



IEC TR 61850-90-4

Edition 2.0 2020-05

TECHNICAL REPORT



**Communication networks and systems for power utility automation –
Part 90-4: Network engineering guidelines**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.200

ISBN 978-2-8322-8137-6

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

CONTENTS

FOREWORD	14
INTRODUCTION	16
1 Scope	17
1.1 General	17
1.2 Namespace name and version	17
1.3 Code Component distribution	18
2 Normative references	19
3 Terms, definitions, abbreviated terms and conventions	22
3.1 Terms and definitions	22
3.2 Abbreviations	26
3.3 Conventions	28
3.3.1 Network diagram symbols	28
3.3.2 Port and link symbols	29
3.3.3 Bridges symbols	30
4 Overview of IEC 61850 networks	30
4.1 Logical allocation of functions and interfaces	30
4.2 IEC 61850 protocol stack	32
4.2.1 General	32
4.2.2 IEC 61850 traffic classes	32
4.2.3 MMS protocol	33
4.2.4 GOOSE protocol	34
4.2.5 SV protocol	36
4.2.6 R-GOOSE and R-SV	36
4.3 Station bus and process bus	37
5 Network design checklist	38
5.1 Design principles	38
5.2 Engineering flow	38
5.3 Checklist to be observed	39
5.3.1 Summary	39
5.3.2 Environmental issues	40
5.3.3 EMI immunity	40
5.3.4 Form factor	40
5.3.5 Physical media	40
5.3.6 Substation application and network topology	41
5.3.7 Redundancy	41
5.3.8 Reliability, availability, maintainability	41
5.3.9 Logical data flows and traffic patterns	41
5.3.10 Latency for different types of traffic	42
5.3.11 Performance	42
5.3.12 Network management	42
5.3.13 Network supervision	42
5.3.14 Time synchronization and accuracy	42
5.3.15 Remote connectivity	42
5.3.16 Cyber security	42
5.3.17 Scalability, upgradeability and future-proof	43
5.3.18 Testing	43

5.3.19	Cost.....	43
6	Ethernet technology for substations	43
6.1	Ethernet subset for substation automation	43
6.2	Topology.....	43
6.3	Physical layer	45
6.3.1	Data rate and medium	45
6.3.2	Full-duplex communication and auto-negotiation.....	45
6.3.3	Copper cabling at 100 Mbit/s	45
6.3.4	Optical cabling at 100 Mbit/s (100BASE-FX).....	47
6.3.5	Optical cabling at 1 Gbit/s (1000BASE-LX)	49
6.3.6	Copper cabling at 1 Gbit/s	49
6.4	Link layer	49
6.4.1	Unicast and multicast MAC addresses	49
6.4.2	Link layer and bridges	50
6.4.3	Bridging nodes	51
6.4.4	Loop prevention and RSTP	51
6.4.5	Traffic control in the bridges	53
6.4.6	Unicast MAC address filtering.....	53
6.4.7	Multicast MAC address filtering.....	54
6.4.8	Virtual LANs (VLANs) traffic control.....	55
6.4.9	Comparison VLAN versus multicast filtering.....	59
6.4.10	Layer 2 redundancy protocols	60
6.5	Network layer.....	64
6.5.1	Internet protocol	64
6.5.2	IP public and private addresses	65
6.5.3	Subnet masks.....	65
6.5.4	Network address translation	66
7	Network and substation topologies	66
7.1	General rule.....	66
7.2	Connection of the SCADA.....	67
7.3	Reference topologies and network redundancy	68
7.4	Reference topologies	71
7.4.1	Station bus topologies	71
7.4.2	Process bus and attachment of primary equipment	89
7.4.3	Station bus and process bus connection	106
8	Addressing in the substation.....	114
8.1	Network IP address plan for substations	114
8.1.1	General structure.....	114
8.1.2	IP address allocation of NET	114
8.1.3	IP address allocation of BAY	115
8.1.4	IP address allocation of device	115
8.1.5	IP address allocation of devices with PRP	116
8.2	Routers and GOOSE / SV traffic	116
8.3	Communication outside the substation	117
9	Application parameters	117
9.1	MMS parameters.....	117
9.2	GOOSE parameters	117
9.3	SV parameters	118

10	Performance	118
10.1	Station bus performance	118
10.1.1	Logical data flows and traffic patterns	118
10.1.2	GOOSE traffic estimation	120
10.1.3	MMS traffic estimation	120
10.1.4	station bus measurements	121
10.2	Process bus performance	122
11	Latency	123
11.1	Application requirements	123
11.2	Latency and determinism	123
11.3	Latency requirements for different types of traffic	125
11.3.1	Latency requirements in IEC 61850-5	125
11.3.2	Latencies of physical paths	125
11.3.3	Latencies of bridges	125
11.3.4	Latency and hop counts	126
11.3.5	Network latency budget	126
11.3.6	Example of traffic delays	127
11.3.7	Engineering a network for IEC 61850 protection	127
12	Network traffic control	128
12.1	Factors that affect performance	128
12.1.1	Influencing factors	128
12.1.2	Traffic reduction	128
12.1.3	Example of traffic reduction scheme	129
12.1.4	Multicast domains in a combined station bus and process bus network	130
12.2	Traffic control by VLANs	131
12.2.1	Trunk traffic reduction by VLANs	131
12.2.2	VLAN usage	132
12.2.3	VLAN handling at the IEDs	132
12.2.4	Example of correct VLAN configuration	132
12.2.5	Example of incorrect VLAN configuration	133
12.2.6	Retaining priority throughout the network	135
12.2.7	Traffic filtering with VLANs	135
12.3	Traffic control by multicast filtering	136
12.3.1	Trunk traffic reduction by multicast filtering	136
12.3.2	Multicast/VLAN management and redundancy protocol reconfiguration	137
12.3.3	Physical topologies and multicast management implications	137
12.3.4	Connecting two HSR RedBoxes over an RSTP network	140
12.4	Configuration support from tools and SCD files	140
13	Dependability	141
13.1	Resiliency requirements	141
13.2	Availability and reliability requirements	141
13.3	Recovery time requirements	142
13.4	Maintainability requirements	142
13.5	Dependability calculations	142
13.6	Risk analysis attached to "unwanted events"	143
14	Time services	143
14.1	Clocks	143
14.1.1	Relative and absolute clocks	143

14.1.2	Absolute time sources	144
14.1.3	Clock synchronization and accuracy requirements	144
14.1.4	Expressing the clock accuracy	145
14.2	Time Scales	146
14.2.1	Definition of the second	146
14.2.2	Time scales	147
14.2.3	Time representation	147
14.2.4	Leap second handling	148
14.3	Synchronization in IEC 61850	152
14.3.1	Time synchronization requirements in IEC 61850-5	152
14.3.2	Time representation objects in IEC 61850 objects	153
14.4	Clock synchronization protocols	155
14.4.1	1 PPS	155
14.4.2	IRIG-B	155
14.4.3	SNTP clock synchronization for IEC 61850-8-1 (station bus)	156
14.4.4	PTP (IEC 61588) synchronization	158
14.5	Merging units synchronization	172
14.6	Degraded situation upon loss of reference	172
14.7	Clock synchronization architecture and testing	173
15	Network security	174
16	Network management	174
16.1	Protocols for network management	174
16.2	Network management tool	175
16.3	Network diagnostic tool	175
17	Remote connectivity	176
18	Network testing	176
18.1	Introduction to testing	176
18.2	Environmental type testing	177
18.3	Conformance testing	178
18.3.1	Protocols subject to conformance testing	178
18.3.2	Integrator acceptance and verification testing	178
18.3.3	Basic verification test set-up	178
18.3.4	Basic VLAN handling test	179
18.3.5	Basic priority tagging test	180
18.3.6	Basic multicast handling test	180
18.3.7	Basic RSTP recovery test	180
18.3.8	Basic PRP test	181
18.3.9	Basic HSR test	182
18.3.10	Basic IEC/IEEE 61850-9-3 test	183
18.3.11	Basic PTP TC test	184
18.3.12	Basic PTP BC test	184
18.4	Factory and site acceptance testing	184
19	IEC 61850 bridge and port object model	185
19.1	Purpose	185
19.2	Bridge model	186
19.2.1	Simple model	186
19.2.2	Bridge Logical Node linking	188
19.3	Clock model	189

19.3.1	General clock model	189
19.3.2	Simple clock model.....	190
19.3.3	PTP datasets	192
19.3.4	PTP clock objects	192
19.3.5	Linking of clock objects.....	192
19.3.6	PTP TC objects	193
19.4	Autogenerated IEC 61850 objects.....	195
19.4.1	Conditions for element presence.....	195
19.4.2	Abbreviated terms used in data object names.....	198
19.4.3	Logical nodes	198
19.4.4	Data semantics.....	221
19.4.5	Enumerated data attribute types	225
19.5	Mapping of bridge objects to SNMP	227
19.5.1	Mapping of LLN0 and LPHD attributes to SNMP	227
19.5.2	Mapping of LBRI attributes to SNMP for bridges	228
19.5.3	Mapping of LPCP attributes to SNMP for bridges	228
19.5.4	Mapping of LPLD attributes to SNMP for bridges	229
19.5.5	Mapping of HSR/PRP link redundancy entity to SNMP	229
19.6	Mapping of clock objects to the IEC 61588 Datasets and IEC 62439-3 SNMP MIB	230
19.7	Machine-readable description of the bridge objects.....	232
19.7.1	Method and examples.....	232
19.7.2	Simple IED with PTP	233
19.7.3	Four-port bridge.....	234
19.7.4	RedBox wit HSR	235
19.7.5	Connected PRP and HSR networks.....	236
Annex A (informative)	Case study – Process bus configuration for busbar protection system	307
A.1	General.....	307
A.1.1	Process bus for busbar protection	307
A.1.2	Preconditions for case studies	307
A.1.3	Case studies.....	308
A.1.4	Calculation scheme for case 1-a	309
A.2	Solutions.....	310
A.2.1	Potential solutions	310
A.2.2	Reduction of sampling rate	310
A.2.3	Increasing the transmission speed.....	310
A.2.4	Controlling the traffic	310
A.2.5	Partitioning the network	310
A.2.6	Conclusions	310
Annex B (informative)	Case study – Simple Topologies (Transener/Transba, Argentina)	311
B.1	Transba architecture and topology – 132 kV substations	311
B.2	Transener architecture and topology – 500 kV substations.....	312
B.3	Transener SAS architectures – Esperanza.....	313
B.4	Transener SAS architectures – El Morejón.....	314
Annex C (informative)	Case study – An IEC 61850 station bus (Powerlink, Australia)	319
C.1	Normative aspects	319
C.2	Substation layout and topologies	319

C.2.1	Reference substation: 275 kV / 132 kV	319
C.2.2	Substation sizes	319
C.2.3	Physical site layout considerations	320
C.2.4	Panel layout for a bay	320
C.2.5	HV building modules	321
C.3	Requirements put on the network	322
C.3.1	Requirement classes	322
C.3.2	Connectivity requirements	322
C.3.3	Redundancy requirements	322
C.3.4	Quality of Service requirements	323
C.3.5	Components (hardware and software)	323
C.4	Equipment Selection	323
C.4.1	Criteria	323
C.4.2	Physical links	323
C.4.3	Node connections	324
C.4.4	Core router firewall	324
C.4.5	Core bridge	324
C.5	Data network topologies	324
C.5.1	Separate and common data network	324
C.5.2	Station bus (station functions) or SCADA gateway / HMI	328
C.5.3	Station core	329
C.5.4	Transformer protection over the network	329
C.5.5	Automated voltage regulation (AVR)	330
C.5.6	External connections	330
C.5.7	Segmentation requirements	330
C.5.8	Station bus and bay domains	331
C.5.9	Multicast filtering	332
C.5.10	Use of VLANs	333
C.5.11	IP addressing	333
C.6	Estimation of the traffic flow	333
C.6.1	Types of traffic	333
C.6.2	GOOSE	333
C.6.3	MMS traffic estimate	333
C.6.4	Other services	333
C.7	Latencies	334
C.8	Conclusion	334
Annex D (informative)	Case study – Station bus with VLANs (Trans-Africa, South Africa)	335
D.1	General	335
D.1.1	Normative aspects	335
D.1.2	Background	335
D.1.3	Electrical network overview	335
D.1.4	Substation communication overview	336
D.1.5	Design and project objectives	336
D.2	Conceptual design	336
D.2.1	Substation automation networks	336
D.2.2	Design parameters	337
D.2.3	Network topology and redundancy	337
D.2.4	Interface standards	339

D.2.5	Inter-VLAN routing	341
D.2.6	Network quality of service policies	341
D.2.7	IP Traffic prioritization and differentiated services (DiffServ).....	341
D.2.8	Packet classification	342
D.2.9	Packet marking	342
D.2.10	Network IP addressing and device allocations	344
D.2.11	IP Address management.....	345
D.2.12	Network coupling	345
D.2.13	Routing requirements and WAN Interfacing	345
D.2.14	Network time synchronization	345
D.2.15	Network time protocol (SNTP)	345
D.2.16	Device management philosophy	345
D.3	Detailed design: solution specifications for substation-A	347
D.3.1	General	347
D.3.2	Physical environment.....	347
D.3.3	Local area network	349
	Bibliography.....	357
	Figure 1 – Network symbols.....	29
	Figure 2 – Port symbols	29
	Figure 3 – Bridge symbol as beam	30
	Figure 4 – Bridge symbol as bus	30
	Figure 5 – Levels and logical interfaces in grid automation (adapted from IEC 61850-5)	31
	Figure 6 – IEC 61850 protocol stack	32
	Figure 7 – MMS protocol time/distance chart	33
	Figure 8 – GOOSE protocol time/space chart.....	35
	Figure 9 – GOOSE protocol time chart.....	35
	Figure 10 – Example of SV traffic (4 800 Hz)	36
	Figure 11 – Station bus, process bus and traffic example	38
	Figure 12 – Example of engineering flow	39
	Figure 13 – Ethernet LAN (with redundant links)	44
	Figure 14 – Bridge with copper (RJ45) ports	46
	Figure 15 – Shielded Cat5e cable	46
	Figure 16 – RJ45 connector.....	47
	Figure 17 – LC connector.....	48
	Figure 18 – Bridge with optical fibres (LC connectors)	49
	Figure 19 – RSTP principle	52
	Figure 20 – IEEE 802.3 frame format without and with VLAN tagging.....	56
	Figure 21 – PRP principle	61
	Figure 22 – HSR principle	63
	Figure 23 – HSR and PRP coupling (multicast)	64
	Figure 24 – Mapping of electrical grid to data network topology	67
	Figure 25 – Example of substation with separation of the station bus into two sections	68
	Figure 26 – Station bus as single bridge	72
	Figure 27 – Station bus as hierarchical star	73

Figure 28 – Station bus as dual star with PRP	74
Figure 29 – Station bus as ring of RSTP bridges.....	76
Figure 30 – Station bus as separated Main 1 (Bus 1) and Main 2 (Bus 2) LANs	77
Figure 31 – Station bus as ring of HSR bridging nodes	79
Figure 32 – Station bus as ring and subrings with RSTP	80
Figure 33 – Station bus as parallel rings with bridging nodes	82
Figure 34 – Station bus as parallel HSR rings	83
Figure 35 – Station bus as hierarchical rings with RSTP bridging nodes	84
Figure 36 – Station bus as hierarchical rings with HSR bridging nodes	86
Figure 37 – Station bus as ring and subrings with HSR	88
Figure 38 – Double busbar bay with directly attached sensors	90
Figure 39 – Double busbar bay with SAMUs and process bus	91
Figure 40 – Double busbar bay with ECT/EVTs and process bus	92
Figure 41 – 1 ½ CB diameter with conventional, non-redundant attachment.....	93
Figure 42 – 1 ½ CB diameter with SAMUs and process bus	94
Figure 43 – 1 ½ CB diameter with ECT/EVT and process bus	95
Figure 44 – Process bus as connection of PIA and PIB (non-redundant protection).....	96
Figure 45 – Process bus as single star (not redundant protection)	98
Figure 46 – Process bus as dual star	100
Figure 47 – Process bus as a single bridge (no protection redundancy)	101
Figure 48 – Process bus as separated LANs for main 1 and main 2	103
Figure 49 – Process bus as ring of HSR nodes	105
Figure 50 – Process bus as star to merging units and station bus as RSTP ring	108
Figure 51 – Station bus and process bus as rings connected by a router	110
Figure 52 – Station bus ring and process bus ring with HSR	111
Figure 53 – Station bus as dual PRP ring and process bus as HSR ring	113
Figure 54 – Station bus used for the measurements	121
Figure 55 – Typical traffic (packet/s) on the station bus	122
Figure 56 – Example of latency in function of traffic	124
Figure 57 – Generic multicast domains	128
Figure 58 – Traffic patterns.....	130
Figure 59 – Multicast domains for a combined process bus and station bus	131
Figure 60 – Bridges with correct VLAN configuration.....	133
Figure 61 – Bridges with poor VLAN configuration	134
Figure 62 – Bridges with traffic segmentation through VLAN configuration	136
Figure 63 – Station bus separated into multicast domains by voltage level.....	137
Figure 64 – Multicast traffic on an RSTP ring	138
Figure 65 – RSTP station bus and HSR ring	139
Figure 66 – RSTP station bus and HSR process bus.....	140
Figure 67 – Clock quality definitions	145
Figure 68 – Deviation between atomic day and Earth day (source: Wikipedia, modified)	146
Figure 69 – TAI, UTC and UT1 time scales	148
Figure 70 – Example of BIMP bulletin (Source: BIMP).....	149

Figure 71 – Leap second transition at UTC midnight according to BIMP.....	151
Figure 72 – 1 PPS synchronisation	155
Figure 73 – SNTP clock synchronization and delay measurement.....	157
Figure 74 – PTP elements.....	159
Figure 75 – PTP clock correction and peer delay measurement (one-step)	160
Figure 76 – PTP two-step clock correction and peer delay measurement	162
Figure 77 – Clock accuracy degradation in a chain of TCs	163
Figure 78 – Doubly attached clocks in a PRP network.....	167
Figure 79 – Clocks in a PRP network coupled by BCs with an HSR ring.....	169
Figure 80 – Hierarchy of clocks.....	171
Figure 81 – Clock synchronization distribution	174
Figure 82 – Quality assurance stages (copied from IEC 61850-4)	177
Figure 83 – Test set-up for verification test	179
Figure 84 – Test set-up for PRP and PUP	182
Figure 85 – Test set-up for HSR and PUP	183
Figure 86 – Multiport device model	187
Figure 87 – Linking of bridge objects	189
Figure 88 – General clock model in a device.....	190
Figure 89 – Clock model for OC and BC	191
Figure 90 – Ordinary Clock and Boundary Clock objects	193
Figure 91 – Transparent Clock objects.....	194
Figure 92 – Transparent Clock linking.....	195
Figure 93 – Class diagram LogicalNodes_90_4::LogicalNodes_90_4	199
Figure 94 – Class diagram LNGroupL::LNGroupLExt	200
Figure 95 – Class diagram LNGroupL::LNGroupLNew1	201
Figure 96 – Class diagram LNGroupL::LNGroupLNew2	202
Figure 97 – Usage of Multicast MAC Filtering	209
Figure 98 – Usage of VLAN filtering	211
Figure 99 – Simple IED with PTP but no LLDP support	233
Figure 100 – Four-port bridge	234
Figure 101 – RedBox with LLDP but no PTP	235
Figure 102 – Coupled PRP and HSR networks.....	236
Figure A.1 – Preconditions for the process bus configuration example	308
Figure B.1 – First Ethernet-based Transba substation automation network	311
Figure B.2 – Transba SAS architecture	312
Figure B.3 – Transener substation automation network	313
Figure B.4 – Transener SAS architecture – ET Esperanza	315
Figure B.5 – Transener 500 kV architecture – El Morejón	316
Figure B.6 – 500 kV kiosk topology	317
Figure B.7 – 33 kV kiosk topology	318
Figure C.1 – Example HV and LV single line diagram and IEDs	319
Figure C.2 – HV bay and cabinet module	321
Figure C.3 – Data network areas.....	325

Figure C.4 – Substation LAN topology	327
Figure C.5 – SAS Gen1 High level traffic flows	328
Figure C.6 – SCADA & gateway connection	329
Figure C.7 – Station Core	329
Figure C.8 – Overall VLANs	331
Figure C.9 – Three domains	331
Figure C.10 – One domain per diameter, bus zone and transformer protection	332
Figure D.1 – Conceptual topology of substation LAN network with redundancy	338
Figure D.2 – Detailed topology of substation LAN with redundancy	339
Figure D.3 – Original IPv4 Type of Service (ToS) octet	342
Figure D.4 – Differentiated Services (DiffServ) codepoint field	343
 Table 1 – Attributes of (Tr)IEC 61850-90-4:2018A namespace	18
Table 2 – IEC 61850-5 interface definitions	31
Table 3 – Example of port ingress setting table	58
Table 4 – Example of port egress settings	58
Table 5 – Advantages and drawbacks of VLAN versus multicast filtering	59
Table 6 – IANA private IP address blocks (copied from RFC 1918)	65
Table 7 – IP address and mask example	66
Table 8 – Summary of reference topologies	69
Table 9 – Reference topologies and redundancy protocols used	70
Table 10 – Station bus as single bridge	72
Table 11 – Station bus as hierarchical star	73
Table 12 – Station bus as dual star	75
Table 13 – Station bus as ring	76
Table 14 – Station bus as separated Main 1 and Main 2 protection	78
Table 15 – Station bus as ring of bridging nodes	79
Table 16 – Station bus as ring and subrings	81
Table 17 – Station bus as parallel rings	82
Table 18 – Station bus as parallel HSR rings	83
Table 19 – Station bus as ring of rings with RSTP	85
Table 20 – Station bus as ring of rings with HSR	87
Table 21 – Station bus as ring and subrings with HSR	88
Table 22 – Process bus as connection of PIA and PIB	97
Table 23 – Process bus as single star	99
Table 24 – Process bus as dual star	100
Table 25 – Process bus as single bridge	102
Table 26 – Process bus as separated LANs	104
Table 27 – Process bus as simple ring	106
Table 28 – Advantages and drawbacks of physical separation	106
Table 29 – Advantages and drawbacks of logical separation	107
Table 30 – Process bus as star to merging units	108
Table 31 – Connection of station bus to process bus by routers	110

Table 32 – Connection of station bus to process bus by RedBoxes	112
Table 33 – Connection of duplicated station bus to process bus by RedBoxes	113
Table 34 – Example IP address allocation of NET	115
Table 35 – Example IP address allocation of BAY	115
Table 36 – Example IP address allocation of device	116
Table 37 – Example IP address allocation of switches in PRP	116
Table 38 – IEC 61850-5 interface traffic	119
Table 39 – Message types and addresses	120
Table 40 – Latency requirements of IEC 61850-5	125
Table 41 – Elapsed time for an IEEE 802.3 frame to traverse the physical medium	125
Table 42 – Delay for an IEEE 802.3 frame to ingress or to egress a port	126
Table 43 – Latencies caused by waiting for a lower-priority frame to egress a port	127
Table 44 – Two representations of a positive leap second	150
Table 45 – Synchronization classes (taken from IEC 61850-5)	152
Table 46 – Network time synchronization classes	153
Table 47 – Time representations in IEC 61850	154
Table 48 – Standards applicable to network elements	178
Table 49 – Conditions for presence of elements within a context	196
Table 50 – Normative abbreviations for data object names	198
Table 51 – Data objects of ClockPortLN	203
Table 52 – Data objects of PortBindingLN	204
Table 53 – Data objects of PTPClockLN	204
Table 54 – Data objects of LCCHExt	205
Table 55 – Data objects of LPHDExt	206
Table 56 – Data objects of LTIMExt	207
Table 57 – Data objects of LBRI	208
Table 58 – Data objects of LCMF	210
Table 59 – Data objects of LCVF	211
Table 60 – Data objects of LPCP	212
Table 61 – Data objects of LPMS	213
Table 62 – Data objects of LTPC	214
Table 63 – Data objects of LTTC	216
Table 64 – Data objects of LTTP	217
Table 65 – Data objects of LTTP	218
Table 66 – Data objects of LBSP	219
Table 67 – Data objects of LPLD	220
Table 68 – Attributes defined on classes of LogicalNodes_90_4 package	221
Table 69 – Literals of RstpStateKind	225
Table 70 – Literals of VlanTagKind	225
Table 71 – Literals of PortStKind	226
Table 72 – Literals of ChannelRedundancyKind	226
Table 73 – Literals of LdpPortCfgKind	227
Table 74 – Mapping of LLN0 and LPHD attributes to SNMP	227

Table 75 – Mapping of LBRI and LBSP attributes to SNMP for bridges	228
Table 76 – Mapping of LPCP attributes to SNMP for bridges.....	228
Table 77 – Mapping of LPLD attributes to SNMP for bridges	229
Table 78 – Mapping of LCCH attributes for SNMP for HSR/PRP LREs	230
Table 79 – Mapping of clock objects in IEC 61850, IEC 61588 and IEC 62439-3 Annex E...	230
Table A.1 – Summary of expected latencies.....	309
Table C.1 – Site categories HV	320
Table C.2 – Site categories MV.....	320
Table C.3 – Building modules	321
Table C.4 – Network modules	326
Table C.5 – Domain assignment for three domains	332
Table C.6 – Domain assignment for one domain per diameter.....	332
Table C.7 – Summary of expected latencies	334
Table C.8 – Traffic types and estimated network load	334
Table D.1 – VLAN numbering and allocation	340
Table D.2 – Prioritization selection for various applications.....	341
Table D.3 – Mapping of applications to service levels	342
Table D.4 – List of DiffServ codepoint field values	343
Table D.5 – Example of DSCP to class of service mapping	344
Table D.6 – Example of DSCP mappings	344
Table D.7 – Typical substation IP Address map (IP range: 10.0.16.0/21)	344
Table D.8 – SNMP MIBs applicable to substation devices	347
Table D.9 – Example of device naming	348
Table D.10 – Example of interface addressing and allocation.....	349
Table D.11 – Example of device access and SNMP assignment.....	349
Table D.12 – Example of hardware identification.....	350
Table D.13 – Example of device name table	351
Table D.14 – Example of firmware and software table.....	351
Table D.15 – Example of interface addressing and allocation.....	352
Table D.16 – Example of network switch details.....	352
Table D.17 – Example of VLAN definitions	352
Table D.18 – Example of IP routing.....	353
Table D.19 – Example of QoS mapping.....	353
Table D.20 – Example of trunk and link aggregation table (void)	354
Table D.21 – LAN switch port speed and duplex configuration	354
Table D.22 – LAN switch port security settings	355
Table D.23 – Example of DHCP snooping	356
Table D.24 – Example of storm control table.....	356

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**COMMUNICATION NETWORKS AND
SYSTEMS FOR POWER UTILITY AUTOMATION –****Part 90-4: 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 61850-90-4, 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 2013. This edition constitutes a technical revision.

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

- New object model for bridges and clocks based on UML autogeneration.
- An example of SCL configuration with a topology
- Extensions to the time distribution and clock
- Extension of the testing

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

Enquiry draft	Report on voting
57/2088/DTR	57/2159/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.

This IEC standard includes Code Components i.e. components that are intended to be directly processed by a computer. Such content is any text found between the markers <CODE BEGINS> and <CODE ENDS>, or otherwise is clearly labeled in this standard as a Code Component. In the current version of this document, such indication is made at the beginning of each concerned top-level clauses

The purchase of this IEC standard carries a copyright license for the purchaser to sell software containing Code Components from this standard directly to end users and to end users via distributors, subject to IEC software licensing conditions, which can be found at: <http://www.iec.ch/CCv1>.

If any updates are required to the published code component that needs to apply immediately and can not wait for an amendment (i.e. fixing a major problem), a new release of the Code Component will be issued and distributed through the IEC WebSite. Any new release of the Code Component related to this part will supersede any previously published Code Component including the one published within the current document.

This publication contains attached.nsd files which compose the Code Component of this part. These files are intended to be used as a complement and do not form an integral part of this standard.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://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

The growing success of the IEC 61850 series calls for guidelines for engineering Ethernet networks. The IEC 61850 series specifies the basic requirements for the networks but not how to achieve them. Indeed, the IEC 61850 series of standards focuses on data modelling and the interchange of that data, leaving out physical interconnection details that are nevertheless needed for interoperability.

This Technical Report provides definitions, guidelines and specifications for the engineering of IEC 61850-based substation networks, which consists of one or several local area networks. It is also applicable to local area networks outside of the substation, e.g. substation-to-substation links or differential protection links, to which IEDs are directly connected. Data communication over Wide Area Networks is treated in IEC TR 61850-90-12.

This Technical Report addresses issues such as Ethernet technology, network topology, redundancy, traffic latency and quality of service, traffic management by multicast and VLAN filtering, network-based clock synchronization and testing of the network.

This Technical Report is based on existing standards for semantics, services, protocols, system configuration language and architecture. It relies on work done by IEC TC 57 WG 10 (Power system IED communication and associated data models) and IEC TC 57 WG 15 (Data and communications security), on IEC 61918 (*Industrial communication networks – Installation of communication networks in industrial premises*), IEC SC65C WG15 IEC 62439 (*Industrial communication networks – High-availability automation networks*) and IEC 61588 (*Precision clock synchronization protocol for networked measurement and control systems*), on the work of the IEEE 802.1 Working Group, the UCA International Users Group 9-2LE, the IEEE Power System Relaying Committee (PSRC) and on contributions by different companies.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-4: Network engineering guidelines

1 Scope

1.1 General

This part of IEC 61850, which is a Technical Report, is intended for an audience familiar with network communication and/or IEC 61850-based systems and particularly for substation protection and control equipment vendors, network equipment vendors and system integrators.

This document focuses on engineering a local area network limited to the requirements of IEC 61850-based substation automation. It outlines the advantages and disadvantages of different approaches to network topology, redundancy, clock synchronization, etc. so that the network designer can make educated decisions. In addition, this document outlines possible improvements to both substation automation and networking equipment.

This document addresses data transfer over the network in IEC 61850, such as transmitting tripping commands for protection via GOOSE messages, and in particular the multicast data transfer of large volumes of sampled values (SV) from merging units (MUs).

This document considers seamless redundancy to increase the network availability under failure conditions and the high precision clock synchronization that is central to the process bus and synchrophasor operation.

This document is not intended as a tutorial on networking or on IEC 61850. Rather, it references and summarizes standards and publications to assist the engineers. Many publications discuss the Ethernet technology but do not address the networks in terms of substation automation. Therefore, many technologies and options have been ignored since they were not considered relevant for a future-proof substation automation network design.

This document does not address network-based security, which is the subject of IEC 62351 and IEC 62443.

This document does not address technologies for wide area networks; these are covered by IEC TR 61850-90-12. Guidelines for communication outside of the substation that uses exclusively the routable Internet Protocol have been published, especially in documents IEC TR 61850-90-1 (substation to substation), IEC TR 61850-90-2 (substation to control center) and IEC TR 61850-90-5 (synchrophasor transmission). However, data flows used in substation-to-substation communication, or substation-to-control centre communication such as R-GOOSE and R-SV are covered when they transit over Ethernet links within the substation.

This document does not dispense the responsible system integrator from an analysis of the actual application configuration, which is the base for a dependable system.

1.2 Namespace name and version

This subclause is mandatory for any IEC 61850 namespace (as defined by IEC 61850-7-1:2011).

Table 1 shows all attributes of (Tr)IEC 61850-90-4:2018A namespace.

Table 1 – Attributes of (Tr)IEC 61850-90-4:2018A namespace

Attribute	Content
Namespace nameplate	
Namespace Identifier	(Tr)IEC 61850-90-4
Version	2018
Revision	A
Full Namespace Name	(Tr)IEC 61850-90-4:2018A
Namespace Type	transitional
Namespace dependencies	
extends	IEC 61850-7-4:2007B version:2007 revision:B
Namespace transitional status	
Future handling of namespace content	The name space (Tr)IEC 61850-90-4:2018A is considered as "transitional" since the models are expected to be included in further editions IEC 61850-7-4xx. Potential extensions/modifications may happen if/when the models are moved to the International Standard status

The table below provides an overview of all published versions of this namespace.

Edition	Publication date	Webstore	Namespace
Edition 1.0	2013-08	IEC TR 61850-90-4:2013	(Tr)IEC 61850-90-4:2013
Edition 2.0	2020-05	IEC TR 61850-90-4:2020	(Tr)IEC 61850-90-4:2018A

1.3 Code Component distribution

The Code Components are in light and full version:

- The full version is named: *IEC_TR_61850-90-4.NSD.2018A.Full*. It contains definition of the whole data model defined in this document with the documentation associated and access is restricted to purchaser of this part
- The light version is named: *IEC_TR_61850-90-4.NSD.2018A.Light*. It does not contain any documentations but contains the whole data model as per full version, and this light version is freely accessible on the IEC website for download at: <http://www.iec.ch/tc57/supportdocuments>, but the usage remains under the licensing conditions

The Code Components for IEC 61850 data models are formated in compliance with the NSD format defined by the standard IEC 61850-7-7. Each Code Component is a ZIP package containing:

- the electronic representation of the Code Component itself (possibly multiple files)
- the grammar files (XSD) enabling to check the consistency of the associated files against the defined version of NSD, but as well against the IEC 61850 flexibility rules in case of private extension
- a file describing the content of the package (IECManifest.xml)

The IECManifest contains different sections giving information on:

- The copyright notice
- The identification of the code component
- The publication related to the code component

- The list of the electronic files which compose the code component
- An optional list of history files to track changes during the evolution process of the code component

The life cycle of a code component is not restricted to the life cycle of the related publication. The publication life cycle goes through two stages, Version (corresponding to an edition) and Revision (corresponding to an amendment). A third publication stage (Release) allows publication of Code Component in case of urgent fixes of InterOp Tissues, thus without need to publish an amendment.

Consequently new release(s) of the Code Component may be released, which supersede(s) the previous release, and will be distributed through the IEC TC57 web site at: <http://www.iec.ch/tc57/supportdocuments>.

The latest version/release of the document will be found by selecting the file named *IEC_TR_61850-90-4.NSD.{VersionStateInfo}.Light* with the filed VersionStateInfo of the highest value.

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 60050-191:1990, *International Electrotechnical Vocabulary (IEV) - Part 191: Dependability and quality of service* (available at: <http://www.electropedia.org>)

IEC/IEEE 60255-118-1, *Measuring relays and protection equipment - Part 118-1: Synchrophasor for power systems - Measurements*

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

IEC 60870-2-2, *Telecontrol equipment and systems - Part 2: Operating conditions - Section 2: Environmental conditions (climatic, mechanical and other non electrical influences)*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments*

IEC 61508-4, *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 4: Definitions and abbreviations* (see <http://www.iec.ch/functionsafety>)

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

IEC 61754-20, *Fibre optic interconnecting devices and passive components - Fibre optic connector interfaces - Part 20: Type LC connector family*

IEC 61800-3, *Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods*

IEC 61850-3, *Communication networks and systems for power utility automation - Part 3: General requirements*

IEC 61850-4, *Communication networks and systems for power utility automation - Part 4: System and project management*

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

IEC 61850-6:2009, *Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs*

IEC 61850-7-1:2011, *Communication networks and systems for power utility automation - Part 7-1: Basic communication structure - Principles and models*

IEC 61850-7-1:2011/AMD1:2020

IEC 61850-7-2:2010, *Communication networks and systems for power utility automation - Part 7-2: Basic information and communication structure - Abstract communication service interface (ACSI)*

IEC 61850-7-2:2010/AMD1:2020

IEC 61850-7-3, *Communication networks and systems for power utility automation - Part 7-3: Basic communication structure - Common data classes*

IEC 61850-7-4, *Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes*

IEC 61850-8-1:2011, *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 61850-8-1:2011/AMD1:2020

IEC 61850-9-2:2011, *Communication networks and systems for power utility automation - Part 9-2: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3*

IEC 61850-9-2:2011/AMD1:2020

IEC/IEEE 61850-9-3:2016, *Communication networks and systems for power utility automation - Part 9-3: Precision time protocol profile for power utility automation*

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

IEC TR 61850-90-5, *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 62351 (all parts), *Power systems management and associated information exchange – Data and communications security*

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

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

IEC 62439-3:2020¹, *Industrial communication networks - High availability automation networks - Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)*

IEC 81346 (all parts), *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations*

ISO/IEC 8802-2, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical link control*

ISO/IEC 8824-1, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

ISO 9506-1:2003, *Industrial automation systems – Manufacturing Message Specification – Part 1: Service definition*

ISO 9506-2:2003, *Industrial automation systems – Manufacturing Message Specification – Part 2: Protocol specification*

IEEE 802-2014, *IEEE standard for local and metropolitan area networks – Overview and Architecture*

IEEE 802.1AB-2005, *IEEE standard for local and metropolitan area networks – Station and Media Access Control Connectivity Discovery*

IEEE 802.1Q-2018, *IEEE standard for local and metropolitan area networks – Media Access Control (MAC) Bridges and Virtual Bridge Local Area Networks*

IEEE 802.3-2012, *IEEE Standard for Ethernet*

IEEE 1613-2009, *IEEE Standard – Environmental and testing requirements for communications networking devices installed in electric power substations*

IEEE 1588-2019, *Precision clock synchronization protocol for networked measurement and control systems*

IEEE C37.118.2-2011, *IEEE standard for synchrophasor data transfer for power systems*

NOTE IETF references are dated with the original Request For Comment (RFC). Subsequent versions receive a new RFC number. Since IETF amends or extends documents and publishes errata on-line, the valid version is available on the internet at <https://tools.ietf.org/>.

IETF RFC 791, *Internet Protocol (IP)*

IETF RFC 792, *Internet Control Message Protocol (ICMP)*

IETF RFC 793, *Transmission Control Protocol (TCP)*

IETF RFC 826, *Address Resolution Protocol (ARP)*

IETF RFC 959, *File Transfer Protocol (FTP)*

¹ Under preparation. Stage at the time of publication: IEC/CCDV 62439-3:2020.

IETF RFC 2328, *OSPF Version 2*

IETF RFC 2661, *Layer Two Tunneling Protocol "L2TP"*

IETF RFC 3416, *Version 2 of the Protocol Operations for the Simple Network Management Protocol (SNMP)*

IETF RFC 4836, *Definitions of Managed Objects for IEEE 802.3 Medium Attachment Units (MAUs)*

IETF RFC 5903, *Network Time Protocol and Algorithms Specification (NTP/SNTP)*