IEC TR 61850-90-12

Edition 2.0 2020-07

TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.200

ISBN 978-2-8322-8657-9

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 12
INTRODUCTION 14
1 Scope 16
2 Normative references 16
3 Terms, definitions, abbreviated terms, acronyms, and symbols 21
3.1 Terms and definitions 21
3.2 Abbreviated terms and acronyms 25
3.3 Network diagram symbols 34
4 Wide area communication in electrical utilities 36
4.1 Executive summary 36
4.2 Network and application example: ENDESA, Andalusia (Spain) 38
4.3 Typical interface between a substation and the WAN 40
4.4 WAN characteristics and actors 41
4.5 Smart Grid Architecture Model (SGAM) Mapping 42
4.6 Network elements and voltage level 44
4.7 WAN interfaces in substation automation (IEC 61850-5) 45
4.8 Logical interfaces and protocols in the architecture in IEC TR 62357-200 46
4.9 Network traffic and ownership 47
5 WAN metrics 48
5.1 Traffic types 48
5.2 Quality of Service (QoS) of TDM and PSN 48
5.3 Latency calculation 48
5.3.1 Latency components 48
5.3.2 Propagation delay 49
5.3.3 Residence delay 49
5.3.4 Latency accumulation 49
5.3.5 Example: latency of a microwave system 49
5.3.6 Latency and determinism 50
5.3.7 Latency classes in IEC 61850-5 50
5.4 Jitter 52
5.4.1 Jitter definition 52
5.4.2 Jitter classes in IEC 61850 53
5.5 Latency symmetry and path congruency 53
5.6 Medium asymmetry 53
5.7 Communication speed symmetry 54
5.8 Recovery delay 54
5.9 Time accuracy 54
5.9.1 Time accuracy definition 54
5.9.2 Time accuracy classes 55
5.10 Tolerance against failures 56
5.10.1 Failure 56
5.10.2 Reliability 57
5.10.3 Redundancy principles 57
5.10.4 Redundancy and reliability 58
5.10.5 Redundancy checking 59
5.10.6 Redundant layout: single point of failure 59

5.10.7 Redundant layout: cross-redundancy 60
5.10.8 Maintainability 61
5.10.9 Availability 61
5.10.10 Integrity 63
5.10.11 Dependability 64
5.10.12 Example: Dependability of GOOSE transmission 64
6 Use cases and WAN communication requirements 65
6.1 List of generic use cases 65
6.2 Teleprotection (IF2 & IF11) 66
6.2.1 Teleprotection schemes 66
6.2.2 Teleprotection data kinds 66
6.2.3 Current differential teleprotection for multi-terminal transmission line 66
6.2.4 Teleprotection communication requirements 67
6.3 Wide area monitoring system (IF13) 69
6.3.1 WAMS overview 69
6.3.2 WAMS topology 70
6.3.3 WAMS communication requirements 72
6.4 Wide area monitoring, protection, and control (WAMPAC) IF13 74
6.4.1 Functional description 74
6.4.2 WAMPAC communication requirements 76
6.5 Fault Location 76
6.5.1 Functional description 76
6.5.2 Fault location communication requirements 78
6.6 Distribution Automation 78
6.6.1 Functional description 78
6.6.2 Distribution automation communication requirements 79
6.7 Condition monitoring and diagnostics (CMD) and asset management (IF7) 80
6.7.1 Functional description 80
6.7.2 CMD communication requirements 80
6.8 Telecontrol (SCADA) 81
6.8.1 Functional description 81
6.8.2 Telecontrol communication requirements 81
6.9 Control centre to control centre (IF12) 82
6.9.1 Functional description 82
6.9.2 Inter control centre communication requirements 83
6.10 Smart metering / advanced metering infrastructure 84
6.10.1 Functional description 84
6.10.2 Smart metering communication requirements 84
6.11 WAN communication requirements summary 85
7 Wide-area and real-time network technologies 86
7.1 General 86
7.2 Topology 86
7.3 Overview 87
7.4 Layer 1 (physical) transmission media 89
7.4.1 Summary 89
7.4.2 Installation guidelines 89
7.4.3 Metallic lines 89
7.4.4 Power line carrier (PLC) 91
7.4.5 Radio transmission 101

7.4.6 Fibre optics 112
7.4.7 Layer 1 redundancy 118
7.4.8 Application example: diverse redundancy against extreme contingencies (Hydro-Quebec) 119
7.4.9 Layer 1 security 120
7.5 Layer 1,5 (physical) multiplexing 120
7.6 Layer 2 (link) technologies 121
7.6.1 Telephony technologies 121
7.6.2 SDH/SONET 123
7.6.3 Optical Transport Network 133
7.6.4 Ethernet 135
7.6.5 Ethernet over TDM 144
7.6.6 Carrier Ethernet 146
7.6.7 Audio-video bridging 147
7.6.8 Provider Backbone Bridge (PBB) 147
7.6.9 Multiprotocol Label Switching (MPLS) 149
7.7 Layer 3 (network) technologies 157
7.7.1 Internet Protocol (IP) 157
7.7.2 IP QoS 167
7.7.3 IP multicast 170
7.7.4 IP redundancy 171
7.7.5 IP security 171
7.7.6 IP communication for utilities 173
7.7.7 IP summary 175
7.8 Layer 4 (transport) protocols 176
7.8.1 Transport layer encapsulation 176
7.8.2 UDP 176
7.8.3 TCP 177
7.8.4 Layer 4 redundancy 178
7.8.5 Layer 4 security 178
7.9 Layer 5 (session) and higher 178
7.9.1 Session layer 178
7.9.2 Routable GOOSE and SMV 179
7.9.3 Example: C37.118 transmission 179
7.9.4 Session protocol for voice and video transmission 180
7.9.5 Application interface redundancy 180
7.9.6 Application device redundancy 181
7.10 Protocol overlay – tunnelling 181
7.10.1 Definitions 181
7.10.2 Tunnelling principle 182
7.10.3 Tunnelling Layer 2 over Layer 3 182
7.10.4 Application Example: Tunnelling GOOSE and SMV in IEC 61850 183
7.11 Virtual private networks (VPNs) 184
7.11.1 VPN principles 184
7.11.2 L2VPNs 184
7.11.3 L2VPN multicast on MPLS 186
7.11.4 L3VPN 186
7.11.5 VPN mapping to application 188
7.12 Cyber security 192

7.12.1 Security circles 192
7.12.2 Network security 193
7.12.3 Access control 195
7.12.4 Threat detection and mitigation 195
7.12.5 Security architecture 199
7.12.6 Application (end-to-end) communication security 200
7.12.7 Security for synchrophasor (PMU) networks (IEC TR 61850-90-5) 201
7.12.8 Additional recommendations 202
7.13 QoS and application-specific engineering 202
7.13.1 General 202
7.13.2 SDH/SONET QoS and SLA 202
7.13.3 PSN QoS and SLA 202
7.13.4 Application and priority 203
7.13.5 QoS chain between networks 203
7.13.6 QoS mapping between networks 204
7.13.7 QoS engineering 205
7.13.8 Customer restrictions 206
7.13.9 Clock services 206
7.14 Configuration and OAM 206
7.14.1 Network configuration 206
7.14.2 OAM 206
7.15 Time synchronization 208
7.15.1 Oscillator stability 208
7.15.2 Mutual synchronization 209
7.15.3 Direct synchronization 209
7.15.4 Radio synchronization 210
7.15.5 GNSS synchronization 210
7.15.6 Frequency distribution 210
7.15.7 Time distribution 212
7.15.8 PTP telecommunication profiles 218
7.15.9 PTP over MPLS 219
7.15.10 Comparison of time distribution profiles based on IEC 61588 219
7.15.11 Application example: synchrophasor time synchronization 220
7.15.12 Application example: Atomic clock hierarchy 221
8 Technology mapping to applications 222
8.1 Overview 222
8.2 Current differential teleprotection for multi-terminal transmission lines 222
8.2.1 General 222
8.2.2 Deterministic fibre-optic PDH loop network 223
8.2.3 Dedicated Gigabit Ethernet network 223
8.2.4 Carrier Ethernet with wide-area time synchronization 224
8.2.5 MPLS based wide area network 225
8.3 Wide area monitoring, protection, and control (WAMPAC) 227
8.3.1 General 227
8.3.2 Wide area stabilizing control using legacy network 227
8.3.3 PMU-based WAMPAC using time-synchronized Layer 2 and Layer 3 network 229
8.4 Fault location 231
8.5 SCADA and facility maintenance 232

8.6 Distribution automation 234
8.7 Smart metering 234
9 Network migration 237
9.1 TDM to packet switched network 237
9.1.1 General 237
9.1.2 Overview 237
9.1.3 Drivers for network migration 237
9.1.4 Considerations for network migration 238
9.1.5 Migration concepts 240
9.1.6 Implementation details 246
9.2 From IPv4 to IPv6 250
9.2.1 IPv4 to IPv6 evolution 250
9.2.2 IPv4 to IPv6 migration 250
9.2.3 IEC 61850 stack with IPv4 and IPv6 251
Annex A (informative) Future promising or upcoming technologies 252
A.1 5G 252
A.1.1 General 252
A.1.2 Different performance requirements 253
A.2 Deterministic networking technologies 256
Bibliography 257

Figure 1 – Symbols 35
Figure 2 – Substation locations in Andalusia 38
Figure 3 – Topology of the Andalusia network 39
Figure 4 – Cabinet of a substation edge node 40
Figure 5 – Communication interfaces in a SEN 41
Figure 6 – Communicating entities 42
Figure 7 – SGAM communication model 43
Figure 8 – Principle of grid voltage level and network technology 44
Figure 9 – Communication paths and interfaces 45
Figure 10 – IEC TR 62357 Interfaces, protocols, and applications 46
Figure 11 – Composition of end-to-end latency in a microwave relay 49
Figure 12 – Example of latency in function of traffic 50
Figure 13 – Jitter for two communication delay types 52
Figure 14 – Precision and accuracy definitions 55
Figure 15 – Redundancy of redundant systems 58
Figure 16 – Redundancy calculation 59
Figure 17 – Redundancy layout with single point of failure 59
Figure 18 – Redundancy layout with cross-coupling 60
Figure 19 – Availability definitions 61
Figure 20 – Residual error rate as a function of BER 63
Figure 21 – Network configurations for multi-terminal line protection 67
Figure 22 – Principle of synchrophasor transmission 71
Figure 23 – PMUs and data flow between TSO and regional data hubs 72
Figure 24 – Target phenomena for WAMPAC 74

Figure 25 – Example of main function and general information flow 75
Figure 26 – Network configuration for a fault locator system 77
Figure 27 – System configuration for distribution automation 79
Figure 28 – Network configurations for CMD and asset management 80
Figure 29 – Logical network configuration for telecontrol (SCADA) 81
Figure 30 – Network configurations for inter-control centre 83
Figure 31 – System configuration for smart metering 84
Figure 32 – Network ring topology example 87
Figure 33 – Narrowband channel plans for LV PLC Europe vs. North America 93
Figure 34 – HF allocated frequency spectrum plans for LV BPL 93
Figure 35 – Narrowband spectrum usage vs. standards and regulation areas [57] 94
Figure 36 – HV PLC link building blocks 96
Figure 37 – Phase-to-ground coupling for PLC 97
Figure 38 – HV PLC coupling with suspended line traps 97
Figure 39 – Phase-to-phase signal coupling for PLC 98
Figure 40 – Phase-to-phase signal coupling 98
Figure 41 – Power line carrier, line traps 99
Figure 42 – Terrestrial microwave link 102
Figure 43 – Layer 2 transport on microwave radio systems 103
Figure 44 – DMR (Digital Mobile Radio) 106
Figure 45 – LoRaWAN™ Protocol Stack 108
Figure 46 – ADSS fibre cable 113
Figure 47 – ADSS installation with splicing box 113
Figure 48 – OPGW in ground cable 114
Figure 49 – OPGW with two "C"-tubes each with 32 fibers 114
Figure 50 – OPGW fibers 115
Figure 51 – Splicing box 116
Figure 52 – WDM over one fibre 117
Figure 53 – OCh optical components 117
Figure 54 – Optical link with microwave back-up 119
Figure 55 – Photograph of a partially destroyed 735 kV line 120
Figure 56 – E1 and E2 channels 122
Figure 57 – Digital transmission hierarchy (T-standards) 122
Figure 58 – Digital transmission hierarchy (E-standard) 123
Figure 59 – Example of an SDH network for utilities 124
Figure 60– SONET multiplexing hierarchy 125
Figure 61 – SDH multiplexing hierarchy 125
Figure 62 – SDH/SONET with point-to-point topology 127
Figure 63 – SDH/SONET with linear topology 127
Figure 64 – BLSR/BSHR topology in normal conditions (from A to D) 129
Figure 65 – BLSR/BSHR topology in failure conditions 129
Figure 66 – SNCP/UPSR topology in normal conditions 130
Figure 67 – SNCP/UPSR topology in failure conditions 131

Figure 68 – Example of information flow relationship in OTN 134
Figure 69 – IEEE 802.3 (Ethernet) frame format 135
Figure 70 – IEEE 802.3 (Ethernet) topology with RSTP switches 136
Figure 71 – IEEE 802.1Q-tagged Ethernet frame format 137
Figure 72 – Direct Ethernet with VLAN in substation-to-substation transmission 138
Figure 73 – Substation-to-substation Layer 2 transmission tunnelled over IP 139
Figure 74 – PRP structure (within and outside a substation) 140
Figure 75 – HSR ring connecting substations and control centre 141
Figure 76 – MACsec frame format 142
Figure 77 – IEEE 802.1X principle 143
Figure 78 – Ethernet for substation-to-substation communication 144
Figure 79 – Packets over TDM 145
Figure 80 – IEEE 802.1Q/ad/ah network configuration 148
Figure 81 – Basic MPLS architecture 150
Figure 82 – Example of MPLS frame format with IPv4 payload 150
Figure 83 – MPLS building blocks 151
Figure 84 – MPLS network architecture for utilities 153
Figure 85 – IP/MPLS and MPLS-TP features 154
Figure 86 – MPLS-TP redundant routing 156
Figure 87 – Ethernet frame with IP network header 157
Figure 88 – Mapping of IPv4 to Ethernet frames 158
Figure 89 – Mapping of IPv6 to Ethernet frames 161
Figure 90 – IPv6 unicast address structure 162
Figure 91 – IPv6 ULA address structure 163
Figure 92 – IPv6 link local address structure 163
Figure 93 – Mapping of IPv4 to IPv6 addresses 166
Figure 94 – DiffServ codepoint field 169
Figure 95 – Unidirectional protocol independent multicast 170
Figure 96 – Bidirectional protocol independent multicast 171
Figure 97 – Frame format for IPsec (authenticated) 172
Figure 98 – Frame format for IPsec (encrypted) 172
Figure 99 – Layer 3 direct connection within same address space 173
Figure 100 – Connecting substations to SCADA by a NAT 174
Figure 101 – Substation to SCADA connection over ALG 175
Figure 102 – Ethernet frame with UDP transport layer 176
Figure 103 – UDP header 177
Figure 104 – TCP header 177
Figure 105 – Session and presentation layers for MMS 179
Figure 106 – Session and presentation layers for R-GOOSE 179
Figure 107 – IEEE C37.118 frame over UDP 180
Figure 108 – Redundant network transmission handled by the application layer 180
Figure 109 – Tunnelling in IEC TR 61850-90-1 182
Figure 110 – L2TP transporting Layer 2 frames over IP 183

Figure 111 – Tunneling SMV over IP in IEC TR 61850-90-5 184
Figure 112 – L2VPNs VPWS and VPLS 185
Figure 113 – L3VPN 186
Figure 114 – Emulation of L3VPN by L2VPN and global router 188
Figure 115 – Tele-protection over VPWS 190
Figure 116 – WAMS over VPLS 190
Figure 117 – VPN for IP-based SCADA/EMS traffic 191
Figure 118 – VPN deployment options 194
Figure 119 – IP network separator 196
Figure 120 – Security architecture (using segmentation and perimeter security) 200
Figure 121 – QoS chain 204
Figure 122 – Timing pulse transmission methods of legacy teleprotection devices 209
Figure 123 – SyncE application 211
Figure 124 – Synchronous Ethernet architecture 211
Figure 125 – SNTP clock synchronization and network delay measurement 213
Figure 126 – Model of GMC, two BCs in series and SC over Layer 3 216
Figure 127 – Timing diagram of PTP (end-to-end, 2-step, TC and BC) 216
Figure 128 – Timing diagram of PTP (peer-to-peer, 2-step TCs) 217
Figure 129 – Substations synchronization over WAN 221
Figure 130 – Example of synchronization network 222
Figure 131 – Distributed loop configuration for HV multi-terminal line protection 223
Figure 132 – Current differential teleprotection for HV multi-terminal transmission line using Layer 2 network 224
Figure 133 – Configuration of wide area current differential primary and backup teleprotection system employing Carrier Ethernet and IEC 61588 time synchronization 225
Figure 134 – Current differential protection communication via MPLS network 226
Figure 135 – System configuration for wide area stabilizing control system 228
Figure 136 – Appearance of typical CCE cubicle 228
Figure 138 – IEEE 802.1Q/ad utility network 232
Figure 139 – Mixed SDH/MPLS network for SCADA and facility maintenance services 233
Figure 140 – Wired technology solutions for distribution automation 234
Figure 141 – Wireless technology solutions for distribution automation (Radio network in feeder automation) 234
Figure 142 – Multi-hop wireless system 235
Figure 143 – NB-PLC system 235
Figure 144 – Cellular services used for a low-density residential area 235
Figure 145 – WAN communication protocols for smart metering 236
Figure 146 – Migration path from TDM to Packet in the Power Utility Operational Network 243
Figure 147 – Ethernet or MPLS beside SDH over separate fibre or wavelength 244
Figure 148 – Ethernet or MPLS-TP and SDH in a Hybrid platform 244
Figure 149 – Pseudo-wire principle 247
Figure 150 – Non-IP voice communication over PSN 248
Figure 151 – Circuit emulation over PSN 249

Figure 152 – IPv6 evolution 250
Figure 153 – IEC 61850 stack with IPv4 and IPv6 (doubly attached) 251
Figure A.1 – Software network technologies in 5G overall architecture 253
Figure A.2 – 5G Conceptual Diagram – NGMN 254
Figure A.3 – NB-IOT deployment models 255

Table 1 – Latency classes in IEC 61850-5 51
Table 2 – Latency classes in IEC TR 61850-90-1 51
Table 3 – Latency classes for WANs 52
Table 4 – Jitter classes in IEC TR 61850-90-1 53
Table 5 – Jitter classes for WAN 53
Table 6 – Recovery delay classes for WAN 54
Table 7 – IEC TR 61850-90-1 time accuracy classes 55
Table 8 – IEC 61850-5 time accuracy classes for IED synchronization 56
Table 9 – WAN time synchronization classes 56
Table 10 – Latency for line protection 68
Table 11 – Summary of operational requirements of line protection 68
Table 12 – Summary of communication requirements for teleprotection 69
Table 13 – Summary of synchrophasor requirements 73
Table 14 – Summary of communication requirements for wide area monitoring 74
Table 15 – Typical communication requirements for WAMPAC 76
Table 16 – Requirements for fault location 78
Table 17 – Requirements for distribution automation communication 79
Table 18 – Communication requirements for CMD 80
Table 19 – Communication requirements for CC to SS/PS 82
Table 20 – Latency and timing requirements from IEC TR 61850-90-2 82
Table 21 – Communication requirements for inter-control centre communications 83
Table 22 – Requirements for smart metering communication 84
Table 23 – Classification of communication requirements 85
Table 24 – Communication requirements of wide-area applications 86
Table 25 – Communication technologies 88
Table 26 – Physical communication media 89
Table 27 – DSL communication over twisted pairs 90
Table 28 – Trade-offs in copper cable communication 90
Table 29 – Power Line Telecommunication advantages and disadvantages 91
Table 30 – HF spectrum allocated for HV/MV PLC systems 92
Table 31 – HF spectrum used for narrowband LV PLC and associated standards 92
Table 32 – Characteristics of common NB-PLC standards 95
Table 33 – HV/MV APLC/DPLC/BPL technology performance 101
Table 34 – Microwave link performance 103
Table 35 – Terrestrial microwave advantages and disadvantages 104
Table 36 – Terrestrial mobile radio technologies 104
Table 37 – Terrestrial radio advantages and disadvantages 105

Table 38 – DMR advantages and disadvantages 106
Table 39 – Satellite radio advantages and disadvantages 107
Table 40 – LPWAN technology capabilities 110
Table 41 – Wireless technologies used for customer-side communications in Japan 111
Table 42 – Optical fibres: advantages and disadvantages 118
Table 43 – SONET and SDH hierarchies 126
Table 44 – Summary of SDH/SONET 133
Table 45 – Ethernet physical layers 135
Table 46 – Payload mapping using SDH/SONET and Next Generation SDH/SONET 145
Table 47 – Carrier Ethernet summary 147
Table 48 – IP/MPLS characteristics 154
Table 49 – MPLS-TP characteristics 155
Table 50 – MPLS summary 156
Table 51 – Differences between IPv4 and IPv6 164
Table 52 – IPv6 vs IPv4 addresses (RFC 4291) 165
Table 53 – List of DiffServ codepoint field values 169
Table 54 – IP Summary 175
Table 55 – VPN services 189
Table 56 – IEC 62351 series 201
Table 57 – Example of simple application priority assignment 203
Table 58 – Typical oscillator stability 208
Table 59 – IEC 61588 option comparison 217
Table 60 – Precision time distribution protocols based on IEC 61588 219
Table 61 – Main system specifications for wide area stabilizing control system 229
Table 62 – Main system specifications for PMU-based WAMPAC system 231
Table 63 – Requirements for the YONDEN IP network 233
Table 64 – Technologies for the YONDEN IP network 233
Table 65 – Pseudowire protocols 250
Table A.1 – 3GPP machine type communications 255

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-12: Wide area network engineering guidelines

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 61850-90-12, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) extension of use case with respect to distribution and customer-side applications;
b) extensions of wireless access technologies as well as power line communication ones applicable to the above-mentioned use case;

c) revisions regarding radio communication technology performance;

d) extension of network migration with respect to packet switched network;

e) a new mapping of multiprotocol label switching technology to teleprotection.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/2136/DTR	57/2203/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61850 series, published under the general title *Communication networks and systems for power utility automation*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "https://www.webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Utilities use data networks to interconnect equipment between their premises, over distances from under a kilometre to thousands of kilometres, called a "Wide Area Network" or WAN.

WANs encompass communication means of different natures (optical, radio, power line carrier, copper, etc.), with a variety of topologies (rings, trees, meshes, etc.), using different protocols (SDH/SONET, Ethernet, IP, MPLS, etc.), medium sharing (packet switching, time division multiplex, etc.) and for different applications (teleprotection, SCADA, voice, video, etc.).

This contrasts with substation automation networks as described in the LAN Engineering Guidelines (IEC TR 61850-90-4), which are based on one technology (switched Ethernet), make extensive use of Layer 2 multicast (GOOSE, SMV, PTP, etc.) and use Layer 3 communication (MMS, FTP, etc.), typically without routers within the substation.

The IEC 61850 series sets up numerous requirements on the network but does not state how to achieve them:

- IEC 61850-5 specifies the basic requirements for data networks used in Power Utility Automation networks;
- IEC 61850-7 focuses on data modelling, leaving out physical interconnection details;
- IEC 61850-8-1 and IEC 61850-9-2 specify interoperable communication within substations;
- IEC TR 61850-90-1 describes substation-to-substation traffic, specifies the requirements for communication, defines object models for substation-to-substation teleprotection, models the gateway and the tunneller, but leaves the WAN undefined;
- IEC TR 61850-90-2[1] provides substation to control centre network configuration for IEDs, proxies and applications;
- IEC TR 61850-90-5 (synchrophasor transmission) addresses the transport of synchrophasor data between PMUs and control centres and defines a tunnelling protocol as well as a data security method;
- IEC TR 61850-90-4 provides guidelines for network engineering focused on Ethernet-based real-time and highly available networks in substations. Some of these guidelines are applicable to networks outside of the substation;
- IEC 61870-6 (TASE2), IEC 61968 and IEC 61970 (CIM) describe the information interchange at the application layer without specifying the network.

Each of these documents deals separately with application, transport, or network layer mechanism. There exist no comprehensive engineering guides for wide-area and real-time networks for control and protection. The growing success of IEC 61850 calls for guidelines for engineering the WANs.

IEC TR 61850-90-4 provides guidelines for engineering of IEC 61850-based, local-area substation networks. In contrast, this Technical Report proposes guidelines for wide-area and real-time networks for various IEC 61850-based applications including teleprotection, wide area measurement, protection, and control (WAMPAC), power system monitoring (WASA, WAMS), operation SCADA, and condition monitoring and diagnosis (CMD) and non-operational traffic.

This document is based on existing standards for semantics, services, protocols, system configuration language and architecture. It is based on work done by various IEC working groups including:

- Power system IED communication and associated data models;

---

[1] In preparation. Stage at the time of publication: IEC TR/PWI 61850-90-2:2019.

- Energy management system application program interface;
- Data and communications security;
- Interoperability within TC 57 in the long term;
- Industrial networks;
- Highly Available Automation Networks.

Contributions were included from:

- IEEE 802.1 WG (Higher layer LAN protocols);
- IEEE 1588 WG (Precise Networked Clock Synchronization);
- IEEE Power System Relaying Committee (PSRC);
- UCA International Users Group;
- The North American Synchrophasor Initiative (NASPI);
- CEN/CENELEC/ETSI Smart Grids Coordination Group;
- CIGRE working groups D2.26, D2.28, D2/B5.30, D2.35; and
- Different utilities, providers and research institutes, in particular the Central Research Institute of Electric Power Industry (Japan), Hydro-Quebec [50][2] (Canada), Swissgrid (Switzerland) and ENEL (Italy).

[2] Numbers in square brackets refer to the bibliography.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-12: Wide area network engineering guidelines

1 Scope

This part of IEC 61850, which is a Technical Report, is intended for an audience familiar with electrical power automation based on IEC 61850 and related power system management, and particularly for data network engineers and system integrators. It is intended to help them to understand the technologies, configure a wide area network, define requirements, write specifications, select components, and conduct tests.

This document provides definitions, guidelines, and recommendations for the engineering of WANs, in particular for protection, control and monitoring based on IEC 61850 and related standards.

This document addresses substation-to-substation communication, substation-to-control centre, and control centre-to-control centre communication. In particular, this document addresses the most critical aspects of IEC 61850 such as protection related data transmission via GOOSE and SMVs, and the multicast transfer of large volumes of synchrophasor data.

The document addresses issues such as topology, redundancy, traffic latency and quality of service, traffic management, clock synchronization, security, and maintenance of the network.

This document contains use cases that show how utilities tackle their WAN engineering.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60834-1, *Teleprotection equipment of power systems – Performance and testing – Part 1: Command systems*

IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*

IEC 61400-25 (all parts), *Wind energy generation systems – Communications for monitoring and control of wind power plants*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61850-8-1, *Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*

IEC 61850-5:2013, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*

IEC 61850-9-2, *Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3*

IEC/IEEE 61850-9-3, *Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

IEC TR 61850-90-1:2010, *Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*

IEC TR 61850-90-2[3], *Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*

IEC TR 61850-90-4:2013, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC TR 61850-90-5:2012, *Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*

IEC 61869-9, *Instrument transformers – Part 9: Digital interface for instrument transformers*

IEC TS 62351-1:2011, *Power systems management and associated information exchange – Data and communications security – Part 1: Communication network and system security – Introduction to security issues*

IEC TS 62351-2:2008, *Power systems management and associated information exchange – Data and communications security – Part 2: Glossary of terms*

IEC 62351-3:2014, *Power systems management and associated information exchange – Data and communications security – Part 3: Communication network and system security – Profiles including TCP/IP*
IEC62351-3:2014/AMD1:2018

IEC TS 62351-4:2007, *Power systems management and associated information exchange – Data and communications security – Part 4: Profiles including MMS and derivatives*

IEC TS 62351-5:2013, *Power systems management and associated information exchange – Data and communications security – Part 5: Security for IEC 60870-5 and derivatives*

IEC TS 62351-6:2007, *Power systems management and associated information exchange – Data and communications security – Part 6: Security for IEC 61850*

IEC TS 62351-7:2017, *Power systems management and associated information exchange – Data and communications security – Part 7: Network and System Management (NSM) data object models*

IEC TS 62351-8:2011, *Power systems management and associated information exchange – Data and communications security – Part 8: Role-based access control*

---

[3] In preparation. Stage at the time of publication: IEC TR/PWI 61850-90-2:2019.

IEC TS 62351-9:2017, *Power systems management and associated information exchange – Data and communications security – Part 9: Cyber security key management for power system equipment*

IEC TR 62351-10:2012, *Power systems management and associated information exchange – Data and communications security – Part 10: Security architecture guidelines*

IEC TR 62351-11:2016, *Power systems management and associated information exchange – Data and communications security – Part 11: Security for XML documents*

IEC TR 62357-200, *Power systems management and associated information exchange – Part 200: Guidelines for migration from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6)*

IEC 62439-1:2010, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods*

IEC 62439-3:2015, *Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)*

ANSI T1.403-1999, *Network and Customer Installation Interfaces – DS1 Electrical Interface*

IEEE 487.3, *IEEE Standard for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Through the Use of Hybrid Facilities*

IEEE 802.1ag, *IEEE standards for local and metropolitan area network; Virtual Bridged Local Area Networks Amendment 5: Connectivity Fault Management*

IEEE 802.1ah, *IEEE standards for local and metropolitan area network; Provider Backbone Bridges*

IEEE 802.1Qay, *Provider Backbone Bridge Traffic Engineering*

IEEE 802.1X, *Port-based Network Access Control*

IEEE 802.3, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

IEEE 487.3, *IEEE Standard for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Through the Use of Hybrid Facilities*

IEEE 802.1Q, *IEEE standards for local and metropolitan area network; Virtual bridged local area networks (VLANs and priorities)*

ITU-T G.703, *Physical/electrical characteristics of hierarchical digital interfaces*

ITU-T G.803, *Architecture of Transport Networks Based on Synchronous Digital Hierarchy (SDH)*

ITU-T G.811, *Timing characteristics of primary reference clocks*

ITU-T G.821, *Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an Integrated Services Digital Network*

ITU-T G.8265, *Architecture and requirements for packet-based frequency delivery*

ITU-T G.8265.1, *Precision Time Protocol telecom profile for frequency synchronization*

ITU-T G.8275.1, *Precision Time Protocol telecom profile for phase/time synchronization*

ITU-T G.7041, *Generic Framing Procedure*

ITU-T G.7042, *Link Capacity Adjustment Scheme*

ITU-T G.8032*, Ethernet ring protection switching*

ITU-T G.8261, *Timing and synchronization aspects in packet networks*

ITU-T G.8262, *Timing characteristics of a synchronous Ethernet equipment slave clock*

ITU-T G.8264, *Distribution of timing information through packet networks*

ITU-T Y.1731, *OAM functions and mechanisms for Ethernet based networks*

RFC 0768, *User Datagram Protocol (UDP)*

RFC 0791, *Internet Protocol (IPv4)*

RFC 0792, *Internet Control Message Protocol (ICMPv4)*

RFC 0793, *Transmission Control Protocol (TCP), Protocol Specification*

RFC 0826, *An Ethernet Address Resolution Protocol (ARP)*

RFC 0894, *A Standard for the Transmission of IP Datagrams over Ethernet Networks*

RFC 1240, *OSI Connectionless Transport Services on top of UDP, Version 1*

RFC 1661, *The Point-to-Point Protocol (PPP)*

RFC 1918, *Address Allocation for Private Internet*

RFC 1981, *Path MTU Discovery for IP version 6*

RFC 2104, *HMAC: Keyed-Hashing for Message Authentication*

RFC 2328, *OSPF Version 2*

RFC 2460, *Internet Protocol, Version 6 (IPv6) Specification*

RFC 2464, *Transmission of IPv6 Packets over Ethernet Networks*

RFC 2474, *Definition of Differentiated Services Field (DS Field) in IPv4 and IPv6 Headers*

RFC 2615, *Point-to-Point Protocol over SDH/SONET*

RFC 2663, *IP Network Address Translator (NAT) Terminology and Considerations*

RFC 3022, *Traditional IP Network Address Translator (Traditional NAT)*

RFC 3031, *Multiprotocol Label Switching Architecture*

RFC 3168, *The Addition of Explicit Congestion Notification (ECN) to IP*

RFC 3246, *An Expedited Forwarding PHB (Per-Hop Behaviour)*

RFC 3247, *Supplemental Information for the New Definition of the EF PHB (Expedited Forwarding Per-Hop Behaviour*

RFC 3260, *New Terminology and Clarifications for DiffServ*

RFC 3261, *SIP: Session Initiation Protocol*

RFC 3315, *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*

RFC 3376, *Internet Group Management Protocol, Version 3*

RFC 3410, *Version 2 of the Protocol Operations for the Simple Network Management Protocol (SNMP)*

RFC 3547, *The Group Domain of Interpretation*

RFC 3985, *Pseudo Wire Emulation Edge-to-Edge (PWE3) Architecture*

RFC 4193, *Unique Local IPv6 Unicast Addresses*

RFC 4213, *Basic Transition Mechanisms for IPv6 Hosts and Routers*

RFC 4291, *IP Version 6 Addressing Architecture*

RFC 4301, *Security Architecture for the Internet Protocol (IPsec)*

RFC 4303, *IP Encapsulating Security Payload (ESP)*

RFC 4330, *Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI*

RFC 4443, *Internet Control Message Protocol (ICMP v6) for the Internet Protocol version 6 (IPv6) specification*

RFC 4459, *MTU and Fragmentation Issues with In-the-Network Tunneling*

RFC 4664, *Framework for* Layer 2 *Virtual Private Networks* (L2VPNs)

RFC 4861, *Neighbor Discovery for IP version 6 (IPv6)*

RFC 4862, *IPv6 Stateless Address Autoconfiguration*

RFC 5246, *The Transport Level Security (TLS) Protocol Version 1.2*

RFC 5424, *The Syslog Protocol*

RFC 5641, Layer *2 Tunneling Protocol Version 3* (L2TPv3) *Extended Circuit Status Values*

RFC 5771, *IANA Guidelines for IPv4 Multicast Address Assignments*

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

RFC 5905, *Network Time Protocol version 4*

RFC 6052, *IPv6 Addressing of IPv4/IPv6 Translators*

RFC 6550, *IPv6 Routing Protocol for Low-Power and Lossy Networks*

RFC 6864, *Updated Specification of the IPv4 ID Field*

RFC 7011, *Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information*