

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Réseaux et systèmes de communication pour l'automatisation des systèmes
électriques –
Partie 7-1: Structure de communication de base – Principes et modèles**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2011 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

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

About IEC publications

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

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

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

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch

Tel.: +41 22 919 02 11

Fax: +41 22 919 03 00

A propos de la CEI

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

A propos des publications CEI

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

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

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

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch

Tél.: +41 22 919 02 11

Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Réseaux et systèmes de communication pour l'automatisation des systèmes
électriques –
Partie 7-1: Structure de communication de base – Principes et modèles**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.200

ISBN 978-2-88912-555-5

CONTENTS

FOREWORD.....	8
INTRODUCTION.....	10
1 Scope.....	11
2 Normative references	12
3 Terms and definitions	13
4 Abbreviated terms	13
5 Overview of the IEC 61850 series concepts.....	14
5.1 Objective.....	14
5.2 Topology and communication functions of substation automation systems	16
5.3 The information models of substation automation systems	16
5.4 Applications modelled by logical nodes defined in IEC 61850-7-4.....	18
5.5 The semantic is attached to data	21
5.6 The services to exchange information	23
5.7 Services mapped to concrete communication protocols	24
5.8 The configuration of the automation system	25
5.9 Summary.....	26
6 Modelling approach of the IEC 61850 series.....	27
6.1 Decomposition of application functions and information.....	27
6.2 Creating information models by stepwise composition	28
6.3 Example of an IED composition	31
6.4 Information exchange models.....	31
6.4.1 General	31
6.4.2 Output model.....	33
6.4.3 Input model	36
6.4.4 Model for statistical and historical statistical data	46
6.4.5 Model for system functions	50
7 Application view	52
7.1 General.....	52
7.2 First modelling step – Logical nodes and data	53
7.3 Mode and behaviour of a logical node	57
7.4 Use of measurement ranges and alarms for supervision functions.....	57
7.5 Data used for limiting the access to control actions	58
7.6 Data used for blocking functions described by logical nodes	58
7.7 Data used for logical node inputs/outputs blocking (operational blocking).....	58
7.7.1 General	58
7.7.2 Blocking incoming commands.....	59
7.7.3 Blocking process outputs.....	59
7.7.4 Blocking oscillating inputs.....	60
7.8 Data used for testing	60
7.8.1 General	60
7.8.2 Multicast signals used for simulation	60
7.8.3 Input signals used for testing.....	61
7.8.4 Test mode	62
7.9 Logical node used for extended logging functions	62
8 Device view.....	63
8.1 General.....	63

8.2	Second modelling step – logical device model	64
8.2.1	The logical device concept	64
8.2.2	The device nameplate	65
8.2.3	Gateways and proxies	66
8.2.4	Logical devices for monitoring external device health	67
8.2.5	Logical devices management hierarchy	68
9	Communication view	70
9.1	General	70
9.2	The service models of the IEC 61850 series	70
9.3	The virtualisation	72
9.4	Basic information exchange mechanisms	73
9.5	The client-server building blocks	75
9.5.1	Server	75
9.5.2	Client-server roles	76
9.6	Logical nodes communicate with logical nodes	77
9.7	Interfaces inside and between devices	78
10	Where physical devices, application models and communication meet	79
11	Relationships between IEC 61850-7-2, IEC 61850-7-3 and IEC 61850-7-4	80
11.1	Refinements of class definitions	80
11.2	Example 1 – Logical node and data class	81
11.3	Example 2 – Relationship of IEC 61850-7-2, IEC 61850-7-3, and IEC 61850-7-4	85
12	Formal specification method	86
12.1	Notation of ACSI classes	86
12.2	Class modelling	87
12.2.1	Overview	87
12.2.2	Common data class	88
12.2.3	Logical node class	91
12.3	Service tables	92
12.4	Referencing instances	93
13	Name spaces	96
13.1	General	96
13.2	Name spaces defined in the IEC 61850-7-x series	97
13.3	Specification of name spaces	101
13.3.1	General	101
13.3.2	Specification	101
13.4	Attributes for references to name spaces	102
13.4.1	General	102
13.4.2	Attribute for logical device name space (ldNs)	103
13.4.3	Attribute for logical node name space (lnNs)	103
13.4.4	Attribute for data name space (dataNs)	104
13.4.5	Attribute for common data class name space (cdcNs)	104
14	Common rules for new version of classes and for extension of classes	104
14.1	General	104
14.2	Basic rules	104
14.3	Rules for LN classes	105
14.3.1	Use of standardized LN classes	105
14.3.2	Extensions to standardized LN classes made by third parties	106
14.3.3	New LN classes	106

14.3.4 New versions of standardized LN classes made by name space owners	107
14.4 Rules for common data classes and control block classes	107
14.4.1 New common data classes and control block classes	107
14.4.2 New versions of standardized common data classes	107
14.4.3 New versions of control block classes.....	107
14.5 Multiple instances of LN classes for dedicated and complex functions.....	108
14.5.1 Example for time overcurrent.....	108
14.5.2 Example for PDIS	108
14.5.3 Example for power transformer.....	108
14.5.4 Example for auxiliary network	108
14.6 Specialisation of data by use of number extensions.....	109
14.7 Examples for new LNs.....	109
14.8 Example for new Data	109
Annex A (informative) Overview of logical nodes and data	110
Annex B (informative) Allocation of data to logical nodes	113
Annex C (informative) Use of the substation configuration language (SCL)	116
Annex D (informative) Applying the LN concept to options for future extensions	118
Annex E (informative) Relation between logical nodes and PICOMs	123
Annex F (informative) Mapping the ACSI to real communication systems.....	124
Bibliography.....	132
Figure 1 – Relations between modelling and mapping parts of the IEC 61850 series	14
Figure 2 – Sample substation automation topology	16
Figure 3 – Modelling approach (conceptual).....	17
Figure 4 – Logical node information categories	20
Figure 5 – Build-up of devices (principle)	20
Figure 6 – Position information depicted as a tree (conceptual)	21
Figure 7 – Service excerpt	23
Figure 8 – Example of communication mapping	25
Figure 9 – Summary	26
Figure 10 – Decomposition and composition process (conceptual).....	27
Figure 11 – XCBR1 information depicted as a tree.....	30
Figure 12 – Example of IED composition.....	31
Figure 13 – Output and input model (principle)	32
Figure 14 – Output model (step 1) (conceptual)	33
Figure 15 – Output model (step 2) (conceptual)	34
Figure 16 – GSE output model (conceptual).....	34
Figure 17 – Setting data (conceptual)	35
Figure 18 – Input model for analogue values (step 1) (conceptual)	37
Figure 19 – Range and deadbanded value (conceptual).....	38
Figure 20 – Input model for analogue values (step 2) (conceptual)	39
Figure 21 – Reporting and logging model (conceptual).....	40
Figure 22 – Data set members and reporting	41
Figure 23 – Buffered report control block (conceptual)	

Figure 24 – Buffer time	43
Figure 25 – Data set members and inclusion-bitstring	44
Figure 26 – Log control block (conceptual).....	44
Figure 27 – Peer-to-peer data value publishing model (conceptual)	45
Figure 28 – Conceptual model of statistical and historical statistical data (1)	47
Figure 29 – Conceptual model of statistical and historical statistical data (2)	49
Figure 30 – Concept of the service tracking model – Example: control service tracking.....	51
Figure 31 – Real world devices	52
Figure 32 – Logical nodes and data (IEC 61850-7-2)	53
Figure 33 – Simple example of modelling.....	55
Figure 34 – Basic building blocks.....	55
Figure 35 – Logical nodes and PICOM	56
Figure 36 – Logical nodes connected (outside view in IEC 61850-7-x series).....	56
Figure 37 – Mode and behaviour data (IEC 61850-7-4)	57
Figure 38 – Data used for limiting the access to control actions (IEC 61850-7-4)	58
Figure 39 – Data used for logical node inputs/outputs blocking (IEC 61850-7-4)	59
Figure 40 – Data used for receiving simulation signals.....	60
Figure 41 – Example of input signals used for testing	61
Figure 42 – Test mode example.....	62
Figure 43 – Logical node used for extended logging functions (GLOG)	63
Figure 44 – Logical device building block.....	64
Figure 45 – Logical devices and LLN0/LPHD	65
Figure 46 – The common data class DPL.....	66
Figure 47 – Logical devices in proxies or gateways.....	67
Figure 48 – Logical devices for monitoring external device health	68
Figure 49 – Logical devices management hierarchy	69
Figure 50 – ACSI communication methods.....	71
Figure 51 – Virtualisation	73
Figure 52 – Virtualisation and usage	73
Figure 53 – Information flow and modelling.....	74
Figure 54 – Application of the GSE model.....	74
Figure 55 – Server building blocks	75
Figure 56 – Interaction between application process and application layer (client/server)	76
Figure 57 – Example for a service.....	76
Figure 58 – Client/server and logical nodes	77
Figure 59 – Client and server roles	77
Figure 60 – Logical nodes communicate with logical nodes.....	78
Figure 61 – Interfaces inside and between devices	79
Figure 62 – Component hierarchy of different views (excerpt)	80
Figure 63 – Refinement of the DATA class.....	81
Figure 64 – Instances of a DATA class (conceptual)	84
Figure 65 – Relation between parts of the IEC 61850 series	85

Figure 66 – Abstract data model example for IEC 61850-7-x.....	87
Figure 67 – Relation of TrgOp and Reporting.....	90
Figure 68 – Sequence diagram	92
Figure 69 – References	93
Figure 70 – Use of FCD and FCDA	94
Figure 71 – Object names and object reference	95
Figure 72 – Definition of names and semantics	96
Figure 73 – One name with two meanings.....	97
Figure 74 – Name space as class repository.....	98
Figure 75 – All instances derived from classes in a single name space	99
Figure 76 – Instances derived from multiple name spaces	100
Figure 77 – Inherited name spaces	100
Figure 78 – Basic extension rules diagram.....	105
Figure B.1 – Example for control and protection LNs combined in one physical device	113
Figure B.2 – Merging unit and sampled value exchange (topology)	114
Figure B.3 – Merging unit and sampled value exchange (data)	114
Figure C.1 – Application of SCL for LNs (conceptual)	116
Figure C.2 – Application of SCL for data (conceptual).....	117
Figure D.1 – Seamless communication (simplified)	118
Figure D.2 – Example for new logical nodes	119
Figure D.3 – Example for control center view and mapping to substation view	121
Figure E.1 – Exchanged data between subfunctions (logical nodes)	123
Figure E.2 – Relationship between PICOMS and client/server model	123
Figure F.1 – ACSI mapping to an application layer.....	124
Figure F.2 – ACSI mappings (conceptual).....	125
Figure F.3 – ACSI mapping to communication stacks/profiles	126
Figure F.4 – Mapping to MMS (conceptual).....	126
Figure F.5 – Mapping approach	127
Figure F.6 – Mapping detail of mapping to a MMS named variable.....	128
Figure F.7 – Example of MMS named variable (process values)	128
Figure F.8 – Use of MMS named variables and named variable list.....	129
Figure F.9 – MMS information report message.....	130
Figure F.10 – Mapping example.....	131
Table 1 – LN groups	18
Table 2 – Logical node class XCBB (conceptual)	29
Table 3 – Excerpt of integer status setting	36
Table 4 – Comparison of the data access methods	41
Table 5 – ACSI models and services.....	71
Table 6 – Logical node circuit breaker	82
Table 7 – Controllable double point (DPC)	83
Table 8 – ACSI class definition	86
Table 9 – Single point status common data class (SPS).....	88

Table 10 – Quality components attribute definition	89
Table 11 – Basic status information template (excerpt)	89
Table 12 – Trigger option	90
Table 13 – GenLogicalNodeClass definition	91
Table 14 – Excerpt of logical node name plate common data class (LPL)	103
Table 15 – Excerpt of common data class	103
Table A.1 – Excerpt of data classes for measurands	111
Table A.2 – List of common data classes (excerpt)	112

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-1: Basic communication structure – Principles and models

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61850-7-1 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this document is based on the following documents:

FDIS	Report on voting
57/1121/FDIS	57/1145/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This second edition cancels and replaces the first edition published in 2003. This second edition constitutes a technical revision.

Compared to the first edition, this second edition introduces:

- the model for statistical and historical statistical data,
- the concepts of proxies, gateways, LD hierarchy and LN inputs,
- the model for time synchronisation,
- the concepts behind different testing facilities,
- the extended logging function.

It also clarifies the following points:

- the use of numbers for data extension,
- the use of name spaces,
- the mode and behaviour of a logical node,
- the use of range and deadbanded values,
- the access to control actions and others.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61850 series, under the general title: *Communication networks and systems for power utility automation* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

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

This document is part of a set of specifications which details a layered communication architecture for power utility automation. 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 by systems for power utility automation but residing in equipment (physical devices) from different suppliers. Interoperable functions may be those functions that represent interfaces to the process (for example, circuit breakers) 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 interoperability is reached.

NOTE Interchangeability is 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, with no impact on the rest of the system. If differences in functionality are accepted, the exchange may also require some changes somewhere else in the system. Interchangeability implies a standardisation of functions and, in a strong sense, of devices which are outside the scope of this standard. Interchangeability is outside the scope, but it will be supported following this standard for interoperability.

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.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-1: Basic communication structure – 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 various parts of the IEC 61850-7-x series. 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 power utility automation systems,
- device functions used for power utility automation purposes, and
- communication systems to provide interoperability within power utility facilities.

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 the IEC 61850-7-x series 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:

- hydroelectric power plants,
- substation to substation information exchange,
- information exchange for distributed automation,
- substation to control centre information exchange,
- 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*

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

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

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

IEC 61850-6, *Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs*

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

IEC 61850-7-3, *Communication networks and systems for power utility automation – Part 7-3: Basic communication structure – Common data classes*

IEC 61850-7-4, *Communication networks and systems for power utility automation – Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*

IEC 61850-8-1, *Communication networks and systems for power utility automation – Part 8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*

IEC 61850-9-2, *Communication networks and systems in substations – Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3*

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

ISO/IEC 8802-3, *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, *Industrial automation systems – Manufacturing Message Specification – Part 1: Service definition*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61850-2 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

[IEC 60050-101:1998, 101-12-01]

3.2 information model

knowledge concerning power utility 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.

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

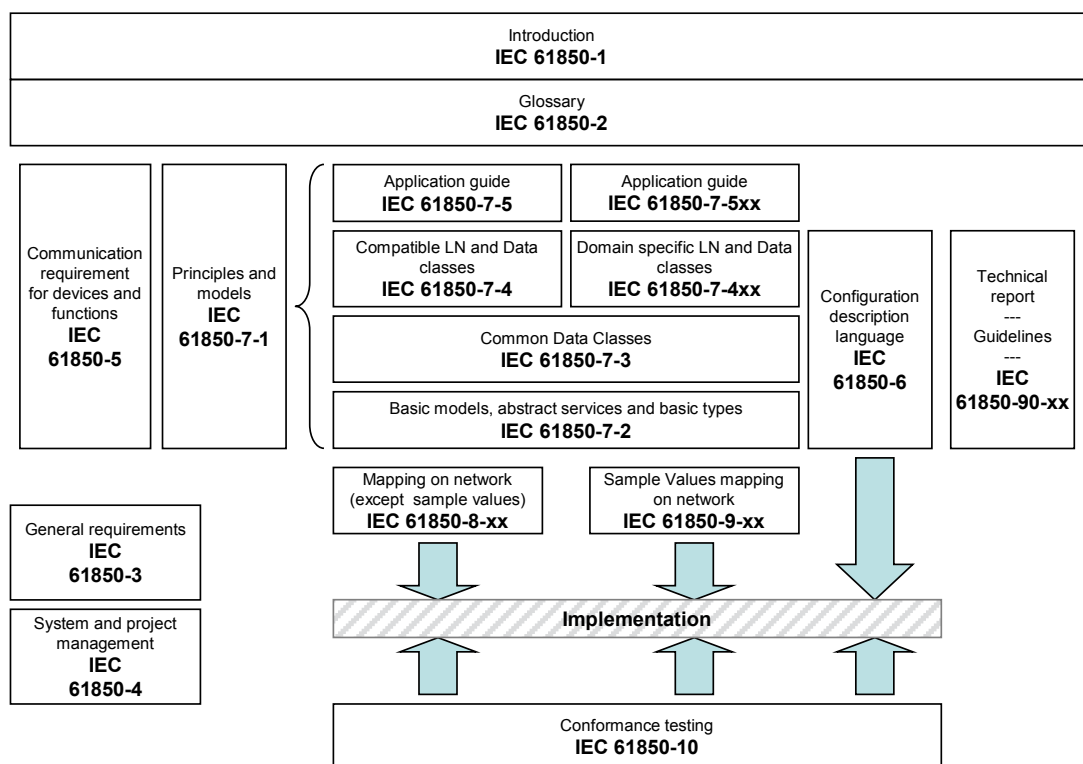
ACSI	Abstract communication service interface
ASN.1	Abstract syntax notation one
API	Application program interface
CDC	Common data class
CT	Current transformer
DST	Daylight saving time
GOOSE	Generic oriented object system event
IED	Intelligent electronic device
LD	Logical device
LN	Logical node
LLN0	Logical node zero
LPHD	Logical node physical device
MMS	Manufacturing message specification
PHD	Physical device

PICOM	Piece of communication
SAS	Substation automation system
SCSM	Specific communication service mapping
SoE	Sequence of events
SMV	Sample values
UCAIug	UCA international users group
UTC	Universal time coordinated
VMD	Virtual manufacturing device
VT	Voltage transformer
XML	extended markup language

5 Overview of the IEC 61850 series concepts

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 they are interwoven. The modelling and implementation methods applied in the different parts of the standard and their relation are shown in Figure 1.



IEC 1402/11

Figure 1 – Relations between modelling and mapping parts of the IEC 61850 series

Each part defines a specific aspect of a substation IED:

- IEC 61850-1 gives an introduction and overview of the IEC 61850 series,
- IEC 61850-2 contains the glossary of specific terminology and definitions used in the context of power utility automation systems within the various parts of the standard,
- IEC 61850-3 specifies the general requirements of the communication network with regard to the quality requirements, environmental conditions and auxiliary services,
- IEC 61850-4 pertains to the system and project management with respect to the engineering process, the life cycle of the SAS and the quality assurance from the development stage to the discontinuation and decommissioning of the SAS.
- IEC 61850-5 specifies the communication requirements of the functions being performed in systems for power utility automation and to device models. All known functions and their communication requirements are identified,
- this part of IEC 61850 defines the basic principles and modelling methods,
- IEC 61850-6 specifies a file format for describing communication related IED (intelligent electronic device) configurations and IED parameters, communication system configurations, switchyard (function) structures, and the relations between them. The main purpose of the format is to exchange IED capability descriptions, and system level descriptions between engineering tools of different manufacturers in a compatible way. The defined language is called substation configuration description language (SCL). Mapping specific extensions or usage rules may be required in the appropriate parts.
- IEC 61850-7-5 defines the usage of information models for substation automation applications. It gives clear examples on how to apply LNs and data defined in IEC 61850-7-4 for different substation applications. The examples cover applications from monitoring function to protection blocking schemes. Other domain specific application guides which are within the scope of IEC technical committee 57 are defined in the IEC 61850-7-5xx series¹. Examples are hydropower and distributed energy resources domains,
- IEC 61850-7-4 defines specific information models for substation automation functions (for example, breaker with status of breaker position, settings for a protection function, etc.) – what is modelled and could be exchanged. Other domain specific information models within the scope of IEC technical committee 57 are defined in the 61850-7-4xx series,
- IEC 61850-7-3 has a list of commonly used information (for example, for double point control, 3-phase measurand value, etc.) – what the common basic information is,
- IEC 61850-7-2 provides the services to exchange information for the different kinds of functions (for example, control, report, get and set, etc.) – how to exchange information,
- IEC 61850-8-1 defines the concrete means to communicate the information between IEDs (for example, the application layer, the encoding, etc.) – how to serialise the information during the exchange,
- IEC 61850-9-2, and particularly the subset 9-2LE described in the “Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2” by the UCAIug, defines the concrete means to communicate sampled values between sensors and IEDs,
- IEC 61850-10 defines the methods and abstract cases for conformance testing of devices and engineering tools as well as the metrics to be measured within devices according to the requirements defined in IEC 61850-5,
- there may be object classes defined for various other application domains outside the scope of IEC technical committee 57. They are relevant to Figure 1 only if they are built according to the approach of the IEC 61850 series.

¹ IEC 61850-7-4xx, -7-5xx, -8-xx, -9-xx and -90-xx are series of documents whose scope is similar. For example, IEC 61850-7-4 deals with data object classes used for substations while IEC 61850-7-410 deals with data object classes used for hydroelectric power plants. IEC 61850-90-xx series is reserved for technical reports or guidelines.

5.2 Topology and communication functions of substation automation systems

As shown by the topology in Figure 2, 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 signals (3),
- trip signals (4),
- engineering and configuration (5),
- monitoring and supervision (6),
- control-center communication (7),
- 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). 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.

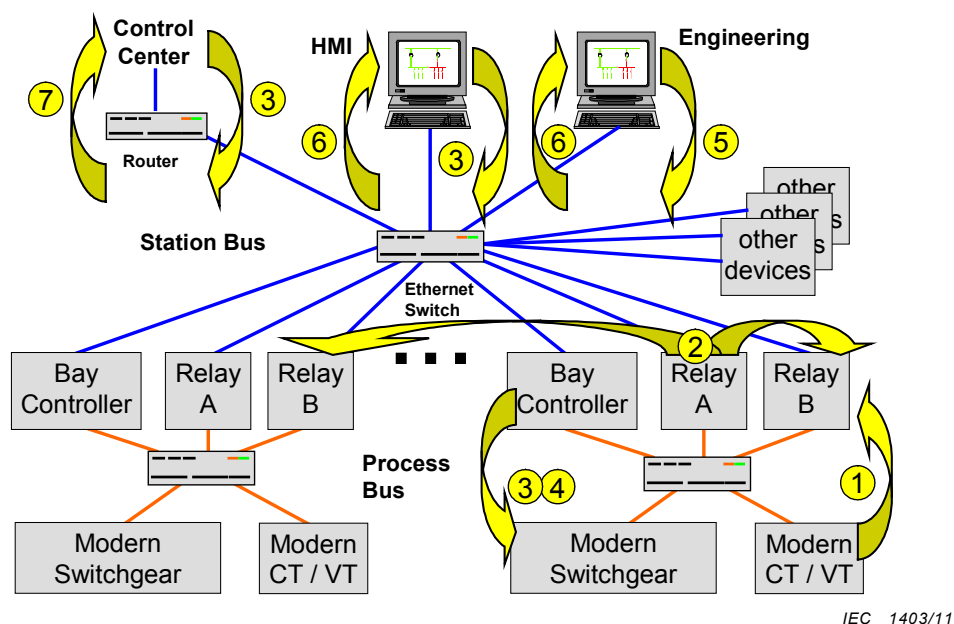


Figure 2 – Sample substation automation topology

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 3. All information made available to be exchanged with other devices is defined in the standard. The model provides for systems for power utility automation 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.

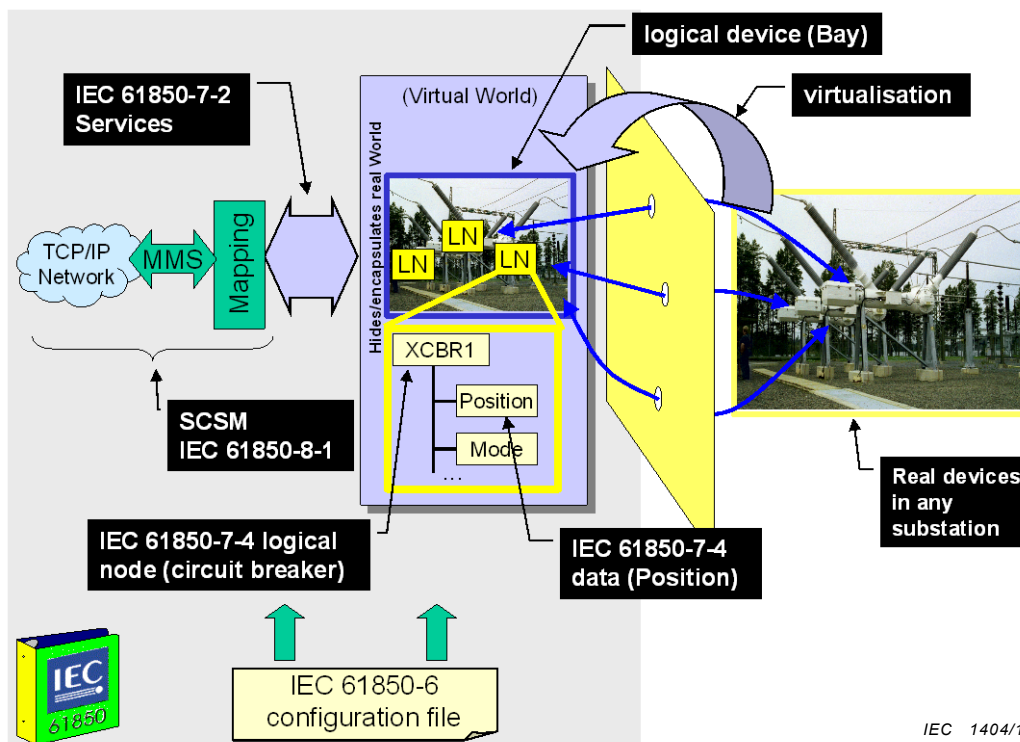


Figure 3 – Modelling approach (conceptual)

Implementations to reach interoperability have to be based on common understanding of definitions. Therefore, the parts describing the data model contain mandatory semantic tables which have to be considered very carefully.

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 do not contain logical nodes from different IEDs.

Real devices on the right-hand side of Figure 3 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 systems for power utility automation or, e.g. more specifically, 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 1 lists all groups of logical nodes defined in IEC 61850-7-4. Over one hundred logical nodes covering the most common applications of substation and feeder equipment are defined. While the definition of information models for protection and protection related applications is important because of the high impact of protection for safe and reliable operation of the power system, the covered applications include many other functions like monitoring, measurement, control and power quality.

Table 1 – LN groups

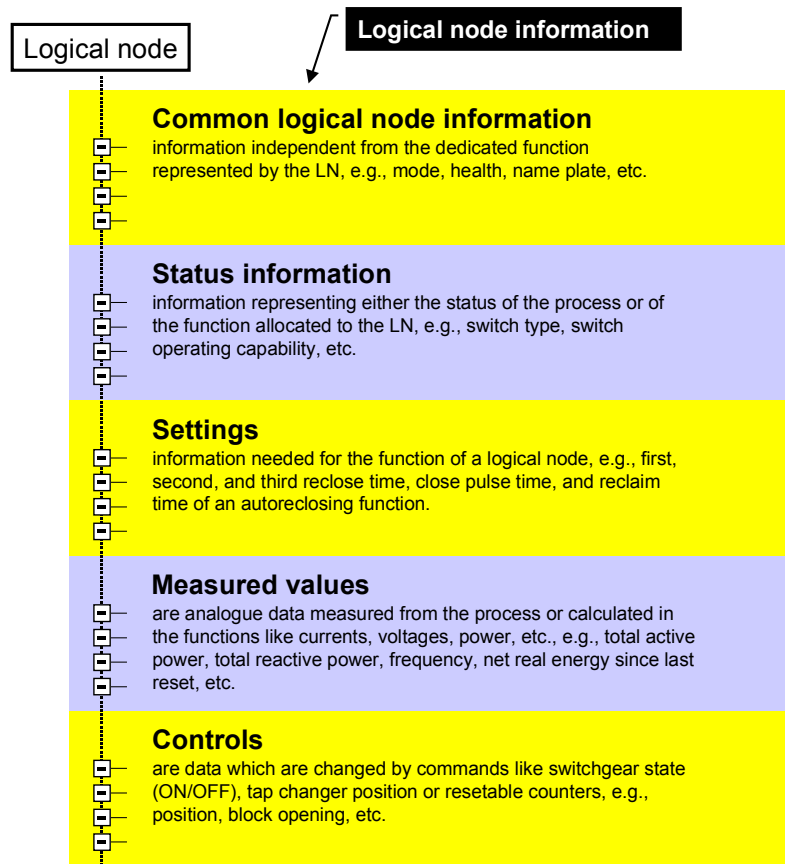
Group indicator	Logical node groups
A	Automatic control
C	Supervisory control
D	DER (Distributed Energy Resources)
F	Functional blocks
G	Generic function references
H	Hydro power
I	Interfacing and archiving
K	Mechanical and non-electrical primary equipment
L	System logical nodes
M	Metering and measurement
P	Protection functions
Q	Power quality events detection related
R	Protection related functions
S	Supervision and monitoring
T	Instrument transformer and sensors
W	Wind power
X	Switchgear
Y	Power transformer and related functions
Z	Further (power system) equipment

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 Clauses 13 and 14 of this standard.

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;
- and others.

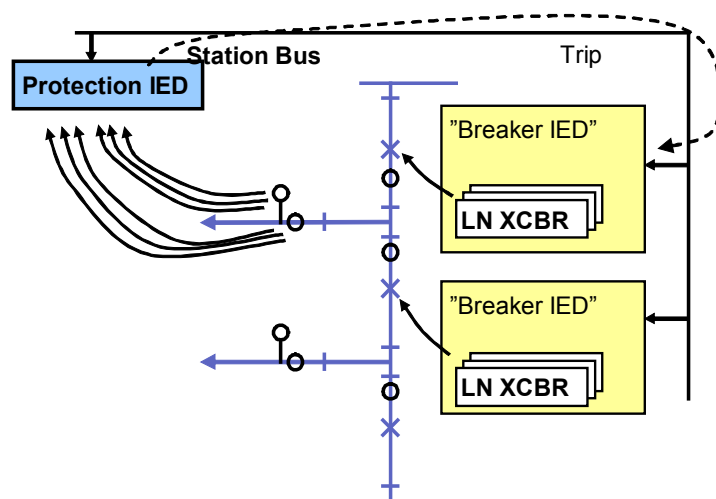
Most logical nodes provide information that can be categorised as depicted in Figure 4. The semantic of a logical node is represented by data and data attributes. Logical nodes may provide a few or up to 30 data. Data may contain a few or even more than 20 data attributes. Logical nodes may contain more than 100 individual information (points) organised in a hierarchical structure.



IEC 1405/11

Figure 4 – Logical node information categories

IEDs are built up by composing logical nodes as depicted in Figure 5. 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.



IEC 1406/11

Figure 5 – Build-up of devices (principle)

In Figure 5, 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 digitizing VTs and CTs sending voltage and current as samples to the protection over a serial

link. The output of conventional VTs and CTs may also be converted at the source to samples and transmitted over this 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 6). 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.

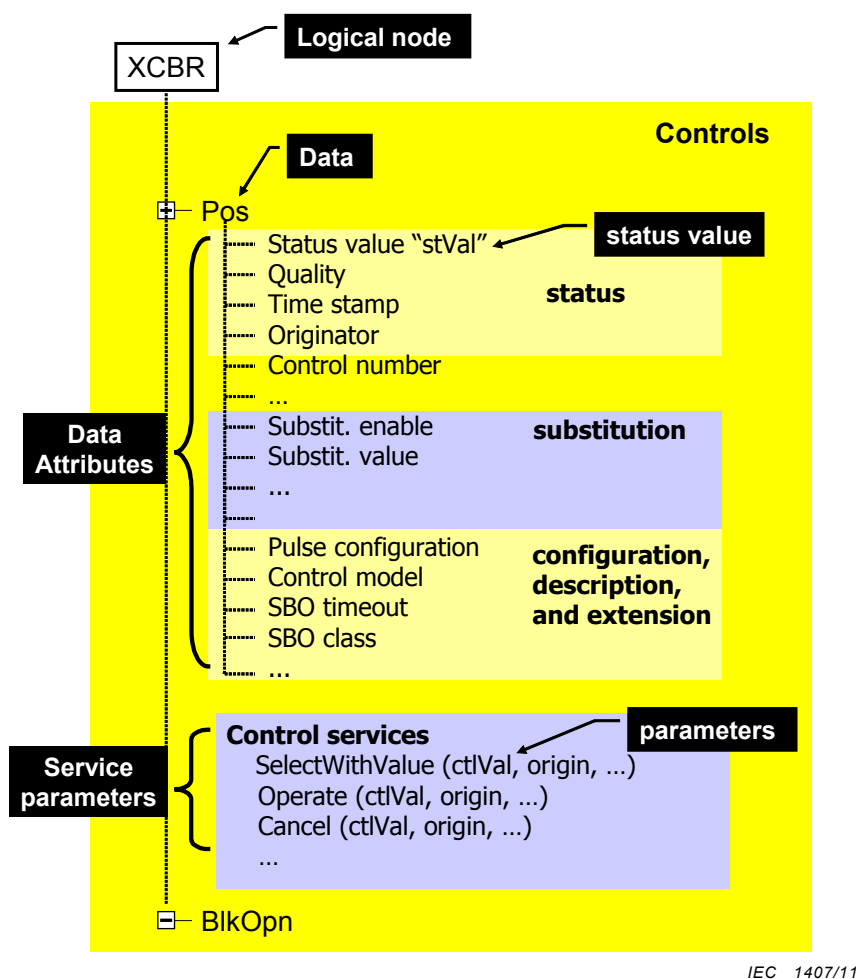


Figure 6 – Position information depicted as a tree (conceptual)

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:

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

The data example Pos has approximately 20 data attributes accessible through different services. The data attribute Pos.stVal represents the position of the real breaker (could be in intermediate-state, off, on, or bad-state).

The position Pos can be controlled by use of control services and the associated service parameters. It is important to understand that these service parameters are not part of the data model: they do not represent data attributes. They only “live” the time of the command execution.

The position also has information about the originator that issued the command and the control number (given by the originator in the request). Furthermore, the position contains the cause diagnosis of a negative control response. 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
stVal	CODED ENUM	ST	dchg	intermediate-state off on bad-state	M
ctlModel	CtlModels	CF	dchg	status-only direct-with-normal-security sbo-with-normal-security directwith-enhanced-security sbo-with-enhanced-security	M

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

- the services allowed: functional constraint -> FC=SV means that specific services shall be applied only (for example SV refers to the substitution 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., they are reserved) names that have a specific semantic in the context of the IEC 61850 series. The semantic of all data attribute names is defined at the end of IEC 61850-7-3; for example:

Data attribute name	Semantics
stVal	Status value of the data.
ctlModel	Configuration information about the control model.

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

The position information Pos as shown in Figure 6 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 “four

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).

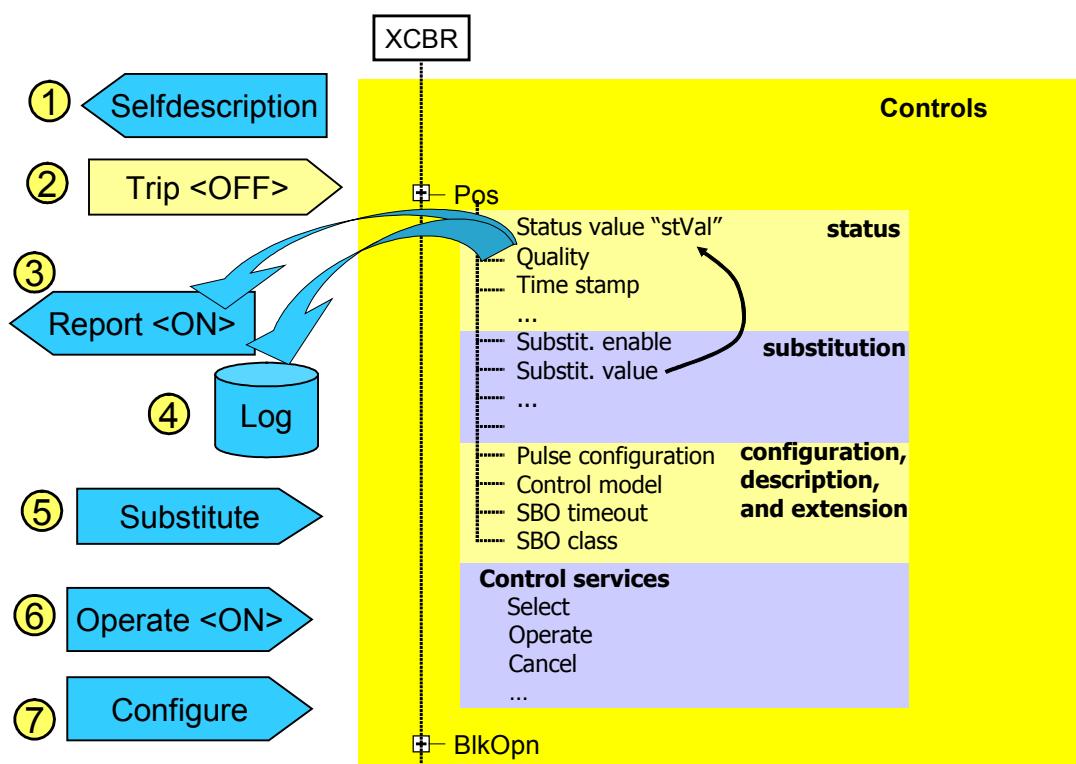
Common data classes provide a useful means to reduce the size of data definitions (in the standard). The data definition does not need to list all the attributes but needs to just reference the common data class. Common data classes are also very useful to keep the definitions of data attributes consistent. 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, data attributes and service parameters 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 7.



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

IEC 1408/11

Figure 7 – Service excerpt

The operate service manipulates the control specific service parameters 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:

- retrieving the self-description of a device, see (1) in Figure 7,
- fast and reliable peer-to-peer exchange of status information (tripping or blocking of functions or devices), see (2) in Figure 7,
- reporting of any set of data (data attributes), SoE – cyclic and event triggered, see (3) in Figure 7,
- logging and retrieving of any set of data (data attributes) – cyclic and event, see (4) in Figure 7,
- substitution, see (5) in Figure 7,
- handling and setting of parameter setting groups,
- transmission of sampled values from sensors,
- time synchronisation,
- file transfer,
- control devices (operate service), see (6) in Figure 7, and
- online configuration, see (7) in Figure 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.

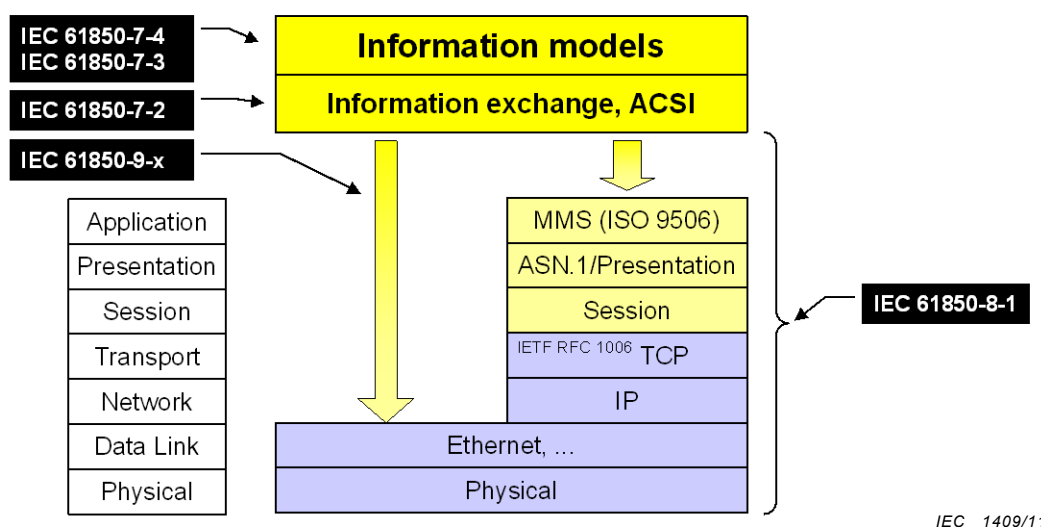
Other services provide a more complex behaviour which is dependent on the state of some specific state machine. A control request may be required to follow a state machine associated with the data attribute, for example, select-before-operate.

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 and sending 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 9506-1 and ISO 9506-2) and other provisions like TCP/IP and Ethernet (see Figure 8), another is IEC 61850-9-2 – the direct mapping on Ethernet.



IEC 1409/11

Figure 8 – Example of communication mapping

Additional mappings to other communication stacks are possible. However, to not jeopardize interoperability, the number of accepted mappings in the standard shall be a minimum. The main purpose of this flexibility is to be able to follow over time the evolution in communication technology. The ACSI is independent of the mappings.

5.8 The configuration of the automation system

IEC 61850-6 specifies a file format for describing communication related IED configurations and IED parameters, communication system configurations, switchyard (function) structures, and the relations between them. The main purpose of this format is to exchange IED capability descriptions, and SA system descriptions between IED engineering tools and the system engineering tool(s) of different manufacturers in a compatible way.

The defined language is called substation configuration description language (SCL). The configuration language is based on the extensible markup language (XML) version 1.0.

To support the intended engineering process, the SCL is capable to describe:

- a) a system specification in terms of the single line diagram, and allocation of logical nodes to parts and equipment of the single line to indicate the needed functionality,
- b) pre-configured IEDs with:
 - the logical node, datasets and report control block definitions,
 - the supported services: GOOSE, sampled values, logging, file handling,
- c) pre-configured IEDs with no semantic or a pre-configured semantic for a process part of a certain structure, for example a double busbar GIS line feeder,
- d) complete process configuration with all IEDs bound to individual process functions and primary equipment, enhanced by the access point connections and possible access paths in subnetworks for all possible clients,
- e) as item d) above, but additionally with all predefined associations and client server connections between logical nodes on data level. This is needed if an IED is not capable of dynamically building associations or reporting connections (either on the client or on the server side).

The scope of SCL is focussed on these purposes:

- 1) SAS functional specification (point a) above),
- 2) IED capability description (points b) and c) above), and

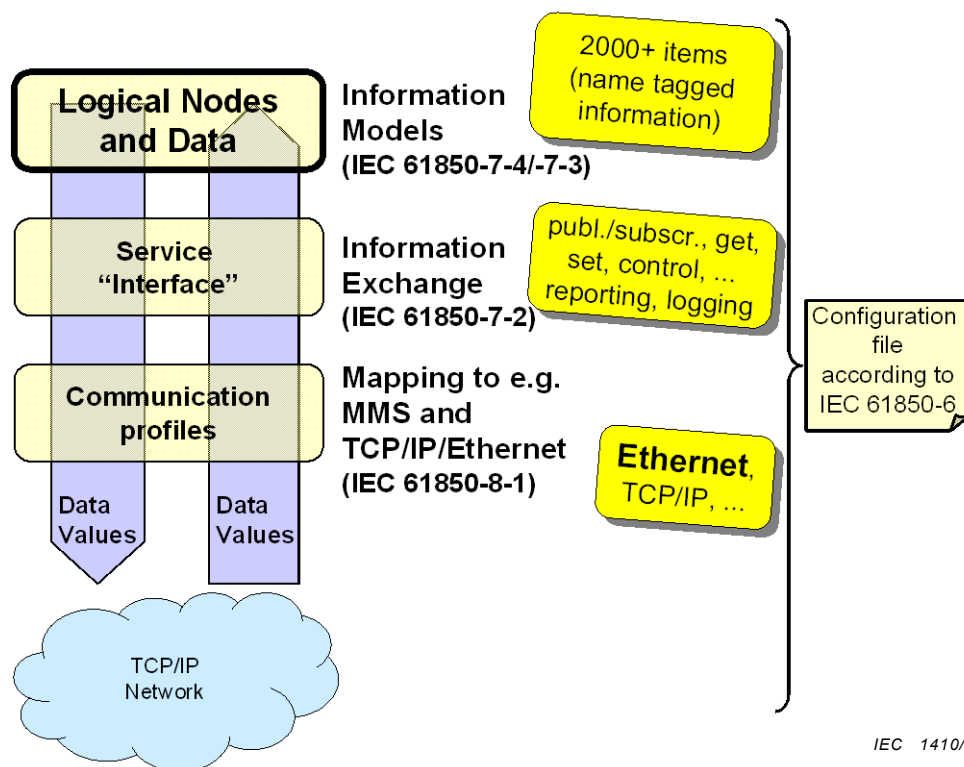
3) SA system description (points d) and e) above).

These purposes shall support in a standardised way system design, communication engineering and the description of the readily engineered system communication for the device engineering tools.

5.9 Summary

Figure 9 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.



IEC 1410/11

Figure 9 – Summary

These four building blocks are to a high degree independent of each other. The information is separated from the presentation and from the information exchange services. The information exchange services are separated from the concrete communication profiles. It means that 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 domain. In the same way, different communication stacks may be used 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.

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

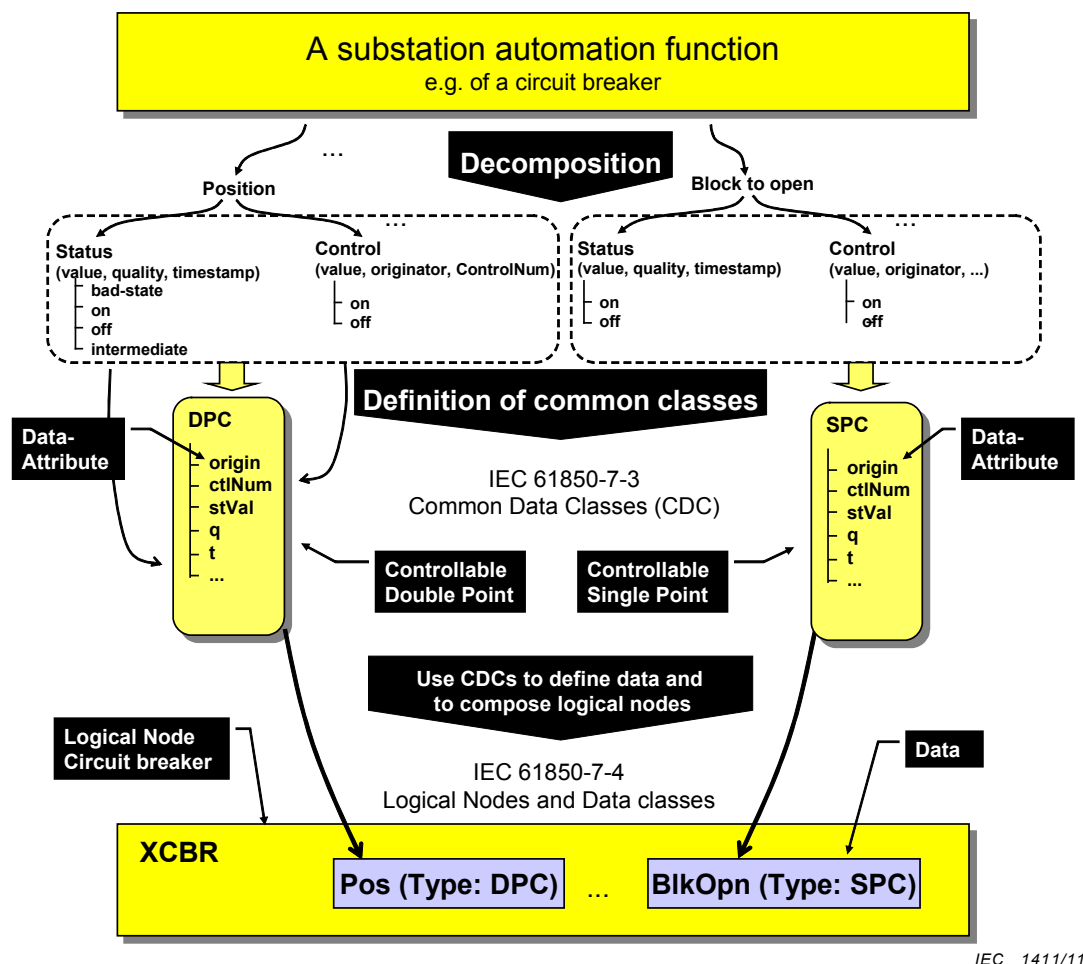
6 Modelling approach of the IEC 61850 series

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 to 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 10. The data classes contained in logical nodes have been defined to support the most common applications in an understandable and commonly accepted way.



IEC 1411/11

Figure 10 – 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, by an operator in service situations, 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 function 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, 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 many common data classes for status, measurands, controllable status, controllable analogue, status settings, and analogue settings.

6.2 Creating information models by stepwise composition

IEC 61850-7-5xx series, IEC 61850-7-4xx series, IEC 61850-7-3, and IEC 61850-7-2 define how to model the information and communication in power utility applications 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 power utility 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 the IEC 61850-7-4xx series. They have been defined in a joint effort of domain experts of the various power utility 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 1 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 (power utility domain-specific) data classes, see lower half of Figure 10. 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 stVal, q, t, 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 several tens of logical nodes making use of hundreds of data names. The logical node XCBR comprises over 15 data classes. A brief description of the logical node XCBR is given in Table 2.

Table 2 – Logical node class XCBR (conceptual)

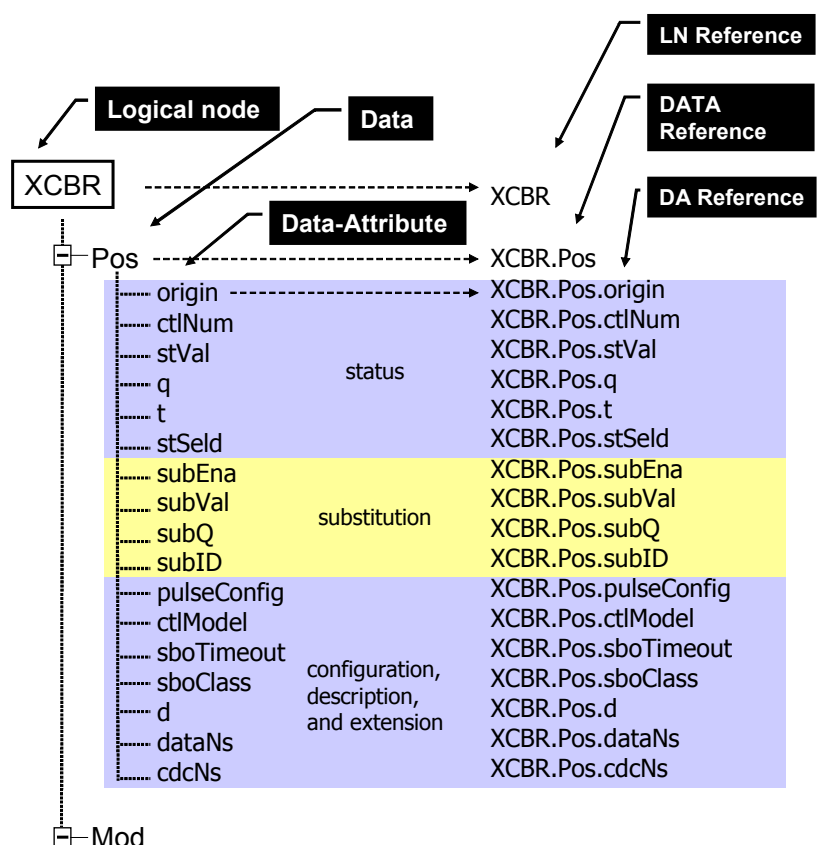
<i>Common logical node information</i>
Mode
Behaviour
Health
Name plate
<i>Logical node information</i>
External equipment health
External equipment name plate
Operation counter
<i>Controls</i>
Switch position (see below for details)
Block opening
Block closing
Charger motor enabled
Control authority at station level. Switches between station and higher level.
<i>Metered values</i>
Sum of switched amperes, resetable
<i>Status information</i>
Local operation (Indicates the switchover between local and remote operation; local = TRUE, remote = FALSE)
Circuit breaker operating capability
Point on wave switching capability
Circuit breaker operating capability when fully charged

NOTE 2 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 11.

IEC 61850-7-x series use tables for the definition of the logical node classes and data classes (see IEC 61850-7-4), the common data classes (see IEC 61850-7-3) and service models (see IEC 61850-7-2). Data classes and data attributes form a hierarchical structure as depicted in Figure 11. The data attributes of the data class Pos are functionally grouped (status, substitution, configuration, etc.).

The data attributes have a standardized name and a standardized 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.



IEC 1412/11

Figure 11 – XCBR1 information depicted as a tree

XCBR is the root at the level of logical nodes. The object reference XCBR references the complete tree below. XCBR 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. Possible states for position are: intermediate state off on bad state.
...	...

The content of the position Pos is a list of some 20 data attributes and 7 controllable parameters. 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 data attribute XCBR.Pos.ctlModel defines the type of control service which is supported. The status information could be referenced as a member (XCBR.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 12 shows examples of different logical nodes being parts of 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).

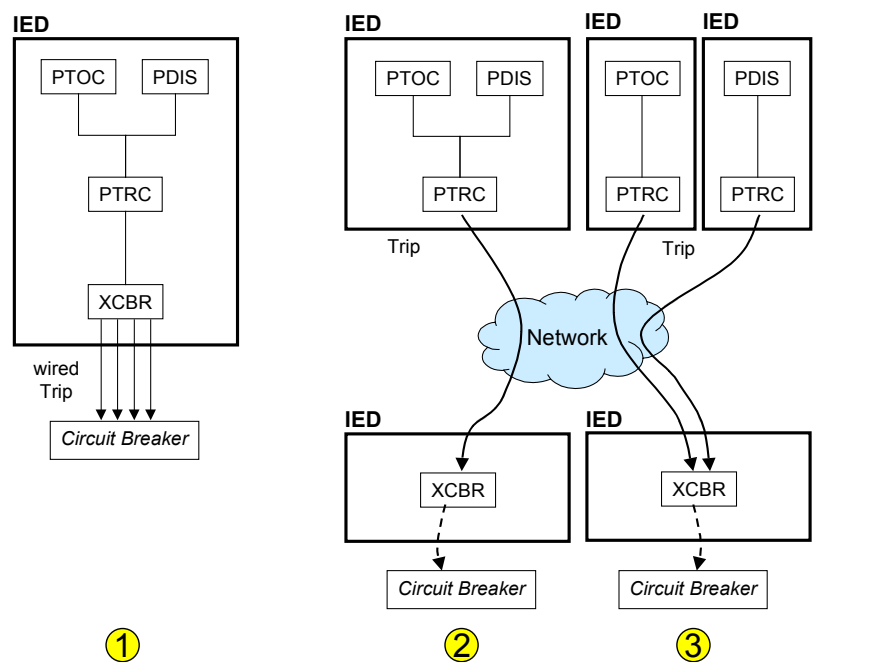


Figure 12 – Example of IED composition

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 General

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:

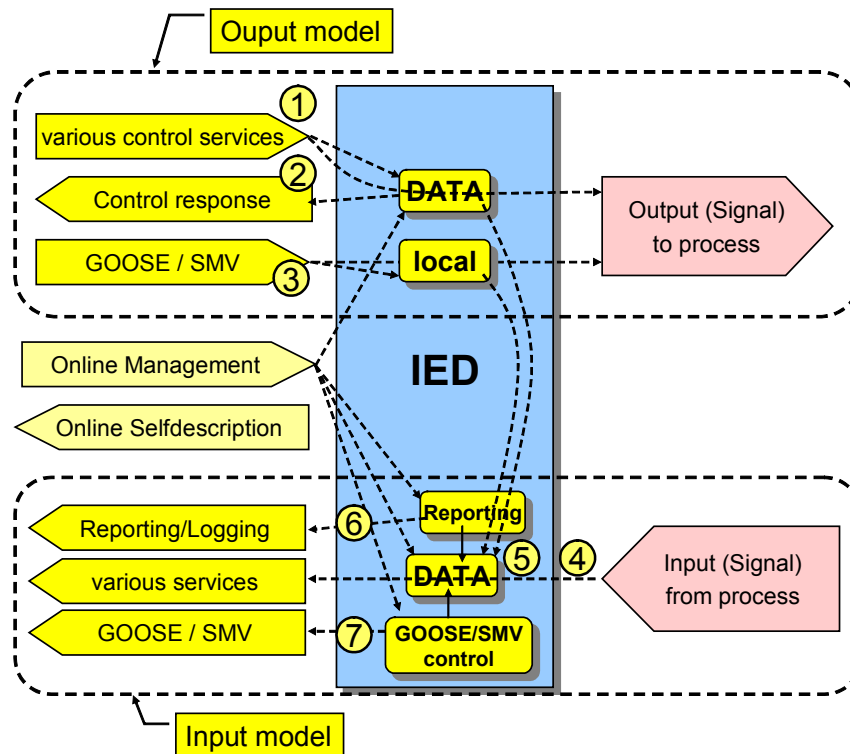
- the output model,
- the input model, and
- the model for online management and self-description.

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

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).



IEC 1414/11

The numbers in the circles in this figure are used in 6.4.2, 6.4.3 and related figures as references for the description.

Figure 13 – 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).

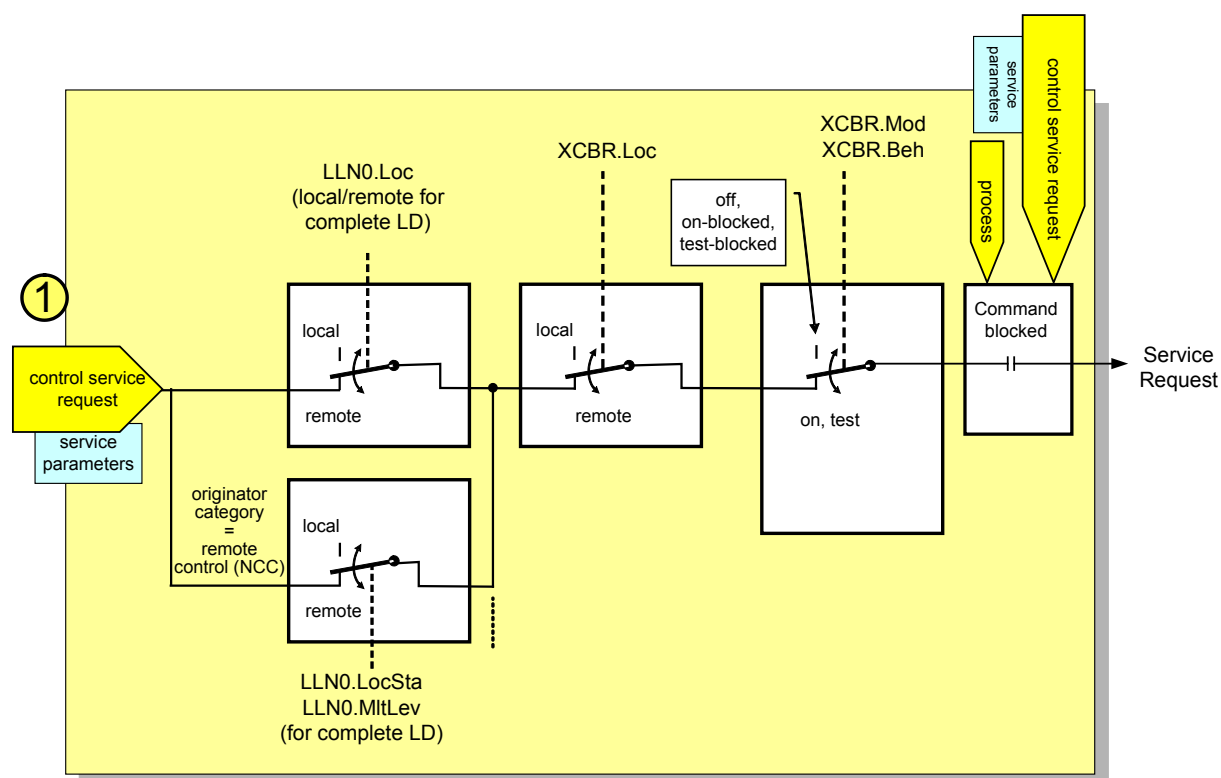
The following description of the output and input models are conceptual only. Details on the information and services involved in the models are defined in IEC 61850-7-4, IEC 61850-7-3, and IEC 61850-7-2.

6.4.2 Output model

6.4.2.1 Control model concept

The concept of the control model is depicted in Figure 14. The example is a circuit breaker logical node (XCBR) with the controllable data object XCBR.Pos (shown in Figure 15). A control service request is issued to the controllable data object. The service request contains service parameters like the control value, the originator of the request, the time when the originator sent the request and others. The data attribute XCBR.Pos.ctlModel (shown in Figure 15) indicates the type of control service to use. Before the right 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 chain of conditions to be met may possibly include:

- the local/remote behavior of the circuit breaker (data object XCBR.Loc) and/or local/remote behaviour of the logical device (LD) (data object LLN0.Loc),
- the control authority condition at the station level (data object LLN0.LocSta),
- the control output signal is not being blocked, either by the process or:
 - by the mode of the circuit breaker (data object XCBR.Mod) or,
 - following an external control request (data object XCBR.BlkOpn and/or XCBR.BlkCls),
- NOTE For controllable data in LNs not having specific data like BlkOpn and BlkCls, the blocked control output signal indication could be CmdBlk.
- check conditions of the device, and
- other attributes of the controllable data, 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).



IEC 1415/11

Figure 14 – 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).

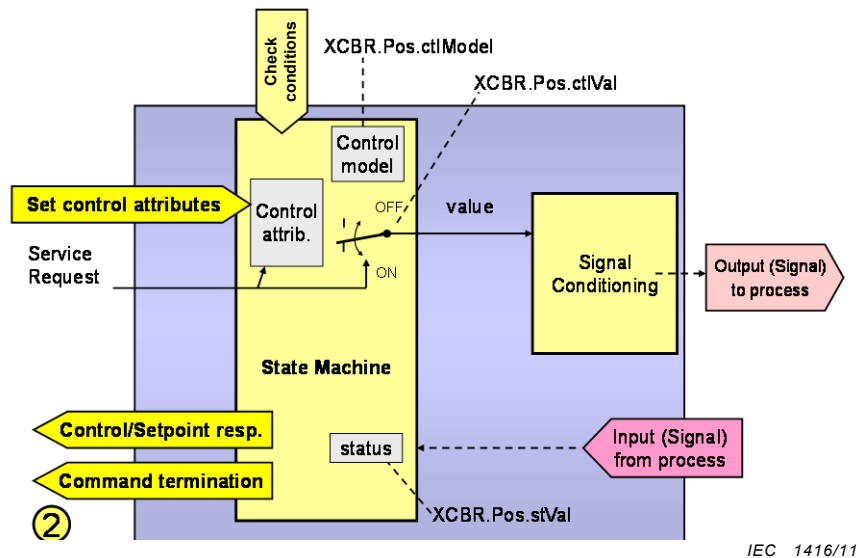


Figure 15 – Output model (step 2) (conceptual)

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 and SMV model concept

The generic substation event (GSE – GOOSE) and the sampled measured values (SMV), as shown in Figure 16, 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 SMV 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 or line current sample values to calculate the fundamental or RMS values.

NOTE 1 The GOOSE/SMV data values are defined in the input model described in 6.4.3.

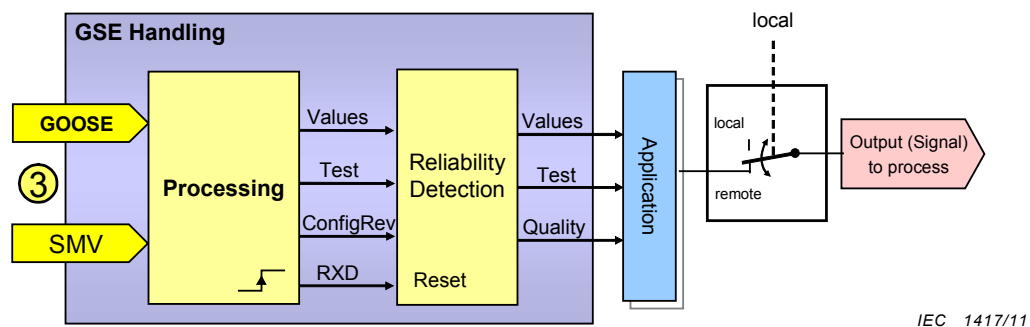


Figure 16 – GSE output model (conceptual)

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 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 their 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 17). 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.

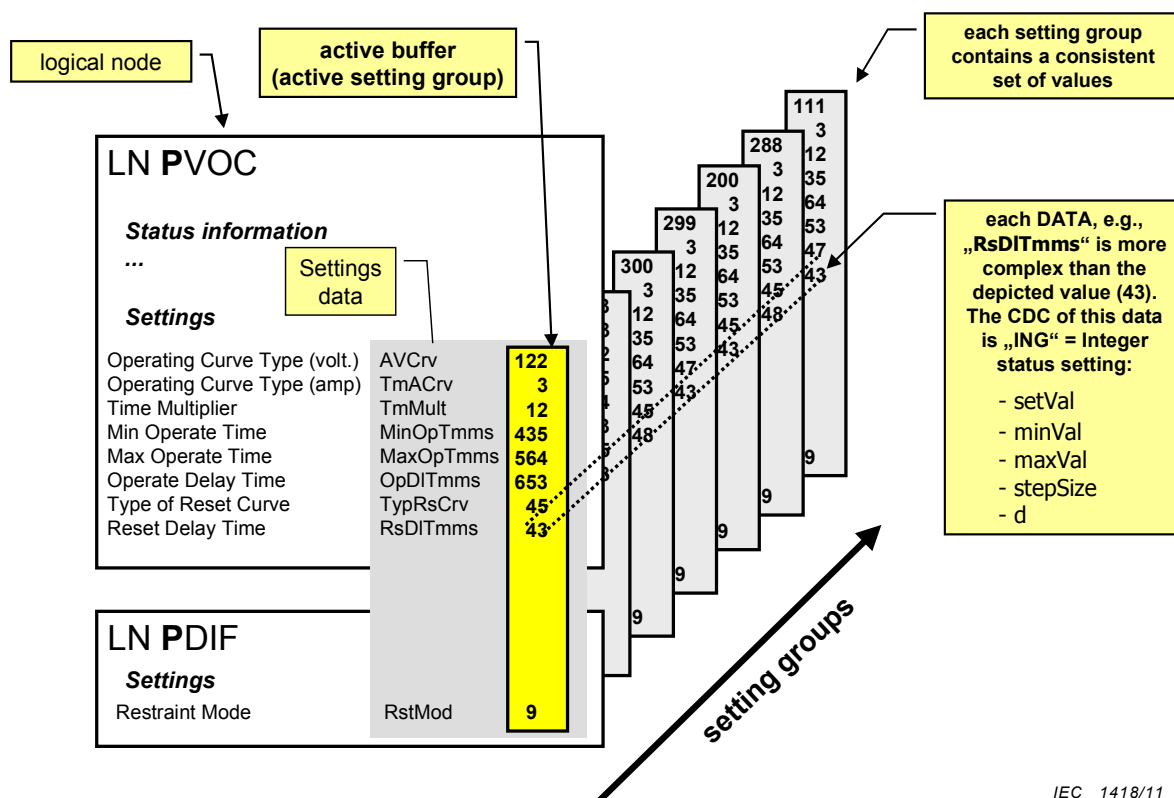


Figure 17 – Setting data (conceptual)

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 3.

Table 3 – Excerpt of integer status setting

ING class					
Attribute name	Attribute type	FC	TrgOp	Value/value range	M/O/C
...	...				
DataAttribute					
<i>setting</i>					
setVal	INT32	SP	dchg		AC_NSG_M
setVal	INT32	SG, SE			AC_SG_M
<i>configuration, description and extension</i>					
minVal	INT32	CF	dchg		O
maxVal	INT32	CF	dchg		O
stepSize	INT32U	CF	dchg	1 ... (maxVal – minVal)	O
units	Unit	CF	dchg		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 18. Normally, the signal is conditioned by a signal conditioner. In the IEC 61850 model, an analogue input does not exist as data 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. Alternatively, the raw digital values may be directly obtained from sample values transmitted over communication links (see also Figure 27). The method used for processing the signal (True RMS, Peak amplitude, ...) may be set through the data ClcMth. In absence of the data ClcMth, the calculation method shall be considered as UNSPECIFIED, meaning UNKNOWN.

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.

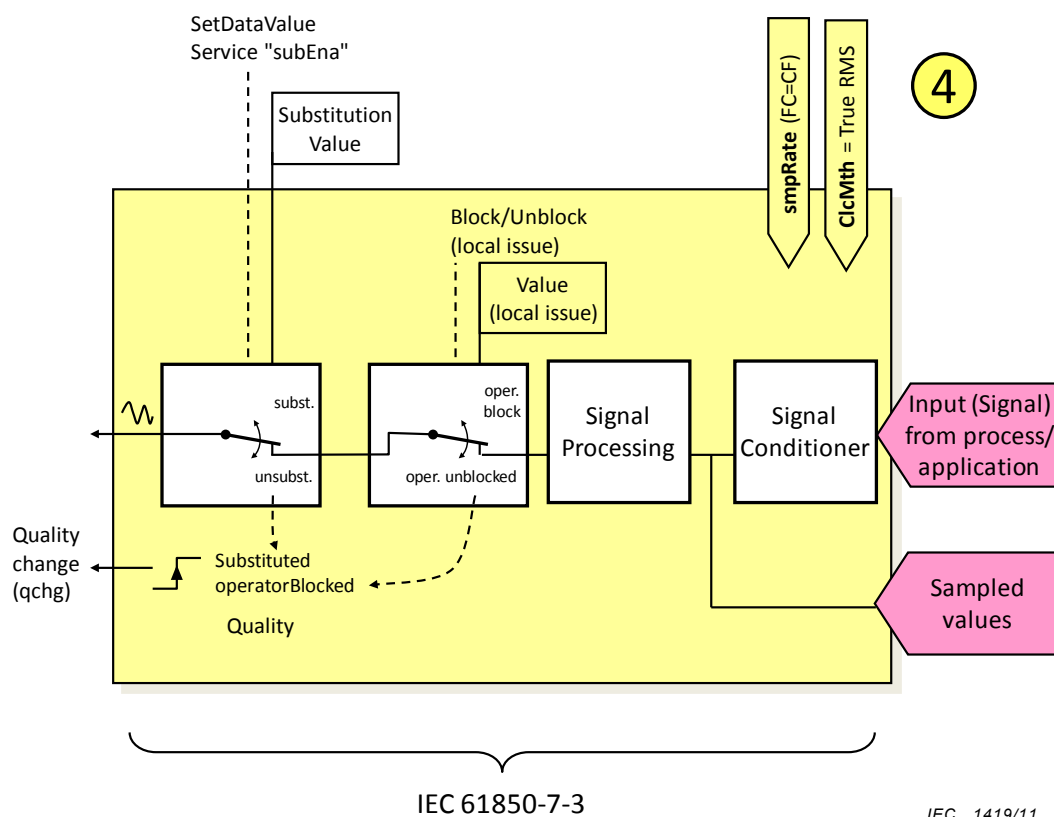
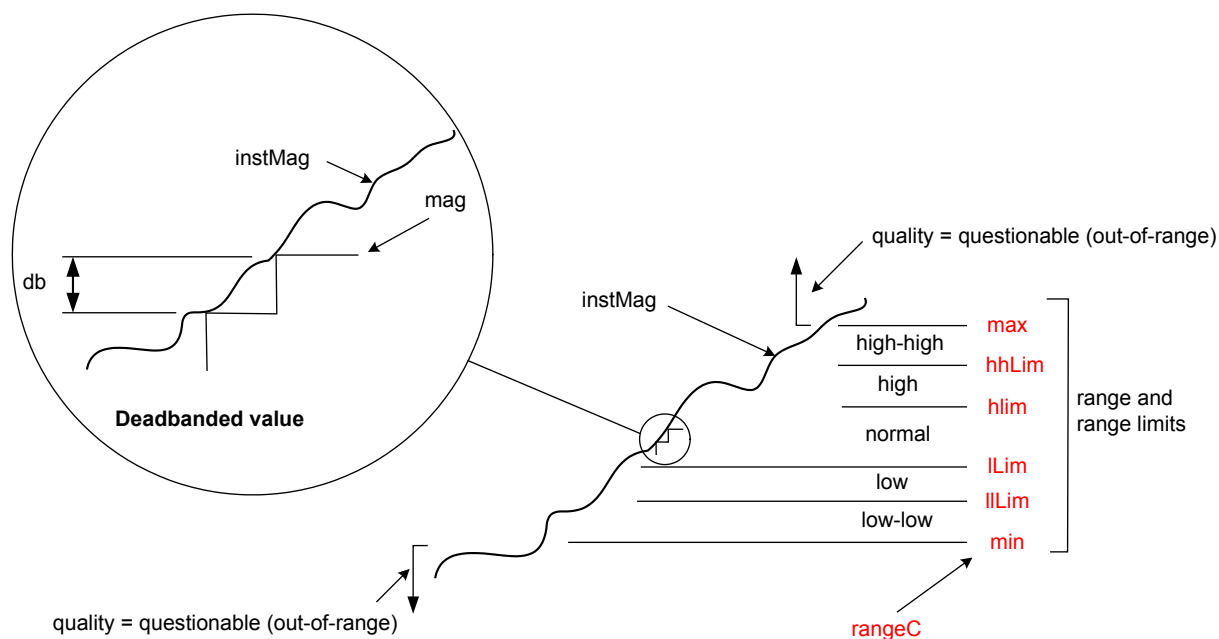


Figure 18 – Input model for analogue values (step 1) (conceptual)

6.4.3.2 Data attribute value processing, monitoring and event detection

The “intermediate value” is used for various purposes. As shown in Figure 20, 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 19. 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.



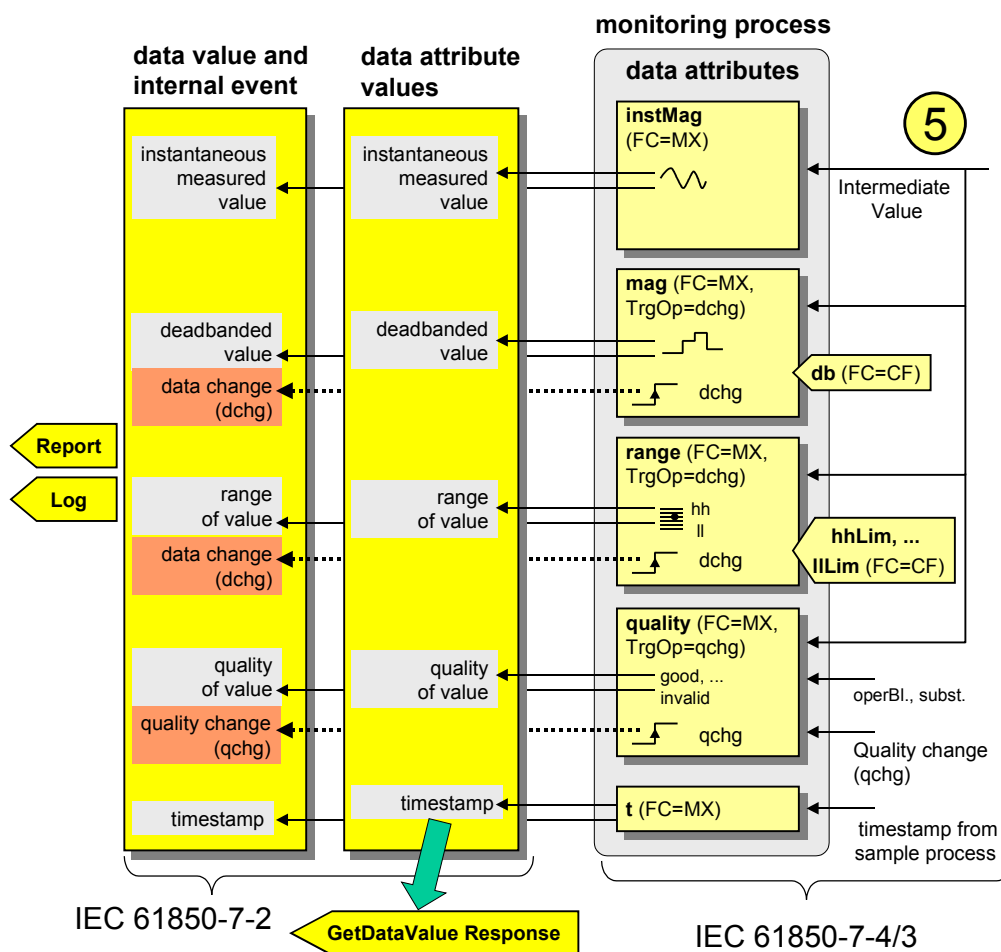
IEC 1420/11

Figure 19 – Range and deadbanded value (conceptual)

The value of the deadband configuration db shall represent the percentage of difference between the max and min parameter value in units of 0,001 %.

NOTE The db value has nothing to do with the accuracy of the data defined both by the accuracy of the analogue transducer and by the accuracy of the A/D conversion.

An internal event is created any time the mag value changes. The deadbanded value mag and the event (data change – according to the trigger option TrgOp=dchg) are made available for further actions, for example, reporting or logging.



IEC 1421/11

Figure 20 – Input model for analogue values (step 2) (conceptual)

A third application is to monitor the “intermediate value” to determine the current range of the value.

An internal event is created any time the instMag value crosses a range limit (see Figure 20). The range value and the event (data change – according to the trigger option TrgOp=dchg) are made available for further actions, for example, reporting or logging. The attribute rangeC is used to configure the parameters associated with the different limits.

In addition to the various values, the two attributes quality and t (time stamp) are available at any time. The time stamp is determined at the time that the value change of the data attributes mag and range has been detected. A change in the quality can be used to issue an internal event as well.

The definitions conceptually depicted on the right-hand side of Figure 19 are defined in IEC 61850-7-4 and IEC 61850-7-3. The left hand side and Figure 21 show the definitions (conceptual) found in IEC 61850-7-2.

6.4.3.3 Data reporting and logging

6.4.3.3.1 General

The internal events (process values, corresponding trigger values that caused the event, time stamps and quality information) are used as a trigger foundation for reporting and logging (see Figure 21). This information is grouped using a data set. The data set is the content basis for reporting and logging. It is also the content basis for GOOSE and SMV messages (see 6.4.3.4 and 6.4.3.5). The data set contain references to the data and data attribute values.

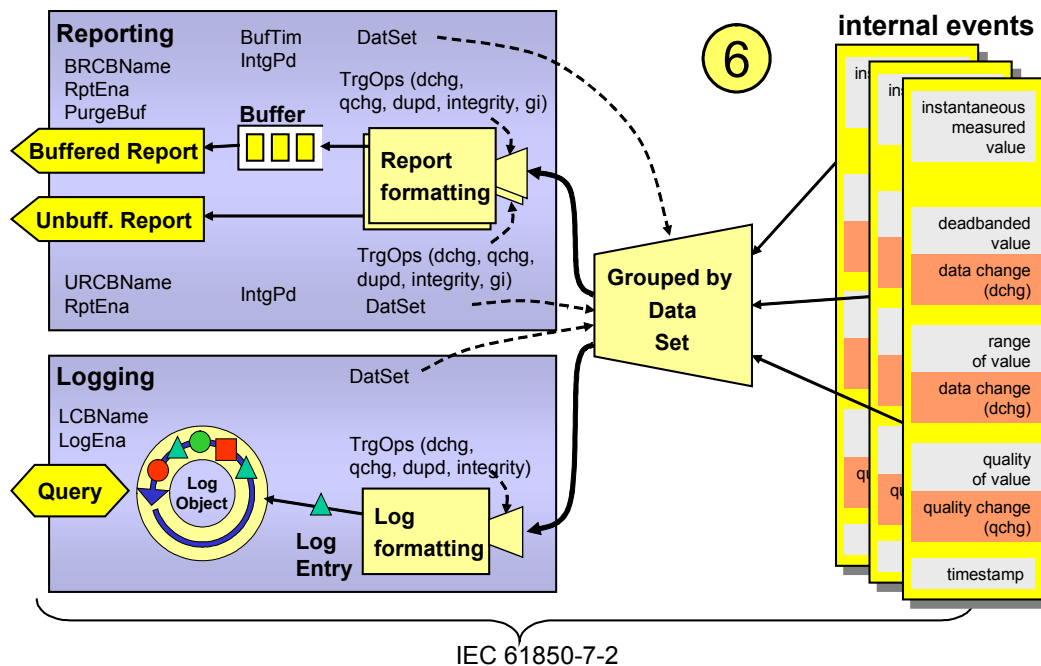
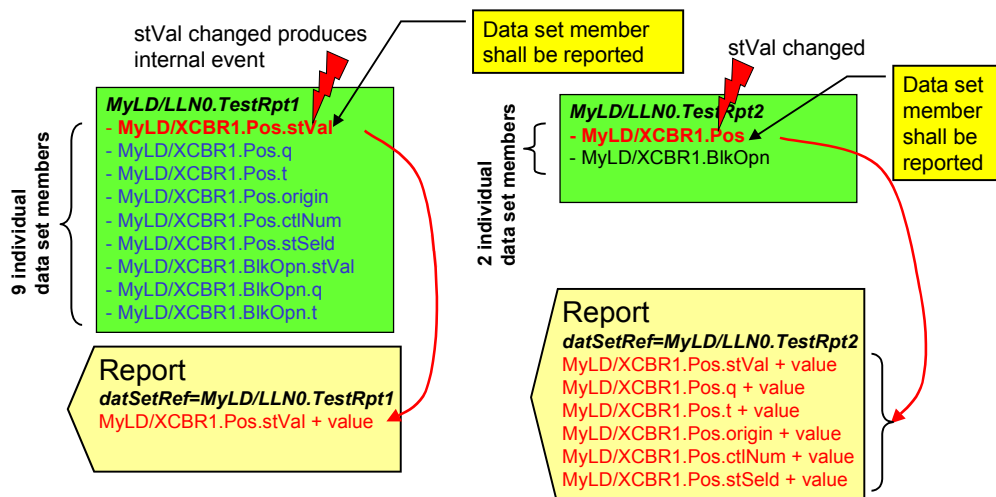


Figure 21 – Reporting and logging model (conceptual)

Which data and data attribute values are to be reported and logged is specified in the data sets. The following example explains the concept.

6.4.3.3.2 Data reporting

The data attribute stVal of the data MyLD/XCBR1.Pos (Position) in Figure 22 is referenced in two different data sets. The figure displays two different instances of data sets that reference the data attributes of the position. In the case on the left, the data set references 9 individual data set members (all of functional constraint ST): Pos.stVal is one of the nine members. In case of the change triggered by the member stVal, the value for exactly that member shall be included in the report. The data set in the example on the right-hand side has just two members. The data Pos (which has six data attributes: stVal, q, t, etc.) is one of the two members. A change triggered in the member Pos (for example, by the change in the DataAttribute stVal) shall cause the inclusion of the values of all data attributes of the data set member Pos (i.e., the complete member comprising all six data attributes stVal, q, t, etc.).



IEC 1423/11

NOTE All data attributes are functionally constrained by FC=ST.

Figure 22 – Data set members and reporting

The data set specifies which data is to be monitored and reported. The next task is to define when and how to report or log the information. The reporting model provides two kinds of report control blocks:

- the unbuffered, and
- the buffered control blocks.

The log model has the log and log control block.

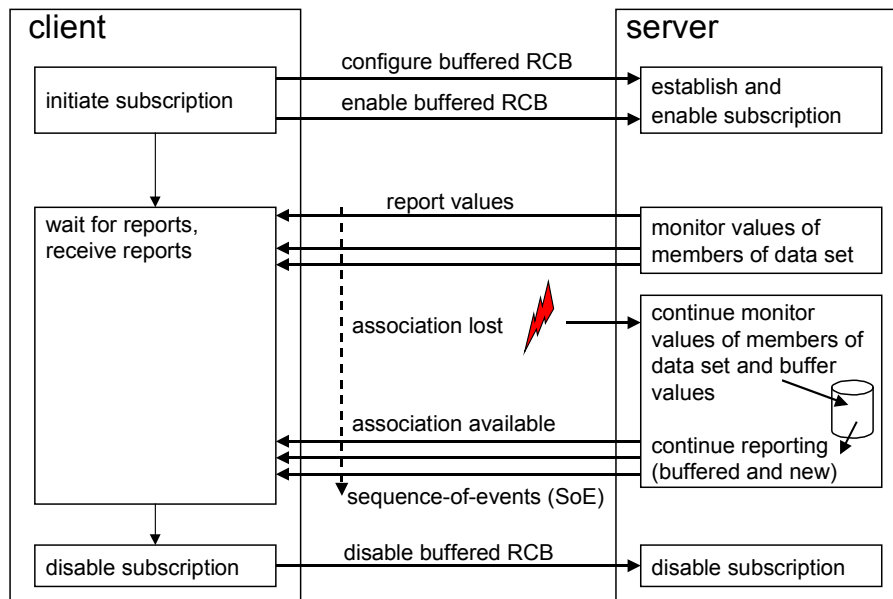
The principle characteristics of the data access methods provided by IEC 61850-7-2 are shown in Table 4.

Table 4 – Comparison of the data access methods

Retrieval method	Time-critical information exchange	Can lose changes (of sequence)	Multiple clients to receive information	Last change of data stored by	Typical client (but not exclusive)
Polling (GetDataValues)	NO	YES	YES	–	Browser
Unbuffered Reporting	YES	YES	NO	–	Real-time GUI
Buffered Reporting	YES	NO	NO	Server	Data concentrator
Log (used for SOE logging)	NO	NO	YES	Client	Engineering stations

Each of the four retrieval methods has a specific characteristic. There is no single method that meets all application requirements. During system design, the designer has to analyse the requirements and to check them against the (implemented) methods provided by a device compliant with the IEC 61850 series.

The basic buffered reporting mechanism is shown in Figure 23. The buffered and unbuffered reporting starts with the configuration of the report control blocks. The reporting starts with setting the enable buffer attribute to TRUE; setting to false stops the reporting.



IEC 1424/11

Figure 23 – Buffered report control block (conceptual)

The specific characteristic of the buffered report control block is that it continues buffering the event data as they occur according to the enabled trigger options in case of, for example, a communication loss. The reporting process continues as soon as the communication is available again. The buffered report control block guarantees the sequence-of-events (SoE) up to some practical limits (for example, buffer size and maximum interruption time).

The unbuffered report control block does not support SoE in case of loss of communication.

The buffered report control block has several attributes that control the reporting process, for example:

- RptID handle provided by the client to identify the buffered report control block,
- RptEna to remotely enable/disable the reporting process,
- DataSet references the data set whose values are to be reported,
- ConfRev contains the configuration revision to indicate addition/deletion of a member of the data set or the reordering of the members,
- OptFlds indicates the optional fields which are to be included in the report; among the optional fields are:
 - sequence-number to get the correct order of events,
 - report-time-stamp to inform the client when the report has been issued,
 - reason-for-inclusion to indicate the trigger that has caused the value to be reported,
 - data-set-name to indicate from which data sets the values have been generated,
 - data-reference to include the object references for the values,
- BufTm contains the time to wait after the first event within a data set has occurred before issuing the report (see Figure 24),
- SeqNum is the current sequence number of the reports,
- TrgOps (trigger options) contains the reasons which cause the control block to report a value into the report. The reasons for reporting may be: data change dchg, data update dupd, or quality change qchg of the data attribute in a logical node,

- IntgPd (integrity period): reporting all values initiated by the server based on this period,
- GI (general interrogation): reporting all values initiated by the client, and
- PurgeBuf set to TRUE indicates to delete all events not yet sent.
- ResvTms indicates if the the buffered report control block is reserved or not by a set of specific clients based upon configuration. The value represents the number of seconds that the reservation will be maintained after association loss.

If it is likely that – after a first event – several other events occur in the direct neighbourhood of the first event (see Figure 24), then the server can reduce the number of reports applying the buffer time attribute. Changes occurring during that time result in a report at the end of the buffer time reporting all changes (according to the reasons and according to the definition of the corresponding data set for a specific report control block).

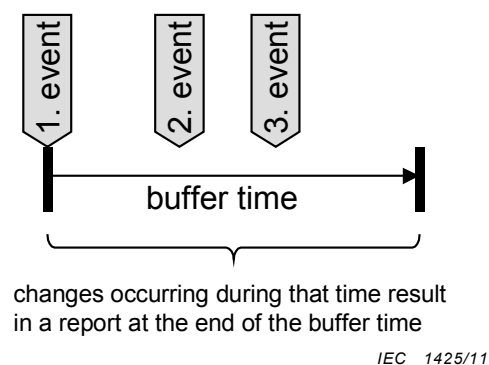


Figure 24 – Buffer time

A report allows sending just the values (according to the reason and according to the definition of the corresponding data set for a specific report control block) without any object reference of the data and data attributes. Then the object references may be retrieved out of the data set definition (see below). The report may also transmit the object references of the data and data attributes together with the data.

If firstly, no object references are sent with the values and secondly, values for a subset of members of a data set only are to be reported, then a provision is provided to determine to which members the reported values belong. The SCSM defined in IEC 61850-8-1 defines an inclusion-bitstring to indicate the member of the data set. The order of the members of the data set is as they are defined in the data set. Figure 25 shows an example.

The data set has two members in the order shown. The report with the inclusion-bitstring has two bits whose values indicate from which members the values have been derived. The first bit is TRUE thus indicating that the values in curly brackets are the values from the member MyLd/XCBR1.Pos. For the second member, no values are reported (second bit is FALSE). The report with the inclusion-bitstring optimises the length of the report message.

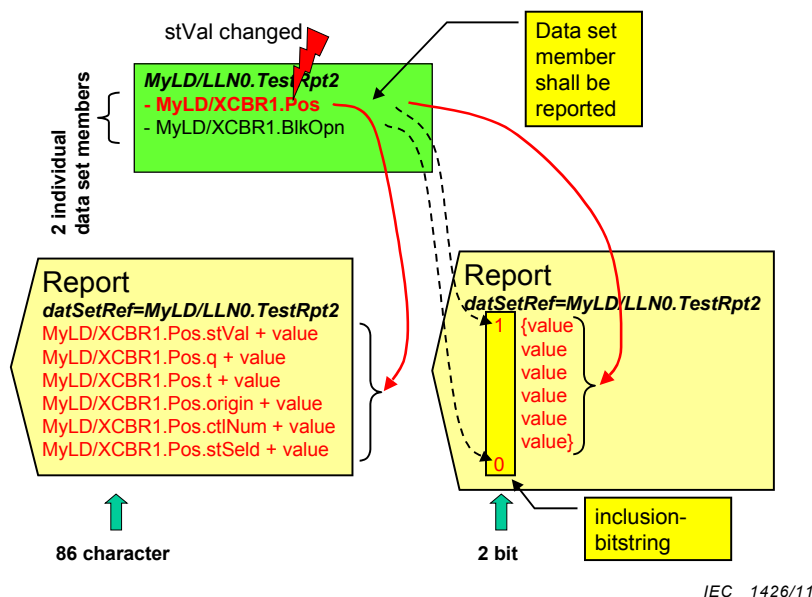


Figure 25 – Data set members and inclusion-bitstring

6.4.3.3.3 Data logging

The logging model provides a log to store values (the log entries). The log control block controls which data values and when these data values are to be stored into the log. The log is organised as a circular buffer as shown in Figure 21. The number of entries that can be stored depends on the size of log entries and on the buffer size.

NOTE Several factors have an impact on the design of a log. The system needs to be designed carefully to implement or configure the log and log control blocks in a way that meets the application requirements. Recommendations with regard to the system design are outside the scope of this standard.

Figure 26 shows an example of a log and three log control blocks. The first step is to configure and enable log control blocks. After enabling the association with that server may be closed. The log entries are stored into the log as they arrive for inclusion into the log. The logs are stored in time sequence order. This allows retrieval of a sequence-of-events (SoE) list.

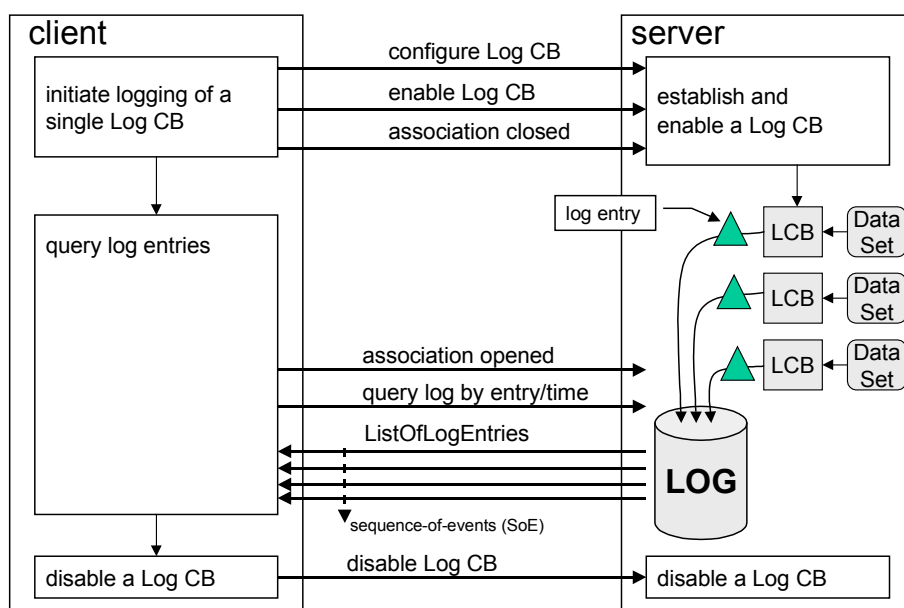


Figure 26 – Log control block (conceptual)

The log (not the log control block) is enabled at any time. The different log control blocks allow storage of information from different data sets into the log. Each log control block is independent of the other control blocks.

The log control block has several attributes that control the logging process, for example:

- LogEna to remotely enable/disable the logging process,
- DataSet references the data set whose values are to be logged,
- TrgOps contains the reasons which cause the control block to store an entry into the log. The reasons for storing a log entry into the log may be: data change dchg, data update dupd, or quality change qchg of the data attribute in a logical node,
- integrity period IntgPd: logging all values initiated by the server based on a given period,
- LogRef indicating in which log the entries are to be stored.

6.4.3.4 Peer-to-peer data value publishing

The peer-to-peer communication provides services for the exchange of generic substation events (GOOSE based on multicast) and for the exchange of sampled values (based on multicast or unicast). The GOOSE message receipt is already explained in the output model in 6.4.2.2.

Figure 27 shows the GOOSE and sampled value models.

The GOOSE model uses data values to be published grouped into data sets. All data and data attributes can be used to create a data set (for example, analogue, binary or integer values).

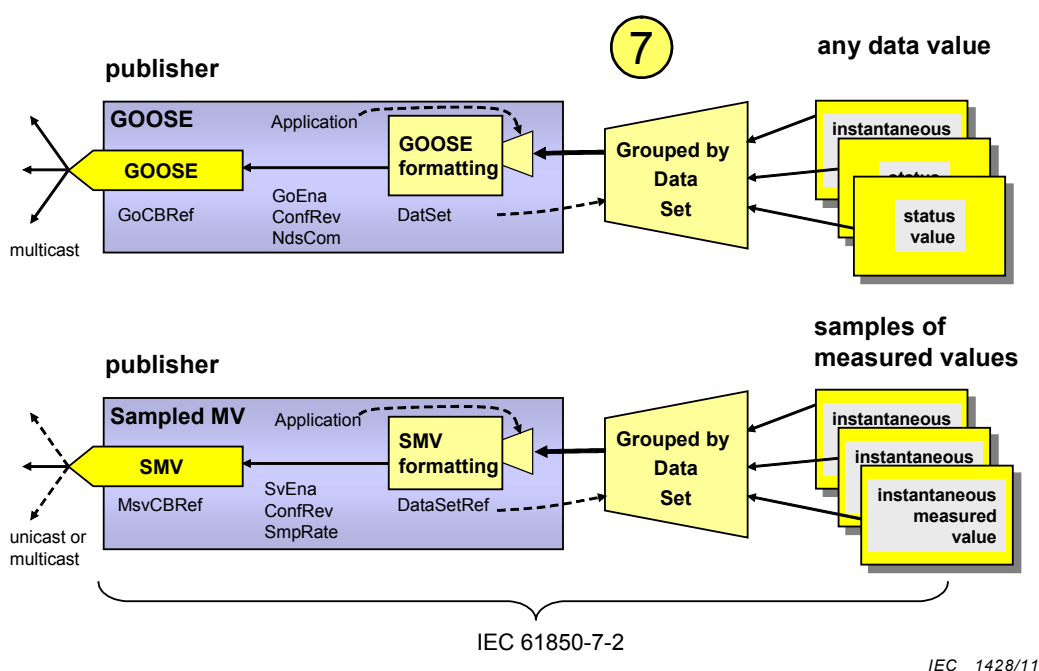


Figure 27 – Peer-to-peer data value publishing model (conceptual)

The GOOSE model has several attributes that control the publishing process, for example:

- GoEna to remotely enable/disable the publishing,
- GoID sent in the message to be used as a handle for the receiving application,
- DataSet references the data set whose values are to be published,
- ConfRev contains the configuration revision to indicate deletion of a member of the data set or the reordering of the members, or changing the DataSet reference,
- NdsCom indicates in the message that some commissioning is required.

Which event triggers the publishing of values as well as how often and how fast the values are to be published is outside the scope of this standard.

6.4.3.5 Sampled value publishing

The sampled value publishing model has several attributes that control the publishing process, for example:

- SvEna to remotely enable/disable the publishing,
- MsvID sent in the message to be used as a handle for the receiving application,
- DataSet references the data set whose values are to be published,
- ConfRev contains the configuration revision to indicate deletion of a member of the data set or the reordering of the members, or changing the DataSet reference,
- SmpRate specifies the samples per unit.

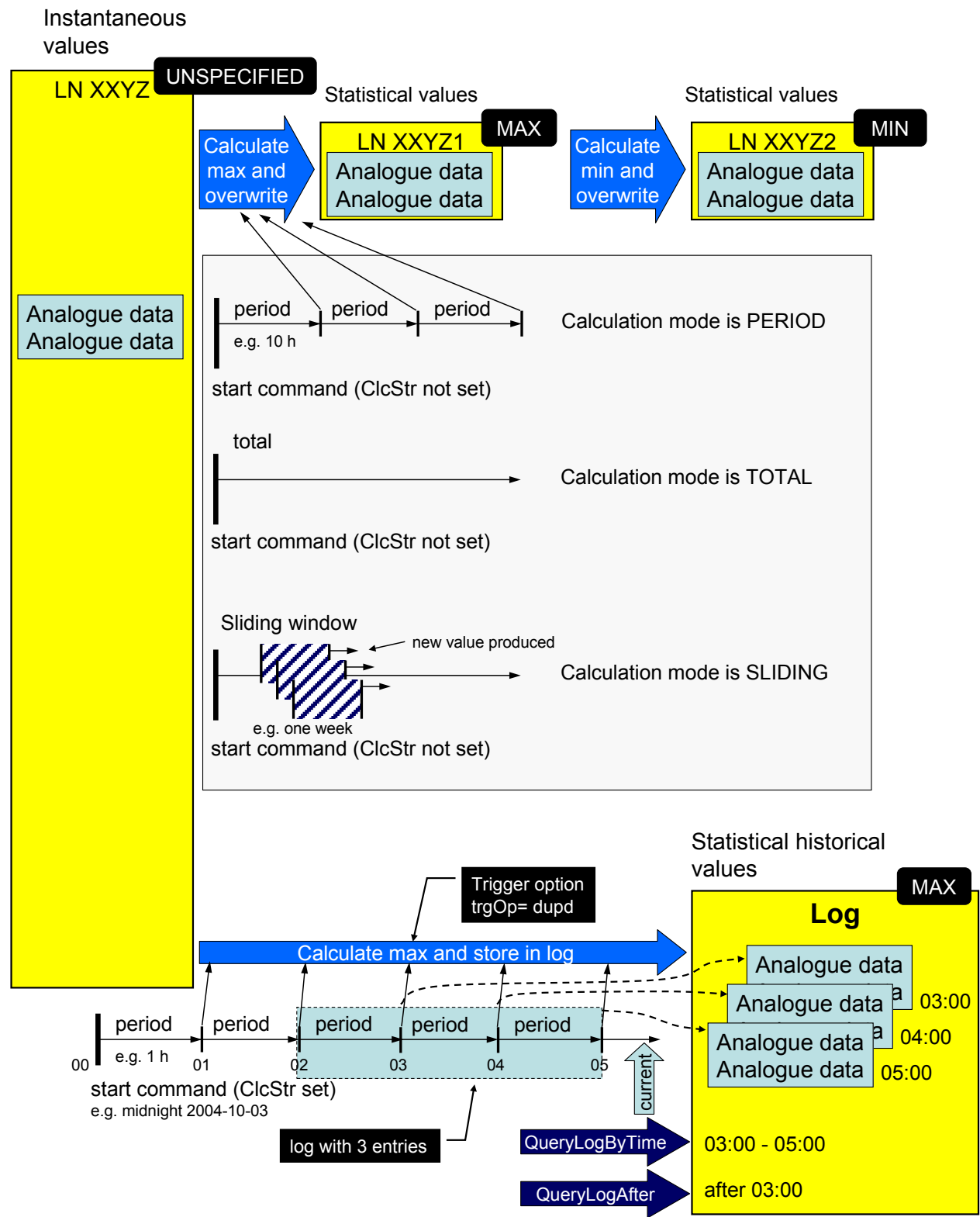
6.4.4 Model for statistical and historical statistical data

In many application domains, it is required to provide additional information of a basic analogue value:

- statistical information (for example, minimum value calculated for a specified time period, for example, minimum value of last 1 h),
- historical statistical information (for example, log of minimum values of the sequence of values calculated above, for example, last 24 hourly values).

This additional information may be derived from the basic analogue values. It may be the only information provided – depending on the application requirements.

The models for the statistical and historical statistical data are explained conceptually in Figure 28. On the left hand side are the basic data representing the current values (UNSPECIFIED), i.e. some instantaneous analogue (or integer) values that are contained in the logical node instance XYZ.



IEC 1429/11

Figure 28 – Conceptual model of statistical and historical statistical data (1)

The upper half depicts the method defined for statistical values. The first example is the instance XYZ1 of the logical node class XYZ. The analogue values represent the calculated maximum values derived from the instance XYZ. The logical node XYZ1 has special setting data that indicate that the values are maximum values and that the calculation method is “periodic”. The period starts after a start command. At the end of the period, the calculated maximum values of the instance XYZ1 are overwritten by the new values.

The maximum values can be used to calculate the minimum maximum values in – of course – a much longer period than for the maximum calculation in XYZ1. The instance XYZ2 may represent the minimum value of the max value of the last 10 days.

Setting parameters other than PERIOD may be used to specify calculation modes. A calculation mode set to TOTAL means that the calculation of maximum values will start as soon as it has been enabled. A calculation mode set to SLIDING means that the calculated maximum values are calculated over a sliding window whose width can be set by means of a special interval type setting (e.g. hour, day, week).

The lower part of the figure shows the conceptual model of the historical statistical data. In this model, the calculated values (in this case the maximum values with calculation mode set to PERIOD) are stored in sequence in a log. The calculation in the example starts at midnight of 2004-10-03. The interval is 1 h. After the first hour, the first log entry is written. After the second hour, the second entry contains the value of the second hour. After 5 h, the log contains the values of the last three hours (intervals 02-03, 03-04, 04-05).

The statistical data model is based on the calculation of analogue values contained in other logical nodes. The Figure 29 comprises three technological logical nodes of the same type (for example MMXU). The top logical node (LN XYZ) represents the RMS measured values. The second and third logical nodes are the statistical logical nodes, i.e., the logical nodes that represent the calculated values (LN XYZ1 represents the MIN values, the LN XYZ2 the MAX values).