PD IEC/TR 61850-1:2013

BSI Standards Publication

Communication networks and systems for power utility automation

Part 1: Introduction and overview

National foreword

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Communication networks and systems for power utility automation – Part 1: Introduction and overview

Réseaux et systèmes de communication pour l'automatisation des systèmes électriques – Partie 1: Introduction et présentation

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 1: Introduction and overview

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.
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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 61850-1, 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 2003. This edition constitutes a technical revision.

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

- Extended application scope of the IEC 61850 standard
  - for the power quality domain;
  - for statistical and historical data;

  - for distributed generation monitoring and automation purpose;
  - for feeder automation purpose;
  - for substation to substation communication;
  - for monitoring functions according to IEC 62271.
- Smart grid considerations.
- Extensions (and provisions for extensions) of the documentation system relating to IEC 61850, especially with part 7-5xx (Application guides) and part 90-xx (Technical report and guidelines).

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

Enquiry draft	Report on voting
57/1233/DTR	57/1304/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 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

IEC 61850 consists of the following parts, under the general title *Communication networks and systems for power utility automation* (all parts may have not been published yet).

Part 1:	Introduction and overview
Part 2:	Glossary
Part 3:	General requirements
Part 4:	System and project management
Part 5:	Communication requirements for functions and device models
Part 6:	Configuration description language for communication in electrical substations related to IEDs
Part 7-1:	Basic communication structure – Principles and models
Part 7-2:	Basic communication structure – Abstract communication service interface (ACSI)
Part 7-3:	Basic communication structure – Common data classes
Part 7-4:	Basic communication structure – Compatible logical node classes and data classes
Part 7-410:	Hydroelectric power plants – Communication for monitoring and control
Part 7-420:	Basic communication structure – Distributed energy resources logical nodes
Part 7-5:	IEC 61850 – Modelling concepts[1]
Part 7-500:	Use of logical nodes to model functions of a substation automation system[1]
Part 7-510:	Use of logical nodes to model functions of a hydro power plant
Part 7-520:	Use of logical nodes to model functions of distributed energy resources[1]
Part 8-1:	Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
Part 80-1:	Guideline to exchange information from a CDC based data model using IEC 60870-5-101/104
Part 9-2:	Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3
Part 90-1:	Use of IEC 61850 for the communication between substations
Part 90-2:	Using IEC 61850 for the communication between substations and control centres[1]
Part 90-3:	Using IEC 61850 for condition monitoring[1]
Part 90-4:	Network Engineering Guidelines - Technical report[1]
Part 90-5:	Using IEC 61850 to transmit synchrophasor information according to IEEE C37.118
Part 10:	Conformance testing

In addition to the above parts IEC technical committee 88 has published the IEC 61850 basic communication structure for Wind Turbines as IEC 61400-25, *Wind turbines – Communications for monitoring and control of wind power plants*.

IEC 61850-1 is an introduction and overview of the IEC 61850 standard series. It describes the philosophy, work approach and contents of the other parts.

1 Under consideration.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 1: Introduction and overview

1 Scope

This technical report is applicable to *power utility automation systems* (PUAS). It defines the communication between intelligent electronic devices (IEDs) in such a system, and the related system requirements.

This part gives an introduction and overview of the IEC 61850 standard series. It refers to and might include text and figures coming from other parts of the IEC 61850 standard series.

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 60870-5-103, *Telecontrol equipment and systems – Part 5-103: Transmission Protocols - Companion standard for the informative interface of protection equipment*

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), *Communications for monitoring and control of wind power plants*

IEC 61850-2, *Communication networks and systems in substations – Part 2: Glossary*

IEC 61850-3, *Communication networks and systems in substations – Part 3: General requirements*

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

IEC 61850-5, *Communication networks and systems in substations – Part 5: Communication requirements for functions and device models*

IEC 61850-6, *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, *Communication networks and systems for power utility automation – Part 7-1: Basic communication structure – Principles and models*

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

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 61850-7-410, *Communication networks and systems for power utility automation – Part 7-410: Hydroelectric power plants – Communication for monitoring and control*

IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*

IEC 61850-7-510, *Communication networks and systems for power utility automation – Part 7-510: Basic communication structure – Hydroelectric power plants – Modelling concepts and guidelines*

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 61850-80-1, *Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104*

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/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 61850-10, *Communication networks and systems in substations – Part 10: Conformance testing*

IEC 62351 (all parts), *Power systems management and associated information exchange – Data and communications security*

IEC/TR 62357-1, *Power systems management and associated information exchange – Part 1: Reference architecture*

IEC 81346-1, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

ISO 9001:2008, *Quality management systems – Requirements*

IEEE C37.2, *IEEE standard electrical power system device function numbers, acronyms and contact designations*

IEEE 100:2000, *The authoritative dictionary of IEEE standards terms seventh edition*

IEEE-SA TR 1550, *Utility Communications Architecture (UCA) Version 2.0 – Part 4: UCA Generic Object Models for Substation and Feeder Equipment (GOMSFE)*

RFC 2246, *The TLS Protocol, Version 1.0*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply. However please refer to part 2 of the standard for the standard glossary of IEC 61850.

3.1.1
Abstract Communication Service Interface
ACSI
virtual interface to an IED providing abstract communication services, for example connection, variable access, unsolicited data transfer, device control and file transfer services, independent of the actual communication stack and profiles used

3.1.2
bay
subpart of a substation, having some common functionality, closely connected to the other subparts, and forming a substation

3.1.3
data object
part of a logical node object representing specific information, for example, status or measurement. From an object-oriented point of view, a data object is an instance of a data object class. Data objects are normally used as transaction objects; i.e., they are data structures

3.1.4
device
mechanism or piece of equipment designed to serve a purpose or perform a function, for example, breaker, relay, or substation computer

[SOURCE: IEEE 100:2000]

3.1.5
functions
tasks which are performed by the substation automation system, i.e. by application functions

Note 1 to entry: Generally, functions exchange data with other functions. The details are dependent on the functions in consideration. Functions are performed by IEDs (physical devices). Functions may be split in parts residing in different IEDs but communicating which each other (distributed function) and with parts of other functions. These communicating function parts are called logical nodes.

Note 2 to entry: In the context of this standard, the decomposition of functions or their granularity is ruled by the communication behaviour only. Therefore, all functions considered consist of logical nodes that exchange data.

3.1.6
Intelligent Electronic Device
IED
any device incorporating one or more processors with the capability of receiving or sending data/controls from or to an external source (for example, electronic multifunction meters, digital relays, controllers)

3.1.7
interchangeability
ability to replace a device supplied by one manufacturer with a device supplied by another manufacturer, without making changes to the other elements in the system

3.1.8
interoperability
ability of two or more IEDs from the same vendor, or from different vendors, to exchange information and use that information for correct execution of specified functions

3.1.9
Logical Node
LN
smallest part of a function that exchanges data

Note 1 to entry: A LN is an object defined by its data and methods.

3.1.10
Logical Device
LD
virtual device that exists to enable aggregation of related logical nodes

3.1.11
open protocol
protocol whose stack is either standardised or publicly available

3.1.12
part
part of the IEC 61850 standard series

EXAMPLE Part 1 refers to IEC 61850-1, Part 7-2 refers to IEC 61850-7-2.

3.1.13
Physical Device
PD
equivalent to an IED as used in the context of this standard

3.1.14
process bus
process bus is the communication network which connects the IEDs at primary equipment level to other IEDs

3.1.15
protocol
set of rules that determines the behaviour of functional units in achieving and performing communication

3.1.16
Power Utility Automation System
PUAS
set of communicating components or devices (IEDs) arranged in a communication architecture to perform any type of power utility automation functions

Note 1 to entry: Power Utility Automation System includes de facto Substation Automation system, as one possible sub-system.

3.1.17
self-description
a device contains information on its configuration

Note 1 to entry: The representation of this information has to be standardised and has to be accessible via communication (in the context of this standard series).

3.1.18
station bus
communication network which inter-connects IEDs at bay level and IEDs at station level, and connects bay-level IEDs to station-level IEDs

3.1.19
system
within the scope of this standard, system always refers to substation automation systems unless otherwise stated

3.1.20
Specific Communication Service Mapping
SCSM
standardised procedure which provides the concrete mapping of ACSI services and objects onto a particular protocol stack/communication profile

Note 1 to entry: To facilitate interoperability it is intended to have a minimum number of standardized mappings (SCSM). Special application subdomains such as "station bus" and "process bus" may result in more than one mapping. However, for a specific protocol stack selected only one single SCSM and one single profile should be specified.

Note 2 to entry: A SCSM should detail the instantiation of abstract services into protocol specific single service or sequence of services which achieve the service as specified in ACSI. Additionally, a SCSM should detail the mapping of ACSI objects into object supported by the application protocol.

Note 3 to entry: SCSMs are specified in the parts 8-x and 9-x of this standard series.

3.2 Abbreviated terms

ACSI	Abstract Communication Service Interface
CDC	Common Data Class
CIM	Common Information Model
DA	Data Attribute
DER	Distributed Energy Resource
DO	Data Object
EMC	Electromagnetic Compatibility
GSE	Generic Substation Event (communication model)
GSSE	Generic Substation State Event (communication model)
GOOSE	Generic Object Oriented System Event (communication model)
IED	Intelligent Electronic Device
LN	Logical Node
LD	Logical Device
PD	Physical Device
PUAS	Power Utility Automation System
SCL	System Configuration description Language
SCSM	Specific Communication Service Mapping
TLS	Transport Layer Security
VLAN	Virtual Local Area Network
XML	eXtensible Markup Language

4 Objectives

The possibility to build Power Utility Automation Systems (PUAS) rests on the strong technological development of large-scale integrated circuits, leading to the present availability of advanced, fast, and powerful microprocessors. The result was an evolution of substation secondary equipment, from electro-mechanical devices to digital devices. This in turn provided the possibility of implementing Power Utility Automation System using several intelligent electronic devices (IEDs) to perform the required functions (protection, local and remote monitoring and control, etc.). As a consequence, the need arose for efficient communication among the IEDs, especially for a standard protocol. Initially specific proprietary communication protocols developed by each manufacturer where used, requiring complicated and costly protocol converters when using IEDs from different vendors.

The industry's experiences have demonstrated the need and the opportunity for developing standard semantics, abstract communication services that can be mapped to different protocols, configuration descriptions and engineering processes, which would support interoperability of IEDs from different manufacturers. Interoperability in this case is the ability to operate on the same network or communication path sharing information and commands. There is also a desire to have IED interchangeability, i.e. the ability to replace a device supplied by one manufacturer with a device supplied by another manufacturer, without making changes to the other elements in the system. Interchangeability would also require standardisation of functions which is beyond this communication standard. Interoperability is a common goal for electric utilities, equipment vendors and standardisation bodies.

The objective of PUAS standardisation is to develop a communication standard that will meet functional and performance requirements, while supporting future technological developments. To be truly beneficial, a consensus must be found between IED manufacturers and users on the way such devices can freely exchange information.

The communication standard must support the operation functions within the substation and distributed throughout the power grid. Therefore, the standard has to consider the operational requirements, but the purpose of the standard is neither to standardise (nor limit in any way) the functions involved in substation operation nor their allocation within the Power Utility Automation System. The application functions will be identified and described in order to define their interface and then their communication requirements (for example, amount of data to be exchanged, exchange time constraints, etc.). The communication standard, to the maximum possible extent, should make use of existing standards and commonly accepted communication and engineering principles.

This standard aims to ensure, among others, the following features:

– That the complete communication profile is based on existing IEC/IEEE/ISO/OSI communication standards, if available.
– That the protocols used will be open and will support self-descriptive devices. It should be possible to add new functionality.
– That the standard is based on data objects related to the needs of the electric power industry.
– That the communication syntax and semantics are based on the use of common data objects related to the power system.
– That the communication services can be mapped to different state-of-the art protocols.
– That the communication standard considers the implications of the substation being one node in the power grid, i.e. of the Power Utility Automation System being one element in the overall power control system.
– That the complete topology of an electrical system (single line diagram), the generated and consumed information, and the information flow between all IEDs is specified, using a machine readable language.

5 Approach of the IEC 61850 standard

5.1 Scope of application

The main parts of the IEC 61850 standard were first published from 2002 to 2005. The standard was the result of nearly ten years of work within IEEE/EPRI on Utility Communications Architecture (UCA) (IEEE-SA TR 1550) and within the working group “Substation Control and Protection Interfaces” of IEC Technical Committee 57. The initial scope of IEC 61850 was standardisation of communication in substation automation systems.

The first edition of the standard was primarily related to protection, control and monitoring. From 2009 onwards the original parts of the IEC 61850 series have been updated and extended to cover also measurement (including statistical and historical data handling) and power quality. New parts of the standard will also be added to handle condition monitoring.

The concepts defined in IEC 61850 have been applied beyond the substation domain:

– The modelling of hydropower plants (see IEC 61850-7-410) distributed energy resources (see IEC 61850-7-420) are also covered by the IEC 61850 series.
– The modelling of wind turbines has been standardized ,according to IEC 61850, within the IEC 61400-25 series, *Communications for monitoring and control of wind power plants*.
– The communication has also been extended to substation to substation communication (see IEC 61850-90-1).

IEC 61850 is planned to be applied to new areas such as:

– Communication to network control centre (IEC/TR 61850-90-2[2])
– Feeder automation domain

Harmonization of IEC 61850 modelling with the IEC Common Information Model (CIM, IEC 61968/61970) is also considered as a high priority item to fulfil Smart Grid objectives.

Given the extended scope, today’s naming of the IEC 61850 standard is *Communication networks and systems for power utility automation*. The final scope of application of IEC 61850 (and affiliates) is described in Figure 1.

2 To be published.

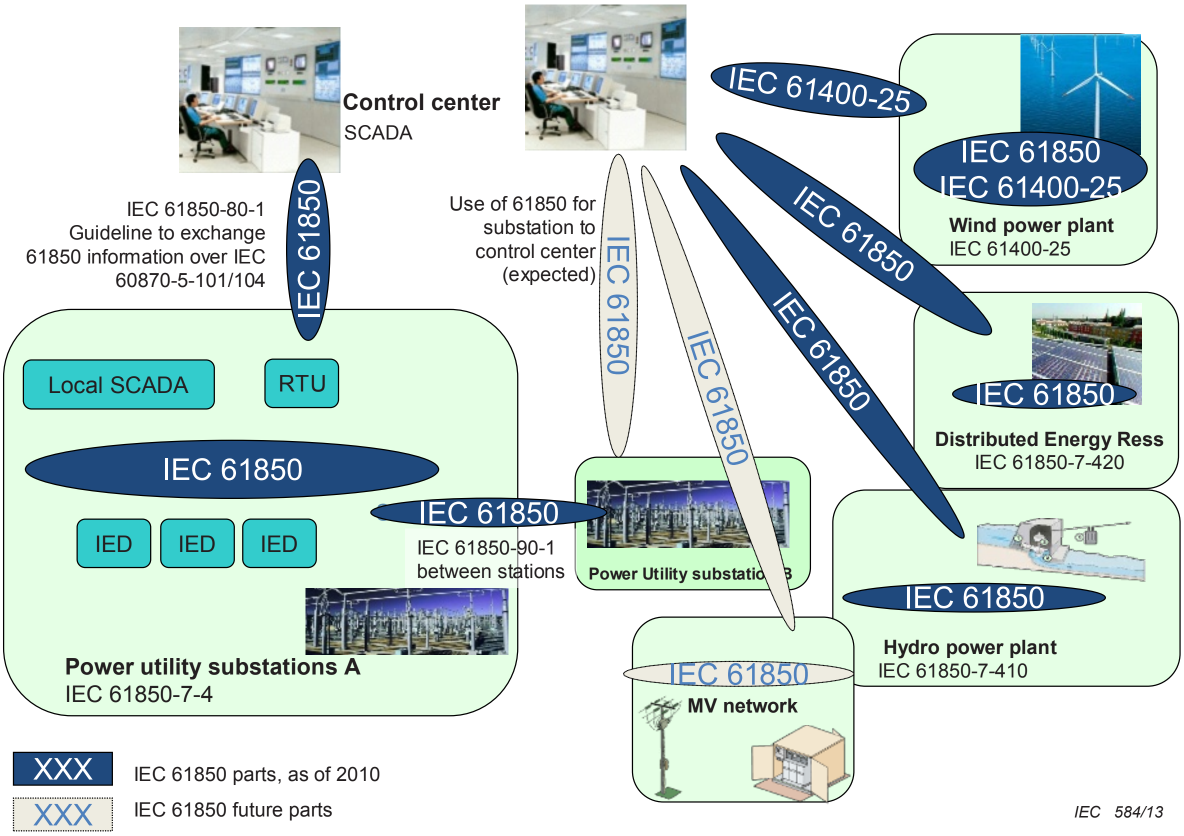


Figure 1 – Scope of application of IEC 61850

5.2 IEC 61850 within the IEC Power Utility control system reference architecture

IEC 61850 is one central communication standard of the Power Utility control system reference architecture of IEC technical committee 57 (IEC 62357) as shown in Figure 2.

IEC 61850 is fully complementary to the Common Information Model Standard (CIM – IEC 61970 – IEC 61968).

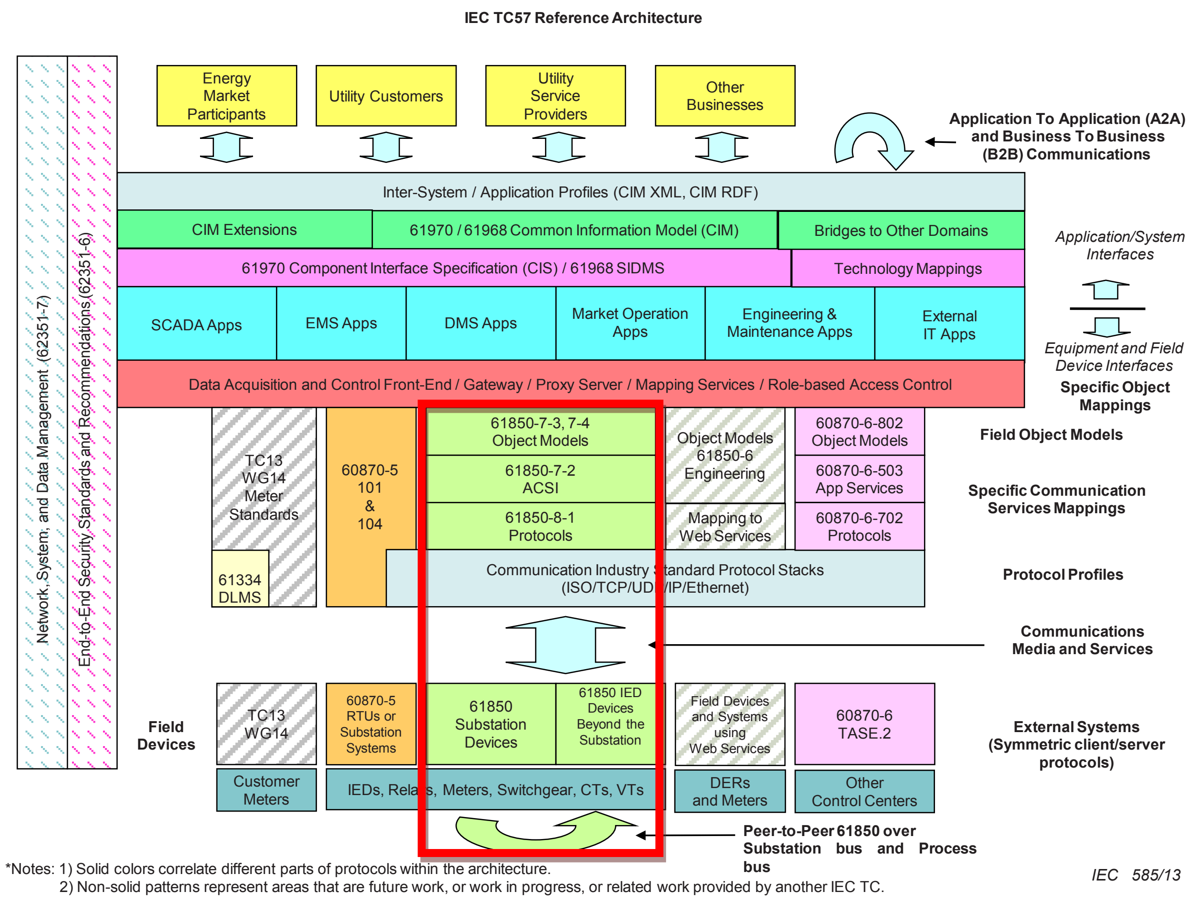


Figure 2 – Power utility control system reference architecture (IEC 62357)

5.3 IEC 61850 within Smart Grid reference architecture

IEC 61850 is one central communication standard of the Smart Grid IEC reference architecture, as published by the IEC Strategic Group 3 on Smart Grid. "Across the IEC Smart Grid Framework, the Application Domain TCs must use the methods delivered by the “horizontal” TCs included in the Framework.

IEC 61850 (existing and extended) will be used for all communications to field equipment and systems, while the IEC 61970 and IEC 61968 will be used within control centres for managing information exchanges among enterprise systems."[3]

5.4 Standardization approach

The approach of the IEC 61850 series is to blend the strengths of the following three methods:

– Functional decomposition
– Data flow modelling
– Information modelling

Functional decomposition is used to understand the logical relationship between components of a distributed function, and is presented in terms of logical nodes (LNs) that describe the functions, subfunctions and functional interfaces.

3 Extract from Standardization Management Board meeting 137, decision 3 (SMB/4175/R 2010-01-11).

Data flow is used to understand the communication interfaces that must support the exchange of information between distributed functional components and the functional performance requirements.

Information modelling is used to define the abstract syntax and semantics of the information exchanged, and is presented in terms of data object classes and types, attributes, abstract object methods (services), and their relationships.

5.5 How to cope with fast innovation of communication technology

In order to cope with the fast innovation of communication technology IEC 61850 makes the communication independence from the application by specifying a set of abstract services and objects. In this way applications can be written in a manner which is independent from a specific protocol. This abstraction allows both vendors and utilities to maintain application functionality and to optimise this functionality when appropriate as explained in Figure 3.

It also allows, as the scope of IEC 61850 is wider and wider, to cope with the diversity of communication solutions required by the new targetted domains, while keeping the same data model.

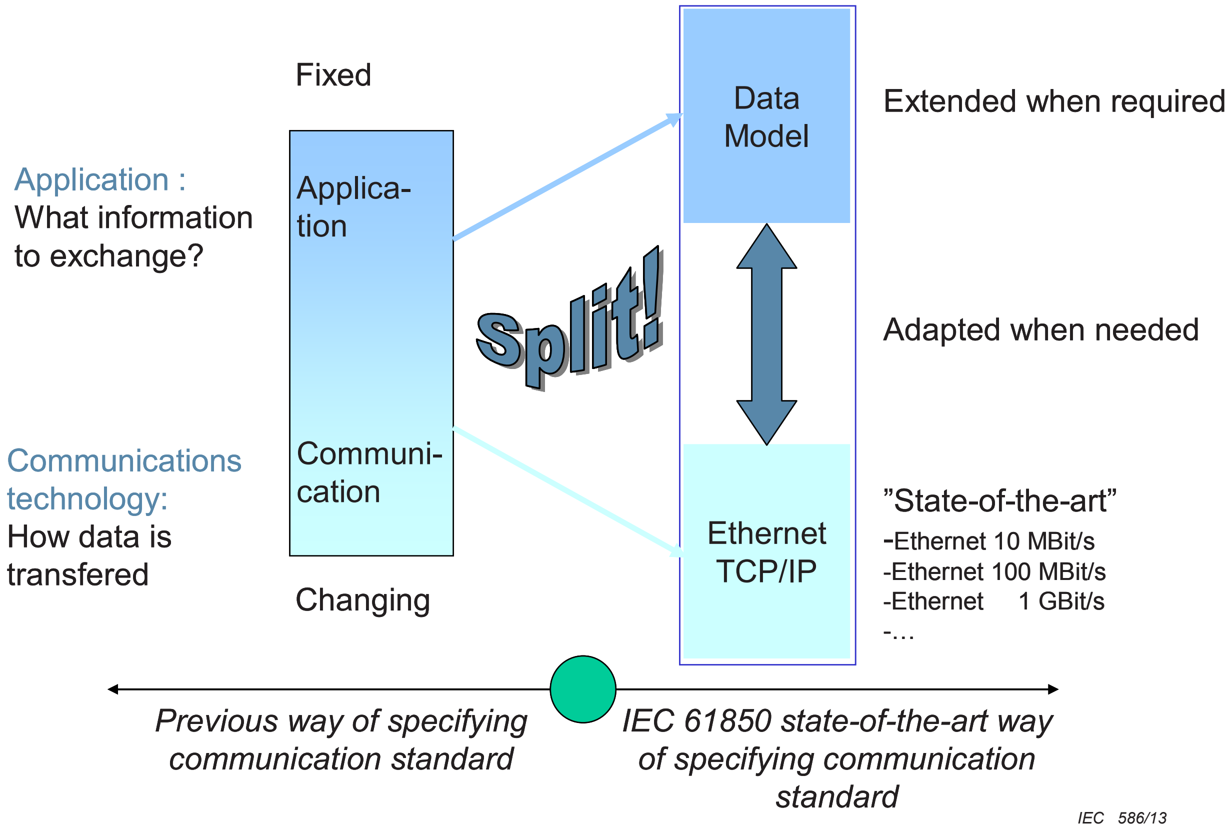


Figure 3 – IEC 61850 specifying approach

5.6 Representation of functions and communication interfaces

The objective of the standard is to provide a framework to achieve interoperability between the IEDs supplied from different suppliers.

The allocation of functions to devices (IEDs) and control levels is not fixed. The allocation normally depends on availability requirements, performance requirements, cost constraints, state of the art of technology, utilities' philosophies etc. Therefore, the standard should support any allocation of functions.

In order to allow a free allocation of functions to IEDs, interoperability shall? be provided between functions to be performed in a power utility automation system but residing in equipment (physical devices in substation) from different suppliers. The functions may be split in modules performed in different IEDs but communicating with each other (distributed function). Therefore, the communication behaviour of such modules (called logical nodes, (LNs)) has to support the requested interoperability of the IEDs.

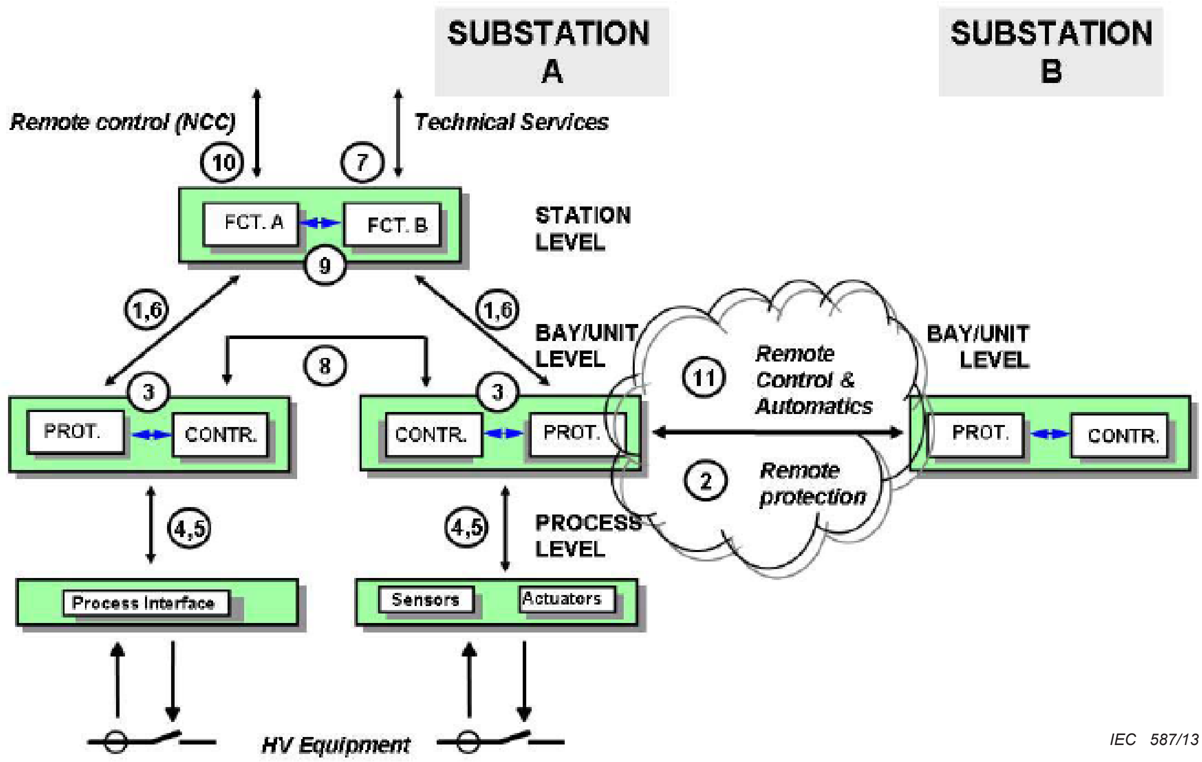
The functions (application functions) of a Power Utility Automation system are control and supervision, as well as protection and monitoring of the primary equipment and of the grid. Other functions (system functions) are related to the system itself, for example supervision of the communication.

Functions can be assigned to three levels: the station level, the bay level and the process level.

NOTE A substation consists of closely connected subparts with some common functionality called bays. Examples are the switchgear between an incoming or outgoing line and the busbar, the bus coupler with its circuit breaker and related isolators and earthing switches, the transformer with its related switchgear between the two busbars representing the two voltage levels. The bay concept may be applied to one and a half breaker and ring bus substation arrangements by grouping the primary circuit breakers and associated equipment into a virtual bay. These bays comprise a power system subset to be protected such as a transformer or a line end, and the control of its switchgear has some common restrictions such as mutual interlocking or well-defined operation sequences. The identification of such subparts is important for maintenance purposes (which parts may be switched off at the same time with a minimum impact on the rest of the substation) or for extension plans (what has to be added if a new line is to be linked in). These subparts are called bays and may be managed by devices with the generic name "bay controller" and have protection systems called "bay protection".

The concept of a bay is not commonly used all over the world. The bay level represents an additional control level below the overall station level.

The logical communication interfaces within substation and between substations are presented in Figure 4.



NOTE Interface numbers are for notational use in other parts of the IEC 61850 series and have no other significance.

Figure 4 – Interface model within substation and between substations

The meanings of the interfaces are as follows:

IF1: protection-data exchange between bay and station level.

IF2: protection-data exchange between bay level and remote protection.

IF3: data exchange within bay level.

IF4: CT and VT instantaneous data exchange (especially samples) between process and bay level.

IF5: control-data exchange between process and bay level.

IF6: control-data exchange between bay and station level.

IF7: data exchange between substation (level) and a remote engineer's workplace.

IF8: direct data exchange between the bays especially for fast functions such as interlocking.

IF9: data exchange within station level.

IF10: remote control-data exchange between substation (devices) and a remote network control centre (called NCC – beyond the scope of this standard).

IF 11: the control-data exchange between different substations.

The devices of a power utility automation system may be physically installed on different functional levels (station, bay, and process). This refers to the physical interpretation of Figure 4.

Process level devices are typically remote I/Os, intelligent sensors and actuators.

Bay level devices consist of control, protection or monitoring units per bay.

Station level devices consist of the station computer with a database, the operator's workplace, interfaces for remote communication, etc.

To reach the standardisation goal of interoperability, common functions in a power utility automation system have been identified and split into sub-functions (logical nodes). Logical nodes may reside in different devices and at different levels. Figure 5 shows examples to explain the relationship between functions, logical nodes, and physical nodes (devices).

A function is termed "distributed" when it is performed by two or more logical nodes that are located in different physical devices. Since all functions communicate in some way, the definition of a local or a distributed function is not unambiguous but depends on the definition of the functional steps to be performed until the function is completed.

When a distributed function is implemented, proper reactions on the loss of a functional component or an included communication link have to be provided, for example the function may be blocked completely or shows a graceful degradation if applicable.

NOTE The implementation is beyond the scope of the standard series.

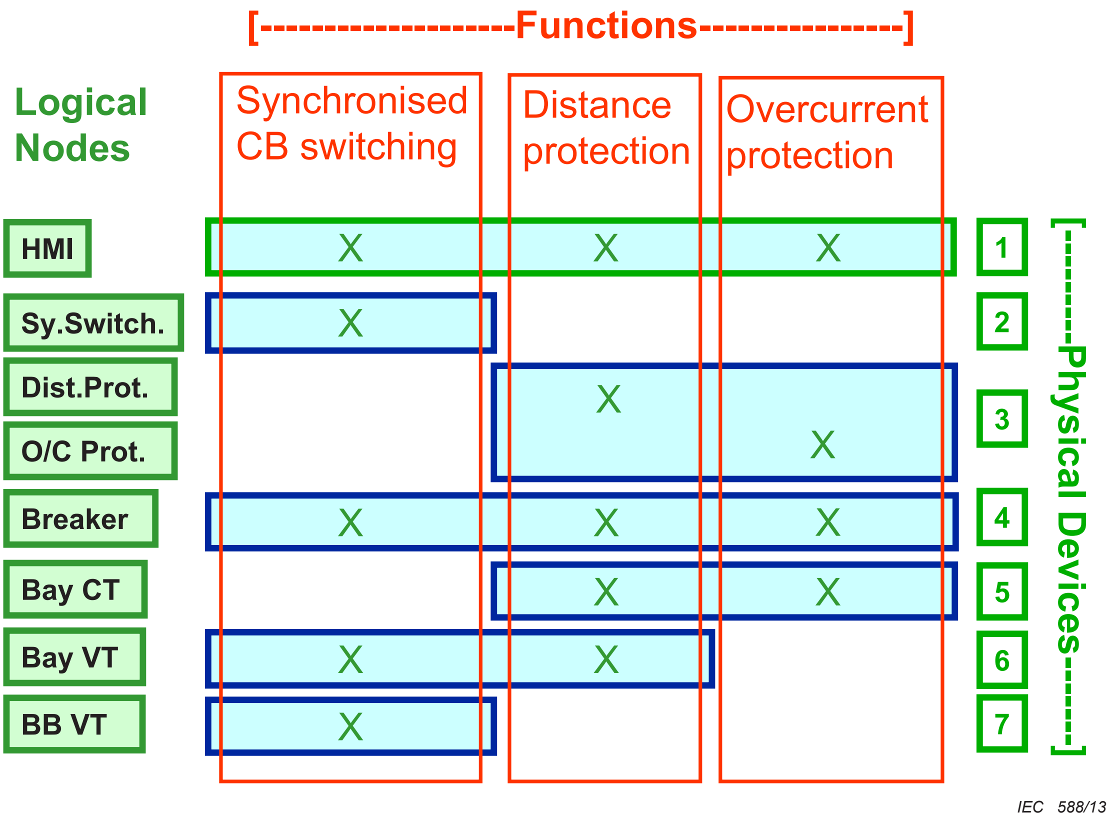


Figure 5 – Relationship between functions, logical nodes, and physical nodes (examples)

Examples in Figure 5: Physical device 1: Station computer, 2: Synchronised switching device, 3: Distance protection unit with integrated overcurrent function, 4: Bay control unit, 5 and 6: Current and voltage instrument transformers, 7: Busbar voltage instrument transformers

Known functions for substation, hydro power, distributed energy resources (DER) applications have been described in IEC 61850-7-4xx. In addition to this, Annex G of part 5 defines:

– task of the function;
– starting criteria for the function;
– result or impact of the function;
– performance of the function;
– function decomposition;
– interaction with other functions.

NOTE standardising functions is not the intention of the IEC 61850 series, only the interaction of functions is covered.

Messages communicated using IEC 61850 are divided into different types with different requirements according to part 5 of the standard.

Messages can be sent using different Abstract Communication Service Interface (ACSI) services (see IEC 61850-7-2).These can be e.g. reporting, GOOSE or control command and can be mapped to different protocols according to IEC 61850-8-x and IEC 61850-9-x.

5.7 Requirements for a physical communication system

Logical interfaces may be mapped to physical interfaces in several different ways. A station bus normally implements the logical interfaces 1, 3, 6, and 9 of Figure 4; a process bus may cover the logical interfaces 4 and 5. The logical interface 8 (‘inter-bay-communication’ using GOOSE messages) may be mapped to either or to both.

Mapping of all logical interfaces to one single bus is possible, if this satisfies the required level of performance (response time, availability, maintainability, etc.). Mapping sets of logical interfaces to dedicated buses is also possible.

Network Engineering Guidelines included in IEC 61850-90-4 standard provides definitions and important recommendations on how to properly specify and design the physical communication system of a Power Utility Automation system based on IEC 61850, depending of the levels of requirement.

6 Content of the IEC 61850 series

6.1 IEC 61850 general requirements (parts 1 to 5)

The titles and contents of the published or planned parts of the IEC 61850 series are as follows (refer to 6.3 and Figure 6 for a global overview of the IEC 61850 documentation):

IEC 61850-1 Introduction and overview

Introduction and overview of IEC 61850 (this document)

IEC 61850-2 Glossary

Collection of terminology and definitions used within the various parts of the standard

IEC 61850-3 General requirements

Quality requirements (reliability, maintainability, system availability, portability, security)

Environmental conditions (including temperature, humidity, EMC and other constraints)

Auxiliary services

Other standards and specifications

IEC 61850-4 System and project management

Engineering requirements (parameter classification, engineering tools, documentation)

System lifecycle (product versions, discontinuation, support after discontinuation)

Quality assurance (responsibilities, test equipment, type tests, system tests, FAT and SAT)

IEC 61850-5 Communication requirements for functions and device models of a Power Utility Automation system

Basic requirements

Functions

Required logical nodes. Each of them has been described by:

– grouping according to their most common application area;
– short textual description of the functionality;
– IEEE device function number if applicable (for protection and some protection related logical nodes only, refer to IEEE C37.2);
– relationship between functions and logical nodes in tables and in the functional description;

Logical communication links i.e. logical exchanged information between logical nodes

Performance

"Dynamic scenarios" (information flow requirements for different operational conditions)

6.2 Three pillars of interoperability and conformance testing (Part 6 and above)

In order to fully define how components can interoperate in a Power Utility Automation System, while remaining independent of the implementation, the IEC 61850 standard provides three main levels of definition:

- A standard name space of logical nodes, data objects and attributes (part 7-3 and 7-4), i.e. the dictionary of standardized function interfaces (logical nodes) and names (data objects and attributes classes). Such a repository is used to describe the information which has to be exchanged between the functions of the physical components of the system, its semantic, its structure and the way this information is exposed. This dictionary is based on a specific modelling approach of device and function interface.
  - The original name space focused on electrical data for protection, monitoring and control purpose mainly.
  - Complementary name spaces have been created to answer for the needs of new application domains such as distributed energy resources. The new name spaces are still relying on the same modelling principle, and on the same data structure basis.
  - Future activities may lead to further extension of the scope of applications of IEC 61850 such as those needed for Smart Grid considerations. Such modelling also supports non-standardised extensions (refer to 6.4.3).

  See 6.4.
- A language (part 6, System Configuration description Language), i.e. a formal grammar enabling the association of elements defined above, the syntax used in order to make machine-level sentences and text. This language, based on the XML meta language, is used to describe IED capabilities and to express how IED are configured. Further it is used to describe a full system, encompassing its electrical topology, the interfaces of each of its components, and the communication network topology and settings.

  SCL supports both functional and product specific naming and allows capabilities and configuration information exchange between communication and application system engineering tools, in a compatible way from different manufacturers as well as from manufacturer independent tools.

  See 6.6.
- A set of communication services to exchange this information in real time (part 7-2, 8 and 9). This set of communication services is defined in a way it can easily evolve, to follow market technology improvement and to be independent of selected communication medium and protocol. Abstract definitions of such set of services are defined in part 7-2, while implementations of mappings to specific protocols are defined in parts 8 and 9.

  Handling such communication services enable a component to exchange data with others, with respect of defined constraints such as response-time, time-tagging, integrity, quality etc.

  See 6.5.

In addition, conformance testing requirements are specified in part 10.

IEC 61850 specifications therefore go much further than a traditional communication protocol definition, and ensure a very high level of interoperability at application level that can adapt to a changing communication infrastructure.

6.3 Understanding the structure of the IEC 61850 documentation

IEC 61850 documentation is quite extensive. Technical specifications give guidelines how to apply the standard for various applications areas such as how to use IEC 61850 between control centre and substations together with IEC 60870-5-101 or 104 (specified in IEC 61850-80-1). Technical Reports give recommendations on how to apply the standard, for example how to create Ethernet networks to support the IEC 61850 (IEC/TR 61850-90-4[4]).

Some basic rules are used for assigning numbers to documents in the IEC 61850 series:

- 7-4xx documents are normative definitions of domain specific name spaces
- 7-5xx documents are informative application guidelines of the 7-x documents, i.e. providing guidance on how to model application functions based on part 7-x
- 8-x documents are normative definitions of the ACSI mapping (except communication services related to sample values)
- 9-x documents are normative definitions of the ACSI mapping dedicated to communication services related to sample values
- 80-x documents are additional informative Technical Specifications related to communication mapping
- 90-x are additional informative Technical Reports for further enhancement/extensions of the IEC 61850 domains

Figure 6 provides an overview of the IEC 61850 series content:

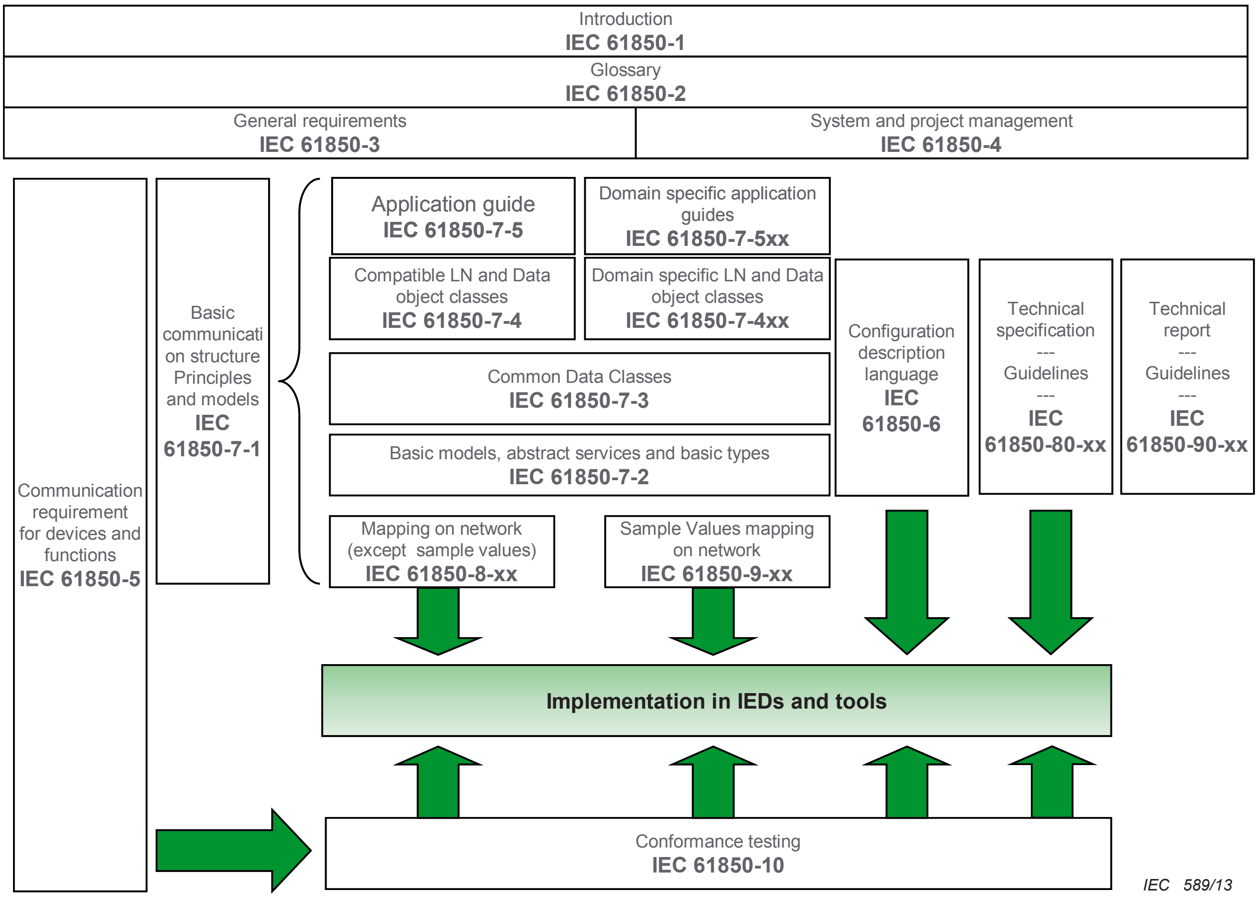


Figure 6 – Links between IEC 61850 parts

4 Under consideration.

More specifically:

IEC 61850-6 specifies a file format for describing communication related to IED (Intelligent Electronic Device) configurations and IED parameters, communication system configurations, switchyard (function) structures, and the relations between them. The main purpose of the format is to exchange IED capability descriptions, and at system level descriptions between engineering tools of different manufacturers in a compatible way. The defined language is called System Configuration description Language (SCL). Mapping specific extensions or usage rules may be required in the appropriate parts.

As a summary, part 6 provides:

- Overview on intended system engineering process.
- Definition of system and configuration parameter exchange file format based on XML containing
  - primary system schematic (single line) description,
  - communication connection description,
  - IED capabilities.
- Allocation of IED logical nodes to primary system.

IEC 61850-7-5 defines the usage of information models for substation automation applications. It gives clear examples on how to apply LNs and data defined in IEC 61850-7-4 for different substation applications. The examples cover applications from monitoring function to protection blocking schemes. Other domain specific application guides which are within the scope of IEC technical committee 57 are defined in the IEC 61850-7-5xx series. Examples are Hydropower and Distributed Energy Resources domains.

IEC 61850-7-4 defines specific information models for substation automation functions (for example, breaker with status of breaker position, settings for a protection function, etc.) – *what is modelled and could be exchanged*. Other domain specific information models within the scope of IEC TC 57 are defined in the IEC 61850-7-4xx series.

IEC 61850-7-3 has a list of commonly used information (for example, for double point control, 3-phase measurand value, etc.) – *what the common basic information is*.

IEC 61850-7-2 provides the services to exchange information for the different kinds of functions (for example, control, report, get and set, etc.) – how to exchange information.

IEC 61850-8-1 defines the concrete means to communicate the information between components of the system (for example, the application layer, the encoding, etc.) except sampled values.

IEC 61850-9-2 defines the concrete means to communicate sampled values between sensors and IEDs.

IEC 61850-10 specifies the methods and abstract test cases which have to be performed in order to ensure the conformance of the implementation of IEC 61850 in targeted devices, and the metrics to be measured – *what to test*. IEC 61850-10 includes:

- Conformance test procedures.
- Quality assurance and testing.
- Required documentation.
- Device related conformance testing.
- Certification of test facilities, requirement and validation of test equipment.

6.4 IEC 61850 data modelling

6.4.1 Main principle (explained in IEC 61850-7-1)

6.4.1.1 General

IEC 61850 information model is based on two main levels of modelling – explained below:

– The breakdown of a real device (physical device) into logical devices
– The breakdown of logical device into logical nodes, data objects and attributes

Figure 7 gives an example of how each level is included into the upper layer.

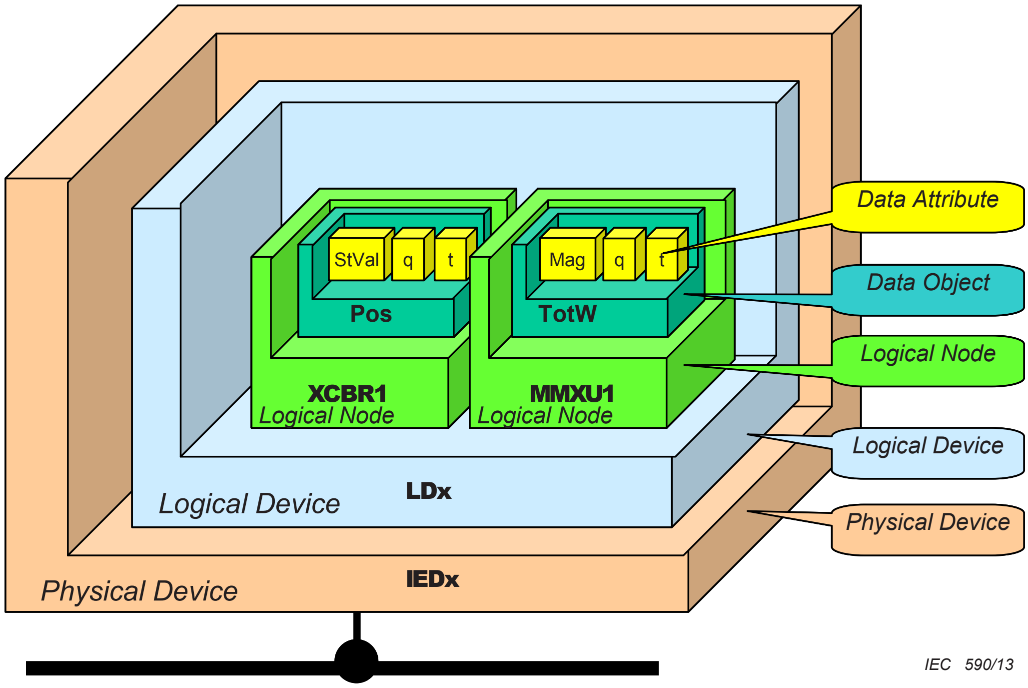


Figure 7 – IEC 61850 Data modelling

6.4.1.2 Breakdown of physical device into logical devices

"Logical Device" is the first level of breaking down the functions supported by a physical device i.e. an IED. No specific rule is given by the standard on how to arrange Logical Devices into a physical device, except that one logical device can't be spread over many IEDs. It shall be hosted by a single IED. Logical device usually represents a group of typical automation, protection or other functions.

The Logical Device hosts communication access point of IEDs and related communication services. It may have its own working mode and behaviour independent of other Logical Devices in a physical device. Logical devices provide information about the physical devices they use as host (nameplate and health) or about external devices that are controlled by the logical device (external equipment nameplate and health).

Logical Device modelling concept helps modelling multifunction IEDs, gateway type IEDs or modular IEDs. It also enables the specification of a power utility automation system without having to specify any given product solution with physical devices.

Because this simple hierarchy model may not be sufficient to model complex functions, e.g. distance protection, Parts 6 and 7 have introduced the ability to manage nested functions and sub-functions, and the ability to manage a hierarchy of Logical Devices and the concept of "root Logical Device".

6.4.1.3 Breakdown of logical devices into logical nodes, data objects and attributes:

The approach of the standard is to decompose the application functions into the smallest entities which are used to exchange information. The granularity is given by a reasonable distributed allocation of these entities to dedicated devices (IED).These entities are called Logical Nodes (for example, a virtual representation of a circuit breaker class, with the standardised class name XCBR). Other examples may be a distance protection function, PDIS or a measurement value, MMXU. The Logical Nodes are first defined from the conceptual application point of view in IEC 61850-5 and then modelled in parts 7-4 and 7-4xx.

Then several Logical Nodes build a Logical Device as defined above (for example, a representation of a Bay unit). Logical Nodes included in a logical device may have a working mode that is different to that of the Logical Device they belong to. For example an individual LN may have behaviour test/blocked without the entire Logical Device being so.

Based on their functionality, a Logical Node contains a list of data (for example, position) with dedicated data attributes. The data have a structure and a well-defined semantic (meaning in the context of systems for power utility automation or, e.g. more specifically, of substation automation systems) and are fully defined through IEC 61850-7.

6.4.2 Standard name space introduction

6.4.2.1 General

The standard name space of the IEC 61850 series, defined in part 7, contains a collection of standard logical nodes, object classes and attributes defining at least:

– its wording (exact spelling)
– its semantic (meaning and possibly also the meaning of each of the states this data may take)
– its type and structure.

6.4.2.2 Compatible LNs and objects classes

Over 280 logical nodes covering the most common applications of substation and feeder equipment are defined in the IEC 61850 and IEC 61400-25 standards name space. While the definition of information models for protection and protection related applications is important because of the high impact of protection for safe and reliable operation of the power system, the covered applications include many other functions like monitoring, measurement, control and power quality. These are defined in IEC 61850-7-4.

Most logical nodes provide information (data object and data attributes) that can be categorised in 5 categories:

– Common logical node information
– Status information
– Settings
– Measured values
– Controls

The data attribute names are standardised (i.e., they are reserved) names that have a specific semantic in the context of the IEC 61850 series. The semantic of all data attribute names is defined at the end of IEC 61850-7-3.

Finally, the semantic of a logical node is represented by the data objects and data attributes it contains.

6.4.2.3 Common Data classes

The whole set of all the data attributes defined for a data object is based on predefined types and structures called “Common Data Class” (CDC).

IEC 61850-7-3 defines common data classes for a wide range of well-known applications. The core common data classes are classified into the following groups:

– status information,
– measurand information,
– controllable status information,
– controllable analogue information,
– status settings,
– analogue settings and
– description information

Data classes of this level are similar to ‘objects’ defined in IEC 60870-5-103. Logical nodes of this level are similar to ‘bricks’ defined in Utility Communications Architecture (UCA) Version 2.0.

6.4.3 Name space extension

As stated in 6.4.2, IEC 61850 defines a set of standard name spaces. However considering that name spaces can be handled by multiple entities, can evolve during time, or may miss some wording, IEC 61850 introduced from its beginning (refer to IEC 61850-7-1):

– the concept of name space owner – IEC technical committee 57 is the owner of the name spaces contained in the IEC 61850 series
– the ability to clearly state and tag to which name space a data refers to, through a specific attribute to any data
– strict rules for managing/expanding name space: rules are provided by owners of name space to allow third parties to make extensions to it in a way that do not jeopardize interoperability. Starting from Edition 2 of this standard, new versions of standardized common data classes shall only be made by the owner of the concerned name space.

A propriety Logical Node expansion (i.e. a set of non-standardized Data object added to the standard one) may be constructed with common data classes from the standard name space.

6.5 IEC 61850 communication services

IEC 61850 standardises the set of abstract communication services (Abstract Communication Service Interface services – ACSI, part 7-2) allowing for compatible exchange of information among components of a Power Utility Automation System.

IEC 61850 offers three types of communication models:

a) Client/Server type communication services model
b) Fast and reliable system-wide distribution of data, based on a publisher-subscriber model (GSE Management). Two control classes are defined for that purpose.
   – GOOSE – analogue and digital multicast
   – GSSE – digital data exchange over multicasts (deprecated)
c) Sample Values (SMV) model for multicast measurement values

The categories of services (defined in IEC 61850-7-2) are as follows:

   – retrieving the self-description of a device,

- fast and reliable peer-to-peer exchange of status information (tripping or blocking of functions or devices),
- reporting of any set of data (data attributes), SoE – cyclic and event triggered,
- logging and retrieving of any set of data (data attributes) – cyclic and event,
- substitution,
- handling and setting of parameter setting groups,
- transmission of sampled values from sensors,
- time synchronisation,
- file transfer,
- control devices (operate service),
- online configuration,

The way this set of abstract communication services and objects is specified, allows applications to be written in a manner which is independent from a specific protocol.

- These abstract services/objects must be "mapped" through the use of concrete application protocols and communication profiles as specified within a given Specific Communication Service Mapping (SCSM) as defined in parts 8 and 9.
- This abstraction allows both vendors and utilities to maintain application functionality and to optimise this functionality when appropriate.
- The concrete implementation of the device internal interface to the ACSI services is a local issue and is beyond the scope of this standard.

The IEC 61850 series provides an assortment of mappings which can be used for communication within the substation; the selection of an appropriate mapping depends on the functional and performance requirements.

NOTE Only application components that implement the same SCSM will be interoperable.

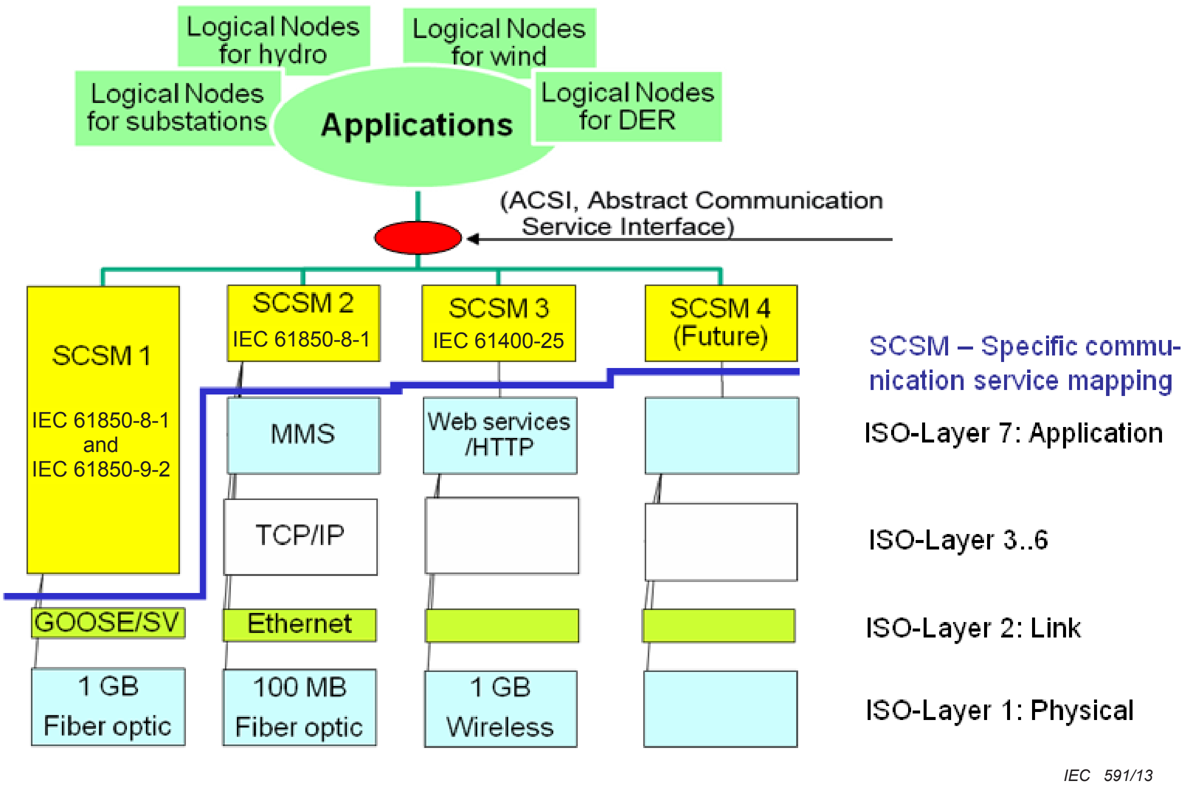


Figure 8 – Basic reference model

This mapping is shown in Figure 8 as “SCSM“. According to the facilities of the related application layer, the extent of the mapping can be different.

6.6 IEC 61850 SCL language

Engineering of a system normally starts before the system is physically available. In addition, modern IEDs are adaptable to a lot of different tasks. However, this might not mean that all possible tasks can run in parallel at the same time, which leads to the situation that several capability subsets for the same device have to be defined, each allowing to instantiate/use all of the contained capabilities.

Therefore, although the devices might be self-descriptive, the device capabilities as well their project specific configuration in general and with respect to the system parameters should be available in a standard way before the IED itself is available and engineered.

To be able to exchange the device descriptions and system parameters between tools of different manufacturers in a compatible way, IEC 61850-6 defines a System Configuration description Language (SCL). This language allows:

- System functional specification
- IED capability description
- Power Utility automation system description

These provide standardized support to system design, communication engineering and to the description of readily engineered system communication for device engineering tools, during the whole life cycle of the installation.

The SCL language itself is based on XML. Through SCL configuration files, the language in its full scope allows to describe an object oriented model of a power utility automation system and can contain the following subsections:

– The primary power system structure: which primary apparatus functions are used, and how the apparatus are connected. This results in a designation of all covered switchgear as substation automation functions, structured according to IEC 81346-1;
– The communication system: how IEDs are connected to sub-networks and networks, and at which of their communication access points, how data is grouped into data sets for sending, how IEDs trigger the sending and which service they choose, which input data from other IEDs is needed;
– Each IED: the logical devices configured on the IED, the logical nodes with class and type belonging to each logical device, the reports and their data contents, the (pre-configured) associations available; and which data shall be logged;
– Logical node (LN) type definitions. It is allowed to add user defined data. In this standard therefore instantiable LNTypes and DOTypes are defined as templates, which contain the actual implemented DOs and services;

SCL allows the description of relationships between instantiated logical nodes and their hosting IEDs on one side and the switch yard (function) parts on the other side."

SCL supports both functional and product specific naming. A power utility automation system can therefore be specified with product names independently of any selection of specific IEDs. Later on, during the engineering, the products can be selected and the product specific names are linked to the functional names.

6.7 IEC 61850 data and communication security

Necessary mechanisms to ensure data and communication cyber security are specified under the banner of the IEC 62351 standards for data and communications security.

The specific part 6 of IEC 62351 applies to the IEC 61850 standard series.

The different communication profiles of IEC 61850 require security enhancements to ensure that they can be implemented and used in non-secure environments.

For Client/Server communication using TCP/IP based protocols like MMS, IEC 62351 specifies security primarily through TLS (as defined by RFC 2246), but may include additional measures to secure remote access to power utility LAN such as VLANs and firewalls

For sampled values and GOOSE peer-to-peer communication that are multicast datagrams and not routable, the messages need to be transmitted and received potentially as fast as within a quarter of a cycle (4 to 5 ms). This implies that most encryption techniques or other security measures which affect transmission rates are not acceptable. Therefore authentication through a digital signature is the only security measure included for these protocols.

6.8 IEC 61850 conformance testing

Conformance claims and the establishment of their validity are important aspects of the acceptance of systems and equipment. IEC 61850-10 specifies conformance testing methods for conformance testing of devices of substation automation systems and in addition gives guidelines for setting up test environments and system testing, thus supporting interoperability of devices and systems.

Safety and EMC compliance requirements are specified in IEC 61850-3.

Further enhancement of testing methods will cover tool, interoperability and functional testing.

6.9 UCA/IEC 61850 international users group

The users of IEC 61850 have formed a community which is hosted by UCA. Under the UCA banner, this international community of IEC 61850 users contributes to the IEC 61850 maintenance process through IEC national committees, as well as in the quality assurance process attached to IEC 61850. The activities related to maintenance of IEC 61850 are described in 6.10.

For conformance testing, the members of the UCA users group have agreed to establish a conformance test program. While IEC 61850-10 specifies what to test, how to test is specified in test procedures created by the UCA/IEC 61850 international users group. Certificates of conformance according to the test program from the UCA users group may then be issued by test facilities that have been accredited by the UCA/IEC 61850 users group as part of this test program.

Any document related to this activity is accessible through www.ucaiug.org.

The main contributions of the UCA/IEC 61850 community in this area are described in 6.10.

6.10 IEC 61850 maintenance

Attached to the release of IEC 61850 standard series and in addition to the standard IEC maintenance process, a specific maintenance process is set up to handle technical issues raised after publication. Here are the main principles:

- Technical issues (called TISSUES) are collected from the release of the new document in cooperation with the UCA/IEC 61850 international users group (see clause 6.9). The collected TISSUES can be categorized in two groups:
  - TISSUES that can threaten interoperability between implementations of the standard and that need either corrections or clarifications (“IntOp” TISSUES)
  - TISSUES that propose new features that will be implemented in future versions of the standard (“next edition” TISSUES)
- IntOp TISSUES require immediate clarification and are following a transparent fixing process handled by the UCA/IEC 61850 international users group together with the editors of the IEC 61850 standard series.
- The detailed specification of this process, the list of TISSUES, associated fix, and their status and their impact on implementation and certification are accessible through the UCA web site (see 6.9).
- IEC recommends implementing the proposed fixes to IntOp TISSUES, as soon as they have reached the “green” status. The list of TISSUES which are implemented in an IED should be transparently stated by its manufacturer.

6.11 Quality assurance process

In the quality assurance process of IEC 61850 series, the testing committee of the UCA international users group (see 6.9), plays an important role. In particular, the UCA/IEC 61850 international users group:

- defines the detailed test procedures used for conformance testing (see 6.8)
- performs the accreditation of test labs that do conformance testing of IEC 61850 products (see 6.8)
- define, handle and maintain the TISSUES process in cooperation with the body in charge of the maintenance of IEC 61850 (see 6.9)
- recommends TISSUES to be implemented between editions of the IEC 61850 standard (“IntOp. TISSUES”)

– is responsible for the hosting of the TISSUES Database
– ensures that the conformance test procedures cover the correct implementation of the fixed IntOp TISSUES.

7 IEC 61850 system life cycle

7.1 Reason for inclusion

If a utility is planning to build a Power Utility Automation System, and is intending to combine IEDs from different vendors, it expects not only interoperability of functions and devices, but also uniform system handling and harmonised general system properties.

This is the reason the IEC 61850 series covers not only communication, but also qualitative properties of engineering-tools, measures for quality management, and configuration management.

7.2 Engineering-tools and parameters

Components of a Power Utility Automation System contain both configuration and operational parameters. Configuration parameters are normally set off-line and require an application restart after any change; operational parameters may be set and changed on-line without disturbing the system operation.

System parameters determine the cooperation of IEDs including the internal structures and procedures of a Power Utility Automation System in relation to its technological limits and available components. System parameters must be consistent; otherwise distributed functions may not work correctly.

Process parameters describe information exchanged between the process environment and the Power Utility Automation System.

Functional parameters describe the qualitative and quantitative features of functionality used by the customer. Normally the functional parameters are changeable on-line.

Tools should be able to exchange at least system and configuration parameters, and to detect (and prevent) violations of consistency. One way to achieve this is illustrated in Figure 9. Syntax and semantics of system parameter exchange is specified in IEC 61850-6.

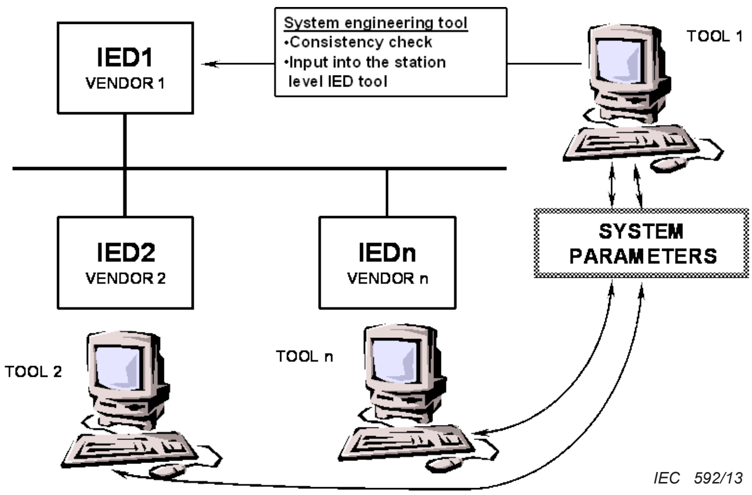


Figure 9 – Exchange of system parameters

Engineering-tools are tools to determine and to document the application specific functionality and the integration of devices into the power utility automation system.

The IEC 61850 series defines requirements on engineering-tools, especially for system configuration and parameterisation.

7.3 Main tools and configuration data flows

According to IEC 61850-6, an IED shall only be considered compatible in the sense of the IEC 61850 series, if it is accompanied either by:

- an SCL file describing its capabilities,
- an SCL file describing its project specific configuration and capabilities,
- or by a tool which can generate one or both, of these files.

The IED shall be able to directly use a system SCL file to set its communication configuration, as far as setting is possible in this IED, or it is accompanied by a tool which can import a system SCL file to set these parameters to the IED.

The **IED Configurator** is a manufacturer-specific, may be even IED specific, tool that is able to import or export the files defined by IEC 61850-6. The tool then provides IED specific settings and generates IED-specific configuration files, or it loads the IED configuration into the IED.

The **System Configurator** is an IED independent system level tool that is able to import or export configuration files defined by IEC 61850-6. It is able to import configuration files from several IEDs, as needed for system level engineering, and used by the configuration engineer to add system information shared by different IEDs. Then the system configurator can generate a substation-related configuration file as defined by IEC 61850-6, which is fed back to the IED Configurator for system-related IED configuration. The System Configurator should also be able to read a System specification file for example as a base for starting system engineering, or to compare it with an engineered system for the same substation.

7.4 Quality and life-cycle management

The IEC 61850 series covers quality assurance for system life-cycles, with definition of the utility’s and the vendor’s responsibilities.

The vendor’s responsibility ranges from development complying with ISO 9001 or similarly internationally recognised quality management system, system test, type test and obtaining certifications (including standards conformance certifications) to service and deliveries after discontinuation.

As the power utility automation system and its components are subject to continuous development, the system, the components, and the engineering tools should be unambiguously identified by version identifiers according to IEC 61850-4.

7.5 General requirements

General requirements of the communication network are defined in IEC 61850-3, with emphasis on the quality requirements. It also deals with guidelines for environmental conditions and auxiliary services, with recommendations on the relevance of specific requirements from other standards and specifications.

Quality requirements are defined in detail, such as reliability, availability, maintainability, security, data integrity and others that apply to the communication systems that are used for monitoring and control of processes within the Power Utility Automation System.

Other "general" requirements of part 3 are geographic requirements. Communication networks within substations should be capable of covering distances up to 2 kilometres. For some components of a Power Utility Automation System, for example bay control units, there is no responsible "product committee" in the IEC. Therefore, environmental conditions have to be standardised by referring to other applicable IEC standards.

References have been made to other IEC normative documents concerning climatic, mechanical, and electrical influences that apply to the communications media and interfaces that are used for monitoring and control of processes within the Power Utility Automation System.

Communications equipment may be subjected to various kinds of electromagnetic disturbances, conducted by power supply lines, signal lines or directly radiated by the environment. The types and levels of disturbance depend on the particular conditions in which the communications equipment has to operate.

For EMC requirements, other IEC standards are referenced. However, additional requirements have been elaborated in IEC 61850-3.

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