabled by default settings, and all Ethernet ports are assigned to the same IP address used in Network 1. If Network 2 is taken into use, the interlink port X3 of the module is assigned to this second network and PTP time synchronization and SMV / GOOSE multicast are disabled for that port.

Figure 80: Communication modules with multiple Ethernet connectors (640 series)
Managed Ethernet switches

A switch is an Ethernet device that filters and forwards data packets between the LAN segments. The switches operate on the data link layer and occasionally the network layer. Packets that arrive on a port are analysed for errors and only forwarded onto the port that has a connection to the destination device.

The AFS family offers many features which are required in the utility environments, including fast protection schemes, redundant power supply and alarm contacts, and enables the step-wise introduction of Smart grid applications. Recommended types of managed Ethernet switches are shown in table below.

Table 6: Recommended Managed Ethernet switches overview for UniGear Digital

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturer</th>
<th>Assembly</th>
<th>Number of ports</th>
<th>HSR Redbox</th>
<th>PRP Redbox</th>
<th>RSTP</th>
<th>SNTP</th>
<th>PTPv2</th>
<th>Station bus</th>
<th>Process bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFS670</td>
<td>ABB</td>
<td>19'</td>
<td>up to 24</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AFS675</td>
<td>ABB</td>
<td>19'</td>
<td>up to 28</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AFS677</td>
<td>ABB</td>
<td>19'</td>
<td>16</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AFS660B</td>
<td>ABB</td>
<td>DIN Rail</td>
<td>8</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AFS665B</td>
<td>ABB</td>
<td>DIN Rail</td>
<td>10</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AFS660C</td>
<td>ABB</td>
<td>DIN Rail</td>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AFS660S</td>
<td>ABB</td>
<td>DIN Rail</td>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>AFS665S</td>
<td>ABB</td>
<td>DIN Rail</td>
<td>11</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RSG2100</td>
<td>Siemens</td>
<td>19'</td>
<td>up to 19</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>RST2228</td>
<td>Siemens</td>
<td>19'</td>
<td>Up to 28</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RSG2300</td>
<td>Siemens</td>
<td>19'</td>
<td>up to 32</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>RS900</td>
<td>Siemens</td>
<td>DIN Rail</td>
<td>up to 9</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>RS900G</td>
<td>Siemens</td>
<td>DIN Rail</td>
<td>10</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>RS950G</td>
<td>Siemens</td>
<td>DIN Rail</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Figure 81: Example of Managed Ethernet Switches from AFS family

Small form-factor pluggable (SFP) module / port

SFP modules allow users to select appropriate transceiver for each SFP port embedded in Ethernet switch to provide the required connection over the available optical fiber type (for example multi-mode fiber or single-mode fiber) or over metal twisted pair type. SFP modules are commonly available in several different categories: multi-mode fiber, single-mode fiber and twisted pair cabling. Fast Ethernet SFP modules are not applicable for the slots (ports) that support only Gigabit Ethernet and Gigabit Ethernet SFP modules are not applicable for the slots (ports) that support Fast Ethernet. Only use ABB SFP modules for AFS family.

Figure 82: 1 - Fast Ethernet fiber optic SFP module, 2 - Gigabit Ethernet fiber optic SFP module

Figure 83: Installed SFP module in managed Ethernet switch AFS677
**Satellite reference clock**

It synchronizes all connected devices using its reference time source. Optional accessories usually are antenna, antenna cable, antenna mount and lightning protection kit.

Recommended type of a compact substation clock, TTM 01-G manufactured by TEKRON, supports accurate GPS (USA) / GLONASS (Russian) clock with sub-microsecond timing that is used to synchronize protection relays. Key features are:

- Synchronization of IEEE 1588-2008 (PTPv2) compatible clients via IEEE C37.238-2011 Power Profile
- Synchronization of NTP and SNTP compatible clients
- 1x RJ-45 or 1x multi-mode fiber optic interface

Parallel Redundancy Protocol support for ultimate reliability is available in a fully customizable satellite reference clock NTS 03-G+ manufactured by TEKRON too.

Refer to [www.tekron.com](http://www.tekron.com) for additional information.

Figure 84: Example of satellite-controlled clock from Tekron with optional accessories
Other recommended type of substation clock is LANTIME M400 manufactured by Meinberg. It supports GPS / GLONASS clock and synchronization of IEEE 1588-2008 (PTPv2) compatible clients via IEEE C37.238-2011 Power Profile, two-step clock. Refer to www.meinberg.de for additional information.

Figure 85: Example of satellite-controlled clock from Meinberg

**Layout**

The communication devices are usually mounted inside the low voltage compartment of the panel. Therefore, the panels are ready for connection. The main benefits of this solution are:

- Cubicles are ready for connection
- Saving space in substation building
- Shorter communication links
- Cheaper solution

Protection relays are connected to the Ethernet network in compliance with the Network Overview Diagrams. It is recommended to wire communication link from Ethernet switch to protection relays and keep minimal allowed bend radius especially for fiber optic patch cords.

Figure 86: Low Voltage Compartment of UniGear panel
3.5.3 **Topologies**

**SINGLE network using Rapid Spanning Tree Protocol (RSTP) / Fast Media Redundancy Protocol (E-MRP)**

The single network topology is the most common one, protection relays are connected to managed Ethernet switch via single connection. The managed Ethernet switches form a physical loop (ring).

RSTP ring offer redundancy mechanism against link between switches failures, but not against protection relay link or switch failure. Rapid Spanning Tree protocol always blocks one path to avoid duplicates. Moreover, the RSTP ring cannot guarantee a zero or near-zero frame loss upon network failure occurrence. It is supported by AFS and RUGGEDCOM family.

![RSTP ring redundant structure](image)

**Figure 87: RSTP ring redundant structure**
Media Redundancy Protocol (MRP) is a ring redundancy protocol defined in IEC 62439-2 standard. One of the Ethernet switches in the ring acts as a Ring Manager. There is exactly one ring manager in the ring. With the help of the ring manager function, the two ends of a backbone in a line structure can be closed to a redundant ring. The Ring Manager keeps the redundant line open if the line structure is intact. If a segment fails, the ring manager immediately closes the redundant line, and line structure is intact again. E-MRP is fast MRP with decreased recovery time (Ring < 10 switches: < 10 ms recovery time, Ring < 100 switches: < 40 ms). It is supported by AFS family.

MRP provides shorter switching times than RSTP, it is limited to ring topology and it covers much bigger networks in comparison to RSTP. Coupling RSTP, MRP and E-MRP networks is possible.

![Figure 88: MRP / E-MRP ring redundant structure](image)

![Figure 89: Single network using RSTP / E-MRP](image)
Network Redundancy

IEC 61850 standard specifies network redundancy that improves the system availability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3 standard: **Parallel Redundancy Protocol** and **High Availability Seamless Redundancy protocol**. Both protocols can overcome failure of a link or switch with zero-switchover time. In both protocols, each node has two identical Ethernet ports for one network connection. They rely on the duplication of all transmitted information and provide zero-switchover time if links or switches fail, thus fulfilling all the stringent real-time requirements of substation automation. The choice between these two protocols depends on the application and the required functionality.

**Parallel Redundancy Protocol (PRP) networks using Rapid Spanning Tree Protocol (RSTP) / Fast Media Redundancy Protocol (E-MRP)**

In PRP, each node is attached to two independent networks operated in parallel. The networks are completely separated to ensure failure independence and can have different topologies. Both networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid failures. The PRP redundancy is supported by Relion® 615 (RED615 only via fiber optic interfaces), 620 and 640 series. SCADA system can be connected to PRP networks via Redbox or directly if PRP redundancy is supported by SCADA.

![PRP networks using RSTP / E-MRP](image)

Figure 90: PRP networks using RSTP / E-MRP
High Availability Seamless Redundancy (HSR) network

The HSR ring applies the PRP principle of parallel operation to a single ring. For each message sent, a node sends two frames, one over each port. Both frames circulate in opposite directions over the ring and every node forwards the frames it receives from one port to the other. When the originating node receives a frame it sent, it discards the frame to avoid loops.

HSR redundancy is supported by Relion® 615 (RED615 only via fiber optic interfaces), 620 and 640 series.

The maximum number of IEDs in the HSR ring is 30. It is not recommended to configure more than four SMV senders due to all information is sent into both directions in parallel.
Combined Parallel Redundancy Protocol (PRP) and High Availability Seamless Redundancy (HSR) networks

Combining PRP and HSR networks can be overcome some drawback of pure PRP or HSR network. PRP and HSR protocols have been developed to work interoperable, because HSR ring applies the PRP principle of parallel operation to a single ring. PRP networks and HSR rings are coupled through PRP / HSR redboxes. Two redboxes should be used per one ring to be redundant and have access to both PRP networks. If one Redbox fails, the seamless redundancy is still available through the other. The redboxes divide HSR ring in two parts of equal size minimizing the maximum number of hops.

Figure 93: Combined PRP and HSR networks
Comparison of network topologies

Comparison of network topologies is shown in table below.

Table 7: Comparison of network topologies

<table>
<thead>
<tr>
<th></th>
<th>SINGLE network + RSTP</th>
<th>PRP networks</th>
<th>HSR network</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARCHITECTURE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supported topologies</td>
<td>Any topology: tree, star, ring, mashed</td>
<td>Any topology: tree, star, ring, mashed</td>
<td>Limited: rings, rings of rings</td>
</tr>
<tr>
<td>Connecting single port protection relays</td>
<td>Yes</td>
<td>Yes, directly to one network</td>
<td>No, only via Redbox</td>
</tr>
<tr>
<td>Number of devices</td>
<td>No limitations, due to flexible topology</td>
<td>No limitations, due to flexible topology</td>
<td>Max 30 per ring</td>
</tr>
<tr>
<td>Network independent of protection relays</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>INTEROPERABILITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interoperability with non-redundant protection relays</td>
<td>Yes</td>
<td>Yes</td>
<td>No, only via Redbox</td>
</tr>
<tr>
<td>Compatible with standard Ethernet Components</td>
<td>Yes</td>
<td>Yes</td>
<td>No, HSR support is needed</td>
</tr>
<tr>
<td><strong>PERFORMANCE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery time</td>
<td>10…500 ms</td>
<td>0 ms</td>
<td>0 ms</td>
</tr>
<tr>
<td>Network bandwidth</td>
<td>Full bandwidth</td>
<td>Full bandwidth</td>
<td>Half bandwidth</td>
</tr>
<tr>
<td>Latency</td>
<td>No latency in protection relay</td>
<td>No latency in protection relay</td>
<td>Latency in each protection relay</td>
</tr>
<tr>
<td><strong>AVAILABILITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure of a switch / active network component</td>
<td>Connected protection relays are lost</td>
<td>No impact</td>
<td>One protection relay is lost</td>
</tr>
<tr>
<td>Failure of 2 or more protection relays</td>
<td>No impact to communication</td>
<td>No impact to communication</td>
<td>Communication between relays interruption</td>
</tr>
<tr>
<td></td>
<td>SINGLE network + RSTP</td>
<td>PRP networks</td>
<td>HSR network</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------</td>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Data loss</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**ECONOMICS**

<table>
<thead>
<tr>
<th></th>
<th>Medium, Ethernet switches</th>
<th>High, double amount of Ethernet switches, protection relay with more interfaces</th>
<th>Medium, Redbox, protection relay with more interfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication Links</td>
<td>Medium, links between protection relays and Ethernet switches</td>
<td>High, double links between protection relays and Ethernet switches</td>
<td>Low, only links between protection relays</td>
</tr>
<tr>
<td>Space requirements</td>
<td>Medium, Ethernet switches</td>
<td>High, Ethernet switches</td>
<td>Low, less devices</td>
</tr>
</tbody>
</table>

**ENGINEERING**

<table>
<thead>
<tr>
<th></th>
<th>Less</th>
<th>More</th>
<th>Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3.5.4 Ethernet traffic estimation**

- **MMS**: 0.01 Mb/s per a single protection relay
- **GOOSE**: 0.1 Mb/s in burst conditions per a single protection relay (2 data sets)
- **SMV**: 5 Mb/s per a source protection relay

Fast Ethernet = 100 Mb/s

The bandwidth of the HSR ring is half of the Fast Ethernet, because each message is sent in parallel into either direction.

For instance, estimated Ethernet traffic volume for a substation consisting of two sections (20x GOOSE sender, 2x SMV sender) is: 
\[20 \times 0.01 + 20 \times 0.1 + 2 \times 5 = 12.2 \text{ Mb/s}\]

Knowledge of data flows and traffic patterns allows for detecting bottlenecks and planning the network segmentation and segregation of traffic.
3.5.5 Naming convention to identify protection relays

The protection relay name must be unique within the planned network. A default name is applied if it is not specified by the client and it is based on the reference designation system of IEC 61346

- **Substation** 3 characters
- **Voltage Level** 1 character
  - B > 420kV
  - C < 380, 420> kV
  - D < 220, 380) kV
  - E < 110, 220) kV
  - F < 60, 110) kV
  - G < 45, 60) kV
  - H < 30, 45) kV
  - J < 20, 30) kV
  - K < 10, 20) kV
  - L < 6, 10) kV
  - M < 1, 6) kV
  - N < 1 kV
- **Voltage Level Index** 1 character
- **Bay** 3 characters, 1st char. = letter, 2nd-3rd char. = digits
- **Protection Relay** 2 characters

For example, SubstationVoltagelevelVoltagelevelindexBayProtectionRelay SUBJ1J01A1

3.5.6 IP address allocation

The IP address is a number that identifies a network device. Each device connected to a network must have a unique address. The default IP address range for a substation is: 172.16.X.X - 172.30.X.X. The IP addresses and IP masks are a specific feature of each device. In case of device failure, the replacement device receives the same IP address. The IP address should be structured in a way to reflect the physical plant layout according to IEC 61850-90-4.

- 172.NET.BAY.DEVICE

Subnet mask 255.255.0.0 (Class B)

- **NET**
  - 16 - 30 16 = the highest voltage level,
  - 17 = the second highest voltage level …

- **BAY**
  - 0 Station level (PC, ZEE600, Satellites reference clock …)
  - 1-169 Bays
  - 170 - 179 Virtual bays (substitution of actual devices by simulation or calculation)
  - 201 - 250 Station Level Ethernet Switches

- **DEVICE**
  - 0 Bay Level Ethernet Switch
  - 1- … Protection relays

Note: PRP redundancy +100
3.5.7 Time synchronization

Accurate time synchronization with precision requirements of sub one microsecond is essential for a proper functionality of process bus. Sampled measured values need to be synchronized between the sending and the receiving protection relays that perform protection or control functions. The 615, 620 and 640 series support the IEEE 1588 (PTPv2) protocol and Power Profile as defined in IEEE C37.238 to reach required timing accuracy over an Ethernet network. Using the Ethernet network to propagate the timing signals eliminates extra cabling requirements.
Using the Best Master Clock (BMC) algorithm devices in the network with the most accurate time are determined, which are to be used as a reference time source (Grandmaster). Subsequently the participating devices synchronize themselves with this reference time source.

The BMC algorithm run continuously to quickly adjust for changes in network configuration. IEEE 1588 networked protocol supports multiple master clock, which improves redundancy and reliability of substation time synchronization system.

**PTP clock types**

- Grandmaster clock is synchronized with an external source as satellites (satellites reference clocks)
- Ordinary clock can act as either a Master or a Slave clock (protection relay). In most network implementations the clocks remain in the Slave state and only become Master when the Grandmaster fails.
- Transparent clock corrects the time information before forwarding it without synchronizing itself (Managed Ethernet switch)

The PTP Clocks can be either one-step or two-step ones; their mixing should be avoided. Two-step clock sends Sync message (contains the approximate time) and follow-up message (contains more precise value of when Sync message left the clock). One-step clock does not send Follow-up message, instead the Sync message carries a precise time stamp. The One-step mode reduces network traffic and is preferable.

**System settings for the 3rd party devices**

To be capable of supporting the IEEE 1588-2008 (PTPv2) version of the standard

Preferably of 1588 type according to the Power profile, either via power profile parameters or by individually setting the parameters according to the Power Profile, with implementation in line with the one-step mode.

Table 8: C37.238 Power Profile key parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path delay</td>
<td>Peer to peer</td>
</tr>
<tr>
<td>VLAN</td>
<td>1 recommended</td>
</tr>
<tr>
<td>Ethertype</td>
<td>0x88f7</td>
</tr>
<tr>
<td>Announce period</td>
<td>1 s</td>
</tr>
<tr>
<td>Sync period</td>
<td>1 s</td>
</tr>
<tr>
<td>Pdelay period</td>
<td>1 s</td>
</tr>
</tbody>
</table>
Time synchronization schemes

Preferred schemes for HSR-PRP and PRP networks

The PRP redundancy protocol foresees that the grandmaster clock is doubly attached to both LANs. An ordinary clock therefore receives the Sync (Follow-Up) and Announce messages from each LAN independently. The ordinary clock treats each side as a different clock, but it does not apply the Best Master Clock algorithm since both have the same identity. Locating two grandmaster clocks, one in each LAN also possible, in that case the doubly attached ordinary clocks execute the Best Master Clock algorithm to select the clock they are synchronized to. However, singly attached nodes do not benefit from redundancy.

Figure 96: IEEE 1588 Time synchronization scheme for HSR-PRP networks

Figure 97: IEEE 1588 Time synchronization scheme for PRP networks
### 3.5.8 Traffic segregation

SMV messages causing high traffic should be filtered out so that they do not reach network devices which do not subscribe to SMV messages. This is done in managed Ethernet switch configuration which must be configured to perform the filtering operation. Traffic over Ethernet network is grouped into several virtual LANs.

- **VLAN ID = 1** (MMS, IEEE 1588, SNMP, …). It exists as default and its usage throughout LAN yields the same behaviour as if there were no VLANs (VLAN ID = 0)
- **VLAN ID = 1 000 – 1 511** (GOOSE messages). It is grouped based on substation, application, …
- **VLAN ID = 3 000 – 3 511** (SMV stream). It is grouped based on sender and associated receivers.

![Figure 98: Example of traffic segregation via building virtual LANs](image1)

![Figure 99: Virtual LANs allocation in PRP-RSTP networks](image2)
Figure 100: Virtual LANs allocation in HSR-PRP networks
3.5.9 Protection relays

Ethernet rear ports and redundancy settings

IED configuration / Configuration / Communication / Ethernet / Communication: 0

- IP address = IP number
- Subnet mask = Subnet mask
- Switch mode = HSR / PRP / Normal

![Communication parameter setting dialog](image)

Figure 101: Communication parameter setting dialog

Ethernet rear ports supervision

RCHLCCH or / and SCHLCCH are used for supervision. RCHLCCH block supervises redundant channels and SCHLCCH block supervises status of Ethernet ports.

RCHLCCH outputs signals

- CHLIV Status of redundant Ethernet channel LAN A. When redundant mode is set to HSR or PRP mode, value is True if the protection relay is receiving redundancy supervision frames. Otherwise value is False.
- REDCHLIV Status of redundant Ethernet channel LAN B. When redundant mode is set to HSR or PRP mode, value is True if the protection relay is receiving redundancy supervision frames. Otherwise value is False.
- LNKLIIV Link status of redundant port LAN A
- REDLNKLIV Link status of redundant port LAN B
SCHLCCH outputs signals

- **CH1LIV** Status of Ethernet channel X1 / LAN1. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- **LNK1LIV** Link status of Ethernet port X1 / LAN1
- **CH2LIV** Status of Ethernet channel X2 / LAN2. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- **LNK2LIV** Link status of Ethernet port X2 / LAN2
- **CH3LIV** Status of Ethernet channel X3 / LAN3. Value is **True** if the port is receiving Ethernet frames. Valid only when redundant mode is set to None or port is not one of the redundant ports (LAN A or LAN B)
- **LNK3LIV** Link status of Ethernet port X3 / LAN3

![Diagram showing SCHLCCH blocks in the Application Configuration Tool](image)

Figure 102: Adding RCHLCCH and SCHLCCH blocks in the Application Configuration Tool
Figure 103: Status of Ethernet rear port displayed via ITT SA Explorer (on top and on bottom)
3.5.10 Managed Ethernet switches

**AFS Family**

After connecting a notebook with the AFS Finder SW tool to any Switch Port except HSR dedicated ports, the following dialogue screen appears. AFS Finder automatically searches the network for those devices, which support the AFS finder protocol. The next dialogue, opened by double clicking on the respective switch in AFS finder, defines the IP address and netmask.

![AFS switch screen](image)

**Figure 104: AFS switch screen**

The user-friendly Web-based interface offers the possibility of operating the device from any location in the network via a standard browser such as Mozilla Firefox or Microsoft Internet Explorer. Being a universal access tool, the Web browser uses an applet which communicates with the device via the Simple Network Management Protocol (SNMP). The Web-based interface allows the device to be graphically configured and it uses Java. Java must be enabled in the security settings of the Web browser.

**Login**

Default User name to configure the AFS67x family is **admin** and the password is **admin**.

Default User name to configure the AFS66x family is **admin** and password is **abbadmin**.

![Login window](image)

**Figure 105: Login window**

**Notes on saving the Configuration profile**

- To copy changed settings to the volatile memory (RAM), click the Set button
- To refresh the display in the dialogs, click the Reload button
- To keep the changed settings even after restarting the device, click the Save button in **Basic Settings / Load / Save** dialog
3.5.10.1 Basic Settings <Mandatory>

Basic Setting / Network

Mode / Local = enabled
VLAN / ID = 1

Local
  - IP address = IP number
  - Netmask = Netmask

AFS Finder Protocol / Operation = ON

Figure 106: Network parameters dialog

Basic Setting / Port configuration

Port on = enabled

Automatic Configuration
  - Enabled, Gigabits ports and TX (RJ-45) ports to protection relay supporting auto negotiation function
  - Disabled, fiber optic ports

Manual Configuration = Fixed speed to protection relay should be set

Manual cable crossing = enabled on one ring port, when automatic configuration is disabled

Flow control = disabled

Figure 107: Port Configuration dialog
Basic Settings / Load / Save

The changes must be stored to Device in a permanent way. If a yellow triangle with the exclamation mark is seen, the configuration does not contain data entered permanently. After saving the configuration to the switch (Device) the yellow triangle symbol disappears.

Figure 108: Load / Save dialog
3.5.10.2  Time Settings <Mandatory>

**Time / PTP / Global**

PTPv2 must be configured in case SMV (IEC 61850-9-2LE) is used.

**Operation IEEE 1588 / PTP = ON**

**Configuration IEEE 1588 / PTP / PTP Version-Mode**

-  V2-transparent-clock; used only to correct and forward PTP messages. The device cannot become a PTPv2 master.

![Figure 109: PTP Global dialog](image)

**Time / PTP / Version 2(TC) / Global**

**Profile Presets / Profile = Power - Defaults**

**Operation IEEE 1588 / PTPv2 TC**

- Delay mechanism = P2P (Peer to Peer)
- Primary Domain = 0
- Network protocol = IEEE 802.3
- Syntonize = enabled to synchronize also local time
- Power TLV Check = enabled
- VLAN = 1

![Figure 110: PTP Version 2 (Transparent Clock) Global dialog](image)
Time / PTP / Version 2(TC) / Port

PTP Enable = enabled on all ports

Figure 111: PTP Version 2 (Transparent Clock) Port dialog
3.5.10.3 Switching Settings <Mandatory>

The traffic segregation is essential especially for process bus to reduce data traffic and to let it go only where needed (for example GOOSE, SMV shared between protection relays should be not sent to the control system; GOOSE, SMV should be sent only where required). Traffic filtering in managed Ethernet switches can be done via logical separation of the data traffic to several VLANs or via multicast MAC address filtering for ports.

**Switching / Global**

Global setting should be kept as default.

**Configuration**

- Activate Flow Control = disabled
- Address Learning = enabled; it is disabled only to observe data at all ports (disable direct packet distribution)
- Frame size = 1 522, 1 552 is intended for double VLAN tagging

![Switching Global dialog in AFS67x (on top) and AFS66x (on bottom)](image)

Figure 112: Switching Global dialog in AFS67x (on top) and AFS66x (on bottom)
**Switching / VLAN / Global**

Configuration

- VLAN 0 Transparent Mode / VLAN Unaware Mode = disabled
- GVRP active = disabled (enabled to synchronize VLAN information between Ethernet switches)

Learning / Mode / Independent VLAN = enabled

![VLAN Global dialog in AFS67x](image)

**Switching / VLAN / Static**

This item is used to configure outgoing packets (Egress filtering) from the switch. New VLAN ID Entries as per the protection relays engineering must be created.

VLAN ID

- GOOSE ranging from 1 000 to 1 511
- SMV ranging from 3 000 to 3 511

Name = for information purpose on the switch only

Untagged ports = U (The port transmits data without the VLAN tag), all ports in VLAN ID 1 except ring, PRP, HSR ports. It is possible to connect engineering tools, Internet Explorer or other features via this untagged VLAN

Tagged ports = T (The port transmits data with the VLAN tag), all ports in the VLAN IDs > 1 (ring, PRP, HSR, GOOSE and SMV receiver)

Default setting = - (The port is not member of the VLAN and does not transmit data packets of the VLAN)

![VLAN Static dialog](image)

Figure 113: VLAN Global dialog in AFS67x

Figure 114: VLAN Static dialog
Switching / VLAN / Port

Ingress Filtering = enabled on all ports. The port evaluates the received VLAN tags and transmits messages relevant to VLANs configured for this port; other messages are discarded.

GVRP = disabled on all ports, (VLANs are manually created and administered)

Figure 115: VLAN Port dialog
Redundancy Settings RSTP <Conditional>

Redundancy / Spanning Tree / Global

Operation = ON

Protocol version = RSTP

Protocol Configuration / Information

- Priority
  - 4 096 for Root (Master) Switch
  - 8 192 for Backup Root Switch
  - 32 768 for all Bay (Slave) Switches

- Hello Time = 2 s

- Forward Delay = 15 s

- Max Age = 20 s

- MRP Compatibility = disabled; enabled if MRP ring ID is used together with RSTP

Figure 116: Spanning Tree Global dialog

Redundancy / Spanning Tree / Port

STP active = enabled for all ports

AdminEdge Port = enabled for all ports except the ring ones

AutoEdge Port = enabled for all ports

Figure 117: Spanning Tree Ports dialog
3.5.10.5 Redundancy Settings E-MRP <Conditional>

E-MRP ring is supported only by AFS family. Spanning Tree Operation is off (Redundancy / Spanning Tree / Global / Operation) or STP protocol is disabled on all ports used for E-MRP (Redundancy / Spanning Tree / Port) before configuring the E-MRP.

**Redundancy / Ring Redundancy**

Version = E-MRP (not all switches support E-MRP; use same version for all switches)

Ring Port 1 & 2 = Ring Ports used for E-MRP

Ring Manager / Mode = enabled in one switch (Ring Manager)

Ring Manager / Mode = disabled in all ring switches except of switch (Ring Manager)

Operation = ON

VLAN / VLAN ID = 1

Switches / Number = the number of switches in the ring

---

Figure 118: E-MRP Ring Redundancy dialog
3.5.10.6 Redundancy Settings PRP and HSR < Conditional>

Supported by AFS66x. The PRP and HSR networks are always connected to AFS66x via ports 1/1 and 1/2, marked as port 1A and port 2B. Both ports support fiber optic connection (SFP slot) or twisted-pair connection (RJ-45 socket). PRP function replaces interfaces 1/1 and 1/2 with interface prp/1 and HSR function replaces interfaces 1/1 and 1/2 with interface hsr/1, that is why it is recommended to initialize configuration process of the Ethernet switch with redundancy settings if it is applicable.

![Figure 119: Example of AFS660 Front view](image)

Switching / Global

Configuration / VLAN Unaware mode = disabled (another name for the VLAN 0 transparent mode). When VLAN Unaware mode is enabled, the device transmits data packets to all learned ports without evaluating or changing the VLAN tagging in the data packet. The priority information remains unchanged.

![Figure 120: Switching Global dialog](image)
L2-Redundancy / PRP / Configuration

MRP and STP protocol cannot operate on the same ports as PRP

- STP protocol is disabled on ports used for PRP (Redundancy / Spanning Tree / Port (both tabs))
- PRP ports are different from MRP or MRP operation is completely disabled

Operation = ON

Ports A, B = ON, other devices not providing support to PRP are connected to other ports.

Figure 121: PRP Configuration dialog

L2-Redundancy / HSR / Configuration

MRP and STP protocol cannot operate on the same ports as HSR

- STP protocol is disabled on ports used for HSR (Redundancy / Spanning Tree / Port (both tabs))
- HSR ports are different from MRP or E-MRP operation is completely disabled

Operation = ON

Ports A, B = ON, other devices not providing support to HSR are connected to other ports.

HSR parameter

- HSR mode = modeu (host operates as a proxy for destination device, it forwards unicast traffic around the ring and forwards it to destination address, when the frames return to the source node it discards the unicast message) / modeh (host operates as a proxy for destination device, it removes unicast traffic from the ring and forwards it to destination address)
- Switching node Type = hsrredboxsan (to connect non HSR device to HSR ring) / hsrredboxrprpa (to connect HSR ring to PRP LAN A) / hsrredboxrprpb (to connect HSR ring to PRP LAN B)
- Redbox Identity = Id1a / Id1b, specifies the tags for PRP LAN traffic
3.5.10.7 Advanced Settings <Optional>

Advanced / Industrial Protocols / IEC61850-MMS

Operation = ON to make information related to the Ethernet switch available on the IEC 61850 network.

Figure 123: IEC61850-MMS Configuration dialog
3.5.11 Satellite controlled clock

3.5.11.1 Tekron

After connecting a notebook with the Tekron clock configuration tool software (available from www.tekron.com) to Ethernet port of Tekron device, the following dialogue screen appears. Tekron clock configuration tool automatically discover connected unit supposing (Discover button).

![Figure 124: Tekron clock configuration Tool](image)

Configuration procedure is initiated by Configure button after selecting of unit from the list. Default login is: User Name - admin, Password - Password. The procedure can be blocked by Windows firewall settings.

**Network / Basic Settings**

Advanced Options = enabled
IPv4
- Method / Static = enabled
- IP address = IP number
- Netmask = Netmask
- Gateway = IP number

VLAN
- Enable = enabled
- ID = 1
- Priority = 4
- Tagged traffic / PTP = enabled

Ethernet
- Link Settings = 100 Mb/s + Full duplex
Figure 125: Basic setting dialog

**Network / PTP Settings**

Enable = enabled

Operating mode = Two-Step

Profiles = C37.238

Grandmaster Priority #1 = 120 (128 default setting)

Figure 126: PTP setting dialog
Ethernet switch - Basic settings / Port configuration

Ethernet switch port, where TEKRON clock is connected, must have Automatic Configuration disabled and 100 Mbit/s FDX mode.

Figure 127: Port Configuration dialog

3.5.11.2 Meinberg

The LANTIME M400 timeserver can be configured via several user interfaces (for example local display, web interface).

Web interface

For first time installation enter IP address, netmask for Ethernet connection LAN0 of LANTIME via local HMI and then connect to the web interface by entering IP address of the LANTIME into the address field of a web browser. Default User name to configure device is *root* and password is *timeserver*.

PTP Settings

Figure 128: PTP setting dialog
PTP Setting / Interface 01 / Global

Select Profile = Power

Priority1 = 120 (128 default setting)

Other setting is default

Figure 129: PTP Global settings dialog
**PTP Setting / Interface 01 / Network**

Enable DHCP-Client = Static

TCP/IP Address = IP number

Netmask = Netmask

Gateway = IP number

Other setting is default

![Figure 130: PTP Network settings dialog](image)
3.6 **Statistical energy meters**

3.6.1 **ESM-ET statistical energy meter**

The statistical energy meter configuration process is carried out via EsConfigurator and ESM Test tools.

3.6.1.1 **EsConfigurator tool**

**Network**

- IP address = IP number
- Subnet mask = Netmask
- Default gateway = IP address

![Figure 131: Network configuration dialog](image)
Measurements / Transformation ratios and measurement units

current = 426.667
voltage = 346.620

Calculate automatically = enabled

Figure 132: Measurements configuration dialog
**Clock**

Synchronization

- Source = NTP

SNTP synchronization

- Server 1 = IP address

![Clock configuration dialog](image.png)

Figure 133: Clock configuration dialog
3.6.1.2 EST Test tool

Due to linear characteristics of the sensor measurement error caused by manufacturing tolerances can be compensated for by using correction factors entered in the statistical energy meter. The correction factors are entered via parameter setting in ESM Test tool.

**Service/ Production / Correction factor (ET and SV)**

- \( U = \) the correction factor for the amplitude of the voltage sensor \( (aU) \)
- \( I = \) the correction factor for the amplitude of the current sensor \( (aI) \)
- \( BU = \) the correction factor for the phase error of the voltage sensor \( (pU) \)
- \( BI = \) the correction factor for the phase error of the current sensor \( (pI) \)

![Figure 134: Example of setting the correction factors for the current and the voltage sensors in ESM Test tool](image)
Glossary

615 series
Relion® 615 series protection and control relays

620 series
Relion® 620 series protection and control relays

640 series
Relion® 640 series protection and control relays

ACT
Application Configuration Tool

AFS Family
ABB FOX Switch family for utility applications

APPID
Application Identifier in GOOSE and SMV messages

ASDU
Application Service Data Unit

BC
Boundary clock

BMC
Best Master Clock algorithm

Control Block
It defines HOW and WHEN data is sent to WHOM

CT
Current Transformer

Data set
It defines WHAT data is sent

EMI
Electro Magnetic Immunity

Ethernet
A standard for connecting a family of frame-based computer networking technologies into a LAN

E-MRP
Fast Media Redundancy Protocol with decreased recovery time

FDX
Full Duplex

FTP
Foiled Twisted pairs

GOOSE
Generic Object-Oriented Substation Event

GLONASS
Global Navigation Satellite System

GoID
GOOSE message identifier

GPS
Global Positioning System

GVRP
Generic VLAN Registration Protocol

HMI
Human Machine Interface

HSR
High Availability Seamless Redundancy

HW
Hardware

ID
Identifier

IGMP
Internet Group Management Protocol

IEC
International Electrotechnical Commission

IEC 61850
International standard for communication networks and systems for power utility automation

IEC 61850-8-1
Station bus (MMS + GOOSE)

IEC 61850-9-2
Process bus

IEC 61439
International standard for High availability automation networks

IED
Intelligent Electronic Device
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers. The IEEE standard groups defined the PTP and Power profile</td>
</tr>
<tr>
<td>IEEE 1588</td>
<td>Standard for Precision Clock Synchronization Protocol for Networked Measurement and Control Systems</td>
</tr>
<tr>
<td>IET600</td>
<td>Integrated Engineering Toolbox</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>ITT</td>
<td>Integrated Testing Toolbox for efficient testing and commissioning of IEC 61850 based Substation Automation Systems</td>
</tr>
<tr>
<td>I/O</td>
<td>Input / Output</td>
</tr>
<tr>
<td>I/U</td>
<td>Current / Voltage</td>
</tr>
<tr>
<td>KECA</td>
<td>Indoor Current Sensor</td>
</tr>
<tr>
<td>KEVA</td>
<td>Indoor Voltage Sensor</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>LC</td>
<td>Type of connector for glass fiber cable</td>
</tr>
<tr>
<td>LE</td>
<td>Light Edition (Lite Edition)</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabit per second</td>
</tr>
<tr>
<td>MMS</td>
<td>Manufacturing Message Specification</td>
</tr>
<tr>
<td>MRP</td>
<td>Media Redundancy Protocol (according IEC 62439)</td>
</tr>
<tr>
<td>MV</td>
<td>Medium voltage</td>
</tr>
<tr>
<td>NTP</td>
<td>Network Time Protocol</td>
</tr>
<tr>
<td>PC</td>
<td>Personal computer</td>
</tr>
<tr>
<td>PCM600</td>
<td>Protection and control relay Manager</td>
</tr>
<tr>
<td>PPS</td>
<td>Pulses per second</td>
</tr>
<tr>
<td>PRP</td>
<td>Parallel Redundancy Protocol</td>
</tr>
<tr>
<td>PTPv2</td>
<td>Precision Time Protocol Version 2</td>
</tr>
<tr>
<td>REF615</td>
<td>Feeder protection and control relay</td>
</tr>
<tr>
<td>REF620</td>
<td>Feeder protection and control relay</td>
</tr>
<tr>
<td>Redbox</td>
<td>Redundancy box connects non-PRP / non-HSR devices to high availability IEC 62439 networks</td>
</tr>
<tr>
<td>RED615</td>
<td>Line differential protection and control relay</td>
</tr>
<tr>
<td>REM615</td>
<td>Motor protection and control relay</td>
</tr>
<tr>
<td>REM620</td>
<td>Motor protection and control relay</td>
</tr>
<tr>
<td>REX640</td>
<td>Protection and control REX640</td>
</tr>
<tr>
<td>RJ-45</td>
<td>Galvanic connector type</td>
</tr>
<tr>
<td>RSTP</td>
<td>Rapid spanning tree protocol</td>
</tr>
<tr>
<td>SA</td>
<td>Substation Automation</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
</tr>
<tr>
<td>SCD</td>
<td>SCL file type (Substation Configuration Description)</td>
</tr>
<tr>
<td>SCL</td>
<td>XML-based substation description configuration language defined by IEC 61850</td>
</tr>
<tr>
<td>SFP</td>
<td>Small form-factor pluggable</td>
</tr>
<tr>
<td>SMV</td>
<td>Sampled Measured Value</td>
</tr>
<tr>
<td>SNMP</td>
<td>Simple Network Management</td>
</tr>
<tr>
<td>SNTP</td>
<td>Simple Network Time Protocol</td>
</tr>
<tr>
<td>SvID</td>
<td>Sampled value message identifier</td>
</tr>
<tr>
<td>TC</td>
<td>Transparent clock</td>
</tr>
<tr>
<td>TLV</td>
<td>Type Length Value</td>
</tr>
<tr>
<td>VLAN</td>
<td>Virtual LAN</td>
</tr>
<tr>
<td>VT</td>
<td>Voltage Transformer</td>
</tr>
<tr>
<td>ZEE600</td>
<td>ABB Ability Operations Data Management system Zenon</td>
</tr>
<tr>
<td>Rev.</td>
<td>Page</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>A</td>
<td>All</td>
</tr>
<tr>
<td>B</td>
<td>All</td>
</tr>
<tr>
<td>C</td>
<td>All</td>
</tr>
<tr>
<td>D</td>
<td>All</td>
</tr>
<tr>
<td>E</td>
<td>All</td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F</th>
<th>All</th>
<th>Statistical Energy meter ESM-ET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UniGear Digital (UniGear ZS1 Double busbar system up to 17.5 kV, UniGear ZS1 63 kA)</td>
</tr>
</tbody>
</table>
Visit us

www.abb.com/mediumvoltage