TECHNICAL REPORT

IEC TR 61850-1

First edition
2003-04

Communication networks and systems in substations –

**Part 1:
Introduction and overview**

Réseaux et systèmes de communication dans les postes –

*Partie 1:
Introduction et vue d'ensemble*

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COMMUNICATION NETWORKS AND SYSTEMS IN SUBSTATIONS –

Part 1: Introduction and overview

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 system control and associated communications

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

Enquiry draft	Report on voting
57/524/CDV	57/561/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.

IEC 61850 consists of the following parts, under the general title *Communication networks and systems in substations* [1].

Part 1: Introduction and overview

Part 2: Glossary [2]

Part 3: General requirements

Part 4: System and project management

Part 5: Communication requirements for functions and device models [3]

Part 6: Configuration description language for communication in electrical substations related to IEDs [2]

Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models

Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)

Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes

Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes

Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISO/IEC 8802-3 [2]

Part 9-1: Specific communication service mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link

Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3 [2]

Part 10: Conformance testing [2]

This part is an introduction and overview of the IEC 61850 standard series. It describes the philosophy, the work approach, the contents of the other parts, and documents of other bodies which have been reviewed.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

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

1 For more details, see Clause 10.

2 Under consideration.

3 To be published.

COMMUNICATION NETWORKS AND SYSTEMS IN SUBSTATIONS –

Part 1: Introduction and overview

1 Scope

This technical report is applicable to substation automation systems (SAS). It defines the communication between intelligent electronic devices (IEDs) in the substation and the related system requirements.

This part gives an introduction and overview of the IEC 61850 standard series. It refers to and includes text and Figures from other parts of the IEC 61850 standard series.

2 Reference documents

IEC 60870-5-103:1997, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*

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

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

IEC 61850-7-1: *Communication networks and systems in substations – Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models*

IEC 61850-7-2: *Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)*

IEC 61850-7-3: *Communication networks and systems in substations – Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes*

IEC 61850-7-4: *Communication networks and systems in substations – Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes*

ISO 9001, 2001: Quality management systems – Requirements

IEEE C37.2,1996 *IEEE Standard Electrical Power System Device Function Numbers and Contact Designations*

IEEE 100,1996, *IEEE Standard Dictionary of Electrical and Electronic Terms*

IEEE-SA TR 1550,1999: *Utility Communications Architecture (UCA) Version 2.0 – Part 4: UCA Generic Object Models for Substation and Feeder Equipment (GOMSFE)*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply:

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
a substation consists of closely connected subparts with some common functionality. 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.

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

[IEEE 100,1996]

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

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/control 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. A LN is an object defined by its data and methods.

3.1.10
open protocol
protocol whose stack is either standardised or publicly available

3.1.11
Physical Device
PD
equivalent to an IED as used in the context of this standard

3.1.12
PICOM
description of an information transfer on a given logical connection with given communication attributes between two logical nodes (Piece of Information for COMmunication). It also contains the information to be transmitted and, in addition, requirement attributes such as performance. It does not represent the actual structure and format for data that is exchanged over the communication network. The PICOM approach was adopted from CIGRE working group 34.03.

3.1.13
protocol
set of rules that determines the behaviour of functional units in achieving and performing communication

3.1.14
self-description
a device contains information on its configuration. The representation of this information has to be standardised and has to be accessible via communication (in the context of this standard series).

3.1.15
system
within the scope of this standard, system always refers to substation automation systems unless otherwise stated

3.1.16
Specific Communication Service Mapping
SCSM
standardised procedure which provides the concrete mapping of ACSI services and objects onto a particular protocol stack/communication profile.

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.

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.

SCSMs are specified in the parts 8-x and 9-x of this standard series.

3.2 Abbreviated terms

ACSI	Abstract Communication Service Interface
AIS	Air Insulated Switchgear
CB	Circuit Breaker
CDC	Common Data Class
DO	Data Object
EMC	Electromagnetic Compatibility
GOMSFE	Generic Object Models for Substation and Feeder Equipment
IED	Intelligent Electronic Device
GIS	Gas Insulated Switchgear
LN	Logical Node
PD	Physical Device
PICOM	Piece of Information for COMmunication
SA	Substation Automation
SAS	Substation Automation System
SCSM	Specific Communication Service Mapping

4 Objectives

The possibility to build SAS 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 SAS 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. Up to now, specific proprietary communication protocols developed by each manufacturer have been 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 communication protocols, 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 is beyond this communication standard. Interoperability is a common goal for electric utilities, equipment vendors and standardisation bodies. In fact, in recent years several National and International institutions started activities to achieve this goal (see Annex B).

The objective of SA 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 of the substation. 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 SAS. The application functions will be identified and described in order to define their communication requirements (for example, amount of data to be exchanged, exchange time constraints, etc.). The communication protocol standard, to the maximum possible extent, should make use of existing standards and commonly accepted communication principles.

The standard should 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 a 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 standard considers the implications of the substation being one node in the power grid, i.e. of the SAS being one element in the overall power control system.

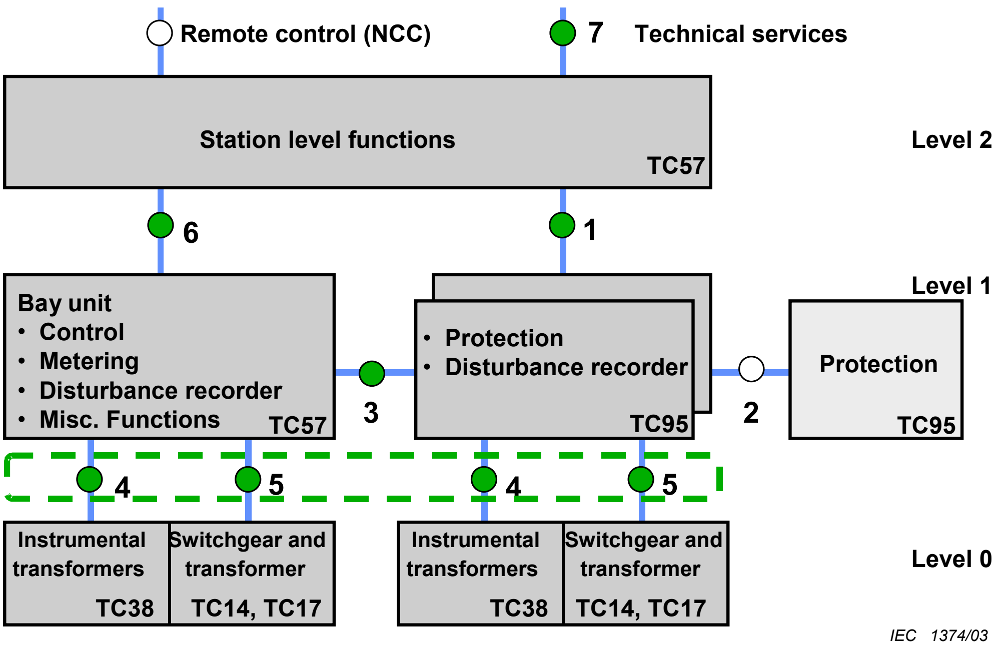
5 History

Starting in 1994, an ad-hoc working group "Substation Control and Protection Interfaces" of IEC Technical Committee 57 elaborated proposals for a standardisation of communication in substation automation systems. The following proposals have been presented to and accepted by the National Committees:

- Elaboration of a standard on functional architecture, communication structure and general requirements;
- Elaboration of a standard on communication within and between unit and substation levels;
- Elaboration of a standard on communication within and between process and unit levels;
- Elaboration of a companion standard for the informative interface of protection equipment.

The companion standard for the informative interface of protection equipment has been elaborated by the ad-hoc working group and has been published as IEC 60870-5-103.

The communication interfaces within the substation automation system may be represented by the general structure shown in Figure 1.



NOTE Logical interface 2 (teleprotection) and the interface to the remote control centre (NCC) are beyond the scope of the IEC 61850 series.

Figure 1 – Logical interfaces of an SAS

The interfaces between the functional blocks do not represent physical interfaces of physical devices – they are "logical interfaces", i.e. they are independent from real communication systems.

Figure 1 shows the IEC Technical Committees that are responsible for standards related to devices; a close co-operation with these committees was considered to be mandatory. To guarantee a close co-operation, all the mentioned committees have delegated specialists to the working groups responsible for elaboration of the IEC 61850 series.

6 Approach to the elaboration of an applicable standard

6.1 General

The approach is to blend the strengths of the following three methods: functional decomposition, data flow, and 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 that describe the functions, subfunctions and functional interfaces.

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.

6.2 Functions and logical nodes

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

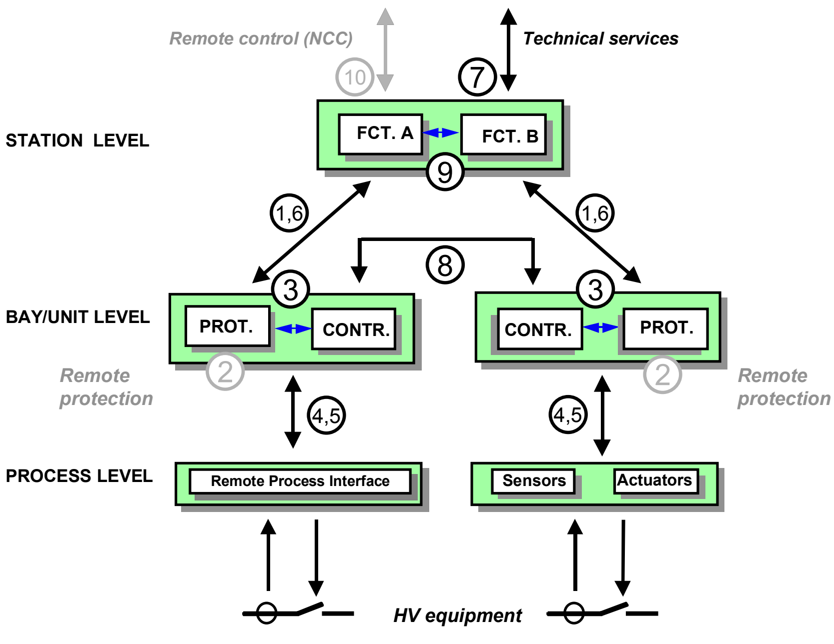
The allocation of functions to devices (IEDs) and control levels is not fixed. The allocation normally depends on availability requirements, performance requirements, cost constraints, the state of the art of technology, utilities' philosophies etc. Therefore, the standard should support any allocation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

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

The functions (application functions) of an SAS 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.

Early on it was realised the logical interfaces shown in Figure 1 were not sufficient; logical interfaces between functions at station level and between functions located in different bays were missing. Therefore a new structure was designed, containing the additional logical interfaces. The diagram shown in Figure 2 is the basis for the IEC 61850 series.



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

Figure 2 – Interface model of a substation automation system

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 (beyond the scope of this standard).

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

The devices of a substation automation system may be **physically** installed on different functional levels (station, bay, and process). This refers to the physical interpretation of Figure 2.

NOTE The distribution of the functions in a communication environment may occur through the use of wide area network, local area network, and process bus technologies. The functions are not constrained to be deployed within/over any single communication technology.

Process level devices are typically remote I/Os, intelligent sensors and actuators (see examples in Figure 2).

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 goals mentioned above, all known functions in a substation automation system have been identified and split into subfunctions (logical nodes). Logical nodes may reside in different devices and at different levels. Figure 3 shows examples to explain the relationship between functions, logical nodes, and physical nodes (devices).

A function is called 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 LN 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.

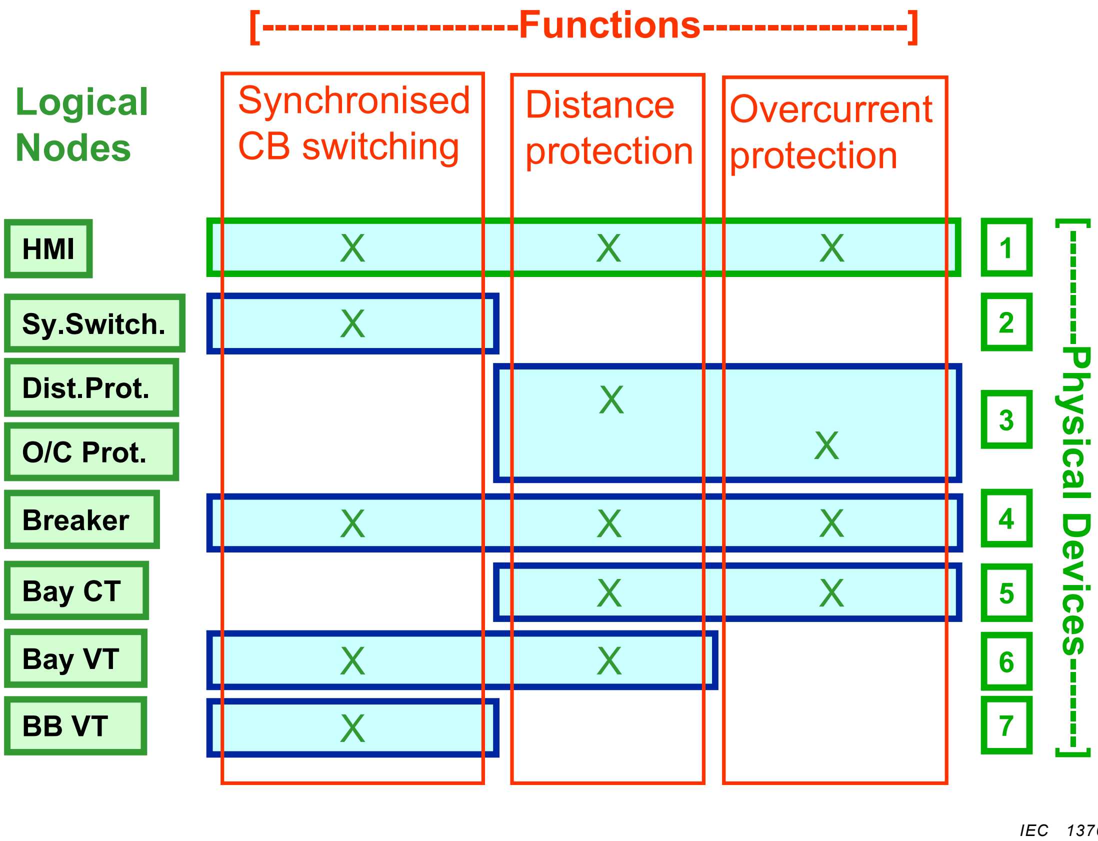


Figure 3 – Relationship between functions, logical nodes, and physical nodes (examples)

Examples in Figure 3: 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.

All known functions have been described in IEC 61850-5 by:

- 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.

All related logical nodes have been described in IEC 61850-5 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 C.37.2,1996);
- relationship between functions and logical nodes in tables and in the functional description;
- exchanged PICOMs described in tables.

'Dynamic' requirements on transmission of explicit PICOMs including their attributes such as the required data integrity have been elaborated by Working Group 03 of CIGRE Study Committee 34; the result has been published in a report and has been used in the IEC 61850 series.

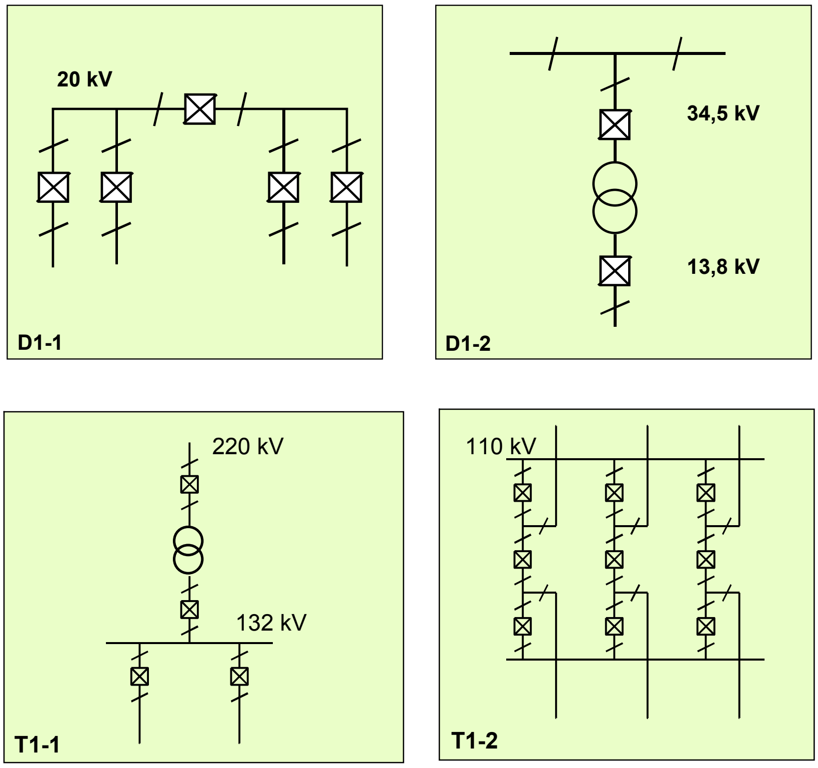
However, to simplify the approach, the PICOMs have been assigned to different message types according to SAS requirements (see Table 1).

Table 1 – Types of messages

Type	Name	Examples
1a	Fast messages – trip	Trips
1b	Fast messages – others	Commands, simple messages
2	Medium speed messages	Measurands
3	Low speed messages	Parameters
4	Raw data messages	Output data from transducers and instrument transformers
5	File transfer functions	Large files
6a	Time synchronisation messages a	Time synchronisation; station bus
6b	Time synchronisation messages b	Time synchronisation; process bus
7	Command messages with access control	Commands from station HMI

6.3 Substation topologies

As stated earlier, functional requirements should be independent of substation sizes. Thus, it is necessary to determine, for the complete range of performance requirements, the resulting data flow (bus load) for different types and sizes of substations. Therefore, representative types of worldwide substations have been analysed and the resulting data flow is documented (see IEC 61850-5). Figure 4 shows typical MV and HV substations. All types of substations that have been considered are described in Annex B.



IEC 1377/03

Figure 4 – Types of MV and HV substations

The identification of the types of substations, for example D1-2, is used as follows: Letter D is used for distribution substations, letter T is used for transmission substations. The first number represents the size of the substation (small, medium, large : the bigger the number, the bigger the size), the second number identifies variants.

6.4 Dynamic scenarios

The data-flow at logical interfaces has been calculated for normal and worst-case conditions for typical substations. Table 2 gives an example for the substation type T1-1. The data flow contains the information bits only and no protocol or message overhead.

Table 2 – Calculated information flow at logical interfaces (example)

Interface number	State of operation	Maximum busload [Kilobytes/s]	Remarks
Single network	Normal	244	
Single network	Worst-case	442	
1, 3, 6	"	123	Station bus
8	"	24	Station bus
4, 5	"	295	Process bus, all feeders
4, 5	"	65	Process bus, one feeder only

NOTE The worst-case scenario includes normal, emergency, abnormal and post-fault state of operations and is assuming the strongest transmission time requirement per signal for all signals (see IEC 61850-5, Clause 12).

6.5 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; a process bus may cover the logical interfaces 4 and 5. The logical interface 8 (‘inter-bay-communication’) may be mapped to either or to both. This mapping will have a major impact on the resulting required performance of the selected communication system (See Figures 5 and 6).

Mapping of all logical interfaces to one single bus is possible, if this satisfies the performance requirements.

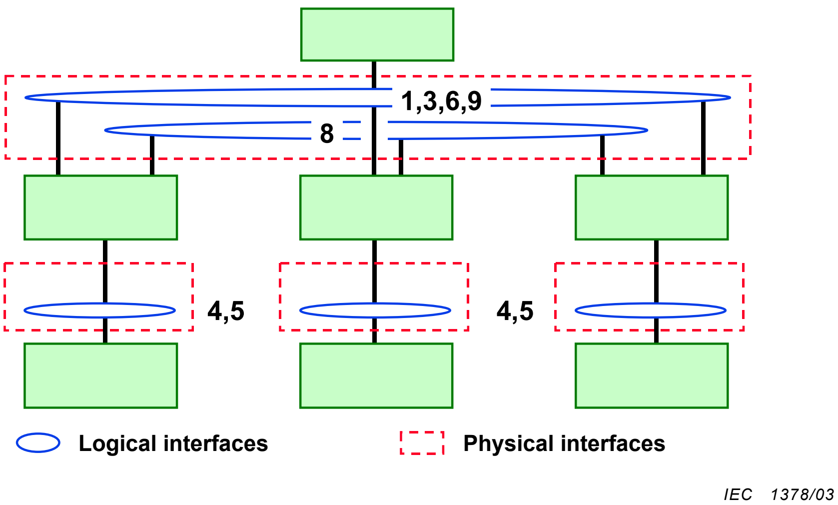


Figure 5 – Mapping of logical interfaces to physical interfaces; mapping of logical interface 8 to the station bus

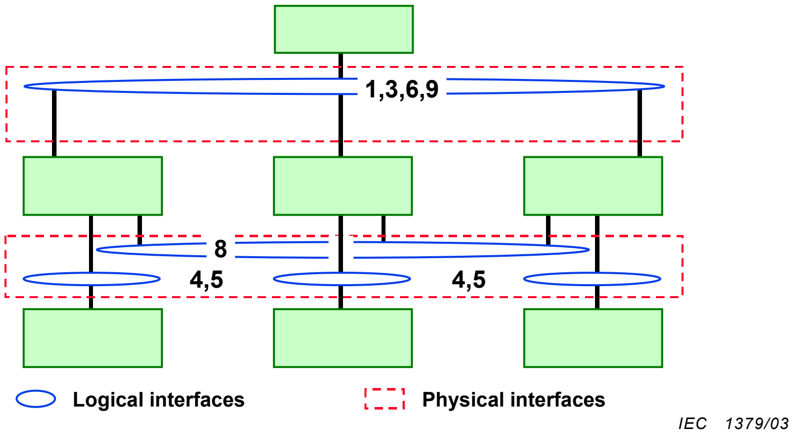


Figure 6 – Mapping of logical interfaces to physical interfaces; mapping of logical interface 8 to the process bus

7 How to cope with fast innovation of communication technology

7.1 Independence of communication from application

This standard specifies a set of abstract services and objects which may allow applications to 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. The application model specified in this standard consists of:

A vendor/user generated application written to invoke or respond to the appropriate set of Abstract Communication Service Interface (ACSI) services.

This standard standardises the set of abstract services to be used between applications and “application objects” allowing for compatible exchange of information among components of a substation automation system. However, these abstract services/objects must be instantiated through the use of concrete application protocols and communication profiles.

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 local ACSI is then mapped onto the appropriate set of concrete application protocol/communication profile services as specified within a given Specific Communication Service Mapping (SCSM). The state or changes of data objects are transmitted as concrete data.

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.

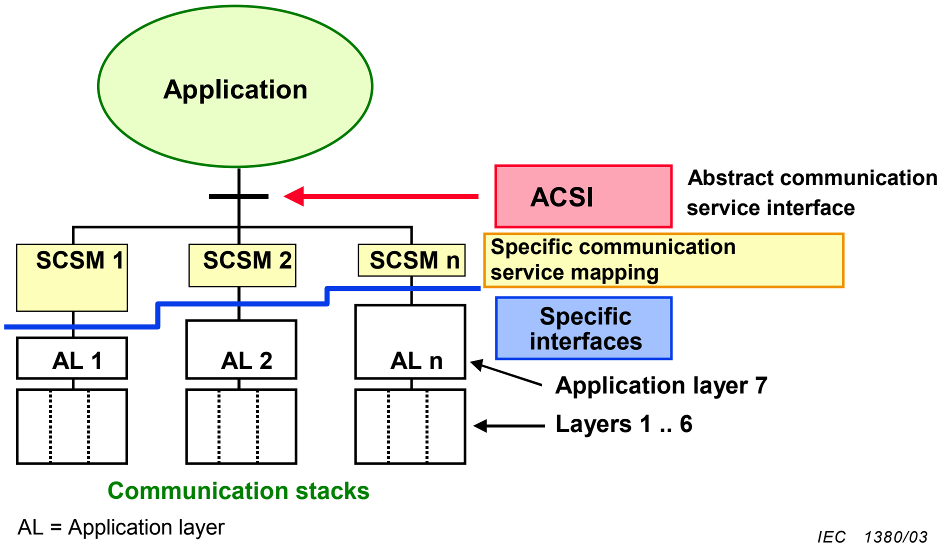


Figure 7 – Basic reference model

This mapping is shown in Figure 7 as "SCSM". According to the facilities of the related application layer, the effort for the mapping can be different.

7.2 Data modelling and services

Logical nodes can only interoperate with each other if they are able to interpret and to process the data received (syntax and semantics) and the communication services used. Thus it is necessary to standardise data objects assigned to logical nodes and their identification within the logical nodes.

Data and services of an application can be modelled in three levels (see Figure 8). The first level describes abstract models and communication services used to exchange information between logical nodes. Levels 2 and 3 define the application domain specific object model. This includes a specification of data classes with attributes and their relation to logical nodes.

Level 1: Abstract Communication Service Interface (ACSI)

The ACSI specifies the models and services used for access to the elements of the domain (substation automation) specific object model. Communication services provide mechanisms not only for reading and writing of object values, but also for other operations, for example for controlling primary equipment.

Level 2: Common Data Classes

The second level defines "Common Data Classes" (CDC). A common data class defines structured information consisting of one or more attributes. The data type of an attribute may be a foundation type (for example INTEGER) as defined in IEC 61850-7-1. More data types are defined as common data attribute types in level 2. Data classes as defined in level 3 are specialisations of CDCs according to their specific use in the application context.

Level 3: Compatible logical node classes and data classes

This level defines a compatible object model specifying logical node classes and data classes. No additional specification is required as the identification and meaning (semantics) of the logical node and data classes are defined. An example for a data class is 'switch position with quality and time stamp'.

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 (see reference in Annex B, point 12)).

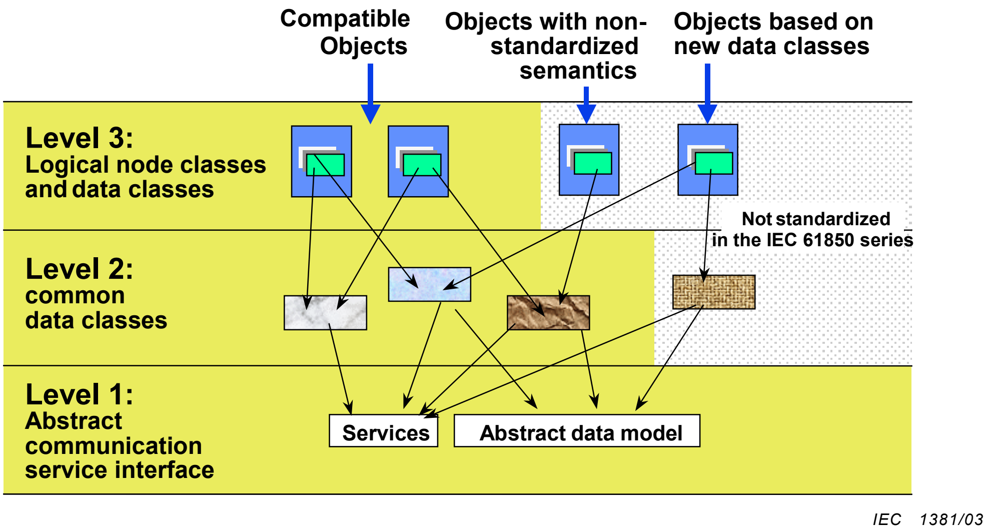


Figure 8 – The modelling approach of the IEC 61850 series

8 General system aspects

8.1 Motivation

If a utility is planning to build an SAS, and is intending to combine IEDs from different vendors, it expects not only interoperability of functions and devices, but also a 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.

8.2 Engineering-tools and parameters

Components of an SAS 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 co-operation of IEDs including the internal structures and procedures of an SAS in relation to its technological limits and available components. System parameters must be consistent; otherwise distributed functions are not working correctly.

Process parameters describe information exchanged between the process environment and the SAS.

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.[4]

[4] Under consideration.

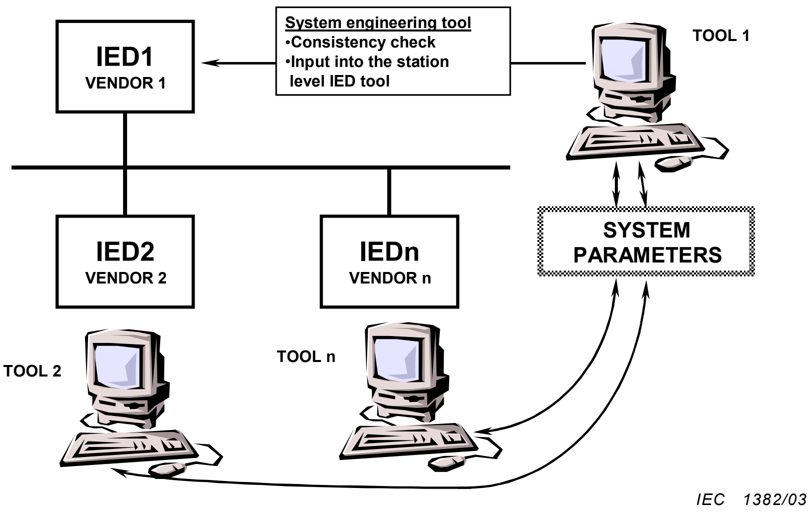


Figure 9 – Exchange of system parameters

Engineering-tools are tools to determine and to document the application specific functionality and the integration of devices into the SAS. They can be classified as

- project design tools;
- parameterising and configuration tools;
- documentation tools.

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

8.3 Substation automation system configuration 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 substation configuration language (SCL). This language allows

- to describe the capabilities of an IED in terms of the models of IEC 61850-5 and IEC 61850-7-x for import to the system engineering tool.
- to describe all data needed to define system parameters for a single IED. This includes especially the binding of the IED and its functions to the substation itself, in terms of its single line diagram, and its place in the communication system.

The language itself is based on XML. For the above purpose it contains the following subsections:

- **Substation subsection:** describes the substation single line diagram, and its binding to logical nodes as well as the placement of logical nodes onto IEDs. Thus also the binding of IEDs to substation parts and substation devices is defined.

- **Communication section:** describes the communication connections between IEDs in terms of connecting communication links.
- **IED section:** describes the capabilities (configuration) of one or more IEDs, and the binding to logical nodes on other IEDs.
- **LNType section:** defines which data objects are actually contained within the logical node instances defined for the IEDs.

8.4 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, system test, type test and certifications (including standards conformance certifications) to service and deliveries after discontinuation.

As SAS and its components are subject to continuous development, the system, the components, and the engineering tools should be unambiguously identified by version identifiers.

An example for vendors' obligations for deliveries after discontinuation is shown in Figure 10.

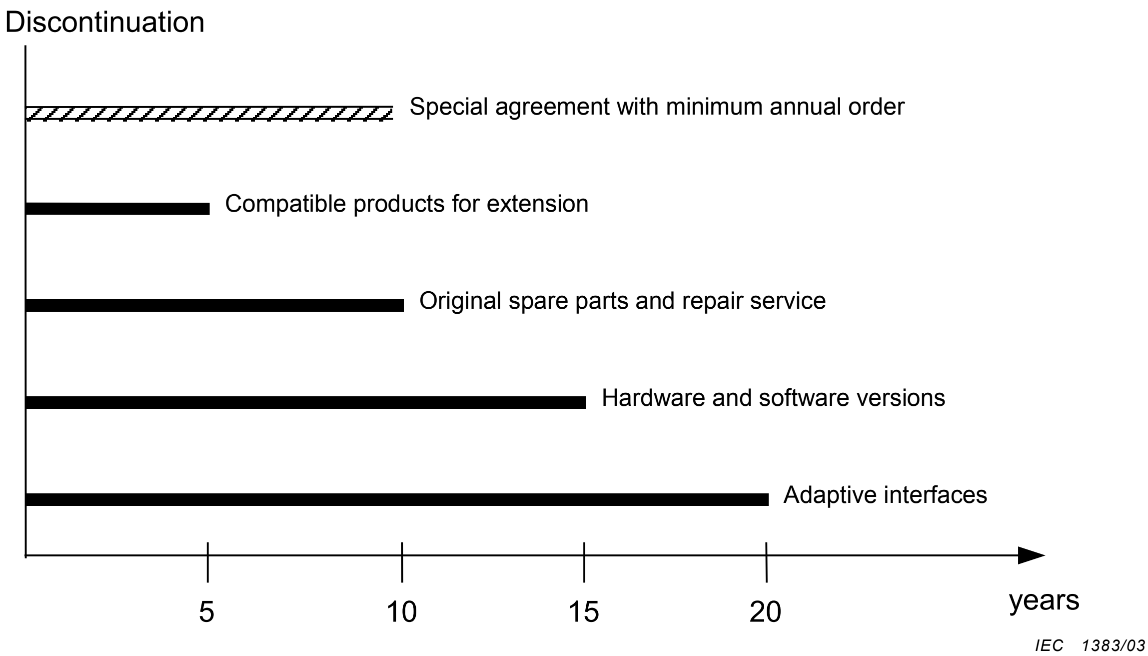


Figure 10 – Periods for delivery obligations (example)

8.5 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 substation.

Other “general” requirements are geographic requirements. Communication networks within substations should be capable of covering distances up to 2 kilometres. For some components of an SAS, 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 substation.

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.

9 Conformance testing

Conformance claims and the establishment of their validity are important parts 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.

10 Structure and contents of the standard series

The titles and contents of the published or planned parts of the IEC 61850 series are as follows:

IEC 61850-1 Introduction and overview

- Introduction and overview of IEC 61850.

IEC 61850-2 Glossary[5]

- Collection of terms.

IEC 61850-3 General requirements

- Quality requirements (reliability, maintainability, system availability, portability, security).
- Environmental conditions.
- Auxiliary services.
- Other standards and specifications.

5 Under consideration.

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

- Basic requirements.
- Logical nodes approach.
- Logical communication links.
- PICOM concept.
- Logical Nodes and related PICOMs.
- Performance.
- Functions.
- "Dynamic scenarios" (information flow requirements for different operational conditions).

IEC 61850-6 Configuration description language for communication in electrical substations related to IEDs [6]

- 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 node to primary system.

IEC 61850-7-1: Basic communication structure for substation and feeder equipment – Principles and models

- Introduction to IEC 61850-7-x;
- Communication principles and models.

IEC 61850-7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)

- Description of the ACSI.
- Specification of the abstract communication services.
- Model of the device database structure.

IEC 61850-7-3: Basic communication structure for substation and feeder equipment – Common data classes

- Common data classes and related attributes.

IEC 61850-7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes

- Definitions of logical node classes and data classes; logical node classes are composed of data classes.

[6] Under consideration.

IEC 61850-8 Specific communication service mapping[7]

- Mapping(s) of services commonly used for communication within the whole substation

IEC 61850-9 Specific communication service mapping[7]

- Mapping(s) of services used for the transmission of sampled analogue values

IEC 61850-10 Conformance testing[7]

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

[7] Under consideration.

Annex A
(informative)

Types of substations and communication bus structures

A.1 Definitions of typical substation configurations

The performance requirements on a communication network in a substation will depend on the size of the substation and its importance in the power system. In the following sections, substations are classified according to their sizes and functions. The power system network function determines the class and the communication requirements.

To establish communication performance requirements, substations are typically divided into distribution and transmission substations. A distribution substation is usually defined as being predominantly equipped with outgoing feeders in the voltage range of 30 kV and under. The one or two incoming feeders may be at a transmission voltage level. A transmission substation is usually defined as being predominantly equipped with transmission-level feeders (i.e., 100 kV and above); although there might be a small distribution-level section. These voltage values are not exact limits; transmission and distribution voltages may be defined differently by different utilities. A further grouping is based on the number of controlled power system elements in the substation. An element will in this sense consist of, for example, a feeder, a transformer or a capacitor bank.

Substations, having no remote control facilities and no SAS (Substation Automation System), are not considered in this document.

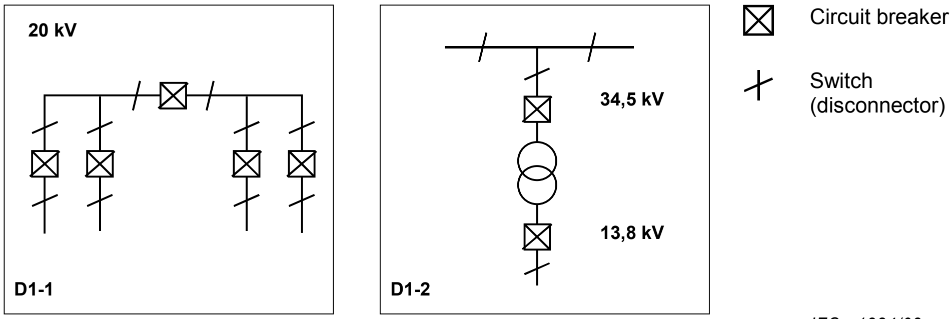
A.2 Types of substations

A.2.1 D1 Small distribution substation

A substation with not more than five elements. A typical example is a switching station with 4 feeders and a tie-breaker. The substation would be equipped only with simple over-current protection, summarised alarms, bay level HMI and limited control facilities, for example only circuit-breaker control. Metering may only include a single phase current from each feeder. Substation automation is limited to the remote control gateway. Communication system interfaces utilised are 3, and 6 plus sometimes 4 and 5.

Usually only a limited substation level in the automation system exists, consisting primarily of the remote control gateway.

For some distribution substations, the primary equipment is designed as enclosed, preassembled modules with all equipment, including bay control and relaying installed by the vendor. This allows for a complete set-up and testing of communication interfaces 3, 4 and 5 at the factory, with very little additional work required at the field site.



IEC 1384/03

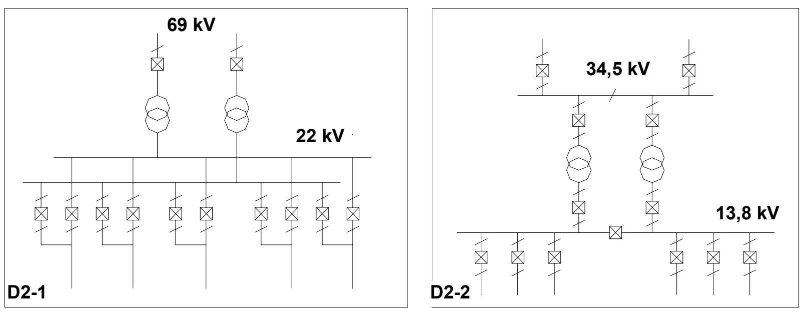
Figure A.1 – Examples of typical single line diagram for type D1

A.2.2 D2 Medium distribution substation

The most common type of substation has more than five but less than twenty elements. A typical example would be a substation with two incoming feeders, two transformers, two busbars on the low voltage side and a number of outgoing feeders, or at least one busbar on each voltage level. The substation will have overcurrent, directional earth fault and transformer differential protection. The busbar is protected by backup overcurrent protection on incoming feeders, with blocking signals from outgoing feeder's relays. Individual alarms will be communicated; metering will include busbar voltage and single phase current from each feeder. Bay level control includes all circuit-breakers and other switches. The substation level will include a simple HMI, a remote control gateway and might also include automatic control functions for voltage level and tuned neutral reactors. Communication between bays is used for directional relay blocking signals and for distributed functions.

For this size of substation and larger substations, a station-wide communication network is necessary.

The SAS communication interfaces utilised are 1, 3, 4, 5, 6, 7 and 8.



IEC 1385/03

Figure A.2 – Examples of typical single line diagrams for type D2

A.2.3 D3 Large distribution substation

A large distribution substation would have more than 20 elements, often considerably more. A typical example might be at least two voltage levels, several busbars, transformers etc. The protection scheme, beside all D2 functions, might include differential busbar protection. The station level includes a full function HMI, all switchgear are controlled and all individual alarms are transmitted. Metering will include busbar voltages and three-phase feeder currents, and active and reactive power etc. The busbar topology might change during the course of operation. Special functions, for example automatic switching sequences are commonly used.

Communication between substation and control centre may consist of main and back-up links. Communication between bays for interlocking, for example, will be required.

For the largest substations, the local communication network might be split in segments connected via routers in order to limit the number of connected nodes on each segment.

The SAS communication interfaces utilised are 1, 3, 4, 5, 6, 7 and 8.

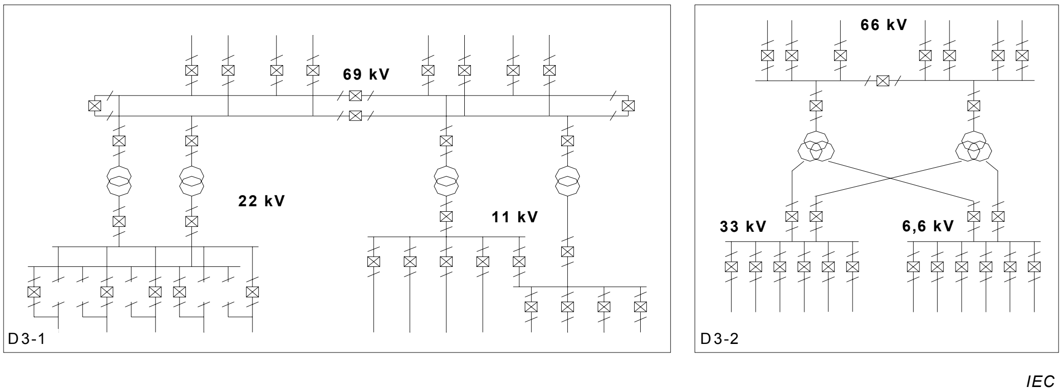


Figure A.3 – Example of typical single line diagram for type D3

A.2.4 T1 Small transmission substation

In contrast to distribution class substations, transmission equipment is often assembled from separate items delivered directly from vendors to the substation site, in which case it is not possible to set up and test communication in full at the factory before delivery.

A small transmission substation will usually have less than 10 elements and will have a less important position in the power system. Redundant protection may be not used in all cases. Feeder protection may normally incorporate transfer tripping (interface 2) and differential busbar protection is common. The substation level automation is limited to a remote control gateway and a simple HMI. Circuit-breakers and sometimes other switches are controlled. Metering will include busbar voltage and feeder single phase currents, active and reactive power. Some utilities may include fault recording on all transmission level feeders.

Communication interfaces 1 – 8 are used.

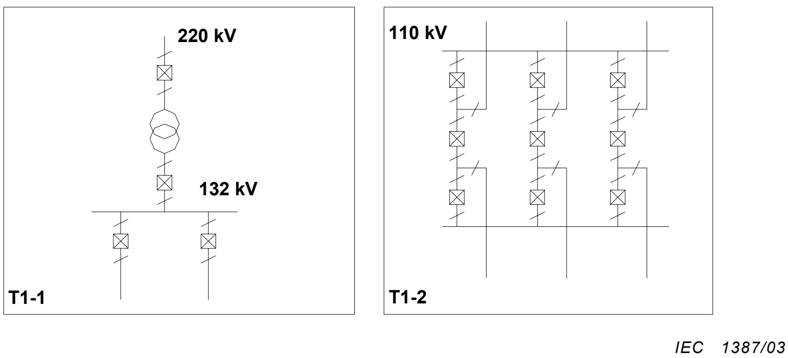


Figure A.4 – Examples of typical single line diagrams for type T1

A.2.5 T2 Large transmission substation

A large transmission substation has more than 10 elements with an important position in the power system. There will be several busbars and transformers. A high standard of protection is used, including both backup and redundant protection systems. Special automatic functions, such as network restoration or pre-set switching sequences, will be included. Fault recording and local handling of alarms and events will be part of the system. There is a full-scale station level automation with HMI, control of all switchgear and station-wide interlocking schemes. Communication between bays will be required.

There may be requirements for redundant communication links both inside the substation as well as between substation and control centre. The substation communication network might be split in sections for the largest substations.

All communication interfaces are used.

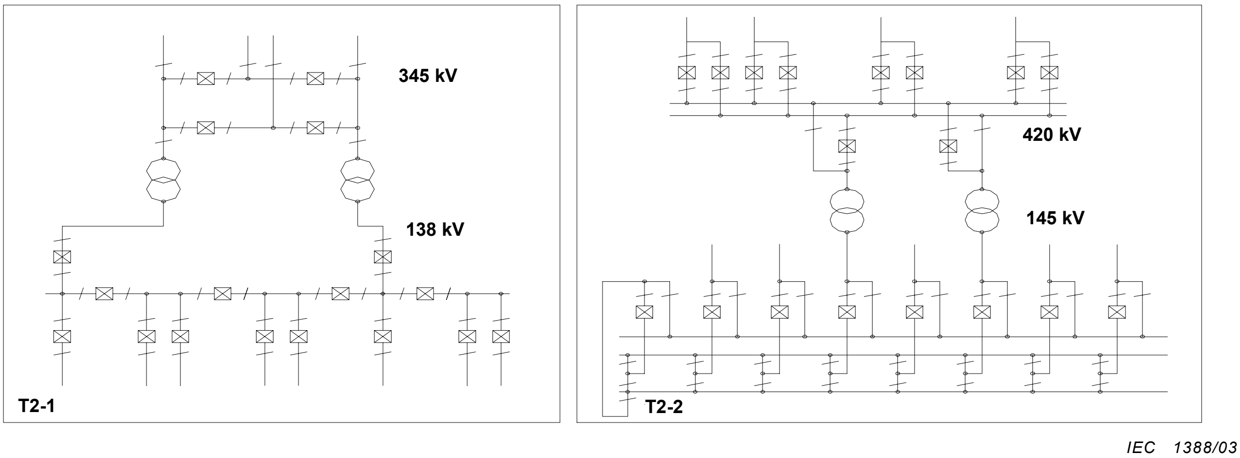


Figure A.5 – Example of typical single line diagram for type T2

A.2.6 Combinations

There can be combinations of two types of substations, for example a transmission substation (T1) that also includes distribution level feeders (D2). In such cases, the combined requirements will apply.

There will be cases when the substation communication network is split. This may be due to different owners (control centres) for different parts, different voltage levels, geographical locations etc.

A.3 Types of substations and interfaces used

Table A.1 summarises the interrelationship between the communication interfaces and the substation types. An X indicates that the corresponding interface is used, an (X) mark indicates the interface might be used by some utilities, but not by all.

Table A.1 – Types of substations and interfaces used

Substation	Interfaces used						
Type	**1**	**3**	**4**	**5**	**6**	**7**	**8**
D1		X			X		
D2	X	X	(X)	(X)	X	(X)	X
D3	X	X	(X)	(X)	X	X	X
T1	X	X	X	X	X	X	X
T2	X	X	X	X	X	X	X

Table A.2 gives an overview of the main distinguishing elements of the substation types. An X indicates that the function is normally found in the substation type, an (X) indicates that the function, whilst normally not found, sometimes is found in the substation type.

Under HMI, “bay level” stands for operation from the switchgear bay itself in case of medium voltage substations or from bay interface cubicle in case of high voltage substations. Simple station level HMI stands for a simple alphanumeric screen showing alarms and switch positions, allowing basic operation. Full station level HMI would normally include one or two full graphic screens, special user functions such as overviews and selections, logging of historical data for trend analysis etc.

Under protection, only a few typical examples, indicating functionality levels, are shown.

Table A.2 – Types of substations and functions used

Substation type	D1	D2	D3	T1	T2
Number of elements	1-5	5-20	>20	1-10	>10
HMI					
Bay level	X	X	X	X	X
Station level, simple		X		X	
Station level, full		(X)	X		X
Control functions					
Circuit-breaker	X	X	X	X	X
Switches/line and earth		(X)	X	X	X
Regulators		X	X	X	X
Automated sequences			X	(X)	X
Synchronising		(X)	(X)	X	X
Alarms					
Summary only	X	X		(X)	
Full alarm handling		(X)	X	X	X
Protection					
Overcurrent	X	X	X	X	X
Backup protection		X	X	X	X
Distance protection			(X)	X	X
Redundant protection				(X)	X
Bus differential protection		(X)	X	X	X
Metering					
Single phase current	X	X	X		
Bus voltage		X	X		
Three phase metering		(X)	(X)	X	X
Energy metering	(X)	(X)	X	(X)	X

A.4 Communication structures

A.4.1 General

For a further assessment of communication requirements in a given substation, the substation can be divided into physical or functional units.

As an example of this, the substation D2-2, as shown in Figure A.2, is chosen. This is one of the most widely used substation types found within most utilities. Figure A.6 is the same as example D2-2, but with current and voltage sensors added.

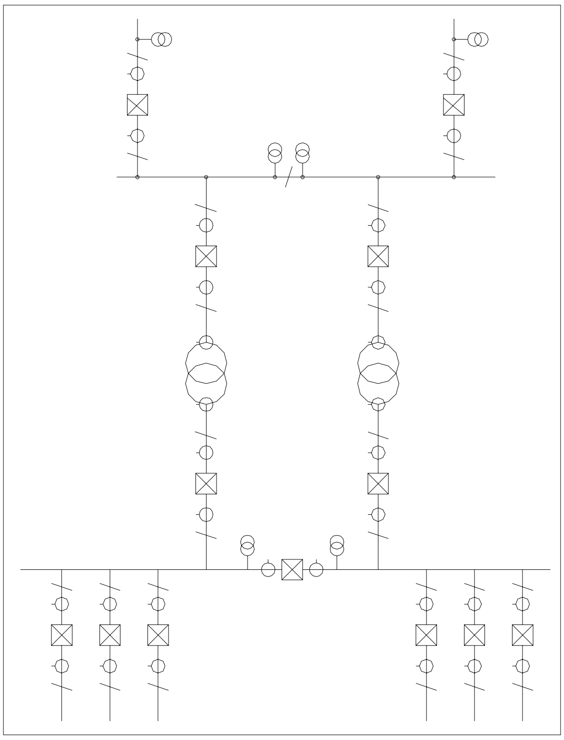


Figure A.6 – Possible locations of current and voltage transformers in substation D2-2

The Figure shows all possible locations of current and voltage transformers. Most utilities would normally not use all of these positions in any one specific substation.

A.4.2 Typical physical units (bays)

A substation can be divided into component parts in different ways, depending on the context. One possibility is the subdivision into bay units, i.e. the substation is divided into the units in which the primary equipment is arranged.

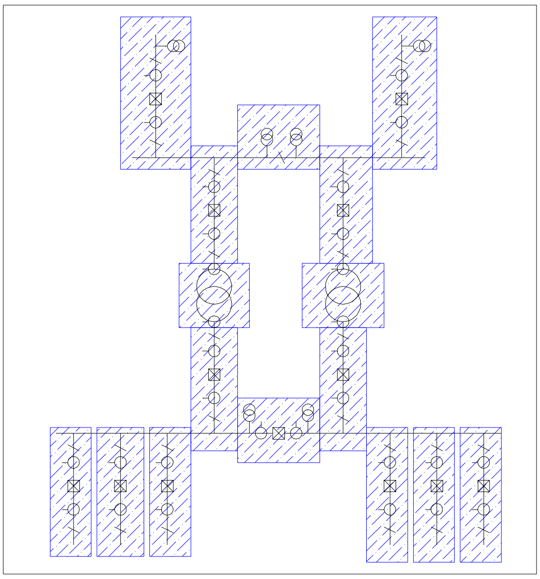
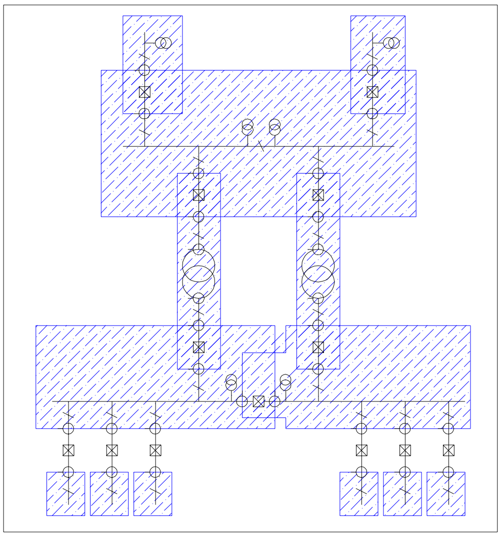


Figure A.7 – Assignment of bay units (example)

Each block in Figure A.7 consists of parts that are either delivered preassembled to the site, or arranged together at site.

A.4.3 Typical function zones

An alternative to the division of physical units is to consider the data flow within the equipment. The substation can then be divided into functional communication blocks, within which different control and/or protection functions share the same data. For example, Figure A.8 shows the protection zones of the relays with overlapping areas.



IEC 1391/03

Figure A.8 – Typical protection zones

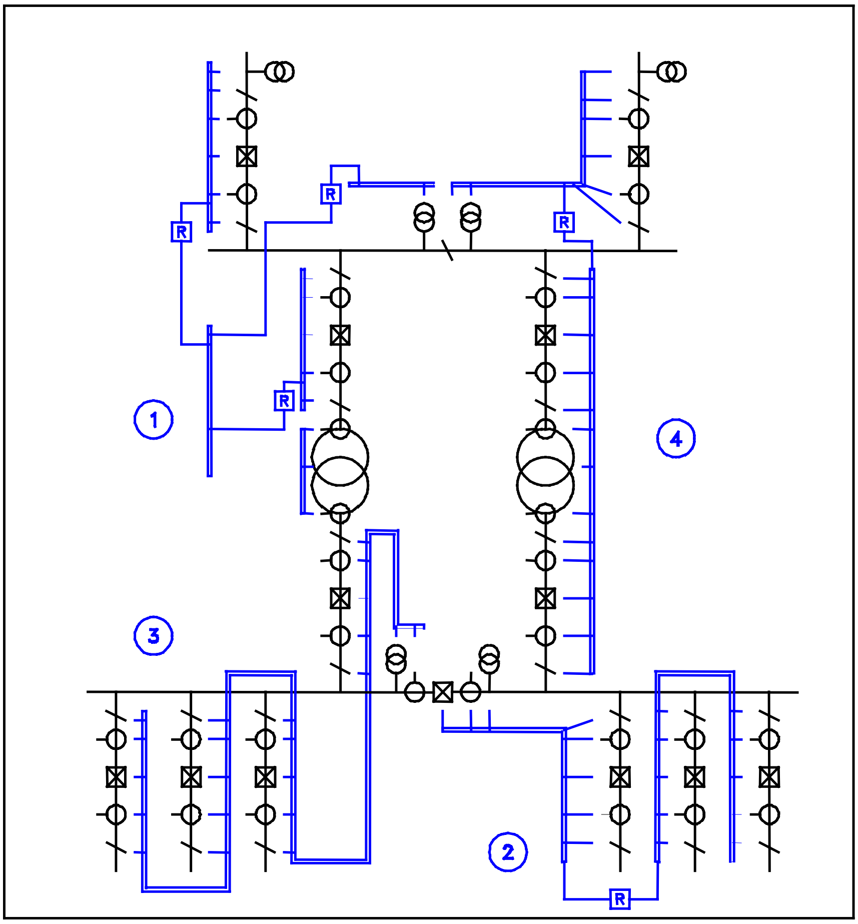
Again, this shows one possible arrangement of protective zones; utilities might prefer other alternatives, depending on the importance of the substation and the general practice within the company.

Each relay in the zone will require data from all current transformers that are located on the border and, in some cases, from voltage transformers within the zone. It will send trip signals to all related circuit breakers.

A.4.4 Process communication bus structures

The process level communication bus can be arranged in several different ways, depending on data flow requirements, reliability requirements or practicalities during installation.

Figure A.9 indicates four alternative solutions.



Key

R = Router

Figure A.9 – Alternative solutions for the process level communication bus

Alternative 1 indicates a communication bus structure where each bay (installation unit) has its own process bus segment. For protection and control equipment that requires data from more than one segment, a separate station-wide communication bus is installed, with routers to each bay segment to transmit the required data streams.

Alternative 2 indicates a similar structure but each bay segment covers more than one bay. Data streams required by more than one segment are transferred by routers. The example shows data from the busbar voltage transformer being used by directional earth-fault relays on all bays.

Alternative 3 indicates a single station-wide communication bus, to which all devices are connected. This requires a very high data rate on the bus, but eliminates the need for routers.

Alternative 4 indicates a function oriented bus structure. In this case, the bus segments are set up to correspond to protection zones. Although routers are required, the segments can be arranged to minimise the data to be transferred between segments.

A.4.5 Station communication bus structures

The station level communication bus structure can be related to the substation type according to the definitions in A.2.

Substation type D1 will require only a very simple communication bus to link bay units to the remote control interface. There is no bay-to-bay communication and no need for fast messages.

Substation type D2 will require a station-wide communication bus, with the ability to handle all types of messages.

Substation type D3 will need a segmented communication bus connected by routers or bridges to process the large amount of data from the connected equipment. The segmentation should be designed to eliminate the need to pass fast messages via routers.

Substation type T1 will require the same type of communication bus as D2 with the added ability to address parallel (redundant) devices.

Substation type T2 may require duplicate (redundant) communication bus structures. In some cases, if the physical size of the substation may also require a segmented communication, the bus must be divided in segments.

It is however important to note that the types defined above, and their communication requirements, must be treated as examples only. The actual importance and thus required reliability of a certain substation does not depend on size and configuration only.

A.4.6 Conclusion

The examples above show, that looking at substation or bay types alone does not provide sufficient information to calculate the communication system load, especially if a process bus is included. To define communication system and process bus structures and performance requirements, the substation structure, the specific functions and their allocation, as well as the layout of switchgear and the manner in which equipment is assembled have to be defined.

The most cost-effective communication system for any given substation, may require more than one type of protocol stack. The actual selection can then be made based on the substation type, i.e. the size, complexity and required reliability of the substation, as well as expected data flow rates on the station and process buses.

Annex B
(informative)

Documents which have been considered in the IEC 61850 series

SAS have been a subject of widespread interest for several years, with organised activities in a number of countries by a number of organisations. The following list identifies the known publications considered in the work of the IEC Technical Committee 57 Working groups' efforts. Each of these has been reviewed and used as input into the Working groups' considerations.

1) *Recommendations for Digital Substation Control, (VDEW)*, German Working Group Substation Control Technology, June 20, 1994.

   The VDEW issued their first draft document on integrated substation control in 1988, this document updates those recommendations based on five years of experience. While the document contains a number of valuable and useful general standards and guidelines, it does not address the data communication standard between bay level devices and station level. Thus, interoperability between vendors is not provided. However, a draft Protection Communication Companion Standard, Revision 3.1 was published on August 20, 1995.

2) IEC 57/214/INF *Report of the Ad-Hoc Working Group on Substation Control and Protection Interfaces*, February 1995.

   This report covers the work of the Ad-Hoc Working Group from March 1994 to April 1995. The group was formed in November 1993 and consisted of 24 members from 12 countries. Four meetings where held in the time period and the results of the work provided the bases for forming Working groups 10, 11, and 12.

3) IEC 57/210/NP *Communication standards for substations – Part 1: Functional architecture, communication structure and the general requirements*, February 1995.

   This document sets up the scope and goals for Working Group 10, based on the input from the Ad-Hoc Working Group.

4) IEC 57/211/NP *Communication standards for substations – Part 2: Communication within and between unit and substation levels*, February 1995.

   This document sets up the scope and goals for Working Group 11, based on the input from the Ad-Hoc Working Group.

5) IEC 57/212/NP *Communication standards for substations – Part 3: Communication within and between process and unit levels,* February 1995.

   This document sets up the scope and goals for Working Group 12, based on the input from the Ad-Hoc Working Group.

6) IEC 57/232/RVN *Results of voting on New Work Proposal, Communication standards for substations – Part 1: Functional architecture, communication structure and the general requirements*, August 1995.

   This document presents the results of the country by country balloting on forming the three new Working groups, 21 countries supported the formation, 11 countries agreed to participate, and three countries did not reply.

7) IEC 95/15/NP IEC 61733-1 *Protection Communication Interface – Part 1: General.*

   This document gives general information about typical hierarchical systems and the typical organisation of devices communicating on an open system.

8) IEC 95/15/NP IEC 61733-2 *Protection Communication Interface – Part 2: Communication Standards in Electrical Installations, Overall Structure*, April 1995.

This document presents the results of work performed by Working Group 6 of IEC Technical Committee 95. This is the second part of a planned seven part series. Both of the first two parts will be used as reference documents. Working Group 6 of IEC Technical Committee 95 has decided to provide active members to Working Group 10, 11 and 12 of IEC Technical Committee 57 and provide review for the results produced.

9) CIGRE WG 34.03, *Communication Requirements in Terms of Data Flow Within Substations, Draft Report*, November 15, 1995.

This report expands the work discussed in the previous paper and develops a model (object) definition for the elements within a substation. These models can then be used to establish the data flow requirements for various operational scenarios.

The final report was published as CIGRE – Technical Report, Ref. No. 180 – *Communication requirements in terms of data flow within substations*. CE/SC 34 03, 2001,112 pp.

10) EPRI RP3599, *Substation Integrated Protection, Control, and Data Acquisition, Requirements Specification, Preliminary Report, Version 1.2*, February, 1998

This document defines a conceptual model and performance requirements for IEDs in substations.

As part of the EPRI-sponsored activities leading up to the publication of UCA Version 2.0, a number of efforts were initiated to develop detailed object models of common field devices, including definitions of their associated algorithms and communications behaviour visible through the communication system. The substation integrated protection, control, and data acquisition (RP3599) project was one of these efforts, which resulted in this report.

11) IEEE-SA TR 1550,1999: *Utility Communications Architecture (UCA) Version 2.0 – Part 3: UCA Common Application Service Models (CASM) and Mapping to MMS*, November, 1999

This document describes the mapping of the UCA Generic Object Models onto the Application Services and the mechanisms for representing the Application Services in the underlying UCA Application Layer Protocol (in this case MMS).

12) IEEE-SA TR 1550,1999: *Utility Communications Architecture (UCA) Version 2.0 – Part 4: UCA Generic Object Models for Substation and Feeder Equipment (GOMSFE)*, November, 1999

This document defines a library of basic common objects and standardised bricks used for modelling substation and feeder protection, control and data acquisition functions.

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