

# TECHNICAL REPORT

# RAPPORT TECHNIQUE



**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**



**THIS PUBLICATION IS COPYRIGHT PROTECTED**  
**Copyright © 2013 IEC, Geneva, Switzerland**

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.  
If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.  
Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### Useful links:

IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,...).

It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).

---

### A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Liens utiles:

Recherche de publications CEI - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,...).

Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).

# TECHNICAL REPORT

# RAPPORT TECHNIQUE



**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

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 33.200

ISBN 978-2-83220-686-7

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references .....	7
3 Terms, definitions and abbreviations .....	9
3.1 Terms and definitions .....	9
3.2 Abbreviated terms .....	11
4 Objectives .....	12
5 Approach of the IEC 61850 standard .....	13
5.1 Scope of application.....	13
5.2 IEC 61850 within the IEC Power Utility control system reference architecture .....	14
5.3 IEC 61850 within Smart Grid reference architecture .....	15
5.4 Standardization approach.....	15
5.5 How to cope with fast innovation of communication technology .....	16
5.6 Representation of functions and communication interfaces.....	16
5.7 Requirements for a physical communication system .....	20
6 Content of the IEC 61850 series .....	20
6.1 IEC 61850 general requirements (parts 1 to 5).....	20
6.2 Three pillars of interoperability and conformance testing (Part 6 and above) .....	21
6.3 Understanding the structure of the IEC 61850 documentation .....	22
6.4 IEC 61850 data modelling .....	24
6.4.1 Main principle (explained in IEC 61850-7-1) .....	24
6.4.2 Standard name space introduction.....	25
6.4.3 Name space extension .....	26
6.5 IEC 61850 communication services .....	26
6.6 IEC 61850 SCL language .....	28
6.7 IEC 61850 data and communication security .....	29
6.8 IEC 61850 conformance testing.....	29
6.9 UCA/IEC 61850 international users group .....	30
6.10 IEC 61850 maintenance .....	30
6.11 Quality assurance process .....	30
7 IEC 61850 system life cycle.....	31
7.1 Reason for inclusion.....	31
7.2 Engineering-tools and parameters .....	31
7.3 Main tools and configuration data flows .....	32
7.4 Quality and life-cycle management.....	32
7.5 General requirements.....	32
Figure 1 – Scope of application of IEC 61850 .....	14
Figure 2 – Power utility control system reference architecture (IEC 62357).....	15
Figure 3 – IEC 61850 specifying approach.....	16
Figure 4 – Interface model within substation and between substations.....	17
Figure 5 – Relationship between functions, logical nodes, and physical nodes (examples).....	19
Figure 6 – Links between IEC 61850 parts.....	22

Figure 7 – IEC 61850 Data modelling.....	24
Figure 8 – Basic reference model.....	28
Figure 9 – Exchange of system parameters .....	31

Single user licence  
EEESC WG on Smart Grids  
IECNORM.COM : Click to view the full PDF of IEC TR 61850 WG 1:2013  
No reproduction or circulation  
Sep 2024

# INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

## 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.
- 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 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<sup>1</sup>
- Part 7-500: Use of logical nodes to model functions of a substation automation system<sup>1</sup>
- 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<sup>1</sup>
- 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<sup>1</sup>
- Part 90-3: Using IEC 61850 for condition monitoring<sup>1</sup>
- Part 90-4: Network Engineering Guidelines - Technical report<sup>1</sup>
- 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.

---

<sup>1</sup> 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 with 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 were 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 61850-90-22)
- 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.

---

<sup>2</sup> To be published.

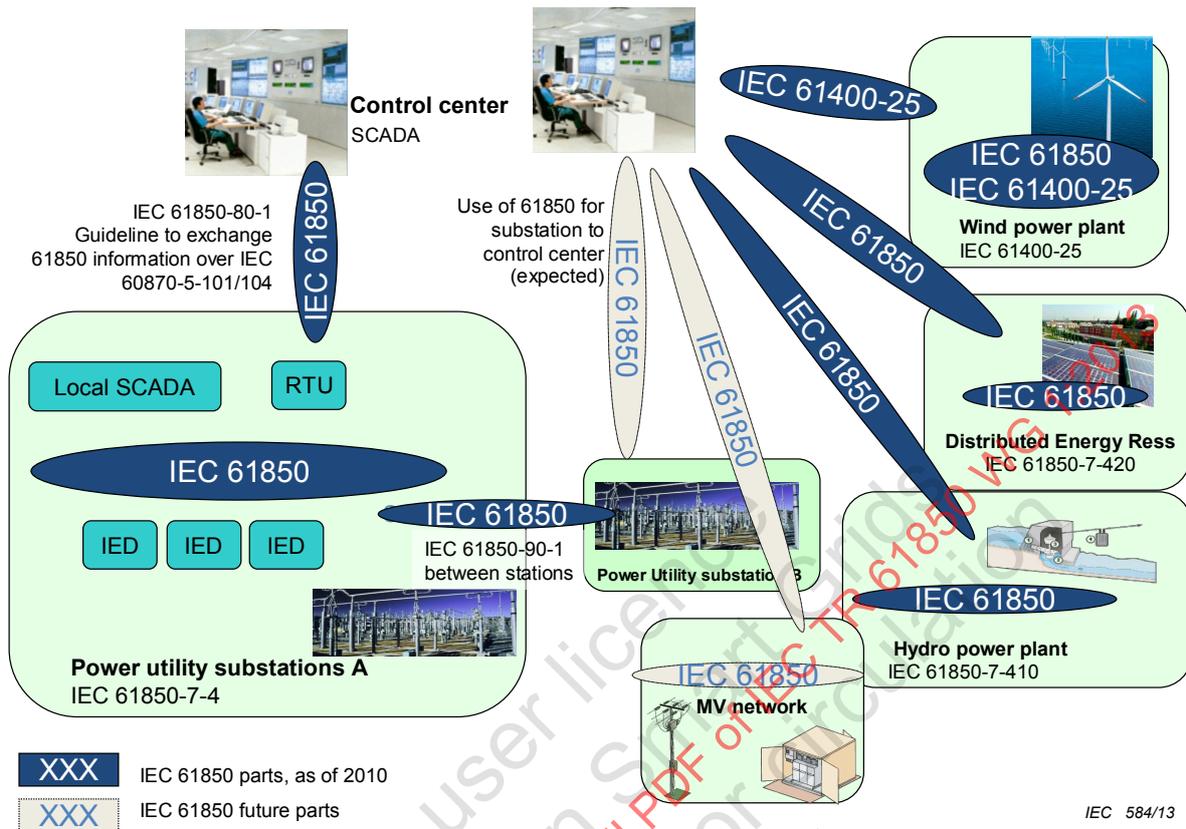
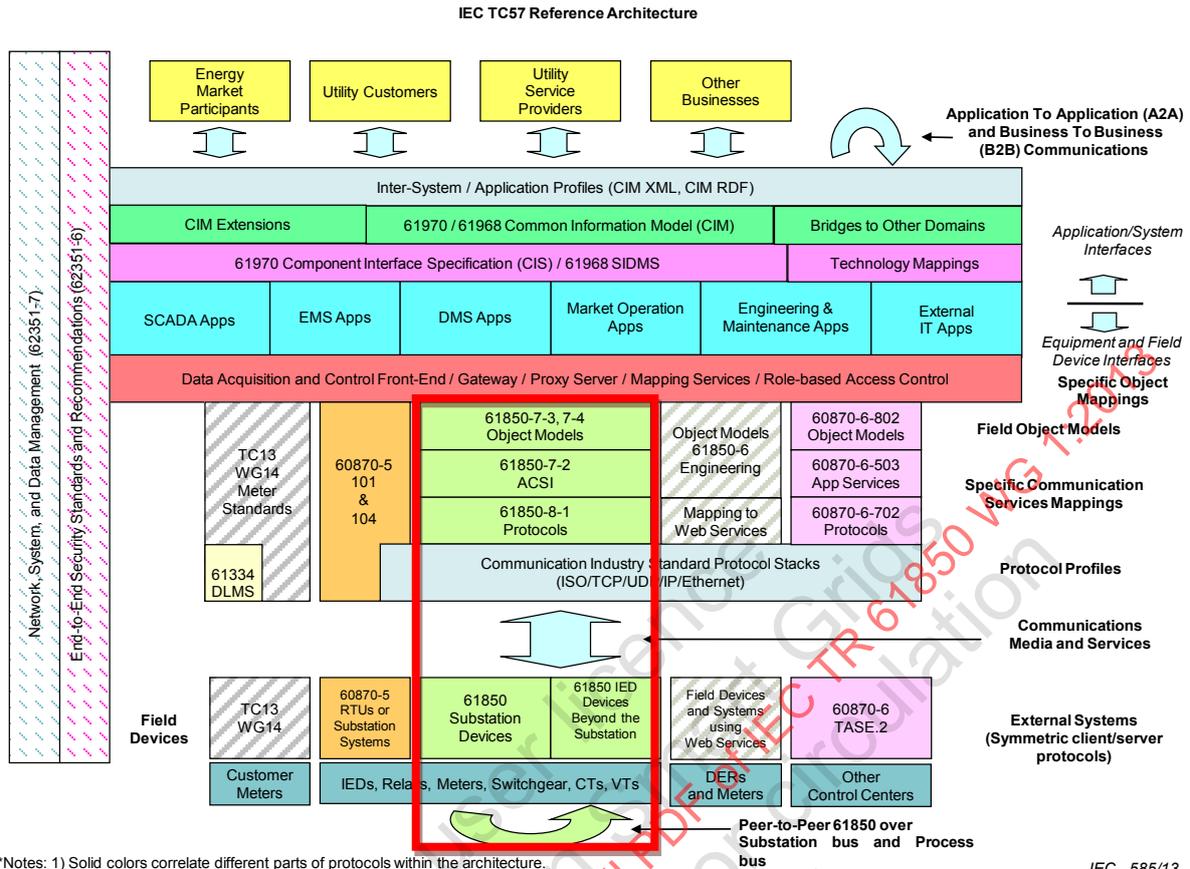


Figure 1 – Scope of application of IEC 61850

## 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."<sup>3</sup>

**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.

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

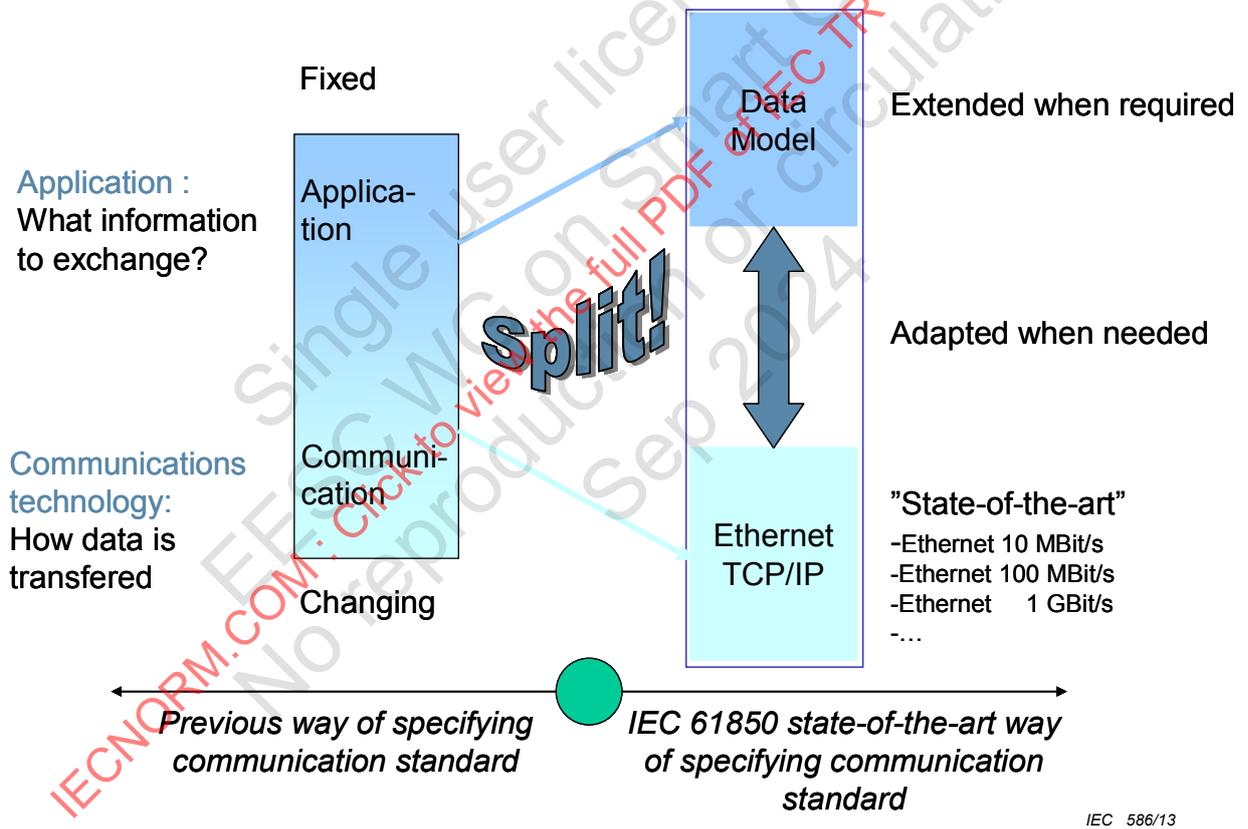
Data flow is used to understand the communication interfaces that must support the exchange of information between distributed functional components and the functional performance requirements.

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.



IEC 586/13

**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.

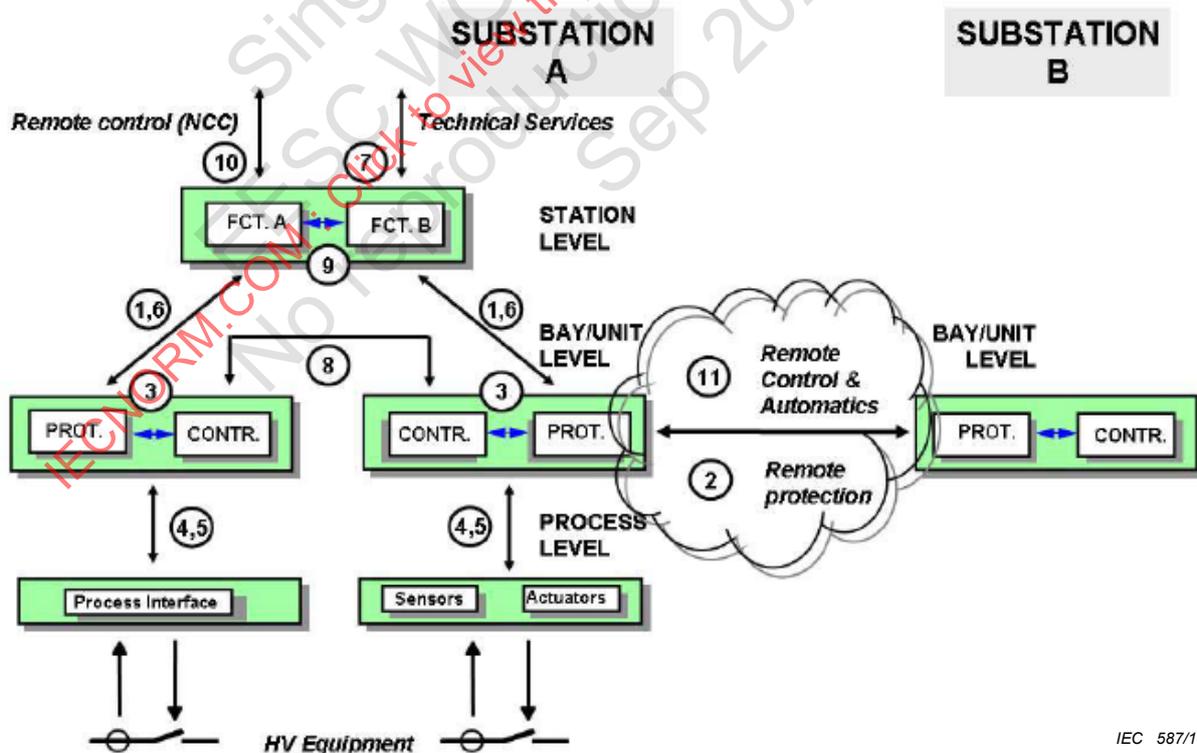
The functions (application functions) of a Power Utility Automation system are control and supervision, as well as protection and monitoring of the primary equipment and of the grid. Other functions (system functions) are related to the system itself, for example supervision of the communication.

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.

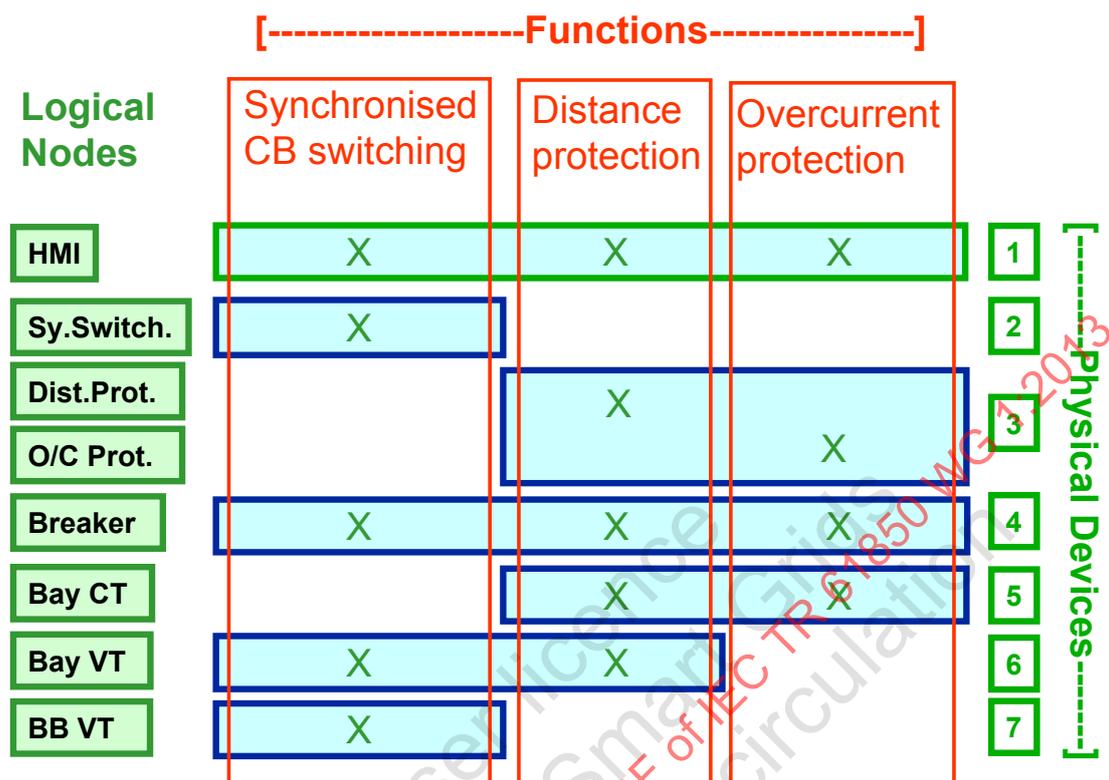
Station level devices consist of the station computer with a database, the operator's workplace, interfaces for remote communication, etc.

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.

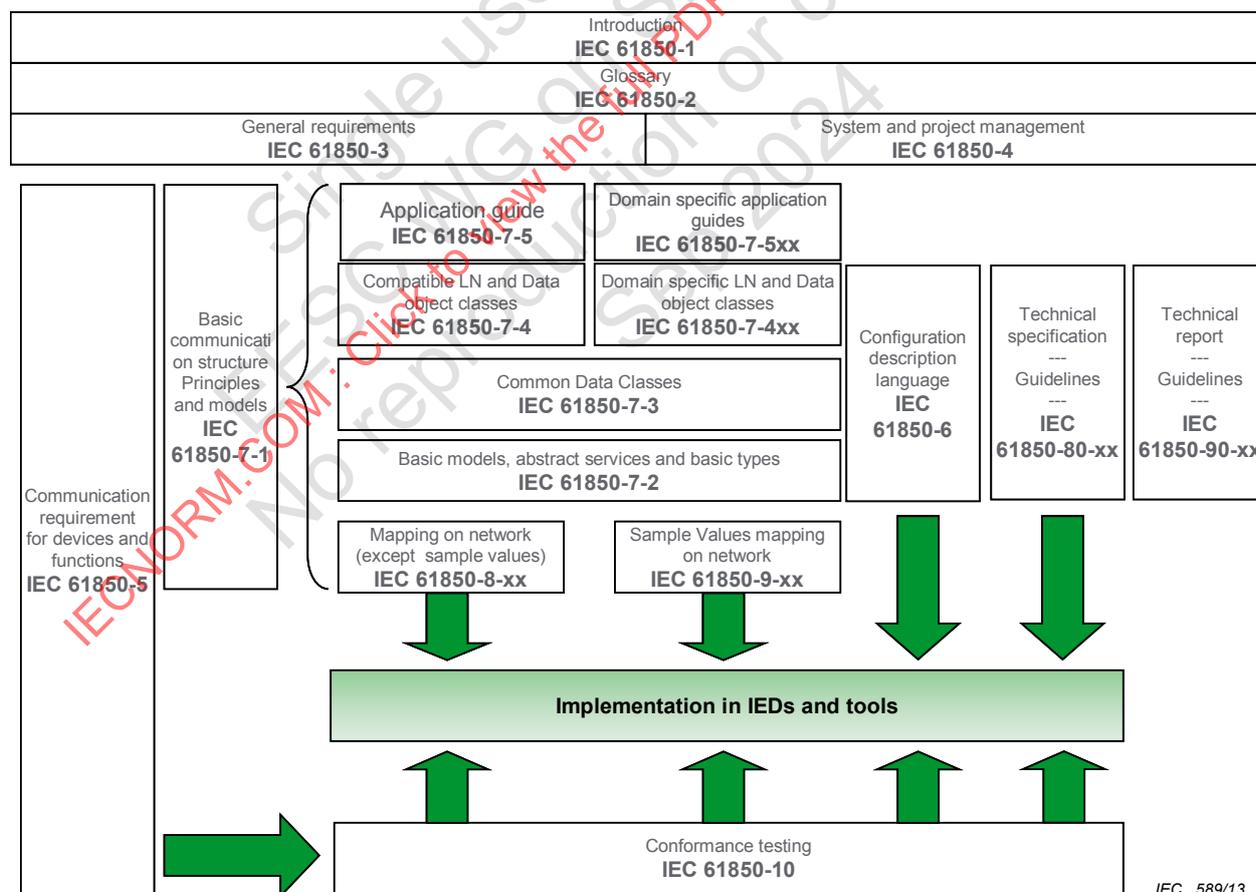
### 6.3 Understanding the structure of the IEC 61850 documentation

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 61850-90-44).

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:



IEC 589/13

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**

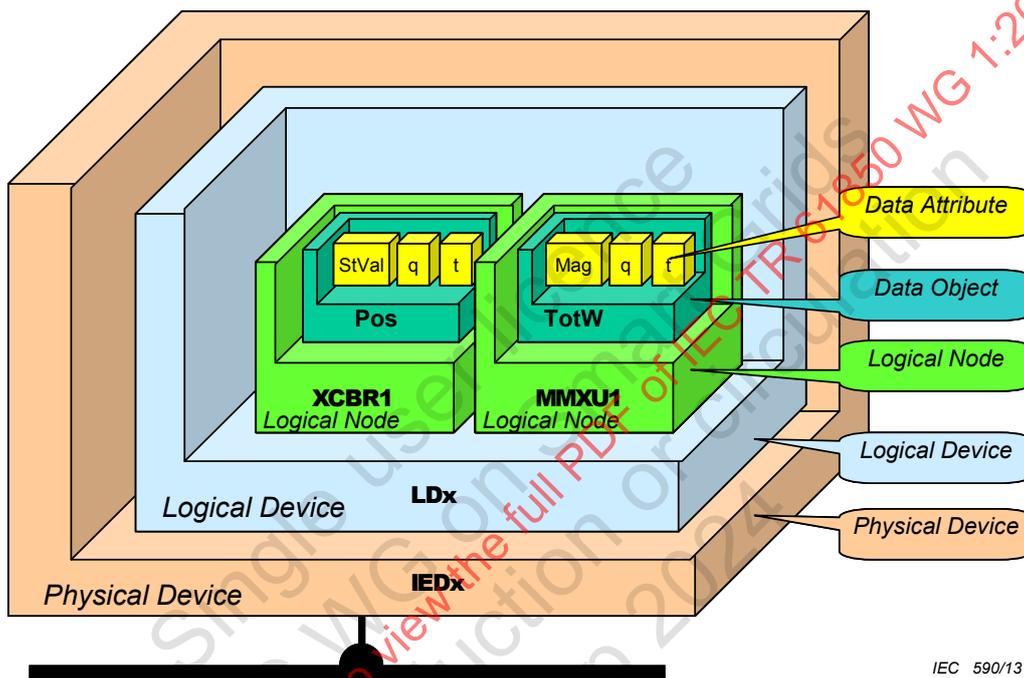
**6.4.1 Main principle (explained in IEC 61850-7-1)**

**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,