

Communication networks and systems in substations —

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

The European Standard EN 61850-7-1:2003 has the status of a
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ICS 33.200

National foreword

This British Standard is the official English language version of EN 61850-7-1:2003. It is identical with IEC 61850-7-1:2003

The UK participation in its preparation was entrusted to Technical Committee PEL/57, Power system control and associated communications, which has the responsibility to:

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**Communication networks and systems in substations
Part 7-1: Basic communication structure for substation
and feeder equipment -
Principles and models
(IEC 61850-7-1:2003)**

Réseaux et systèmes de communication
dans les postes
Partie 7-1: Structure des communications
de base pour les postes électriques
et les équipements de lignes -
Principes et modèles
(CEI 61850-7-1:2003)

Kommunikationsnetze und -systeme
in Stationen
Teil 7-1: Grundlegende
Kommunikationsstruktur für stations-
und feldbezogene Ausrüstung -
Grundsätze und Modelle
(IEC 61850-7-1:2003)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of document 57/637/FDIS, future edition 1 of IEC 61850-7-1, prepared by IEC TC 57, Power system control and associated communications, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61850-7-1 on 2003-09-01.

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with the EN have to be withdrawn (dow) 2006-09-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA is normative and annexes A to F are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61850-7-1:2003 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

This part of the IEC 61850 series provides an overview of the architecture for communication and interactions between substation devices such as protection devices, breakers, transformers, substation hosts etc.

This document is part of a set of specifications which details a layered substation communication architecture. This architecture has been chosen to provide abstract definitions of classes (representing hierarchical information models) and services such that the specifications are independent of specific protocol stacks, implementations, and operating systems.

The goal of the IEC 61850 series is to provide interoperability between the IEDs from different suppliers or, more precisely, between functions to be performed in a substation but residing in equipment (physical devices) from different suppliers. Interoperable functions may be those functions that represent interfaces to the process (for example, circuit breaker) or substation automation functions such as protection functions. This part of the IEC 61850 series uses simple examples of functions to describe the concepts and methods applied in the IEC 61850 series.

This part of the IEC 61850 series describes the relationships between other parts of the IEC 61850 series. Finally this part defines how inter-operability is reached.

NOTE Interchangeability, i.e. the ability to replace a device from the same vendor, or from different vendors, utilising the same communication interface and as a minimum, providing the same functionality, and with no impact on the rest of the system. If differences in functionality are accepted, the exchange may require some changes somewhere in the system also. Interchangeability implies a standardisation of functions and, in a strong sense, of devices which are both outside the scope of this standard. Interchangeability is outside the scope, but it will be supported following this standard for interoperability.

Table 1 – Guide for the reader

User		IEC 61850-1 (Introduction and overview)	IEC 61850-5 (Requirements)	IEC 61850-7-1 (Principles)	IEC 61850-7-4 (Logical nodes and data classes)	IEC 61850-7-3 (Common data classes)	IEC 61850-7-2 (Information exchange)	IEC 61850-6^a (Configuration language)	IEC 61850-8-x IEC 61850-9-x^a (Concrete communication stack)
Utility	Manager	x	–	Clause 5	–	–	–	–	–
	Engineer	x	x	x	x	x	In extracts	x	–
Vendor	Application engineer	x	x	x	x	x	In extracts	x	In extracts
	Communication engineer	x	x	x	–	–	x	–	x
	Product manager	x	x	x	x	In extracts	In extracts	In extracts	–
	Marketing	x	x	Clause 5	In extracts	In extracts	In extracts	In extracts	–
Consultant	Application engineer	x	x	x	x	x	–	x	–
	Communication engineer	x	–	x	–	–	x	x	x
All others		x	x	x	–	–	–	–	–
The “x” means that this part of the IEC 61850 series should be read. The “in extracts” means that extracts of this part of the IEC 61850 series should be read to understand the conceptual approach used. The “–” means that this part of the IEC 61850 series may be read.									
^a These documents are under consideration.									

This part of the IEC 61850 series is intended for all stakeholders of standardised communication and standardised systems in the utility industry. It provides an overview of and an introduction to IEC 61850-7-4, IEC 61850-7-3, IEC 61850-7-2, IEC 61850-6, and IEC 61850-8-1.

Table 1 provides a simplified guide as to which parts of the IEC 61850 series should be read by various stakeholders. Four groups are shown: utility, vendor, various consultants, and others.

COMMUNICATION NETWORKS AND SYSTEMS IN SUBSTATIONS –

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

1 Scope

This part of the IEC 61850 series introduces the modelling methods, communication principles, and information models that are used in the parts of IEC 61850-7-x. The purpose of this part of the IEC 61850 series is to provide – from a conceptual point of view – assistance to understand the basic modelling concepts and description methods for:

- substation-specific information models for substation automation systems,
- device functions used for substation automation purposes, and
- communication systems to provide interoperability within substations.

Furthermore, this part of the IEC 61850 series provides explanations and provides detailed requirements relating to the relation between IEC 61850-7-4, IEC 61850-7-3, IEC 61850-7-2 and IEC 61850-5. This part explains how the abstract services and models of IEC 61850-7-x are mapped to concrete communication protocols as defined in IEC 61850-8-1.

The concepts and models provided in this part of the IEC 61850 series may also be applied to describe information models and functions for:

- substation to substation information exchange,
- substation to control centre information exchange,
- information exchange for distributed automation,
- information exchange for metering,
- condition monitoring and diagnosis, and
- information exchange with engineering systems for device configuration.

NOTE 1 This part of IEC 61850 uses examples and excerpts from other parts of the IEC 61850 series. These excerpts are used to explain concepts and methods. These examples and excerpts are informative in this part of IEC 61850.

NOTE 2 Examples in this part use names of classes (e.g. XCBR for a class of a logical node) defined in IEC 61850-7-4, IEC 61850-7-3, and service names defined in IEC 61850-7-2. The normative names are defined in IEC 61850-7-4, IEC 61850-7-3, and IEC 61850-7-2 only.

NOTE 3 This part of IEC 61850 does not provide a comprehensive tutorial. It is recommended that this part be read first – in conjunction with IEC 61850-7-4, IEC 61850-7-3, and IEC 61850-7-2. In addition, it is recommended that IEC 61850-1 and IEC 61850-5 also be read.

NOTE 4 This part of IEC 61850 does not discuss implementation issues.

2 Normative references

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

IEC 61850-2, *Communication networks and systems in substations – Part 2: Glossary*¹

IEC 61850-5, *Communication networks and systems in substations – Part 5: Communication requirements for functions and devices models*³

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/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 8825 (all parts), *Information technology – ASN.1 encoding rules*

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

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

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in IEC 61850-2³ as well as the following, apply.

3.1 information

knowledge concerning objects, such as facts, events, things, processes, or ideas, including concepts, that within a certain context has a particular meaning

(IEV 101-12-01)

3.2 information model

represents the knowledge concerning substation functions and devices in which the functions are implemented. This knowledge is made visible and accessible through the means of the IEC 61850 series. The model describes in an abstract way a communication oriented representation of a real function or device.

¹ To be published.

3.3 model

a representation of some aspect of reality. The purpose of creating a model is to help understand, describe, or predict how things work in the real world by exploring a simplified representation of a particular entity or phenomenon. The focus of the model defined in IEC 61850-7-x is on the communication features of the data and functions modelled.

4 Abbreviated terms

ACSI	Abstract Communication Service Interface
ASN.1	Abstract Syntax Notation One
API	Application Program Interface
CDC	Common Data Class
CT	Current Transformer
IED	Intelligent Electronic Device
LD	Logical Device
LN	Logical Node
LLN0	Logical Node Zero
LPHD	Logical Node Physical Device
MMS	Manufacturing Message Specification
PHD	Physical Device
PICOM	Piece Of Communication
SCSM	Specific Communication Service Mapping
SoE	Sequence Of Events
UML	Unified Modelling Language
VMD	Virtual Manufacturing Device
VT	Voltage Transformer
XML	eXtended Markup Language

5 Overview of concepts the IEC 61850 series

5.1 Objective

IEC 61850-7-4, IEC 61850-7-3, IEC 61850-7-2, IEC 61850-6, and IEC 61850-8-1 are closely related. This Subclause provides an overview of these parts and it describes how these parts are interwoven.

Each part defines a specific aspect of a substation IED:

- 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,
- 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 61850-6 offers the formal configuration description of a substation IED including the description of the relations with other IEDs and with the power process (single line diagram) – how to describe the configuration, and
- IEC 61850-8-1 defines the concrete means to communicate the information between IEDs (for example, the application layer, the encoding, etc.) – how to serialise the information during the exchange.

5.2 Topology and communication functions of substation automation systems

As shown by the topology in Figure 1, one focus of the IEC 61850 series is the support of substation automation functions by the communication of (numbers in brackets refer to the figure):

- sampled value exchange for CTs and VTs (1),
- fast exchange of I/O data for protection and control (2),
- control and trip signals (3),
- engineering and configuration (4),
- monitoring and supervision (5),
- control-center communication (6),
- time-synchronisation,
- etc.

Support for other functions such as metering, condition monitoring, and asset management is provided as well.

Many functions are implemented in intelligent electronic devices (IED); various IEDs are shown in Figure 1. Several functions may be implemented in a single IED or one function may be implemented in one IED and another function may be hosted by another IED. IEDs (i.e., the functions residing in IEDs) communicate with functions in other IEDs by the information exchange mechanisms of this standard. Therefore, functions distributed over more than one IED may be also implemented.

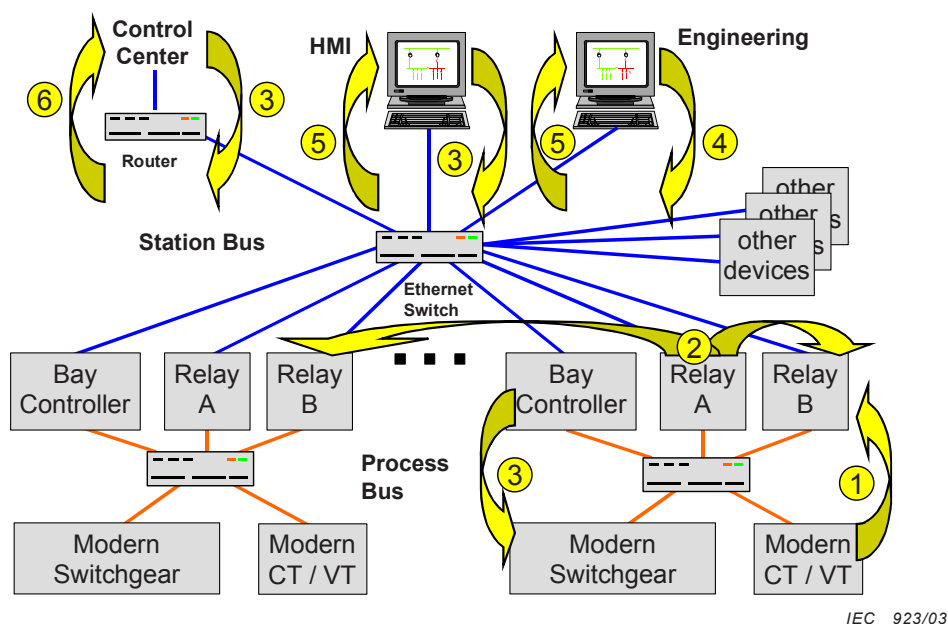
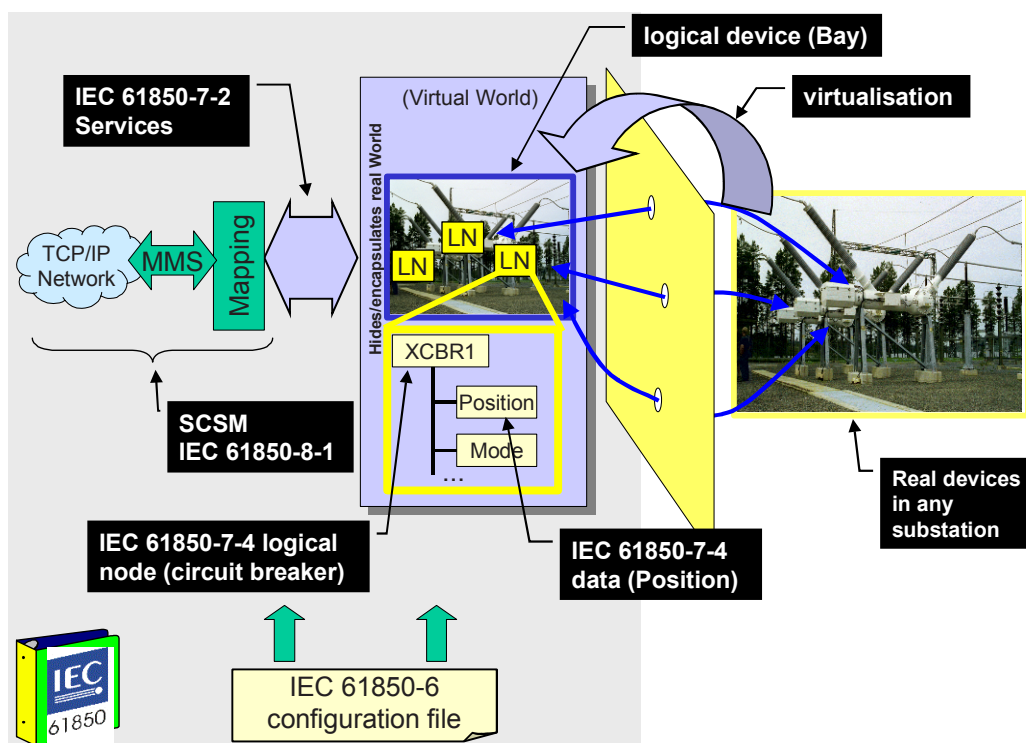


Figure 1 – Sample substation automation topology

5.3 The information models of substation automation systems

The information exchange mechanisms rely primarily on well defined information models. These information models and the modelling methods are at the core of the IEC 61850 series. The IEC 61850 series uses the approach to model the common information found in real devices as depicted in Figure 2. All information made available to be exchanged with other devices is defined in the standard. The model provides for the substation automation system an image of the analogue world (power system process, switchgear).

NOTE 1 “The common information” in the context of the IEC 61850 series means that the stakeholders of substation automation systems (users and vendors) have agreed that the information defined in the IEC 61850 series is widely accepted and required for the open exchange of information between any kind of substation IEDs.



IEC 924/03

Figure 2 – Modelling approach (conceptual)

The IEC 61850 series defines the information and information exchange in a way that it is independent of a concrete implementation (i.e., it uses abstract models). The standard also uses the concept of virtualisation. Virtualisation provides a view of those aspects of a real device that are of interest for the information exchange with other devices. Only those details that are required to provide interoperability of devices are defined in the IEC 61850 series.

As described in IEC 61850-5, 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**). The logical nodes are modelled and defined from the conceptual application point of view in IEC 61850-5. Several logical nodes build a logical device (for example, a representation of a Bay unit). A logical device is always implemented in one IED; therefore logical devices are not distributed.

Real devices on the right hand side of Figure 2 are modelled as a virtual model in the middle of the figure. The logical nodes defined in the logical device (for example, bay) correspond to well known functions in the real devices. In this example the logical node **XCBR** represents a specific circuit breaker of the bay to the right.

NOTE 2 The logical nodes of this example may be implemented in one or several IEDs as appropriate. If the logical nodes are implemented in different IEDs, they need exchange information over a network. Information exchange inside a logical node is outside the scope of the IEC 61850 series.

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 substation automation systems). The information represented by the data and their attributes are exchanged by the services according to the well-defined rules and the requested performance as described in IEC 61850-5. The services are implemented by a specific and concrete communication means (SCSM, for example, using MMS, TCP/IP, and Ethernet among others).

The **logical nodes** and the **data** contained in the **logical device** are crucial for the **description** and **information exchange** for substation automation systems to reach interoperability.

The logical devices, the logical nodes and the data they contain need to be configured. The main reason for the configuration is to select the appropriate logical nodes and data from the standard and to assign the instance-specific values, for example, concrete references between instances of the logical nodes (their data) and the exchange mechanisms, and initial values for process data.

5.4 Applications modelled by logical nodes defined in IEC 61850-7-4

Table 2 lists all groups of logical nodes defined in IEC 61850-7-4. About 90 logical nodes covering the most common applications of substation and feeder equipment are defined. One main focus is the definition of information models for protection and protection related applications (38 logical nodes out of 88). These two groups comprise nearly half of the logical nodes. This impression results from the very dedicated definition of protection functions in history because of the high importance of protection for safe and reliable operation of the power system.

NOTE Some attention is given to control functions which historically have not been defined in such a granularity since they represent a few very common and also important tasks.

The importance of monitoring functions is increasing.

Table 2 – LN groups

Logical node groups	Number of logical nodes
System logical nodes	3
Protection functions	28
Protection related functions	10
Supervisory control	5
Generic references	3
Interfacing and archiving	4
Automatic control	4
Metering and measurement	8
Sensors and monitoring	4
Switchgear	2
Instrument transformer	2
Power transformer	4
Further power system equipment	15
Total number of logical nodes	92

IEC 61850 has well-defined rules to define additional logical nodes and data, for example, for additional functions within substations or for other application domains such as wind power plants. For details on the extension rules, see Clause 14 of this standard and the Annex A of IEC 61850-7-4.

The following excerpt of the logical nodes has been included to provide an example of what kind of real applications the logical nodes represent:

- Distance protection
- Differential protection
- Overcurrent
- Undervoltage
- Directional over power
- Volts per Hz relay
- Transient earth fault
- Directional element
- Harmonic restraint
- Protection scheme
- Zero speed or underspeed
- ...
- Measurement
- Metering
- Sequence and imbalance
- Harmonics and interharmonics
- Differential measurements
- ...
- Switch control
- Circuit breaker
- Circuit switch
- ...

Most logical nodes provide information that can be categorised as depicted in Figure 3. The semantic of a logical node is represented by data and data attributes. Logical nodes may provide a few or up to 30 data. Data may contain a few or even more than 20 data attributes. Logical nodes may contain more than 100 individual information (points) organised in a hierarchical structure.

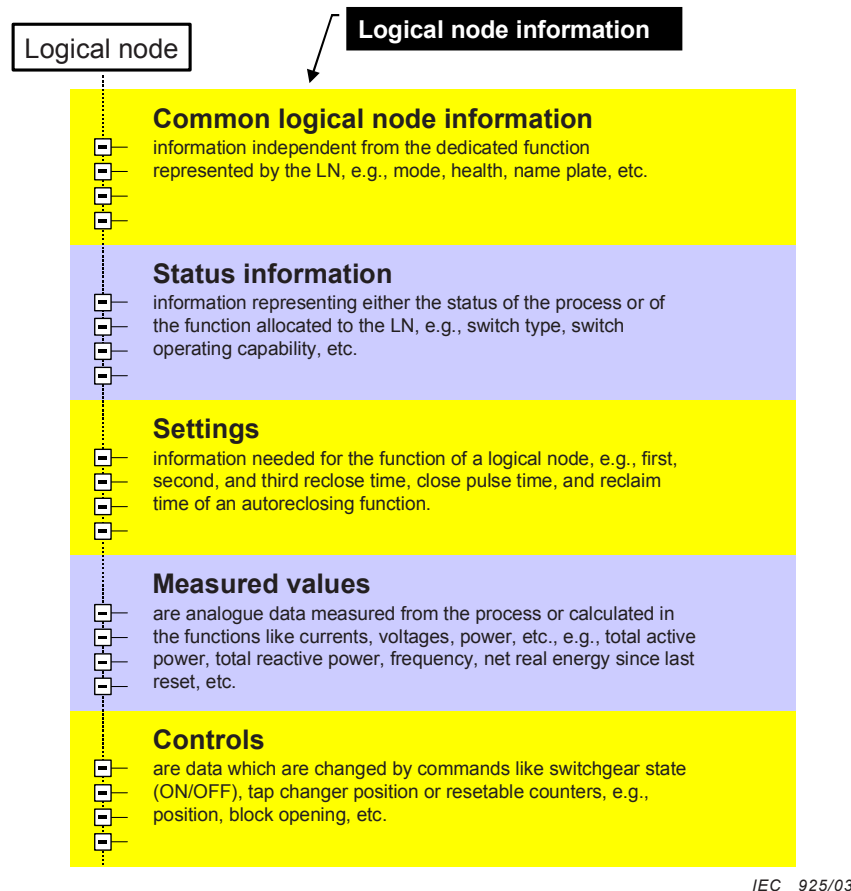


Figure 3 – Logical node information categories

IEDs are built up by composing logical nodes as depicted in Figure 4. The logical nodes are the building blocks of substation IEDs, for example, circuit breaker (**XCBR**) and others. In the example for each phase, one instance of XCBR is used.

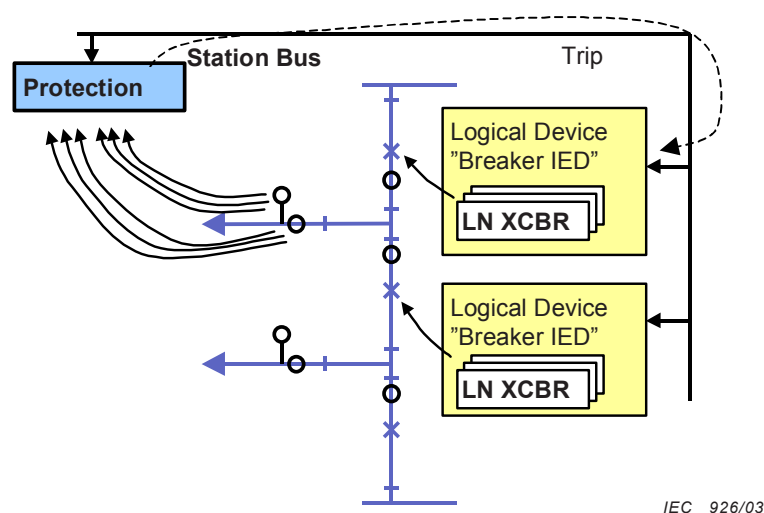


Figure 4 – Build up of devices (principle)

In Figure 4, the protection IED receives the values for the voltage and current from conventional VT and CT. The protection functions in the protection device may detect a fault and issue or send a trip signal via the station bus. The standard supports also IEDs for non-conventional VTs and CTs sending voltage and current as samples to the protection over a serial link.

The **logical nodes** are used to build up substation IEDs.

5.5 The semantic is attached to data

The mean number of specific data provided by logical nodes defined in IEC 61850-7-4 is approximately 20. Each of the data (for example, position of a circuit breaker) comprises several details (the data attributes). The position (named "**Pos**") of a circuit breaker is defined in the logical node **XCBR** (see Figure 5). The position is defined as data. The category of the position in the logical node is "controls" – the position can be controlled via a control service.

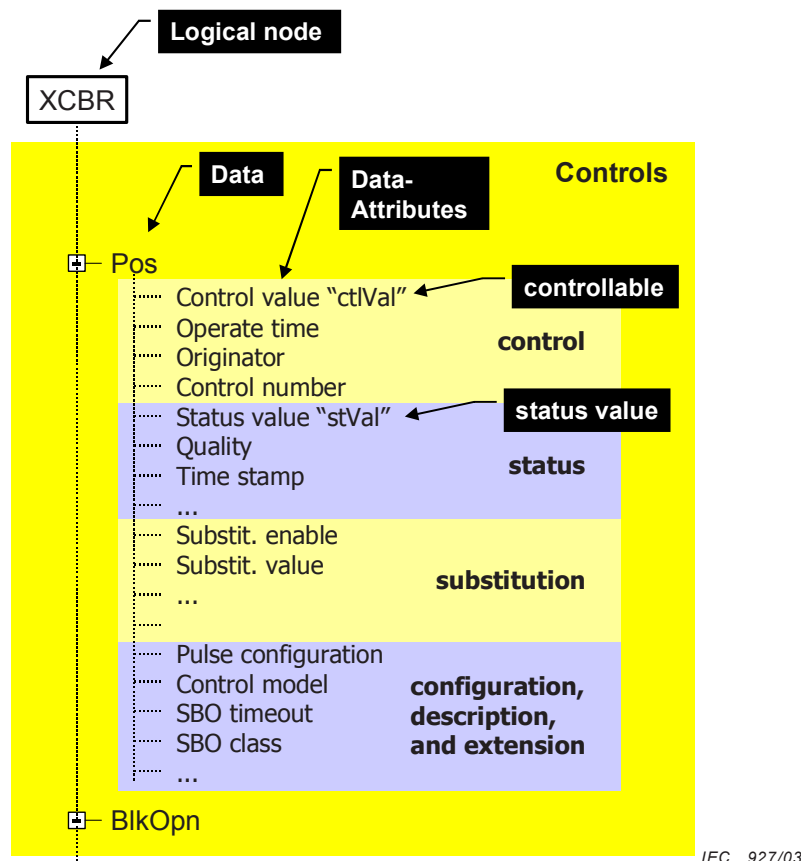


Figure 5 – Position information depicted as a tree (conceptual)

The position **Pos** is more than just a simple "point" in the sense of simple RTU protocols. It is made up of several data attributes. The data attributes are categorised as follows:

- control (status, measured/measured values, or settings),
- substitution,
- configuration, description and extension.

The data example **Pos** has approximately 20 data attributes. The data attribute **Pos.ctlVal** represents the controllable information (can be set to ON or OFF). The data attribute **Pos.stVal** represents the position of the real breaker (could be in intermediate-state, off, on, or bad-state).

The position also has information about when to process the control command (**Operate time**), the originator that issued the command, and the control number (given by the originator in the request). The quality and time stamp information indicate the current validity of the status value and the time of the last change of the status value.

The current values for **stVal**, the quality and the time stamp (associated with the **stVal**) can be read, reported or logged in a buffer of the IED.

The values for **stVal** and quality can be remotely substituted. The substituted values take effect immediately after enabling substitution.

Several data attributes are defined for the configuration of the control behaviour, for example, pulse configuration (single pulse or persistent pulses, on/off-duration, and number of pulses) or control model (direct, select-before-operate, etc.).

Data attributes are defined primarily by an attribute name and an attribute type:

Attribute name	Attribute type	FC	TrgOp	Value/value range	M/O/C
ctlVal	BOOLEAN	CO		off (FALSE) on (TRUE)	AC_CO_M
stVal	CODED ENUM	ST	dchg	intermediate-state off on bad-state	M

Additional information provides further details (one could say provides meta-data) on:

- the services allowed: functional constraint -> FC=CO means that specific services can be applied only (for example CO refers to the control service),
- the trigger conditions that cause a report to be sent: TrgOp=dchg means that a change in the value of that attribute causes a report,
- the value or value range,
- the indication if the attribute is optional (O), mandatory (M), conditional mandatory (X_X_M), or conditional optional (X_X_O). The conditions result from the fact that not all attributes are independent from each other.

The data attribute names are standardised (i.e., these 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; for example:

Data attribute name	Semantics
ctlVal	Determines the control activity.
stVal	Status value of the data.

The names of the **data** and **data attributes** carry the **crucial semantic** of a substation IED.

The position information **Pos** as shown in Figure 5 has many data attributes that can found in many other switching-specific applications. The prime characteristic of the position is the data attribute **stVal** (status value) which represents four states: intermediate-state | off | on | bad-state. These four states (represented usually with two bits) are commonly known as “double point” information. The whole set of all the data attributes defined for the data **Pos** (position) is called a “common data class” (CDC). The name of the common data class of the double point information is **DPC** (controllable double point).

Common data classes provide an useful means to reduce the size of data definitions (in the standard). The data definition does not need to list all the attributes but needs to just reference the common data class. Common data classes are also very useful to keep the definitions of data attributes consistent. A change in the double point control CDC specific data attributes only needs to be made in a single place – in the **DPC** definition of IEC 61850-7-3.

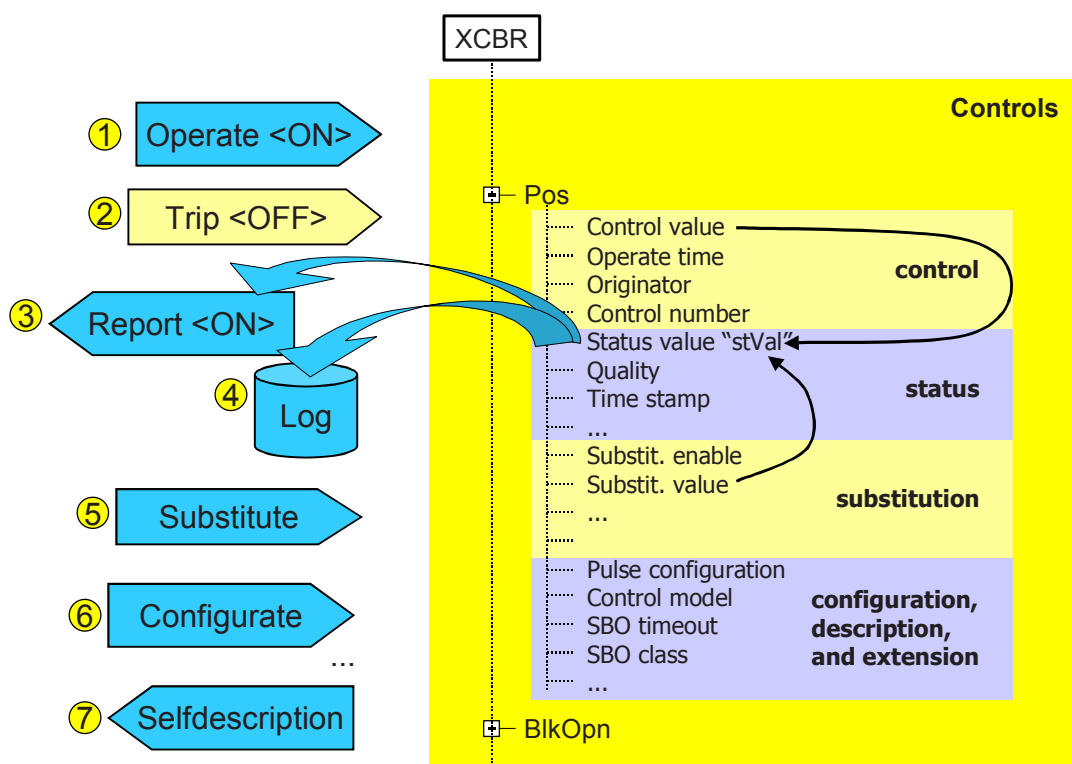
IEC 61850-7-3 defines common data classes for a wide range of well known applications. The core common data classes are classified into the following groups:

- status information,
- measurand information,

- controllable status information,
- controllable analogue information,
- status settings,
- analogue settings, and
- description information.

5.6 The services to exchange information

The logical nodes, data, and data attributes are defined mainly to specify the information required to perform an application, and for the exchange of information between IEDs. The information exchange is defined by means of services. An excerpt of the services is displayed in Figure 6.



NOTE The circles with the numbers ① to ⑦ refer to the bulleted list below.

IEC 928/03

Figure 6 – Service excerpt

The operate service manipulates the control specific data attributes of a circuit breaker position (open or close the breaker). The report services inform another device that the position of the circuit breaker has been changed. The substitute service forces a specific data attribute to be set to a value independent of the process.

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

- control devices (operate service or by multicast trip signals) (see Figure 6, ①),
- fast and reliable peer-to-peer exchange of status information (tripping or blocking of functions or devices) (see Figure 6, ②),
- reporting of any set of data (data attributes), SoE – cyclic and event triggered (see Figure 6, ③),
- logging and retrieving of any set of data (data attributes) – cyclic and event triggered (see Figure 6, ④),
- substitution (see Figure 6, ⑤),

- handling and setting of parameter setting groups,
- transmission of sampled values from sensors,
- time synchronisation,
- file transfer,
- online configuration (see Figure 6, ⑥), and
- retrieving the self-description of a device (see Figure 6, ⑦).

Many services operate directly on the attributes of the information model (i.e., on the data attributes of data contained in logical nodes). The pulse configuration of the data attribute **Pos** of a specific circuit breaker can be set directly by a client to a new value. Directly means that the service operates on the request of the client without specific constraints of the IED.

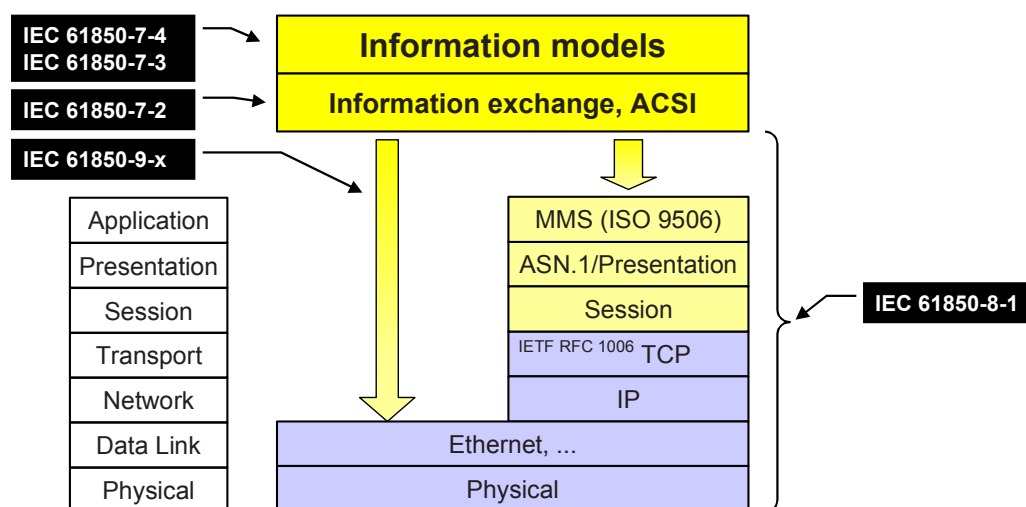
Other services provide a more complex behaviour which is dependent on the state of some specific state machine. A control request may be required to follow a state machine associated with the data attribute, for example, select-before-operate.

There are also several application-specific communication services that provide a comprehensive behaviour model which partially act autonomously. The reporting service model describes an operating-sequence in which the IED acts automatically on certain trigger conditions defined in the information model (for example, report on data-change of a status value) or conditions defined in the reporting service model (for example, report on a periodical event).

5.7 Services mapped to concrete communication protocols

The services defined in IEC 61850-7-2 are called abstract services. Abstract means that only those aspects that are required to describe the required actions on the receiving side of a service request are defined in IEC 61850-7-2. They are based on the functional requirements in IEC 61850-5. The semantic of the service models with their attributes and the semantic of the services that operate on these attributes (including the parameters that are carried with the service requests and responses) are defined in IEC 61850-7-2.

The specific syntax (format) and especially the encoding of the messages that carry the service parameters of a service and how these are passed through a network are defined in a specific communication service mapping (SCSM). One SCSM – IEC 61850-8-1 – is the mapping of the services to MMS (ISO 9506) and other provisions like TCP/IP and Ethernet (see Figure 7) other ones are IEC 61850-9-1 and IEC 61850-9-2.



IEC 929/03

Figure 7 – Example of communication mapping

Additional mappings to other communication stacks are possible. The ACSI is independent of the mappings.

5.8 The configuration of a substation

The logical nodes, data, and data attributes as well as the services used and concrete communication means provided by a physical IED must be configured. The configuration contains the formal description of the various objects and the relations between these objects and the concrete substation equipment (switchyard). At the application level the switchyard topology itself and the relation between the switchyard structure and the SAS functions (the corresponding logical nodes, data and data attributes configured in the IEDs) are described.

IEC 61850-6 specifies a description language for configurations of electrical substation IEDs. This language is called substation configuration description language (SCL).

The substation configuration contains a static view of the complete substation. The configuration may be used for describing re-usable parts or for complete IEDs that can be employed immediately:

- pre-configured IEDs with a fixed number of logical nodes based on a function library, but with no binding to a specific process;
- pre-configured IEDs with a pre-configured semantic for a process part of a certain structure, for example a double busbar GIS line feeder;
- complete process configuration with all IEDs bound to individual process functions and primary equipment, enhanced by the access control object definitions (access allowances) for all possible communication partners;
- ready to run IED with all communication links ready to run. This is required if an IED is not capable dynamically opening connections;

The configuration language is based on the XML schema language.

5.9 Summary

Figure 8 exhibits a summary of Clause 5. The four main building blocks are

- the substation automation system specific information models,
- the information exchange methods,
- the mapping to concrete communication protocols, and
- the configuration of a substation IED.

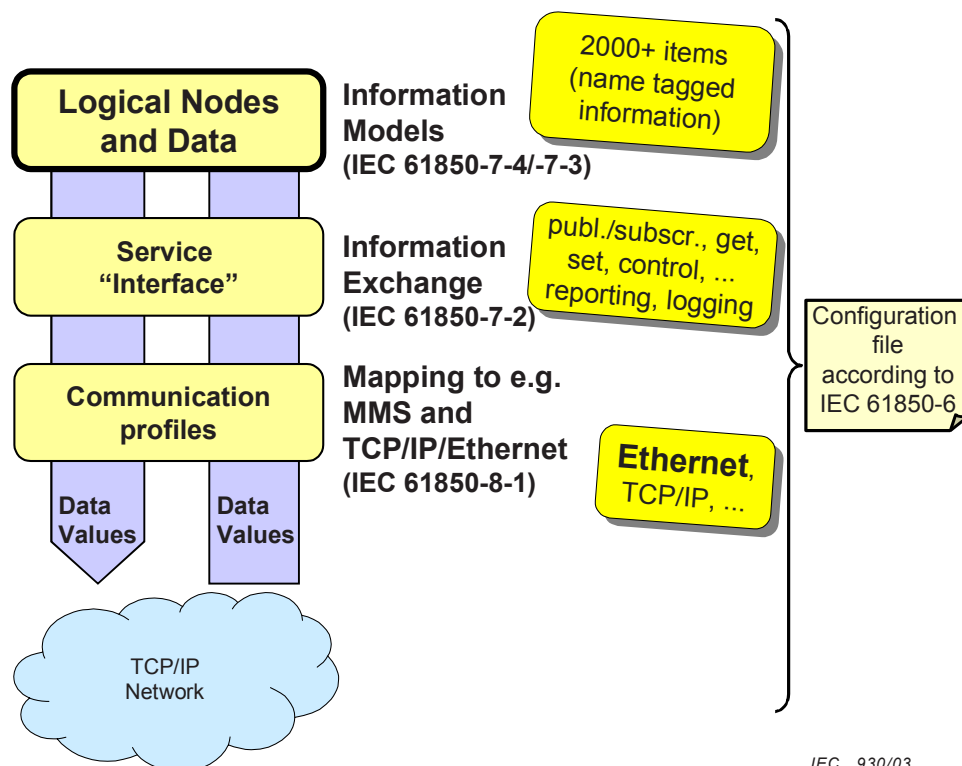


Figure 8 – Summary

These four building blocks are to a high degree independent of each other. The information models can easily be extended by definition of new logical nodes and new data according to specific and flexible rules – as required by another application domains. In the same way, communication stacks may be exchanged following the state-of-the-art in communication technology. But to keep interoperability simple, one stack only should be selected at one time. For the selection, see IEC 61850-8-x and IEC 61850-9-x.

The information is separated from the presentation and from the information exchange services.

The information exchange services are separated from the concrete communication profiles.

Clause 6 provides a more detailed view of the four building blocks.

6 Modelling approach of the IEC 61850 series

6.1 Decomposition of application functions and information

As described in IEC 61850-5, the general approach of the IEC 61850 series is to decompose application functions into the smallest entities, which are then used to communicate. The granularity is given by a reasonable distributed allocation of these entities to dedicated devices (IED). The entities are called logical nodes. The requirements for logical nodes are defined – from an application point of view – in IEC 61850-5.

Based on their functionality, these logical nodes comprise data with dedicated data attributes. The information represented by the data and the data attributes are exchanged by dedicated services according well-defined rules and the performance requested as required in IEC 61850-5.

The decomposition process (to get the most common logical nodes) and the composition process (to build up devices using logical nodes) are depicted in Figure 9. The data classes contained in logical nodes have been defined to support the most common applications in an understandable and commonly accepted way.

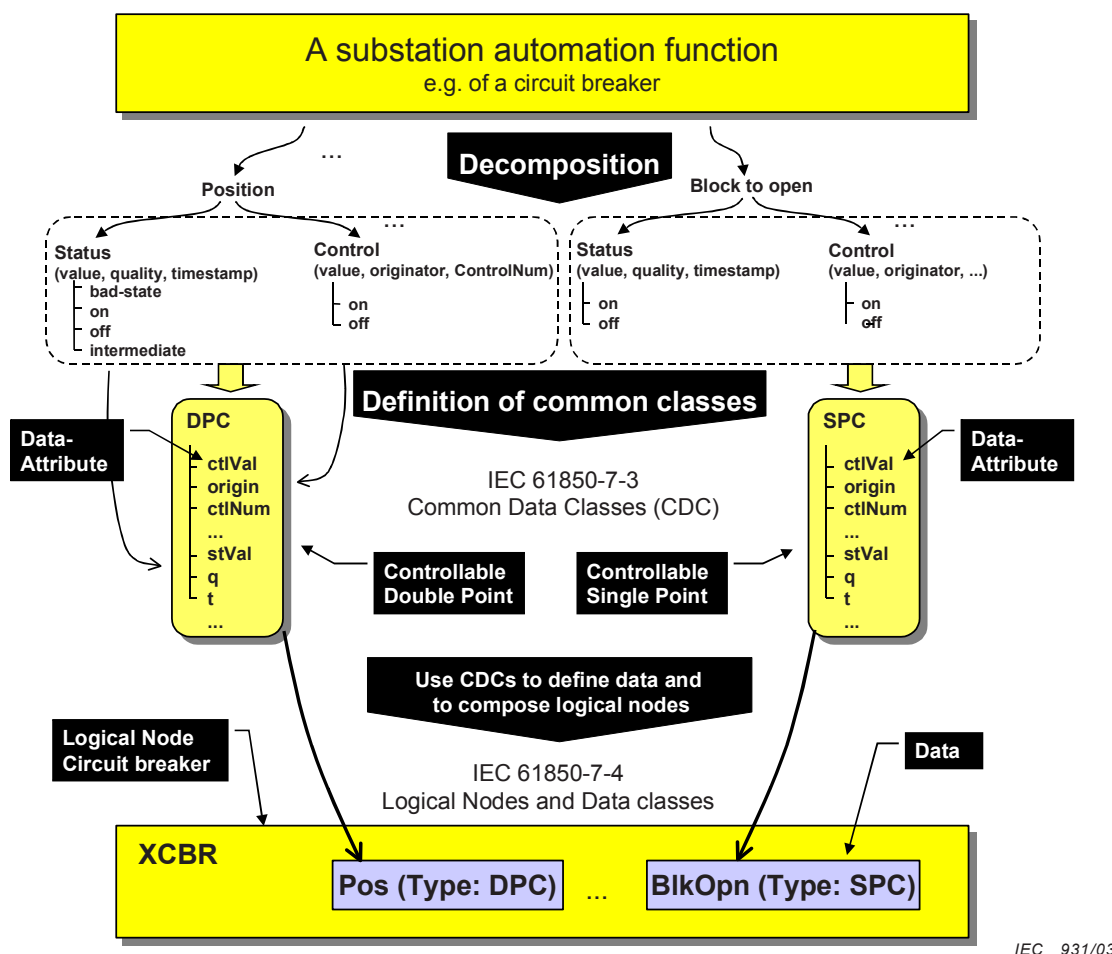


Figure 9 – Decomposition and composition process (conceptual)

A small part of a function (an excerpt of a circuit breaker model) has been selected as an example to explain the decomposition process. The circuit breaker has, among many other attributes, a position which can be controlled and monitored and the capability to prevent the switch being opened (for example, for interlocking purposes; block to open). The position comprises some information that represents the status of the position providing the value of the status (on, off, intermediate, bad state), the quality of the value (good, etc.), and the timestamp of the time of the last change of the position. In addition, the position provides the capability to control the switch: Control value (on, off). To keep track of who controlled the switch, the originator stores the information about the entity that issued the last control command. A control number stores the sequence number of the last control command.

The information grouped under the position (status, control, etc.) represents a very common group of a four-state value that can be reused many times. Similarly the “Block to open” groups information of a two-state value. These groups are called common data classes (CDC):

- four-state reusable class is defined as **Controllable double point (DPC)**, and
- two-state reusable class is defined as **Controllable single point (SPC)**.

IEC 61850-7-3 defines some 30 common data classes for status, measurands, controllable status, controllable analogue, status settings, and analogue settings.

6.2 Creating information models by stepwise composition

IEC 61850-7-4, IEC 61850-7-3, and IEC 61850-7-2 define how to model the information and communication in substations according to the requirements defined in IEC 61850-5. The modelling uses the logical nodes (and their data that represent a huge amount of semantical definitions) primarily as building blocks to compose the visible information of a substation automation system. The models are used for description of the information produced and consumed by applications and for the exchange of information with other IEDs.

The logical nodes and data classes introduced in IEC 61850-5 are refined and precisely defined in IEC 61850-7-4. They have been defined in a joint effort of domain experts of the various substation application domains and modelling experts. The logical nodes and their data are defined with regard to content (semantic) and form (syntax). The approach uses object oriented methods.

NOTE The logical node classes and data classes modelled and defined in IEC 61850-7-4 meet the requirements listed in IEC 61850-5.

In the next step, the common data classes are used to define the (substation domain-specific) data classes (see lower half of Figure 9). These data classes (defined in IEC 61850-7-4) are specialised common data classes, for example, the data class **Pos** (a specialisation of **DPC**) inherits all data attributes of the corresponding common data class **DPC**, i.e., the **ctlVal**, **origin**, **ctlNum**, etc. The semantic of the class **Pos** is defined at the end of IEC 61850-7-4.

A logical node groups several data classes to build up a specific functionality. The logical node **XCBR** represents the common information of a real circuit breaker. The **XCBR** can be reused to describe the common information of circuit breakers of various makes and types.

IEC 61850-7-4 defines some 90 logical nodes making use of the some 450 data classes. The logical node **XCBR** comprises about 20 data classes. A brief description of the logical node **XCBR** is given in Table 3.

Table 3 – Logical node class XCBR (conceptual)

Common Logical Node Information
Mode
Behaviour
Health
Name plate
Optional Logical Node Information
Local operation
External equipment health
External equipment name plate
Operation counter resetable
Operation counter
Operation time
Local operation (local means without substation automa- tion communication, hardwired direct control)
Operation counter
External equipment health
External equipment name plate
Controls
Switch position (see below for details)
Block opening
Block closing
Charger motor enabled
Metered Values
Sum of Switched Amperes, resetable
Status Information
Circuit breaker operating capability
Point On Wave switching capability
Circuit breaker operating capability when fully charged

NOTE IEC 61850-7-4 defines a standardised name for each item such as **Pos** for the switch position. Additionally, the tables for logical nodes contain the common data class to be used for the corresponding data class. Finally the tables define if the data class in the table is mandatory or optional. These details are explained later in this part.

The content of the marked “switch position” (name = **Pos**) is introduced in Figure 10.

IEC 61850-7-x uses tables for the definition of the logical node classes and data classes (IEC 61850-7-4), the common data classes (IEC 61850-7-3) and service models (IEC 61850-7-2). Data classes and data attributes form a hierarchical structure as depicted in Figure 10. The data attributes of the data class **Pos** are organised in a way that all attributes for control (status, substitution, configuration, etc.) are listed together.

The data attributes have a standardised name and a standardised type. On the right hand side the corresponding references (object reference) are shown. These references are used to provide the path information to identify the information in the tree.

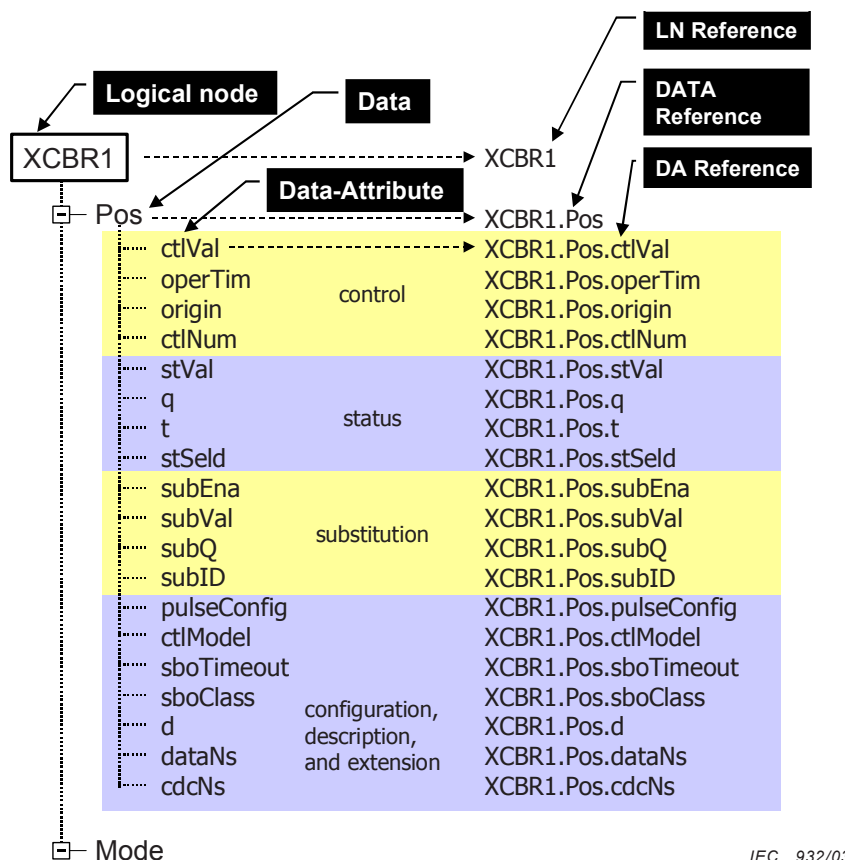


Figure 10 – XCBR1 information depicted as a tree

The instance **XCBR1** (the first instance of **XCBR**) is the root at the level of logical nodes. The object reference **XCBR1** references the complete tree below. The **XCBR1** contains data, for example, **Pos** and **Mode**. The data **Pos** (position) is precisely defined in IEC 61850-7-4 (see excerpt of the description):

Description of data

Data Name	Semantics
...	...
Pos	This data is accessed when performing a switch command or to verify the switch status or position. When this data is also used for a hand-operated switch, the (optional) CtIVal attribute in IEC 61850-7-3 does not exist.
...	...

The content of the position **Pos** is a list of some 20 data attributes. The attributes are derived from the common data class **DPC** (double point control). The data attributes defined in the DPC are partly mandatory and others are optional. Only those data attributes that are required for a specific application are inherited by a data object. For example, if the position does not require the support of substitution, then the data attributes **subEna**, **subVal**, **subQ**, and **subID** are not required in the data object **Pos**.

The information exchange services that access the data attributes make use of the hierarchical tree. The controllable data attribute is defined with **XCBR1.Pos.ctIVal**. The control service operates on exactly that controllable data attribute of the circuit breaker. The status information could be referenced as a member (**XCBR1.Pos.stVal**) of a data set named "AlarmXCBR". The data set could be referenced by a reporting control block named

“Alarm”. The report control block could be configured to send a report to a specific computer each time a circuit breaker changes its state (from open to close or from close to open).

6.3 Example of an IED composition

Figure 11 shows examples of different logical nodes composed into an IEDs. The logical nodes involved are **PTOC** (time overcurrent protection), **PDIS** (distance protection), **PTRC** (trip conditioning) and **XCBR** (circuit breaker). Case 1 shows a protection device with two functions, which are hardwired with the circuit breaker. Case 2 shows a protection device with two functions where the trip is communicated via a trip message over a network to the circuit breaker LN. Case 3 shows the two protection functions in dedicated devices, which may operate both in a fault and where the trips are transmitted as trip messages via the network independently to the circuit breaker LN (**XCBR**).

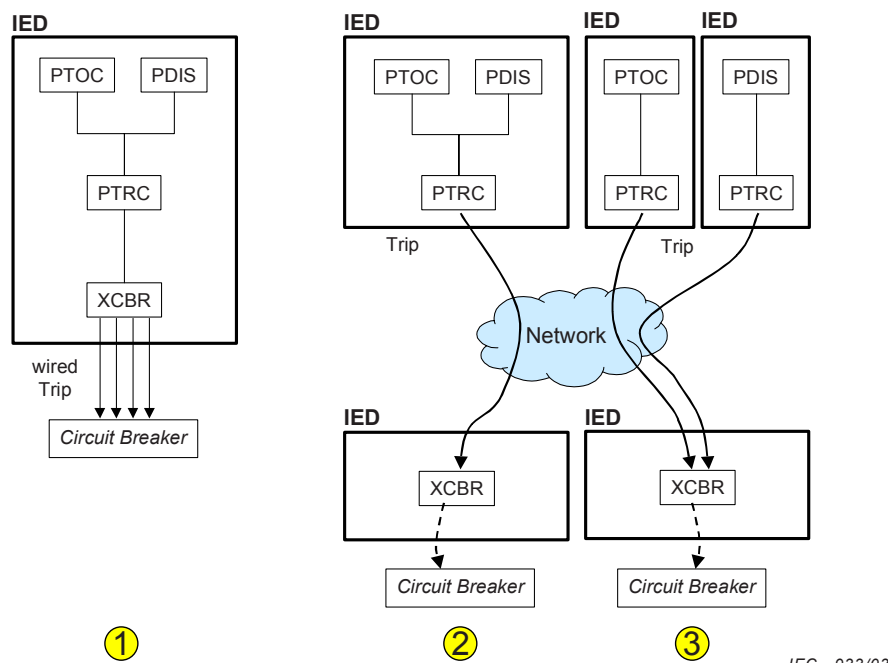


Figure 11 – Example of IED composition

In cases 2 and 3 the IED that hosts the **XCBR** LNs may be integrated in the real circuit breaker device or hardwired with it as in case 1, but this is outside the scope of the IEC 61850 series. The real breaker is represented for the substation automation system according to the IEC 61850 series by the XCBR LNs.

The IED composition is very flexible to meet current and future needs.

6.4 Information exchange models

6.4.1 Introduction

The information contained in the hierarchical models of IEC 61850-7-4 can be communicated using services defined in IEC 61850-7-2. The information exchange methods (depicted in Figure 12) fall mainly into three categories:

- the output model,
- the input model, and
- the model for online management and self-description.

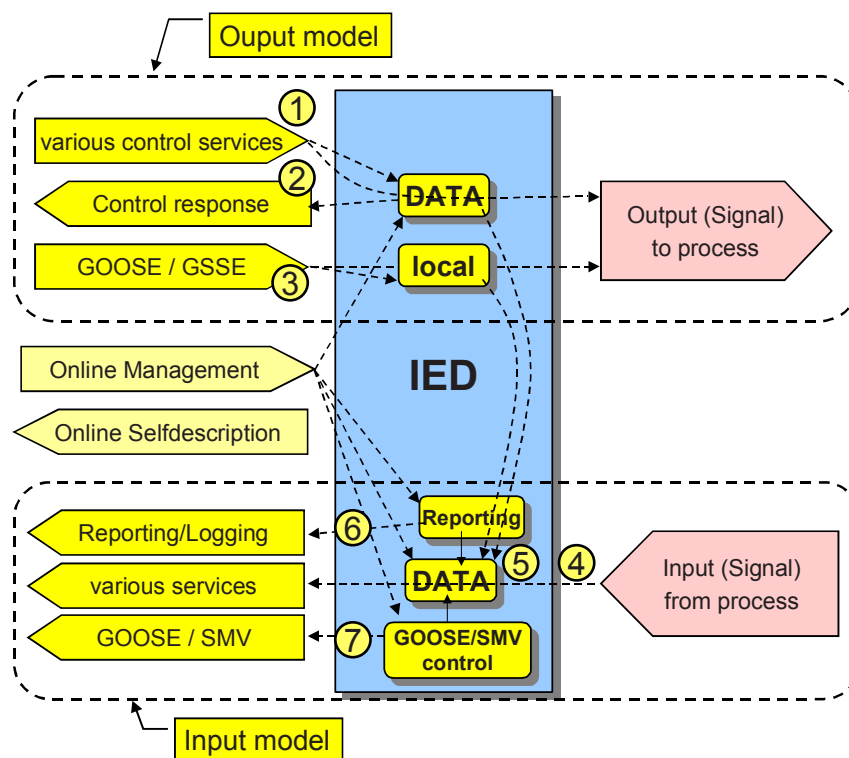
Several services are defined for each model. The services operate on data, data attributes, and other attributes usually contained in logical nodes. The numbers in the circles in

Figure 12 are used in 6.4.2 and Figures 13, 14, 15, 17, 19 and 21 as references for the description.

NOTE 1 Services operate actually on instances of data. To increase the readability the term “instance of” has been omitted in most places throughout this part of IEC 61850.

Services for the **output** model may have an impact on an internal process only, may produce an output signal to the process via a process interface, or may change a state value of a data attribute triggering a report. If the process interface is an IED in conformance with the IEC 61850 series, this service will produce an output signal to the process directly.

NOTE 2 The terms “input” and “output” are relative to the direction from the IED to the process (output) and from the process to the IED (input).



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The numbers in the circles in this figure are used in 6.4.2 and Figures 13, 14, 15, 17, 19 and 21 as references for the description.

Figure 12 – Output and Input model (principle)

Several services are defined for the **input** model. The services communicating input information may carry information directly from the process interface or may have been computed inside an IED.

There are also several services that may be used to remotely manage the IED to some (restricted) degree, for example, to define a data set, to set a reference to a specific value, or to enable sending specific reports by a report control block. The information models (logical nodes and data classes) and the service models (for example, for reporting and logging) provide means to retrieve comprehensive information about the information model and the services that operate on the information models (self-description).

The following description of the output and input models are conceptual only. Details on the information and services involved in the models are defined in IEC 61850-7-4, IEC 61850-7-3, and IEC 61850-7-2.

6.4.2 Output model

6.4.2.1 Control model concept

The concept of the control model is depicted in Figure 13. The example is a circuit breaker logical node (**XCBR**) with the data attribute **XCBR.Pos.ctlVal** (shown in Figure 14). Before the control service request performs the change of the position of a real device, some conditions have to be met, for example, the output can be generated only if the local/remote switch is in the “remote” position and the interlocking node (**CILO**) has released this operation. The following chain of conditions to be met may possibly include:

- local/remote switch of the circuit breaker **XCBR.Loc**,
- mode information of the circuit breaker **XCBR.Mod**,
- check conditions of the device, and
- other attributes of the controllable date, for example, interlocking, pulse configuration, control model, sbo class, and sbo timeout as defined in the common data class **DPC** (controllable double point in IEC 61850-7-3).

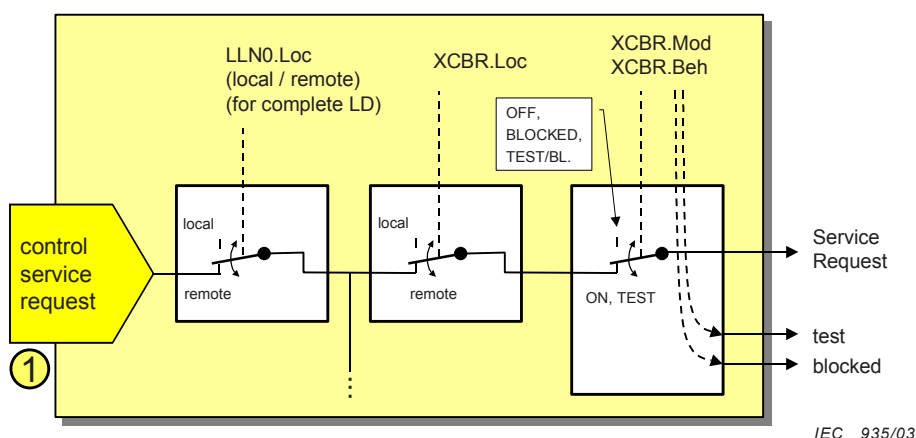


Figure 13 – Output model (step 1) (conceptual)

After all conditions have been met and all checks are positive, the output signal can be conditioned and control the real equipment (the circuit breaker – not shown).

The output signal may be issued over a wired interface to the circuit breaker or may be communicated over a bus interface.

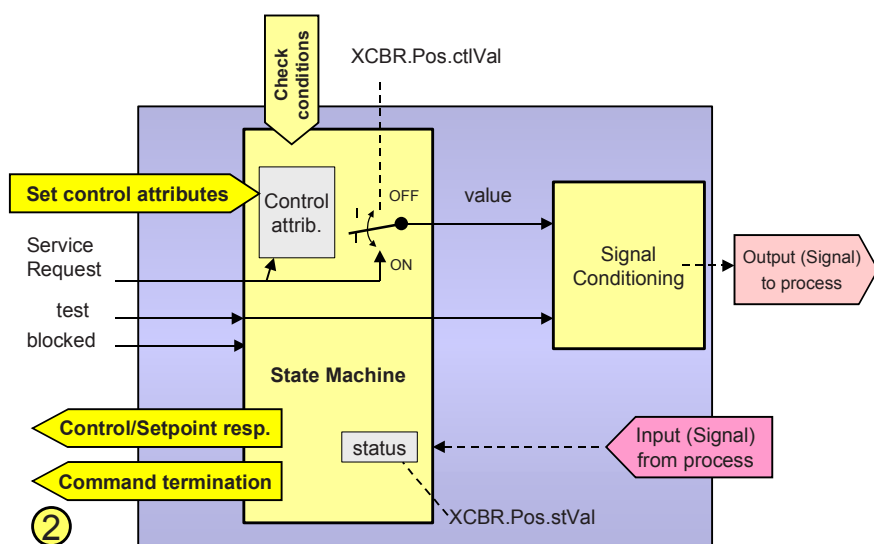


Figure 14 – Output model (step 2) (conceptual)

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The state change of the real circuit breaker causes a change in the status information modelled with the data attribute **XCBR.Pos.stVal**. The status change issues a control service response. A command termination completes the control transaction.

6.4.2.2 GSE model concept

The generic substation event (GSE – GOOSE and GSSE) provides the peer-to-peer information exchange between the input data values of one IED to the output data of many other IEDs (multicast). The GOOSE and GSSE messages received by an IED may be used to compute data for internal purposes also. An example for internal purposes are received switch positions to calculate the interlocking conditions locally.

NOTE 1 The GOOSE and GSSE data values are defined in the input model described in 6.4.3.

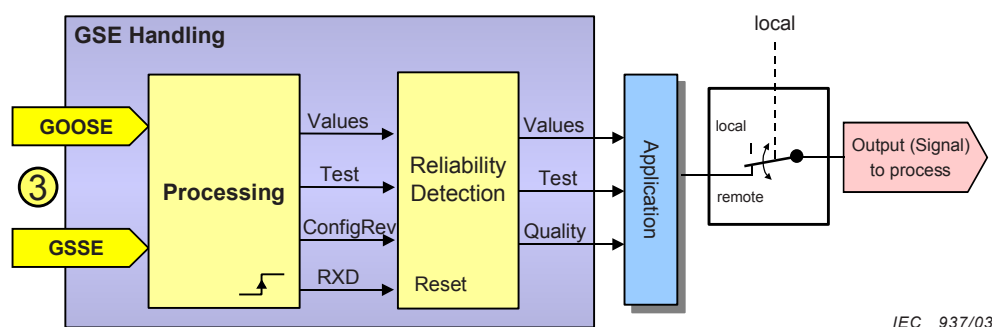


Figure 15 – GSE output model (conceptual)

The conditions to be met and the checks to run before the values are used as output signals such as interlocking are partly described within the IEC 61850 series and partly defined by the local application outside the scope of the IEC 61850 series.

NOTE 2 Many GOOSE and GSSE messages may be transmitted in certain cases, for example, fault detected by a protection relay. A SCSM usually filters these messages at the data link layer to prevent flooding the IEDs.

6.4.2.3 Attributes of data and control blocks

Many data attributes of the hierarchical information model can be set with a Set-service, for example, **SetDataValues** and **SetDataSetValues**. Setting the values of data attributes is usually constrained only by the application.

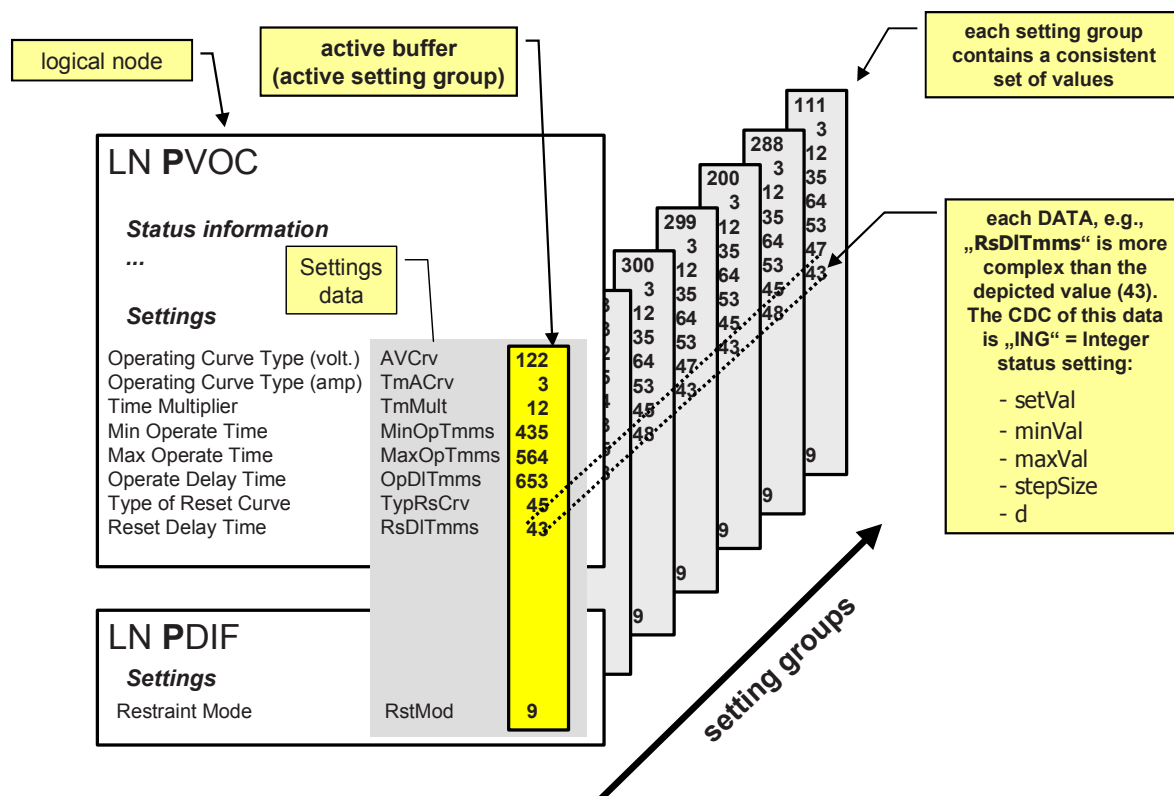
The various control blocks, for example, the setting group control block (**SGCB**), the buffered report control block (**BRCB**) and log control block (**LCB**), have control block attributes that can usually be set to a specific value. The services to set these attributes are defined with the control blocks in IEC 61850-7-2. Setting the values of the control block attributes is constrained by the state machine of the corresponding control block.

The control blocks behave according to the values of its attribute set. The values may also be configured using the SCL file or by other local means.

All control block attributes can be read by another IED.

6.4.2.4 Setting data and setting group control block

A special treatment of output data values is required for setting data contained in several logical nodes as defined in IEC 61850-7-4, for example, the settings for the voltage controlled overcurrent protection logical node **PVOC** (see Figure 16). The setting data (for example **AVCrv**, **TmACrv**, **TmMult**, etc.) have as many values as setting groups are defined. Each setting group has a consistent set of values.



IEC 938/03

Figure 16 – Setting data (conceptual)

The values depicted are complex in the sense that each data has a type derived from a common data class. The **RsDITmms** is derived from the common data class **ING**. The ING has several data attributes as listed in Table 4.

Table 4 – Excerpt of integer status setting

ING class					
Attribute name	Attribute type	FC	TrgOp	Value/value range	M/O/C
...	...				
DataAttribute					
setting					
setVal	INT32	SP			AC_NSG_M
setVal	INT32	SG, SE			AC_SG_M
configuration, description and extension					
minVal	INT32	CF			O
maxVal	INT32	CF			O
stepSize	INT32U	CF		1 ... (maxVal – minVal)	O
d	VISIBLE STRING255	DC		Text	O
...	...	...			...

The values of a specific setting group contained in the setting data can be set only if that group is in the “EDIT” state (indicated by the **FC=SE**; edit setting data). After all values of that group are set, the values of that group can be confirmed as containing a consistent set of values. This newly confirmed set of values can then be selected for use by the application (setting group in active state: **FC=SG**; active setting data).

The **setVal** of **FC=SP** means “simple” setting data (set point); applied when the setting group control model is not supported. This value can be set as a regular data attribute.

6.4.3 Input model

6.4.3.1 Input analogue signal acquisition

The concept of the input analogue signal acquisition is depicted in Figure 17. Normally, the raw signal is conditioned by a signal conditioner. For our model, an analogue input exists as data not before it is converted from analogue to digital. The sample rate (data attribute **smpRate** of a configurable data) determines how often the value shall be sampled. The conditions to be met before the value can be communicated (modelled as the data attribute **instMag** of the data, for example, a voltage of a specific phase – see Figure 18) may comprise the values of the following attributes:

- substitute/unsubstitute “switch” of the data (modelled as the data attribute **subMag** of the data, for example, a voltage of a specific phase),
- operator blocked or unblocked “switch”.

The result of these first steps is the “intermediate value” (still an analogue value) accompanied by the corresponding quality information.

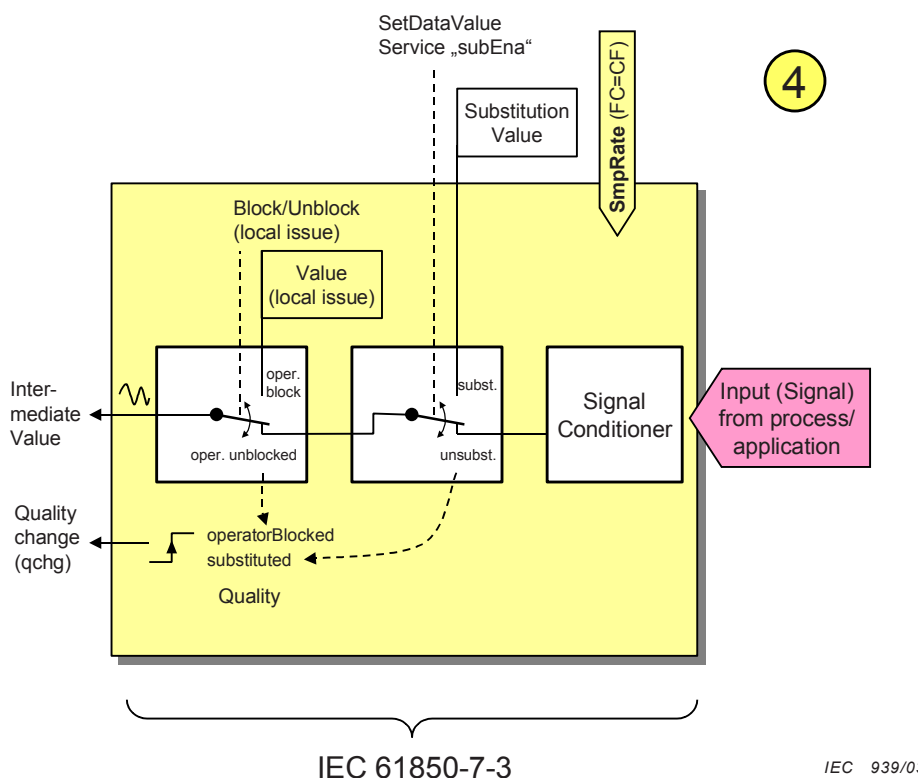


Figure 17 – Input model for analogue values (step 1) (conceptual)

6.4.3.2 Data attribute value processing, monitoring and event detection

The “intermediate value” is used for various purposes. The first use is to provide this value as the instantaneous data attribute value (magnitude) of the data. The data attribute has the name **instMag**; with the functional constraint **FC=MX** (indicating a measurand value). There is no trigger option associated with the instantaneous value.

The second application is the calculation of the deadbanded value, the **mag** value. The deadbanded value shall be based on a deadband calculation from **instMag** as illustrated in Figure 18. The value of **mag** shall be updated to the current value of **instMag** when the value has changed according the value of the configuration parameter **db** of this data.