

INTERNATIONAL STANDARD



**Communication networks and systems for power utility automation –
Part 5: Communication requirements for functions and device models**

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV





THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2022 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.

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

Tel.: +41 22 919 02 11
info@iec.ch
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

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

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IECNORM.COM : Click to view the full PDF of IEC 60350-3:2013+AMD1:2022 CSV



IEC 61850-5

Edition 2.1 2022-03
CONSOLIDATED VERSION

INTERNATIONAL STANDARD



**Communication networks and systems for power utility automation –
Part 5: Communication requirements for functions and device models**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.200

ISBN 978-2-8322-1095-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD	9
INTRODUCTION	11
1 Scope	12
2 Normative references	12
3 Terms and definitions	15
3.1 General	15
3.2 Connections	17
3.3 Relations between IEDs	18
3.4 Substation structures	18
3.5 Power utility automation functions at different levels	19
3.6 Miscellaneous	20
4 Abbreviations	20
5 Power utility automation functions	21
5.1 General	21
5.2 Example substation automation system	21
5.2.1 General	21
5.2.2 Logical allocation of application functions and interfaces	21
5.2.3 The physical allocation of functions and interfaces	23
5.2.4 The role of interfaces	23
5.3 Other application examples	24
5.3.1 Substation – Substation	24
5.3.2 Substation – Network Control Center	24
5.3.3 Wind	24
5.3.4 Hydro	24
5.3.5 DER and distribution automation	24
5.3.6 FACTS and Power Conversion	25
5.3.7 Distribution Automation and Feeder Automation	25
6 Goal and requirements	26
6.1 Interoperability	26
6.2 Static design requirements	26
6.3 Dynamic interaction requirements	27
6.4 Response behaviour requirements	27
6.5 Approach to interoperability	28
6.6 Conformance test requirements	28
7 Categories of application functions	28
7.1 General	28
7.2 System support functions	29
7.3 System configuration or maintenance functions	29
7.4 Operational or control functions	29
7.5 Bay local process automation functions	29
7.6 Distributed process automation functions	30
8 Description and requirements of application functions	30
8.1 Approach	30
8.2 Application function description	31
8.3 The PICOM description	31

8.3.1	The PICOM approach	31
8.3.2	The content of PICOM description	31
8.3.3	Attributes of PICOMs	32
8.3.4	PICOM attributes to be covered by any message	32
8.3.5	PICOM attributes to be covered at configuration time only	32
8.3.6	PICOM attributes to be used for data flow calculations only	32
8.4	Logical node description	32
8.4.1	The logical node concept	32
8.4.2	Logical nodes and logical connections	33
8.4.3	Examples for decomposition of common functions into logical nodes	34
8.5	List of logical nodes	35
8.5.1	Logical Node allocation and distributed application functions	35
8.5.2	Explanation of tables	36
8.5.3	Defining and modelling of protection functions	37
8.5.4	Defining and modelling of protection related functions	43
8.5.5	Defining and modelling control functions	45
8.5.6	Definition and modelling Interfaces, logging and archiving functions	46
8.5.7	Defining and modelling automatic process control functions	47
8.5.8	Defining and modelling functional block functions	48
8.5.9	Defining and modelling metering and measurement functions	49
8.5.10	Defining and modelling power quality functions	51
8.5.11	Defining and modelling physical device functions and common data	52
8.5.12	Defining and modelling of system services	52
8.5.13	Definition and modelling of switching devices	53
8.5.14	Definition and modelling of supervision and monitoring functions	54
8.5.15	Definition and modelling of Instrument transformer functions	56
8.5.16	Definition and modelling of position sensors functions	56
8.5.17	Definition and modelling of material status sensors functions	56
8.5.18	Definition and modelling of flow status sensor functions	57
8.5.19	Definition and modelling of generic sensor functions	57
8.5.20	Definition and modelling of power transformer functions	58
8.5.21	Definition and modelling of further power system equipment	58
8.5.22	Definition and modelling of generic process I/O	59
8.6	Definition and modelling of mechanical non-electrical process equipment	60
9	The application concept for Logical Nodes	60
9.1	Example out of the substation automation domain	60
9.2	Typical allocation and use of Logical Nodes	60
9.2.1	Free allocation of Logical Nodes	60
9.2.2	Station level	60
9.2.3	Bay level	60
9.2.4	Process/switchgear level	61
9.2.5	The use of generic Logical Nodes	61
9.3	Basic examples	61
9.4	Additional examples	62
9.5	Modelling	64
9.5.1	Important remarks	64
9.5.2	Object classes and instances	64
9.5.3	Requirements and modelling	64
9.5.4	Logical Nodes and modelling	64

9.5.5	Use of Logical Nodes for applications	65
10	System description and system requirements	65
10.1	Need for a formal system description	65
10.2	Requirements for Logical Node behaviour in the system	65
11	Performance requirements.....	66
11.1	Time synchronisation	66
11.1.1	Basics	66
11.2	Message performance requirements	70
11.2.1	Basic definitions and requirements	70
11.2.2	Concepts of message types and performance classes	73
11.2.3	Definition of transfer time and synchronization classes	75
11.3	Definition of messages types and performances classes	76
11.3.1	Type 1 – Fast messages ("Protection")	76
11.3.2	Type 2 – Medium speed messages ("Automatics").....	77
11.3.3	Type 3 – Low speed messages ("Operator")	77
11.3.4	Type 4 – Raw data messages ("Samples").....	77
11.3.5	Type 5 – File transfer functions.....	78
11.3.6	Type 6 – Command messages and file transfer with access control	78
11.4	Requirements for data and communication quality	79
11.4.1	General remarks	79
11.4.2	Data integrity	79
11.4.3	Reliability.....	80
11.5	Requirements concerning the communication system	82
11.5.1	Communication failures	82
11.5.2	Requirements for station and bay level communication	82
11.5.3	Requirements for process level communication	83
11.5.4	Requirements for recovery delay	83
11.5.5	Requirements for communication redundancy	83
11.6	System performance requirements	84
12	Additional requirements for the data model.....	84
12.1	Semantics	84
12.2	Logical and physical identification and addressing	84
12.3	Self-description	84
12.4	Administrative issues	84
Annex A	(informative) Logical nodes and related PICOMs	86
Annex B	(informative) PICOM identification and message classification.....	101
B.1	General.....	101
B.2	Identification and type allocation of PICOMs	102
Annex C	(informative) Communication optimization.....	109
Annex D	(informative) Rules for function definition.....	110
D.1	Function definition	110
D.2	Function description.....	110
D.2.1	Task of the function	110
D.2.2	Starting criteria for the function.....	110
D.2.3	Result or impact of the function	110
D.2.4	Performance of the function.....	110
D.2.5	Function decomposition	110
D.2.6	Interaction with other functions	110

D.3	Logical node description	111
D.3.1	General	111
D.3.2	Starting criteria	111
D.4	PICOM description	111
D.4.1	Input and outputs by PICOMs	111
D.4.2	Operation modes	111
D.4.3	Performance	111
Annex E (informative)	Interaction of functions and logical nodes	112
Annex F (informative)	Functions	113
F.1	System support functions	113
F.1.1	Network management	113
F.1.2	Time synchronization	114
F.1.3	Physical device self-checking	114
F.1.4	Software management	115
F.1.5	Configuration management	116
F.1.6	Operative mode control of logical nodes	117
F.1.7	Setting	118
F.1.8	Test mode	119
F.1.9	System security management	120
F.2	Operational or control functions	120
F.2.1	Access security management	120
F.2.2	Control	122
F.2.3	Operational use of spontaneous change of indications	123
F.2.4	Synchronized switching (point-on-wave switching)	124
F.2.5	Parameter set switching	125
F.2.6	Alarm management	125
F.2.7	Event management (SER)	126
F.2.8	Data retrieval of configuration data and settings	127
F.2.9	Disturbance/fault record retrieval	128
F.2.10	Log management	128
F.3	Local process automation functions	128
F.3.1	Protection function (generic)	128
F.3.2	Distance protection (example of protection function)	129
F.3.3	Bay interlocking	130
F.4	Distributed automatic functions	130
F.4.1	Station-wide interlocking	130
F.4.2	Distributed synchrocheck	131
F.4.3	Breaker failure	132
F.4.4	Automatic protection adaptation (generic)	133
F.4.5	Reverse blocking function (example for automatic protection adaptation) ...	133
F.4.6	Load shedding	134
F.4.7	Load restoration	134
F.4.8	Voltage and reactive power control	135
F.4.9	Infeed switchover and transformer change	135
F.4.10	Automatic switching sequences	136
Annex G (informative)	Results from function description	138

Annex H (informative) Substation configurations	144
H.1 Selected substations and associated layouts	144
H.2 Assigned protection and control functions	145
H.2.1 General	145
H.2.2 Substation T1-1	145
H.2.3 Substation D2-1	147
H.2.4 Substation T1-2	147
H.2.5 Substation T2-2	147
Annex I (informative) Examples for protection functions in compensated networks	149
I.1 The Transient Earth Fault (PTEF)	149
I.2 Short term bypass (YPSH)	150
I.3 The double earth fault (PTOC)	150
Bibliography	151
Figure 2 – Levels and logical interfaces in substation automation systems	22
Figure 3 – The logical node and link concept (explanation see text)	34
Figure 4 – Examples of the application of the logical node concept (explanation see text) ...	35
Figure 5 – Protection function consisting of three Logical Nodes	36
Figure 6 – The basic communication links of a logical node of main protection type	43
Figure 7 – Decomposition of functions into interacting LNs on different levels: Examples for generic automatic function, breaker control function and voltage control function	61
Figure 8 – Decomposition of functions into interacting LN on different levels: Examples for generic function with telecontrol interface, protection function and measuring/metering function	62
Figure 9 – Example for control and protection LNs of a transformer bay combined in one physical device (some kind of maximum allocation)	62
Figure 10 – Example for interaction of LNs for switchgear control, interlocking, synchrocheck, autoreclosure and protection (Abbreviation for LN see above)	63
Figure 11 – Example for sequential interacting of LNs (local and remote) in a complex function like point-on-wave switching (Abbreviations for LN see above) – Sequence view	63
Figure 12 – Circuit breaker controllable per phase (XCBR instances per phase) and instrument transformers with measuring units per phase (TCTR or TVTR per phase)	64
Figure 14 – Transfer time for binary signal with conventional output and input delays	71
Figure 15 – Definition of transfer time t for binary signals in case of line protection	72
Figure 16 – Definition of transfer time t over serial link in case of line protection	73
Figure H.1 – T1-1 Small size transmission substation (single busbar 132 kV with infeed from 220 kV)	144
Figure H.2 – D2-1 Medium size distribution substation (double busbar 22 kV with infeed from 69 kV)	144
Figure H.3 – T1-2 Small size transmission substation (1 1/2 breaker busbar at 110 kV)	144
Figure H.4 – T2-2 Large size transmission substation (ring bus at 526 kV, double busbar at 138 kV)	145
Figure H.5 – Substation of type T1-1 with allocation functions	146
Figure H.6 – Substation of type D2-1 with allocated functions	147
Figure H.7 – Substation of type T1-2 (functions allocated same as for T2-2 in Figure H.8)	147
Figure H.8 – Substation of type T2-2 with allocated functions	148
Figure I.1 – The transient earth fault in a compensated network	149

Figure I.2 – Short term bypass for single earth fault in compensated networks..... 150
 Figure I.3 – Double earth fault in compensated networks 150

Table 8 – Logical Nodes for protection functions 37
 Table 9 – Logical Nodes for protection related functions 43
 Table 10 – Logical Nodes for control functions 45
 Table 11 – Logical Nodes for interface functions 46
 Table 12 – Logical Nodes for automatic process control functions 47
 Table 13 – Logical Nodes for functional block functions 49
 Table 14 – Logical Nodes for metering and measurement functions 50
 Table 15 – Logical Nodes for power quality functions 51
 Table 16 – Logical Nodes for physical device functions and common data 52
 Table 17 – Logical Nodes for time, supervision and testing 53
 Table 18 – Logical Nodes for system and device security 53
 Table 19 – Logical Nodes for switching devices 54
 Table 20 – Logical Nodes for supervision and monitoring functions 54
 Table 21 – Logical Nodes for instrument transformers functions 56
 Table 22 – Logical Nodes for position sensor functions 56
 Table 23 – Logical Nodes for material status sensor functions 57
 Table 24 – Logical Nodes for flow status sensor functions 57
 Table 25 – Logical Nodes for Generic Sensor Functions 58
 Table 26 – Logical Nodes for power transformer functions 58
 Table 27 – Logical Nodes for further power system equipment 58
 Table 28 – Logical Nodes for generic process I/O 59
 Table 29 – Logical Nodes for mechanical non-electrical process equipment 60
 Table 2 – Time synchronization classes for AC applications synchronization 68
 Table 3 – Time synchronization classes for time tagging or sampling 68
 Table 30 – Classes for transfer times 75
 Table 31 – Data integrity classes 79
 Table 32 – Security classes 80
 Table 33 – Dependability classes 81
 Table 34 – Requirements for recovery time (examples) 83
 Table A.1 – PICOM groups 86
 Table A.2 – Logical node list 87
 Table B.1 – PICOM identification (Part 1) 102
 Table B.2 – PICOM identification (Part 2) 103
 Table B.3 – PICOM allocation (Part 1) 104
 Table B.4 – PICOM allocation (Part 2) 105
 Table B.5 – PICOM types 107
 Table G.1 – Function-function interaction (Part 1) 138
 Table G.2 – Function-function interaction (Part 2) 139
 Table G.3 – Function decomposition into logical nodes (Part 1) 140
 Table G.4 – Function decomposition into logical nodes (Part 2) 141

Table G.5 – Function decomposition into logical nodes (Part 3) 142
Table G.6 – Function decomposition into logical nodes (Part 4) 143
Table H.1 – Definition of the configuration of all substations evaluated 145

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 5: Communication requirements for functions and device 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.

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 61850-5 edition 2.1 contains the second edition (2013-01) [documents 57/1286/FDIS and 57/1309/RVD] and its amendment 1 (2022-03) [documents 57/2448/FDIS and 57/2467/RVD].

International Standard IEC 61850-5 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The changes, corrections and updates have been made mainly according to the comments received.

The major changes of this consolidated version with regard to the edition 2 are as follows:

- a) extensions of the requirements with some Logical Nodes
- b) errors and typos have been corrected
- c) harmonization of all Logical Node descriptions (impact on all Logical Node tables)
- d) re-organization of selected clause structures
- e) updating of headlines
- f) re-ordering subclauses in the chapter about performances

to provide

- ease of reading and understanding of the requirements for the IEC 61850 series
- consistent and updated requirement references for the data model and communication service parts

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

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under 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 IEC 61850 is part of a set of standards, the IEC 61850 series. The IEC 61850 series is intended to provide interoperability between all devices in power utility automation systems. Therefore, it defines communication networks and systems for power utility automation, and more specially the communication architecture for subsystems like substation automation systems. The sum of all subsystems may result also in the description of the communication architecture for the overall power system management.

Communication between these devices in subsystems and between the subsystems within the overall power utility automation system fulfils a lot of requirements imposed by all the functions to be performed in power utility automation systems starting from the core requirements in substations. These requirements are stated both for the data to be organized in a data model and for the data exchange resulting in services. Performance of the data exchange means not only transfer times but also the quality of the data exchange avoiding losses of information in the communication.

Depending on the philosophy both of the manufacturer and the user and on the state-of-the-art in technology, the allocation of functions to devices and control levels is not commonly fixed. Therefore, the standard shall support any allocation of functions. This results in different requirements for the different communication interfaces within the substation or plant, at its border and beyond.

The IEC 61850 series shall be long living but allow following the fast changes in communication technology by both its technical approach and its document structure. The IEC 61850 series has been organized so that at least minor changes to one part do not require a significant rewriting of another part. For example, the derived data models in subsequent parts (IEC 61850-7-x) and mappings to dedicated stacks (IEC 61850-8-x and IEC 61850-9-x) based on the communication requirements in IEC 61850-5 will not change the requirements defined in IEC 61850-5. In addition, the general parts, the requirement specification and the modelling parts are independent from any implementation. The implementation needed for the use of the standard is defined in some few dedicated parts referring to main stream communication means thus supporting the long living of the standard and its potential for later technical changes.

This consolidated version of IEC 61850-5:2013 and its Amendment 1 defines the communication requirements for functions and device models for power utility automation systems.

The modelling of communication requires the definition of objects (e.g., data objects, data sets, report control, log control) and services accessing the objects (e.g., get, set, report, create, delete). This is defined in IEC 61850-7 with a clear interface to implementation. To use the benefits of communication technology, in this standard no new protocol stacks are defined but a standardized mapping on existing stacks is given in IEC 61850-8 and IEC 61850-9. A System configuration language (IEC 61850-6) for strong formal description of the system usable for software tools and a standardized conformance testing (IEC 61850-10) complement the standard.

NOTE 1 To keep the layered approach of the standard not mixing application and implementation requirements, terms like client, server, data objects, etc. are normally not used in IEC 61850-5 (requirements). In IEC 61850-7 (modelling), -8 and -9 (specific communication service mapping) terms belonging to application requirements like PICOM are normally not used.

NOTE 2 Specific requirements concerning extensions of part 8 are covered in separate technical reports, e.g. IEC TR 61850-80-3.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 5: Communication requirements for functions and device models

1 Scope

The specifications of this document refer to general, respectively core, communication requirements of the application functions in all domains of power utility automation systems. Dedicated communication requirements and most examples of application functions in this document are from the domain substation automation but may be reused in or extended to other domains within power utility automation systems. Note that sometimes instead of the term substation automation domain the term substation domain is used, especially if both the switchyard devices (primary system) and the automation system (secondary system) are regarded.

The description of the application functions is not used to standardize these functions, but to identify communication requirements between Intelligent Electronic Devices (IEDs) hosting these functions within plants and substations in the power system, between such stations (e.g. between substation for line protection) and between the plant or substation and higher-level remote operating places (e.g. network control centres) and maintenance places. In addition interfaces to remote technical services (e.g. maintenance centres) are considered. The general scope is the communication requirements for power utility automation systems. The basic goal is interoperability for all interactions providing a seamless communication system for the overall power system management. Another prerequisite for interoperability is a commonly defined method for time synchronization.

Standardizing application functions and their implementation is completely outside the scope of this document. Therefore, it cannot be assumed a single philosophy of allocating application functions to devices. To support the resulting request for free allocation of these functions, a proper breakdown of these functions into parts relevant for communication is defined. The exchanged data and their required performance are defined.

The same or similar IEDs from substations like protective and control devices are found in other domains like power plants also. Using this document for such devices in these plants facilitates the system integration e.g. between the power plant control and the related substation automation system. For some of such other application domains like wind power plants, hydro power plants and distributed energy resources specific standard parts according to the IEC 61850 series have been already defined and published.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60617, *Graphical symbols for diagrams – 12-month subscription to regularly updated online database comprising parts 2 to 13 of IEC 60617*

IEC 60834-1:1999, *Teleprotection equipment of power systems – Performance and testing – Part 1: Command systems*

IEC 60834-2:1993, *Performance and testing of teleprotection equipment of power systems – Part 2: Analogue comparison systems*

IEC 60870-4:1990, *Telecontrol equipment and systems. Part 4: Performance requirements*

IEC 60870-5 (all parts), *Telecontrol equipment and systems – Part 5: Transmission protocols*

IEC 61000-4-15:2010, *Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques – Flickermeter – Functional and design specifications*

IEC 61000-4-30:2015, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC TR 61850-1:2013, *Communication networks and systems for power utility automation – Part 1: Introduction and overview*

IEC TS 61850-2:2019, *Communication networks and systems for power utility automation – Part 2: Glossary*

IEC 61850-3:2013, *Communication networks and systems for power utility automation – Part 3: General requirements*

IEC 61850-4:2011, *Communication networks and systems for power utility automation – Part 4: System and project management*

IEC 61850-6:2009, *Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs*
IEC 61850-6:2009/AMD1:2018

IEC 61850-7-1:2011, *Communication networks and systems for power utility automation – Part 7-1: Basic communication structure – Principles and models*
IEC 61850-7-1:2011/AMD1:2020

IEC 61850-7-2:2010, *Communication networks and systems for power utility automation – Part 7-2: Basic information and communication structure – Abstract communication service interface (ACSI)*
IEC 61850-7-2:2010/AMD1:2020

IEC 61850-7-3:2010, *Communication networks and systems for power utility automation – Part 7-3: Basic communication structure – Common data classes*
IEC 61850-7-3:2010/AMD1:2020

IEC 61850-7-4:2010, *Communication networks and systems for power utility automation – Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*
IEC 61850-7-4:2010/AMD1:2020

IEC TR 61850-7-5, *Communication networks and systems for power utility automation – Part 7-5: IEC 61850 modelling concepts*

IEC TR 61850-7-500:2017, *Communication networks and systems for power utility automation – Part 7-500: Basic information and communication structure – Use of logical nodes for modeling application functions and related concepts and guidelines for substations*

IEC TR 61850-7-510:2012, *Communication networks and systems for power utility automation – Part 7-510: Basic communication structure – Hydroelectric power plants – Modelling concepts and guidelines*

IEC TR 61850-7-6:2019, *Communication networks and systems for power utility automation – Part 7-6: Guideline for definition of Basic Application Profiles (BAPs) using IEC 61850*

IEC TS 61850-7-7:2018, *Communication networks and systems for power utility automation – Part 7-7: Machine-processable format of IEC 61850-related data models for tools*

IEC 61850-8-1:2011, *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 61850-8-1:2011/AMD1:2020

IEC 61850-8-2:2018, *Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)*

IEC 61850-9-2:2011, *Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3*

IEC 61850-9-2:2011/AMD1:2020

IEC/IEEE 61850-9-3:2016, *Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

IEC 61850-10:2012, *Communication networks and systems for power utility automation – Part 10: Conformance testing*

IEC TR 61850-80-3:2015, *Communication networks and systems for power utility automation – Part 80-3: Mapping to web protocols – Requirements and technical choices*

IEC TR 61850-90-1:2010, *Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*

IEC TR 61850-90-2:2016, *Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for communication between substations and control centres*

IEC TR 61850-90-4:2020, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC TR 61850-90-5:2012, *Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*

IEC TR 61850-90-12:2020, *Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*

IEC 61869 (all parts), *Instrument transformers*

IEC TR 62357-1:2016, *Power systems management and associated information exchange – Part 1: Reference architecture*

IEC 81346 (all parts), *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61850-2, as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General

3.1.1

application function

task which is performed in or by power utility automation systems

Note 1 to entry: Generally, an application function consists of subparts which may be distributed to different IEDs, which exchange data with each other. More precisely these sub-functions implemented in the IEDs exchange data. Also, between different functions data are exchanged. The exchanged data exposed to the communication system shall be standardized based on the semantic content to be understandable by the receiving function. For this purpose, the standard groups the exchanged data in objects called Logical Nodes which refer to the name of the allocated functions by their mnemonic name.

3.1.2

local function

application function which is performed by sub-functions in one physical device

Note 1 to entry: If the performance of the functions is not depending on functions in other devices no standardized link is needed. Sometimes, functions with a weak dependency only from other ones are also called local functions. The loss of such links should not result in blocking these functions but in worst case to some graceful degradation.

3.1.3

distributed function

application function which is performed by sub-functions in two or more different physical devices

Note 1 to entry: The exchanged data is contained in Logical Nodes having a common semantic reference to the distributed function. Since all functions communicate in some way, the definition of a local or a distributed function is not unique but depends on the definition of the functional steps to be performed until the function is defined as complete. In case of losing the data of one Logical Node or losing one included communication link the function may be blocked completely or show a graceful degradation if applicable.

3.1.4

system

set of interacting entities which perform a common functionality

Note 1 to entry: The backbone of the system is the data exchange.

3.1.5

logical system

communicating set of all application functions performing some overall task like "management of a substation" or "management of a plant"

Note 1 to entry: The boundary of a logical system is given by its logical interfaces. The backbone of the logical system is the communication relationship between its functions and sub-functions. The exchanged data are grouped in Logical Nodes.

3.1.6

physical system

set of all interacting devices hosting the application functions and the interconnecting physical communication network

Note 1 to entry: The boundary of a physical system is given by its physical interfaces. Examples are industrial systems, management systems, information systems, and within the scope of this standard, substation or power utility automation systems. The backbone of physical system is its communication system together with all implemented data.

3.1.7

substation automation system

system which operates, protects, monitors, etc. the substation, i.e. the primary system

Note 1 to entry: For this purpose, it uses fully numerical technology and digital communication links (LAN as communication system).

Note 2 to entry: See 3.1.9 for a definition of primary system.

3.1.8

secondary system

power utility automation system

interacting set of all components and subsystems to operate, to protect and to monitor the primary system

Note 1 to entry: In case of full application of numerical technology, the secondary system is synonymous with the power utility automation system. For this purpose, it uses fully numerical technology and digital communication links (WAN as communication system). Substation automation systems are one kind of power utility automation systems responsible for the nodes in the power system or power grid.

Note 2 to entry: See 3.1.9 for a definition of primary system.

3.1.9

primary system

power system

set of all components for generating, transmitting and distributing electrical energy

Note 1 to entry: Parts of the power system are also all consumers of electrical energy.

Note 2 to entry: Examples are generators, power transformers, and switchgear in substations, overhead line and cables.

3.1.10

communication system

interconnected set of all communication links

Note 1 to entry: Depending on the size it is called either LAN (local area network) as used in substations or plants, or WAN (wide area network) as used globally in the power utility system.

3.1.11

device

mechanism or piece of equipment designed to serve a purpose or to perform a function

Note 1 to entry: Communication relevant properties are described in the related device model.

Note 2 to entry: Examples are a breaker, relay, or the computer of the operator's work place.

3.1.12

intelligent electronic device (IED)

device incorporating one or more processors with the capability to execute application functions, store data locally in a memory and exchange data with other IEDs (sources or sinks) over a digital link

Note 1 to entry: Examples are electronic meters, digital/numerical relays, and digital controllers. They host the data according to the data model and allow exchanging data according to the IEC 61850 services/interfaces. If not stated

otherwise, intelligent electronic devices have an internal clock by definition. This allows fulfilling the requirements for time tagging of events or synchronized sampling. The clocks of different IEDs have to be synchronized for time coherent data if requested by the hosted application functions.

Note 2 to entry: This note applies to the French language only.

3.1.13

physical device

intelligent electronic device as used in the context of this standard

3.1.14

abstract data models for communication

data standardized with their semantic meaning exchanged between the application functions hosted by the IEDs

Note 1 to entry: All application functions shall trust these data and perform their algorithm using this data. The formal description of the automation system by SCL is also based on this standardized data.

3.1.15

PICOM

Piece of Information for COMMunication describing the information transfer with given communication attributes between two Logical Nodes

Note 1 to entry: It contains, in addition to the information to be transmitted, requirement attributes like performance and was adopted from CIGRÉ working group 34.03. It does not represent the actual message structure and the format for data as exchanged over the communication network. This implementation information is found in the standard parts IEC 61850-8-x and IEC 61850-9-x. The assumed logical point-to-point connection describes the source and sink of this information transfer but does not define the communication procedures like client-server or publisher-subscriber for multicast and broadcast.

Note 2 to entry: This note applies to the French language only.

3.1.16

Logical Node (LN)

object where standardized data for communication are grouped according to their relationship to application functions

Note 1 to entry: The granularity of data or to how many Logical Nodes (LN) the data are distributed depends on the granularity of the application functions. The granularity stops at the smallest function parts which may be implemented as single-stand-alone application functions acting also as atomic building blocks for complex application functions. The Logical Nodes may be seen also as containers containing the data provided by a dedicated function for exchange (communication). The name of the Logical Node is then the label attached to this container telling to what function the data belong. Logical Nodes related to primary equipment are not the primary equipment itself but a data image in the secondary system needed for performing the application functions of the power utility automation system.

3.2 Connections

3.2.1

logical connection

communication link between application functions represented by Logical Nodes

3.2.2

physical connection

communication link between intelligent electronic devices (IEDs) and is providing all logical connections for the implemented application functions represented by Logical Nodes

3.2.3

exposed connection

communication link outside the IED i.e. between IEDs

Note 1 to entry: The data running over exposed connections are visible and may be used by other IEDs requesting interoperability. Therefore, these data and the related communication procedures shall be standardized according to IEC 61850 series. An exception may be data which are needed for some private purpose not impacting the interoperability.

3.2.4

hidden connection

communication inside the IED

Note 1 to entry: This data exchange is not visible and cannot be used by other IEDs therefore not requesting interoperability. It should be noted that by distributing combined application functions in one IED to more than one IED hidden connections may get exposed ones which shall be standardized.

3.2.5

digital connection

any communication data coded and transmitted as bits

3.2.6

serial connection

communication with data coded and transmitted as series of bits over one communication line

3.3 Relations between IEDs

3.3.1

interoperability

the ability of two or more intelligent electronic devices (IED) from the same manufacturer, or different manufacturers, to exchange information and use that information for their own functionality and correct co-operation with other IEDs

Note 1 to entry: Interoperability is within the scope of the standard and is a prerequisite for interchangeability (see 3.3.2).

3.3.2

interchangeability

the possibility to replace an IED by an IED from the same manufacturer or from a different manufacturer providing the same functionality with no impact on the rest of the system

Note 1 to entry: Interchangeability requires standardization of application functions and, in a strong sense, of IEDs also. Both such requirements are outside the scope of this standard. Utilizing interoperable IEDs (see definition of interoperability in 3.3.1) with the same communication interface and about the same data (LNs) according to IEC 61850 series, with the same functionality and performance or minor accepted differences, the exchange may be possible but some engineering actions may be still needed. This depends on the implementation of the standard and is always within the responsibility of the engineer of the IEDs, not of IEC 61850 series.

Note 2 to entry: Re-engineering and re-testing are not needed.

3.4 Substation structures

3.4.1

bay

closely connected subpart of the substation with some common functionality

Note 1 to entry: Examples are the switchgear between an incoming or outgoing line and the busbar, the bus coupler with its circuit breaker and related isolators and earthing switches, the transformer with its related switchgear between the two busbars representing the two voltage levels, the diameter (see 3.4.2) in a 1 ½ breaker arrangement, virtual bays in ring arrangements (breaker and adjacent isolators), etc. These subparts very often comprise a device to be protected such as a transformer or a line end. The control of the switchgear in such a subpart has some common restrictions like mutual interlocking or well-defined operation sequences. The identification of such subparts is important for maintenance purposes (what parts may be switched off at the same time with a minimum impact on the rest of the substation) or for extension plans (what has to be added if a new line is linked in). These subparts are called "bays" and managed by devices with the generic names "bay controller" and "bay protection". The functionality of these devices represents an additional logical control level below the overall station level that is called "bay level". Physically, this level may not exist in any substation; i.e. there may be no physical device "bay controller" at all. The functionality of this level may be hosted by other IEDs.

3.4.2

diameter

complete switchgear between the two busbars of a 1-½-breaker arrangement, i.e. the 2 lines and the 3 circuit breakers with all related isolators, earthing switches, CTs and VTs

Note 1 to entry: It has some common functionality and restriction like a bay both for operation, maintenance and extensions. Therefore, the "diameter protection" and "diameter control" represents a special type of bay level (see 3.5.3). In most cases these bay level application functions may be implemented in one or many IEDs. In the last case e.g. one of three control IEDs may be responsible each for one the three circuit breakers of the diameter. One of two protection IEDs may be responsible each for one of the two lines being connected to the diameter.

3.5 Power utility automation functions at different levels

3.5.1

network level functions

power system application functions which exceed at least the boundary of one substation or plant

Note 1 to entry: Examples of such functions are line protection, telecontrol, telemonitoring, etc.

3.5.2

station level functions

power system application functions referring to the substation or plant as whole

Note 1 to entry: There are two classes of station level functions; i.e. process related station level functions and interface related station level functions.

3.5.3

bay level functions

application functions using mainly the data of one bay and acting mainly on the primary equipment of one bay

Note 1 to entry: In the context of this standard a bay means any subpart of the substation like a line feeder, a diameter or a transformer feeder. The definition of a bay is considering some kind of a meaningful substructure in the primary substation configuration and some local functionality, restriction or autonomy in the secondary system (substation automation). Examples for such functions are line protection or bay control. These functions communicate via the logical interface IF3 (Fig. 2) within the bay level and via the logical interfaces IF4 and IF5 to the process level, i.e. with any kind of remote I/Os or intelligent sensors and actuators. Interfaces IF4 and IF5 may be hardwired also but hardwired interfaces are outside the scope of IEC 61850 series.

Note 2 to entry: Bay is defined in 3.4.1.

3.5.4

process level functions

application functions interfacing to the process, i.e. basically binary and analogue I/O functions like data acquisition (including sampling) and issuing of commands related to one primary object (e.g. circuit breaker)

Note 1 to entry: These functions communicate via the logical interfaces IF4 and IF5 to the bay level. The process level functions may be implemented in the bay level IEDs together with the bay level functions if no process bus is applied. If a process bus is applied the process level functions are implemented in process level IEDs.

3.5.5

process related station level functions

application functions using the data of more than one bay or of the complete substation and acting on the primary equipment of more than one bay or of the complete substation

Note 1 to entry: Examples of such functions are station wide interlocking, automatic sequencers or busbar protection. These functions communicate mainly via the logical interface IF8.

3.5.6

interface related station level functions

application functions representing the interface of the power automation system to the local station operator named HMI (human machine interface), to a remote control centre named TCI (telecontrol interface) or to the remote engineering workplace for monitoring and maintenance named TMI (telemonitoring interface)

Note 1 to entry: These functions communicate in substations via the logical interfaces IF1 and IF6 with the bay level and via the logical interface IF7 and the remote control interface to the outside world. Logically, there is no difference if the HMI is local or remote. In the context of the substation there exists at least one logical interface for

the substation automation system at the boundary of the substation. Same holds both for the TCI and TMI. These logical interfaces may be realized in some implementations as proxy servers.

3.6 Miscellaneous

3.6.1

local issue

some functionality which is performed only inside an IED without communication to other IEDs which is outside the scope of IEC 61850 series

Note 1 to entry: Since the standard defines data to be exchanged and communications but not application functions this term refers in most cases to a local function like the display of data or how an application reacts if it is missing data or if it gets bad data. Since this depends from the detailed behaviour of the function and its implementation it cannot be standardized within the scope of IEC 61850 series.

3.6.2

granularity

extent to that the application function and their allocated data are split in sub-functions and subgroups respectively

Note 1 to entry: Any sub-function which may be implemented also in an IED not containing all other related sub-functions has to communicate in a standardized way with other IEDs hosting these related sub-functions. The guideline is the maximum required granularity to have data grouping which fits in nearly any distribution of functions and sub-functions.

4 Abbreviations

CT	Current Transformer
FACTS	Flexible AC Transmission Systems
GPS	Global Positioning System (time source)
HMI	Human Machine Interface
I/O	Input and Output contacts or channels (depending on context)
IED	Intelligent Electronic Device
IF	(Serial) Interface
ISO	International Organization for Standardization
LAN	Local Area Network
LC	Logical Connection
LN	Logical Node
MMS	Manufacturing Message Specification
NCC	Network Control Centre
OSI	Open System Interconnection
PC	Physical Connection
PD	Physical Device
PICOM	Piece of Information for COMmunication
SAS	Substation Automation System
SGAM	Smart Grid Architecture Model
TCI	Telecontrol Interface (for example, to Network Control Centre, NCC)
TMI	Telemonitoring Interface (for example, to engineers workplace)
VT	Voltage Transformer
WAN	Wide Area Network

5 Power utility automation functions

5.1 General

The power utility automation functions refer to tasks which have to be performed by the power utility automation system. These are functions to operate, supervise, protect and monitor the system to keep it running in the best way as possible and to guarantee the reliable and economic power supply. Since both the sensors and actuators for these tasks are implemented in a power plant being the generating node or in a substation being the connecting node in the power grid, the power utility automation system may be seen as front-end to all these functions and, therefore, a very important subsystem. The SAS is used as an example in the following for defining the communication requirements for application functions and device models.

How the domains and application functions are grouped is outside this document which is requirement focused. But it should be noted that a structured bridge between requirements and implementation exists by the Smart Grid Architecture Model (SGAM) as referenced in the IEC TC 57 reference architecture (IEC 62357-1).

5.2 Example substation automation system

5.2.1 General

The application functions of a substation automation system (SAS) refer to tasks which have to be performed in the substation. These are application functions to control, monitor and protect the equipment of the substation and its feeders. In addition, there exist application functions, which are needed to maintain the SAS, i.e. for system configuration, communication management or software management and, very important, for time synchronization.

5.2.2 Logical allocation of application functions and interfaces

The application functions of a substation automation system may be allocated logically to three different levels (station, bay/unit, or process). These levels are shown by the logical interpretation of Figure 2 together with the logical interfaces 1 to 12.

Process level application functions are all functions interfacing to the process. These application functions communicate via the logical interfaces 4 and 5 to the bay level.

Bay level application functions (see bay definition above) are all functions using mainly the data of one bay and acting mainly on the primary equipment of this one bay. These application functions communicate via the logical interface 3 within the bay level and via the logical interfaces 4 and 5 to the process level, i.e. with any kind of remote I/Os or intelligent sensors and actuators. Interfaces 4 and 5 may be hardwired also but hardwired interfaces are outside the scope of the IEC 61850 series.

There are two classes of station level application functions:

Process related station level application functions are application functions using the data of more than one bay or of the complete substation and acting on the primary equipment of more than one bay or of the complete substation. These application functions communicate mainly via the logical interface 8.

Interface related station level application functions are application functions representing the interface of the SAS to the local station operator (Human machine interface (HMI)), to a remote control centre (Telecontrol interface (TCI)) or to the remote engineering place for monitoring and maintenance (Telemonitoring interface (TMI)). These functions communicate via the logical interfaces 1 and 6 with the bay and via the logical interfaces 7 and 10 to the outside world.

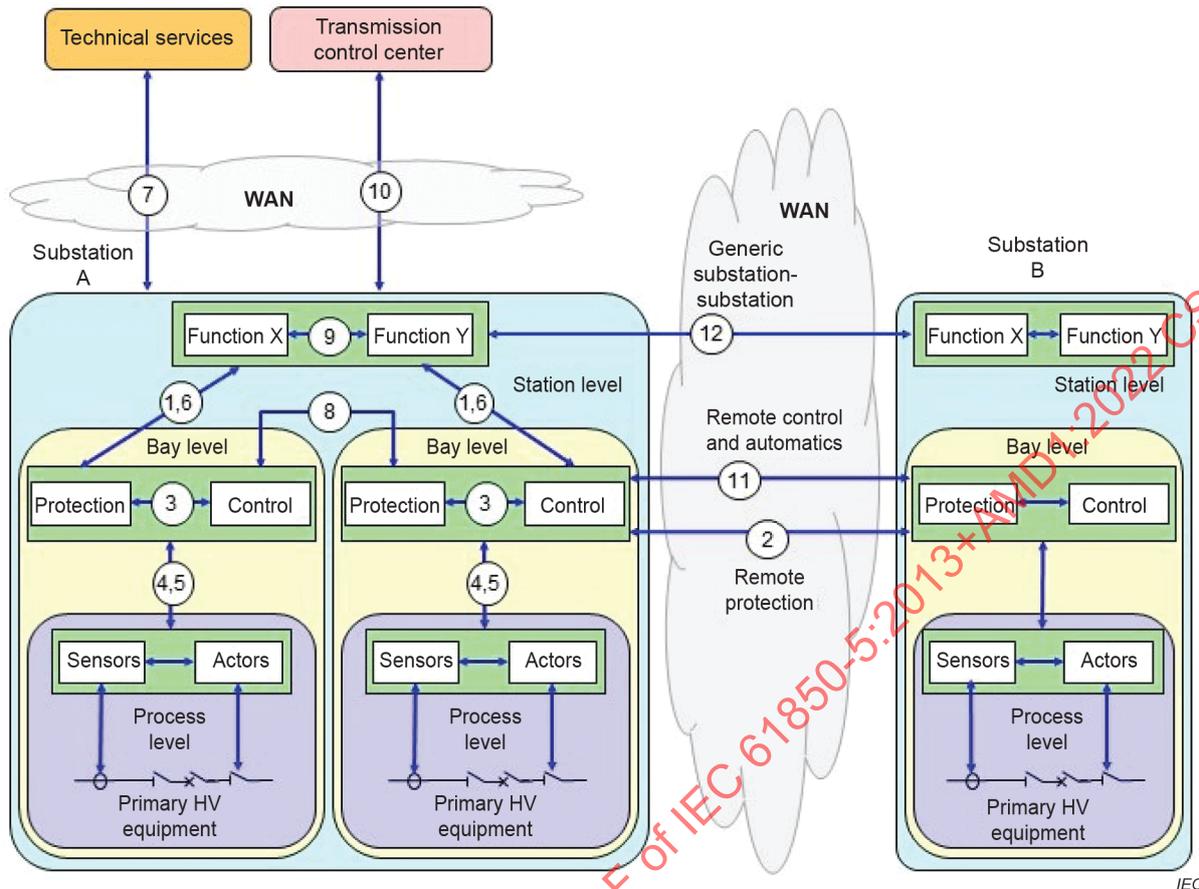


Figure 2 – Levels and logical interfaces in substation automation systems

The meaning of the interfaces:

- IF1: protection-data exchange between bay and station level
- IF2: protection-data exchange between bay level and remote protection (e.g. line protection)
- IF3: data exchange within bay level
- IF4: digitized analogue data exchange between process and bay level (samples from CT and VT)
- IF5: control data exchange between process and bay level
- IF6: control data exchange between bay and station level
- IF7: data exchange between substation (level) and a remote engineer’s workplace
- IF8: direct data exchange between the bays especially for distributed functions
- IF9: data exchange within station level
- IF10: control-data exchange between the substation and remote Network Control Centre(s)
- IF11: control-data exchange between substations. This interface refers mainly to binary data e.g. for interlocking functions or other inter-substation automatics
- IF12: generic substation-substation link e.g. for FACTS control

Measurements in different kinds e.g. RMS values or synchrophasors, may be part of the different interfaces. Furthermore, requirements for time synchronization to be covered by the different interfaces are depending on the application functions.

The cloud(s) around IF2, IF11 and IF12 indicate(s) that there may be also an external communication system applied for which the requirements as defined in IEC 61850-90-1,

IEC 61850-90-2, IEC 61850-90-5, IEC 61850-90-12 or IEC 61850-80-3 may apply. In case of implementation based on external communication systems, which are not in accordance with the data model and services defined in the IEC 61850 series, some kind of protocol conversion is needed.

NOTE The distribution of the functions in a communication environment may occur through the use of Wide Area Network (WAN), Local Area Network (LAN) and Process Bus technologies. At requirement level, the functions are not constrained to be deployed within/over any single communication technology.

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

- a) process level devices are typically remote process interfaces like I/Os, intelligent sensors and actuators connected by a process bus as indicated in Figure 2;
- b) bay level devices consist of control, protection or monitoring units per bay;
- c) station level devices consist of the station computer with a database, the operator's workplace, interfaces for remote communication, etc.

5.2.3 The physical allocation of functions and interfaces

Despite of the similarity of logical and physical levels there is no unique way for mapping the logical function structure to the physical device structure. The mapping is depending on availability and performance requirements, cost constraints, the state of the art in technology, etc. It is influenced also by the operation philosophy and the acceptance of the users i.e. of the power utilities.

The station computer may act as client only with the basic application functions HMI, TCI and TMI. All other station level application functions may be distributed completely over the bay level devices. In this case the interface 8 is the backbone of the system. On the other side all these station wide application functions like interlocking etc. may reside in the station computer acting now both as client and server. In this case the interface 1 and 6 take over the complete functionality of interface 8. Many other solutions are possible.

The bay level application functions may be implemented in dedicated bay level devices (protection unit, control unit, without or with redundancy) or in combined protection and control units. Some of these application functions may be moved physically down to the process level supported by the free allocation of functions.

If there are no interfaces 4 and 5, the process level application functions are implemented in the bay level devices. The realization of the interfaces 4 and 5 may include remote I/O devices only or intelligent sensors and actuators, which provide some bay level functionality on process level already.

The logical interfaces may be implemented as dedicated physical interfaces (plugs). Two or more may be combined also into a single common physical interface. In addition, these interfaces may be combined and implemented into one or more physical LANs. The requirements for these physical interfaces depend upon the allocation of the application functions to levels and devices.

The teleprotection interface 2 may be also implemented as dedicated link (power line carrier, etc.) or combined with other boundary interfaces as 7, 10, 11 and 12 connected physically to WAN.

5.2.4 The role of interfaces

Not all interfaces have to be present in any substation. This flexible approach covers both the retrofit of existing substations and the installation in new substations, today and tomorrow.

The numbering of interfaces according to Figure 2 is helpful for the identification of the kind of interfaces needed in substations and for data flow calculations.

The interface numbers allow defining easily the two important LANs or bus systems: Commonly, the interfaces 1, 6, 3, 9, 8 are combined to the station bus which connects both the station level with the bay level and the different bays itself. The interfaces 4 and 5 are combined to the process bus which connects the bay level with the process level and the different process level IEDs with each other. Very often, the process bus is restricted to one single bay only. If the process bus is extended to other bays it may also take over the role of interface 8, at least for raw data.

The interface 7 is dedicated for external communication with a remote monitoring/maintenance centre. It could be realized by a direct interface to the station bus also.

According to the function allocation, the message types of Clause 10 based on communication performance requirements may be assigned to the different interfaces. The free allocation of application functions means that such an assignment may not be common for all substation automation systems.

5.3 Other application examples

5.3.1 Substation – Substation

The communication between Substations is also introduced in Figure 2 referring to interfaces 2, 11 and 12. The requirements are the same as inside the substation. Binary values (blocking, release, etc. for distance protection and automatics) and analogue values (samples of current for current differential protection) have to be exchanged depending on the application functions applied. Differences are the longer communication distance and the potential transparent use of an external communication system with higher or lower bandwidth which may increase the transmission delay and impact other constraints like jitter and channel symmetry.

5.3.2 Substation – Network Control Center

The communication between the Substation and the Network Control Center is also introduced in Figure 2 referring to interface 10. The requirements are the same as inside the substation for the connection between bay and station level. Binary values (status information, events, alarms, commands, etc. for remote control) and measured values (calculated values e.g. for the energy flow, synchrophasors) have to be exchanged depending on the application functions applied. Differences are the longer communication distance and the potential transparent use of an external communication system with higher or lower bandwidth which may increase the transmission delay and impact other constraints like jitter.

5.3.3 Wind

Basic application functions like collecting binary and analogue data and issuing commands are the same as for substations. The specific requirements are to model the wind power generating part (wind turbine as primary mover and connected generator) and the environmental conditions like wind strength and direction. The wind power automation system has also an interface to the network system management similar as interface 10 in substations.

5.3.4 Hydro

Basic applications like collecting binary and analogue data and issuing commands are the same as for substations. The specific requirements are to model the hydro power generating part (water turbine as primary mover and connected generator) and the environmental conditions like water level and flow. The hydro power automation system has also an interface to the network system management similar as interface 10 in substations.

5.3.5 DER and distribution automation

Distributed Energy Resources (DER) may be defined as a distributed set of one or more energy service resources, including generators, energy storage, and controllable load, that are connected at the medium or low voltage levels (distribution power system). Some DERs are

considered as sources of renewable energy, while others are fossil fuel based, or a combination of different types. They may provide energy as well as ancillary services. Communications may include direct interactions with utility automation systems, through facility energy management systems which manage their own DERs, and through aggregators. Some typical types of DER include:

- Wind turbines and wind power plants
- Photovoltaic systems (PV) and PV plants: PV plus battery storage
- Hydro and thermal generation
- Pumped water storage systems
- Battery-based energy storage systems
- Gas turbines
- Combined heat and power (CHP)
- Electric vehicles (EVs) and their chargers: electric vehicle service elements (EVSE)
- Virtual Power Plants (VPP) and micro grids
- Biomass plants
- Fuel cells

Automation systems for distributed energy resources may have also an interface to some higher level power control system similar as interface 10 in substations. Due to more limited amount of information to be exchanged and restrictions in bandwidth / and or communication technologies additional communication mappings like IEC 61850-8-2 may apply. Related requirements are gathered in IEC 61850-80-3.

Similar requirements and solutions may apply for Distribution Automation.

5.3.6 FACTS and Power Conversion

Flexible AC Transmission Systems (FACTS) devices or controllers are used to enhance controllability and increase or limit power transfer capability of the electric network. It uses power electronic or other static equipment to control AC power system parameters to achieve this. There exist several different power system applications of FACTS controllers classified in to two kinds based on how the FACTS Controller is connected to the power system grid; Shunt connected and Series connected. Some other examples for application may also exist.

Power converters are progressively used in all areas of an electrical system. Although their different technologies, various applications (e.g. HVDC long distance transmission, HVDC back-to-back, UHVDC, grid access, SFC, railway grid converters) and topologies (e.g. long-distance Overhead Lines, DC cable, back-to-back, mono/bipolar topologies, serial converters, parallel converters, multiterminal DC grids) may differ significantly from each other, they all have one thing in common: A power conversion process always considers and modifies the current flow between the converter as such and a connected electrical grid at a defined Point of Connection.

5.3.7 Distribution Automation and Feeder Automation

Distribution Automation (DA) is a concept emerged in the 1970s to promote the application of computer and communication technologies for the betterment of distribution system operating performance. It is in general used as an umbrella term to capture the deployment of automation technologies for protection, control, monitoring, and operation of distribution systems. These technologies enable electric utilities to monitor, control, and operate distribution components in a real-time or non-real-time mode. "The move towards smart and active distribution networks which support the high penetration of Distributed Energy Resources (DERs) and provide better supply reliability and operation efficiency has started. As a result, DA concepts are also being extended in the form of Advanced Distribution Automation or (ADA), which includes automation of DERs and demand response programs.

6 Goal and requirements

6.1 Interoperability

The goal of this standard is to provide interoperability between the IEDs from different manufacturers or, more precisely, between application functions to be performed in the power system hosted in the IEDs from different manufacturers. Interchangeability is outside the scope of this standard, but the objective of interchangeability will be supported by following this standard.

Reaching this goal means to address four basic requirements:

- a) To have a lower layer connectivity;
- b) To talk the same language regarding syntax, semantic and convention;
- c) To use the same model (how to describe a device or an equipment);
- d) To have a common configuration language giving the means to organise all exchanges between IEDs (who is who, who needs what, who sends what to who...).

NOTE This goal of interoperability for this standard refers to interoperability between application functions. This is of special importance for transfer time requirements and compliance testing.

Since there are no constraints regarding system structure and data exchange, some static and dynamic requirements shall be fulfilled to provide interoperability.

To reach interoperability in systems with IEDs from different manufacturers, the dedicated task of the system integrator should be allocated to one party/person from the beginning. The system integrator is responsible that the delivered system is performing as specified by the customer.

6.2 Static design requirements

The standard shall support all configurations for Power Utility Automation Systems and, especially for Substation Automation Systems to suit the needs of all users (power utilities) and to be applied to the related technologies. This shall be valid today and in the future.

The goal of interoperability for any configuration results in the following static design requirements, which are not completely independent from each other:

- a) The free allocation of application functions to devices shall be supported by the communication; i.e. communications shall be able to permit any function to take place in any device. It does not mean that all devices shall support all application functions. This allows fulfilling different system design philosophies and enabling future improvements. The application functions of the power utility automation system and their communication behaviour shall be described device independent i.e. from the implementation in IEDs.
- b) The application functions shall be described as far as necessary only to identify the information to be exchanged. This shall allow grouping the data to be exchanged properly according to production and consumptions of data by the functions. Any standardization of application functions itself is outside the scope of this standard.
- c) To keep interoperability, all existing means within IEC 61850 series shall be used before private extensions are made. For all such extensions restrictive and well-defined rules shall be given.
- d) The interaction of device independent distributed application functions shall be described by the logical interfaces in between. For implementation these logical interfaces may be freely allocated to physical interfaces and to LANs or WANs if applicable.
- e) The application functions used today and their communication requirements are well known but the standard shall be open also for communication requirements arising from any future function.
- f) To keep interoperability easy there shall be a minimum number of protocols defined in Parts 8-x and 9-x as valid at one time by an application domain.

- g) To reach interoperability in projects with real IEDs connectors depending on the communication medium should be defined. Otherwise, patch cables or boxes have to be used.
- h) The system configuration with all data exchanged and the communication mechanisms applied shall be described in a strong formal way. Details are out of scope of this part but within the scope of IEC 61850-6.

6.3 Dynamic interaction requirements

The goal of interoperability for any data exchange results in the following dynamic interaction requirements, which are not completely independent from each other:

- a) The standard shall define generic information to be communicated and generic communication behaviour of the application functions to support planned and future functional extensions of the substation automation system. Extension rules shall be given.
- b) The transfer of information (data) shall be defined with all related attributes (see PICOMs).
- c) The exchanged information (data) shall carry all attributes for unambiguous understanding by the receiver. If this is fixed information, they may be provided from the sender to the receiver already at engineering time.
- d) The maximal allowed transfer times shall fulfil the requirements of the application functions involved. Therefore, it shall be defined as overall transfer time (performance) from application to application including the coding at the sender side, the delay in the communication network and the decoding at the receiver side.
- e) The acceptable overall transfer time (performance) of exchanged data shall be defined in performance classes. The performance of the related class shall be guaranteed in any situation. Exceptions are outside the scope of this part and shall be indicated for implementations.
- f) Performance shall include not only the transfer time but also other figures like quality related data as data integrity etc.
- g) A safe system means that the system is never in an unsafe i.e. unknown state. The probability for such safeness is never 100 %. The related standard IEC 61508 is dependent on a lot of parameters from design and production to function and system engineering. As far as the communication functions are referred to this safety they shall allow the highest safety class requested.
- h) The protection against cyber-attacks and all unauthorized actions belong also to the data integrity. Proper means shall avoid or minimize such kind of risks. The needed measures like encryption or Role Based Access (RBAC) are outside the scope of this part of the standard but they shall not impact the usability like maintenance measures (quick replacement of a faulty IED etc.).

6.4 Response behaviour requirements

Since interoperability is claimed for proper running of all application functions in the system, the reaction of the application in the receiving node shall be considered. The exchanged data may have quality attributes and operative attributes. Quality attributes like “good” or “bad” emerging by dedicated system supervision automatically. Operation modes like “on”, “off” or “in test mode” are created by the operator or maintenance people. These modes may request certain quality attributes for the data like “test data”.

- a) The reaction of the receiving node shall fit into the overall requirement of the distributed application function to be performed.
- b) The generic reaction on operation modes and related attributes shall be standardized as part of the interoperability.
- c) The dedicated response on quality attributes i.e. in any degraded case like on erroneous messages, lost data by communication interrupts, resource limitations, out of range data, etc. belongs to the function itself and, therefore, is outside the scope of the standard. But this behaviour shall be described in the function or IED manual elsewhere. This is important

if the overall task cannot be closed successfully, e.g. if the remote node does not respond in time or does not react in a proper way.

The reaction and the behaviour of the application functions itself are function related local issues and, therefore, outside the scope of this standard. But the requirement left for this standard is the provision of proper quality attributes to be transferred with the data under consideration.

6.5 Approach to interoperability

To approach interoperability, the application functions to be performed in power systems and, especially, in substations are identified in the following clauses to find the appropriate data objects for exchange which shall be standardized. The requirements for data exchange shall be clearly defined. The interoperability for freely allocated and distributed functions shall imply an appropriate decomposition of functions in communicating entities to get the right object oriented grouping of data for standardization.

The requested mutual understanding of devices from different manufacturers shall result in a proper data and communication service model as given in IEC 61850-7-x series. Last not least, the mapping of this model to state-of-the-art communication stacks (coding/decoding) shall be defined unambiguously in IEC 61850-8-x and IEC 61850-9-x series. Configuration files standardized in part IEC 61850-6 support interoperability by appropriate engineering tools.

It should be noted that interoperability is not a device property but a system goal.

6.6 Conformance test requirements

Interoperability depends both on the device properties and the system design and engineering. Conformance tests shall be performed to verify that the communication behaviour of a device as system component is compliant with the interoperability definition of this standard. Since the goal of IEC 61850 is interoperability, conformance with the standard means that interoperability is proven. The conformance test specification shall describe what tests have to be applied to a device checking that the communication function is correctly performed with a complementary device or, generally, with the rest of the system. Also the pass criteria have to be well defined. Since it is not possible to test any device against any other device on the market, conformance tests may involve the use of various simulators to represent the context of the system and of the communication network.

If it is not possible to test an IED in a reasonable test system for interoperability then a limited performance test shall prove conformance of the data model according to the implemented functions with IEC 61850-5 and of the implemented services according to the communication behaviour needed by implemented application functions according to IEC 61850-5. This will reduce the risk not to match interoperability in the system.

The engineering process as such is outside the scope of the standard. Nevertheless, building interoperable systems requests standardized configuration files to be exchanged between engineering tools. Therefore, the tools shall also fulfil all requirements for such an exchange of the relevant configuration files. Definitions of the configurations files and testable tool requirements are defined in IEC 61850-6. Definitions of the needed conformance tests both for IEDs and tools are given in IEC 61850-10

7 Categories of application functions

7.1 General

Different categories of application functions are identified. Some functions may belong not uniquely to the given category and its category allocation is a convention only. The category of the function is defined below but the functions are listed as bullet points in the following subclauses only. Generic function descriptions are given in Annex F.

7.2 System support functions

These functions are used to manage the system itself. They have no direct impact on the applications but support the total system. These functions are performed continuously in the background of the system. Their goal is a well running system with synchronized nodes. Examples:

- network management,
- time synchronisation,
- physical device self-checking,
- communication supervision.

7.3 System configuration or maintenance functions

These functions are used to set-up or evolve (maintain) the system. They include the setting and changing of configuration data and the retrieval of configuration information from the system. These functions are performed once in the configuration or set-up phase of the power automation system only. Upgrades, extensions or other major changes will call up these functions later in the life cycle of the system also. The response time of system configuration or maintenance functions and, therefore, of the related communication has not to be much faster than 1 s (human time scale). Examples:

- node identification,
- software management,
- configuration management,
- system security management,
- setting,
- operative mode control of functions by data,
- test mode.

7.4 Operational or control functions

These application functions are needed for the normal operation of the substation or plant every day. In these application functions, an HMI either local or remote is included. They are used to present process or system information to an operator or to allow him the process control by commands. The feedback response times of the operational functions and, therefore, of the related communication have not to be much faster than 1 s (human time scale). Examples:

- access security management,
- control,
- operational use of spontaneous change of indications,
- synchronous switching (point-on-wave switching),
- changing of parameters and parameter set switching,
- alarm management,
- event (management and) recording,
- data retrieval,
- disturbance/fault record retrieval.

7.5 Bay local process automation functions

“Bay local” application functions mean that the data are acquired by the sensors (CT, VT) of one bay and that the resulting actions (commands/trips/releases) are performed by actuators (switches) in the same bay. The word “bay” stands here for any restricted local substructure of the substation, respectively of the substation automation system.

These application functions are operating with process and system data directly on the process without the interference of the operator. Local automation functions are not local in a strong sense but consist of three LN in minimum. There is the LN with the core functionality itself, which is called local automation function in the context of this standard part. In addition, there is the process interface LN and the HMI (human-machine interface) LN providing the human access to the function. Examples out of the domain substation automation:

- protection functions like overcurrent or distance protection,
- bay interlocking,
- measuring, metering and power quality monitoring.

7.6 Distributed process automation functions

“Distributed” application functions mean that the data are acquired by the sensors (CT, VT) of more than one bay and that the resulting actions (commands/trips/releases) are performed by actuators (switches) in more than one bay. Also, the functionality may split to different IEDs (i.e. being decentralized) as for the decentralized busbar protection with bay units for pre-processing the current samples, acquiring the input for the busbar image and issuing the trips, and the central unit keeping the actual busbar image and making the trip decision.

These application functions check automatically without the interference of the operator the conditions, which are needed (block or release) by the operational functions or by the process automation functions. They do not act directly on the process. They are safety related to avoid danger for people or damage for equipment. Normally, they consider information from the whole plant or substation and are implemented locally or distributed. Since the distributed implementations especially call for the standardization of communication, these functions are listed here. The local implementations behave always like a local automation function. Examples out of the domain substation automation:

- station-wide interlocking,
- distributed synchrocheck,
- breaker failure,
- automatic protection adaptation (generic): most simple example reverse blocking,
- load shedding,
- load restoration,
- voltage and reactive power control,
- infeed switchover and transformer change,
- automatic switching sequences.

For some functions depending on their implementation the definition of “local” and “distributed” may not be unambiguous. For the requirements it is important only that the potentially decentralized character of functions is noticed i.e. an appropriate communication support must be provided by the communication system according to this document.

8 Description and requirements of application functions

8.1 Approach

To get the communication requirements in a substation or plant, the identification of all application functions is necessary. IEDs host a lot of simple and complex application functions different from manufacturer to manufacturer. The identification of these functions has to be done independently from the implementation of IEDs. In addition, these functions have to be divisible in pieces with indivisible core functionality which may be implemented by alone by itself also. This allows covering all implementations today and tomorrow by dedicated combinations. Each of these core pieces have allocated high-level data objects (Logical Nodes,

LN) which contain all data to be exchanged (Piece of Information for Communication, PICOM) between these core functions respectively between the IEDs which host these functions.

This approach consists of three steps.

- function description including the decomposition represented by LNs with the allocated data;
- PICOM description including the attributes;
- Logical Node (LN) description.

Any identification of application functions both in power systems and in substations or plants may be incomplete, but the assumption is made that the identified functions cover in a very representative way all communication requirements needed.

8.2 Application function description

The function description – more details are found in the Annex – provides the following information:

- task of the function,
- starting criteria for the function,
- result or impact of the function,
- performance of the function,
- interaction with other functions,
- function decomposition if applicable.

The last bullet refers how functions are decomposed by using LNs and how many decomposition sets exist typically. This information is very important since the communication requirements shall be based on interacting functions with maximum granularity for multiple use.

8.3 The PICOM description

8.3.1 The PICOM approach

The PICOM (Piece of Information for Communication) is focused by definition on the exchanged data between two application functions or subfunctions. Also functions like HMI and Gateway are included. Both the sending and the receiving part shall be identified. The communication requirements are based on such point-to-point connections. If multicast and broadcast messages maybe more convenient for the communication is a matter of implementation.

PICOMs describe exchanged information (“content”) and communication requirements (“attributes”). The “bits on the wire” are found in the mappings, i.e. in the parts IEC 61850-8 and IEC 61850-9.

Tables of exchanged data (PICOMs) between identified functions out of the domain substation automation are found in the Annex.

8.3.2 The content of PICOM description

PICOMs introduced by CIGRÉ WG34.03 are used to describe the information to be exchanged between LNs. The components or attributes of a PICOM are:

- data referring to the content of information and its identification as needed by the functions (semantics);
- logical connection containing the logical source (sending logical node, source) and the logical sink (receiving logical node, sink);

- type describing the structure of the data, i.e. if it's an analogue or a binary value, if it's a single value or a set of data, etc.;
- performance meaning the permissible transmission time (defined by performance class), the data integrity and the method or cause of transmission (e.g. periodic, event driven, on request).

8.3.3 Attributes of PICOMs

There are three types of attributes defined by their purpose.

8.3.4 PICOM attributes to be covered by any message

- Value: value of the information itself if applicable
- Name: for identification of the data
- Source: the LN where the signal comes from
- Sink: the LN where the signal goes to
- Time tag: absolute time to identify the age of the data if applicable
- Priority of transmission: to be used for
 - LN input queues (if more than one)
 - LN input and output (re-transmission order) in case of intermediate LNs
- Time requirements: cycle time or overall transfer time to check the validity with help of the time tag

8.3.5 PICOM attributes to be covered at configuration time only

- Value for transmission (see above): test or default value if applicable
- Attributes for transmission (see above)
- Accuracy: classes or values
- Tag information: if time tagged or not (most data will be time tagged for validation)
- Type: analog, binary, file, etc.
- Kind: alarm, event, status, command, etc.
- Importance: high, normal, low
- Data integrity: the importance of the transmitted information for checks and re-transmissions (details formulated as requirements, see 11.4.2)

8.3.6 PICOM attributes to be used for data flow calculations only

- Value for transmission/configuration (see above): test or default value if applicable
- Attributes for transmission/configuration (see above)
- Format: value type of the signal: I, UI, R, B, BS, BCD, etc.
- Length: the length: l bit, j byte, k word
- State of operation: reference to scenarios

Format and length are a matter of implementation and not a requirement. But for data flow calculations, assumptions about these two attributes have to be made or taken from the applied implementation.

8.4 Logical node description

8.4.1 The logical node concept

To set up a data model for the data to be exchanged per function, the data at the source shall be defined in the standard.

The logical node description – listed later in the body of this part – provides the following information:

- grouping according to their most common application area,
- short textual description of the functionality,
- IEEE device function number if applicable (for protection and some protection related logical nodes only),
- IEC graphical or alphanumeric symbol if applicable,
- abbreviation/acronym used within the documents of IEC 61850,
- relation between functions and logical nodes in tables and in the function description (see Annex F).

8.4.2 Logical nodes and logical connections

To facilitate fulfilling all the requirements stated above, especially the interoperability and both the arbitrary distribution and allocation of application functions, the data of all these functions shall be grouped in objects with a high level semantic meaning. The Logical Node concept groups for the object oriented approach the data in function related objects called Logical Nodes (LN). Any Logical Node resides in one physical device (IEDs). Depending on the functionality of the IED, a large number of Logical Nodes may be hosted by one IED.

The granularity of data or in how many Logical Nodes the data are distributed depends on the granularity of functions which may be implemented stand alone and re-used for other IEDs. The Logical Nodes may be seen as containers of the data provided by a dedicated function for exchange (communication). The Name of the Logical Node is then the label attached to this container telling to what function the data belong. Logical nodes related to primary equipment are not the primary equipment itself but data images in the secondary system to be needed for performing the application functions and the data exchange in the power utility automation system.

There are some data to be communicated which do not refer to any application function but to the physical device (IED) itself like nameplate information or the result of device self-supervision. Therefore, a logical node “physical device” is needed named LPHD as seen later. There may be also common data (mostly administrative ones) for all functions respectively LNs in a device which may be contained in a logical node LLN0.

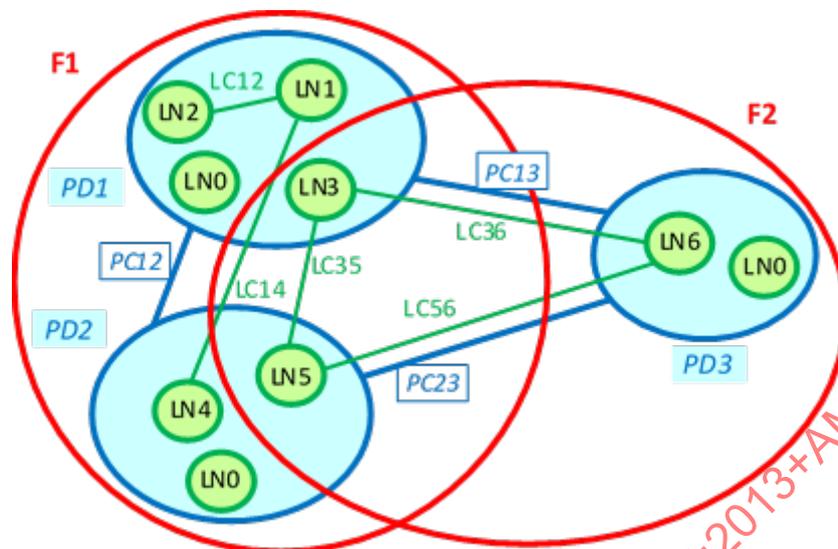
This naming of LNs is given here only to understand the Figures below. The names of the Logical Nodes shall be mnemonic regarding to the application functions allocated.

The Logical Nodes representing the boundary of the automation system with the external equipment like switchgear shall be able to provide also data from the external non-electronic equipment like the name plate of a switchgear component which is different from the name plate of the corresponding IED. The same is valid for health information from the external equipment if available.

The LNs are linked by logical connections (LC) for a dedicated exchange of data in between. Therefore, the standard shall define the communication between these LNs. This approach is shown in Figure 3. The logical nodes (LN) are both allocated to functions (F) and physical devices (PD). The logical nodes are linked by logical connections (LC), the devices by physical connections (PC). Any logical node is part of a physical device; any logical connection is part of a physical connection. The logical node “physical device” dedicated for any physical device is displayed as LPHD and the common data of all LNs in a logical device are in LLN0.

Since it is impossible to define all functions for today and tomorrow and any kind of distribution and interaction, it is very important to specify and standardize the interaction between the logical nodes in a generic way.

This logical node concept shall be used by the IEC 61850-5. The modelling details are found in the parts 7-x of the series (IEC 61850-7-x).



IEC 2381/12

Figure 3 – The logical node and link concept (explanation see text)

8.4.3 Examples for decomposition of common functions into logical nodes

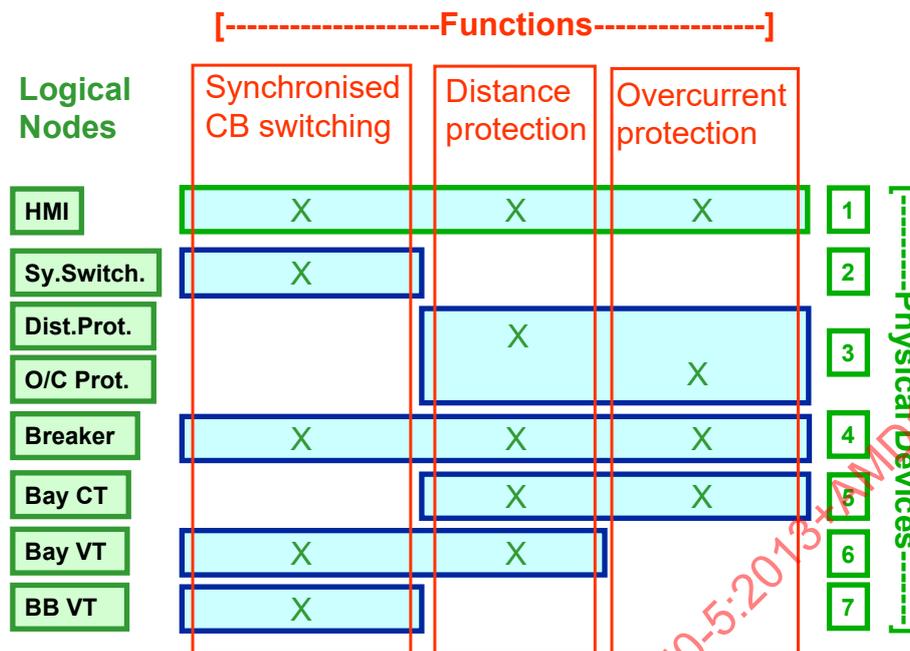
In Figure 4, examples of common application functions of the domain substation are given

- synchronized circuit breaker switching,
- distance protection,
- overcurrent protection.

The functions are decomposed into logical nodes listed in the figure; the allocated physical devices (IEDs) are described by numbers

- 1) station computer,
- 2) synchronized switching (point on wave switching) device,
- 3) distance protection unit with integrated overcurrent function,
- 4) bay control unit,
- 5) current instrument transformer,
- 6) voltage instrument transformer,
- 7) busbar voltage instrument transformer.

The logical node “physical device” (LPHD) as contained in any physical device is not shown.



IEC 2382/12

Figure 4 – Examples of the application of the logical node concept (explanation see text)

8.5 List of logical nodes

8.5.1 Logical Node allocation and distributed application functions

Most of the functions may be represented in minimum by three logical nodes, i.e. the LN with the data of the core application function itself, the LN representing the process interface and the LN representing the HMI (Human-Machine Interface meaning the gender neutral human access to the function in the system like by an operator). If there is no process bus, the LNs of the remote process interface are allocated to another physical device (in the example shown in Figure 5 the physical “Protection device”). If more than one protection function is hosted by the protection device, their trips (operates) have to be combined to a common trip by the additional LN PTRC (trip conditioning).

To have a modular, object oriented function related data model we shall use the function name (e.g. “protection function”) for its core functionality only. Therefore, the function list given e.g. in the report of CIGRÉ 34.03 is a list of logical nodes according to definitions in IEC 61850 series. The standardization of application functions in substations or plants itself is not within the scope of IEC 61850-5. But if any of these functions is used the data communicated shall be based on the introduced LN structure. All details needed to model the data in IEDs potentially communicated and the communicated data itself shall be based on the Logical Nodes defined here. The Logical Nodes are standardized with all their data and attributes in Part 7 of the series (IEC 61850-7-x).

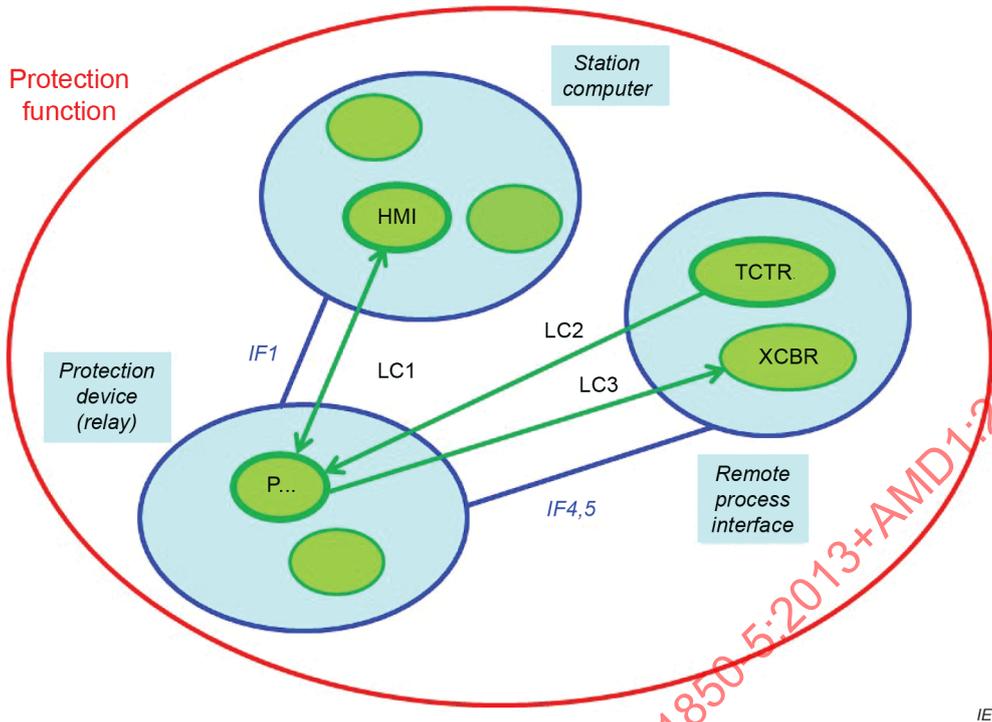


Figure 5 – Protection function consisting of three Logical Nodes

The three Logical Nodes (HMI, P.=protection, XCBR=circuit breaker to be tripped) reside in three physical devices (Station computer, Protection device and Remote process interface). The Logical Node names are the same as introduced in the tables below. If more than one protection function is hosted by the protection device, their trips (operates) have to be combined to a common trip by the additional LN PTRC (trip conditioning).

8.5.2 Explanation of tables

In the tables below the following columns are used. The column headers and Logical Node names are written in bold.

Functionality allocated to LN describes in one term the functionality where the Logical Node is allocated to.

IEC 60617 means the IEC graphical symbols according to IEC 60617 in the alphanumeric representation if available.

IEEE C37.2 means device function numbers and contact designations used in IEEE Std C37.2-2008. Note that the reference to the IEEE device number means not the related devices but its **core functionality only** (see definition of LN and Figure 5) in the context of this standard. Because of their device related definition there is not always a 1:1 relation to the function related definition of Logical Nodes. Allocations of contact designations can also not be made to contact designations. A result, therefore exist not Logical Nodes for all IEEE numbers.

Description or comments display the slightly modified description of the IEEE device number if applicable or/and other descriptive text.

LN function means abbreviations/acronyms as defined in IEC 61850-5 with the systematic syntax used in IEC 61850-7-4 focused on functional requirements.

LN class means the abbreviations/acronyms as defined in IEC 61850-7-4 to reach consistency, but the order has to follow the tables in part 5.

LN class naming displays the short name of the LN class from IEC 61850-5

8.5.3 Defining and modelling of protection functions

In Table 8 the Logical Nodes for the requested protection functions are listed with related definitions and references.

Table 8 – Logical Nodes for protection functions

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
Transient earth fault protection			This LN shall be used to represent the transient earth fault protection function. This type of fault happens if there is a fault to ground (isolation breakdown) in compensated networks. The fault disappears very fast since there is not sufficient current to feed it. No trip happens but the fault direction/location has to be detected to repair the faulted part. At least the degradation of the impacted line/cable is reported.	PTEF	PTEF	Transient earth fault
Sensitive directional earth fault		(37) (67N)	This LN shall be used to represent the directional earth fault protection function in compensated and isolated networks. The use of "operate" is optional and depends both on protection philosophy and on instrument transformer capabilities (see Annex I). For compensated networks, this function is often called watt-metric directional earth fault protection. The very high accuracy needed for fault current measurement in compensated networks may require phase angle compensation. This shall be realized by the related LN TCTR with correction data for the current transformer. NOTE In the comparison table provided in IEEE C37.2-2008 PSDE has no IEEE device number associated.	PSDE	PSDE	Sensitive directional earth fault
Thyristor protection			This LN shall be used to represent a thyristor (valve) protection function in a power plant. This function will typically be included in the excitation system.	PTHF	PTHF	Thyristor protection
Over speed protection	$\omega >$	12	This LN shall be used to represent a protection function that operates on machine overspeed.	POVS		
Zero speed and under speed protection	$\omega <$	14	This LN shall be used to represent a protection function that operates when the speed of a machine falls below a predetermined value.	PZSU	PZSU	Zero speed or underspeed

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
Distance protection	Z<	21	<p>This LN shall be used to represent a protection function that operates when the circuit admittance, impedance, or reactance increases or decreases beyond a predetermined value.</p> <p>The change of the impedance seen by PDIS is caused by a fault. The impedance characteristic is a closed line set in the complex impedance plane. – The reach of the distance protection is normally split into different zones (e.g. 1...4 forward and 1 backward) represented by dedicated characteristics. To combine the different PDIS zones a protection scheme represented by the LN PSCH is needed.</p>	PDIS	PDIS	Distance protection
					PSCH	Protection Scheme
Volt per Hz protection		24	<p>This LN shall be used to represent a protection function that operates when the ratio of voltage to frequency exceeds a preset value. The function may have an instantaneous or a time characteristic.</p> <p>A function that operates when the ratio of voltage to frequency is above a preset value or is below a different preset value. The function may have any combination of instantaneous or time-delayed characteristics.</p>	VVPH	VVPH	Volts per Hz
Over temperature protection	g>	26	<p>This LN shall be used to represent a protection function that operates when the temperature of the protected apparatus (other than the load-carrying windings of machines and transformers as covered by device function number 49), or that of a liquid or other medium, exceeds a predetermined value; or when the temperature of the protected apparatus or that of a liquid or other medium exceeds a predetermined value or decreases below a predetermined value.</p>	PTTR	PTTR	Thermal overload
(Time) Undervoltage protection	U<	27	<p>This LN shall be used to represent a protection function that operates when its input voltage is less than a predetermined value.</p>	PTUV	PTUV	Undervoltage
DC Undervoltage protection	U<	27DC	See above PTUV/27	PTUV	PTUV	Undervoltage
Directional power /reverse power protection	→ P >	32	<p>This LN shall be used to represent a protection function that operates on a predetermined value of power flow in a given direction, such as reverse power flow resulting from the motoring of a generator upon loss of its prime mover.</p>	PDPR	PDOP	Directional over power
					PDUP	Directional under power
Undercurrent/ underpower protection	P<	37	<p>This LN shall be used to represent a protection function that operates when the current decreases below a predetermined value.</p> <p>This LN shall be used to represent a protection function that operates when the power flow decreases below a predetermined value.</p>	PUCP	PTUC	Under current
					PDUP	Directional under power

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
DC Undercurrent/ underpower protection	$P <$	37DC	See above PUCP/37	PDUCP	PTUC	Under current
					PDUP	Directional under power
Loss of field/ Underexcitation protection		40	This LN shall be used to represent a protection function that operates upon a given or abnormally high or low value or failure of machine field current, or on an excessive value of the reactive component of armature current in an AC machine indicating abnormally high or low field excitation. Underexcitation results in under power.	PUEX	PDUP	Directional under power
					PDIS	(Distance) Impedance
Reverse phase or phase balance current protection, Negative sequence current relay	$I_2 >$	46	This LN shall be used to represent a protection function in a polyphase circuit that operates when the polyphase currents are of reverse-phase sequence, or when the polyphase currents are unbalanced, or when the negative phase-sequence current exceeds a preset value.	PPBR	PTOC	Time overcurrent
Phase sequence or phase-balance voltage protection, Negative sequence voltage relay	$U_2 >$	47	This LN shall be used to represent a protection function in a polyphase circuit that operates upon a predetermined value of polyphase voltage in the desired phase sequence when the polyphase voltages are unbalanced, or when the negative phase-sequence voltage exceeds a preset value.	PPBV	PTOV	Overvoltage protection
Motor start-up protection		48, 49, 51LR66	(48) This LN shall be used to represent a protection function that returns the equipment to the normal or off position and locks it out if the normal starting, operating, or stopping sequence is not properly completed within a predetermined time. (49) See below (PTTR/49) (51LR) See below (PTOC/51) (66) See below (----/66) This protection function prevents any overload of the motor	PMSU	PMRI	Motor restart inhibition
					PMSS	Motor starting time supervision
Thermal overload protection	$\theta >$	49	This LN shall be used to represent a protection function that operates when the temperature of a machine armature winding or other load-carrying winding or element of a machine or power transformer exceeds a predetermined value.	PTTR	PTTR	Thermal overload
Rotor thermal overload protection		49R	See above (49)	PROL	PTTR	Thermal overload
Rotor protection			This LN shall be used to represent a rotor interturn short-circuit protection function based on the 6th harmonic	PROT	PRTR	6 th harmonic overcurrent as defined in the description field
					PTTR	Thermal overload

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
		49R 64R (40) 50 51	(300 Hz). This protection is normally included in the excitation system. (49) See above (PTTR/49) (64) See below (PHIZ/64). (40) See above (PUEX/40) (50) See below (PIOC/50) (51) See below (PTOC/51)		PTOC PHIZ PDUP PDIS	Time overcurrent Ground detector Directional under power Distance (impedance)
Stator thermal overload protection		49S	See above (49)	PSOL	PTTR	Thermal overload
Instantaneous overcurrent or rate of rise protection	$I >>$	50	This LN shall be used to represent a protection function that operates with no intentional time delay when the current exceeds a preset value. The suffix TD should be used (e.g., 50TD) to describe a definite time overcurrent function. Use 50BF for a current monitored breaker failure function.	PIOC	PIOC	Instantaneous overcurrent
AC time overcurrent protection	$I >, t$	50TD 51	This LN shall be used to represent a protection function that operates when the AC input current exceeds a predetermined value, and in which the input current and operating time are inversely related through a substantial portion of the performance range.	PTOC	PTOC	Time overcurrent
Voltage controlled/dependent time overcurrent protection		51V 50/27	See above (PTOC/51) with voltage control/dependency.	PVOC	PVOC	Voltage controlled time overcurrent
Power factor protection	$\cos \varphi >$ $\cos \varphi <$	55	This LN shall be used to represent a protection function that operates when the power factor in an AC circuit rises above or falls below a predetermined value	PPFR	POPF PUPF	Over power factor Under power factor
(Time) Overvoltage protection	$U >$	59	This LN shall be used to represent a protection function that operates when its input voltage exceeds a predetermined value.	PTOV	PTOV	Overvoltage
DC-overvoltage protection		59DC	See above (PTOV/59)	PDOV	PTOV	Overvoltage
Voltage or current balance protection		60	This LN shall be used to represent a protection function that operates on a given difference in voltage, or current input or output, of two circuits.	PVCB	PTOV PTOC	Overvoltage Time overcurrent
Earth fault protection, Ground detection	$I_E >$	64	This LN shall be used to represent a protection function that operates upon the insulation failure of a machine or other apparatus to ground. NOTE This function is not applied to a device connected in the secondary circuit of current transformers in a normally grounded power system where other overcurrent device numbers with the suffix G or N should be used; for example, 51 N for an AC time overcurrent function operating at a desired value of AC overcurrent flowing in a predetermined direction of the secondary neutral of the current transformers.	PHIZ	PTOC PHIZ	Time overcurrent Ground detector

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
Rotor earth fault protection		64R	See above (PHIZ/64)	PREF	PTOC	Time overcurrent
					PHIZ	Ground detector
Stator earth fault protection		64S	See above (PHIZ/64)	PSEF	PTOC	Time overcurrent
					PHIZ	Ground detector
Interturn fault protection		64W	See above (PHIZ/64)	PITF	PTOC	Time overcurrent
Notching or jogging function		66	A function that operates only a specified number of operations of a given device or piece of equipment, or a specified number of successive operations within a given time of each other. It is also a device that functions to energize a circuit periodically or for fractions of specified time intervals, or that is used to permit intermittent acceleration or jogging of a machine at low speeds for mechanical positioning.	Not modelled as LN To be used only for explanation of the device number 66 as cited e.g. in the description of the motor start-up protection function (PMSU)		
AC directional overcurrent protection	$\vec{I} >$	67	This LN shall be used to represent a protection function that operates at a desired value of AC overcurrent flowing in a predetermined direction.	PDOC	PTOC	Time overcurrent
Directional protection		67B	The operate decision is based on an agreement of the fault direction signals from all directional fault sensors (for example directional relays) surrounding the fault. The directional comparison for lines is made with PSCH combined with PDIS. NOTE: In the comparison table provided in IEEE C37.2-2008 PDIR has the IEEE device number 67B associated.	PDIR	PDIR	Direction comparison
Directional earth fault protection	$\vec{I}_E >$	67N	See above (PDOC/67)	PDEF	PTOC	Time overcurrent
DC time overcurrent protection		76	This LN shall be used to represent a protection function that operates when the current in a DC circuit exceeds a given value.	PDCO	PTOC	Time overcurrent
Phase angle or out-of-step protection	$\varphi >$	78	This LN shall be used to represent a protection function that operates at a predetermined phase angle between two voltages, between two currents, or between a voltage and a current.	PPAM	PPAM	Phase angle measuring
Frequency protection		81 7	This LN shall be used to represent a protection function that responds to the frequency of an electrical quantity, operating when the frequency or rate of change of frequency exceeds or is less than a predetermined value.	PFRQ	PTOF	Over-frequency
					PTUF	Under-frequency
					PFRC	Rate of change of frequency
Differential protection		87	This LN shall be used to represent a protection function that operates on a percentage, phase angle, or other quantitative difference of two or more currents or other electrical quantities.	PDIF	PDIF	Differential
					87B	PBDF

Functionality allocated to LN	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
Busbar protection ^a			See above (PDIF/87) – The complexity of the busbar node with changing topology up to a split into two or more nodes needs special means like a dynamic busbar image. It has to be considered that at least a second busbar protection algorithm exists which is based on the direction comparison of the fault direction in all feeders.		PDIR	Direction comparison
Generator differential protection ^b		87G	See above (PDIF/87)	PGDF	PDIF	Differential
Differential line protection		87L	See above (PDIF/87)	PLDF	PDIF	Differential
Motor differential protection ^b		87M	See above (PDIF/87)	PMDF	PDIF	Differential
Restricted earth fault protection		87N	See above (PDIF/87)	PNDF	PDIF	Differential
Phase comparison protection		87P	See above (PDIF/87)	PPDF	PDIF	Differential
Differential transformer protection		87T	See above (PDIF/87) – Special for transformers are inrush currents with dedicated harmonics which request the use of the harmonic restraint function (PHAR).	PTDF	PDIF	Differential
Voltage differential protection		87V	See above (PDIF/87 ... for other electrical quantities: voltage). A function that works as a capacitor unbalance function to detect internal element faults. This function is applied if the capacitor offers a voltage tap to measure the 3-phase voltage within the capacitor installation. By also measuring the 3-phase bus voltage, a differential voltage is calculated.	PTDV	PTDV	Voltage differential
Harmonic restraint			This LN shall be used to represent the harmonic restraint data object especially for transformer differential protection function (PTDF). There may be multiple instantiations with different settings, especially with different data object HaRst.	PHAR	PHAR	Harmonic restraint
Trip conditioning			This LN shall be used to represent a function which is used to connect the “trip/operate” outputs of one or more protection functions to a common “trip” to be transmitted to XCBR similar like a conventional trip matrix. In addition, or alternatively, any combination of “operate” outputs of the protection functions may be combined to a new “operate” of PTRC (equivalent to trip matrix). In addition specific requirements for the trip pulse may be defined also.	PTRC	PTRC	Trip conditioning
Switch on to fault protection		Prefix SOTF	This LN shall be used to represent a protection function intended to trip the circuit breaker when the breaker is closed onto a fault. Different methods to detect the switch-on-to-fault situation may be applied.	PSOF	PSOF	Switch on to fault
<p>^a The decentralized busbar protection consists in addition to the central decision making instance of the PBDF also of an instance per bay with appropriate pre-processing and trip output.</p> <p>^b Both the Motor Protection and the Generator Protection are no single LNs but a set of related LNs. The most important component is the differential LN mentioned here.</p>						

All main protection LNs have the following communication structure indicated in Figure 6.

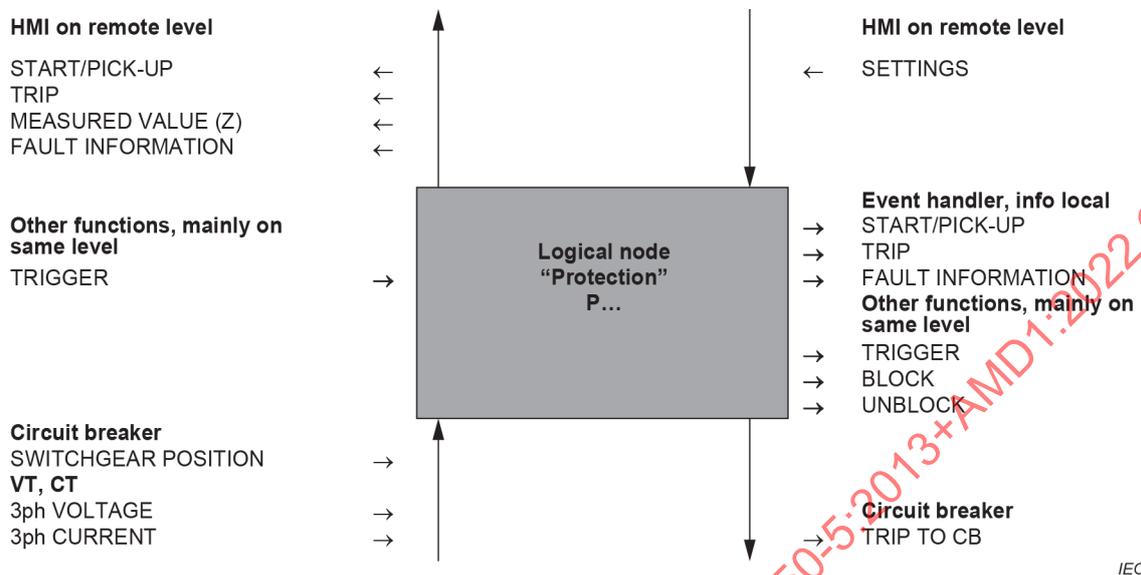


Figure 6 – The basic communication links of a logical node of main protection type

Data from and to the process (switchgear XCBR, CT TCTR, VT TVTR) referring to interface 4 and/or 5.

Data to logical nodes on the same level referring to interface 3 and/or 8.

Data to logical nodes like IHMI on the station level referring to interface 1.

8.5.4 Defining and modelling of protection related functions

In Table 9 the Logical Nodes for the requested protection related functions are listed with definitions and references.

Table 9 – Logical Nodes for protection related functions

Logical node	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN Class naming
Disturbance recording (bay/process level: acquisition)			This LN shall be used to represent an acquisition function for voltage and current waveforms from the power process (CTs, VTs), and for position indications of binary inputs. Also calculated values like power and calculated binary signals may be recorded by this function if applicable.	RDRE	RDRE	Disturbance recorder function
					RADR	Disturbance recorder channel analogue
					RBDR	Disturbance recorder channel binary
Disturbance recording (station level: evaluation)			This LN shall be used to represent the disturbance recording evaluation function which is needed as a server for HMI on station level (or even on a higher level) or for calculation of combined disturbance records.	RDRS	RDRE	Disturbance recorder function
					RADR	Disturbance recorder channel analogue

Logical node	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN Class naming
					RBDR	Disturbance recorder channel binary
Automatic reclosing		79	<p>This LN shall be used to represent a function that controls the automatic reclosing and locking out of an AC circuit breaker.</p> <p>After any successful protection trip the automatic reclosing function tries up to a preset number of times to reclose the open breaker again with different time delays assuming a transient fault.</p>	RREC	RREC	Autoreclosing
Breaker failure		50BF	<p>This LN shall be used to represent a function that operates after an unsuccessful trip command if the current still exceeds a pre-set value. The suffix TD should be used (e.g., 50TD) to describe a definite time overcurrent function. Use 50BF for a current monitoring breaker failure function.</p> <p>In case of a breaker failure the fault is not cleared. Therefore, neighbouring breakers have to be tripped. This means the use of topology information.</p>	RBRF	RBRF	Breaker failure
Carrier or pilot wire protection ^a		85	This LN shall be used to represent a function based on the exchange of signals from the protection units at the line ends, in order to operate, restrain or modify the protection function.	RCPW	PSCH	Protection scheme
Fault locator			This LN shall be used to represent a function which calculates the location of the fault out of the protection information (e.g. fault impedance).	RFLO	RFLO	Fault locator
Synchrocheck/ Synchronizing or Synchronism-Check		25	<p>This LN shall be used to represent a synchronizing function that produces a release for a closing command of a circuit breaker between two circuits whose voltages are within prescribed limits of magnitude, phase angle, and frequency. It may or may not include voltage or speed control. A synchronism check function permits the paralleling of two circuits that are within prescribed (usually wider) limits of voltage magnitude, phase angle, and frequency.</p> <p>To avoid stress for the switching device and the network, closing of circuit breaker is allowed by the synchrocheck only, if the differences of voltage, frequency and phase angle are within certain limits.</p>	RSYN	RSYN	Synchronism-check
Power swing blocking		78	This LN shall be used to represent a function that blocks other functions at a predetermined phase angle between two voltages, between two currents, or between a voltage and a current.	RPSB	RPSB	Power swing detection/blocking

Logical node	IEC 60617	IEEE C37.2	Description or comments	LN function	LN class	LN Class naming
Directional element			This LN shall be used to represent all directional data objects in a dedicated LN used for directional relay settings. The protection function itself is modelled by the dedicated protection LN. LN RDIR may be used with functions 21, 32 or 67 according to IEEE device function number designation	RDIR	RDIR	Directional element
Differential measurements			This LN shall be used to represent a function which provides locally calculated process values (phasors calculated out of samples or the samples itself) representing the local current values which are sent to the remote end and which are used for the local differential protection function (PDIF). Therefore, the LN RMXU together with LN PDIF models the core functionality of the differential protection function number 87 according to the IEEE (C37.2) designation. In addition, the LNs RMXU on both sides of the line represent also the function to synchronize the samples. Therefore also the samples sent from the local TCTR to the local PDIF are routed through the function represented by RMXU. The local RMXU is therefore the source of synchronized samples or phasors from the local current sensor which sends its information to the local PDIF and to all required remote PDIF nodes.	RMXU	RMXU	Differential measurements
<p>^a De facto a communication device which establishes an analogue connection between two relays (e.g. distance or differential protection) in two adjacent substations. If this connection is not serial it is outside the scope of IEC 61850-5, if it is serial it belongs to interface 2. The involved PICOMs refer all to the related protection LNs, e.g. PLDF and PDIS.</p>						

8.5.5 Defining and modelling control functions

In Table 10 the Logical Nodes for the requested control functions are listed with related definitions and references.

Table 10 – Logical Nodes for control functions

Logical node	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
Alarm handling (creation of group alarms and group events)		<p>This LN shall be used to represent a function for the alarm handling. There is no difference between alarms and events, if a time tag is added to any data transmitted.</p> <p>If several events or alarms have to be combined to group alarms, a separate, configurable function is needed. The related LN may be used to calculate new data out of individual data from different logical nodes.</p> <p>Remote acknowledgement with different priority and authority shall be possible.</p> <p>The definition and handling of alarms is an engineering issue.</p>	CALH	CALH	Alarm handling
Switch controller controls any		This LN shall be used to represent a function to control all switchgear operations from the operator and from related automatics. It checks the	CSWI	CSWI	Switch controller

Logical node	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
switchgear, i.e. the devices described by XCBR and XSWI		authorization of the commands. It supervises the command execution and gives an alarm in case if improper ending of the command. It checks for releases from interlocking, synchrocheck, autoreclosure, etc. if applicable.			
Point-on-wave breaker controller controls a circuit breaker with point-on-wave switching capability		This LN shall be used to represent a function to control a circuit breaker with point-on-wave switching capability. It provides all the functionality to close or open a circuit breaker at a certain instant of time, i.e. at a certain point of the voltage or current wave. It is started by a request either from switchgear controller or from recloser. Based on the specific load that is being switched on or off, the point-on-wave application will try to close or open the contacts exactly at a specific time. For these calculations, the conditions in all three phases are considered. If switching per phase is applicable, three execution times are provided.	CPOW	CPOW	Point-on-wave switching
Interlocking function at station and/or bay level	3	This LN shall be used to represent a function to prevent switchgear maloperation. Interlocking may be totally centralized or totally decentralized. Since the interlocking rules are basically the same on bay and station level and based on all related position indications the different interlocking LNs may be seen as instances of the same LN class Interlocking (CILO). 1) Interlocking of switchgear at bay level: All interlocking rules referring to a bay are included in this LN. Releases or blockings of requested commands are issued. In case of status changes affecting interlocking blocking commands are issued. 2) Interlocking of switchgear at station level: All interlocking rules referring to the station are included in this LN. Releases or blockings of requested commands are issued. Information with the LN bay interlocking is exchanged.	CILO	CILO	Interlocking
Cooling group control		This LN shall be used to represent a function to control the cooling equipment. One LN instance per cooling group shall be used.	CCGR	CCGR	Cooling group control
Synchronizer control		This LN shall be used to represent a function to control the synchronizing conditions i.e. voltage, frequency and phase.	CSYN	CSYN	Synchronizer controller

8.5.6 Definition and modelling Interfaces, logging and archiving functions

In Table 11 the Logical Nodes for the requested interface, logging and archiving functions are listed with related definitions and references.

Table 11 – Logical Nodes for interface functions

Logical Node	Description or Comments	LN Function	LN Class	LN Class naming
Operator interface – control local at bay level – control at station level	This LN shall be used to represent a function to interface the system to the operator, e.g. 1) Front-panel operator interface at bay level to be used for configuration, etc. and local control 2) Local operator interface at station level to be used as work place for the station operator. The role of the different HMI is not fixed for most of the functions and is defined in the engineering phase.	IHMI	IHMI	Human machine interface

Logical Node	Description or Comments	LN Function	LN Class	LN Class naming
Hand interface – control local at bay level – control at station level	This LN shall be used to represent a generic physical human-machine interface. e.g. a push-button or another physical device that can be used as input to the controller (see IEEE 1: Master element in the initiation device)	IHND	IHND	Hand interface
Remote control interface, Telecontrol interface	This LN shall be used to represent a telecontrol interface to be used for remote control from higher control level. Basically, the TCI will communicate the same data as the station level HMI or a subset of these data. The role of the different interfaces is not fixed for most of the functions and defined in the engineering phase.	ITCI	ITCI	Telecontrol interface
Remote monitoring interface, Telemonitoring interface	This LN shall be used to represent a telemonitoring interface to be used for remote monitoring and maintenance using a subset of all information available in the substation but allows no control. The role of the different interfaces is not fixed for most of the functions and defined in the engineering phase.	ITMI	ITMI	Telemonitoring interface
Remote protection interface, Teleprotection interface	This LN shall be used to represent a teleprotection interface to be used for remote protection, i.e. for line protection where exchange of data between the two substations on both sides of the line is needed. It is applicable also for multi-end lines. The role of the different interfaces is not fixed for most of the functions and defined in the engineering phase.	ITPI	ITPI	Teleprotection interface
Logging	This LN shall be used to represent a function which allows logging not only changed data itself but also any related data being defined in the settings of LN GLOG. The logging may be started by data change or by operator request.	GLOG	GLOG	Generic log
Archiving	This LN shall be used to represent a function which is used as sink and source for archiving long-term historical data, normally used globally for the complete substation on station level.	IARC	IARC	Archiving
Safety alarm function	This LN shall be used to represent an alarm push-button or any other device that is used to set an alarm in case of danger to persons or property.	ISAF	ISAF	Safety alarm function
In case of seamless communication some of the remote interfaces may exist only virtual. Depending on the outside world they may be proxy servers or any kind of gateways also.				

8.5.7 Defining and modelling automatic process control functions

In Table 12 the Logical Nodes for the requested automatic process control functions are listed with related definitions and references.

Table 12 – Logical Nodes for automatic process control functions

Logical node	Description or comments	LN function	LN class	LN class naming
Automatic tap changer control	This LN shall be used to represent an automatics function to maintain the voltage of a busbar within a specific range using tap changers. This node operates the tap changer automatically according to given setpoints or by direct operator commands (manual mode).	ATCC	ATCC	Automatic tap changer controller

Logical node	Description or comments	LN function	LN class	LN class naming
Automatic voltage control	This LN shall be used to represent an automatics function to control the voltage of a busbar within a specific range independent of the means used	AVCO	AVCO	Voltage control
Reactive control	This LN shall be used to represent an automatics function to control the reactive power flow in a substation within a specific range using capacitors and/or reactances.	ARCO	ARCO	Reactive power control
Resistor control	This LN shall be used to represent an automatics function to control the resistor between neutral (star point) and ground. This Logical Node is used for the automatic wattmetric increase with thermal supervision.	ARIS	ARIS	Resistor control
Earth fault neutralizer control (control of Petersen coil)	This LN shall be used to represent an automatics function for grounding the transformer star point which influences the short circuit in a network. This grounding is dynamically determined by a Petersen coil (LN YENF) controlled by ENFC.	ANCR	ANCR	Neutral current regulator
Zero-voltage tripping	This LN shall be used to represent an automatics function to automatically switched off a line without voltage longer than a predefined time which is connected to a substation.	AZVT	PTUV	Under-voltage
Generic automatic process control Means a generic, programmable LN for sequences, unknown functions, etc. Also member of the Generic LN group <i>IEEE C73.2 reference:</i> <i>LGC—scheme logic</i>	This LN shall be used to represent an automatics function without standardized semantics. This is a generic node for all undefined automation or control functions at the same control level as the LNs of the A, P or the C group. These functions may be implemented using standard PLC languages. The data access and exchange is completely the same as for all other LNs. Examples are 1) Load shedding to shed in overload situations in a very selective way parts of the consumers to avoid the collapse of the network. This load-shedding function may not be restricted on frequency criteria only like PFRQ but include actual power balance etc. 2) Infeed transfer switching to detect a weak infeed e.g. to an industrial plant and to switch over to another feeding line. Boundary conditions have to be considered like the synchronization of motors if applicable 3) Transformer switch-over to switchover in case of overload to another transformer or to distribute the load more evenly to all related transformers on the busbar. 4) Busbar switch-over To start by one single operator command a sequence of switching operations resulting in a busbar change of a dedicated line or transformer if applicable 5) Automatic clearing & voltage restoration to trip all circuits connected to a busbar after detecting zero-voltage conditions (black-out) and to close the same breakers following certain pre-defined rules.	GAPC	GAPC	Generic automatic process control

8.5.8 Defining and modelling functional block functions

In Table 13 the Logical Nodes for the requested functional block functions are listed with related definitions and references.

Table 13 – Logical Nodes for functional block functions

Logical node	Description or comments	LN function	LN class	LN class naming
Counter	This LN shall be used to represent a function which is used to count incoming pulses not related to the electrical network i.e. not for energy counting.	FCNT	FCNT	Counter
Curve shape description	This LN shall be used to represent a function which comprises the data object classes that model the curve shaped output values. The values can be dynamically modified online. The curves entered in the table can be based on statistics obtained following a series of index tests. The allocated function is used to adapt an incoming value to a specified curve function. For example, it may adjust 2-dimensionally non-linear transmitters to the correct physical values or, by instantiation, for 3-dimensional surface mapping.	FCSD	FCSD	Curve shape description
Generic filter	This LN shall be used to represent a function which is used to filter an incoming value with the following transfer function $G(s) = K \frac{1 + sT_1}{1 + sT_3 + sT_2^2}$	FFIL	FFIL	Generic filter
Control function output limitation	This LN shall be used to represent a function which is used to set temporary or permanent operational limits to create an output signal of a control function. The FLIM logical node should not be used to replace FXOT or FXUT.	FLIM	FLIM	Control function output limitation
PID regulator	This LN shall be used to represent a function which comprises the data that represent proportional, integral and derivative information for a PID controller.	FPID	FPID	PID regulator
Ramp function	This LN shall be used to represent a function which is used to provide output data in form of a generic ramp if for an analogue set-point a continuous change is needed.	FRMP	FRMP	Ramp function
Schedule controller	This LN shall be used to represent a function which is used to control the assignment of schedules to the scheduled entities. LN FSCH manages the selection of different running schedules according to highest priority.	FSCC	FSCC	
Schedule	This LN shall be used to represent a function which is used to set and run a schedule. The LN FSCH shall be modelled together with a schedule controller LN FSCC.	FSCH	FSCH	
Set-point control function	This LN shall be used to represent a function which is used to provide the common set-point control characteristics found in all controller or regulator type logical nodes.	FSPT	FSPT	Set-point control function
Action at over threshold	This LN shall be used to represent a function which is used to set a high-level threshold value if needed in control sequences. If a second level is necessary, a second instance may be modelled. FXOT may be typically used whenever a protection, control or alarm function is based on other physical measurements than primary electrical data.	FXOT	FXOT	Action at over threshold
Action at under threshold	This LN shall be used to represent a function which is used to Logical node FXUT is used to set a low-level threshold value if needed in control sequences. If a second level is necessary, a second instance may be modelled. FXUT may be typically used whenever a protection, control or alarm function is based on other physical measurements than primary electric data.	FXUT	FXUT	Action at under threshold

8.5.9 Defining and modelling metering and measurement functions

In Table 14 the Logical Nodes for the requested metering and measurement functions are listed with related definitions and references.

Table 14 – Logical Nodes for metering and measurement functions

Logical node	Description or comments	LN function	LN class	LN class naming
Environmental measurements	This LN shall be used to represent a function which is used to model the characteristics of environmental conditions such as emissions, temperatures and lake levels and other key environmental data objects. In addition, many of the environmental sensors may be located remotely from the instantiated logical node. This logical node may therefore represent a collection of environmental information from many sources.	MENV	MENV	Environmental information
			MMET	Meteorological information
			MHYD	Hydrological information
Flicker measurements	This LN shall be used to represent a function which is used to calculate flicker inducing voltage fluctuations according to IEC 61000-4-15. The main use is for operative applications.	MFLK	MFLK	Flicker measurement
Flow measurement	This LN shall be used to represent a function which is used to measure flows of liquid or gas materials (air, water, steam, oil, etc.) used for heating, cooling, lubrication, and other auxiliary functions.	MFLW	MFLW	Flow measurement
Harmonics and interharmonics – e.g. for power quality purpose	This LN shall be used to represent a function which is used to calculate harmonics, interharmonics and related values in the power system mainly used for determining power quality.	MHAI	MHAI	Harmonics or interharmonics
			MHAN	Non-phase-related harmonics or interharmonics
Heat measurement	This LN shall be used to represent a function which is used to measure the heat of the medium used for heating and cooling (air, water, steam, etc.).	MHET	MHET	Heat measurement
Metering – for commercial purpose <i>IEEE C37.2 Group reference MET Substation Metering</i>	This LN shall be used to represent a function which is used to calculate the integrated values of energy out of the acquired magnitudes of voltages and currents. Metering is normally used for billing and has to provide the requested accuracy. A dedicated instance of this LN may calculate energy values e.g. by collecting pulses from external meters.	MMTR	MMTR	Metering 3 Phase
			MMTN	Metering Single Phase
Measuring – for operative purpose <i>IEEE C37.2 Group reference MET Substation Metering</i>	This LN shall be used to represent a function which is used to calculate measurands like rms values for current and voltage or power flows out of the acquired magnitudes of voltages and currents. These values are normally used for operational purposes like power flow supervision and management, screen displays, state estimation, etc. The requested accuracy for these functions has to be provided. The measuring procedures in the protection devices are part of the dedicated protection algorithm represented by the Logical Nodes Pxyz. Protection algorithms like any function are outside the scope of the communication standard. Therefore, the LN Mxyz shall not be used as input for Pxyz. Fault related data like fault peak value, etc. are always provided by the LNs of type Pxyz and not by LNs of type Mxyz.	MMXU	MMXU	Measurement (3 phase)
			MMXN	Non-phase-related measurement
			MMDC	DC measurement
Sequences and imbalances – e.g. for stability purpose	This LN shall be used to represent a function which is used to calculate the sequence and imbalance values in a three/multi-phase power system.	MSQI	MSQI	Sequence and imbalance

8.5.10 Defining and modelling power quality functions

In Table 15 the Logical Nodes for the requested power quality functions are listed with related definitions and references. *IEEE C37.2 group reference PQM (Power Quality Monitoring)*

Table 15 – Logical Nodes for power quality functions

Logical node	Description or comments	LN function	LN class	LN class naming
Frequency supervision	This LN shall be used to represent a function which is used to supervise the frequency for variations. A frequency variation event is started if the frequency exceeds the settable boundary for the frequency and is finalized as soon as the frequency comes back into the normal range as defined by the boundary. The maximum frequency deviation and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of deviation and event time length). Over and under frequency events may be detected and registered separately. Definition based on IEC 61000-4-30	QFVR	QFVR	Frequency variation
Current supervision	This LN shall be used to represent a function which is used to supervise the rms current value for variations. The current transient event is started if the rms current value exceeds the settable boundary for current and is finalized as soon as the current comes back into the normal range as defined by the boundary. The maximum current transient excess and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of excess and event time length). Definition based on IEC 61000-4-30	QITR	QITR	Current transient
Current unbalance supervision	This LN shall be used to represent a function which is used to supervise the current for balance variations. The current unbalance variation event is started if in a poly-phase circuit the rms phase currents are unbalanced (the negative sequence current exceeds a settable boundary) and is finalized as soon as the negative sequence current comes back into the normal range as defined by the boundary. The maximum current unbalance and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of unbalance and event time length). Definition based on IEC 61000-4-30	QIUB	QIUB	Current unbalance variation
Voltage supervision	This LN shall be used to represent a function which is used to supervise the voltage for variations. The voltage transient event is started if the rms voltage exceeds the settable boundary for voltage and finalized as soon as the voltage comes back into the normal range as defined by the boundary. The maximum voltage transient excess and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of excess and event time length). Definition based on IEC 61000-4-30	QVTR	QVTR	Voltage transient
Voltage unbalance supervision	This LN shall be used to represent a function which is used to supervise the voltage for balance variations. The voltage unbalance variation event is started if in a poly-phase circuit the rms phase voltages are unbalanced (the negative sequence voltage exceeds a settable boundary) and finalized as soon as the negative sequence voltage comes back into the normal range as defined by the boundary. The maximum voltage unbalance and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of unbalance and event time length). Definition based on IEC 61000-4-30	QVUB	QVUB	Voltage unbalance variation

Logical node	Description or comments	LN function	LN class	LN class naming
Voltage variation	This LN shall be used to represent a function which is used to supervise the voltage for variations. The voltage variation event is started if the rms voltage exceeds the settable boundary for the voltage and finalized as soon as the voltage comes back into the normal range as defined by the boundary. The maximum voltage deviation and the length of this event are registered. The occurrences of these events are registered in a histogram (ranges both of deviation and event time length). Definition based on IEC 61000-4-30	QVVR	QVVR	Voltage variation

8.5.11 Defining and modelling physical device functions and common data

In Table 16 the Logical Nodes for the requested physical device functions and common data are listed with related definitions and references.

Table 16 – Logical Nodes for physical device functions and common data

Logical node	Description or comments	LN function	LN class	LN class naming
Physical device data	This LN shall be used to represent a function which is used to model common features of the physical device (IED).	LPHD	LPHD	Physical device information
Logical device data	This LN shall be used to provide data of the logical device independently from all application function related logical nodes (device identification/name plate, messages from device self-supervision, etc.). This LN may be used also for actions common to all related logical nodes (mode setting, settings, etc.) if applicable. This LN does not restrict the dedicated access to any single LN by definition. Possible restrictions are a matter of implementation and engineering.	LLN0	LLN0	Logical node zero
It may be convenient for modelling in IEC 61850-7-4 to introduce more of such nodes e.g. for device substructures but this is not a requirement!				

8.5.12 Defining and modelling of system services

8.5.12.1 System time, supervision and testing

System functions like time synchronization and system supervision are requirements from the Substation automation system and have to be supported by the standard. Depending on the selected stack these support functions maybe provided from a level below the application. The Test generator (GTES) is depending on the function to be tested and, therefore, declared as a generic logical node as listed in Table 17.

In Table 17 the Logical Nodes for the requested time, supervision and testing functions are listed with related definitions and references.

Table 17 – Logical Nodes for time, supervision and testing

Logical node	Description or comments	LN function	LN class	LN class naming
Time master	This LN shall be used to represent a function which is used to provide the time to the system (configuration, setting and synchronization).	STIM	LTIM LTMS	Time management Time master supervision
Physical channel supervision	This LN shall be used to represent a function which is used to model common issues of physical communication channels. It is instantiated for each physical channel or each pair of link level redundant physical channels.	LCCH	LCCH	Physical communication channel supervision
System supervision	This LN shall be used to represent a function which is used to start, collect and process all data for system supervision.	SSYS	n.a.	
Test generator	This LN shall be used to represent a function which is used to perform tests by using process signals but avoiding any impact on the process (blocking of process outputs).	GTES	n.a.	

8.5.12.2 System and device security

In Table 18 the Logical Nodes for the requested system and device security are listed with related definitions and references

Table 18 – Logical Nodes for system and device security

Logical Node	Description or comments	LN function	LN class	LN class naming
General security application	This LN shall be used to represent a function which collects data about security violations	GSAL	GSAL	Generic security application

8.5.13 Definition and modelling of switching devices

The switchgear related logical nodes represent the power system, i.e. the process seen by the substation automation system via the I/Os. Using switchgear related LNs means a dedicated grouping of I/Os predefined according to a physical device like a circuit breaker as listed in Table 19.

Table 19 – Logical Nodes for switching devices

Logical Node	IEEE C37.2	Description or comments	LN function	LN class	LN class naming
The LN "circuit breaker" covers all kind of circuit breakers, i.e. switches able to interrupt short circuits – without point-on-wave switching capability – with point-on-wave switching capability	52	This LN shall be used to represent a circuit breaker which is a device that is used to close and interrupt a power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions. If phase selective operating is required, then one LN instance per phase shall be used.	XCBR	XCBR	Circuit breaker
Fuse		This LN shall be used to represent a fuse which is a one-way/one-time operating equipment with a thermal characteristic for open conditions.	XFUS	XFUS	Fuse
The LN "switch" covers all kind of switching devices not able to switch short circuits – Load breakers – Disconnectors – Earthing switches – High-speed earthing switches	29	This LN shall be used to represent a switch which is a device that is used to disconnect, load-interrupt, isolate or earth a power circuit. If phase selective operating is required, then one LN instance per phase shall be used.	XSWI	XSWI	Circuit switch
These logical nodes represent the mentioned switching devices and related equipment with their entire inputs, outputs and communication relevant behaviour in the substation automation system.					

8.5.14 Definition and modelling of supervision and monitoring functions

In Table 20 the Logical Nodes for the requested supervision and monitoring functions are listed with related definitions and references.

Table 20 – Logical Nodes for supervision and monitoring functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Supervision, monitoring and diagnostics for arcs	This LN shall be used to represent a function which is used to supervise the gas compartments of GIS (Gas Insulated Switchgear) regarding arcs caused by switching or fault.	SARC	SARC	Monitoring and diagnostics for arcs
Circuit breaker supervision	This LN shall be used to represent a function which is used to supervise the operation of a circuit breaker and to provide data about the circuit breaker status and maintenance like the switched current, contact abrasion and increasing time delays indicating ageing. If phase selective supervision is required, then one LN instance per phase shall be used.	SCBR	SCBR	Circuit breaker supervision
Insulation Medium Supervision	This LN shall be used to represent a function which is used to supervise the insulation medium like the gas of GIS (Gas Insulated Switchgear) regarding density, pressure, temperature.	SIMS	SIMG	Insulation medium supervision (gas)
			SIML	Insulation medium supervision (liquid)

Logical Node	Description or comments	LN function	LN class	LN class naming
Tap changer supervision	This LN shall be used to represent a function which is used to supervise a tap changer. It provides data about the operation mechanism status, ageing and maintenance request. Depending on the used technology the data refer to motor drive load, contact abrasion, oil flow, vacuum status, etc.	SLTC	SLTC	Supervision of operating mechanism
Switch drive supervision	This LN shall be used to represent a function which is used to supervise the operation mechanism of switches and provides data about the operation mechanism status, ageing and maintenance request. Today, different technologies for operating mechanisms are available. Operating mechanisms for circuit breakers contain energy storage to provide the required switching energy within a short time. Examples for today's storage medias are springs or compressed gas. To operate the switch, the energy is transferred by means of a mechanical linkage or hydraulics. A charger motor is used to compensate for energy losses due to leakages or to recharge the storage (hydraulics, spring) after a switch operation. The data provided cover the status of the relevant components either by hydraulic or spring system. The data available slightly differ depending on the used technology. This LN can also be used for supervision function of a simple operating mechanism that is directly driven by a motor.	SOPM	SOPM	Supervision of operating mechanism
Supervision, monitoring and diagnostics for partial discharge	This LN shall be used to represent a function which is used to supervise the gas volumes of GIS (Gas Insulated Switchgear) regarding signatures of partial discharges.	SPDC	SPDC	Monitoring and diagnostics for partial discharges
Supervision of objects such as shafts, turbines, generators etc. regarding pressure	This LN shall be used to represent a function which is used to represent various devices that supervise the pressure of major plant objects. It provides alarm and trip / shutdown functions. If more than one sensor (LN TPRS) is connected, then LN SPRS shall be instantiated for each sensor.	SPRS	SPRS	Pressure supervision
Power transformer supervision	This LN shall be used to represent a function which is used to supervise a power transformer. It provides data about the transformer status, ageing (remaining life time) and maintenance request. This LN provides mainly data about the temperatures; other data relevant for the transformer are given e.g. in LN SIML (liquid oil) and SPTR (allocated tap changer).	SPTR	SPTR	Power transformer supervision
Switch supervision	This LN shall be used to represent a function which is used to supervise the operation of a switch (isolator or earthing switch) and provides data about the switch breaker status and maintenance like the contact abrasion and increasing time delays indicating ageing. If phase selective supervision is required, then one LN instance per phase shall be used.	SSWI	SSWI	Circuit switch supervision
Supervision of temperature	This LN shall be used to represent a function which is used to represent various devices that supervise the temperatures of major plant objects. It provides alarm and trip / shutdown functions. If more than one sensor (LN TTMP) is connected, then LN STMP shall be instantiated for each sensor.	STMP	STMP	Temperature supervision
Supervision, monitoring and diagnostics of vibrations	This LN shall be used to represent a function which is used to represent various devices that supervise the vibrations in rotating plant objects such as shafts, turbines, generators etc. It provides alarm and trip / shutdown functions. If more than one sensor (LN TVBR) is connected, then LN SVBR shall be instantiated for each sensor.	SVBR	SVBR	Vibration supervision
These logical nodes represent the mentioned supervision with their entire inputs and communication relevant behaviour in the SA system.				

8.5.15 Definition and modelling of Instrument transformer functions

In Table 21 the Logical Nodes for the requested instrument transformer functions are listed with related definitions and references.

Table 21 – Logical Nodes for instrument transformers functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Current transformer	This LN shall be used to represent a function which is used to model a current transformer. There is one instance per phase.	TCTR	TCTR	Current transformer
Voltage transformer	This LN shall be used to represent a function which is used to model a voltage transformer. There is one instance per phase.	TVTR	TVTR	Voltage transformer
These logical nodes represent the mentioned instrument transformers with all its data and related settings (if applicable), and communication relevant behaviour in the substation automation system.				

8.5.16 Definition and modelling of position sensors functions

In Table 22 the Logical Nodes for the requested position sensor functions are listed with related definitions and references.

Table 22 – Logical Nodes for position sensor functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Angle	This LN shall be used to represent a function which is used to measure an angle between two objects (one of which might be a theoretical vertical or horizontal line). The measurement can be returned optionally as degrees or radians (° or rad)	TANG	TANG	Angle
Axial displacement	This LN shall be used to represent a function which is used to measure an axial displacement value. The axial displacement can, depending on the application, be either longitudinal or transverse to the shaft. This sensor is often used together with vibration sensors as input to a vibration monitoring system.	TAXD	TAXD	Axial displacement
Distance	This LN shall be used to represent a function which is used to measure the distance between a fixed location and a movable object. The distance is given in m.	TDST	TDST	Distance
Movement	This LN shall be used to represent a function which is used to measure movement or speed. It is intended to provide measurements of the speed in m/s with which two objects (one of which may be fixed) are moving in relation to each other.	TMVM	TMVM	Movement sensor
Position indication	This LN shall be used to represent a function which is used to model the position of a movable device, actuator or similar. The position is given as a percentage of the full movement of the device being monitored.	TPOS	TPOS	Position indicator
Rotation transmitter	This LN shall be used to represent a function which is used to measure the rotational speed of a rotating device. Different measurement principles may be used, the presented result is however the same.	TRTN	TRTN	Rotation transmitter

8.5.17 Definition and modelling of material status sensors functions

In Table 23 the Logical Nodes for the requested material status functions are listed with related definitions and references.

Table 23 – Logical Nodes for material status sensor functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Frequency	This LN shall be used to represent a function which is used to measure frequency. It is intended for any frequency that is not related to electrical AC measurements. It can be used e.g. for sound measurements, vibrations and timing of repeated occurrences. If a pure vibration is to be measured, where the movement rather than the frequency is of interest, the Logical Node TVBR is recommended.	TFRQ	TFRQ	Frequency
Humidity	This LN shall be used to represent a function which is used to measure humidity in the media that is monitored. The result is given in percentage of maximum possible humidity.	THUM	THUM	Humidity
Magnetic field	This LN shall be used to represent a function which is used to measure the magnetic field strength at the place where the measurement is located.	TMGF	TMGF	Magnetic field
Pressure	This LN shall be used to represent a function which is used to measure the pressure of a gas. Different measurement principles may be used.	TPRS	TPRS	Pressure sensor
Temperature	This LN shall be used to represent a function which is used to measure a single temperature.	TTMP	TTMP	Temperature sensor
Mechanical tension Mechanical stress	This LN shall be used to represent a function which is used to measure the mechanical tension in an object.	TTNS	TTNS	Mechanical tension / stress
Vibration	This LN shall be used to represent a function which is used to measure a vibration. In case the vibration can be defined as a frequency, the TFRQ logical node could be used instead.	TVBR	TVBR	Vibration sensor

8.5.18 Definition and modelling of flow status sensor functions

In Table 24 the Logical Nodes for the requested flow status sensor functions are listed with related definitions and references.

Table 24 – Logical Nodes for flow status sensor functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Liquid flow	This LN shall be used to represent a function which is used to measure a media flow rate through the device where it is located.	TFLW	TFLW	Liquid flow
Media level	This LN shall be used to represent a function which is used to measure the media level in the container where it is located. The level is expressed as a percentage of the full container.	TLVL	TLVL	Media level
Sound pressure	This LN shall be used to represent a function which is used to measure the sound pressure at the location where the sensor is located.	TSND	TSND	Sound pressure sensor
Water acidity	This LN shall be used to represent a function which is used to measure a water pH value.	TWPH	TWPH	Water acidity

8.5.19 Definition and modelling of generic sensor functions

In Table 25 the Logical Nodes for the requested generic sensor functions are listed with related definitions and references.

Table 25 – Logical Nodes for Generic Sensor Functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Generic sensor	This LN shall be used to represent a function which is used to measure the value of a generic sensor. The use of TGSN is only allowed if for the intended use no LNs with standardised semantics are existing	TGSN	TGSN	Generic sensor

8.5.20 Definition and modelling of power transformer functions

In Table 26 the Logical Nodes for the requested power transformer functions are listed with related definitions and references.

Table 26 – Logical Nodes for power transformer functions

Logical Node	Description or comments	LN function	LN class	LN class naming
Power transformer	This LN shall be used to represent a power transformer which is a device that is used to connect the voltage levels of the power system.	YPTR	YPTR	Power transformer
Tap changer	This LN shall be used to represent a tap changer which is a device that is used to select the taps of the winding for voltage regulation.	YLTC	YLTC	Tap changer
Earth fault neutralizer (Petersen coil)	This LN shall be used to represent an earth-fault neutralizer which is a device with a variable inductance (plunge core coil) which is used to adapt the grounding of the transformer star point to minimize the ground fault current.	YEFN	YEFN	Earth fault neutralizer (Petersen coil)
Power shunt	This LN shall be used to represent a power shunt which is a device which is used to connect the grounding of the transformer star point over resistance.	YPSH	YPSH	Power shunt

These logical nodes represent the mentioned power transformers and related equipment with all its data and related settings (if applicable), and communication relevant behaviour in the substation automation system.

8.5.21 Definition and modelling of further power system equipment

In Table 27 the Logical Nodes for the requested power system equipment are listed with related definitions and references.

Table 27 – Logical Nodes for further power system equipment

Logical Node	Description or comments	LN function	LN class	LN class naming
Auxiliary network	This LN shall be used to represent a function to model the auxiliary network (power supply).	ZAXN	ZAXN	Auxiliary network
Battery	This LN shall be used to represent a function to model a battery, providing status information and allowing control of the charging/de-charging cycles.	ZBAT	ZBAT	Battery
Bushing	This LN shall be used to represent a function to model a bushing as used for transformers or GIS-line connections.	ZBSH	ZBSH	Bushing
Power cable	This LN shall be used to represent a function to model a power cable.	ZCAB	ZCAB	Power cable
Capacitor bank	This LN shall be used to represent a function to model a capacitor bank for controlling the reactive power flow.	ZCAP	ZCAP	Capacitor bank
Converter	This LN shall be used to represent a function to model a generic frequency converter including AC/DC conversion.	ZCON	ZCON	Converter

Logical Node	Description or comments	LN function	LN class	LN class naming
Generator	This LN shall be used to represent a function to model (operation, supervision) a generic generator.	ZGEN	ZGEN	Generator
Gas isolated Line (GIL)	This LN shall be used to represent a function to model a gas-isolated line. This LN provides the rating data. For supervision, relevant LNs like SIMS, SARC and SPDC shall be used.	ZGIL	ZGIL	Gas insulated line
Power overhead line	This LN shall be used to represent a function to model an overhead power line. This LN provides the rating data.	ZLIN	ZLIN	Power overhead line
Motor	This LN shall be used to represent a function to model a generic motor.	ZMOT	ZMOT	Motor
Reactor	This LN shall be used to represent a function to model a reactor for controlling the reactive power flow.	ZREA	ZREA	Reactor
Resistor	This LN shall be used to represent a function to model an ohmic resistor.	ZRES	ZRES	Resistor
Rotating reactive component	This LN shall be used to represent a function to model a rotating reactive component controlling the reactive power flow.	ZRRC	ZRRC	Rotating reactive component
Surge arrester	This LN shall be used to represent a function to model a surge arrester which cuts off line surges at a line end.	ZSAR	ZSAR	Surge arrester
Semi-conductor controlled rectifier	This LN shall be used to represent a function to model a semiconductor-controlled rectifier. A typical use for such a rectifier is to provide the controllable DC current within an excitation system.	ZSCR	ZSCR	Semi-conductor controlled rectifier
Synchronous machine	This LN shall be used to represent a function to model a generic synchronous machine. This LN provides the rating data.	ZSMC	ZSMC	Synchronous machine
Thyristor controlled frequency converter	This LN shall be used to represent a function to model a generic thyristor-controlled frequency converter including AC/DC conversion.	ZTCF	ZTCF	Thyristor controlled frequency converter
Thyristor controlled reactive component	This LN shall be used to represent a function to model a thyristor-controlled reactive component for controlling the reactive power flow	ZTCR	ZTCR	Thyristor controlled reactive component
<p>These logical nodes represent the mentioned power system equipment with all its data and related settings (if applicable), and communication relevant behaviour in the substation automation system. Since entities like generators are outside the scope of this standard for substations and are described by one single LN only. If the data exchange needs more details, these have to be covered by appropriated PICOMs or the additional use of generic LNs like GGIO.</p>				

8.5.22 Definition and modelling of generic process I/O

In Table 28 the Logical Nodes for the generic process I/O equipment are listed with related definitions and references.

Table 28 – Logical Nodes for generic process I/O

Logical Node	Description or comments	LN function	LN class	LN class naming
Generic I/O	<p>This LN shall be used to represent a function which is used to model and operate a process device (as such modelled by LN groups X, Y, Z) which is not semantically pre-defined like switchgear and other switchyard devices.</p> <p>The use of LN GGIO is only allowed if for the intended application no LNs with standardised semantics are existing.</p>	GGIO	GGIO	Generic I/O

8.6 Definition and modelling of mechanical non-electrical process equipment

In Table 29 the Logical Nodes for the mechanical non-electrical process equipment are listed with related definitions and references.

Table 29 – Logical Nodes for mechanical non-electrical process equipment

Logical Node	Description or comments	LN function	LN class	LN class naming
Fan	This LN shall be used to represent a function which is used to model and operate a fan..	KFAN	KFAN	Fan
Filter	This LN shall be used to represent a function which is used to model a mechanical filter.	KFIL	KFIL	Filter
Pump	This LN shall be used to represent a function which is used to model and operate a pump.	KPMP	KPMP	Pump
Tank	This LN shall be used to represent a function which is used to model a physical tank, such as a hydraulic oil tank. The typical content is a liquid like oil. The typical magnitude is the liquid level. If the tank is filled with gas, then the typical magnitude is the gas pressure.	KTNK	KTNK	Tank
Valve	This LN shall be used to represent a function which is used to model and operate a mechanical valve or gate where the position can be given as a percentage of total open position (optionally, the angle 0°-90° may be used).	KVLV	KVLV	Valve control

9 The application concept for Logical Nodes

9.1 Example out of the substation automation domain

The application concept for logical nodes is demonstrated in the domain substation automation. All modelling features are found in the parts IEC 61850-7-1 to IEC 61850-7-4. More dedicated application examples for the domain substation automation and other utility automation domains will be given in the scheduled parts IEC 61850-7-5xx.

9.2 Typical allocation and use of Logical Nodes

9.2.1 Free allocation of Logical Nodes

The free (arbitrary) allocation of functions or Logical Nodes respectively is not restricted to the common level structure. The levels below are mentioned for convenience only. All the figures shown with these levels are examples only demonstrating the requested flexibility and interaction.

9.2.2 Station level

These Logical Nodes represent the station level, i.e. not only the station level IHMI, but all other functions like station wide interlocking (CILO), alarm- and event handling (CALH), station-wide voltage control (ATCC), etc. The most common prefix is I, but others like A and C may appear also.

9.2.3 Bay level

These Logical Nodes represent the bay level control and automatic functions (e.g. CILO, ATCC, MMXU, CSWI) of the system same as the most protection LN (e.g. PDIS, PZSU, PDOC). Therefore, for combined control and protection devices, the protection LN appears here together with the control LN. In case of no process bus, the LNs of bay level and process level are hosted together in one single physical device. The XCBR represents now the I/O card functionality and the CSWI the control processor functionality. The most common prefixes are P, C and A, but others like X may appear also.

9.2.4 Process/switchgear level

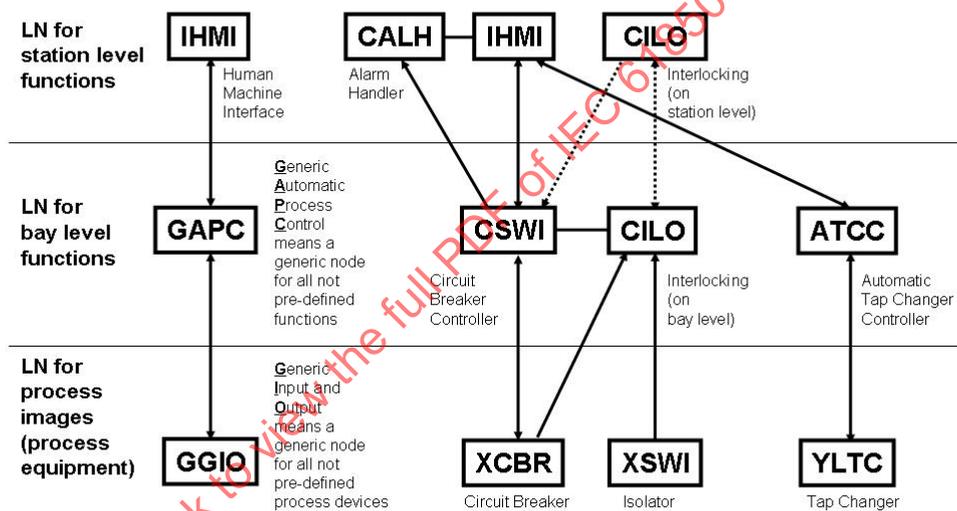
These Logical Nodes represent the power (primary) system, i.e. the power system world as seen from the secondary system via the I/Os. They may contain some simple functionality like device-related supervision and blocking also. In case of intelligent I/Os, logical nodes from the bay level may move down to the process level also. The most common prefixes are T, X, Y and Z.

9.2.5 The use of generic Logical Nodes

Generic Logical Nodes are requested to provide data for functions which are not standardized by Logical Nodes with semantic meaning. Generic logical nodes shall not be used instead of Logical Nodes with semantic meaning since such an approach would make interoperability much more complicated. This strong restriction is valid both for the implementers creating IEDs and for the users writing specifications.

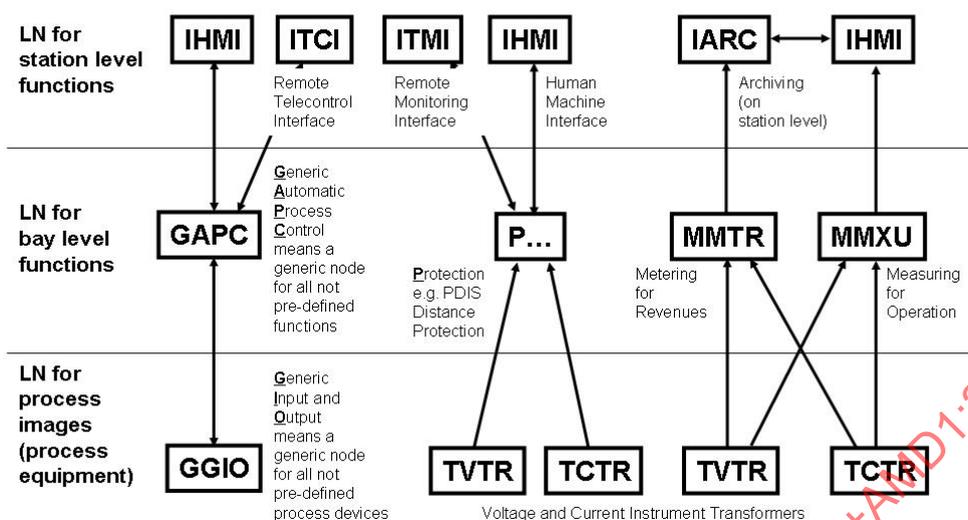
9.3 Basic examples

In the following figures (Figure 7, Figure 8) some basic examples for system modeling with Logical Nodes are given.



IEC 2385/12

Figure 7 – Decomposition of functions into interacting LNs on different levels: Examples for generic automatic function, breaker control function and voltage control function

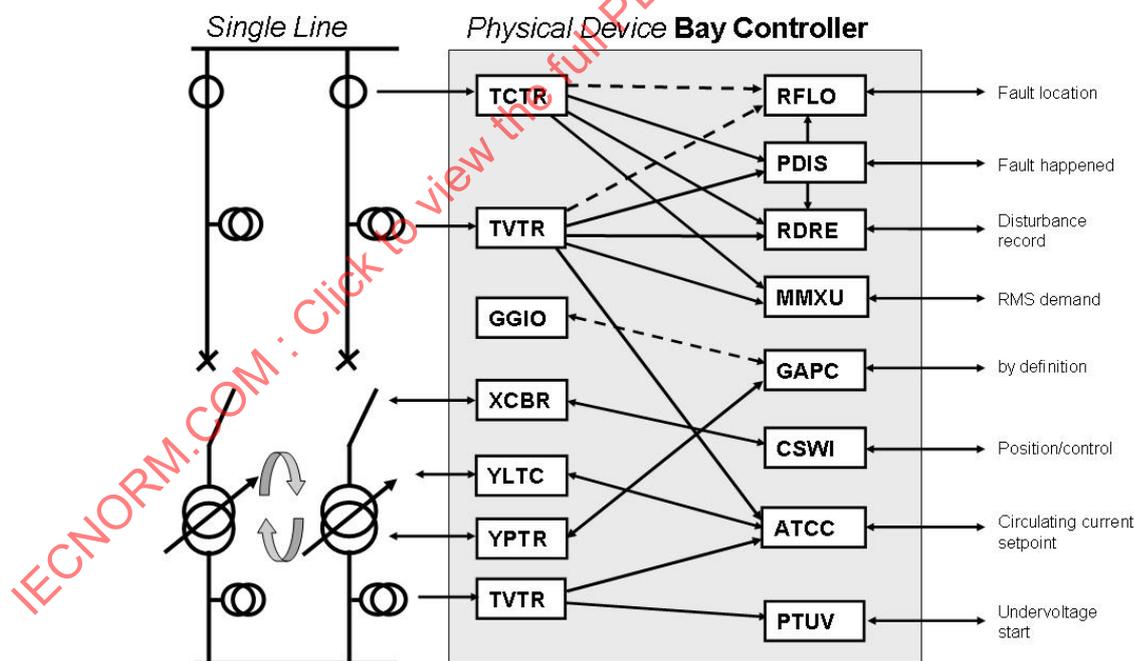


IEC 2386/12

**Figure 8 – Decomposition of functions into interacting LN on different levels:
Examples for generic function with telecontrol interface,
protection function and measuring/metering function**

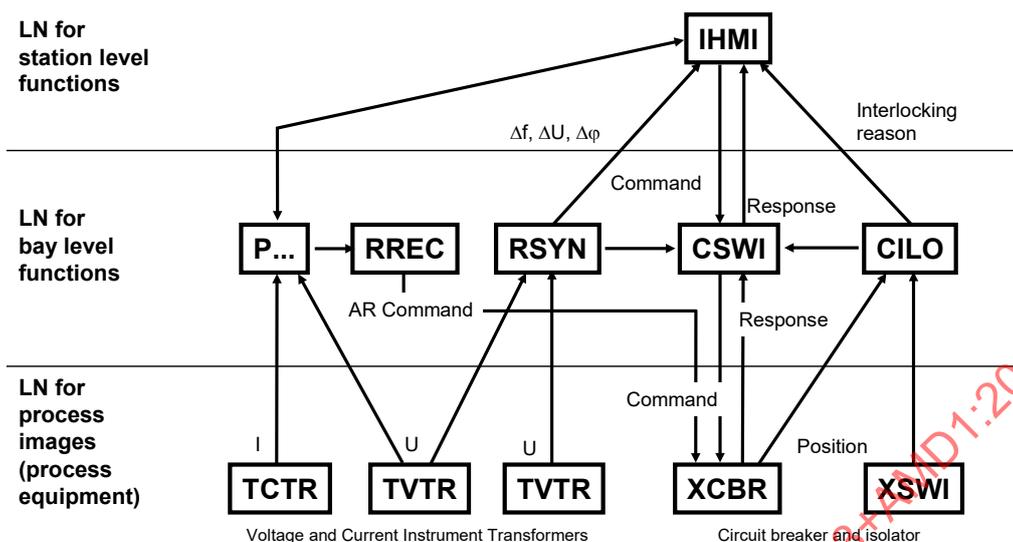
9.4 Additional examples

In the following figures (Figure 9, Figure 10, Figure 11 and Figure 12) some examples for modeling more complex functions and system parts with Logical Nodes are given.



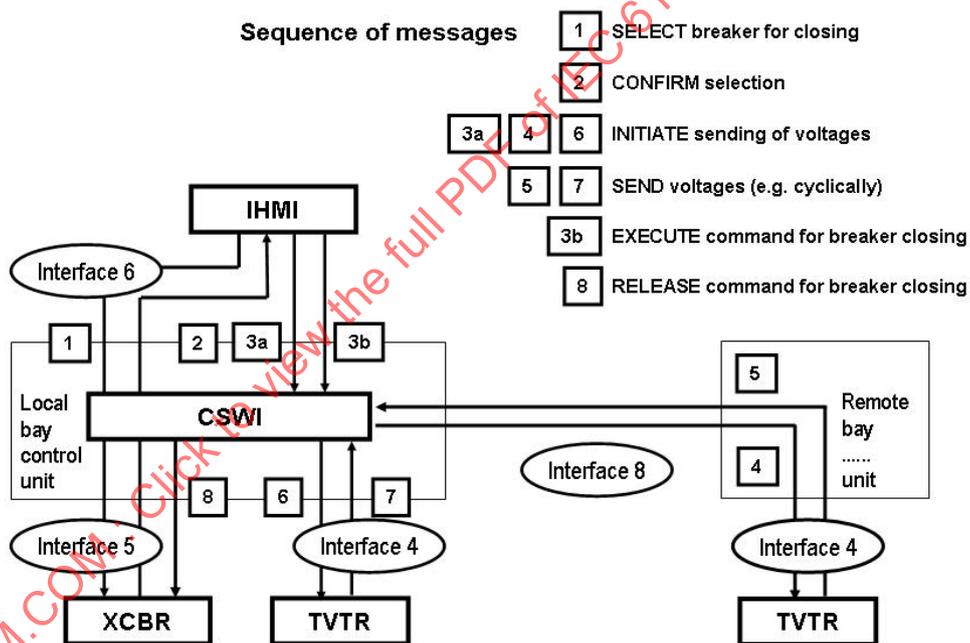
IEC 2387/12

Figure 9 – Example for control and protection LNs of a transformer bay combined in one physical device (some kind of maximum allocation)



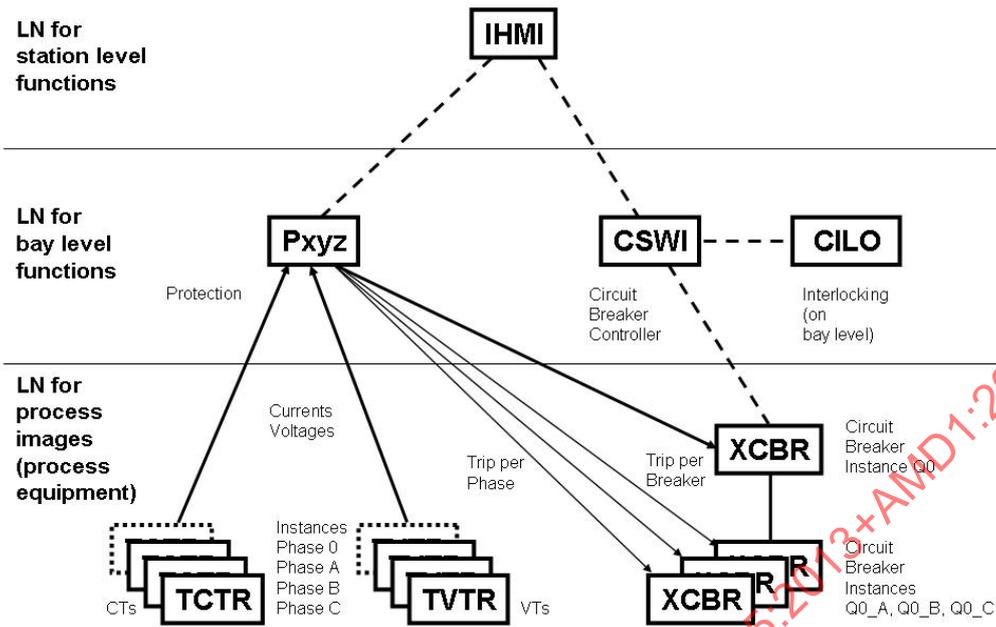
IEC 2388/12

Figure 10 – Example for interaction of LNs for switchgear control, interlocking, synchrocheck, autoreclosure and protection (Abbreviation for LN see above)



IEC 2389/12

Figure 11 – Example for sequential interacting of LNs (local and remote) in a complex function like point-on-wave switching (Abbreviations for LN see above) – Sequence view



IEC 2390/12

Figure 12 – Circuit breaker controllable per phase (XCBR instances per phase) and instrument transformers with measuring units per phase (TCTR or TVTR per phase)

9.5 Modelling

9.5.1 Important remarks

All the modelling for implementation is defined in IEC 61850-7-x series. The following remarks show some important points of the relationship between Part 5 and Part 7 of this series (IEC 61850-7-x).

9.5.2 Object classes and instances

The LNs described here provide the common functionality for all implementations, i.e. they represent in terms of object modelling LN classes. In a real implementation the LNs appear single or multiple as individuals (individual identification, individual data to be exchanged), i.e. they represent in terms of object modelling LN instances.

9.5.3 Requirements and modelling

The communication requirements described in this standard are independent from any modelling. To reach the goal of interoperability, a proper modelling as basis for the implementation of this standard is requested and described in IEC 61850-7 series.

9.5.4 Logical Nodes and modelling

The Logical Nodes in Part 5 are defined by the requirements only. If a client-server model is used for the modelling, some of the interface LNs like IHMI, ITCI, and ITMI may appear as clients and, therefore, will be modelled having no data objects.

The introduction of additional structures like Logical Devices (see Part 7 of this series ((IEC 61850-7-x)) grouping Logical Nodes is not an application requirement but may be helpful for handling common management features like switching a group of functions in test mode.

Split and combinations of Logical Nodes for more convenient modelling do not impact the requirements.

9.5.5 Use of Logical Nodes for applications

Informative examples how to use Logical Nodes for applications will be given in parts of IEC 61850-7-5 (basic applications) and IEC 61850-7-5xx (domain specific applications) referring to the full modelling definitions of IEC 61850-7-1, IEC 61850-7-2, IEC 61850-7-3 and IEC 61850-7-4.

10 System description and system requirements

10.1 Need for a formal system description

Where the data is coming from (sending Logical Node) and is going to (receiving Logical Node), i.e. the static structure of the communication system, has to be engineered or negotiated during the set-up phase of the system. All functions in the IEDs have to know what data to send when and what data they need from functions in other IEDs to be able to fulfil their functions. To control the free allocation of functions respectively Logical Nodes and to create interoperable systems, a strong formal device and system description for communication engineering shall be provided. Such a description (System Configuration description Language) is defined in Part 6 of this standard (IEC 61850-6). This formal description shall also support the data exchange between different tools if applicable.

10.2 Requirements for Logical Node behaviour in the system

As indicated already above each “receiving” function represented by the “receiving Logical Node” shall know what data is needed for performing his task; i.e. it shall be able to check if the delivered data are complete, valid and have the proper quality. In real-time power utility automation systems like in substation automation, the most important validity criterion is the age of the data. The sending Logical Node may set most quality attributes. The decision if data are “old” is the genuine task of the receiving Logical Node. Missing or incomplete information belongs also to this requirement since in this case no data with an acceptable age are available. Therefore, the requirements for communication providing interoperability between distributed Logical Nodes are reduced to the standardization of the data to be available or needed and the assignment of validity (quality) attributes in an appropriate data model as defined in Part 7 of this series (IEC 61850-7-x).

The requirements mentioned above imply that the sending Logical Node is also the source of the primary data, i.e. it keeps the most actual values of these data, and the receiving Logical Node is processing these data for the allocated functionality. In case of mirrored data (data base image of the process, proxy server, etc.) these mirrored data shall be kept as actual (“valid”) as needed by the function using these data.

In case of corrupted or lost data, the receiving Logical Node cannot operate in a normal way but may be in a degraded mode. Therefore, the behaviour of the Logical Node both in the normal and degraded mode has to be indicated and well defined but the degradation behaviour of the function has to be designed individually depending on the function and is beyond the scope of this standard. Also, the other Logical Nodes of the distributed function and the system supervision including HMI shall be informed about this degradation by a standardized message or proper data quality attributes to take the actions requested. If there is e.g. enough time, a request for sending valid data could be sent out also (retry). The detailed sequential behaviour of the distributed functions cannot be standardized at all and is seen as local issue.

Examples of data based complex interoperability are the different interlocking algorithms (e.g. Boolean or topology based interlocking) which can be performed with the same data set (the position indications of the switchgear). The reaction of the receiver beyond blocking or releasing the intended switchgear is a local issue like in the cases of unclear switch position indication.

Since the Logical Node concept covers all essential requirements in a consistent and comprehensive way, this concept itself is seen as a requirement, which shall be used in the detailed modelling given in Part 7 of this series (IEC 61850-7-x).

11 Performance requirements

11.1 Time synchronisation

11.1.1 Basics

11.1.1.1 Applications and definitions

To compare two or more data (values, events) with highest precision all have to be sampled or at the identical time ($\Delta t = 0$) without any jitter. Since this is conceptually and technically impossible, the term "real-time" for capturing and processing data was introduced. But this term consists same ambiguity since real time may mean something totally different for the impacted entities e.g. is not the same for a racing horse or a snail. They have different embedded time scales. This is valid also for technical constructs like IEDs with different functions.

The term time-critical refers to the different requirements of functions. It refers to the time which is critical to perform a dedicated function. It should be noted that time requirements are explicitly requested for communication i.e. for transmission and response times. Since application functions are not standardized in IEC 61850, the time for performing such a function is out of scope.

IEC 61850 compatible devices from multiple manufacturers may not only be used in substations but also everywhere in the power system. Therefore, a common global format for time tagging done by all these devices shall be used. It shall be possible to compare the sequence of events system-wide ("globally") for any kind of event analysis to detect causal relationships. The resulting requirement is that the time between the IEDs respectively the clocks within all IEDs shall be synchronized with reasonable accuracy. Since not all data have to be globally synchronized, for the clocks under consideration the term "time-coherent" data is introduced.

11.1.1.1.1 Event time tagging

Events could be e.g. signal changes on binary inputs of the IED from the process or calculated ones in the application functions. To get a correct sequence of events across different places in the power system an event time tagging with a precise coherent time has to be provided. Therefore, all devices in this coherent time zone shall be synchronized with the requested accuracy. The commonly requested time accuracy for time tagging of events is 1 ms. This means, that the detection of state changes (scanning cycle) for events shall be short enough for allocating the event to the correct time slot. The time-coherent zone includes normally at least the responsibility area of a utility allowing for sequence of events (timely ordered list) representing the diary of the system.

11.1.1.1.2 Coherent samples of analogue values

Analogue data which are used for calculations like impedance (voltage and current for distance protection) or difference (two or more currents for differential protection) must be taken from the same instant in time with a minimum jitter, i.e. the corresponding samples shall be time coherent. To compare values from different places (e.g. sampled values from different merging units, synchrocheck) or to calculate expressions out of these (e.g. current and voltage for distance protection, actual power), these values have to be coherent with accuracy fitting to AC values. The resulting requirement is that the time between the IEDs respectively the clocks within all IEDs providing the samples shall be synchronized for a coherent time zone with reasonable accuracy. The common time accuracy for synchronized samples is 1 μ s. The common order for analogue samples with 50 Hz or 60 Hz power frequency is 1 μ s. Synchronized samples may be created by high-precision interpolation to a common sample base or, more convenient, by synchronized sampling.

NOTE The samples must be delivered as continuous data stream similar as with wires allowing the detection of deviations from the normal state like faults by protection at any time.

11.1.1.2 Time synchronisation and master clocks

To compare data in one IED only, no external reference clock named master clock is needed. The micro-processor represents the internal clock for all hosted data. If data in smaller or larger areas have to be compared, external master clocks have to be applied.

The choice of master clock technology (atomic clock, satellite-based clock or a so-called network clock) and applied level of redundancy are matter of implementation and, therefore, outside the scope of this part.

Master clocks have to synchronize the microprocessor-based clocks in the IEDs which are responsible that changes are detected in time respectively analogue values are sampled at the same time (synchronized sampling).

11.1.1.3 Time synchronisation and clock requirements

Since this part of the standard defines and lists requirements and not implementations, all performance classes refer to applications (functions) and not to clock operations. It is a matter of the clock implementation to provide the requested times for the applications. Therefore, also synchronization implementation dependent clock messages are not considered.

These basic time requirements are system requirements, but the system consists of devices hosting functional and communication functionalities. Therefore, all these devices shall support these requirements if applicable.

11.1.1.4 Time model and format requirements

Specific requirements for the time model and time format are as follows:

- 1) Classes are defined below.
- 2) The time stamp shall be based on an existing time standard. UTC is generally accepted as the base time standard.
- 3) The time model shall be able to track leap seconds and provide enough information to allow the user to perform delta time calculations for paired events crossing the leap second boundary.
- 4) The time stamp model shall contain sufficient information that would allow the client to compute a date and time without additional information such as the number of leap seconds from the beginning of time in the used time standard.
- 5) The timestamp information shall be easily derivable from commercially available time reference system,
- 6) The overall time model shall include information to allow the computation of the local time.
- 7) The time model shall allow for ½ hour offset of the local time.
- 8) The time model shall indicate whether Daylight Saving is in effect or not.
- 9) The format shall last at least 100 years.
- 10) The timestamp format shall be compact and easily machine processed.

11.1.1.5 Specific issues for time synchronization

- 1) The choice of reference clock technology (atomic clock, satellite-based clock or network clock) is a matter of implementation and, therefore, outside the scope of this document.
- 2) The accuracy is always the difference between the master clock and the slave clock in the device (IED) hosting the application function i.e. $\Delta t_{\text{acc}} = |t_{\text{master}} - t_{\text{slave}}|$. Therefore, the maximum time difference between two IEDs is $2 \Delta t_{\text{acc}}$ since the difference between the master clock and the slave clock may have a different sign for two IEDs.
- 3) The time synchronization procedure shall fulfil the performance classes according to Table 2 and Table 3 as far as applicable.

- 4) The messages for time synchronization should use the same communication infrastructure as the data exchange to facilitate both the IED and the communication system design.

11.1.1.6 Time synchronization classes

The different requirements may be ordered in classes as shown in Table 2.

For simplicity of definition and verification, the accuracy is defined as difference to a common time reference e.g. a master clock.

Table 2 – Time synchronization classes for AC applications synchronization

Time synchronization class	Accuracy	Phase angle accuracy for 50 Hz	Phase angle accuracy for 60 Hz	Fault location accuracy ^b
	[μs]	[°]	[°]	[%]
TL ^a	> 10 000	> 180	> 216	n.a.
T0	10 000	180	216	n.a.
T1	1 000	18	21,6	7,909
T2	100	1,8	2,2	0,780
T3	25	0,5	0,5	0,195
T4	4	0,1	0,1	0,031
T5	1	0,02	0,02	0,008

^a TL stands for time synchronization "low".

^b Only considering the quotient of voltage and current with the time jitter of the given accuracy. Since details in the fault location algorithms are not considered this column indicates only some reasons for requiring certain time synchronization classes to reach a requested accuracy of the fault location. Reference for 100 % is the full line length.

The time synchronization classes may be allocated also to typical application functions which need time synchronization as shown in Table 3.

Table 3 – Time synchronization classes for time tagging or sampling

Time synchronization class	Accuracy [μs] Synchronization error	Application
TL	> 10 000	Low time synchronization accuracy – miscellaneous
T0	10 000	Time tagging of events with an accuracy of 10 ms
T1	1 000	Time tagging of events with an accuracy of 1 ms
T2	100	Time tagging of zero crossings and of data for the distributed synchrocheck. Time tags to support point on wave switching
T3	25	Miscellaneous
T4	4	Time tagging of samples respectively synchronized sampling
T5	1	High precision time tagging of samples respectively high synchronized sampling

The accuracy i.e. how the primary signal is represented depends on the given sensing principle (magnetic, optic, etc.), of the sampling rate (may be a parameter) and on the dynamic response of the A/D conversion (frequency response and step response depending on the conversion algorithm). The accuracy in general or dedicated for protection, measurement, revenue metering, power quality supervision and other functions is outside the scope of IEC 61850 series and defined in the related product standards.

This accuracy for measuring current and voltage with classical instrument transformers or advanced optical sensors is outside the scope of the IEC 61850 series and defined in the standard series IEC 61869. The bit resolution has to be high enough for the accuracy requested by the application. Normally, the common 16 bit resolution covers all accuracy requirements in power utility automation systems. The accuracy of the sampled analogue data is not influenced by the communication.

If one set of samples (defined by the identical sampling time) is transferred together in one frame the transfer rate (frame rate) is identical with the sampling rate of the data in the sample stream. If two or more consecutive samples are combined in one frame the frame rate will go down releasing the load on the communication link but increasing the time until all data are available for the application.

The sample stream shall be usable by functions like protection same as the hardwired analogue values. The implementation of the serial communication shall provide enough bandwidth for the applied data streams.

If data from different analogue measuring points (different sample streams) have to be processed together, these data have to be provided time coherent i.e. either time tagged or synchronized sampled with the high precision needed by the application. The requirement classes for time synchronization are given in Table 2 respectively Table 3.

11.1.1.7 Event time definition

There are four different kinds of events with recommended time allocation procedures:

- If an event is defined as a change of a computed value (internal or calculated event) the allocation of time (time tagging) shall be done immediately when the result is available within the time resolution of the clock. No special measures are needed. It should be noted that the time tag accuracy cannot be higher than the clock time resolution. The time stamp difference of calculated result from the process inputs mirrors the calculation (cycle) time.
- If an event is defined as a change of the value of a binary input, also the delay of the debounce procedure for the input contact has to be considered. The event time shall be locally corrected, i.e. the time stamp shall give the event time before debouncing. The event is caused from outside the IED (intelligent electronic device) but the time resolution cannot be higher than the input supervision cycle which is at least by definition independent from the computation cycle of any application function.
- If an event is defined as a change of the value of an analogue input, also the delay of the filtering procedure of the input circuit has to be considered. The event time shall be locally corrected. The event is caused by the limit supervision of data from outside IED but the time resolution cannot be higher than the analogue input supervision cycle inside the IED which is at least by definition independent from the computation cycle of any application function. For derived values like frequencies or phasors, the definition for the first kind is applicable.
- Results from computations and changes causing events shall be monitored and detected at least in time intervals corresponding to the accuracy class of the time stamp stated. Otherwise, the accuracy of the time stamp has no meaning. This requirement is valid for all IEDs which claim conformance with IEC 61850 series.

This strong event time definition results from the requirements that the time tag of the transmitted binary or analogue events/values

- shall be as accurate as possible for post-fault/failure event sequence analysis,
- shall need no correction at the receiver.

11.2 Message performance requirements

11.2.1 Basic definitions and requirements

11.2.1.1 General

The communication between Logical Nodes is performed by many individual messages described by thousands of individual PICOMs (see Annex A and Annex B). Nevertheless, there are a lot of similarities between these PICOMs, e.g. all PICOMs describing trips have besides the individual sources more or less the identical communication requirements as described by the PICOM attributes. Therefore, the classification of PICOMs according to these similar requirements provides a comprehensive overview on the requirements, supports a strong modelling, facilitates implementation and defines verifiable message performance requirements.

In a first step, all PICOMs from the most Logical Nodes of the domain substation automation as example are identified and allocated to a PICOM type using a common purpose and having common attributes. The result is found in Table B.2.

The resulting PICOM types with their most important common attributes are given in Table B.3. The broad range of transfer time requirements reflects the individual needs of the application functions. Since the higher requirements cover always the lower ones, these requirements may be condensed in requirement classes. The resulting figures for the message types are introduced below.

For the user of the system, the performance of the local and distributed functions is of interest i.e. the sum of the processing and communication time. Since IEC 61850 standardizes not the functions but only the communication, an appropriate definition of the maximum time allowed for the data exchange called "overall transfer time" is needed and defined in 11.2.1.2.

For defining time stamps and transfer times the basic definition of time and time synchronization have to be clear. These requirements are stated in 11.1.1.1 and 11.1.1.7. Transfer time requirements are system requirements, time stamp requirements are device requirements but refer to the system support function "Time synchronization".

In 11.3 the PICOM types are condensed into message types. The range of their attributes is structured by performance classes. Some hints to typical applications and interface allocation are given also.

Introduction and use of message types is described in 11.2.2.1, introduction and use of performance classes is described in 11.2.2.2.

System performance requirements shall be tested also e.g. with system simulators. Their testing shall be properly addressed in the conformance testing part (IEC 61850-10).

IEC 61850 is not only applicable inside the substation or plant according to the application domain of interest like "substation" or any other local system but also between such IEC 61850 islands. Examples are the communication between substations (e.g. for "teleprotection") or between the substation and the network control centre (e.g. for "telecontrol"). Therefore, the message performance requirements are applicable in principle also for larger distances depending on the functions to be supported, but the requirements inside local islands are often more demanding than in between.

11.2.1.2 Transfer time

11.2.1.2.1 Basic definitions

The complete transfer time t is specified as complete transmission time of a message including the handling at both ends (sender, receiver). The time counts from the moment the sender puts the application data content on top of its transmission stack (coding and sending) up to the

moment the receiver extracts the data from its transmission stack (receiving and decoding). These coding/decoding processes may be handled by the main processor or by a dedicated communication processor (outside the scope of the standard). This requirement is independent from the stack selected in other parts of the series.

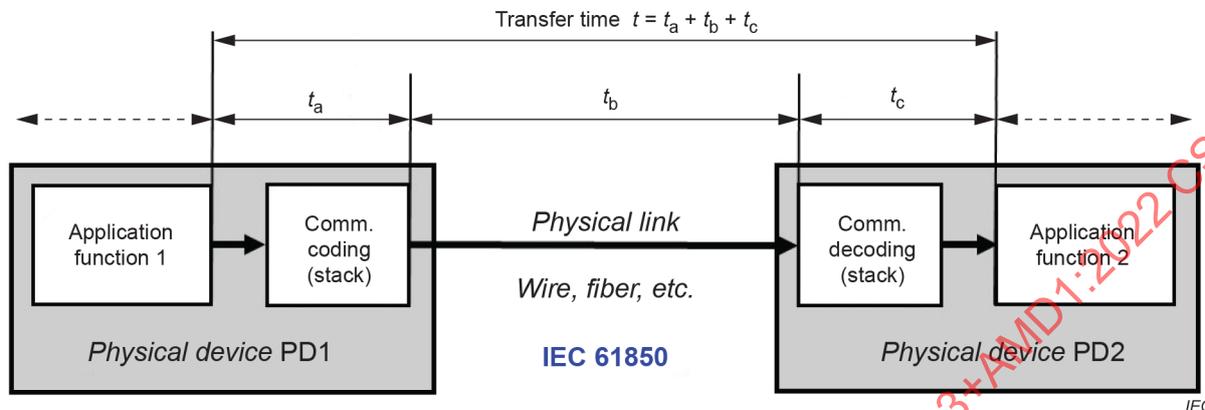


Figure 13 – Definition of "overall transfer time" t and indication of processing times

This time definition is applicable for the complete transmission chain as indicated in Figure 13. In physical device PD1, a function f_1 sends data to another function f_2 , located in physical device PD2. The overall transfer time t will however consist of the individual times of the stack processing (t_a , t_c) and of the network transfer time (t_b). The network transfer time (t_b) includes waiting times and time delays caused by routers and other active communication devices being part of the complete communication path.

The coding and decoding times in Figure 13 refer to the contact times (electromechanical relays) in Figure 14 for IEDs connected by hardwires including the conversion of binary contact positions from and to digital data (B/D conversion). For analogue values, they represent the A/D conversion (see 11.2.3.2). If collisions or losses have to be compensated e.g. by repetitions also these times contribute, mostly leading to a statistical distribution of the transfer time length.

11.2.1.2.2 Processing vs. transfer time

To react on the process after a stimulus from the process, also the processing time is of interest for the user. An example is a distributed protection function consisting of two physical devices having current and/or voltage as input and the trip as output. Since the communication is important but an auxiliary function only, the transfer time shall be normally small compared to the processing times: $t \ll t_{f1} + t_{f2}$.

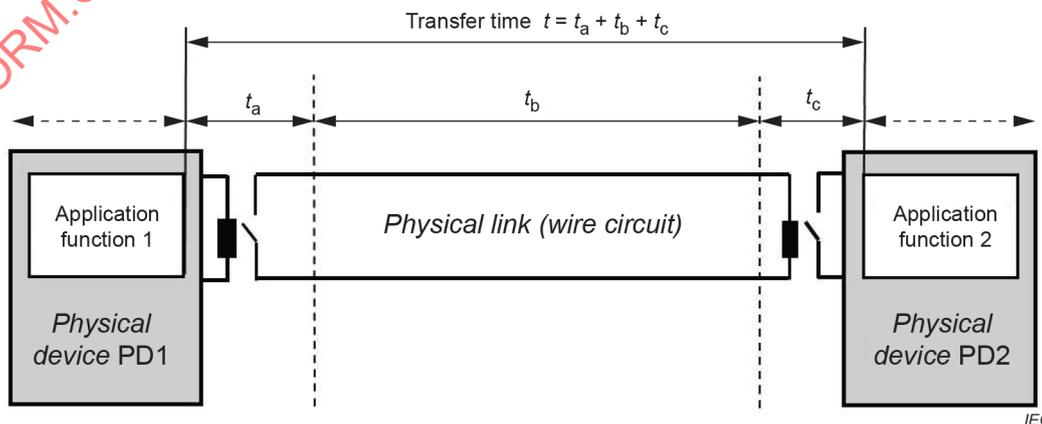
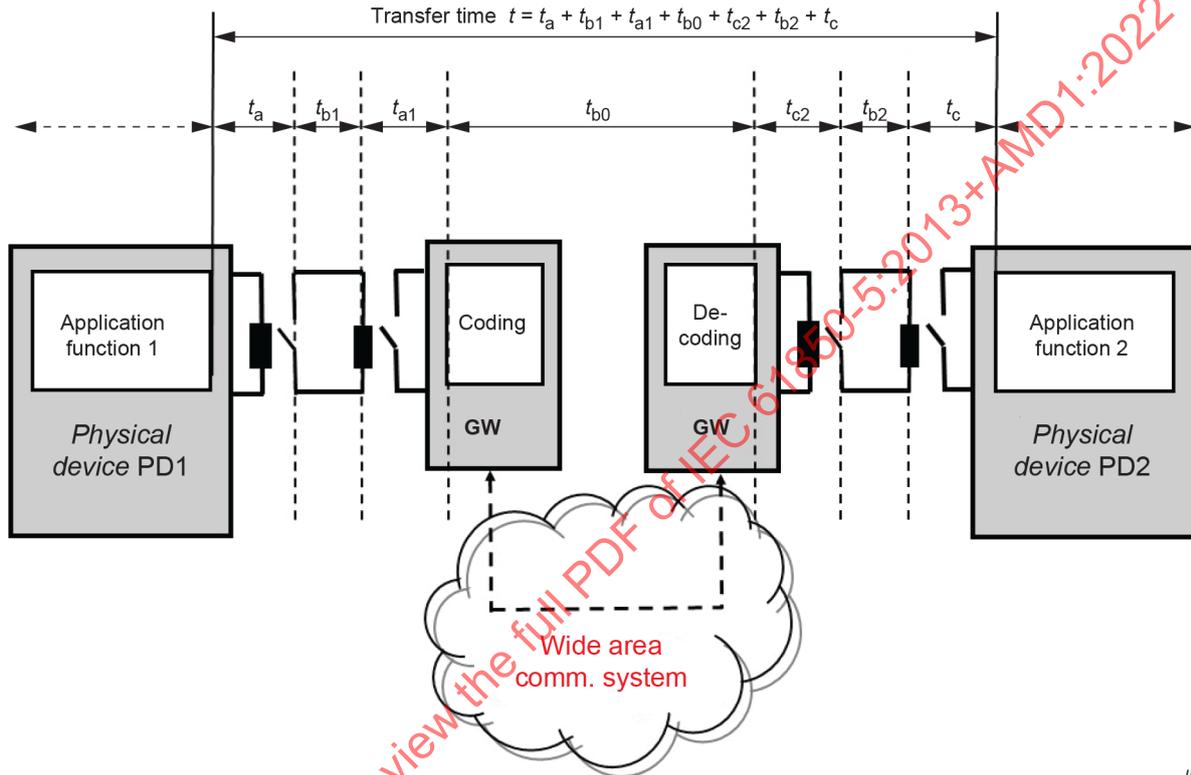


Figure 14 – Transfer time for binary signal with conventional output and input delays

11.2.1.3 Transfer times for substation-substation connections

If the connection between two IEDs is a direct link, the time t_b for distances within substations and in power systems is negligible since the signal speed is – depending on the transmission mode and the impedance of the line for the signals of this mode – in between 2/3 and the full speed of light i.e. about between 200 million and 300 million meters per second. If there are switches, routers and other active communication devices in the communication path their processing times contribute reasonable to the network transfer time t_b . If collisions or losses have to be compensated e.g. by repetitions also these times contribute, mostly leading to a statistical distribution of the transfer time length.



IEC

Figure 15 – Definition of transfer time t for binary signals in case of line protection

This is valid also for links beyond the substation boundary where the time delay in the interconnecting network is also part of t_b . In Figure 15 and Figure 16 some dedicated times contributing to t_b are shown. Contact times (Figure 15) are replaced by coding and decoding times (Figure 16). In case of full digital communication (Figure 16) coding and decoding for the Wide Area communication system are replaced by recoding for the Local Area communication.

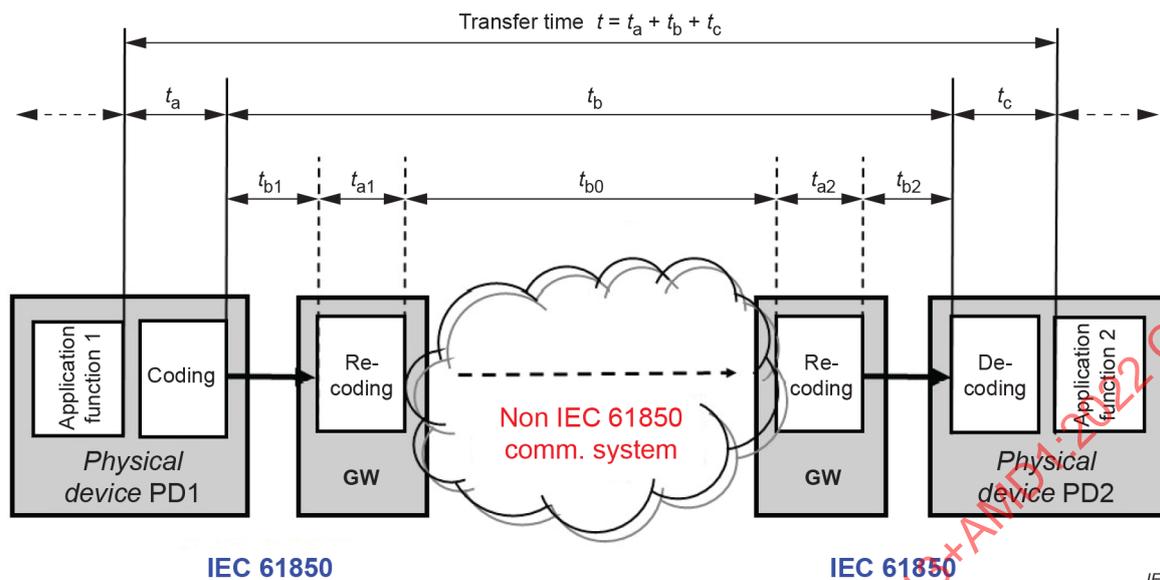


Figure 16 – Definition of transfer time t over serial link in case of line protection

The teleprotection operating time t_A in Figure 2 of IEC 60834-2:1993 is defined in about the same way as the transfer time t in this document.

All transfer time requirements are given by the needs of the application functions and, therefore, have to be kept in any case under normal conditions without disturbance. If these requirements kept it is an implementation issue if the transfer happens by some kind of tunnelling the messages unchanged in case of broadband channels or by some kind of recoding in case of narrow band channels if applicable. The measures against disturbances are outside the scope of this standard.

Disturbances may need a logical reconnection of the communication link, repetition of messages or other means increasing the transfer time. This behaviour is a matter of the services defined in the IEC 61850-7-2 and of the implementation within the IEDs. Any possible delay has to be defined and considered for the transfer time. What normal and delayed transfer times are acceptable is depending on the project specification for functions.

11.2.1.4 Transmission of analogue signals

The definition of transfer times for binary signals refers to the related contact times. Analogue signals have no contacts but instead already in legacy systems A/D conversion. The difference is that digitized analogue data are normally not converted back to analogue ones after the transmission. The time requirements for transmission of analogue signals are the same as for binary ones.

11.2.1.5 Links to operator places

Operator places are connected already for a long time by serial links with devices for control, protection, monitoring and other functionalities. The requirements for such links are less demanding since they are related to the human operator response time ≥ 1 s.

11.2.2 Concepts of message types and performance classes

11.2.2.1 Introduction and use of message types

As mentioned above, the communication requirements in terms of PICOMs between Logical Nodes result in requirements for communication links within a Substation Automation System Messages have a varying complexity regarding their content, length, allowed transfer time and security. Therefore, all the message types used by the actual messages will vary from moment

to moment depending on the activity in the Substation Automation System or in systems of any other application domain.

The main difference between PICOMs and message types is that PICOMs refer to information transfer for only one single dedicated function and include both source and sink. The message types are based on a grouping of PICOMs according to common performance attributes and, therefore, define the performance requirements to be supported commonly for the complete group (see Annex B).

Since the message performance requirements are defined per message, they are valid independently from the size of the system. Since message requirements are given by the application functions using these messages it is of outmost importance that these requirements for each message are fulfilled in nearly any situation. The size of the system may have an impact how these requirements are fulfilled. This may need message priorities to fulfil also time critical performance requirements. Avalanche conditions may result for some time in increased transfer times. If this is acceptable has to be decided per project and – if not – fixed by the architecture of the communication system and communication parameters of the IEDs if applicable.

All requirements are valid under normal conditions without disturbed communication links. Such disturbances may need a logical reconnection of the communication link, repetition of messages or other means increasing the transfer time. This behaviour is given by the definition of services (IEC 61850-7-2) and by the selected stacks (IEC 61850-8-x and IEC 61850-9-x). How the disturbances are handled and to what extent the transfer times are increased is depending on the implementation. What can be tolerated is depending on the application. This might mean that certain implementations are not suitable for certain applications.

11.2.2.2 Introduction and use of performance classes

To adapt to different requirements from different functions the message types are subdivided into performance classes.

For some message types, there are e.g. two groups of function related performance classes identified i.e. one for control and protection focused and another one for metering and power quality. For other messages, there is a more dedicated dependence on functions.

Within any substation, not all communication links have to support the same performance classes. For example, station level events and process level samples for protection may have different requirements independent of each other. These links may be implemented in dedicated interfaces or in a common LAN. The common LAN shall fulfil all requirements of the communication links embedded in the LAN.

As reference for the class with the highest transfer time requirement the best operation time of an electro-mechanical contact (5 ms) is used. If no contact reference is applicable also higher performance values may be introduced.

For instantaneous analogue values like AC currents and voltages, the number of samples per time interval is requested by the function using the data. The transfer time delay has to be small enough that it does not impact the requested performance of the protection function i.e. the time from fault detection to trip issuing (typically up to 40 ms) respectively together with the circuit breaker operation time the requested fault clearing time of ≤ 100 ms (preferred 80 ms)

The performance classes are numbered continuously across all message types. There is no explicit relationship to voltage levels or substation layouts.

11.2.2.3 Implementation issues

On a direct connection between two IEDs all messages travel with the same speed (refer to fb in Figure 16). Different priorities and performances classes are not feasible. All active elements

in the communication link like switches (if applicable) but also the sender and receiver at both ends of the link do some coding and decoding consuming time (refer to t_a and t_c in Figure 13) maybe different for the different message types. Different stacks and queues with different priorities may be needed to realize different performance classes. These implementation issues have to be considered in the relevant parts of the standard series (IEC 61850-8-x and IEC 61850-9-x) and in selecting active elements.

11.2.3 Definition of transfer time and synchronization classes

11.2.3.1 Transfer time classes for control and protection

The transfer time requirements for functions as given in Table 30 may be different depending on the voltage level and role of substation, i.e. on distribution and transmission level. These algorithmic requirements are important for the users but outside the scope of IEC 61850 series.

The relay (contact) operation time is small compared to the function performance time and, normally, the same both for transmission and distribution IEDs. The transfer time requested has to be so small that it does not influence the operation time of the function. Since for legacy solutions the transfer times over copper wires is the same both for distribution and transmission, the acceptable delay depends on the function but not on voltage level.

Table 30 – Classes for transfer times

Transfer time class	Transfer time [ms]	Application examples: Transfer of
TT0	>1 000	Files, events, log contents
TT1	500 < t ≤ 1 000	Events, alarms
TT2	100 < t ≤ 500	Operator commands
TT3	20 < t ≤ 100	Slow automatic interactions
TT4	10 < t ≤ 20	Fast automatic interactions
TT5	3 < t ≤ 10	Releases, status changes
TT6	≤ 3	Trips, blockings

11.2.3.2 Analogue data for protection, control and metering

Analogue data for protection and control are mainly the actual voltages and currents. Since they are provided by instrument transformers or sensors directly from the power system they are often called raw data in contrast to RMS values which are processed data.

In serial communication systems analogue data are digitized and transmitted as samples or, e.g. in case of continuous supervision of power system, current and voltage as sample stream. Therefore, three performance figures characterize the analogue data i.e. sample rate, transfer time and accuracy. The requested performance figures are determined by the functions which are using this data.

Generally, the transfer time requested for analogue values has to be so small that it does not influence the operation time e.g. of the protection function using this data. Therefore, the classes for transfer times listed in Table 1 are applicable also for the transfer of analogue data. Regarding the fast operation requested for protection functions, at least for the current and protection the transfer time class TT6 is requested.

The accuracy i.e. how the primary signal is represented depends on the given sensing principle (magnetic, optic, etc.), of the sampling rate (may be a parameter) and on the dynamic response of the A/D conversion (frequency response and step response depending on the conversion algorithm). This accuracy is outside the scope of IEC 61850 series.

If the transfer rate is identical with the sampling rate creating the sample stream and the bit resolution high enough for the requested accuracy, the accuracy figures of the analogue data are not influenced by the communication. Normally, the common 16 bit resolution covers all accuracy requirements generally in power systems and especially in substation automation systems. The sample stream shall be usable by functions like protection same as the hardwired analogue values. The implementation of the serial communication shall provide enough bandwidth for the applied data streams.

If data from different analogue measuring points (different sample streams) have to be processed together like currents for differential protection, these data have to be provided time coherent i.e. either time tagged or synchronized sampled with reasonable high precision. The requirement classes for time synchronization are given in 11.1.1.6.

The accuracy for protection, measurement, revenue metering, power quality supervision and other functions are defined in many product standards outside the scope of IEC 61850 series.

11.3 Definition of messages types and performances classes

11.3.1 Type 1 – Fast messages ("Protection")

11.3.1.1 General

This type of message typically contains a simple binary code containing data, command or simple message, for example "Trip", "Close", "Reclose order", "Start", "Stop", "Block", "Unblock", "Trigger", "Release", "State change", maybe "State" for some functions also. The receiving IED will normally act immediately in some way by the related function on receipt of this type of message since otherwise, no fast messages are needed. All such fast messages refer to time critical, protection like functions. Trips, blocks, releases and similar signals to the neighbouring substation (e.g. for line protection (see IEC/TR 61850-90-1)) belong to this class. Performance class P1 is typical for such messages inside the substation or any other local system, performance class P2 for messages in between.

11.3.1.2 Type 1A "Trip"

The trip is the most important fast message in the substation. Therefore, this message has more demanding requirements compared to all other fast messages. Same performance may be requested for interlocking, intertrips and logic discrimination between protection functions.

Performance class	Requirement description	Transfer time		Typical for Interface (IF ^a)
		Class	ms	
P1	The total transmission time shall be below the order of a quarter of a cycle (5 ms for 50 Hz, 4 ms for 60 Hz).	TT6	≤ 3	3,5,8
P2	The total transmission time shall be in the order of half a cycle (10 ms for 50 Hz, 8 ms for 60 Hz).	TT5	≤ 10	2,3,11

^a Interfaces according to Figure .

11.3.1.3 Type 1B "Others"

All other fast messages are important for the interaction of the automation system with the process but have less demanding requirements compared to the "trip". The performance for automation functions are typically between the response time of operators (order of 1 000 ms) and of protection (order of 10 ms). This performance is also valid for such messages between a substations automation systems and other local systems.

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P3	The total transmission time shall be the order of one cycle (20 ms for 50 Hz, 17 ms for 60 Hz).	TT4	≤ 20	2,3,8,11

11.3.2 Type 2 – Medium speed messages ("Automatics")

These are messages, as defined in 11.2.1, where the time at which the message originated is important but where the transmission time is less critical. It is expected that IEDs will have their own clocks. The message shall include a time-tag set by the sender, and the receiver will normally react after an internal time delay, which then will be calculated from the time given in the time-tag. Also normal "state" information belongs to this type of message. All such medium speed messages refer to less time critical automation related messages.

This type may include analogue values such as the r.m.s. values calculated from type 4 messages (samples). This performance type is also applicable for messages between substations for automatic functions.

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P4	The transfer time for automation functions is less demanding than protection type messages (trip, block, release, critical status change) but more demanding than operator actions.	TT3	≤ 100	2,3,8,9,11

11.3.3 Type 3 – Low speed messages ("Operator")

This type includes complex messages that may require being time-tagged. This type should be used for slow speed auto-control functions, transmission of event records, reading or changing set-point values and general presentation of system data. Whether a time-tag is required (normally) or not (exception) will be stated by the actual application. Also time tagged alarms and events for normal alarm/event handling and non-electrical measurands like temperature belong to this type, but some automatics and values (e.g. pressure) may request message type 2. All such low speed messages refer to operator messages not time critical, referring to the slow response type of a human being (reaction time > 1 s).

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P5	The total transmission time shall be half the operator response time of ≥ 1 s regarding event and response (bidirectional)	TT2	≤ 500	1, 3, 4, 5, 6, 7, 8, 9, 10
P6	The total transmission time shall be in line with the operator response time of ≥ 1 s regarding unidirectional event	TT1	≤ 1 000	1, 3, 4, 5, 6, 7, 8, 9, 10

11.3.4 Type 4 – Raw data messages ("Samples")

This message type includes the output data from digitizing transducers and digital instrument transformers independent from the transducer technology (magnetic, optic, etc.). The data will consist of continuous streams of synchronized samples from each IED, interleaved with data from other IEDs.

Transfer time means for the stream of synchronized samples a constant delay resulting in a delay for the functions using the samples e.g. for protection. Therefore, this transfer time shall be so small that no negative impact on application function is experienced.

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P7 ^a	Delay acceptable for protection functions using these samples	TT6	≤ 3	4,8
P8 ^b	Delay acceptable for other functions using these samples	TT5	≤ 10	2,4,8

^a equivalent to P1.
^b equivalent to P2.

11.3.5 Type 5 – File transfer functions

This type of message is used to transfer large files of data from disturbance recording, for information purpose, settings for IEDs, etc. Data shall be split in blocks of limited length, to allow for other communication network activities. Typically, the bit lengths of the file type PICOMs are equal or greater than 512 bits.

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P9	Transfer times for files are not critical. Typically, files with process data are used either for post-mortem analysis or for off-line statistics. Files with configuration data require a careful installation and check process. Therefore, no quick operator action of about 1 s is requested. Therefore, 10 000 ms fit very well the file transfer requirements.	TT0	≤ 10 000	1, 4, 5, 6,7,10

11.3.6 Type 6 – Command messages and file transfer with access control

This type of message is used to transfer control orders, issued from local or remote HMI functions, where a higher degree of security is required. All messages using interface 10 (remote control) and interface 7 (external technical services) shall include access control. This type of message is based on Type 3 but with additional password and/or verification procedures.

Performance class	Requirement description	Transfer time		Typical for Interface (IF)
		Class	ms	
P10 ^a	Type 3.P5 message with access control: The total transmission time shall be half the operator response time of ≥ 1 s regarding event and response (bidirectional)	TT2	≤ 500	1,3, 4, 5, 6, 7, 8, 9, 10
P11 ^b	Type 3.P6 message with access control: The total transmission time shall be in line with the operator response time of ≥ 1 s regarding unidirectional event	TT1	≤ 1 000	1, 3, 4, 5, 6, 7, 8, 9, 10
P12 ^c	Type 5 message with access control: Transfer times for files are not critical. Typically, the time requirements are in the order of the operator response time (≥ 1 s) or of archives for post-mortem analysis (>> 1 s).	TT0	≤ 10 000	1, 4, 5, 6,7,10

^a equivalent to P5.
^b equivalent to P6.
^c equivalent to P9.

These requirements for the transfer times are valid independently how many intermediate control levels represented by intermediated devices like IEDs and gateways are in between the remote HMI and the IED performing the command on the process. If these command messages propagating over some intermediate control levels from the operator down to the switchgear or to some other controllable object they may be converted, e.g. near process level to messages requesting Type 1 properties but the total transfer time requirements shall be fulfilled.

11.4 Requirements for data and communication quality

11.4.1 General remarks

Requirements for data and communication quality not mentioned explicitly in the first edition of this standard are valid also for communication over the substation LAN but get an increased importance by extending the IEC 61850 communication from LAN to WAN. To facilitate the comparison with the first edition of this standard these requirements are not integrated in the performance clause but kept separately in 11.4.

11.4.2 Data integrity

The background noise and electromagnetic interferences (EMI) may produce in both electronics and communication links errors in the digital data. In substations especially the operation of slow running switches (isolators, earthing switches) creates high frequent noise by flashovers between the contacts which are amplified in GIS enclosures by reflections at the ends. Since electronics for substation automation systems and other power utility automation systems is built in metal closed IEDs which are also mostly installed in screening cubicles, the endangered parts are the communication network in between. Data integrity means that for a given error rate (e.g. caused by noise) the resulting undetected errors (residual error rate) remain below certain acceptable limits.

In communication networks, the resulting data degradation has traditionally been related to the signal noise. In cable-bound optical fibre data networks of high quality such as switched networks, failure modes within devices and transceivers outweigh transient noise on the medium in most cases. Therefore, this approach is not applicable in the same way.

Nevertheless, data integrity is expressed as a function of the residual error rate, regardless of its origin and place of infeed. The noise level is assumed to be given by the operating environment as by HV switchgear in the substation switchyard. Independently from the origin of any disturbance the requirement is the guaranteed residual error rate.

IEC 61850-3 references the three integrity classes (see Table 31) according to IEC 60870-4. IEC 61850-5:2013, 8.3.3 also introduces data integrity as a PICOM attribute. All safety-related messages such as commands and trips with direct impact on the process shall have the highest integrity class, i.e. class 3. All other messages may be transmitted with lower data integrity, but not lower than class 2.

Table 31 – Data integrity classes

Data integrity class	Residual error probability
I1	10^{-6}
I2	10^{-10}
I3	10^{-14}

Normally, the noise level is given by the operating environment and cannot be influenced. To reach nevertheless the requested integrity class defined by the residual error probability (see Table 4), three groups of known measures exist to cope with electromagnetic interference:

- a) Proper design of devices and the communication system to keep bit error probability low, for example, protecting enclosures, properly shielded cables and, most efficiently, use of optical fibre cables at least outside protecting cubicles.
- b) Application of appropriate error detection coding of the data in the telegrams that guarantees residual error probability below the acceptable limit for the given bit error rate. Applying this coding to the signal on the communication link only does not protect however against failures in IEDs. But these are less common as mentioned above.
- c) Use for critical applications of at least two step sequences such as select-before-operate (SBO) for switching commands and appropriate integrity checks if not prohibited by the application functions as for trips from protection.

11.4.3 Reliability

11.4.3.1 Security and dependability

For the various protection schemes the Cigre Technical Brochure 192 (TB192) (see bibliography) addresses the requirements of protection for the teleprotection interfaces and communication channels. The term “teleprotection” refers either to the line protection as such or to the equipment needed to interface the protection equipment to the telecommunication network. This communication links typically between the substations may be used also for non-protective automatics like interlocking. This subclause will focus on communication with the required security and dependability. These requirements are valid both inside and outside the substation if applicable.

11.4.3.2 Security requirements for protection schemes

“Security” S means the security against “unwanted commands” e.g. unwanted trips of protection if these are not requested by the protection scheme in the actual situation. If the probability for unwanted commands is P_{uc} then the security S is defined as

$$S = 1 - P_{uc}$$

Such security requirements for protection schemes with telecommunication are declared in Tables 6-1-1 and 6-1-2 of TB192 as “medium” to “high” with a reference to IEC 60834-1. Figure 21 in IEC 60834-1:1999 shows that P_{uc} shall be less than 10^{-4} for blocking schemes and down to 10^{-8} for inter-tripping schemes. Therefore, the complete communication path including the protection application in the tripping IED shall allow for P_{uc} of lower than 10^{-8} to be usable for inter-tripping protection schemes. The split between the different contributing parts is a matter of modelling and function allocation. These requirements are valid both inside and outside the substation if applicable. The security classes are summarized in Table 32.

Table 32 – Security classes

Security class: $S = 1 - P_{uc}$		P_{uc}	Application
S1	Medium	10^{-4}	Blocking schemes
S2	High	10^{-8}	Inter-tripping schemes

11.4.3.3 Dependability requirements for protection schemes

Dependability D means the dependability against “missing commands” i.e. for protection missing trips if these are requested from the protection scheme in the actual situation. If the probability for missing commands is P_{mc} then the dependability is defined as

$$D = 1 - P_{mc}$$

The “Dependability” requirements for protection schemes with telecommunications are declared in Tables 6-1-1 and 6-1-2 of the TB192 as “medium” to “high” with a reference to IEC 60834-1. IEC 60834-1:1999, Figure 21, shows that P_{mc} should be less than 10^{-2} for permissive under-reach schemes down to 10^{-4} for inter-tripping schemes. Figure 21 shows also that the “maximum actual transmission time” should be < 10 ms for all the protection schemes (see also 11.2.3.1).

Therefore, the complete communication path including the protection application in the tripping IED shall allow for > 10 ms message-latency probability of lower than 10^{-4} to be usable for inter-tripping protection schemes. The split between the different contributing parts is a matter of modelling and function allocation. These requirements are valid both inside and outside the substation if applicable. The dependability classes are summarized in Table 33.

Table 33 – Dependability classes

Dependability class: $D = 1 - P_{mc}$		P_{mc}	Application
D1	Low	10^{-2}	Inter-tripping schemes
D2	Medium	10^{-3}	
D3	High	10^{-4}	Permissive under-reach schemes
D4	Very high	10^{-5}	

11.4.3.4 Availability

11.4.3.4.1 Availability in general

Availability is the probability that a system is operational at a certain point in time. Availability depends on two factors: the failure rate of the elements and the repair rate. While the former can be improved by better quality elements, condition monitoring and redundancy, the latter depends on the maintenance strategy of the operator and is beyond the scope of this standard.

The requested availability level has to be provided already by the system design. It may request in many cases redundant elements. If the designed availability is degraded and gets insufficient, redundant elements have to be automatically activated if possible. If this possibility exists but the activation takes too long, the system under consideration shuts down normally to a safe state. The maximum delay e.g. by communication disruption that the system tolerates is called the grace time. The grace time regarding communication depends on the function that the communication system enables. The recovery delay of the system shall be smaller than its grace time.

The following requirements apply under the single fault criterion i.e. if one fault occurs a second unrelated failure affecting the system is assumed not to occur before the first one is repaired. In particular, common mode failures are expected to be excluded by design (e.g. separate power supplies for pair-wise redundant elements). Under this assumption, the probability of a system failure is given by the probability of a second failure happening before the first one is repaired.

11.4.3.4.2 Substation availability

Substations as nodes in the power system operate round the clock all year round and are very seldom shut down for maintenance. This is valid also for other utility automation systems e.g. for power plants. Live removal and reinsertion of components is commonly required if applicable. This means that the same criteria apply for insertion of redundant components in case of failure as for the reinsertion of repaired components.

In protected power systems, a failure of a protection component may have one of the two results:

- overfunction: the power system is shut down unnecessarily;
- underfunction: the power system is not any more protected; subsequent internal faults or external threats occurring in this state may cause severe losses.

For this second class of protection systems IEC 61508 prefers for “Availability” the notion of “Probability to Fail on Demand” (PFD) that expresses the probability that a system is in an unprotected state when a fault occurs.

11.5 Requirements concerning the communication system

11.5.1 Communication failures

Failures of the communication system may have several effects:

- inability to control part or whole of the plant. This situation can be tolerated for a certain time (e.g. a few seconds depending on the operator requirements) since controlled switching operations are infrequent;
- inability to distinguish the plant state from a fault situation is causing overfunction. For instance, if the communication network is used for current differential protection, failure to compute the difference and check for zero due to unexpected changes in the communication path (sudden change in delay) may trigger the protection trip;
- inability to propagate protection operation in reverse blocking is causing overfunction. For instance, larger parts of the substation than needed may be shut down (loss of selectivity). When the communication system is used directly to operate protection elements, the availability of the communication system is security-(underfunction) relevant. In this case, one should design that these components are completely redundant (e.g. main/backup protection). Regarding the definition of operability of a communication system, two levels of requirements may be distinguished:
- strong operational definition which states that the communication system is operational only when any node can communicate with any other node;
- weak operational definition which states that the communication system is in a degraded but still operational mode when only one node is not operational and this node is not backed up by a redundant one. This assumes that within the substation or the power system independent functional areas may be defined which means that e.g. the failure of a function in one area has no impact on a function in the other.

Given the complexity of substation automation or power utility automation any per-function analysis may be too complex. In substations, the two communication areas to be considered may be the station bus and the process bus with dedicated functionalities. In such a case, the weak definition may be applied. If parts of the functionality of the process bus and station bus are merged on the same communication system the stronger definition applies.

11.5.2 Requirements for station and bay level communication

The communication and their requirements may be grouped. Vertical refers to communication between different control levels, horizontal within the same control level.

- Vertical communication, e.g. between SCADA or telecontrol equipment at station level and IEDs at bay level which serve mainly control and supervision. Communication interruptions may occur as long as they do not disturb the human operator, so the grace time is relatively long but no event shall be lost. The “no event loss” requirement may be covered by a combination of retransmission and event buffering in the IEDs.
- Horizontal communication between IEDs especially at bay level. A disruption of communication shall not cause a loss of control, e.g. that a switch cannot be operated because interlocking assumes due to lack of communication that another switch is in undefined state. In some applications the horizontal communication is also used to execute staggered or reverse blocking. A malfunction of horizontal communication causes then an overfunction since non-faulted parts of the substation or the power

system may be shut down as a precaution since the exact source of the fault cannot be identified. The grace time is therefore quite short.

- The same weak and strong interconnections of functions may happen also beyond the substation.

11.5.3 Requirements for process level communication

For the process level, the term vertical and horizontal cannot be defined unambiguously. Since these services are critical for the operation of the substation, the process has to be designed so that no underfunction may take place. Specific is the need for time-critical transmission of synchronized samples in a data stream. The acceptable recovery time for the sample stream depends on the algorithm; some few sample losses are normally tolerated. If the communication sending single trips to the breaker is interrupted underfunction may happen. Therefore, this interruption shall be detected and handled before the trip happens. Generally, underfunction shall be mitigated by the protection scheme applied.

11.5.4 Requirements for recovery delay

The following table gives an example for recovery delay requirements on an end (sender) to end (receiver) basis in the domain substation automation. If a recovery happens during the stated time, the function is considered to stay available. If recovery lasts longer, the function is considered to be not available. The recovery delay of the communication (as service function) shall be lower than that of the application (as application function to be performed). Examples are given in Table 34.

Table 34 – Requirements for recovery time (examples)

Communicating partners	Application recovery delay	Recovery delay of communication
SCADA to IED, client-server	800 ms	400 ms
IED to IED interlocking	12 ms	4 ms
IED to IED, reverse blocking	8 ms	4 ms
Protection trip excluding Bus Bar protection	8 ms	4 ms
Bus Bar protection	< 1 ms	bumpless
Sampled values	Less than some few consecutive samples	bumpless

NOTE The absolute recovery time is not so important, if a recovery is needed seldom enough, i.e. if even with long recovery times the specified response time is met within the specified dependability class.

11.5.5 Requirements for communication redundancy

Redundancy is not a basic requirement but an option to reach the requested availability. Communication redundancy in substations automation or power plant systems means dual port redundancy. It shall be supported that any IED may have two ports which send and receive data in redundant way. Devices with one port only shall be connectable to a redundant network if applicable. IEDs with dual ports shall not require a dedicated communication configuration compared to the non-redundant ones. Dual port redundancy shall be supported in the same way on all levels if applicable. Redundant communication links may be required also beyond the substation or plant.

One of the goals of the standard is using mainstream communication means referring to the communication stack (coding/decoding). These main-stream communication means may be used also by other communication protocols. To facilitate systems where IEC 61850 subsystems and another subsystems may profit from using the same communication infrastructure, the redundancy shall be based on a common stack level not specific for IEC 61850.

Due to the presence of non-IEC 61850 communication devices or other protocols (see above) any network management necessary shall not rely on stack levels dedicated for IEC 61850. However, results from the supervision shall be reportable as IEC 61850 data.

11.6 System performance requirements

To ensure that the transmission times specified in Clause 10 are met under any operating conditions and contingencies in the substation with the needed dependability, the dynamic performance shall be considered and studied during the planning stage especially in case of burst situations needing process related actions.

IEC TR 61850-1 is defining main types of substations with examples of typical functionality levels. A number of possible bus structures are also presented, the actual communication bus structure shall be selected on the base of requirements and requested performance class, as specified in 11.2.2.

12 Additional requirements for the data model

12.1 Semantics

For interoperability, a data model shall describe the semantics of exchanged data from the user's point of view.

12.2 Logical and physical identification and addressing

The purpose of the utility automation systems is to operate the utility power system. Therefore, the objects of the power system are closely related to these of the power utility automation system and, therefore, shall be used for the identification of the latter one.

Therefore, for the logical addressing scheme in the power utility automation systems – example domain substation automation – the hierarchical name structure and object data dictionary specialized for electrical substations like IEC 81346 series shall be used.

Since communication takes place between Logical Nodes, which are not specifically allocated to devices, each Logical Node (LN) shall be addressable by itself (requirement).

12.3 Self-description

The data model shall support the following features:

- Self-description shall be provided by all devices regarding functions (LNs) and transmittable data. Standardized rules shall allow interoperable extensions within the framework of the standard: – Both will avoid the need of a private range in the standard.
- HMI's need besides the information contained in the data model also text information which should be retrievable out of the system in English and at least optional in the language of the operator. This may request text fields in the data objects of the data model. The presentation of the information itself by the HMI is out of the scope of this standard.
- For an unambiguous machine-machine communication, i.e. for data exchange without operator interference, the data and attribute identifiers shall be understandable for machines without human interpretation.

12.4 Administrative issues

The data model parts hosted by the IEDs should be retrievable by simple procedures.

The data model shall also define data which are important to maintain interoperability over the system life-time cycle like version identification and revision indices.

The data model shall provide also all data for asset management from static name plate information to dynamic information about the condition of the assets.

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

Annex A
(informative)

Logical nodes and related PICOMs

The following examples refer to the domain substation automation.

The PICOMs are defined from the source point of view. For compact description, PICOMs which common to a lot of protection LNs are combined in PICOM groups (see Table A.1).

The LN names used in Table A.2 refer to the abbreviations/acronyms as defined in IEC 61850-5 with the systematic syntax used in IEC 61850 focused on functional requirements (see sub-clause 8.5).

Table A.1 – PICOM groups

Gr	PICOM Name	Source	Sink 1	Sink 2	Sink 3	Sink 4	Sink 5
Fault handling with start (P_fh_1)		P...					
	Start indication	P...	CALH	IHMI	ITCI		
	Trip indication	P...	CALH	IHMI	ITCI	RBRF	
	Trip command	P...	XCBR				
	Settings	P...	IHMI	ITCI	ITMI		
	Fault information	P...	IHMI	ITCI	ITMI		
	<Depending on function/some examples given>	P...					
Fault handling without start (P_fh_2)		P...					
	Trip indication	P...	CALH	IHMI	ITCI	RBRF	
	Trip command	P...	XCBR				
	Settings	P...	IHMI	ITCI	ITMI		
	Fault information	P...	IHMI	ITCI	ITMI		
	<Depending on function/some examples given>	P...					
Fault handling without start and trip (P_fh_3)		P...					
	Trigger indication	P...	CALH	IHMI	ITCI		
	Trigger	P...	P...	R...	A...	C...	
	Settings	P...	IHMI	ITCI	ITMI		
	Fault information	P...	IHMI	ITCI	ITMI		
	<Depending on function/some examples given>	P...					

Table A.2 – Logical node list

LN	PICOM name	Source	Sink 1	Sink 2	Sink 3	Sink 4	Sink 5
Transient earth fault protection		PTEF					
	P_fh_3	PTEF	CALH	IHMI	ITCI	P...R...	A...C...
	<fault signature>	PTEF					
Zero speed and underspeed protection		PZSU					
	P_fh_1	PZSU	CALH	IHMI	ITCI	RBRF	XCBR
	<Rotor locked>	PZSU	CALH	IHMI	ITCI	RBRF	XCBR
	<Underspeed>	PZSU	CALH	IHMI	ITCI	RBRF	XCBR
Distance protection		PDIS					
	P_fh_1	PDIS	CALH	IHMI	ITCI	RBRF	XCBR
	<Fault impedance Z>	PDIS					
	Operated	PDIS	RREC				
	Trigger	PDIS	RDRE	RFLO			
Volt per Hz protection		PVPH					
	P_fh_1	PVPH	CALH	IHMI	ITCI	RBRF	XCBR
Undervoltage protection		PTUV					
	P_fh_1	PTUV	CALH	IHMI	ITCI	RBRF	XCBR
	<minimum voltage>	PTUV					
Directional power /reverse power protection		PDPR					
	P_fh_1	PDPR	CALH	IHMI	ITCI	RBRF	XCBR
	<power direction>	PDPR					
Directional earth fault wattmetric protection		PSDE					
	P_fh_1	PSDE	CALH	IHMI	ITCI	XCBR	
	<fault direction>	PSDE					
Undercurrent/underpower protection		PUCP					
	P_fh_1	PUCP	CALH	IHMI	ITCI	RBRF	XCBR
	<minimum current>	PUCP					
	<minimum power>	PUCP					
Loss of field/underexcitation protection		PUEX					
	P_fh_1	PUEX	CALH	IHMI	ITCI	RBRF	XCBR
	<Field value>	PUEX					
Reverse phase or phase balance current protection		PPBR					
	P_fh_1	PPBR	CALH	IHMI	ITCI	RBRF	XCBR
	<phase sequence>	PPBR					
	<negative phase sequence component>	PPBR					
Phase sequence voltage protection		PPBV					
	P_fh_1	PPBV	CALH	IHMI	ITCI	RBRF	XCBR
	<phase sequence>	PPBV					

Motor start-up protection		PMSU					
P_fh_1		PMSU	CALH	IHMI	ITCI	ZMOT	XCBR
	<Restart inhibited>	PMSU					
	<Restart inhibition time>	PMSU					
Overload protection, thermal protection		PTTR					
P_fh_1		PTTR	CALH	IHMI	ITCI	RBRF	XCBR
	<Actual temperature>	PTTR					
	<Integrated current>	PTTR					
Rotor thermal overload protection		PROL					
P_fh_1		PROL	CALH	IHMI	ITCI	RBRF	XCBR
	<Actual temperature>	PROL					
	<Integrated current>	PROL					
Stator thermal overload protection		PSOL					
P_fh_1		PSOL	CALH	IHMI	ITCI	RBRF	XCBR
	<Actual temperature>	PROL					
	<Integrated current>	PROL					
Instantaneous overcurrent or rate of rise protection		PIOC					
P_fh_1		PIOC	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PIOC					
	<rise of current>	PIOC					
AC time overcurrent relay same holds for		PTOC					
P_fh_1		PTOC	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PTOC					
Voltage controlled/dependent time overcurrent protection		PVOC					
P_fh_1		PVOC	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PVOC					
Power factor protection		PPFR					
P_fh_1		PPFR	CALH	IHMI	ITCI	RBRF	XCBR
	<power factor>	PPFR					
Overvoltage protection		PTOV					
P_fh_1		PTOV	CALH	IHMI	ITCI	RBRF	XCBR
	<maximum voltage>	PTOV					
DC overvoltage protection		PDOV					
P_fh_1		PDOV	CALH	IHMI	ITCI	RBRF	XCBR
Voltage or current balance protection		PVCB					
P_fh_1		PVCB	CALH	IHMI	ITCI	RBRF	XCBR
	<Voltage difference>	PVCB					
Earth fault protection / ground detection		PHIZ					
P_fh_1		PHIZ	CALH	IHMI	ITCI	RBRF	XCBR
	<Zero current>	PHIZ					
Rotor earth fault		PREF					
P_fh_1		PREF	CALH	IHMI	ITCI	RBRF	XCBR
	<Zero current>	PREF					

Stator earth fault		PSEF					
	P_fh_1	PSEF	CALH	IHMI	ITCI	RBRF	XCBR
	<Zero current>	PSEF					
Interturn fault		PITF					
	P_fh_1	PITF	CALH	IHMI	ITCI	RBRF	XCBR
	<Zero current>	PITF					
AC directional overcurrent protection		PDOC					
	P_fh_1	PDOC	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PDOC					
	<direction>	PDOC					
Directional earth fault protection		PDEF					
	P_fh_1	PDEF	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PDEF					
	<direction>	PDEF					
DC time overcurrent		PDCO					
	P_fh_1	PDCO	CALH	IHMI	ITCI	RBRF	XCBR
	<peak current>	PDCO					
Phase angle or out of step (trip) protection		PPAM					
	P_fh_1	PPAM	CALH	IHMI	ITCI	RBRF	XCBR
	<phase angle>	PPAM					
Frequency protection		PFRQ					
	P_fh_1	PFRQ	CALH	IHMI	ITCI	RBRF	XCBR
	<Frequency>	PFRQ					
	<Change of rate>	PFRQ					
	Restoration release	PFRQ	GAPC				
	Shedding request	PFRQ	GAPC				
Differential protection (see below)		PDIF					
Phase comparison protection		PPDF					
	P_fh_1	PPDF	CALH	IHMI	ITCI	RBRF	XCBR
	<phase angle difference>	PPDF					
Line differential protection		PLDF					
	P_fh_2	PLDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Current difference>	PLDF					
	Operated	PLDF	RREC				
	Trigger	PLDF	RDRE				
Restricted earth fault protection		PNDF					
	P_fh_2	PNDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Current difference>	PNDF					
Transformer differential protection		PTDF					
	P_fh_2	PTDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Current difference>	PTDF					

Busbar protection		PBDF					
P_fh_2		PBDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Current difference>	PBDF					
	<Faulted zone information>	PBDF					
Motor differential protection		PMDF					
P_fh_2		PMDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Start-up current>	PMDF					
	<Violating value>	PMDF					
Generator differential protection		PGDF					
P_fh_2		PGDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Current difference>	PGDF	CALH	IHMI	ITCI	RBRF	XCBR
	<Maximum voltage>	PDOV					
Disturbance recording (acquisition at bay/process level)		RDRE					
	Fault record	RDRE	RDRS				
	<time and date of rec.>	RDRE					
	<Cause of rec.>	RDRE					
	<waveform data>	RDRE					
	<current phase 1>	RDRE					
	<current phase 2>	RDRE					
	<current phase 3>	RDRE					
	<voltage phase 1>	RDRE					
	<voltage phase 2>	RDRE					
	<voltage phase 3>	RDRE					
	<Event data>	RDRE					
	<settings>	RDRE					
	<parameters last fault>	RDRE					
	<parameters last fault -1>	RDRE					
	<parameters last fault -2>	RDRE					
	Recorder faulty	RDRE	CALH	IHMI	ITCI	RDRS	
	Recorder memory full	RDRE	CALH	IHMI	ITCI	RDRS	
	Recorder operated	RDRE	CALH	RDRS			
	Trigger	RDRE	RDRE				
	Settings	RDRE	IHMI	ITCI	RDRS		
Disturbance recording (evaluation at station level)		RDRS					
	Date and time	RDRS	RDRE				
	Fault record	RDRS	IARC				
	<time and date of rec.>	RDRS					
	<Cause of rec.>	RDRS					
	<waveform data>	RDRS					
	<current phase 1>	RDRS					
	<current phase 2>	RDRS					
	<current phase 3>	RDRS					
	<voltage phase 1>	RDRS					

	<voltage phase 2>	RDRS					
	<voltage phase 3>	RDRS					
	<Event data>	RDRS					
	<settings>	RDRS					
	<parameters last fault>	RDRS					
	<parameters last fault -1>	RDRS					
	<parameters last fault -2>	RDRS					
	Settings	RDRS	IHMI	ITCI	RDRE		
Automatic reclosing		RREC					
	Alarms	RREC	CALH				
	Events	RREC	CALH				
	Bay auto reclose status	RREC	IHMI	ITCI			
	Commands to circuit breaker directly or via CPOW	RREC	XCBR	CPOW			
	<Close to circuit breaker>	RREC					
	Sync request	RREC	RSYN				
	Command to circuit breaker with controlled switching	RREC	CSWI				
	<Close to circuit breaker>	RREC					
	Settings	RREC	IHMI	ITCI			
Breaker failure		RBRF					
	Fault information	RBRF	IHMI	ITCI			
	Trip indication	RBRF	CALH	IHMI	ITCI		
	Trip command	RBRF	XCBR				
	Settings	RBRF	IHMI	ITCI			
Carrier or pilot wire protection		RCPW					
	P_fh_3	PMDF	CALH	IHMI	ITCI	P...R...	A...C...
Fault locator function		RFLO					
	Fault location	RFLO	IHMI	ITCI			
	Settings	RFLO	IHMI	ITCI			
Synchrocheck		RSYN					
	In synchronism indication	RSYN	CSWI	IHMI	ITCI	RREC	GAPC
	Settings	RSYN	IHMI	ITCI			
Power swing blocking		RPSB					
	P_fh_3	PMDF	CALH	IHMI	ITCI	P...R...	A...C...
Alarm Handling		CALH					
	Function supervision	CALH	IHMI	ITCI	SSYS		
	Alarms (sum)	CALH	IHMI	ITCI			
	Alarm indication	CALH	IHMI	ITCI			
	Alarm list update	CALH	IHMI	ITCI			
	Alarms (list)	CALH	IARC				
	Acknowledge	CALH	IHMI	ITCI			
	Event indication	CALH	IHMI	ITCI			
	Events (sum)	CALH	IHMI	ITCI			
	Event list update	CALH	IHMI	ITCI			
	Events (history list)	CALH	IARC				

	Settings	CALH	IHMI	ITCI			
Switch controller (command handling at bay level)		CSWI					
	Commands to switch directly or via CPOW if applicable	CSWI	X...	XCBR	XSWI	CPOW	
	<switch ON>	CSWI					
	<switch OFF>	CSWI					
	Function supervision	CSWI	CALH	IHMI	ITCI		
	Indications	CSWI	SSYS				
	Events / Position change	CSWI	CALH	IHMI	ITCI		
	Position indications	CSWI	IHMI	ITCI			
	No-operation information	CSWI	IHMI	ITCI			
	Releases	CSWI	IHMI	ITCI			
	Request	CSWI	CILO				
	Sync request	CSWI	RSYN				
	Settings	CSWI	IHMI	ITCI			
Point on wave breaker controller		CPOW					
	Commands to breaker directly	CPOW	XCBR				
	<Breaker ON>	CPOW					
	<Breaker OFF>	CPOW					
	Function supervision	CPOW	CALH	IHMI	ITCI		
	Indications	CPOW	SSYS				
	Events / Position change	CPOW	CALH	IHMI	ITCI		
	Position indications	CPOW	IHMI	ITCI			
	No-operation information	CPOW	IHMI	ITCI			
	Releases	CPOW	IHMI	ITCI			
	Settings	CPOW	IHMI	ITCI			
Interlocking		CILO					
	Events	CILO	CALH	IHMI	ITCI	SSYS	
	Indications	CILO	CSWI	IHMI	(CILO)	SSYS	
	Releases	CILO	CSWI	(CILO)			
	Request	CILO	(CILO)				
	Switchgear position	CILO	(CILO)				
	Settings	CILO	IHMI	ITCI	(CILO)		
Operator Interface at Device or Station Level – same for		IHMI					
Remote control interface (maybe with some restrictions)		ITCI					
	Acknowledge	IHMI	CALH				
	Commands	IHMI	GGIO	GAPC	...		
	Commands to switchgear and transformers	IHMI	CSWI	ATCC			
	Examples	IHMI					
	<Switch ON>	IHMI					
	<Switch OFF>	IHMI					
	<tap changer UP>	IHMI					
	<tap changer DOWN>	IHMI					

IEC 61850-5:2013+AMD1:2022 CSV
Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

	Indications	IHMI	CALH	ITCI	IHMI	ITMI	SSYS
	Settings (for configuration/operation to all LN if applic.)	IHMI	P...	A...	C...	I...	A...
	Settings (for configuration/operation to all LN if applic.)	IHMI	G...	M...	L...	T...	X...
	Settings (for configuration/operation to all LN if applic.)	IHMI	Y...	Z...	S...		
	Examples	IHMI					
	<Date and time>	IHMI					
	<Mode of operation>	IHMI					
	<In service>	IHMI					
	<Reclose release>	IHMI					
	<parameters for CB>	IHMI					
	<parameters for disconnects>	IHMI					
	<parameters for tap changer >	IHMI					
	<parameters for current data acquisition>	IHMI					
Remote monitoring interface		ITMI					
	Acknowledge	ITMI	CALH	IHMI			
	Commands (if applicable/no operation of switchgear)	ITMI	GGIO	GAPC	ATCC	...	
	Settings (for configuration/operation to all LN if applic.)	ITMI	P...	A...	C...	I...	A...
	Settings (for configuration/operation to all LN if applic.)	ITMI	G...	M...	L...	T...	X...
	Settings (for configuration/operation to all LN if applic.)	ITMI	Y...	Z...	S...		
Archiving		IARC					
	Events	IARC	IHMI	ITCI			
	Function supervision	IARC	IHMI	ITCI			
	Indications	IARC	IHMI	ITCI	SSYS		
	Stored values/records	IARC	IHMI	ITCI	ITMI	RDRS	
	<disturbance records>	IARC					
	<statistics>	IARC					
	Settings	IARC	IHMI	ITCI	ITMI		
Automatic tap changer control		ATCC					
	Commands	ATCC					
	<tap changer UP>	ATCC	YLTC				
	<tap changer DOWN>	ATCC	YLTC				
	Switchgear operation	ATCC	CSWI				
	Function supervision	ATCC	CALH	IHMI	ITCI		
	<status M-Process not o.k.>	ATCC					
	<status peripherals units not o.k. >	ATCC					
	<status sub-units>	ATCC					
	<power supply voltage>	ATCC					
	<spontaneous buffer overflow>	ATCC					
	<parallel operation error>	ATCC					
	Operation supervision	ATCC	CALH	IHMI	ITCI		
	<undervoltage>	ATCC					

	<overvoltage>	ATCC					
	<overcurrent>	ATCC					
	Mode of operation	ATCC	IHMI	ITCI			
	<local operation>	ATCC					
	<remote operation>	ATCC					
	<manual operation>	ATCC					
	<automatic operation>	ATCC					
	<single operation>	ATCC					
	<parallel operation>	ATCC					
	Settings	ATCC	IHMI	ITCI			
	<local operation>	ATCC					
	<remote operation>	ATCC					
	<manual operation>	ATCC					
	<automatic operation>	ATCC					
	<undervoltage limit>	ATCC					
	<overvoltage limit>	ATCC					
	<overcurrent limit>	ATCC					
	<selected setpoint>	ATCC					
	<selected line comp.>	ATCC					
Automatic voltage control		AVCC					
	Commands	AVCC					
	<tap changer UP>	AVCC	YLTC				
	<tap changer DOWN>	AVCC	YLTC				
	Function supervision	AVCO	CALH	IHMI	ITCI		
	Mode of operation	AVCO	CALH	IHMI	ITCI		
	Settings	AVCO	IHMI	ITCI			
Reactive control		ARCO					
	Function supervision	ARCO	CALH	IHMI	ITCI		
	Mode of operation	ARCO	CALH	IHMI	ITCI	ZRRC	ZTCR
	Settings	ARCO	IHMI	ITCI			
	Switchgear operation	ARCO	CSWI				
Earth fault neutralizer (Petersen coil) control		ANCR					
	Commands	ANCR					
	<plunge core UP>	ANCR	YEFN				
	<plunge core DOWN>	ANCR	YEFN				
	Function supervision	ANCR	CALH	IHMI	ITCI		
	Mode of operation	ANCR	CALH	IHMI	ITCI		
	Settings	ANCR	IHMI	ITCI			
Zero voltage tripping		AZVT					
	P_fh_2	PGDF	CALH	IHMI	ITCI	RBRF	XCBR
Automatic process control (generic, programmable)		GAPC					
	Examples below:	GAPC					
Load shedding		GAPC					

	Function supervision	GAPC	IHMI	ITCI			
	Mode of operation	GAPC	IHMI	ITCI			
	Operation indication	GAPC	IHMI	ITCI			
	Switchgear operation	GAPC	CSWI				
	Settings	GAPC	IHMI	ITCI			
Infeed transfer switching		GAPC					
	Function supervision	GAPC	IHMI	ITCI			
	Operation indication	GAPC	IHMI	ITCI			
	Switchgear operation	GAPC	CSWI				
	Settings	GAPC	IHMI	ITCI			
Transformer change		GAPC					
	Function supervision	GAPC	IHMI	ITCI			
	Operation indication	GAPC	IHMI	ITCI			
	Switchgear operation	GAPC	CSWI				
	Settings	GAPC	IHMI	ITCI			
Busbar change		GAPC					
	Function supervision	GAPC	CALH	IHMI	ITCI		
	Operation indication	GAPC	CALH	IHMI	ITCI		
	Switchgear operation	GAPC	CSWI				
	Switchgear position	GAPC	IHMI	ITCI			
	Commands	GAPC	CSWI				
	Settings	GAPC	IHMI	ITCI			
Automatic clearing and voltage restoration		GAPC					
	Function supervision	GAPC	CALH	IHMI	ITCI		
	Operation indication	GAPC	IHMI	ITCI			
	Switchgear operation	GAPC	IHMI	ITCI			
	Sync request	GAPC	RSYN				
	Indications	GAPC	IHMI	ITCI			
	Commands	GAPC	CSWI				
	Settings	GAPC	IHMI	ITCI			
Measuring (acquisition and calculation)		MMXU					
	Function supervision	MMXU	CALH	IHMI	ITCI		
	Integrated totals	MMXU	IARC	IHMI	ITCI		
	<energy (quadrant I)>	MMXU					
	<energy (quadrant II)>	MMXU					
	<energy (quadrant III)>	MMXU					
	<energy (quadrant IV)>	MMXU					
	<max power (quadrant I)>	MMXU					
	<max power (quadrant II)>	MMXU					
	<max power (quadrant III)>	MMXU					
	<max power (quadrant IV)>	MMXU					
	Metering values	MMXU	IHMI	ITCI			
	Settings	MMXU	IHMI	ITCI	MMXU		

Metering (acquisition and calculation)		MMTR					
	Function supervision	MMTR	CALH	IHMI	ITCI		
	Integrated totals	MMTR	IARC	IHMI	ITCI		
	<energy (quadrant I)>	MMTR					
	<energy (quadrant II)>	MMTR					
	<energy (quadrant III)>	MMTR					
	<energy (quadrant IV)>	MMTR					
	<max power (quadrant I)>	MMTR					
	<max power (quadrant II)>	MMTR					
	<max power (quadrant III)>	MMTR					
	<max power (quadrant IV)>	MMTR					
	Metering values	MMTR	IHMI	ITCI			
	Settings	MMTR	IHMI	ITCI			
	Reports	MMTR	IHMI	ITCI			
Sequences and imbalances		MSQI					
	Function supervision	MSQI	CALH	IHMI	ITCI		
	Calculated values	MSQI	IARC	IHMI	ITCI		
Harmonics and interharmonics		MHAI					
	Function supervision	MHAI	CALH	IHMI	ITCI		
	Calculated values	MHAI	IARC	IHMI	ITCI		
Logical node device		LLNO					
	ID-data	LLNO	IHMI	ITCI	ITMI		
	<identifiers/...>	LLNO					
	Settings	LLNO	IHMI	ITCI	ITMI		
	<configuration>	LLNO					
General security application		GSAL					
	Events	GSAL	CALH	IHMI	ITCI	ITMI	
	Diagnostic data	GSAL	IHMI	ITCI	ITMI		
Circuit breaker		XCBR					
	Function supervision	XCBR	CALH	IHMI	ITCI		
	<position/blocking for closing>	XCBR					
	<position/blocking for opening>	XCBR					
	<Auto reclosure lockout>	XCBR					
	<main circuit alarm>	XCBR					
	<main circuit warning>	XCBR					
	<auxiliary circuit alarm>	XCBR					
	<auxiliary circuit warning>	XCBR					
	<operating mechanism alarm>	XCBR					
	<operating mechanism warning>	XCBR					
	<power supply alarm>	XCBR					
	<power supply waning>	XCBR					

Events	XCBR	CALH	IHMI	ITCI		
Position indication	XCBR	CSWI	IHMI	ITCI		
<position/CB ON>	XCBR					
<position/CB OFF>	XCBR					
<position/CB INTERMED>	XCBR					
s-t-diagram	XCBR	CSWI	IHMI	ITCI		
Status indications	XCBR	XCBR	IHMI	ITCI		
<local mode>	XCBR					
<remote mode>	XCBR					
<opening time>	XCBR					
<closing time>	XCBR					
<general lockout>	XCBR					
Measurands/counter values	XCBR	TCTR				
<position/operations counter, perm>	XCBR					
<position/operations counter, resetable>	XCBR					
<various data>	XCBR					
Diagnostic data	XCBR	CSWI	IHMI	ITCI		
ID-data	XCBR	CSWI	IHMI	ITCI		
<identifiers/...>	XCBR					
<.../manufacturer id>	XCBR					
<.../HV bay-id>	XCBR					
<.../address>	XCBR					
<.../hardware version>	XCBR					
<.../firmware version>	XCBR					
<.../software version>	XCBR					
<nameplate/...>	XCBR					
<.../rated voltage>	XCBR					
<.../rated lightning impulse withstand voltage>	XCBR					
<.../rated short duration power frequency withstand voltage>	XCBR					
<.../rated frequency>	XCBR					
<.../rated normal current>	XCBR					
<.../rated short time withstand current>	XCBR					
<.../rated breaking-current>	XCBR					
<.../rated duty cycle>	XCBR					
<.../auxiliary voltage>	XCBR					
Settings	XCBR	CSWI	IHMI	ITCI		
Disconnecter/earth switch/...	XSWI					
Function supervision	XSWI	CALH	IHMI	ITCI		
Events	XSWI	CALH	IHMI	ITCI		
Position indication	XSWI	IHMI	ITCI			
<position ON>	XSWI					
<position OFF>	XSWI					
<position INTERMED>	XSWI					
s-t-diagram	XSWI	IHMI	ITCI			

	Settings	XSWI	IHMI	ITCI			
Insulation medium supervision, e.g. GIS-SF6-Mon.		SIMS					
	Function supervision	SIMS	CALH	IHMI	ICTI		
	Alarms	SIMS	CALH	IHMI	ICTI		
	<low pressure 3 alarm>	SIMS					
	Events	SIMS	IHMI	ICTI			
	<over pressure>	SIMS					
	<low pressure 1 warning>	SIMS					
	<low pressure 2 warning>	SIMS					
	Diagnostic data	SIMS	IHMI	ICTI			
	Settings	SIMS	IHMI	ICTI			
GIS-ARC-Monitoring		SARC					
	Function supervision	SARC	CALH	IHMI	ICTI		
	Alarms	SARC	CALH	IHMI	ICTI		
	<alarm ARC occurred>	SARC					
	Events	SARC	CALH	IHMI	ICTI		
	Diagnostic data	SARC	IHMI	ICTI			
	Settings	SARC	CSDA	IHMI	ICTI		
GIS-PD-Monitoring		SPDC					
	Function supervision	SPDC	CALH	IHMI	ICTI		
	Events	SPDC	CALH	IHMI	ICTI		
	<warning PD occurred>	SPDC					
	Diagnostic data	SPDC	IHMI	ICTI			
	Settings	SPDC	IHMI	ICTI			
Current transformer (CT)		TCTR					
	Process value (current sample)	TCTR	P...	R ...	M ...	A ...	
	Settings	TCTR	IHMI	ITCI			
Voltage transformer (VT)		TVTR					
	Process value (voltage sample)	TVTR	P...	R ...	M ...	A ...	
	Settings	TVTR	IHMI	ITCI			
Power transformer		YPTR					
	Function supervision	YPTR	CALH	IHMI	ICTI		
	Events	YPTR	CALH	IHMI	ICTI		
	Settings	YPTR	ATCC	IHMI	ICTI		
Tap changer		YLTC					
	Function supervision	YLTC	CALH	IHMI	ICTI		
	Events	YLTC	CALH	IHMI	ICTI		
	Tap changer motor running	YLTC	ATCC				
	Tap position (BCD)	YLTC	ATCC	IHMI	ICTI		
	Settings	YLTC	ATCC	IHMI	ICTI		
Earth fault neutralizer (Petersen coil)		YEFN					

	Function supervision	YEFN	CALH	IHMI	ITCI		
	Events	YEFN	CALH	IHMI	ITCI		
	Coil changer motor running	YEFN	GAPC				
	Coil position	YEFN	IHMI	ITCI	ITCI		
	Settings	YEFN	GAPC	IHMI	ITCI		
Power shunt		YPSH					
	Function supervision	YPSH	CALH	IHMI	ITCI		
	Events	YPSH	CALH	IHMI	ITCI		
	Shunt switch running	YPSH					
	Shunt position	YPSH	GAPC	IHMI	ITCI		
	Settings	YPSH	GAPC	IHMI	ITCI		
Auxiliary network		ZAXN					
Battery		ZBAT					
Bushing		ZBSH					
HV cable		ZCAB					
Capacitor bank		ZCAP					
Converter		ZCON					
Generator		ZGEN					
Gas isolated line (GIL)		ZGIL					
Power overhead line		ZLIN					
Motor		ZMOT					
Reactor		ZREA					
Rotating reactive component		ZRRC					
Surge arrester		ZSAR					
Thyristor controlled frequency converter		ZTCF					
Thyristor controlled reactive component		ZTCR					
Generic General I/O		GGIO					
	Alarms	GGIO	CALH	IHMI	ITCI		
	Events	GGIO	CALH	IHMI	ITCI		
	Aux. device supervision	GGIO	GAPC	CALH	ARCO	ATCC	
	Indications	GGIO	IHMI	ITCI			
	Settings	GGIO	IHMI	ITCI			
	Status	GGIO	SSYS				
Time synchronization/central clock		STIM					
	Operation indication	STIM	LLN0				
	Time	STIM	All if applic.				
System supervision		SSYS					
	Events	SSYS	IHMI	ITCI	CALH		
	Function supervision	SSYS	IHMI	ITCI			
	Indications	SSYS	IHMI	ITCI	SSYS		
	Failure	SSYS	CALH	IHMI	ITCI		

	Restart unit operation	SSYS	CALH	IHMI	ITCI		
	Stop unit operation	SSYS	CALH	IHMI	ITCI		
	Unit buffer overflow	SSYS	CALH	IHMI	ITCI		
	Urgent error	SSYS	CALH	IHMI	ITCI		
Test generator		GTES					
	Test message	GTES	All if applic.				

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

Annex B (informative)

PICOM identification and message classification

B.1 General

- 1) The LN names used refer to the abbreviations/acronyms as defined in IEC 61850-5 with the systematic syntax used in IEC 61850 focused on functional requirements (see 8.5).
- 2) The communication between LNs is described by the exchange of thousands of individual PICOMs. Nevertheless, there are a lot of similarities between these PICOMs, e.g. all PICOMs describing trips have besides the individual sources more or less the identical communication requirements as described by the PICOM attributes. Therefore, a classification of PICOMs would both allow getting a comprehensive overview on the requirements and supporting a strong modelling and definition of the requested communication performance.
- 3) In a first step, all PICOMs from the most LNs are identified by semantics (Table B.1) and allocated to a PICOM message type (Table B.2) using a common purpose and having common attributes. The result is found in Clause B.2 below.
- 4) The resulting PICOM types with its most important common attributes are given in the Table B.3 below. The broad range of transfer time requirements reflects the individual needs of the functions. Since the higher ones always cover lower requirements, the requirements may be condensed in figures for the message types introduced below.
- 5) Essential for a proper running of functions and crucial for any performance a requirement of the supporting communication system is the maximum time allowed for the data exchange. In the context of the standard, this time is called "overall transfer time" and had been clearly defined in 11.2.1.2.
- 6) In 8.3, the PICOM types had been more condensed to 7 message types and the range of its attributes is structured by performance classes. Some hints to typical applications and interface allocation had been given also.
- 7) The introduction and use of message types had been described in 11.2.2.1, the introduction and use of performance classes in 11.2.2.2.

IECNORM.COM : Click to view the PDF of IEC 61850-5:2013+AMD1:2022 CSV

B.2 Identification and type allocation of PICOMs

Table B.1 – PICOM identification (Part 1)

PICOM TYPE ID ^a	1	5	6	7	10	10	12	12	22	24	9	10	17	19	16	13	18	12	10	10	10	10	11	26	10
	Current/voltage (samples)	Non-electric process data	Fault information (short)	Fault info (long)	Start indication	Trip indication	Operated	Trigger	Trip command	Settings	Fault record	Recorder memory full	In service	Mode of operation	Status	Station interlocking	External conditions	Synchronism detected	Fuse failure detected	Group alarm	Alarm indication	Alarm list update	Alarm list	Acknowledgement	Alarm
P... (Protection)			X	X	X	X	X	X	X	X															
RDRE (Dist.Rec.Bay)							X	X		X	X														
RDRS (Dist.Eva.Stat.)										X	X														
RREC (Autom.Recl.)										X		X	X	X											X
RBRF (Breaker fail.)			X			X			X	X															
RCPW (Carr./pilot w.r.)																									
RFLO (Fault locator)			X	X						X															
RSYN (Synchrocheck)										X							X								
RPSB (Power sw. bl.)																									
CALH (Alarm handl.)										X									X	X	X	X	X		
CSWI (Switch controller)										X															
CILO (Interlocking)										X															
ATCC (Tap changer controller)										X															
IHMI (human mach.int.)										X		X	X												X
ITCI (Telecontrol int.)										X		X	X												X
ITMI (Telemon.) Int.)										X			X												X
IARC (Archiving)			X	X						X	X														
AVCO (Volt. Control)										X			X	X											
ARCO (Reactive cont.)										X			X												
ANCR (earth fault n.) n.).C.)																									
AZVT (Zero voltage tripping)			X	X	X	X	X	X	X	X															
GAPC (Aut.proc.con.)										X			X	X											

^a PICOM TYPE ID gives a rough classification of all requested PICOM according to their attributes.

Table B.2 – PICOM identification (Part 2)

PICOM TYPE ID ^a	1	5	6	7	10	10	12	12	22	24	9	10	17	19	16	13	18	12	10	10	10	10	11	26	10			
													19		17			10		11		11						
PICOMs by semantics																												
LOGICAL NODE	Current/voltage	Non-electric process	Fault information	Fault info (long)	Start indication	Trip indication	Operated	Trigger	Trip command	Settings	Fault record	Recorder memory full	In service	Mode of operation	Status	Station interlocking	External conditions	Synchronism detected	Fuse failure detected	Group alarm	Alarm indication	Alarm list update	Alarm list	Acknowledgement	Alarm			
MMXU (Measuring)										X							X		X	X								
MMTR (Metering)										X																		
MSQI (Sequences ...)										X							X		X	X								
MHAI (Harmonics ...)										X							X		X	X								
LLN0 (Device supervision & identification)							X																			X		
GSAL (General security application identification)			X							X											X						X	
XCBR (Circuit breaker)								X		X																		
XSWI (Disconnecter)										X																		
SIMS (Ins. med. sup.)										X																	X	
SARC (Arc detection)										X																	X	
SPDC (Part.Discharge)										X																	X	
TCTR (Current transf.)	X									X																		
TVTR (Voltage transf.)	X									X																		
YPTR (Power transf.)		X						X		X																		
YLTC (Tap changer)															X												X	
YEFN (Earth fault neutr., Petersen coil)																												
YPSH (Power shunt)																												
ZGEN (Generator)		X								X					X												X	
ZTCF (Thyr. contr.c.)		X								X					X												X	
ZCON (Converter)		X								X					X												X	
ZMOT (Motor)		X								X					X												X	
ZSAR (Surge arrester)		X								X					X												X	
ZTCR (Thyr. contr. reac. Element)	X									X					X												X	
ZRRC (Rot. Contr. reac.)	X									X					X												X	
ZCAP (Capacitor bank)	X									X					X												X	
ZREA (Reactor)	X									X					X												X	
ZCAB (Cable mon.)	X	X								X					X												X	
ZGIL (Gas isol. line)	X	X								X					X												X	
ZLIN (Power OH line)	X	X								X					X												X	
ZBAT (Battery)	X	X								X					X												X	
ZAXN (Aux. network)	X	X								X					X												X	
GGIO (Generic I/O)	X		X					X		X					X		X										X	
STIM (Time master)										X																		
SSYS (Syst. Supervis.)				X				X		X																	X	
GTES (Test Generator)																												

^a PICOM TYPE ID gives a rough classification of all requested PICOM according to their attributes.

Table B.3 – PICOM allocation (Part 1)

PICOM TYPE ID ^a	1	1	1	1	1	2	2	1	1	2	2	1	1	1	1	1	1	4	4	6	9	2	4	2	2
	0	0	0	1	0	7	8	0	0	1	1	0	6	7	2	4	4	4	4	6	9	5	4	5	4
PICOMs by message type	1	1	1									1													
LOGICAL NODE	Event indication	Group event	Event list update	Event list archive	Event	Date and time	Synchronization (clock)	Recorder faulty	Function supervision	Command to switchgear	Command to aux. Devices	Indications	Position indications	No-operation information	Releases	Request to ITL	Request to SYNC	Integrated totals	Metered values	Reports	Archived data	S-t-diagram	Counter values	Diagnostic data	ID data
P... (Protection)																									
RDRE (Dist.Rec.Bay)								X																	
RDRS (Dist.Eva.Stat.)					X		X																		
RREC (Autom.Recl.)				X				X	X							X									
RBRF (Breaker fail.)																									
RCPW (Carr./pilot w.r.)																									
RFLO (Fault locator)																									
RSYN (Synchrocheck)																									
RPSB (Power sw. bl.)																									
CALH (Alarm handl.)	X	X	X	X		X	X		X																
CSWI (Switch controller)				X				X	X		X	X	X	X	X	X	X								
CILO (Interlocking)									X			X		X		X									
ATCC (Tap changer controller)				X				X		X	X	X	X												
IHMI (human mach.int.)					X	X			X	X	X				X										
ITCI (Telecontrol int.)					X				X	X					X										
ITMI (Telemon. Int.)					X										X										
IARC (Archiving)				X				X			X										X				
AVCO (Volt. control)								X	X	X		X													
ARCO (Reactive cont.)								X	X																
ANCR (earth fault n.) n.).C.)																									
AZVT (Zero voltage tripping)																									
GAPC (Aut.proc.con.)									X	X		X	X			X	X								

^a PICOM TYPE ID gives a rough classification of all requested PICOM according to their attributes.

PICOM TYPE ID ^a	1	1	1	1	1	2	2	1	1	2	2	1	1	1	1	1	4	4	6	9	2	4	2	2
	0	0	0	1	0	7	8	0	0	1	1	0	6	7	2	4	4	4	4	6	9	5	5	5
PICOMs by message type		1	1									1												
LOGICAL NODE	Event indication	1	1									1												
	Group event	1	1									2												
	Event list update																							
	Event list archive																							
	Event																							
	Date and time																							
	Synchronization (clock)																							
	Recorder faulty																							
	Function supervision																							
	Command to switchgear																							
	Command to aux. Devices																							
	Indications																							
	Position indications																							
	No-operation information																							
	Releases																							
	Request to ITL																							
	Request to SYNC																							
	Integrated totals																							
	Metered values																							
	Reports																							
	Archived data																							
	S-t-diagram																							
	Counter values																							
	Diagnostic data																							
	ID data																							
ZGIL (Gas isol. line)					X				X														X	
ZLIN (Power OH line)	X	X								X						X								X
ZBAT (Battery)					X				X														X	
ZAXN (Aux. network)	X	X								X						X								X
GGIO (Generic I/O)					X				X	X	X	X	X	X	X								X	X
STIM (Time master)						X	X																	
SSYS (Syst. Supervis.)					X				X			X												
GTES (Test Generator)																								

^a PICOM TYPE ID gives a rough classification of all requested PICOM according to their attributes.

The PICOM types appearing by the decomposition of logical nodes into PICOMs according to the PICOM table are summarized in the following table with their range of attributes:

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

Table B.5 – PICOM types

PICOM TYPE ID	Meaning of PICOM and its value attribute ^a	Type Mode	Number of value attributes combined – range – typically figures	Size of value attribute in bits ^b	Transfer time ^c (response/cycle) – range – typically figure given in ms	Message type ^d
1	Process value (sample)	Value Cyclic	1 – 8 1, 2, 3, 5	16	– 10, 0,1, 0,5, 1,2,5,10	4 ^a
2	Process value (rms)	Value Cyclic	1 – 8 1, 2, 3, 5	16	– 1 000, 50, 100, 500, 1 000	2 ^b
3	Measured value (calculated) like energy	Value Cyclic Requ.	1 – 64, 4, 6, 64	16	– 1 000, 100, 500, 1 000	3
4	Metered value (calculated) like energy	Value Cyclic Requ.	1 – 512 1, 512	16	– 1 000, 100, 500, 1 000	3
5	Process value (non-electrical) like temperature	Value Cyclic	1 – 8 1	16	1 000 – 5 000 1 000, 5 000	3 ^c
6	Report (calculated) like energy list	File Requ.	1	1 024	1 000 – 5 000 1 000, 5 000	5
7	Fault value (calculated) like fault distance	Value Requ.	1 – 2 1	16	1 000 – 5 000 1 000, 5 000	3
8	Mixed fault info (calculated) extensive	File Requ.	1	512	1 000 – 5 000 1 000, 5 000	5
9	Mixed fault data (calculated) like disturbance rec.	File Requ.	1	20 000 200 000	5 000	5
10	Event/alarm	Event Spont.	1 – 16 1	1	100 – 1 000 100, 500, 1000	3 ^d
11	Event/alarm list/group	File Spont. Requ.	1	128 1 024	100 – 1 000 100, 500, 1 000	5
12	Trigger (calc.) e.g. for start of another function	Event Spont.	1	1	10 – 1 000 10, 50, 100, 1 000	1
13	Complex block or release (calculated)	Event Spont.	1	16	10 – 100 10, 100	1
14	Request (calc.) for sync, interlock, etc.	Event Spont. Requ.	1	1	10 – 100 10, 100	2
15	Fast broadcast Message, e.g. for block/release	Event Spont.	1	1	1 1	1

^a By basic definition, a PICOM consists of one data element (value only). Some of these basic data elements may be combined if this makes sense from the application point of view.

^b Without time tag; no requirement but some idea about the net data and input for data flow calculations.

^c Definition see 12.2.

^d According to 12.4.

PICOM TYPE ID	Meaning of PICOM and its value attribute ¹	Type Mode	Number of value attributes combined - range - typically figures	Size of value attribute in bits ²	Transfer time ³ (response/cycle) - range - typically figure given in ms	Message type ⁴
16	Process state	Status Requ. Cyclic	1	1	1 – 100 1, 10, 20, 50, 100	2 ^e
17	Calculated state	Status Requ.	1	1	1 – 100 1, 10, 20, 50, 100	2 ^e
18	External condition	Status Requ. Cyclic	1	1	1 – 100 1, 10, 20, 50, 100	2 ^e
19	Mode of operation	Status Requ. Cyclic	1	1 16	10 – 100 10, 100	3
20	Process state changed	Event Spont.	1	1	1 – 10 1, 10	1
21	Command	Cmd. Spont.	1, 5	1	1 – 1 000 1, 2, 5, 10, 50, 100, 1 000	7 ^f
22	Trip	Cmd. Spont.	1	1	1	1
23	Set point	Value Spont.	1	16	100 – 1 000 100, 1 000	3
24	ID data, setting	File Spont. Requ.	1	1 024	1 000 – 5 000 1 000, 5 000	5
25	Diagnostic data	File Spont. Requ.	1	1 024	5 000	5
26	Acknowledge by operator or auto.	Cmd. Spont.	1	1	10 – 1 000 10, 100, 1 000	3
27	Date and time	Value Cyclic Requ.	1	32	100 – 1 000 100, 1 000	3
28	Synchronization "pulse"	Cmd. Cycl.	1	1	0,1 – 10, 0,1, 0,5, 1, 2, 5, 10	6

¹ By basic definition, a PICOM consists of one data element (value only). Some of these basic data elements may be combined if this makes sense from the application point of view.

² Without time tag; no requirement but some idea about the net data and input for data flow calculations.

³ Definition see 12.2.

⁴ According to 12.4.

^a Accuracy 25 μs or less.

^b In future, some values regarding power quality maybe of message type 1a.

^c Special values like pressure may be need message type 2.

^d Alarms and events as seen from the alarm and event handling, automatics may need message class 2.

^e For some fast functions, message type 1 may be requested.

^f The command message created as type 7 by the operator may be propagate at lower levels faster, e.g. according to type 1 on the process bus like a trip.

Annex C (informative)

Communication optimization

Retaining full flexibility but to reduce the load on the communication system the following principles have to be considered.

Instead of asking cyclically for data (polling) there should be an appropriate use of event driven spontaneous transfers and time driven continuous data streams between the logical nodes to keep the load limited,

Allow for transmission of long comprehensive data description in the initialization phase and short identifiers in the operative phase. The initialization phase may also be seen as the engineering phase of the communication system and handled by proper tools and configuration files.

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

Annex D (informative)

Rules for function definition

D.1 Function definition

To get the communication requirements on the basis of the LN and PICOM approach, the function definition consists of three steps.

- function description including the decomposition into LNs,
- logical node description including the exchanged PICOMs,
- PICOM description including the attributes.

D.2 Function description

D.2.1 Task of the function

For each function a description is given to understand its task within the substation automation system independently of its distribution into LNs. This clause shall specify the context needed for the execution of the function also.

D.2.2 Starting criteria for the function

There is always some reason why a specific function is initiated, e.g.

- a human operator starts this function via an HMI,
- another function sends a request (typical of automatics),
- a status change in the process triggers this function (typical of protection).

This start reason has to be defined.

D.2.3 Result or impact of the function

Any function results either in some change of the process (e.g. by switching a breaker), in some trigger for another function or in some notification of the human operator. This result or impact has to be defined.

D.2.4 Performance of the function

This subclause shall define the requested overall performance of the function from a system and application point of view. Examples: Total requested response time of the function by adding up the starting time, the internal processing time, the overall transfer time per PICOM, and the delay time in the related process interface. It means that the pure data transfer time on the communication link has to be shorter than this figure. Additional performance criteria are e.g. the accuracy for the synchronization needed.

D.2.5 Function decomposition

This subclause shall describe how the function may be decomposed in LNs and how many decomposition sets exist typically.

D.2.6 Interaction with other functions

Data may be exchanged with other functions. These data and its importance for the function under consideration shall be stated.

D.3 Logical node description

D.3.1 General

For each LN a description is given to understand its task within the overall function. This clause shall also specify the context needed for the execution of the LN.

D.3.2 Starting criteria

This subclause shall identify the starting criteria and other inputs of the LN from a communication point of view.

D.4 PICOM description

D.4.1 Input and outputs by PICOMs

The input and outputs of the LN are described by the data to be exchanged, i.e. by PICOMs with all related attributes as given in 8.3.

Inputs may be start, trip, block, settings, fault record, fault information, time tagged events, supervision alarm, position indication, position indication, commands, and request for information, etc.

The meaning of starting criteria and inputs depends on the LN in consideration.

- Data coming from (input) and data going to (output) the communication network are described informally here. This means data with all related application attributes but without implementation or coding rules.
- The sending LN is the source, the receiving LN is the sink of data stated within the context of the overall function.
- The receiving LN has to know what it needs, i.e., it shall be able to check if the delivered data are complete and valid for performing its task. It has to be able to check the quality of the incoming data including its age. Therefore, all data have to be time tagged, if the communication system is not delivering data in well-defined time slots (implicit time tagging). Each sending LN has to identify possible doubts about the quality of the data sent and issue error messages if applicable.

D.4.2 Operation modes

Other LNs of distributed functions have to be informed about any degradation by a PICOM. If the receiver has enough time, a request for sending valid data could be sent. Nevertheless, the reaction in case of degraded data exchange has to provide a fail-safe behaviour of the function. A PICOM is also required for return to normal mode.

The detailed sequential behaviour of the distributed LNs is beyond the scope of this standard. The requirement for interoperable communication between distributed LNs shall be based on standardization of syntax, semantics and quality of the data to be exchanged.

D.4.3 Performance

The performance requirements for the communication in substations are based on the performance attributes of the PICOMs.

Annex E (informative)

Interaction of functions and logical nodes

The interaction between application functions is described by the interaction of the related LNs.

There are basically two types of interaction between LNs.

- Informative interactions: The exchanged data provide some information. The exchanged data are no prerequisite for the performance of the LN and, therefore, the LNs stay autonomously. Functions composed by such LNs are often called local functions or stand-alone functions.
- Functional interactions: The exchanged data are needed for performing the functions, they are not autonomous. Functions composed by such LNs are often called distributed functions.

IECNORM.COM : Click to view the full PDF of IEC 61850-5:2013+AMD1:2022 CSV

Annex F **(informative)**

Functions

F.1 System support functions

F.1.1 Network management

F.1.1.1 Task

Network management is needed to configure and maintain the communication network. The communication network is composed out of nodes.

The basic task is the node identification. Both the addition and the removal of a node have to be detected. All nodes have allocated identification and status information. The network management evaluates this information. The identification of a node is distributed with broadcast service, when the node gets on-line. A human operator or a system may request the identification of the logical node.

F.1.1.2 Starting criteria

There are different starting criteria

- set up or restart of the system,
- operator request from an HMI,
- addition of a physical or logical node,
- call by a configuration manager.

F.1.1.3 Result

All nodes are identified and configured to a system. The actual status of all physical devices (LN0) and logical nodes is known. The actual status and the data traffic for all physical and logical links between the LNs are known. Degraded nodes and links are detected and their impact on the system is minimized. The resources of the communication network are properly shared. Interoperability is supported by the means of the network. The system is a reliable and safe status.

F.1.1.4 Performance

Depending on the different performance requirements for the communication, different performance levels for the network management function are allowed. The range of these levels is between 1 ms and 1 min.

To reach a very high availability, the node identification times should be very short. They shall be same as the self-check times. Depending on the function of interest, they will be in the order of seconds or minutes.

F.1.1.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN, system supervision SSYS.

F.1.1.6 Interaction

Physical device self-checking, configuration management, operative mode control of LN, alarm management, event management.

F.1.2 Time synchronization

F.1.2.1 Task

Time synchronization is used for the synchronization of the devices within the system. One LN with a precision time source acts as the time master. A second LN of the same type may be defined to act as a backup time master. The time is provided normally by an external source (radio or satellite clock).

Time synchronization consists of two subtasks:

- setting of absolute time in the distributed nodes by the time master or via HMI. This task is done by mapping the time from the user layer to the application layer,
- continuous synchronization of the clocks in the distributed nodes. For the requested high efficiency this task is done preferentially by means provided by the protocol stack already (somewhere between application and link layer).

Therefore, the time synchronization method shall be standardized per stack.

F.1.2.2 Starting criteria

System start-up, continuous clock messages, changes by HMI.

F.1.2.3 Result

The time in all devices of the system is synchronized with the requested accuracy.

F.1.2.4 Performance

For the accuracy of time requirements, classes are defined in 11.1.1.6 of the body of this document.

NOTE 1 These are functional requirements. It is up to the implementation if e.g. the time synchronizing of the clocks in IEDs has to be one order of magnitude better than requested by the functional requirements.

NOTE 2 These figures can be matched only if both the time synchronization and the tagging mechanism within the IEDs provide this performance but is supported by the communication services also.

F.1.2.5 Decomposition

External time source providing time synchronization with the appropriate accuracy level:

Time master STIM, device clock in LLN0.

F.1.2.6 Interaction

No direct interaction, but time synchronization is important for functions like synchronized switching, event management, distributed synchrocheck, sampling of CT/VT data.

F.1.3 Physical device self-checking

F.1.3.1 Task

The self-check detects, if a physical device is fully operational, partially operational or not operational. More detailed information is proprietary and available via generic services.

If a human operator or a system supervision function requests a self-check from a device, a link shall be established to the LN, which is related to common device properties (LN0).

If a human operator or a system supervision function wants to be spontaneously informed about changes of self-check information, he has to establish a link to this device common LN0 and subscribe this self-check information.

The LN common for the physical device performs in regular intervals a self-check on device level.

F.1.3.2 Starting criteria

System start-up, event driven status messages, request by HMI or system supervision function.

F.1.3.3 Result

Self-check information is an output of this provided to the requesting user.

F.1.3.4 Performance

To reach a very high availability the self-check times should be very short. Depending on the function of interest, they will be in the order of seconds or minutes.

F.1.3.5 Decomposition

IHMI, ITCI, ITMI, LLN0, SSYS, CALH.

F.1.3.6 Interaction

Network management

System configuration or maintenance functions

F.1.4 Software management

F.1.4.1 Task

The functions are implemented by software. The software management function is used to:

- download software to a device;
- upload software from a device;
- get the list of software contained on a device and their identification;
- activate the software.

The requesting human operator or system supervision function shall be informed of the result of its request (accepted or failed). There is no back-up procedure in case of failure.

Software to be loaded is considered as a single file from the communication point of view. Software identification is manufacturer specific and considered as a string.

Some operational performances of the device may be affected during software downloading and shall be specified by the manufacturer.

Starting the software and reading its status are part of another function („Operative mode control of LN“).

F.1.4.2 Starting criteria

The starting criterion is a request. It is motivated e.g. by the download of a new release adding functions or fixing bugs and/or extending the functionality.

F.1.4.3 Result

The device will be ready for the execution of the new software.

F.1.4.4 Performance

Software download shall be less than 5 min.

F.1.4.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN, SSYS.

F.1.4.6 Interaction

Configuration management, operative mode control of LN, access security management.

F.1.5 Configuration management**F.1.5.1 Task**

A device may contain one or more databases in order to customize and co-ordinate its behaviour with the rest of the system.

The function is used to:

- download a database to a device,
- upload a database from a device,
- get the list of databases contained on a device, their identification and their status,
- change the status of a database in a device,
- activation or deactivation of the configuration data.

The requesting human operator or system supervision function shall be informed of the result of its request (accepted or failed). There is no back-up procedure in case of failure.

Each database is considered as a single file from the communication point of view. Database identification is manufacturer specific and considered as a string.

The status of a database is:

- loaded,
- ready to be executed,
- executed.

The database is first loaded. A second step is to make it ready to be executed. When entering into the executing step, the previous executed database, if any, is replaced by the new one. The previous one enters in the ready to execute state. It may then be uploaded.

Operational performances of the device should not be affected during software downloading and when changing the executed database from one to another. The continuity of service has to be maintained. If operational performances are affected it shall be specified by the manufacturer in detail.

F.1.5.2 Starting criteria

The starting criterion is a request. It is motivated by the download of a new database adding functions, fixing bugs or substation extension/modification.

F.1.5.3 Result

The device will be using the new database.

F.1.5.4 Performance

Database download shall be less than 5 min. Switching between two databases shall be less than 1 min.

F.1.5.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN, SSYS.

F.1.5.6 Interaction

Network management, software management, operative mode control of LN, data retrieval.

F.1.6 Operative mode control of logical nodes**F.1.6.1 Task**

The operative mode control function allows an authorized operator to start and stop any logical node in the system or to get its status to control and supervise the behaviour of the system.

The status of a LN is one of the following:

- Not existent. The equipment does not know the LN. Therefore, no communication takes place at all, also not LN supervision and system information.
- Stopped. The LN is known by the equipment but is idle. No communication regarding the function of the LN takes place in neither direction. Only LN supervision information is exchanged which is needed to maintain the status “known”.
- Started. The LN is known by the equipment and is performing its tasks with no restriction. Full communications in both directions (send & receive).
- Maintenance. The LN is known by the equipment and is performing its tasks with some restrictions (local resources corrupted, change of a parameter under processing, ...). The data exchange is restricted. The most common examples are
 - full or limited data exchange but with indication of test status,
 - blocking of control direction to avoid outputs to the process during testing etc.,
 - blocking of the monitoring direction to avoid unnecessary alarms,
 - blocking of both communication directions during local tests of the LN function.

Logical links are only permitted with LN that are started or in maintenance modes.

The operator is able to:

- get the list and status of the LN supported by equipment,
- subscribe to the status of one or more LN supported by equipment,
- start a LN when stopped,
- stop a LN when started,
- force a LN into maintenance when started,
- resume a LN when in maintenance.

NOTE This function is only permitted after completion of the security check function (authorization).

F.1.6.2 Starting criteria

Operator request e.g. for initialization of a device or reconfiguration of the system.

F.1.6.3 Result

The device will be running.

F.1.6.4 Performance

Less than 1 s.

F.1.6.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN.

F.1.6.6 Interaction

Network management, software management, and configuration management.

F.1.7 Setting**F.1.7.1 Task**

The setting function allows an operator to read and to change one or more parameters affecting the behaviour of the functionality represented by the LN.

The changes of values will become active after the operator has read back what has been sent, confirmed his settings, and the application has then successfully performed a consistency check on its setting values. This allows changing multiple interrelated parameters without violating their consistency.

Depending on the setting and the implementation of the application, the operator may be obliged to force the LN or the application into maintenance mode during the change of the settings. The standard does not specify the cases where this shall be done, but permit a LN or an application to answer that a given setting change needs to 'freeze' it first.

To avoid setting conflicts in case that several operators attempt to change simultaneously the settings of an LN, for changing a change session has to be opened with the LN, and only one change session can be open at the moment. Multiple reading, however, is allowed.

An application on a LN may have several possible parameter sets, but only one active set. It is possible to switch the active set to any of the defined sets. How many sets are possible respective defined, is implementation dependent, but shall be shown as an application parameter. Switching of the active set needs not a change session but is a single operation step, so that no problem with multiple access occurs. But parameter set switching shall be blocked, if a change session is open.

The function does not specify the list of parameters that can be set, but only the way of doing it.

Change of settings shall be protected by state-of-the-art means. Use of access security means for reading or switching of active set is optional (customer requirement).

Previous setting values of an LN shall be stored, and a fall back to previous values shall be possible, if either the application consistency check refuses the new values, or if after some time the new values prove to be insufficient. It is recommended to archive more than only the last released parameter set for possible reuse / fall back (e.g. the three last ones). It is not prescribed where these sets are archived. Common sense would store the last released one on the LN, and all others on the operator HMI side.

F.1.7.2 Starting criteria

The setting function is started by a human operator.

Switching of active parameter sets can be started by a human operator, or by some automatic function based on change of state.

F.1.7.3 Result

The possible results are

- information of human operator about existing and active parameters on all LN applications,
- changed settings for some LN applications,
- changed active parameter set for some LN application.

F.1.7.4 Performance

The communication performance should allow feedback of read values within 1 s, sending value sets and read back within 2 s. A consistency check on a confirmed new set or a switching of the active set may last several seconds depending on the application and its implementation. Performance is not critical (i.e. above are average values, not worst case).

F.1.7.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN.

F.1.7.6 Interaction

Automatic process functions like Automatic protection adaptation may trigger the Setting as parameter set switching, which is interlocked against the parameter setting session. Since setting refers to any LN, there is an interaction with all functions.

F.1.8 Test mode

F.1.8.1 Task

The test mode function allows the local or remote operator to check at any time any function of the system using process signals also but avoiding any impact on the process (blocking of process outputs).

F.1.8.2 Starting criteria

Operator request.

F.1.8.3 Result

Positive or negative test results provide information to the operator what functions or parts of the system are in proper operation.

F.1.8.4 Performance

Test sequence depending on the functionality to be tested. Test analysis shall be within the human operator response time (about 1 s). Detailed evaluation may take much more time.

F.1.8.5 Decomposition

IHMI, ITCI, ITMI, LLN0, GTES, any other LN.

F.1.8.6 Interaction

Access security management, Alarm management, Event management, and Operative mode control.

F.1.9 System security management**F.1.9.1 Task**

The system security management function allows to control and to supervise the security of the system against unauthorized access and loss of activity. The function monitors and provides all activities regarding security violations.

F.1.9.2 Starting criteria

System start.

F.1.9.3 Result

All security relevant data including are logged, the security level has to be known at any time. Dedicated data may result in immediate blocking of sensitive functions like the attempted system access. The operator or system supervisor is informed by an alarm.

F.1.9.4 Performance

The security supervision function shall be as comprehensive as possible. In case of endangered security, blocking shall be issued immediately (10 ms). Any alarm shall be provided within the human operator response time (about 1 s).

F.1.9.5 Decomposition

IHMI, ITCI, ITMI, LLN0, GSAL, CALH.

F.1.9.6 Interaction

Network management, access security management, alarm management, and event management.

F.2 Operational or control functions**F.2.1 Access security management****F.2.1.1 Task**

The human access to functions or the related LNs, especially to operational functions, has to be controlled by a set of rules. The access security management for automatic data exchange between the different LNs is handled during the system configuration by the function node identification. The access security management as described here is related to HMI type of users only.

The set of rules define:

- Authentication:

The accessed LN is responsible for ensuring that the user has the authority to use the LN application. The LN shall support authentication. In certain circumstances (for example sensitive information retrieval or high security control) an encryption procedure may be used in conjunction with authentication. The user authentication process allows the LN to differentiate between users (for example substation operators, administrators, maintenance staff, etc.) and then allows the LN to model different access rights for these users.

- Access control

Access control is to provide the capability to restrict an authenticated user to a pre-determined set of services and object attributes. Access control is implemented using privileges:

- A **create** authorization allows the user to create certain classes of application objects within the specific LN.
- A **delete** authorization allows the user to delete application objects within the specific LN.
- A **view** authorization allows the user to acquire details concerning the existence of an object and the object definition.
- A **set/write** authorization allows the user to set attribute values of an object.
- A **get/read** authorization allows the user to get attribute values of an object.
- An **execute** authorization allows the user to execute the permitted application service.

Each LN shall provide access types of users with an allocated set of access rights. The sets of access rights may be defined by:

- The type of action: control of the process, control of the system, maintenance of the system, etc.
- The area of knowledge of the operator: protection, control, etc.
- The level of expertise of the operator: manager, substation operator, administrator, etc.
- The name of the bay or diameter, or equipment, or voltage level concerned, when a substation controlled by a same system is shared by different customers, etc.

Access control authorization may be dynamically altered and has to allow resolving conflicting requirements of multiple users.

F.2.1.2 Starting criteria

There are different starting criteria:

- log in of an operator, selection of an action in the user node,
- authentication is performed at the time when the user is linked to the LN,
- access control is validated at the time of an access to an object or service.

F.2.1.3 Result

Authentication is reported with either a positive response or a negative response to the user. A negative response will cause all subsequent object or service access requests to be rejected with a not authenticated error code.

Access control to an object or service, after successful authentication, is reported with either a positive response or a negative response to the user. A negative response will include an error code to indicate the reason for access denial.

F.2.1.4 Performance

Not critical to the security management, but shall meet the demands of the LN application.

F.2.1.5 Decomposition

IHMI, ITCI, ITMI, LLN0, any other LN.

F.2.1.6 Interaction

All functions with operator access.

F.2.2 Control**F.2.2.1 Task**

Control function allows an operator or an automatic function to operate HV/MV equipment like switchgear or transformer and any auxiliary equipment in the substation. The control is applied to a controlled item.

Control function is used to:

- Open or Close a breaker, disconnecter or earthing switch.
- Raise or Lower a transformer tap,
- Set to On or Off a LV equipment.

Control function may optionally include a "Select" step, used to check that the control may be valid and to eventually lock a resource.

Control is subject to miscellaneous filters that check that there will be no damage if the control is issued. These functions are listed under „System control functions“ and include (optional per control):

- Control unity (on the controlled item, in the bay, in the voltage level, in the substation).
- Interlock validity. Interlocking is a parallel function that delivers a status to enable or disable a control (if interlock is set to on). The control message may contain an interlock violation status to bypass it.
- Synchrocheck validity. When closing a breaker, the synchrocheck will verify some electro-technical conditions and enable or not the control depending of its type.
- Time validity. The control contains a time attribute that specifies the time limit for issuing the control. This avoids issuing an old control that would have been stacked into the network.
- Locked status. A controlled item may be under lock status when the substation is partly into maintenance mode. This prohibits any control on a breaker if an operator is performing some repair on the line for example. Note that locking an item is an example of control.
- Control authorization. This is needed if an operator expects to control an item to check his authorization.
- Substation and bay mode status. The substation automation shall be in remote mode to enable remote control (i.e. from SCADA) and in local mode to enable control issued inside the substation. The bay mode shall be in remote mode to enable control from the station level or remote control level (SCADA).
- State of the controlled item. The control shall lead the controlled item into an authorized state (for example, it is impossible to open an open disconnecter). When the controlled item is in an unknown state (double point status have the same value for example), this filter is optionally suppressed.

Control is cancelled if one of these filters is not verified or if a cancel order is received from the control point.