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

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

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FOREWORD

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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.

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

Enquiry draft	Report on voting
57/1536/DTR	57/1576/RVC

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 "http://webstore.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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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 kilometer to thousands of kilometers, called a “Wide Area Network” of WAN.

WANs encompass communication means of different nature (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 suite 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 tunneler, 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 tunneling 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 60870-6 (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.

Complementing IEC TR 61850-90-4, 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 Technical Report 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;

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1 To be published.

- 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 Technical Report is intended for an audience familiar with electrical power automation based on IEC 61850 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 Technical Report 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 Technical Report addresses substation-to-substation communication, substation-to-control centre and control centre-to-control centre communication. In particular, this Technical Report 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 Technical Report addresses issues such as topology, redundancy, traffic latency and quality of service, traffic management, clock synchronization, security and maintenance of the network.

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

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050, *International Electrotechnical Vocabulary*

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

IEC 60834-2, *Performance and testing of teleprotection equipment of power systems – Part 2: Analogue comparison 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 turbines – 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 61850-5:2013, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*

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

IEC PAS 61850-9-3:2015, *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 61850-90-2:2015, *Communication networks and systems for power utility automation – Part 90-2: Use of IEC 61850 for the communication between substations and control centres*[3]

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*[3]

IEC TS 62351-1, *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, *Power systems management and associated information exchange – Data and communications security – Part 2: Glossary of terms*

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

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

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

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

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IEC TS 62351-7, *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, *Power systems management and associated information exchange – Data and communications security – Part 8: Role-based access control*

IEC TS 62351-9, *Power systems management and associated information exchange – Data and communications security – Part 9: Cyber security key management for power system equipment*[4]

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

IEC 62351-11, *Power systems management and associated information exchange – Data and communications security – Part 11: Security for XML files* [5]

IEC TR 62357-200, *Power systems management and associated information exchange – Part 200: Guidelines for migration 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:––, *Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)* [6]

IEC TS 62443-1-1, *Industrial communication networks – Network and system security – Part 1-1: Terminology, concepts and models*

IEC 62443-2-1, *Industrial communication networks – Network and system security – Part 2-1: Establishing an industrial automation and control system security program*

IEC TR 62443-3 (all parts), *Industrial communication networks – Network and system security*

IEC TR 62443-3-1, *Industrial communication networks – Network and system security – Part 3-1: Security technologies for industrial automation and control systems*

IEC 62488-1, *Power line communication systems for power utility applications – Part 1: Planning of analogue and digital power line carrier systems operating over EHV/HV/MV electricity grids*

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

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*

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4 To be published.

5 To be published.

6 To be published.

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.707/Y.1322, *Network node interface for the synchronous digital hierarchy (SDH)*

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

ITU-T G.810, *Definitions and terminology for synchronization networks*

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

ITU-T G.812, *Timing Requirements of SDH Equipment Slave Clocks (SEC)*

ITU-T G.813, *Timing Requirements of Slave Clocks Suitable as Node Clocks in Synchronization Networks (SEC)*

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.8260, *Definition and terminology for synchronization in Packet Networks*

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 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 Behavior)*

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

RFC 3260, *New Terminology and Clarifications for DiffServ*

RFC 3261, *SIP: Session Initiation Protocol*

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 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 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 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*