BSI Standards Publication

# Communication networks and systems for power utility automation

## Part 5: Communication requirements for functions and device models

bsi.

...making excellence a habit.™

## National foreword

This British Standard is the UK implementation of EN 61850-5:2013. It is identical to IEC 61850-5:2013. It supersedes BS EN 61850-5:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/57, Power systems management and associated information exchange.

A list of organizations represented on this committee can be obtained on request to its secretary.

Published by BSI Standards Limited 2013

ISBN 978 0 580 75141 7

ICS 33.200

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2013.

### Amendments issued since publication

| Amd. No. | Date | Text affected |
|---|---|---|

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

**EN 61850-5**

May 2013

ICS 33.200

Supersedes EN 61850-5:2003

English version

# Communication networks and systems for power utility automation - Part 5: Communication requirements for functions and device models

(IEC 61850-5:2013)

Réseaux et systèmes de communication pour l'automatisation des systèmes électriques -
Partie 5: Exigences de communication pour les modèles de fonctions et d'appareils
(CEI 61850-5:2013)

Kommunikationsnetze und -systeme für die Automatisierung in der elektrischen Energieversorgung -
Teil 5: Kommunikationsanforderungen für Funktionen und Gerätemodelle
(IEC 61850-5:2013)

This European Standard was approved by CENELEC on 2013-03-06. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

**Management Centre: Avenue Marnix 17, B - 1000 Brussels**

---

Ref. No. EN 61850-5:2013 E

## Foreword

The text of document 57/1286/FDIS, future edition 2 of IEC 61850-5, prepared by IEC/TC 57 "Power systems management and associated information exchange" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61850-5:2013.

The following dates are fixed:

| | | |
|---|---|---|
| • latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2013-12-06 |
| • latest date by which the national standards conflicting with the document have to be withdrawn | (dow) | 2016-03-06 |

This document supersedes EN 61850-5:2003.

EN 61850-5:2013 includes the following significant technical changes with respect to EN 61850-5:2003:

- extension from substation automation systems to utility automation systems;
- including the interfaces for communication between substations (interfaces 2 and 11);
- requirements from communication beyond the boundary of the substation.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

## Endorsement notice

The text of the International Standard IEC 61850-5:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | | |
|---|---|---|
| IEC 60834-1:1999 | NOTE | Harmonised as EN 60834-1. |
| IEC 60870-5 Series | NOTE | Harmonised as EN 60870-5 Series (not modified). |
| IEC 61000-4-30 | NOTE | Harmonised as EN 61000-4-30. |
| IEC 61850-3 | NOTE | Harmonised as EN 61850-3. |
| IEC 61850-7 Series | NOTE | Harmonised as EN 61850-7 Series (not modified). |
| IEC 61850-7-1 | NOTE | Harmonised as EN 61850-7-1. |
| IEC 61850-7-2 | NOTE | Harmonised as EN 61850-7-2. |
| IEC 61850-7-3 | NOTE | Harmonised as EN 61850-7-3. |
| IEC 61850-7-4 | NOTE | Harmonised as EN 61850-7-4. |
| IEC 61850-8 Series | NOTE | Only Part 8-1 is Harmonised as EN 61850-8-1. |
| IEC 61850-9 Series | NOTE | Harmonised as EN 61850-9-2 Series (not modified). |
| IEC 61850-10 | NOTE | Harmonised as EN 61850-10. |

## Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 61000-4-15 | - | Electromagnetic compatibility (EMC) - Part 4-15: Testing and measurement techniques - Flickermeter - Functional and design specifications | EN 61000-4-15 | - |
| IEC/TS 61850-2 | - | Communication networks and systems in substations - Part 2: Glossary | - | - |
| IEC 61850-6 | - | Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs | EN 61850-6 | - |
| IEC 81346 | Series | Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations | EN 81346 | Series |
| Cigre JWG 34./35.11 | 2007 | Protection using telecommunication, Cigre Technical Brochure (TB) 192 | - | - |

## CONTENTS

# INTRODUCTION

This part of IEC 61850 is part of 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 vendor 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.

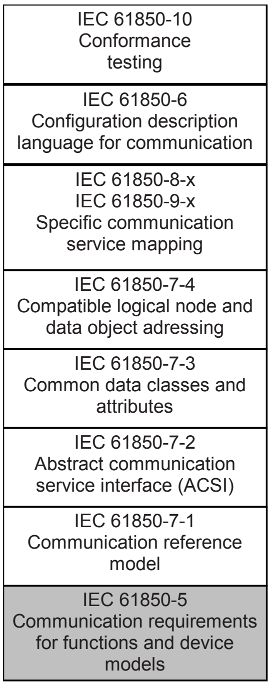
The standard series shall be long living but allow following the fast changes in communication technology by both its technical approach and its document structure. Figure 1 shows the relationship of Part 5 to subsequent parts of IEC 61850 series.

The standard series IEC 61850 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 Part 5 will not change the requirements defined in Part 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 Part 5 of the standard IEC 61850 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 Part 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 Part 8 and Part 9. A System configuration language (Part 6) for strong formal description of the system usable for software tools and a standardized conformance testing (Part 10) complement the standard. Figure 1 shows the general structure of the documents of IEC 61850 as well as the position of the clauses defined in this document.

NOTE 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 Part 5 (requirements). In Parts 7 (modelling), 8 and 9 (specific communication service mapping) terms belonging to application requirements like PICOM are normally not used.



*IEC 2379/12*

**Figure 1 – Relative position of this part of the standard**

# COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

## Part 5: Communication requirements for functions and device models

## 1 Scope

This part of IEC 61850 applies to power utility automation systems with the core part of substation automation systems (SAS). It standardizes the communication between intelligent electronic devices (IEDs) and defines the related system requirements to be supported.

The specifications of this part refer to the communication requirements of the functions in power automation systems. Most examples of functions and their communication requirements in this part are originated primarily from the substation automation domain and may be reused or extended for other domains within power utility automation if applicable. 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) is regarded.

The description of the functions is not used to standardize the functions, but to identify communication requirements between Intelligent Electronic Devices within plants and substations in the power system, between such stations s (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. Also 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.

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

The same or similar intelligent electronic devices from substations like protective and control devices are found in other installations like power plants also. Using this standard 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 IEC 61850 series have been already defined and published.

## 2 Normative references

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

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

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

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

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

Cigre JWG 34./35.11 – *Protection using Telecommunication, Cigre Technical Brochure (TB) 192* (111 pages), 2007

## 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.

### 3.1 General

**3.1.1**
**application function**
task, which is performed in or by power utility automation systems

Note 1 to entry: Generally, a 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**
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**
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, 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 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 functions 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 also requirement attributes like performance and was adopted from CIGRE 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

object where standardized data for communication are grouped in 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 functions. The granularity stops at the smallest function parts which may be implemented as single-stand-alone functions acting also as atomic building blocks for complex 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 than 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 applications functions of the power utility automation system.

### 3.2 Connections

#### 3.2.1
#### logical connection

communication link between 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 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: These data exchange is not visible and cannot be used by other IEDs therefore not requesting interoperability. It should be noted that by distributing combined 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 vendor, or different vendors, 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 prerequisite for interchangeability (see 3.3.2).

### 3.3.2
**interchangeability**
the possibility to replace an IED from the same vendor or from different vendors providing the same functionality with no impact on the rest of the system

Note 1 to entry: Interchangeability requires standardization of 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 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 functions which exceed at least the boundary of one substation or plant

Note 1 to entry: A plant is a line protection, a telecontrol, a telemonitoring, etc.

### 3.5.2

**station level functions**

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**

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 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 IEC 61850 series.

Note 2 to entry: Bay is defined in 3.4.1.

### 3.5.4

**process level functions**

all functions interfacing to the process, i.e. basically binary and analogue I/O functions like data acquisition (including sampling) and issuing of commands

Note 1 to entry: These functions communicate via the logical interfaces 4 and 5 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**

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 8.

### 3.5.6

**interface related station level functions**

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 1 and 6 with the bay level and via the logical interface 7 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 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 of 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 functions 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

| | |
|---|---|
| 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 |
| TCI | Telecontrol Interface (for example, to NCC) |
| TMI | Telemonitoring Interface (for example, to engineers workplace) |
| WAN | Wide Area Network |

## 5 Power utility automation functions

### 5.1 General

The power utility functions refer to tasks which have to be performed by the utility power 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 nodes in the power grid, the power 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 functions and device models.

## 5.2 Example substation automation system

### 5.2.1 General

The functions of a substation automation system (SAS) refer to tasks which have to be performed in the substation. These are functions to control, monitor and protect the equipment of the substation and its feeders. In addition, there exist 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 functions and interfaces

The 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 11.

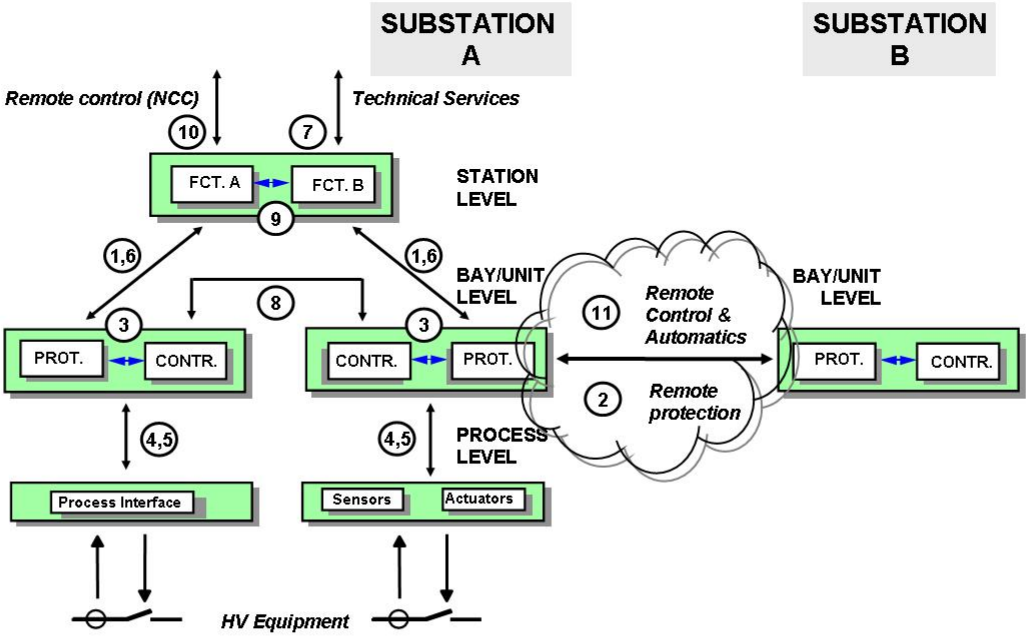
Process level functions are all functions interfacing to the process. These functions communicate via the logical interfaces 4 and 5 to the bay level.

Bay level functions (see bay definition above) are functions using mainly the data of one bay and acting mainly on the primary equipment of one bay. These 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 IEC 61850 series.

There are two classes of station level functions:

Process related station level functions are 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 functions communicate mainly via the logical interface 8.

Interface related station level functions are 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.



IEC 2380/12

**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: 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 fast functions like interlocking

IF9: data exchange within station level

IF10: control-data exchange between the substation and remote 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

The cloud around IF2 and IF11 indicates that there may be also an external communication system applied which is not according to the data model and the services defined in IEC 61850 series.

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

NOTE The distribution of the functions in a communication environment can 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.

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 functions HMI, TCI and TMI. All other station level 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 station wide 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 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 may be moved physically down to the process level supported by the free allocation of functions.

If there are no serial interfaces 4 and 5, the process level functions are implemented in the bay level devices. The realization of the serial 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 function 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 and 11 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: Very common, the interfaces 1, 6, 3, 9, 8 are combined to the station/interbay 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 take over the role of interface 8 also, at least for raw data.

The interface 7 is dedicated for external communication with a remote monitoring centre. It could be realized by a direct interface to the station/interbay 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 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 and 11. 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 functions applied. Differences are the longer communication distance and the transparent use of an external communication system with higher or lower bandwidth which may increase the transmission delay.

### 5.3.2 Substation – Network Control

The communication between the substation and the network control centre 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 analogue values (calculated values e.g. for the energy flow) have to be exchanged depending on the functions applied Differences are the longer communication distance and the transparent use of an external communication system with higher or lower bandwidth which may increase the transmission delay.

### 5.3.3 Wind

Basic applications 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

Distributed energy resources (DER) refer to any kind of power generation with the exception of thermal, nuclear, wind and water. Typical examples are diesel generators or photovoltaic systems. This means either a rotating generation part (e.g. diesel engine as primary mover and connected generator) or a solar power collecting. Automation system for distributed energy resources may have also an interface to some higher level power control system similar as interface 10 in substations.

# 6 Goal and requirements

## 6.1 Interoperability

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

Interoperability has the following levels for devices from different suppliers:

a) the devices shall be connectable to a common bus with a common protocol (syntax);
b) the devices shall understand the information provided by other devices (semantics);
c) the devices shall perform together a common or joint function if applicable (distributed functions).

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.

### 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 able being 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 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 functions. This allows fulfilling different system design philosophies and enabling future improvements.
b) The functions of the power utility automation system and their communication behaviour shall be described device independent i.e. from the implementation in IEDs.
c) The 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 functions itself is outside the scope of this standard.
d) 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.
e) The interaction of device independent distributed 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.
f) The functions used today and their communication requirements are well known but the standard shall be open also for communication requirements arising from future functions.
g) To keep interoperability there shall be minimum number of protocols defined in Parts 8-x and 9-x as valid at one time.
h) To reach interoperability in projects with real IEDs connectors depending on the communication medium should be defined.
i) 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 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.
d) The maximal allowed transfer times shall fulfil the requirements of the 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 is dependent on a lot of parameters from design and production to function and system engineering. As far as the communication processes of the standard are touched they shall allow reaching the highest safety class requested.
h) The protection against cyber-attacks belongs also to the data integrity. Proper means shall avoid or minimize such kind of risks. The needed measures like encryption 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 functions, 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”, “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 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 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 functions to be performed in power systems and, especially, in substations are identified in the following 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 suppliers 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.

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 the standard 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 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 which may be exchanged between engineering tools. Therefore, they have to fulfil with some minimum requirements regarding the exchange of these files. Definitions of the configurations files and minimum tool requirements are found in IEC 61850-6.

Definitions of the conformance tests applicable are given in IEC 61850-10-x series.

## 7 Categories of functions

### 7.1 General

Different categories of 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 in the following 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 process. These support the total system. These functions are performed continuously in the background of the system normally. Their goal is a well running system with synchronized nodes. Examples:

- network management,
- time synchronization,
- physical device self-checking.

### 7.3 System configuration or maintenance functions

Those 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 one second (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 functions are needed for the normal operation of the substation or plant every day. In these 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 response times of the operational functions and, therefore, of the related communication have not to be much faster than one second (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” function means 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 system.

These 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,
  - Examples: overcurrent function, distance protection,
- bay interlocking,
- measuring, metering and power quality monitoring.

## 7.6 Distributed process automation functions

“Distributed” function means 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, providing 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 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 security related to avoid damage for people or equipment. Normally, they consider information from the whole plant or substation and are maybe implemented locally or distributed. Since the distributed solution especially calls for the standardization of communication, these functions are listed here. The local versions 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)
  - 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 the IEC 61850-5.

## 8 Function description and function requirements

### 8.1 Approach

To get the communication requirements in a substation or plant, an identification of all functions is necessary. IEDs contain a lot of simple and complex functions different from supplier to supplier. The identification of functions has to be done independently from the implementation of IEDs. Additionally the functions have to be split in pieces with indivisible core functionality which may be implemented by alone 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 where the functions are implemented.

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

## 8.2 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 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 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 CIGRE WG34.03 are used to describe the information 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 transm.: | to be used for<br>– LN input queues (if more than one)<br>– 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 11.3) |

### 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: I 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 an implementation available.

## 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 functions, the data of all 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 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.

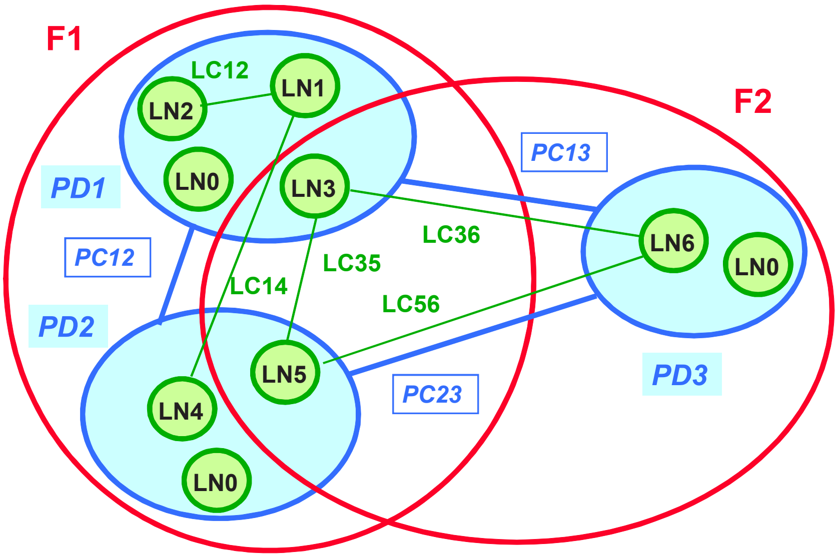
This naming of LNs is given here only to understand the Figures below. The names of the Logical Nodes shall be mnemonic regarding to the functions allocated.

The Logical Nodes representing at the boundary of the automation system 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

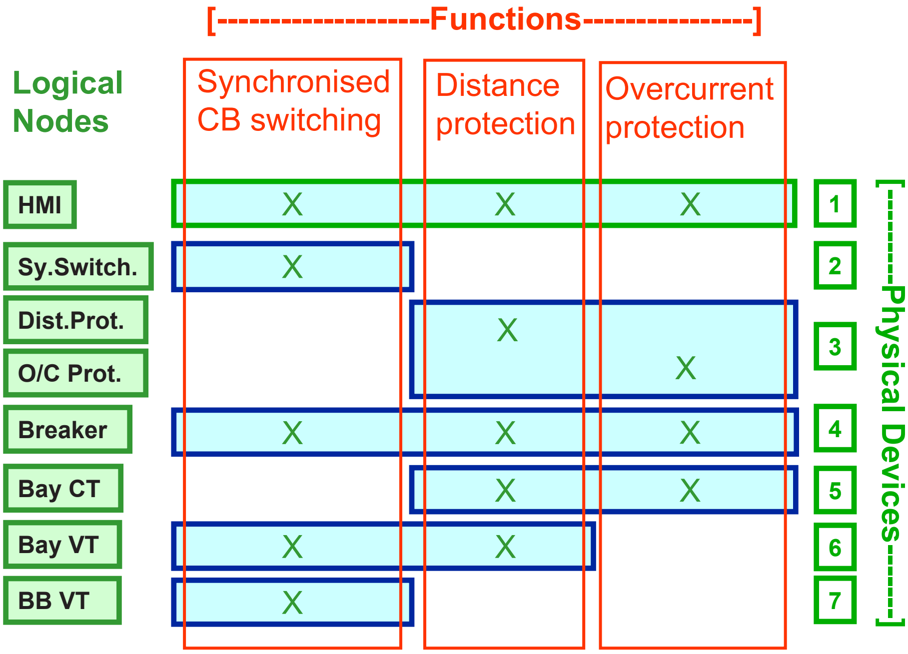
In Figure 4, examples of common functions out of the domain substation are given

- 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

a) station computer,
b) synchronized switching device,
c) distance protection unit with integrated overcurrent function,
d) bay control unit,
e) current instrument transformer,
f) voltage instrument transformer,
g) 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 functions

Most of the functions may be represented by three logical nodes in minimum, i.e. the LN with the data of the core functionality itself, the LN with the process interface data and the LN for the data of 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”).

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 CIGRE 34.03 is a list of logical nodes according to definitions in IEC 61850 series. The standardization of functions in substations or plants 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).

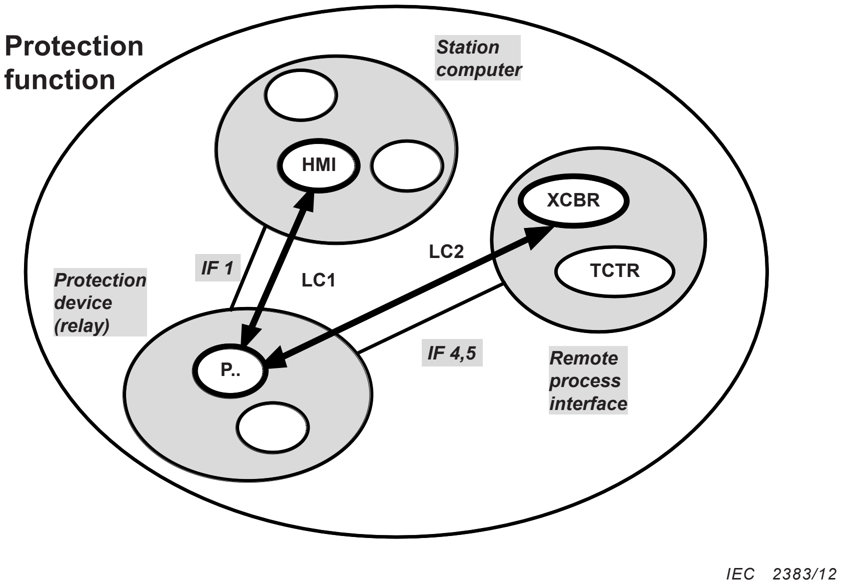


**Figure 5 – Protection function consisting of 3 logical nodes**

The 3 Logical Nodes (IHMI, P..=protection, XCBR=circuit breaker to be tripped) reside in 3 physical devices (Station computer, Protection device and Remote process interface). The Logical Node names are the same as introduced in the tables below.

### 8.5.2 Explanation to tables

The following table 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** means the IEC graphical symbols according to IEC 60617 in the alphanumeric representation if available.

**IEEE** 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 abbreviations/acronyms as defined in IEC 61850-7-4.

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

### 8.5.3 Protection

| Functionality allocated to LN | IEC | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Transient earth fault protection | | | Transient earth faults happen 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)<br>(67N) | This function is used for directional earth fault handling 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.<br>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 in a power plant. This protection will typically be included in the excitation system. | **PTHF** | **PTHF** | Thyristor protection |
| Protection trip conditioning | | | This LN shall be used to connect the “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. | **PTRC** | **PTRC** | Protection trip conditioning |
| Checking or interlocking relay | | 3 | A function that issues a release or a block for a command in response to the position of one or more other devices or predetermined conditions.<br>in a piece of equipment or circuit, to allow an operating sequence to proceed, or to stop, or to provide check of the position of these devices or conditions for any purpose<br>This LN belongs to the group of Logical Nodes for Control, see 8.5.5. | **CILO** | **CILO** | Interlocking |
| Over speed protection | $\omega>$ | 12 | A function that operates on machine overspeed. | **POVS** | | |
| Zero speed and under speed protection | $\omega<$ | 14 | A 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 | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Distance protection | $Z<$ | 21 | A function that operates when the circuit admittance, impedance, or reactance increases or decreases beyond a predetermined value.<br>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. | **PDIS** | **PDIS** | Distance protection |
| | | | | | **PSCH** | Protection Scheme |
| Volt per Hz protection | | 24 | Voltage per Hertz relay is a relay that functions when the ratio of voltage to frequency exceeds a preset value. The relay may have an instantaneous or a time characteristic.<br>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. | **PVPH** | **PVPH** | Volts per Hz |
| Synchronism check | | 25 | A function that produces a closing for a circuit breaker closing command for connection 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 relay permits the paralleling of two circuits that are within prescribed (usually wider) limits of voltage magnitude, phase angle, and frequency.<br>This LN belongs to the group of Logical Nodes for Protection related functions, see 8.5.4. | **RSYN** | **RSYN** | Synchronism-check |
| Over temperature protection | $\vartheta>$ | 26 | A 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. | **PTTR** | **PTTR** | Thermal overload |
| (Time) Undervoltage protection | $U<$ | 27 | A function that operates when its input voltage is less than a predetermined value. | **PTUV** | **PTUV** | Undervoltage |
| Directional power /reverse power protection | $\vec{P} >$ | 32 | A 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. | **PDPR** | **PDOP** | Directional over power |
| | | | | | **PDUP** | Directional under power |

| Functionality allocated to LN | IEC | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Undercurrent/ underpower protection | $P<$ | 37 | Undercurrent or underpower relay is a relay that functions when the current or power flow decreases below a predetermined value.<br>A function that operates when the current or power flow decreases below a predetermined value. | **PUCP** | **PTUC** | Under current |
| | | | | | **PDUP** | Directional under power |
| Loss of field/ Underexcitation protection | | 40 | A function that operates upon a given or abnormally high or low value or failure of machine field current, or<br>on an excessive value of the reactive component of armature current in an a.c. machine indicating abnormally high or low field excitation.<br>Underexcitation results in under power. | **PUEX** | **PDUP** | Directional under power |
| | | | | | **PDIS** | (Distance) Impedance |
| Reverse phase or phase balance current protection,<br>Negative sequence current relay | $I_2>$ | 46 | A 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,<br>Negative sequence voltage relay | $U_2>$ | 47 | A 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) A 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.<br>(49) See below (PTTR/49)<br>(51LR) See below (PTOC/51)<br>(66) See below (----/66)<br>→ These protection prevents any overload of the motor | **PMSU** | **PMRI** | Motor restart inhibition |
| | | | | | **PMSS** | Motor starting time supervision |
| Thermal overload protection | $\Theta>$ | 49 | A 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 |

| Functionality allocated to LN | IEC | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Rotor protection | | 49R<br>64R<br>(40)<br>50<br>51 | (49) See above (PTTR/49)<br>(64) See below (PHIZ/64).<br>(40) See above (PUEX/40)<br>(50) See below (PIOC/50)<br>(51) See below (PTOC/51)<br>This LN shall be used to represent a field short-circuit protection based on the 6th harmonic (300 Hz). The protection is normally included in the excitation system. | **PROT** | **PTTR** | Thermal overload |
| | | | | | **PTOC** | Time overcurrent |
| | | | | | **PHIZ** | Ground detector |
| | | | | | **PDUP** | Directional under power |
| | | | | | **PDIS** | Distance (impedance) |
| Stator thermal overload protection | | 49S | See above (49) | **PSOL** | **PTTR** | Thermal overload |
| Instantaneous overcurrent or rate of rise protection | *I>>* | 50 | A 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<br>51 | A function that operates when the a.c. 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 | See above (PTOC/51) with voltage control/dependency. | **PVOC** | **PVOC** | Voltage controlled time overcurrent |
| Power factor protection | $\cos\varphi>$<br>$\cos\varphi<$ | 55 | A function that operates when the power factor in an a.c. circuit rises above or falls below a predetermined value | **PPFR** | **POPF** | Over power factor |
| | | | | | **PUPF** | Under power factor |
| (Time) Overvoltage protection | *U>* | 59 | A 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 | A device that operates on a given difference in voltage, or current input or output, of two circuits. | **PVCB** | **PTOV** | Overvoltage |
| | | | | | **PTOC** | Time overcurrent |

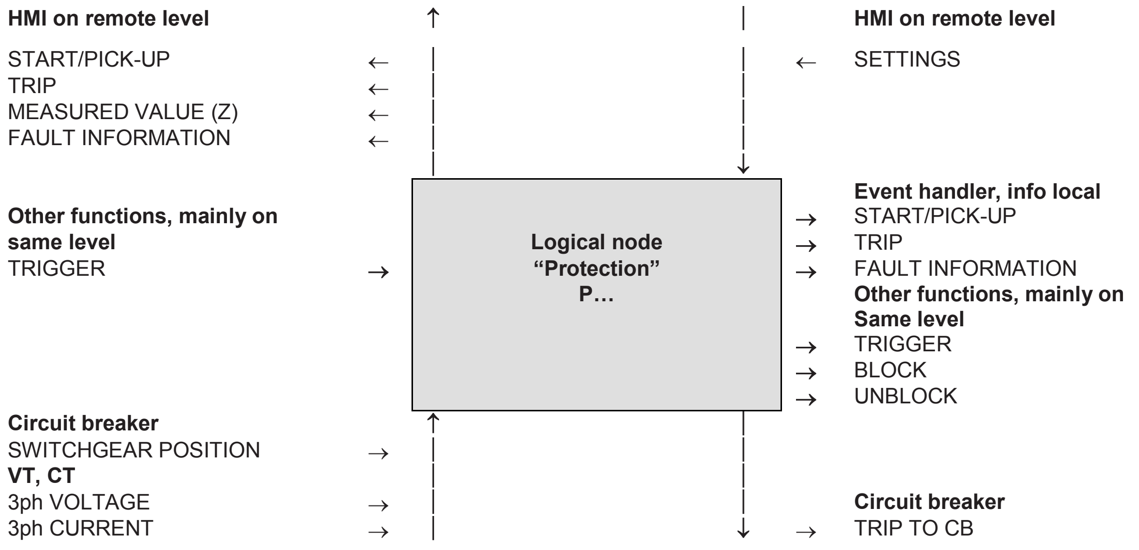
| Functionality allocated to LN | IEC | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Earth fault protection,<br>Ground detection | $I_E>$ | 64 | A function that operates upon the insulation failure of a machine or other apparatus to ground.<br>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 a.c. time overcurrent function operating at a desired value of a.c. overcurrent flowing in a predetermined direction of the secondary neutral of the current transformers. | **PHIZ** | **PTOC** | Time overcurrent |
| | | | | | **PHIZ** | Ground detector |
| 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<br>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 | A function that operates at a desired value of a.c. overcurrent flowing in a predetermined direction. | **PDOC** | **PTOC** | Time overcurrent |
| Directional protection | | 87B | 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.<br>NOTE In the comparison table provided in IEEE C37.2-2008 PDIR has the IEEE device number 87B 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 | A function that operates when the current in a d.c. circuit exceeds a given value. | **PDCO** | **PTOC** | Time overcurrent |
| Phase angle or out-of-step protection | $\varphi>$ | 78 | A 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 |

| Functionality allocated to LN | IEC | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|---|
| Frequency protection | | 81 | A 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 |
| | | 7 | | | **PFRC** | Rate of change of frequency |
| Differential protection | | 87 | A function that operates on a percentage, phase angle, or other quantitative difference of two or more currents or other electrical quantities. | **PDIF** | **PDIF** | Differential (Impedance) |
| Busbar protection[a] | | 87B | 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. | **PBDF** | **PDIF** | Differential |
| | | | | | **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 |
| 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 |

[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.

[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.

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



*IEC 2384/12*

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

Data from and to the process (switchgear XCBR, c.t. TCTR, v.t. 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 Logical nodes for protection related functions

| Logical node | IEC | IEEE | Description or comments | LN function | LN class | LN Class naming |
|---|---|---|---|---|---|---|
| Disturbance recording (bay/process level: acquisition) | | | Acquisition functions 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) | | | The disturbance recording evaluation 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 |
| | | | | | **RBDR** | Disturbance recorder channel binary |
| Automatic reclosing | | 79 | A function that controls the automatic reclosing and locking out of an a.c. circuit breaker.<br>After any successful protection trip the automatic reclosing function tries 1 to 3 times to reclose the open breaker again with different time delays assuming a transient fault. | **RREC** | **RREC** | Autoreclosing |
| Breaker failure | | 50BF | A 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 monitoring breaker failure function.<br>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. | **RBRF** | **RBRF** | Breaker failure |
| Carrier or pilot wire protection[a] | | 85 | A function that is operated, restrained, or has its function modified by communications transmitted or received via any media used for relaying. | **RCPW** | **PSCH** | Protection scheme |
| Fault locator | | | The fault locator calculates out of the protection information (e.g. the fault impedance of the LN distance function) the location of the fault in km. | **RFLO** | **RFLO** | Fault locator |
| Synchrocheck/ Synchronizing or Synchronism-Check | | 25 | A synchronizing function that produces an release for a closing commend 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.<br>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. | **RSYN** | **RSYN** | Synchronism-check |

| Logical node | IEC | IEEE | Description or comments | LN function | LN class | LN Class naming |
|---|---|---|---|---|---|---|
| Power swing blocking | | 78 | 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 |
| 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 provide 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 designation (C37.2). 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 |

[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.

### 8.5.5 Control

| Logical node | IEEE | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|---|
| Alarm handling (Creation of group alarms and group events) | | For the communication, there is no difference between alarms and events, if a time tag is added to any data transmitted.<br>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.<br>Remote acknowledgement with different priority and authority shall be possible.<br>The definition and handling of alarms is an engineering issue. | **CALH** | **CALH** | |
| Switch controller controls any switchgear, i.e. the devices described by XCBR and XSWI | | The switch control LN handles all switchgear operations from the operators and from related automatics. It checks the authorization of the commands. It supervises the command execution and gives an alarm in case if improper ending of the command. It asks for releases from interlocking, synchrocheck, autoreclosure, etc. if applicable. | **CSWI** | **CSWI** | |
| Point-on-wave breaker controller controls a circuit breaker with point-on-wave switching capability | | The point-on-wave breaker controller LN provides all 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 request either from CSWI or RREC. For closing normally it compares similar as RSYN the voltages on both sides of the breaker to get the minimum stress. This holds also if one of the voltages is zero. For opening the point of minimum stress is calculated referring to the zero crossing of current wave.<br>Normally, the current and one voltage are locally available at any time. For closing the selection command detects and activates the remote voltage sending either from the v.t. at the busbar if applicable or in any connected bay.<br>For these calculations the conditions in all three phases are considered. If switching per phase is applicable three execution times are provided. | **CPOW** | **CPOW** | |
| Interlocking function at station and/or bay level | 3 | 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 (IL).<br>1) Interlocking of switchgear at bay level<br>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.<br>2) Interlocking of switchgear at station level<br>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 class shall be used to control the cooling equipment. One instance per cooling group shall be used. | **CCGR** | **CCGR** | Cooling group control |
| Synchronizer control | | This LN class shall be used to control the synchronizing conditions i.e. voltage, frequency and phase. | **CSYN** | **CSYN** | Synchronizer controller |

### 8.5.6 Interfaces, logging, and archiving

| Logical Node | Description or Comments | LN Function | LN Class | LN Class naming |
|---|---|---|---|---|
| Operator interface<br>– control local at bay level<br>– control at station level | 1) Front-panel operator interface at bay level<br>to be used for configuration, etc. and local control<br>2) Local operator interface at station level<br>to be used as work place for the station operator<br>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 |
| Hand interface<br>– control local at bay level<br>– control at process level | Generic physical human – machine interface.<br>e.g. a push-button or another physical device<br>that can be used as input to a controller<br>(see "IEEE" 1: Master element is the initiating device). | **IHND** | **IHND** | Hand interface |
| Remote control interface, Telecontrol interface | Telecontrol interface to be used for remote control from higher control level.<br>Basically, the TCI will communicate the same data as the station level HMI or a subset of these data.<br>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 | Telemonitoring interface to be used for remote monitoring and maintenance using a subset of all information available in the substation and allows no control.<br>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 | 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.<br>It is applicable also for multi-end lines (T-connections).<br>The role of the different interfaces is not fixed for most of the functions and defined in the engineering phase. | **ITPI** | **ITPC** | Teleprotection communication interface |
| Logging | This LN refers to 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 | Archiving to be used as sink and source for 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 Automatic process control

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Automatic tap changer control | Automatics 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 |
| Automatic voltage control | Automatics to control the voltage of a busbar within a specific range independent of the means used | **AVCO** | **AVCO** | Voltage control |
| Reactive control | Automatics to control the reactive power flow in a substation within a specific range using capacitors and/or reactances. | **ARCO** | **ARCO** | Reactive power control |
| Earth fault neutralizer control (control of Petersen coil) | The grounding of the transformer star point influences the short circuit in a network. This grounding is dynamically determined by a Petersen coil (LN ENF) controlled by ENFC. | **ANCR** | **ANCR** | Neutral current regulator |
| Zero-voltage tripping | If a line connected to a substation is without voltage longer than a predefined time, the line is switched off automatically. | **AZVT** | **PTUV** | Undervoltage |
| Generic automatic process control<br>Means a generic, programmable LN for sequences, unknown functions, etc.<br>Also member of the Generic LN group | This is a generic node for all undefined automation or control functions at the same control level as the LNs of the P or the C group. These functions may be implemented with standard PLC languages. The data access and exchange is completely the same as for all other LNs. Examples are<br>1) Load shedding<br>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.<br>2) Infeed transfer switching<br>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<br>3) Transformer change<br>to switchover in case of overload to another transformer or to distribute the load more evenly to all related transformers on the busbar.<br>4) Busbar change<br>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<br>5) Automatic clearing & voltage restoration<br>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 Functional blocks

| **Logical node** | **Description or comments** | **LN function** | **LN class** | **LN class naming** |
|---|---|---|---|---|
| Counter | Logical node FCNT shall be used to count incoming pulses not related to the electrical network i.e. not for energy counting | **FCNT** | **FCNT** | Counter |
| Curve shape description | Logical node FCSD shall comprise the data object classes that represent 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.<br>The allocated function is used to adapt an incoming value to a specified curve function. For example, it may adjust 2-dimensionally nonlinear transmitters to the correct physical values or, by instantiation, for 3-dimensional surface mapping. | **FCSD** | **FCSD** | Curve shape description |
| Generic filter | Logical node FFIL shall be used to filter an incoming value with the following transfer function<br>$G(s) = K \frac{1 + sT_1}{1 + sT_3 + sT_2{}^2}$ | **FFIL** | **FFIL** | Generic filter |
| Control function output limitation | This logical node is used to set temporary or permanent operational limits to an output signal (MV) from a control function. The FLIM logical node should not be used to replace FXOT or FXUT. | **FLIM** | **FLIM** | Control function output limitation |
| PID regulator | Logical node FPID shall comprise the data that represent proportional, integral and derivative information for a PID controller. | **FPID** | **FPID** | PID regulator |
| Ramp function | The ramp function with data of the logical node FRMP is used as a generic ramp if for an analogue set-point if a continuous change is needed. | **FRMP** | **FRMP** | Ramp function |
| Set-point control function | Logical node FSPT shall be 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 | Logical node FXOT is used to set a high-level threshold value if needed in control sequences. If a second level is necessary, a second instance can be modelled. FXOT can typically be 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 | 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 can be modelled. FXUT can typically be 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 Metering and measurement

| Logical node | Description or comments | LN function | LN class | LN Class naming |
|---|---|---|---|---|
| Measuring<br>– for operative purpose | To acquire values from CTs and VTs and calculate measurands like r.m.s. values for current and voltage or power flows out of the acquired voltage and current samples. 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.<br>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 |
| Metering<br>– for commercial purpose | To acquire values from CTs and VTs and calculate the energy (integrated values) out of the acquired voltage and current samples. Metering is normally used also for billing and has to provide the requested accuracy.<br>A dedicated instance of this LN may take the energy values from external meters e.g. by pulses instead directly from CTs and VTs. | **MMTR** | **MMTR** | Metering 3 Phase |
| | | | **MMTN** | Metering Single Phase |
| | | | **MSTA** | Metering statistics |
| Sequences and imbalances<br>– e.g. for stability purpose | To acquire values from CTs and VTs and to calculate the sequences and imbalances in a three/multi-phase power system. | **MSQI** | **MSQI** | Sequence and imbalance |
| Harmonics and interharmonics<br>– e.g. for power quality purpose | To acquire values from CTs and VTs and 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 |
| Environmental measurements | Logical node MENV shall be used for modelling 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 for calculation of flicker inducing voltage fluctuations according to IEC 61000-4-15. The main use is for operative applications. | **MFLK** | **MFLK** | Flicker measurement |

### 8.5.10 Power quality

| **Logical node** | **Description or comments** | **LN function** | **LN class** | **LN class naming** |
|---|---|---|---|---|
| Frequency supervision | The frequency variation event is started if the frequency exceeds the settable boundary for the frequency and finalized if 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.<br>Definition based on IEC 61000-4-30 | **QFVR** | **QFVR** | Frequency variation |
| Current supervision | The current transient event is started if the r.m.s. current exceeds the settable boundary for current and finalized if 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).<br>Definition based on IEC 61000-4-30 | **QITR** | **QITR** | Current transient |
| Current unbalance supervision | The current unbalance variation event is started if in a poly-phase circuit the r.m.s. phase currents are unbalanced (the negative sequence current exceeds a settable boundary) and finalized if 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).<br>Definition based on IEC 61000-4-30 | **QIUB** | **QIUB** | Current unbalance variation |
| Voltage supervision | The voltage transient event is started if the r.m.s. voltage exceeds the settable boundary for voltage and finalized if 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).<br>Definition based on IEC 61000-4-30 | **QVTR** | **QVTR** | Voltage transient |
| Voltage unbalance supervision | The voltage unbalance variation event is started if in a poly-phase circuit the r.m.s. phase voltages are unbalanced (the negative sequence voltage exceeds a settable boundary) and finalized if 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).<br>Definition based on IEC 61000-4-30 | **QVUB** | **QVUB** | Voltage unbalance variation |
| Voltage variation | The voltage variation event is started if the r.m.s. voltage exceeds the settable boundary for the voltage and finalized if 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).<br>Definition based on IEC 61000-4-30 | **QVVR** | **QVVR** | Voltage variation |

### 8.5.11 Physical device and common data

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Physical device | This LN is introduced in this part to model common features of physical device (IED) | **LPHD** | **LPHD** | Physical device information |
| | | | **LTIM** | Time management |
| Logical device data | This LN is containing the data of the logical device independently from all application function related logical nodes (device identification/name plate, messages from device self-supervision, etc.).<br>This LN may be used also for actions common to all included logical nodes (mode setting, settings, etc.) if applicable.<br>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! | | | | |

## 8.6 LNs related to system services

### 8.6.1 System and device security

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Time master | This LN shall be used to provide the time to the system (configuration, setting and synchronization) | STIM | n.a. | |
| Physical channel supervision | This LN shall be used to model common issues for 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 | LN shall be used to start, collect and process all data for system supervision | SSYS | n.a. | |
| Test generator | LN shall be used to start tests by using process signals but avoiding any impact on the process (blocking of process outputs) | GTES | n.a. | |

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.

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| General security application | Containing logs about security violations | GSAL | GSAL | Generic security application |

### 8.6.2 Switching devices

The switchgear related logical nodes represent the power system, i.e. the world 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 (see CB below).

| **Logical node** | **IEEE** | **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<br>– without point-on-wave switching capability<br>– with point-on-wave switching capability | 52 | AC circuit breaker is a device that is used to close and interrupt an a.c. power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions.<br>There is an XCBR instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear. | **XCBR** | **XCBR** | Circuit breaker |
| The LN "switch" covers all kind of switching devices not able to switch short circuits<br>– Load breakers<br>– Disconnectors<br>– Earthing switches<br>– High-speed earthing switches | 29 | Line switch is a switch used as a disconnecting, load-interrupter, or isolating switch on an a.c. or d.c. power circuit.<br>There is an XSWI instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear. | **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 SA system. | | | | | |

### 8.6.3 LN for supervision and monitoring

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Insulation Medium Supervision | LN to supervise the insulation medium e.g. the gas volumes of GIS (Gas Insulated Switchgear) regarding density, pressure, temperature, etc. | **SIMS** | **SIMG** | Insulation medium supervision (gas) |
| | | | **SIML** | Insulation medium supervision (liquid) |
| Supervision, monitoring and diagnostics for arcs | LN to supervise the gas compartments of GIS (Gas Insulated Switchgear) regarding arcs switching or fault arcs | **SARC** | **SARC** | Monitoring and diagnostics for arcs |
| Supervision, monitoring and diagnostics for partial discharge | LN 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 temperature | Logical node STMP shall be 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 the LN STMP shall be instantiated for each sensor. | **STMP** | **STMP** | Temperature supervision |
| Supervision, monitoring and diagnostics of vibrations | Logical node SVBR shall be 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, the LN SVBR shall be instantiated for each sensor. | **SVBR** | **SVBR** | Vibration supervision |
| Circuit breaker supervision | This function supervises the operation of the circuit breaker and provides data about the circuit breaker status and maintenance like the switch current load, contact abrasion and increasing time delays indicating ageing. | **SCBR** | **SCBR** | Circuit breaker supervision |
| Switch supervision | This function supervises 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. | **SSWI** | **SSWI** | Circuit switch supervision |
| Switch drive supervision | This function supervises the operation mechanism of switches and provides data about the operation mechanism status, ageing and maintenance request.<br>Today, different technologies for operating mechanisms are available. Typically 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.<br>To operate the switch, the energy is transferred by means of a mechanical linkage or hydraulics.<br>A charger motor is used to compensate for energy losses due to leakages or to recharge the storage (hydraulics, spring) after a switch operation.<br>The data provided cover the status of the relevant components both of the hydraulic and the spring system. The data available slightly differ depending on the used technology.<br>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 |
| Tap changer supervision | This function is used for supervision of 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 |
| Power transformer supervision | This LN is used for supervision of 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 |
| These logical nodes represent the mentioned supervision with their entire inputs and communication relevant behaviour in the SA system. | | | | |

### 8.6.4 Instrument transformers

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Current transformer | There is one instance per phase. These three/four instances may be allocated to different physical devices mounted in the instrument transformer per phase. | **TCTR** | **TCTR** | Current transformer |
| Voltage transformer | There is one instance per phase. These three/four instances may be allocated to different physical devices mounted in the instrument transformer 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 SA system. | | | | |

### 8.6.5 Position sensors

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Angle | Logical Node TANG shall be used to represent a measurement of 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 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 measurement of the distance to an object that can move. It is intended to provide a measurement between a fixed location and a movable object. | **TDST** | **TDST** | Distance |
| Movement | This LN shall be used to represent a measurement of 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 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. Compare with TDST that returns the distance in m. | **TPOS** | **TPOS** | Position indicator |
| Rotation transmitter | This LN shall be used to represent the rotational speed of a rotating device. Different measurement principles may be used, the presented result is however the same. | **TRTN** | **TRTN** | Rotation transmitter |

### 8.6.6 Material status sensors

| **Logical node** | **Description or comments** | **LN function** | **LN class** | **LN class naming** |
|---|---|---|---|---|
| Frequency | This LN shall be used to represent a measurement of frequency. It is intended for any frequency that is not related to electrical a.c. measurements. It can be used for example 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 TVBR logical node is recommended. | **TFRQ** | **TFRQ** | Frequency |
| Humidity | This LN shall be used to represent a measurement of 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 measurement of the magnetic field strength at the place where it is located. | **TMGF** | **TMGF** | Magnetic field |
| Temperature | This LN shall be used to represent a single temperature measurement. | **TTMP** | **TTMP** | Temperature sensor |
| Mechanical tension<br>Mechanical stress | This LN shall be used to represent a measurement of the mechanical tension in an object. | **TTNS** | **TTNS** | Mechanical tension / stress |
| Pressure | This LN shall be used to represent the pressure in a gas. Different measurement principles may be used, the presented result is however the same. | **TPRS** | **TPRS** | Pressure sensor |
| Vibration | This LN shall be used to represent a vibration level value. In case the vibration can be defined as a frequency, the TFRQ logical node could be used instead. | **TVBR** | **TVBR** | Vibration sensor |

### 8.6.7 Flow status sensors

| **Logical node** | **Description or comments** | **LN function** | **LN class** | **LN class naming** |
|---|---|---|---|---|
| Liquid flow | Logical Node TFLW shall be used to represent a measurement of media flow rate through the device where it is located. | **TFLW** | **TFLW** | Liquid flow |
| Media level | This LN shall be used to represent a measurement of 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 the sound pressure level at the location where the sensor is located. | **TSND** | **TSND** | Sound pressure sensor |
| Water acidity | This LN shall be used to represent a water pH level value. | **TWPH** | **TWPH** | Water acidity |

### 8.6.8 Generic sensors

| **Logical Node** | **Description or comments** | **LN function** | **LN class** | **LN class naming** |
|---|---|---|---|---|
| Generic sensor | Logical Node TGSN shall be used to represent a generic sensor if there is no specific sensor available. It can also be used for modelling the health and name of an external equipment (sensor). | **TGSN** | **TGSN** | Generic sensor |

### 8.6.9 Power transformers

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Power transformer | Connects in different configurations (Δ, Y, two/three windings) the voltage levels of the power system. | **YPTR** | **YPTR** | Power transformer |
| Tap changer | Device allocated to YPRT allowing changing taps of the winding for voltage regulation. | **YLTC** | **YLTC** | Tap changer |
| Earth fault neutralizer (Petersen coil) | Variable inductance (plunge core coil) allowing adaptive grounding of transformer star point to minimize the ground fault current. | **YEFN** | **YEFN** | Earth fault neutralizer (Petersen coil) |
| Power shunt | To bypass the resistor of a resistive grounded transformer star point for fault handling. | **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 SA system. | | | | |

### 8.6.10 Further power system equipment

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Auxiliary network | Generic node for information exchange with auxiliary networks (power supplies) | **ZAXN** | **ZAXN** | Auxiliary network |
| Battery | Provides data about battery status and for control of the charging/de-charging cycles | **ZBAT** | **ZBAT** | Battery |
| Bushing | Provides properties and supervision of bushings as used for transformers or GIS-line connections | **ZBSH** | **ZBSH** | Bushing |
| Power cable | Supervised power system element | **ZCAB** | **ZCAB** | Power cable |
| Capacitor bank | Controls reactive power flow | **ZCAP** | **ZCAP** | Capacitor bank |
| Converter | Frequency conversion including AC/DC conversion | **ZCON** | **ZCON** | Converter |
| Generator | Generic node for information exchange with generators | **ZGEN** | **ZGEN** | Generator |
| Gas isolated Line (GIL) | Mixture of data from SIMS, SARC and SPDC | **ZGIL** | **ZGIL** | Gas insulated line |
| Power overhead line | Supervised overhead line | **ZLIN** | **ZLIN** | Power overhead line |
| Motor | Generic node for information exchange with motors | **ZMOT** | **ZMOT** | Motor |
| Reactor | Controls reactive power flow | **ZREA** | **ZREA** | Reactor |
| Resistor | Logical Node ZRES shall be used to represent an ohmic resistor. A typical application is the resistor of the star point (a neutral resistor). This resistor is normally not controlled. | **ZRES** | **ZRES** | Resistor |
| Rotating reactive component | Controls reactive power flow | **ZRRC** | **ZRRC** | Rotating reactive component |
| Surge arrestor | Generic node for information exchange with surge arrestors | **ZSAR** | **ZSAR** | Surge arrestor |
| Semi-conductor controlled rectifier | Logical node ZSCR shall be used to represent a controllable rectifier. A typical use is to provide the controllable d.c. current within an excitation system. | **ZSCR** | **ZSCR** | Semi-conductor controlled rectifier |
| Synchronous machine | Logical node ZSMC shall be used to represent any type of synchronous machine. The logical node only includes rating data. | **ZSMC** | **ZSMC** | Synchronous machine |
| Thyristor controlled frequency converter | Frequency conversion including AC/DC conversion | **ZTCF** | **ZTCF** | Thyristor controlled frequency converter |
| Thyristor controlled reactive component | Controls reactive power flow | **ZTCR** | **ZTCR** | Thyristor controlled reactive component |

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| These logical nodes represent the mentioned power system equipment with all its data and related settings (if applicable), and communication relevant behaviour in the SA 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. | | | | |

### 8.6.11 Generic process I/O

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Generic I/O | Outputs like analogue outputs, auxiliary relays, etc. not covered by the above-mentioned switchgear related LNs are sometimes needed. On the other side, there are additional I/O's representing not predefined devices like horn, bell, target value etc. There are input and outputs from non-defined auxiliary devices also. For all these I/O's, the generic logical node GIO is used to represent a generic primary or auxiliary device (type X…, Y… , Z…). | **GGIO** | | |

## 8.7 Mechanical non-electrical primary equipment

| Logical node | Description or comments | LN function | LN class | LN class naming |
|---|---|---|---|---|
| Fan | Logical node KFAN shall be used to represent a fan. It can be seen as an extended nameplate that allows the temporary setting of data object. | **KFAN** | | Fan |
| Filter | Logical node KFIL shall be used to represent a (mechanical) filter. It can be seen as an extended nameplate that allows the temporary setting of data object. | **KFIL** | | Filter |
| Pump | Logical node KPMP shall be used to represent a pump. It can be seen as an extended nameplate that allows the temporary setting of data objects. | **KPMP** | | Pump |
| Tank | Logical node KTNK shall be used to represent the physical device of a tank, such as a hydraulic oil tank. The tank can be pressurized or not. If used to represent a tank for pressurized gas, only the pressure MV will be used. If used for an oil sump, only the level MV will be used. For a simple level sensor, the SLVL logical node can be used instead. | **KTNK** | | Tank |
| Valve | Logical node KVLV shall be used to represent a valve or gate where the position can be given as a percentage of full open position (optionally, the angle 0°-90° may be used). | **KVLV** | | Valve control |

# 9 The application concept for logical nodes

## 9.1 Example out of the domain substation automation

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 LNs

The free (arbitrary) allocation of functions or LNs 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 as very common today, the LNs of bay level and process level appear 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

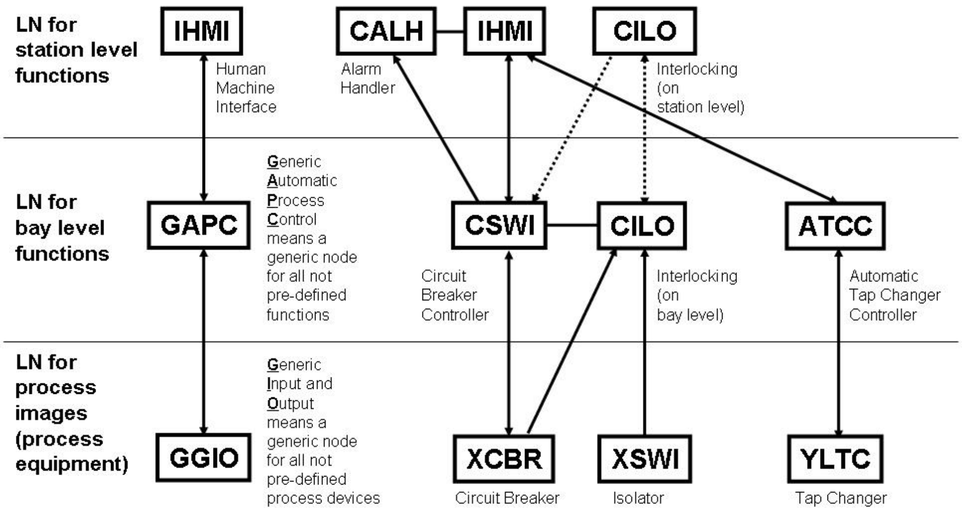
These logical nodes represent the power (primary) system, i.e. the power system world as seen from the secondary system via the I/Os. They may contain some simple functionality like device-related supervision and blocking also. In case of intelligent I/Os, logical nodes from the bay level may move down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

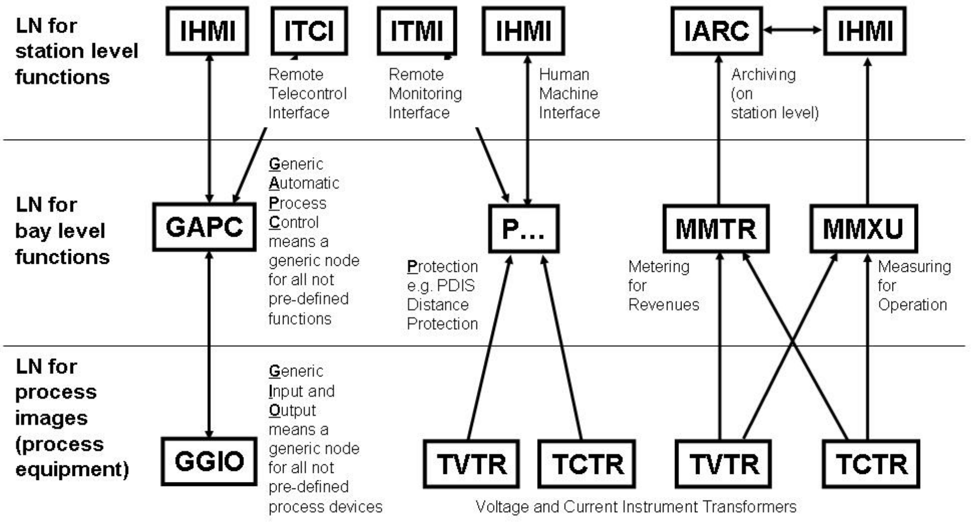
## 9.3 Basic examples

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**

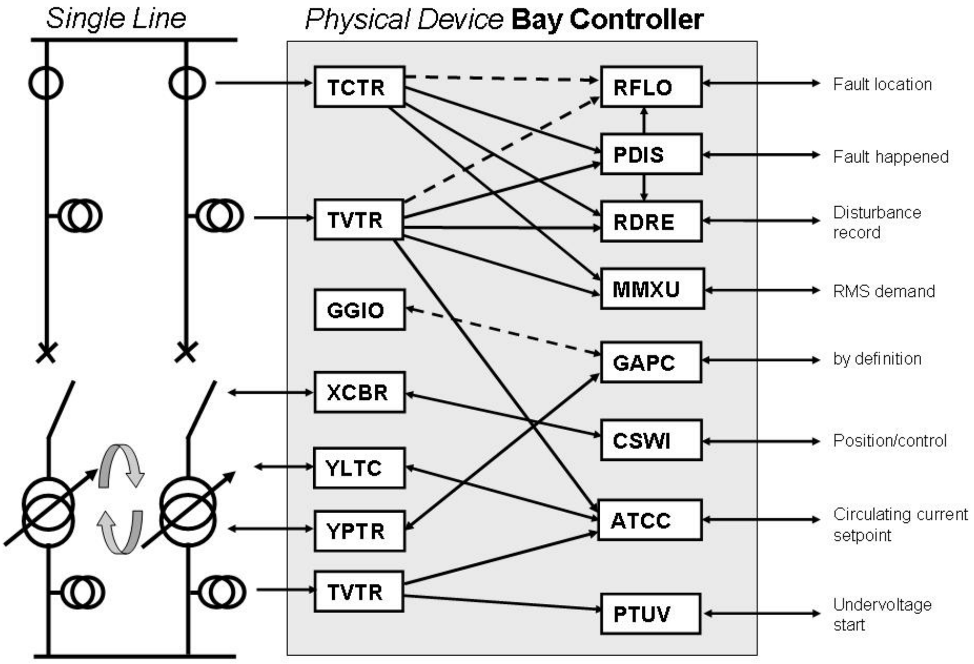


IEC 2386/12

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

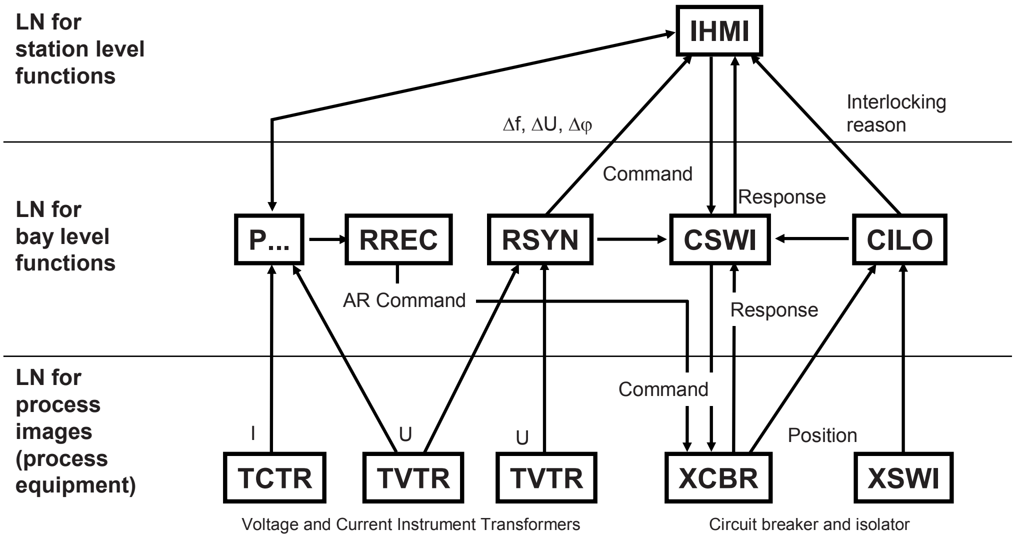
## 9.4 Additional examples

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.



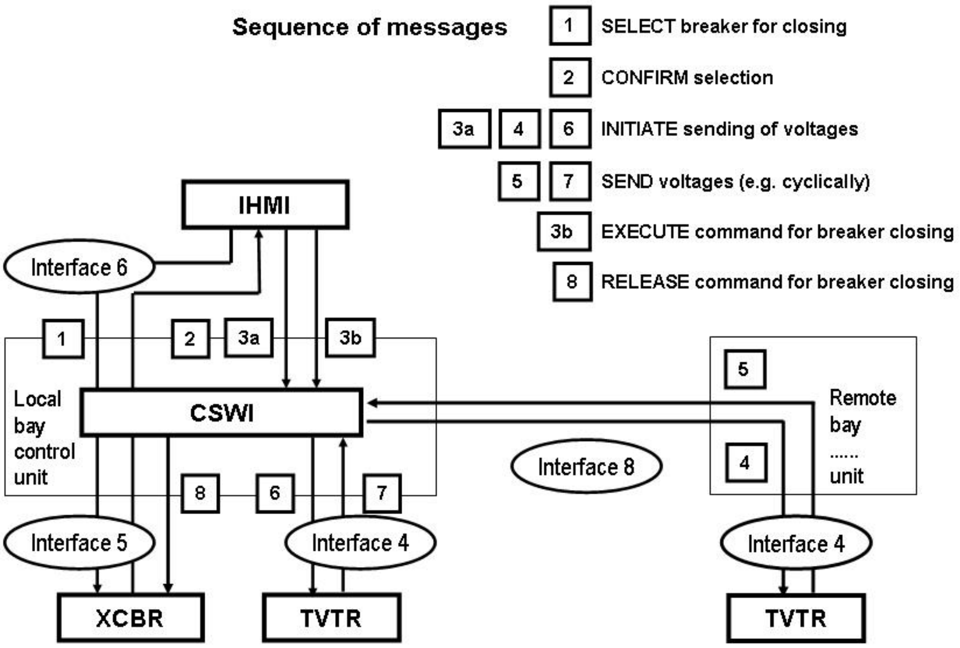
IEC 2387/12

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



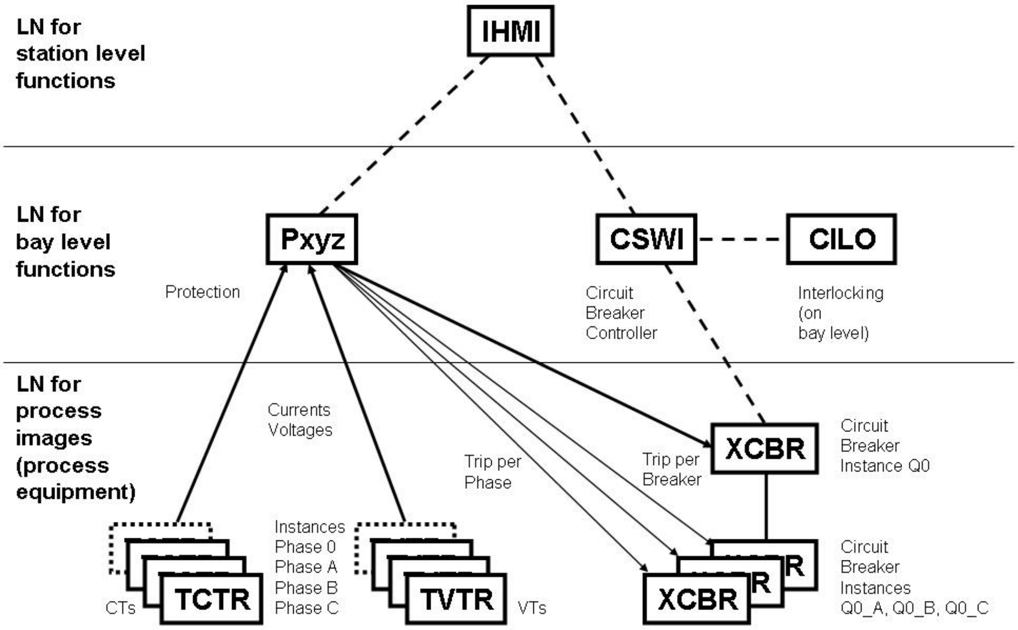
IEC 2388/12

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) for 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 help show some important points of the relationship between Part 5 and Part 7.

### 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 LN 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 not be modelled having no data objects.

The introduction of additional structures like logical devices (see Part 7) being composed of logical nodes is not an application requirement but may be helpful for the modelling.

Split and combinations of logical nodes for more convenient modelling do not impact the requirements.

### 9.5.5 Use of LN 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 potentially coming from (sending LN) and going to (receiving LN), 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 LN” shall know what data is needed for performing his task; i.e. it shall be able to check if the delivered data are complete and valid having 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 LN may set most quality attributes. The decision if data are “old” is the genuine task of the receiving LN. 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 LNs 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 LN is also the source of the primary data, i.e. it keeps the most actual values of these data, and the receiving LN 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 LN cannot operate in a normal way but may be in a degraded mode. Therefore, the behaviour of the LN 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 LNs 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 Message performance requirements

### 11.1.1 Basic definitions and requirements

### 11.1.1.1 General

The communication between LNs 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 LNs 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 the 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 11.1.1.4 below.

For defining time stamps and transfer times the basic requirements for the definition of time and time synchronization have to be clear. These requirements are stated below in 11.1.1.2 and 11.1.1.3. Transfer time requirements are system requirements, time stamp requirements are device requirements but refer to the system support function “Time synchronization”.

In 11.2 below 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 11.1.2.1, introduction and use of performance classes is described in 11.1.2.2.

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.

#### 11.1.1.2 Time and time synchronization

IEC 61850 compatible devices from multiple vendors may not only be found in substations but also everywhere in the power system. Therefore, a common format for time tagging done by all these devices shall be used. It shall be possible to compare the sequence of events in the system for any kind of event analysis. The resulting requirement is that the time between the IEDs respectively the clocks within all these IEDs is synchronized for a coherent time zone with reasonable accuracy.

If analogue data are used for calculations like impedance (voltage and current for distance protection) or difference (two or more currents for differential protection) their corresponding samples shall be time coherent by synchronized sampling. The resulting requirement is that the time between the IEDs respectively the clocks within all IEDs providing the samples is synchronized for a coherent time zone with reasonable accuracy.

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

a) Depending on the application, different time accuracies are required. These requirements are defined below.
b) The time stamp shall be based on an existing time standard. UTC is generally accepted as the base time standard.
c) The time model shall be able to track leap seconds and provide enough information to allow the user to perform delta time calculation for paired events crossing the leap second boundary.
d) 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.
e) The timestamp information shall be easily derived from commercially available time sources like GPS.
f) The overall time model shall include information to allow the computation of the local time.
g) The time model shall allow for ½ hour offset of the local time.
h) The time model shall indicate whether Daylight Saving is in effect or not.
i) The format shall last at least 100 years.
j) The timestamp format shall be compact and easily machine manipulated.

Specific requirements for the time synchronization are as follows:

1) The time for time synchronization shall be easily derived from a global time reference system like GPS.
2) The accuracy is always the difference between the master clock (GPS) and the slave clock in the device (IED) hosting the application function i.e. $\Delta t_{acc} = \left| t_{master} - t_{slave} \right|$.Therefore, the maximum time difference between two IEDs is 2 $\Delta t_{acc}$ 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 in 11.1.3.3 as far as applicable.
4) The telegrams for time synchronization should use the same communication infrastructure as the data exchange to facilitate both the IED and the communication system design.

These basic time requirements are system requirements but the system consists of devices. Therefore, the devices shall support these requirements if applicable.

#### 11.1.1.3 Event time definition

There are three different kinds of events which need dedicated time allocation procedures:

- If an event is defined as result of computation (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 change 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 change of an analogue input 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.
- 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.

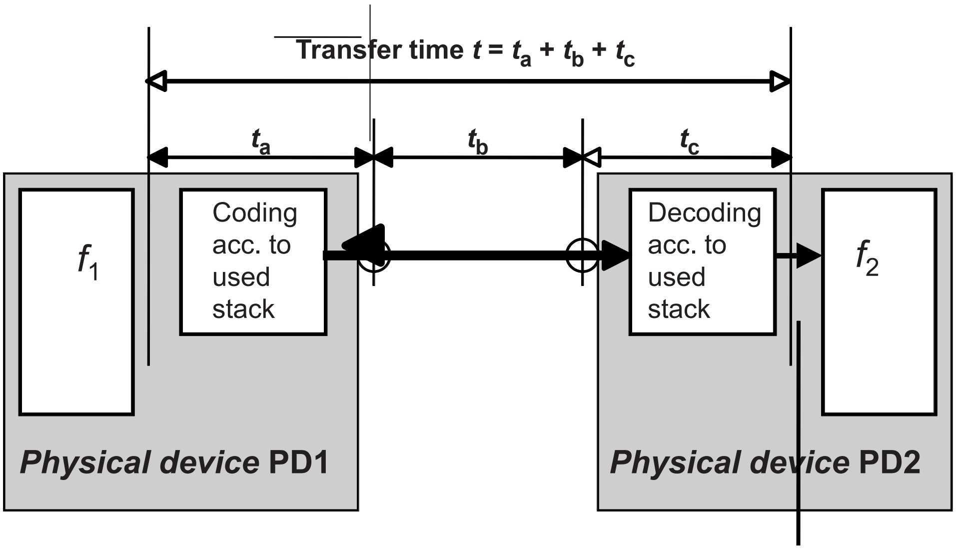
This strong event time definition results from the requirements that the time tag of the transmitted binary or analogue events/values

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

#### 11.1.1.4 Transfer time

##### 11.1.1.4.1 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.



IEC 2391/12

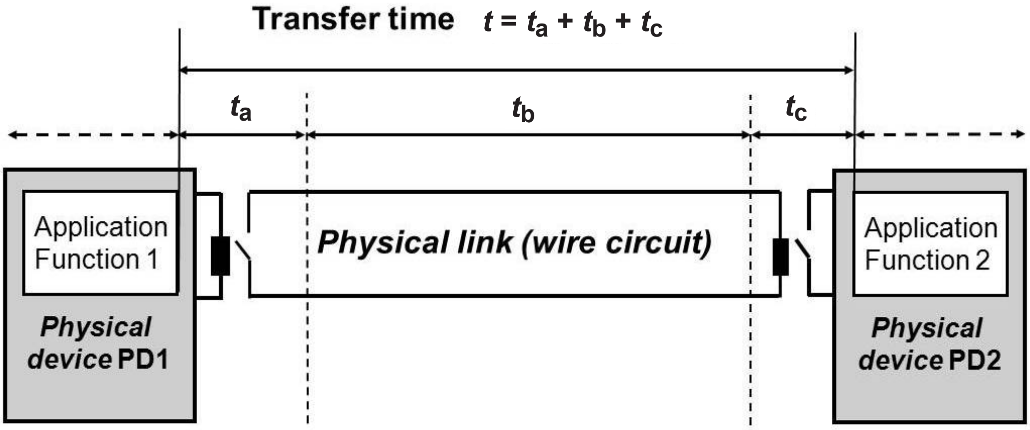
**Figure 13 – Definition of "overall transfer time" *t* and indication of processing times**

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 11.1.3.2). 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.

#### 11.1.1.4.2 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: $t << t_{f1} + t_{f2}$.

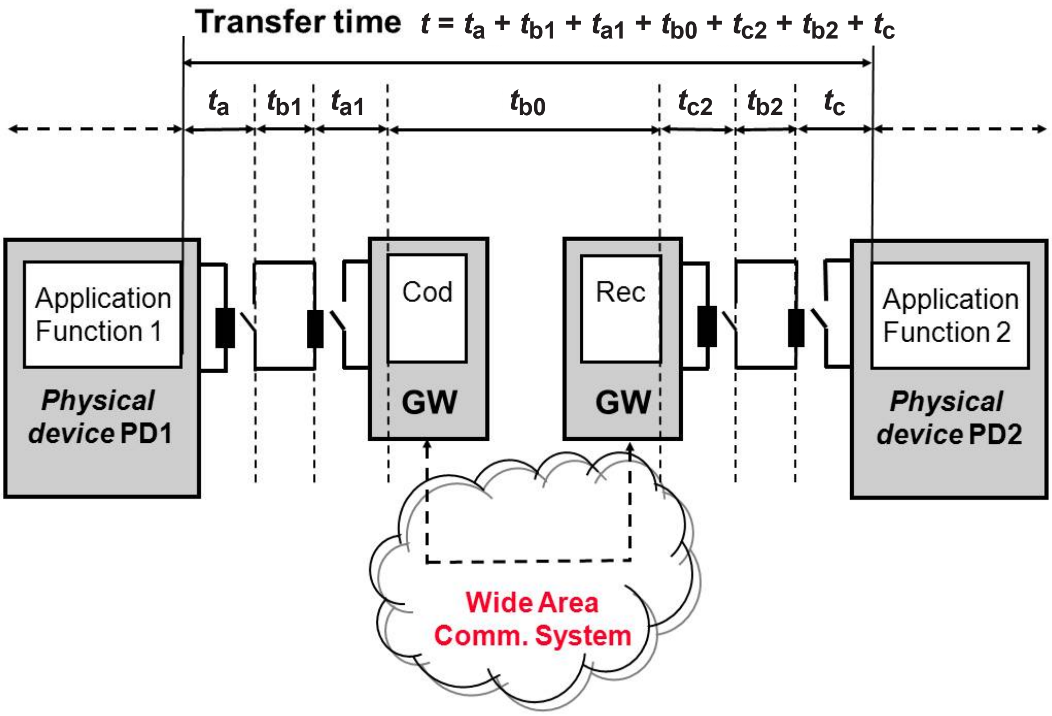


IEC 2392/12

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

#### 11.1.1.5 Transfer times for substation-substation connections

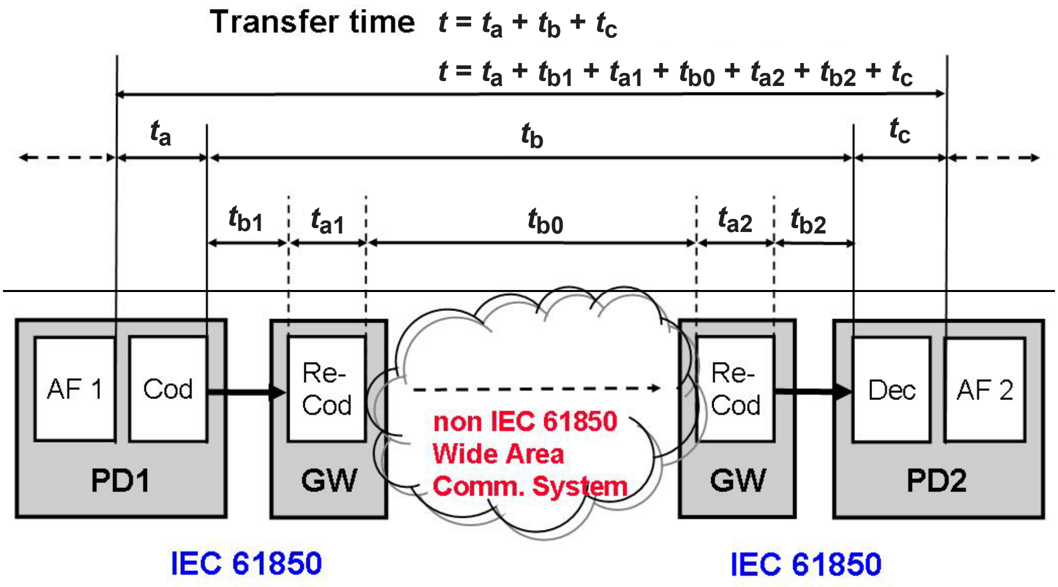
If the connection between two IEDs is a direct link, the time $t_b$ for distances within substations and in power systems is negligible since the signal speed is – depending on the transmission mode and the impedance of the line for the signals of this mode – in between 2/3 and the full speed of light 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 2393/12

**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.



IEC 2394/12

**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 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.

#### 11.1.1.6 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.

#### 11.1.1.7 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.

### 11.1.2 Message types and performance classes

#### 11.1.2.1 Introduction and use of message types

As mentioned above, the communication requirements in terms of PICOMs between LNs 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 is 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.

### 11.1.2.2 Introduction and use of performance classes

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

For some messages 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 influence the performance of the related function e.g. the fault clearance time of a protection (typically up to 40 ms).

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

### 11.1.2.3 Implementation issues

On a direct connection between two IEDs all messages travel with the same speed (refer to $t_b$ 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 series (IEC 61850-8-x and IEC 61850-9-x) and in selecting active elements.

### 11.1.3 Definition of transfer time and synchronization classes

### 11.1.3.1 Transfer times classes for control and protection

The transfer time requirements for functions 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 1 – Classes for transfer times**

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

#### 11.1.3.2 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 r.m.s. 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 samples 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 11.1.3.3.

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.

#### 11.1.3.3 Time synchronization classes

To get a correct sequence of events across different places in the power system a time tagging with a precise global time has to be provided. Therefore, all related devices shall be synchronized with the requested accuracy. Common for events is 1 ms.

To compare values from different places (e.g. currents for differential protection, 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. Common for analogue samples with 50 Hz or 60 Hz power frequency is 1 μs

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 global GPS based master clock.

**Table 2 – Time synchronization classes for IED synchronization**

| **Time synchronization class** | **Accuracy** [μs] | **Phase angle accuracy for 50 Hz** [°] | **Phase angle accuracy for 60 Hz** [°] | **Fault location accuracy**[b] [%] |
|---|---|---|---|---|
| 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 – Application of 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 |

## 11.2 Messages types and performances classes

### 11.2.1 Type 1 – Fast messages (“Protection”)

#### 11.2.1.1 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 (voir CEI 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.

#### 11.2.1.2 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 2.

#### 11.2.1.3 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 |

### 11.2.2 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 |

### 11.2.3 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 |

### 11.2.4 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.

### 11.2.5 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 |

### 11.2.6 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.

## 11.3 Requirements for data and communication quality

### 11.3.1 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 11.3.

### 11.3.2 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 according to IEC 60870-4. IEC 61850-5, 8.3.3 also introduced 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 4 – 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.

The use of these measures is outside the scope of Part 5 but the required data integrity shall be considered in modelling the services (IEC 61850-7-2, e.g. SBO), defining the mapping (IEC 61850-8-x, 61850-9-x, e.g. coding), implementing the standard and selecting communication equipment.

### 11.3.3 Reliability

#### 11.3.3.1 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.

#### 11.3.3.2 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. The 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 5.

**Table 5 – Security classes**

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

#### 11.3.3.3 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. The 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 12.2.1.1 above).

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 6.

**Table 6 – 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 | $10^{-5}$ | |

### 11.3.4 Availability

#### 11.3.4.1 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.

#### 11.3.4.2 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.

### 11.4 Requirements concerning the communication system

### 11.4.1 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.

### 11.4.2 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.

### 11.4.3 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.

### 11.4.4 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 7.

**Table 7 – Requirements on 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 | | |
| 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. | | |

### 11.4.5 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.

### 11.5 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 11.1.2.

## 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 automation system and, therefore, shall be used for the identification of the latter one.

Therefore, for the logical addressing scheme in the 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.
- HMIs 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.

# 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 8.5.2).

**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** | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | 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 |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 **Remote control interface** (maybe with some restrictions) | | **IHMI**<br>**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 | | | | | |
| | 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… |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | 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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | 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** | | **AVCO** | | | | | |
| | 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 | | | | |
| | <plange 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 | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | 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 | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| **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** | | **LLN0** | | | | | |
| | 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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 | TCPT | | | | |
| | <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 | | |
| **Disconnector/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 | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | <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 | ITCI | | |
| | Alarms | SARC | CALH | IHMI | ITCI | | |
| | <alarm ARC occurred> | SARC | | | | | |
| | Events | SARC | CALH | IHMI | ITCI | | |
| | Diagnostic data | SARC | IHMI | ITCI | | | |
| | Settings | SARC | CSDA | IHMI | ITCI | | |
| **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 | ITCI | | |
| | Events | YPTR | CALH | IHMI | ITCI | | |
| | Settings | YPTR | ATCC | IHMI | ITCI | | |
| **Tap changer** | | **YLTC** | | | | | |
| | Function supervision | YLTC | CALH | IHMI | ITCI | | |
| | Events | YLTC | CALH | IHMI | ITCI | | |
| | Tap changer motor running | YLTC | ATCC | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | Tap position (BCD) | YLTC | ATCC | IHMI | ITCI | | |
| | Settings | YLTC | ATCC | IHMI | ITCI | | |
| **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 arrestor** | | **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** | | | | | |

| LN | PICOM name | Source | Sink 1 | Sink 2 | Sink 3 | Sink 4 | Sink 5 |
|---|---|---|---|---|---|---|---|
| | 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. | | | | |

# Annex B
(informative)

# PICOM identification and message classification

## B.1 General

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.

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.

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.

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 the 11.1.1.2.

In 11.2 , 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.

The introduction and use of message types had been described in 11.1.2.1, the introduction and use of performance classes in 11.1.2.2.

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | 19 | | 17 | | | 10 | | 11 | | 11 | | | |
| PICOMs by semantics<br>LOGICAL NODE | 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 | X | | | | | | | | | | | | | |
| RDRS (Dist.Eva.Stat.) | | | | | | | | | | X | X | | | | | | | | | | | | | | |
| RREC (Autom.Recl.) | | | | | | | | | | X | | | 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**<br>**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 super-vision & identification) | | | | | | | X | | | | | | | | | | | | | | | | | | X |
| **GSAL** (General security application) identification | | | X | | | | | | | X | | | | | | | | | | | X | | | | X |
| **XCBR** (Circuit breaker) | | | | | | | X | | | X | | | | | | | | | | | | | | | |
| **XSWI** (Disconnector) | | | | | | | | | | 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 arrestor) | | X | | | | | | | | X | | | | | X | | | | | | | | | | X |
| **ZTCR** (Thyr.cont.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] | **10** | **10** | **10** | **11** | **10** | **27** | **28** | **10** | **10** | **21** | **21** | **10** | **16** | **17** | **12** | **14** | **14** | **4** | **4** | **6** | **9** | **25** | **4** | **25** | **24** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **11** | **11** | | | | | | | | | **12** | | | **12** | | | | | | | | | | |
| **PICOMs by message type** <br> **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 | | | | | | | | |
| **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.

## Table B.4 – PICOM allocation (Part 2)

| **PICOM TYPE ID** [a] | 10 | 10 | 10 | 11 | 10 | 27 | 28 | 10 | 10 | 21 | 21 | 10 | 16 | 17 | 12 | 14 | 14 | 4 | 4 | 6 | 9 | 25 | 4 | 25 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 11 | 11 | | | | | | | | | 12 | | | 12 | | | | | | | | | | |
| **PICOMs**<br>**by message type**<br>**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** |
| **MMXU** (Measuring) | | | | | | | | | | X | | | | | | | x | | x | x | | | | | |
| **MMTR** (Metering) | | | | | | | | | | X | | | | | | | | | | | | | | | |
| **MSQI** (Sequences ...) | | | | | | | | | | X | | | | | | | x | | x | x | | | | | |
| **MHAI** (Harmonics ...) | | | | | | | | | | X | | | | | | | x | | x | x | | | | | |
| **LLN0** (Device super-vision & identification | | | | | X | | | | | | | | | | | | | | | | | | | | X |
| **GSAL** (General security application) identification | | | | | X | | | | | | | | | | | | | | | | | | | | X |
| **XCBR** (Circuit breaker) | | | | | X | | | | X | X | | | | | | | | | | | | | | | |
| **XSWI** (Disconnector) | | | | | X | | | | X | | | | X | | | | | | | | | X | | | |
| **SIMS** (Ins. med. sup.) | | | | | X | | | | X | | | | | | | | | | | | | | | X | |
| **SARC** (Arc detection) | | | | | X | | | | X | | | | | | | | | | | | | | | X | |
| **SPDC** (Part.Discharge) | | | | | X | | | | X | | | | | | | | | | | | | | | X | |
| **TCTR** (current transf.) | | | | | | | | | | | | | | | | | | | | | | | | | |
| **TVTR** (voltage transf.) | | | | | | | | | | | | | | | | | | | | | | | | | |
| **YPTR** (Pow.transf.3ph) | | | | | X | | | | X | | | | | | | | | | | | | | | X | X |
| **YLTC** (Tap changer) | | | | | X | | | | | | | X | X | X | | | | | | | | | | | |
| **YEFN** (Earth fault neutr., Petersen coil) | | | | | | | | | | | | | | | | | | | | | | | | | |
| **YPSH** (Power shunt) | | | | | | | | | | | | | | | | | | | | | | | | | |
| **ZGEN** (Generator) | | | | | X | | | | X | | | X | | | | | | | | | | | | X | X |
| **ZTCF** (Converter) | | | | | X | | | | X | | | X | | | | | | | | | | | | X | X |
| **ZCON** (Converter) | | X | | | | | | | | X | | | | | X | | | | | | | | | | X |
| **ZMOT** (Motor) | | | | | X | | | | X | | | X | | | | | | | | | | | | | |
| **ZSAR** (Surge arrestor) | | | | | X | | | | | | | X | | | | | | | | | | | | | |
| **ZTCR** (Thyr.cont.reac.) Element) | | | | | X | | | | | | | | | | | | | | | | | | | | |
| **ZRRC** (Rot.contr.reac.) | | | | | X | | | | | | | | | | | | | | | | | | | | |
| **ZCAP** (Capacitor bank) | | | | | X | | | | | | | | | | | | | | | | | | | | |
| **ZREA** (Reactor) | | | | | X | | | | | | | | | | | | | | | | | | | | |
| **ZCAB** (Cable mon.) | | | | | X | | | | X | | | | | | | | | | | | | | | X | |

| PICOM TYPE ID [a] | 10 | 10 | 10 | 11 | 10 | 27 | 28 | 10 | 10 | 21 | 21 | 10 | 16 | 17 | 12 | 14 | 14 | 4 | 4 | 6 | 9 | 25 | 4 | 25 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| |  | 11 | 11 |  |  |  |  |  |  |  |  | 12 |  |  | 12 |  |  |  |  |  |  |  |  |  |  |
| PICOMs by message type<br>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 |
| **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:

## Table B.5 – PICOM types

| PICOM TYPE ID | Meaning of PICOM and its value attribute[a] | Type Mode | Number of value attributes combined<br>– range<br>– typically figures | Size of value attribute in bits[b] | Transfer time[c] (response/cycle)<br>– range<br>– typically figure given in ms | Message type[d 4] |
|---|---|---|---|---|---|---|
| **1** | Process value (sample) | Value<br>Cyclic | 1 – 8<br>1, 2, 3, 5 | 16 | – 10,<br>0,1, 0,5, 1,2,5,10 | 4[a] |
| **2** | Process value (r.m.s.) | Value<br>Cyclic | 1 – 8<br>1, 2, 3, 5 | 16 | – 1 000,<br>50, 100, 500, 1 000 | 2[b] |
| **3** | Measured value (calculated) like energy | Value<br>Cyclic<br>Requ. | 1 – 64,<br>4, 6, 64 | 16 | – 1 000,<br>100, 500, 1 000 | 3 |
| **4** | Metered value (calculated) like energy | Value<br>Cyclic<br>Requ. | 1 – 512<br>1, 512 | 16 | – 1 000,<br>100, 500, 1 000 | 3 |
| **5** | Process value (non-electrical) like temperature | Value<br>Cyclic | 1 – 8<br>1 | 16 | 1 000 – 5 000<br>1 000, 5 000 | 3[c] |
| **6** | Report (calculated) like energy list | File<br>Requ. | 1 | 1 024 | 1 000 – 5 000<br>1 000, 5 000 | 5 |
| **7** | Fault value (calculated) like fault distance | Value<br>Requ. | 1 – 2<br>1 | 16 | 1 000 – 5 000<br>1 000, 5 000 | 3 |
| **8** | Mixed fault info (calculated) extensive | File<br>Requ. | 1 | 512 | 1 000 – 5 000<br>1 000, 5 000 | 5 |
| **9** | Mixed fault data (calculated) like disturbance rec. | File<br>Requ. | 1 | 20 000<br>200 000 | 5 000 | 5 |
| **10** | Event/alarm | Event<br>Spont. | 1 – 16<br>1 | 1 | 100 – 1 000<br>100, 500, 1000 | 3[d] |
| **11** | Event/alarm list/group | File<br>Spont.<br>Requ. | 1 | 128<br>1 024 | 100 – 1 000<br>100, 500, 1 000 | 5 |
| **12** | Trigger (calc.) e.g. for start of another function | Event<br>Spont. | 1 | 1 | 10 – 1 000<br>10, 50, 100, 1 000 | 1 |
| **13** | Complex block or release (calculated) | Event<br>Spont. | 1 | 16 | 10 – 100<br>10, 100 | 1 |
| **14** | Request (calc.) for sync, interlock, etc. | Event<br>Spont.<br>Requ. | 1 | 1 | 10 – 100<br>10, 100 | 2 |
| **15** | Fast broadcast Message, e.g. for block/release | Event<br>Spont. | 1 | 1 | 1<br>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<br>- range<br>- typically figures | Size of value attribute in bits[2] | Transfer time[3] (response/cycle)<br>- range<br>- typically figure given in ms | Message type[4] |
|---|---|---|---|---|---|---|
| **16** | Process state | Status<br>Requ.<br>Cyclic | 1 | 1 | 1 – 100<br>1, 10, 20, 50, 100 | 2[e] |
| **17** | Calculated state | Status<br>Requ. | 1 | 1 | 1 – 100<br>1, 10, 20, 50, 100 | 2[e] |
| **18** | External condition | Status<br>Requ.<br>Cyclic | 1 | 1 | 1 – 100<br>1, 10, 20, 50, 100 | 2[e] |
| **19** | Mode of operation | Status<br>Requ.<br>Cyclic | 1 | 1<br>16 | 10 – 100<br>10, 100 | 3 |
| **20** | Process state changed | Event<br>Spont. | 1 | 1 | 1 – 10<br>1, 10 | 1 |
| **21** | Command | Cmd.<br>Spont. | 1, 5 | 1 | 1 – 1 000<br>1,2,5,10,50, 100,1 000 | 7[f] |
| **22** | Trip | Cmd.<br>Spont. | 1 | 1 | 1 | 1 |
| **23** | Set point | Value<br>Spont. | 1 | 16 | 100 – 1 000<br>100,1 000 | 3 |
| **24** | ID data, setting | File<br>Spont.<br>Requ. | 1 | 1 024 | 1 000 – 5 000<br>1 000,5 000 | 5 |
| **25** | Diagnostic data | File<br>Spont.<br>Requ. | 1 | 1 024 | 5 000 | 5 |
| **26** | Acknowledge by operator or auto. | Cmd.<br>Spont. | 1 | 1 | 10 – 1 000<br>10,100,1 000 | 3 |
| **27** | Date and time | Value<br>Cyclic<br>Requ. | 1 | 32 | 100 – 1 000<br>100,1 000 | 3 |
| **28** | Synchronization "pulse" | Cmd.<br>Cycl. | 1 | 1 | 0,1 – 10,<br>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.

# 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 7.1.

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 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.

# 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 11.1.3.3 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 (radio/e.g. DCF77, satellite/GPS):

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, it 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 red 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, disconnector 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 disconnector). 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.

#### F.2.2.2 Starting criteria

Request from a human operator or from an automatic function.

#### F.2.2.3 Result

Changes in the process by changed status of the process (primary equipment).

#### F.2.2.4 Performance

Depending on the controlled object under consideration.

Depending on the starting criteria, i.e. about ≤1 s for a human operator, ≤ 100 ms for automatics.

#### F.2.2.5 Decomposition

IHMI, ITCI, GAPC, CSWI, XCBR, XSWI, (GGIO).

#### F.2.2.6 Interaction

Access security management, management of spontaneous change of indications, synchronized switching, bay level interlocking, station wide interlocking, distributed synchrocheck.

### F.2.3 Operational use of spontaneous change of indications

#### F.2.3.1 Task

To monitor all spontaneous changes of states (indications) in the substation and to provide this information to all functions, which need this information.

#### F.2.3.2 Starting criteria

Change of a state in the power equipment, e.g. position change of a circuit breaker.

#### F.2.3.3 Result

Information about this change provided to all functions, which need this information.

#### F.2.3.4 Performance

Depending on the source of this change and the use of this information about this change.

Detection ≤ 1 ms, transmission ≤1 s for a human operator, ≤ 100 ms for automatic functions.

#### F.2.3.5 Decomposition

CALH, CILO, IHMI, ITCI, ITMI, all other LNs related to primary equipment (X…, Y…, Z…) including GGIO.

#### F.2.3.6 Interaction

Control, alarm management, event management, bay level interlocking, station wide interlocking.

### F.2.4 Synchronized switching (point-on-wave switching)

#### F.2.4.1 Task

The function synchronized switching allows closing or opening of the circuit breaker on a dedicated point of wave with a certain accuracy to limit the transient stress both for the breaker and the object to be energized e.g. line. Since waves mean the sinusoidal currents and voltages, the point on wave refers to a dedicated instant of time resulting in synchronized switching.

Closing:

The contacts of the breaker shall be closed at the instant of same potential on both sides to avoid or minimize strokes in between. Therefore, the time-dependent potentials (samples with amplitude, frequency and phase information measured e.g. by VTs) from both sides of the breaker have to be compare for the calculation of the proper instant of contact touching. This calculated instant of time shall be reached by the closing operation within 0,1 ms to minimize strokes appearing for contact distances below the voltage-dependent isolation distance.

For this purpose, the local/bay potential has to be compared with a remote potential from the busbar or from another bay. Using the knowledge about the actual busbar configuration, the proper remote VT has to be selected. This information may be provided from the station level or known at the bay level already.

The high accuracy needed for comparison of the voltage sample could be provided by synchronized sampling or by asynchronous samples time tagged with the same accuracy for waveform reconstruction. This is a matter of function implementation and the selected communication implementation (bus/stack).

Opening:

The contact separation of the breaker shall occur at a certain instant of time around current zero with an accuracy of 1 ms to reach optimum arcing time.

The information from the local/bay CT is needed only to calculate this instant of time.

Common:

Since this goal is determined by the mechanical behaviour of the breaker, this behaviour is monitored during any switching operation. Based on this monitoring the settings of the function are adapted from operation to operation.

#### F.2.4.2 Starting criteria

Selection of breaker for synchronized switching.

#### F.2.4.3 Result

The circuit breaker has been closed at point of wave accurate ≤ 0,1 ms.

The circuit breaker has been opened at point of wave accurate ≤ 1 ms.

#### F.2.4.4 Performance

Command sequence steps ≤ 1 s.

Accuracy for closing time in relation to the wave ≤ 0,1 ms.

Closing time < 500 ms depending on the type of breaker.

Time synchronization for the used samples < 50 µs.

### F.2.4.5 Decomposition

IHMI, ITCI, CSWI, XCBR, TCTR, TVTR (local and remote).

### F.2.4.6 Interaction

Control, bay level interlocking, station wide interlocking, automatic switching sequences.

## F.2.5 Parameter set switching

### F.2.5.1 Task

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 accesses may occurs. But switching shall be blocked, if a change session is open.

### F.2.5.2 Parameter set and general settings

The parameter set switching is subset of the setting from the system configuration or maintenance functions restricted to changes of predefined parameters sets needed to cope with changing operating conditions. The restriction to predefined parameter sets reduces drastically the consistency checks requested.

All other features are the same as for the setting function.

## F.2.6 Alarm management

### F.2.6.1 Task

Alarm management function allows an operator to visualize, to acknowledge and clear alarms. Several operators may have access simultaneously to this function. The alarms are presented in alarm list(s) and marked in process or system overview displays if applicable.

An alarm is generated when a data of the system takes a value that shall be specially considered by the operator. The data may be representative of the process state or of the substation automation system itself. The value may be invalid, unexpected, out of limit, etc. The data may be issued from single equipment or calculated with data coming from several equipment (group alarms)

The status of an alarm is calculated with:

- the presence and the value of the data that have generated the alarm (one or more data),
- the actions performed by the operator on this alarm.

The alarm will remain if the cause has disappeared, until the operator has acknowledged and cleared the alarm. If alarms are sent to different places, the request for single or multiple acknowledgements has to be defined.

An alarm has several attributes that shall be displayed to the operator:

- location/source of the alarm,
- cause of the alarm,

- acknowledgement made on the alarm,
- urgency and gravity of the alarm,
- audible alarms (if applicable).

#### F.2.6.2 Starting criteria

Status changes from “normal” to “alert” or “emergency”, status change from “alert” to “emergency”.

#### F.2.6.3 Result

Information of the local or remote operator about a critical situation in the primary or secondary system.

Acknowledgement of the alarm.

#### F.2.6.4 Performance

Needed performance for alarm detection depending on the function in consideration. Information to the operator and acknowledgement confirmation within the human operator time scale (1 s).

#### F.2.6.5 Decomposition

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

#### F.2.6.6 Interaction

Physical device self-checking, event management, any function.

### F.2.7 Event management (SER)

#### F.2.7.1 Task

To continually collect and process the status changes from equipment, operator control actions and changes in process state, and to record the events chronologically with date and time information. All equipment is included, i.e. typically plant, protection and control equipment. The archiving and display of events in event list(s) would typically be done in work places at station level, the detection and time tagging would typically be happen at bay level or below. Nevertheless, there is event buffering and may be display at bay level and event detection on station level, e.g. for operator actions.

The content of event list(s) may be different for different operator places if applicable. The events in the list(s) may be sorted and selected according to their attributes (source, cause, time, etc.).

If the events are polled from the higher level device or sent automatically (event driven) up to the higher level device depends on the implementation of communication. In any case, the events shall be retrievable on request if the communication comes back after some downtime.

This function provides all features of a sequence of event recorder (SER).

#### F.2.7.2 Starting criteria

There are different starting criteria:

- continuous scanning (e.g. from station level work station),
- change of state,
- request (e.g. after a communication outage).

### F.2.7.3 Result

The event database will be updated with the event including identification, the date and time. If applicable the events are printed.

### F.2.7.4 Performance

Events have to be time tagged at source with an accuracy of 1 ms for process data. Some data may have a lower accuracy, e.g. operator actions are often time tagged with reference to the human operator time scale (1 s).

### F.2.7.5 Decomposition

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

### F.2.7.6 Interaction

Since nearly all LN may be sources of events, all functions are interacting with the event management function.

## F.2.8 Data retrieval of configuration data and settings

### F.2.8.1 Task

To get data from one logical node to another dedicated logical node who has requested the data. The requesting IED would typically be located at the station level and the data typically stored in the logical node of an IED placed at bay level. Typical data would be configuration data and relay settings. The typical reasons for retrieving the data will be for the purpose of display, verification and bulk storage such data. Relay settings may, however, be requested for the purpose of display, editing and changing the original settings of the source logical node.

### F.2.8.2 Starting criteria

There are different starting criteria:

- operator request from station level,
- auto poll from station level.

### F.2.8.3 Result

Data is received at the requesting logical node. The data will be in the form of a file(s), which may be stored.

### F.2.8.4 Performance

The performance or speed of uploading will depend on the size of the file. Settings and measurement data should upload in less than 1 s.

### F.2.8.5 Decomposition

IHMI, ITCI, ITMI, LLN0, all other settable LNs.

### F.2.8.6 Interaction

Configuration management.

### F.2.9 Disturbance/fault record retrieval

#### F.2.9.1 Task

To get a dsturbance/fault record held in the logical node of an IED to the dedicated logical node who has requested the data. The requesting IED would typically be located at the Station level and the record typically stored in the logical node of an IED placed at bay level. The normal reasons for retrieving a record will be for the purpose of display and bulk storage of fault data.

#### F.2.9.2 Starting criteria

There are different starting criteria:

- operator request from station level,
- auto poll from station level.

#### F.2.9.3 Result

The record is received at the requesting logical node. The record will be in the form of a file(s), which may be stored.

#### F.2.9.4 Performance

The performance or speed of uploading will depend on the size of the file. A single fault record should upload within 5 s.

#### F.2.9.5 Decomposition

IHMI, ITCI, ITMI, RDRE, RDRS, IARC, TVTR, TCTR, all LNs related to primary equipment (X…, Y…, Z…) including GGIO.

#### F.2.9.6 Interaction

Protection function, management of spontaneous change of indications.

### F.2.10 Log management

Function covered by event management.

## F.3 Local process automation functions

### F.3.1 Protection function (generic)

#### F.3.1.1 Task

The task of any protection function is to monitor values from the power network or switchgear (voltage, current, temperature, etc.). If the actual value exceeds a predefined first boundary (if applicable), the protection function goes in an alert state (alarm, start, pickup). If a second boundary is crossed (fault indicator) a trip is issued which switches off the protected object (cable, line, transformer, switchgear, etc.). The behaviour of any protection function, i.e. the protection algorithm is controlled by a set of parameters, which may be changed by the protection engineer via HMI, or by some automatics.

If a protection function is listed as local process automation function it operates independent from other functions or communication links. In case of a remote process interface (I/O) separated by a process bus, these parts have to be in proper operation also.

#### F.3.1.2 Starting criteria

The monitoring part of the function is set into operation if the function is started.

The function issues a start (pickup) signal in case of an alert situation (boundary crossing 1) and a trip in case of an emergency situation (boundary crossing 2).

#### F.3.1.3 Result

The endangered object is in a safe mode, i.e. switched off normally.

#### F.3.1.4 Performance

Depending on the type of protection function the requested performance for fault detection and tripping is between 10 ms and 100 ms. These internal requirements of the protection function itself evolve to communication requirements in case of a process bus transferring the trip command.

#### F.3.1.5 Decomposition

IHMI, ITCI, ITMI, P…, TCTR, TVTR, XCBR, other primary equipment related LN.

#### F.3.1.6 Interaction

Alarm management, event management, disturbance/fault record retrieval, other protection functions, automatic protection adaptation, reverse blocking.

### F.3.2 Distance protection (example of protection function)

#### F.3.2.1 Task

The line distance protection function is related to the protection of one line.

It monitors the line impedance using voltage and current. The line distance protection trips starts and trips if changes in the line impedance, admittance or reactance exceed a certain predefined limits. It has different zones in reach. The fault distance is given at least as fault impedance (or admittance, reactance) which could be converted in the geographical distance to the fault location.

#### F.3.2.2 Starting criteria

The monitoring part of the function is set into operation if the function is started.

The function issues a start (pickup) signal in case of an alert situation (impedance is crossing boundary 1) and a trip in case of an emergency situation (impedance is crossing boundary 2).

#### F.3.2.3 Result

The line is protected by switching off the fault current using the related line circuit breakers.

#### F.3.2.4 Performance

Monitoring continuously voltage and currents with sample rates from some hundred Hz up to some thousands Hz. To reach an accurate fault location, the relative accuracy of voltage and current samples shall be $\leq 25$ μs. The response time (tripping time) shall be in the order of 5 ms to 20 ms. These internal requirements of the protection function itself evolve to communication requirements in case of a process bus transferring the trip command.

#### F.3.2.5 Decomposition

IHMI, ITCI, ITMI, PDIS, TCTR, TVTR, XCBR, other primary equipment related LN.

#### F.3.2.6 Interaction

Alarm management, event management, disturbance/fault record retrieval, other protection functions, and automatic protection adaptation.

### F.3.3 Bay interlocking

#### F.3.3.1 Task

According to interlocking rules commands to the switchgear are supervised and in the case of a possible malfunction or danger blocked by the bay level interlocking function.

Interlocking rules are implemented in the bay unit and checked always before the switchgear is operated. As an example the circuit breaker cannot be closed if the grounding disconnector at the feeder side is in on position.

For test purposes, the interlocking rules can be changed or set out of operation on-line by the HMI.

#### F.3.3.2 Starting criteria

The recalculation of interlocking conditions starts by any position change of the switchgear (circuit breaker, isolator, grounding switch). Depending on implementation, the recalculation may start not before switchgear selection.

#### F.3.3.3 Result

Release or blocking of the intended switching operation. Depending on implementation the interlocking reason may be supplied also to the HMI.

#### F.3.3.4 Performance

All kinds of selection, release or blocking signals have to be transmitted with an overall transfer time of about 10 ms. The recalculation time of the interlocking is outside the scope of this standard but should be in the order of the human operator time (1 s).

#### F.3.3.5 Decomposition

IHMI, ITCI, CILO, CSWI, XCBR, XSWI, (PTUV) – if applicable.

#### F.3.3.6 Interaction

Control, bay level interlocking in other bays, station-wide interlocking.

## F.4 Distributed automatic functions

### F.4.1 Station-wide interlocking

#### F.4.1.1 Task

The interlocking function is solved in a distributed way including the reservation principle.

The communication needed between the distributed units is solved using a general bay to bay communication with no special adaptation.

The following general requirements shall be fulfilled as far as possible:

- command handling performance shall be sufficiently high, i.e. response time below 1 s from the moment a command is given by the operator until the switch starts to move;
- interlocking safety shall be sufficiently high, i.e. no permanent or temporary node failure shall lead to a dangerous command, and the probability of (spontaneous) undetected state changes during the command handling time shall be sufficiently low;
- engineering effort for configuration and handling of possible fault situations shall be low;
- the solution shall be flexible so special conditions can be fulfilled, e.g. two commands executing at the same time;
- standard communication messages according to the data dictionary shall be used. No application level programs for the communication network with special messages shall be necessary.

#### F.4.1.2 Starting criteria

Position change of a switching device or request of the command function.

#### F.4.1.3 Result

Release or block for all switching devices or for the switching device of interest.

#### F.4.1.4 Performance

There are different performance requirements:

- – blocking and release 10 ms;
- – reservation 100 ms;
- – recalculation < 1 s.

#### F.4.1.5 Decomposition

IHMI, ITCI, CILO, CSWI, XCBR, XSWI, (PTUV) – if applicable.

#### F.4.1.6 Interaction

Control, bay level interlocking.

### F.4.2 Distributed synchrocheck

#### F.4.2.1 Task

The function distributed synchrocheck allows releasing the command “Close” in a proper time window where the differences of the voltages on both sides of the open breaker are in within an acceptable range regarding amplitude, frequency and phase.

For this purpose, the local/bay voltage has to be compared with a remote voltage from the busbar or from another bay. Using the knowledge about the actual busbar configuration the proper remote VT has to be selected. This information may be provided by the station level or known at the bay level already.

The high accuracy needed for comparison of the voltage sample could be provided by synchronized sampling or by asynchronous samples time tagged with the same accuracy for waveform reconstruction. This is a matter of function implementation and the selected communication implementation (bus/stack). By definition, at least the remote voltage is delivered via a serial bus (e.g. interface 9).

The functionality of the voltage comparison part with all related requirements is the same as for the closing part of the function “Synchronized switching”. The conventional (= local) “Synchrocheck” function has the same functionality but is getting all voltages hardwired.

#### F.4.2.2 Starting criteria

Selection of circuit breaker for synchronized switching or continuously running.

#### F.4.2.3 Result

Time window for “Close release” of the selected circuit breaker.

#### F.4.2.4 Performance

There are different performance requirements:

- release calculation ≤ 1 s;
- time synchronization for samples < 50 μs;
- time synchronization for zero crossing time tag 0,1 ms.

#### F.4.2.5 Decomposition

IHMI, ITCI, RSYN, TVTR (local and remote).

#### F.4.2.6 Interaction

Control, automatic switching sequences.

Distributed process automation functions.

### F.4.3 Breaker failure

#### F.4.3.1 Task

If a breaker tripped by some protection (e.g. line protection) does not open because of an internal failure, the fault has to be cleared by the adjacent breakers. The adjacent breakers may include breakers in the neighbouring substations (remote line ends). For this purpose the breaker failure protection is started by the protection trip and supervises if the fault current disappears or not. If not, a trip signal is sent to all adjacent breakers after a preset delay.

#### F.4.3.2 Starting criteria

The protection trip makes the breaker failure protection alert.

#### F.4.3.3 Result

The fault is clear by the adjacent breakers.

#### F.4.3.4 Performance

Fast detection of trip signal and fault current and very fast reset in case of a disappearing fault current. Delay settable ≤ 100 ms. The trip transfer time shall be in the order of 5 ms.

#### F.4.3.5 Decomposition

IHMI, ITCI, ITMI, P…, RBRF, TCTR, CSWI.

#### F.4.3.6 Interaction

Protection.

### F.4.4 Automatic protection adaptation (generic)

#### F.4.4.1 Task

The protection specialist may change the protection parameters (settings) if needed by static or slow predictable power system reconfiguration.

If the conditions for protection are dynamically changing during operation, the parameters of the protection may be changed by local or remote functions. Very often no single parameters are changed but complete pre-tested sets of parameters.

#### F.4.4.2 Starting criteria

Change of conditions detected and communicated by some other functions.

#### F.4.4.3 Result

The protection function is adapted to the changed power system condition.

#### F.4.4.4 Performance

Depending on the considered function and the rate of condition change in the power network the change command has to be communicated between 1 ms and 100 ms.

#### F.4.4.5 Decomposition

IHMI, ITCI, ITMI, P…

#### F.4.4.6 Interaction

Protection.

### F.4.5 Reverse blocking function (example for automatic protection adaptation)

#### F.4.5.1 Task

When a fault occurs in a radial network, the fault current flows between the source and the fault location:

- the upstream protections are triggered;
- the downstream protections are not triggered;
- only the first upstream protection has to trip.

The reverse blocking function is a distributed function that eliminates a fault in a minimum and constant time, wherever it occurs in a radial electric network. It offers a full tripping discrimination and a substantial reduction in delayed tripping of the circuit breaker located nearest to the source (the first upstream protection/breaker). It concerns phase overcurrent and earth fault protections of different types: definite time (DT) and IDMT (standard inverse time SIT, very inverse time VIT and extremely inverse time EIT).

#### F.4.5.2 Starting criteria

When a protection is triggered by an overcurrent

- it sends a blocking signal to the upstream protections,
- it trips (opens) its associated circuit breaker if it does not receive a blocking signal issued by a downstream protection.

#### F.4.5.3 Result

Only the first upstream protection has tripped the related breaker in a minimum and constant time.

#### F.4.5.4 Performance

Depending on the applied time delay based fault discrimination scheme the block command has to be communicated within the order of 5 ms (transfer time).

#### F.4.5.5 Decomposition

IHMI, ITCI, ITMI, P… (more than one).

#### F.4.5.6 Interaction

Protection, automatic protection adaptation.

### F.4.6 Load shedding

#### F.4.6.1 Task

To shed load in case of supply shortage to stabilize the power frequency.

#### F.4.6.2 Starting criteria

There are different starting criteria:

- the power frequency drops below a certain limit (multiple limits, e.g. four levels): $f < f_n$;
- the decay of frequency is faster than a given limit: $df/dt > (df/dt)_m$;
- the power flow is not balanced: $\Sigma P_i \neq 0$ (production ≠ consumption).

#### F.4.6.3 Result

The load is reduced to such an extent, that the power balance is zero, i.e. the frequency stays at its nominal value or within an acceptable, predefined range.

#### F.4.6.4 Performance

$f$, $df/dt$ relay oriented, not communication oriented.

#### F.4.6.5 Decomposition

IHMI, ITCI, ITMI, GAPC, PFRQ, MMXU, CSWI, XCBR, XSWI, (GGIO).

#### F.4.6.6 Interaction

Control, protection (frequency), automatic switching sequences.

### F.4.7 Load restoration

#### F.4.7.1 Task

Restore the local grid (busbar) after a tripping of one or more feeders. Maybe the complete busbar has been tripped by the busbar protection. The reconnection of feeders and consumers is made in a proper sequence according to some predefined priority and/or according to the network conditions.

#### F.4.7.2 Starting criteria

Disappearance of the fault condition or manually from the HMI.

#### F.4.7.3 Result

All feeders and consumers are connected again and the power delivery is restored.

#### F.4.7.4 Performance

Within the human operator time or switchgear time scale, i.e. ≤ 1 s per switching step.

#### F.4.7.5 Decomposition

IHMI, ITCI, ITMI, GAPC, CSWI, XCBR, XSWI.

#### F.4.7.6 Interaction

Control, distributed synchrocheck, automatic switching sequences.

### F.4.8 Voltage and reactive power control

#### F.4.8.1 Task

The voltage on a busbar in the power network depends on the position of the transformer taps and on the amount of reactive power to be moved around. By controlling both the voltage is kept at its nominal value or in a very small well-defined range. The control is made by changing the tap positions or by stepwise switching capacitor or reactor banks. Very often only one these means are available for such a control function in the substation under consideration.

#### F.4.8.2 Starting criteria

Deviations of U or Q form their set points. For more than one transformer: the circulating reactive current is above its accepted limit.

#### F.4.8.3 Result

The voltage or the reactive power is back to its nominal value or in a very small well-defined range. The circulating reactive current is below its accepted limit.

#### F.4.8.4 Performance

Detection fast but response limited by the switching mechanism.

#### F.4.8.5 Decomposition

IHMI, ITCI, ATCC, ARCO, TVTR, (TCTR), YLTC, YPTR.

#### F.4.8.6 Interaction task

Control, protection (transformer differential, over-/undervoltage).

### F.4.9 Infeed switchover and transformer change

#### F.4.9.1 Task

There are different kind of tasks:

a) Busbars with multiple infeed have to be switched over in case that the main infeed is disturbed or lost. The switchover has to take place bump less in such a way that no problems regarding the synchronization of lines and loads (e.g. motors) appear.

b) In case of parallel transformers, the load of an overloaded, endangered or faulted transformer has to be switched over to a healthy, parallel running transformer. The switchover has to take place bump less in such a way that no problems regarding the synchronization of lines and loads (e.g. motors) appear. This includes a proper setting of the tap position of the transformer also.

### F.4.9.2 Starting criteria

There are different starting criteria:

- disturbance or loss of feeding line;
- overloaded, endangered or faulted transformer.

### F.4.9.3 Result

Uninterrupted (if applicable) power flow by a sound feeding line or transformer.

### F.4.9.4 Performance

≤ 100 ms.

### F.4.9.5 Decomposition

IHMI, ITCI, PTUV (infeed) or PTDF/PTTR (transformer), TVTR, TCTR, YPTR, GAPC, RSYN, CSWI, XCBR, XSWI.

### F.4.9.6 Interaction

Control, distributed synchrocheck, voltage and reactive power control, automatic switching sequences.

## F.4.10 Automatic switching sequences

### F.4.10.1 Task

To change the process state by one single operator command also if a sequence of switching operations is needed. This function facilitates the task of the operator especially in complex substations, avoids unnecessary switching and may be used for automatics also.

### F.4.10.2 Starting criteria

Request from a human operator or from an automatic function.

### F.4.10.3 Result

Changes in the process by changed status of the process (primary equipment).

### F.4.10.4 Performance

Depending on the controlled objects under consideration.

Depending on the starting criteria, i.e. about ≤ 1 s for a human operator, ≤ 100 ms for automatics.

### F.4.10.5 Decomposition

IHMI, ITCI, GAPC, CSWI, XCBR, XSWI.

### F.4.10.6 Interaction

Access security management, control, bay level interlocking, station wide interlocking, distributed synchrocheck.

# Annex G
(informative)

## Results from function description

### Table G.1 – Function-function interaction (Part 1)

| FUNCTION<br>FUNCTION | Network management | Time synchronization | Physical device self-checking | Node identification | Software management | Configuration management | Operative mode control of LN | Setting | Test mode | System security management | Access security management | Control | Management of spontaneous change | Synchronized switching | Parameter set switching | Alarm management | Event management/Log management |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Network management** | o | | x | x | | x | x | | | | | | | | | x | x |
| **Time synchronization** | - | o | - | - | - | - | - | - | - | | - | - | - | x | - | - | x |
| **Physical device self-checking** | x | - | o | | | | | | | | | | | | | x | |
| **Node identification** | x | - | | o | | | | | | | | | | | | | |
| **Software management** | | - | | | o | x | x | | | | x | | | | | | |
| **Configuration management** | x | - | | | x | o | x | | | | | | | | | | |
| **Operative mode control of LN** | x | - | | | x | x | o | | | | | | | | | | |
| **Setting** | - | - | - | - | - | - | - | o | - | | - | - | - | - | - | - | - |
| **Test mode** | | - | | | | | | | o | | x | | | | | x | x |
| **System security management** | - | - | - | - | - | - | - | - | - | o | | - | - | - | - | - | - |
| **Access security management** | - | - | - | - | - | - | - | - | - | | o | - | - | - | - | - | - |
| **Control** | | - | | | | | | | | | x | o | x | x | | | |
| **Management of spontaneous change of** | | - | | | | | | | | | | x | o | | | | |
| **Synchronized switching** | | - | | | | | | | | | | x | | o | | x | x |
| **Parameter set switching** | - | - | - | - | - | - | - | - | - | | - | - | - | - | o | - | - |
| **Alarm management** | x | - | x | - | - | - | - | - | - | | - | - | x | - | - | o | - |
| **Event management/Log management** | - | - | - | - | - | - | - | - | - | | - | - | x | - | - | - | o |
| **Data retrieval** | | - | | | | x | | | | | | | | | | | |
| **Disturbance/fault record retrieval** | | - | | | | | | | | | | | x | | | | |
| **Protection function (generic) / Examples** | | - | | | | | | | | | | | | | | x | x |
| **Bay level interlocking** | | - | | | | | | | | | | x | | | | | |
| **Station wide interlocking** | | - | | | | | | | | | | x | | | | | |
| **Distributed synchrocheck** | | x | | | | | | | | | | x | | | | | |
| **Breaker failure** | | - | | | | | | | | | | | | | | | |
| **Automatic protection adaptation /** | | - | | | | | | | | | | | | | | | |
| **Reverse blocking function** | | - | | | | | | | | | | | | | | | |
| **Load shedding** | | - | | | | | | | | | | x | | | | | |
| **Load restoration** | | - | | | | | | | | | | x | | | | | |
| **Voltage and reactive power control** | | - | | | | | | | | | | x | | | | | |
| **Infeed switchover and transformer** | | - | | | | | | | | | | x | | | | | |
| **Automatic switching sequences** | | - | | | | | | | | | x | x | | | | | |

EXPLANATION OF SYMBOLS:

o Identical function (diagonal of the interaction matrix)

x Dedicated function interaction

- Common service interaction

## Table G.2 – Function-function interaction (Part 2)

| FUNCTION<br>FUNCTION | Data retrieval | Disturbance/fault record retrieval | Protection function (generic) | Bay level interlocking | Station wide interlocking | Distributed synchrocheck | Breaker failure | Automatic protection adaptation Examples | Reverse blocking function | Load shedding | Load restoration | Voltage and reactive power control | Infeed switchover and transformer change | Automatic switching sequences |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Network management** | | | | | | | | | | | | | | |
| **Time synchronization** | - | - | - | - | - | x | - | - | - | - | - | - | - | - |
| **Physical device self-checking** | | | | | | | | | | | | | | |
| **Node identification** | | | | | | | | | | | | | | |
| **Software management** | | | | | | | | | | | | | | |
| **Configuration management** | x | | | | | | | | | | | | | |
| **Operative mode control of LN** | | | | | | | | | | | | | | |
| **Setting** | - | - | - | - | - | - | - | x | | - | - | - | - | - |
| **Test mode** | | | | | | | | | | | | | | |
| **System security management** | - | - | - | - | - | - | - | - | | - | - | - | - | - |
| **Access security management** | - | - | - | - | - | - | - | - | | - | - | - | - | - |
| **Control** | | | | x | x | x | | | | | | | | |
| **Management of spontaneous change of** | | | | | | | | | | | | | | |
| **Synchronized switching** | | | | x | x | | | | | | | | | |
| **Parameter set switching** | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Alarm management** | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Event management/Log management** | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Data retrieval** | o | | | | | | | | | | | | | |
| **Disturbance/fault record retrieval** | | o | x | | | | | | | | | | | |
| **Protection function (generic) / Examples** | | x | o | | | | | x | x | | | | | |
| **Bay level interlocking** | | | | o | x | | | | | | | | | |
| **Station wide interlocking** | | | | x | o | | | | | | | | | |
| **Distributed synchrocheck** | | | | | | o | | | | | | | | |
| **Breaker failure** | | | x | | | | o | | | | | | | |
| **Automatic protection adaptation / Examples** | | | x | | | | | o | | | | | | |
| **Reverse blocking function** | | | x | | | | | | 0 | | | | | |
| **Load shedding** | | | x | | | | | | | o | | | | x |
| **Load restoration** | | | | | | x | | | | | o | | | x |
| **Voltage and reactive power control** | | | x | | | | | | | | | o | | |
| **Infeed switchover and transformer change** | | | | | | x | | | | | | x | o | x |
| **Automatic switching sequences** | | | | x | x | x | | | | | | | | o |

EXPLANATION OF SYMBOLS:

o Identical function (diagonal of the interaction matrix)

x Dedicated function interaction

- Common service interaction

## Table G.3 – Function decomposition into logical nodes (Part 1)

| **FUNCTION**<br><br>**LOGICAL NODE** | **Network management** | **Time synchronization** | **Physical device self-checking** | **Node identification** | **Software management** | **Configuration management** | **Operative mode control of LN** | **Setting** | **Test mode** | **Access security management** | **Control** | **Management of spontaneous change of ind.** | **Synchronized switching** | **Parameter set switching** | **Alarm management** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **P… (Protection, generic)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RDRE (Dist. recording at by level)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RDRS (Dist. Evaluation at station level)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RREC (Automatic reclosing)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RBRF (Breaker Failure)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RCPW (Carrier or pilot wire relay)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RFLO (Fault locator)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RSYN (Synchrocheck)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **RPSB (Power swing blocking)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **CALH (Creation of group alarms/events)** | | - | - | x | x | x | x | x | x | x | | x | | x | x |
| **CSWI (Switch controller)** | | - | - | x | x | x | x | x | x | x | x | | x | x | |
| **CILO (interlocking bay/station)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **IHMI (Human machine interface)** | x | - | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **ITCI (Telecontrol interface)** | x | - | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **ITMI (Telemonitoring interface)** | | | x | x | x | x | x | x | x | x | | x | | x | |
| **IARC (Archiving)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **ATCC (Automatic tap changer control)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **AVCO (Voltage control)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **ARCO (Reactive control)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **ANCR (Earth fault neutral control/P.C.)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **AZVT (Zero voltage tripping)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **GAPC (Automatic process control)** | | - | - | x | x | x | x | x | x | x | | | x | x | |
| **MMXU (Measurand unit /op.)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MMTR (Metering / acqu. and calc.)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MSQI (Sequences and imbalances)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MHAI (Harmonics and interharmonics)** | | - | - | x | x | x | x | x | x | x | | | | x | |

EXPLANATION OF SYMBOLS:

x Dedicated function decomposition

- Common service function decomposition

## Table G.4 – Function decomposition into logical nodes (Part 2)

| FUNCTION<br>LOGICAL NODE | Network management | Time synchronization | Physical device self-checking | Node identification | Software management | Configuration management | Operative mode control of LN | Setting | Test mode | Access security management | Control | Management of spontaneous changes of ind. | Synchronized switching | Parameter set switching | Alarm management |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LLN0 (Related to PD)** | x | x | x | x | x | x | x | x | x | x | | | | x | |
| **GSAL (Generic security application)** | x | x | x | x | x | x | x | x | x | x | | | | x | |
| **XCBR (Circuit breaker)** | | - | - | x | x | x | x | x | x | x | x | x | x | x | |
| **XSWI (Disconnector)** | | - | - | x | x | x | x | x | x | x | x | x | | x | |
| **SIMS (Insulation medium supervision)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **SARC (Arc detection)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **SPDC (Partial discharge detection)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **TCTR (Current transformer)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **TVTR (Voltage transformer)** | | - | - | x | x | x | x | x | x | x | | | x | x | |
| **YPTR (Power transformer)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **YLTC (Tap changer)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **YEFN (Earth fault neutralizer/Petersen coil)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **YPSH (Power shunt)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZGEN (Generator)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZTCF (Thyristor controlled converter)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZCON (Converter)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZMOT (Motor)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZSAR (Surge arrestor)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZTCR (Thyristor controlled reactive element)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZRRC (Rotating reactive component)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZCAP (Capacitor bank)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZREA (Reactor)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZCAB (Cable monitoring)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZGIL (Gas isolated line monitoring)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZBAT (Battery monitoring)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZAXN (Auxiliary network)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **GGIO (Generic I/O)** | | - | - | x | x | x | x | x | x | x | x | x | | x | |
| **STIM (Time master)** | | x | - | x | x | x | x | x | x | x | | | | | |
| **SSYS (System supervision)** | x | x | x | x | x | x | x | x | x | x | | | | | |
| **GTES (Test Generator)** | | - | - | x | x | x | x | x | x | x | | | | x | |

EXPLANATION OF SYMBOLS:

x Dedicated function decomposition

- Common service function decomposition

## Table G.5 – Function decomposition into logical nodes (Part 3)

| **FUNCTION**<br>**LOGICAL NODE** | **Event management/Log management** | **Data retrieval** | **Disturbance/fault record retrieval** | **Protection function (generic)** | **Bay level interlocking** | **Station wide interlocking** | **Distributed synchrocheck** | **Breaker failure** | **Automatic protection adaptation / Examples** | **Reverse blocking function** | **Load shedding** | **Load restoration** | **Voltage and reactive power control** | **Infeed switchover and transformer change** | **Automatic switching sequences** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **P… (Protection, generic)** | x | x | | x | | | | x | x | x | x | | | x | |
| **RDRE (Dist. recording at by level)** | x | x | x | | | | | | | | | | | | |
| **RDRS (Dist. Evaluation at station level)** | x | x | x | | | | | | | | | | | | |
| **RREC (Automatic reclosing)** | x | x | | x | | | | | | | | | | | |
| **RBRF (Breaker Failure)** | x | x | | | | | | x | | | | | | | |
| **RCPW (Carrier or pilot wire relay)** | x | x | | x | | | | | | | | | | | |
| **RFLO (Fault locator)** | x | x | | x | | | | | | | | | | | |
| **RSYN (Synchrocheck)** | x | x | | x | | | x | | | | | | | x | |
| **RPSB (Power swing blocking)** | x | x | | x | | | | | | | | | | | |
| **CALH (Creation of group alarms/events)** | x | x | | | | | | | | | | | | | |
| **CSWI (Switch controller)** | x | x | | | | | | | | | | x | | x | x |
| **CILO (Interlocking bay/station)** | x | x | | | x | x | | | | | | | | | |
| **IHMI (Human machine interface)** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **ITCI (Telecontrol interface)** | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| **ITMI (Telemonitoring interface)** | x | x | x | x | | | | x | x | x | x | x | x | x | x |
| **IARC (Archiving)** | x | x | x | | | | | | | | | | | | |
| **ATCC (Automatic tap changer control)** | x | x | | | | | | | | | | | x | | |
| **AVCO (Voltage control)** | x | x | | | | | | | | | | | x | | |
| **ARCO (Reactive control)** | x | x | | | | | | | | | | | x | | |
| **ANCR (Earth fault neutral. Control/P.C.)** | x | x | | | | | | | | | | | | | |
| **AZVT (Zero voltage tripping)** | x | x | | | | | | | | | | | | | |
| **GAPC (Automatic process control)** | x | x | | | | | | | | | x | x | | | x |
| **MMXU (Measuring unit /op.)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MMTR (Metering / acqu. and calc.)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MSQI (Sequences and imbalances)** | | - | - | x | x | x | x | x | x | x | | | | x | |
| **MHAI (Harmonics and interharmonics)** | | - | - | x | x | x | x | x | x | x | | | | x | |

EXPLANATION OF SYMBOLS:

x Dedicated function decomposition

- Common service function decomposition

## Table G.6 – Function decomposition into logical nodes (Part 4)

| FUNCTION<br>LOGICAL NODE | Event management/Log management | Data retrieval | Disturbance/fault record retrieval | Protection function (generic) | Bay level interlocking | Station wide interlocking | Distributed synchrocheck | Breaker failure | Automatic protection adaptation / Examples | Reverse blocking function | Load shedding | Load restoration | Voltage and reactive power control | Infeed switchover and transformer change | Automatic switching sequences |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LLN0 (Related to PD)** | x | x | | | | | | | | | | | | | |
| **GSAL (Generic security application)** | x | x | | | | | | | | | | | | | |
| **XCBR (Circuit breaker)** | x | x | - | x | x | x | x | | | | | | | | X |
| **XSWI (Disconnector)** | x | x | - | | x | x | | | | | | | | | x |
| **SIMS (Insulation medium supervision)** | x | x | - | | | | | | | | | | | | |
| **SARC (Arc detection)** | x | x | - | | | | | | | | | | | | |
| **SPDC (Partial discharge detection)** | x | x | - | | | | | | | | | | | | |
| **TCTR (Current transformer)** | x | x | - | x | | | | x | | | | | | x | |
| **TVTR (Voltage transformer)** | x | x | - | x | | | x | | | | | | x | x | |
| **YPTR (Power transformer)** | x | x | - | | | | | | | | | | | x | |
| **YLTC (Tap changer)** | x | x | - | | | | | | | | | | | | |
| **YEFN (Earth fault neutralizer/Petersen coil)** | x | x | - | | | | | | | | | | | | |
| **YPSH (Power shunt)** | x | x | - | | | | | | | | | | | | |
| **ZGEN (Generator)** | x | x | - | x | | | | | | | | | | | |
| **ZTCF (Thyristor controlled converter)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZCON (Converter)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **ZMOT (Motor)** | x | x | - | x | | | | | | | | | | x | |
| **ZSAR (Surge arrestor)** | x | x | - | | | | | | | | | | | | |
| **ZTCR (Thyristor controlled reactive element)** | x | x | - | | | | | | | | | | | | |
| **ZRRC (Rotating reactive component)** | x | x | - | | | | | | | | | | | | |
| **ZCAP (Capacitor bank)** | x | x | - | | | | | | | | | | | | |
| **ZREA (Reactor)** | x | x | - | | | | | | | | | | | | |
| **ZCAB (Cable monitoring)** | | | | x | | | | | | | | | | | |
| **ZGIL (Gas isolated line monitoring)** | | | | x | | | | | | | | | | | |
| **ZBAT (Battery monitoring)** | | | | x | | | | | | | | | | | |
| **ZAXN (Auxiliary network)** | | - | - | x | x | x | x | x | x | x | | x | | x | |
| **GGIO (Generic I/O)** | x | x | - | x | | | | | | | | | | | |
| **STIM (Time master)** | x | x | | | | | | | | | | | | | |
| **SSYS (System supervision)** | | | - | | | | | | | | | | | | |
| **GTES (Test generator)** | x | x | | | | | | | | | | | | | |

EXPLANATION OF SYMBOLS:

x Dedicated function decomposition

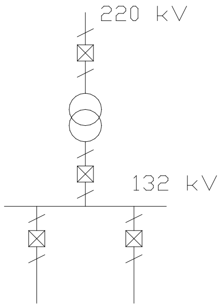
- Common service function decomposition

# Annex H
(informative)

# Substation configurations

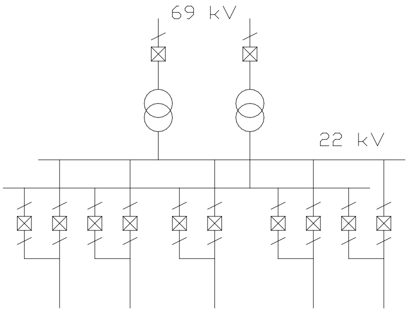
## H.1 Selected substations and associated layouts

The following four layouts and configurations of substations represent transmission and distribution substations in order to cover a wide range of applications. There are many other configurations but the most ones are different only by the numbers of feeders (bays) and the voltage levels applied. These examples given in the following Figures (Figure H.1, Figure H.2, Figure H.3 and Figure H.4) are referred in other parts of the standard also.



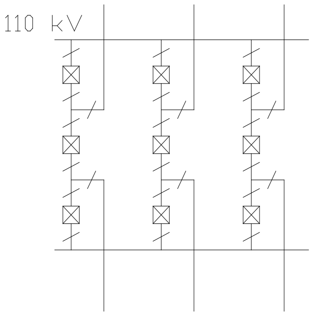
IEC 2395/12

Figure H.1 – T1-1 Small size transmission substation (single busbar 132 kV with infeed from 220 kV)



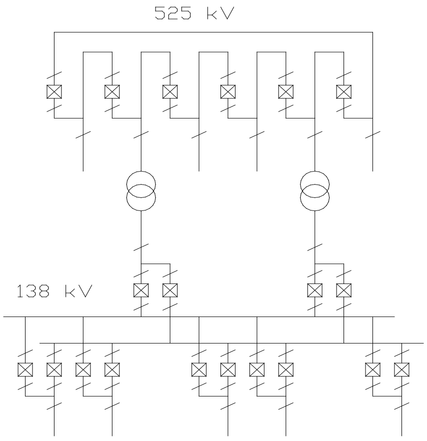
IEC 2396/12

Figure H.2 – D2-1 Medium size distribution substation (double busbar 22 kV with infeed from 69 kV)



IEC 2397/12

Figure H.3 – T1-2 Small size transmission substation (1 1/2 breaker busbar at 110 kV)



IEC 2398/12

**Figure H.4 – T2-2 Large size transmission substation (ring bus at 526 kV, double busbar at 138 kV)**

**Table H.1 – Definition of the configuration of all substations evaluated**

| Example | Number of busbars | Number of incoming feeders | Number of outgoing feeders | Number of couplings | Number of transformers |
|---|---|---|---|---|---|
| **T1-1** | 1 | 1 | 2 | - | 1 |
| **D2-1** | 2 | 2 | 5 | - | 2 |
| **T1-2** | 2 | - | 6 | 1 | - |
| **T2-2** | 2 | 4 | 5 | - | 2 |

## H.2 Assigned protection and control functions

### H.2.1 General

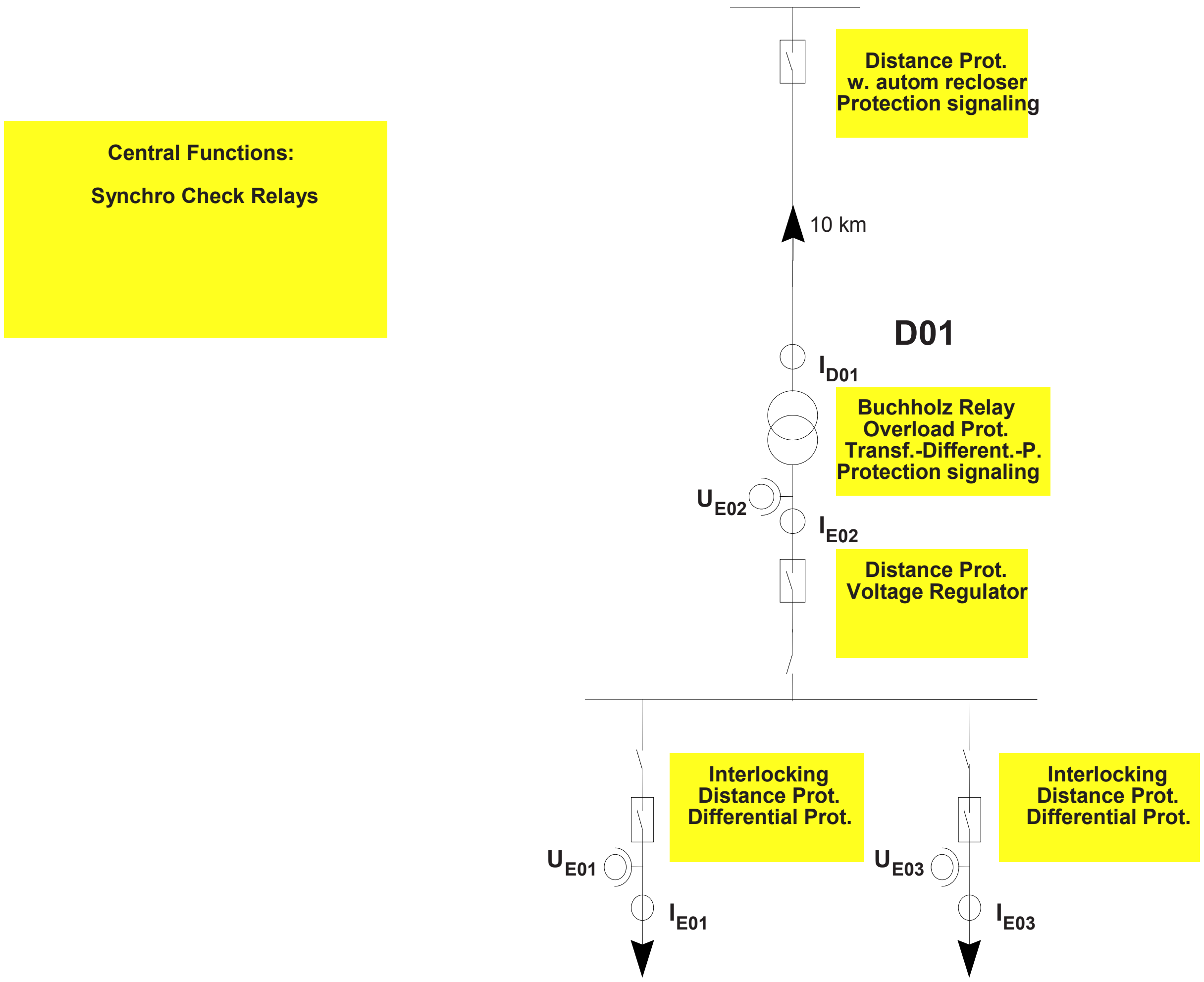
Due to different substation arrangements respectively protection and operation philosophies all over the world it is necessary to define functions of the secondary equipment regarding existing applications. Logical nodes and their assignment to physical devices is based on existing protection and operation schemes and done for each scenario separately. The assignment of logical nodes hosted finally in IEDs to the power system (switchyard) devices for each substation configuration is shown in the figures.

Compared with the first edition of IEC 61850-5 there are no results from any data flow calculation given since

- the data flow is not a requirement but the response times as listed in Clause 11;
- the data flow depends on the implementation which is outside the scope of Part 5.

### H.2.2 Substation T1-1

The protection scheme and associated control functions of this small transmission substation with single busbar are shown in Figure H.5:

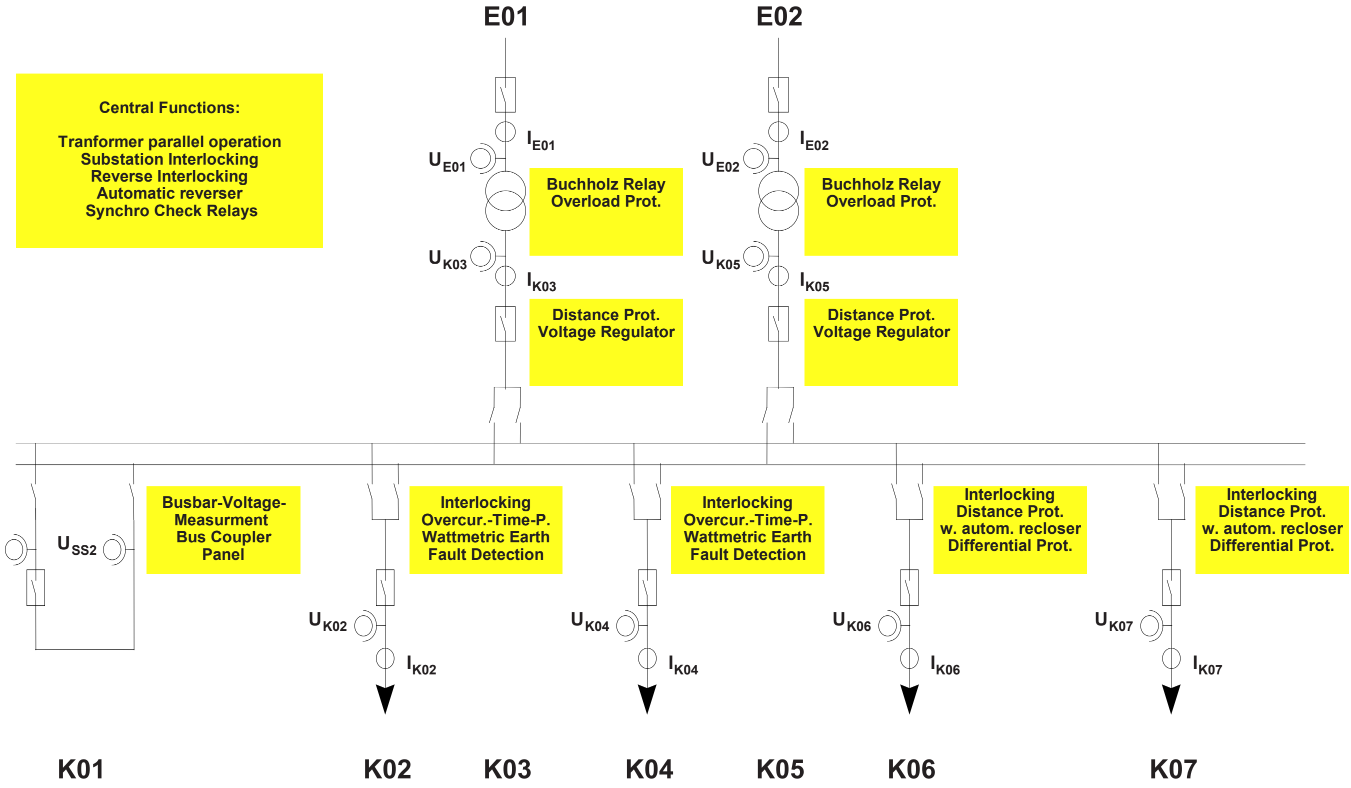


*IEC 2399/12*

**Figure H.5 – Substation of type T1-1 with allocation functions**

### H.2.3 Substation D2-1

The protection scheme and associated control functions of this medium size distribution substation with two in-feeding HV bays are shown in Figure H.6.

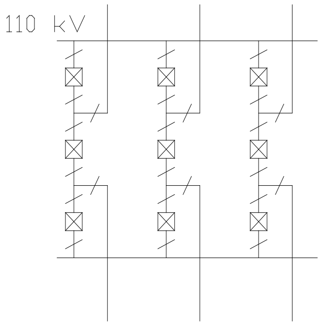


IEC 2400/12

Figure H.6 – Substation of type D2-1 with allocated functions

### H.2.4 Substation T1-2

The protection scheme and associated control functions of this small transmission substation with 1 1/2 breaker busbar are based on the T2-2 scenario (H.2.5), see Figure H.7:

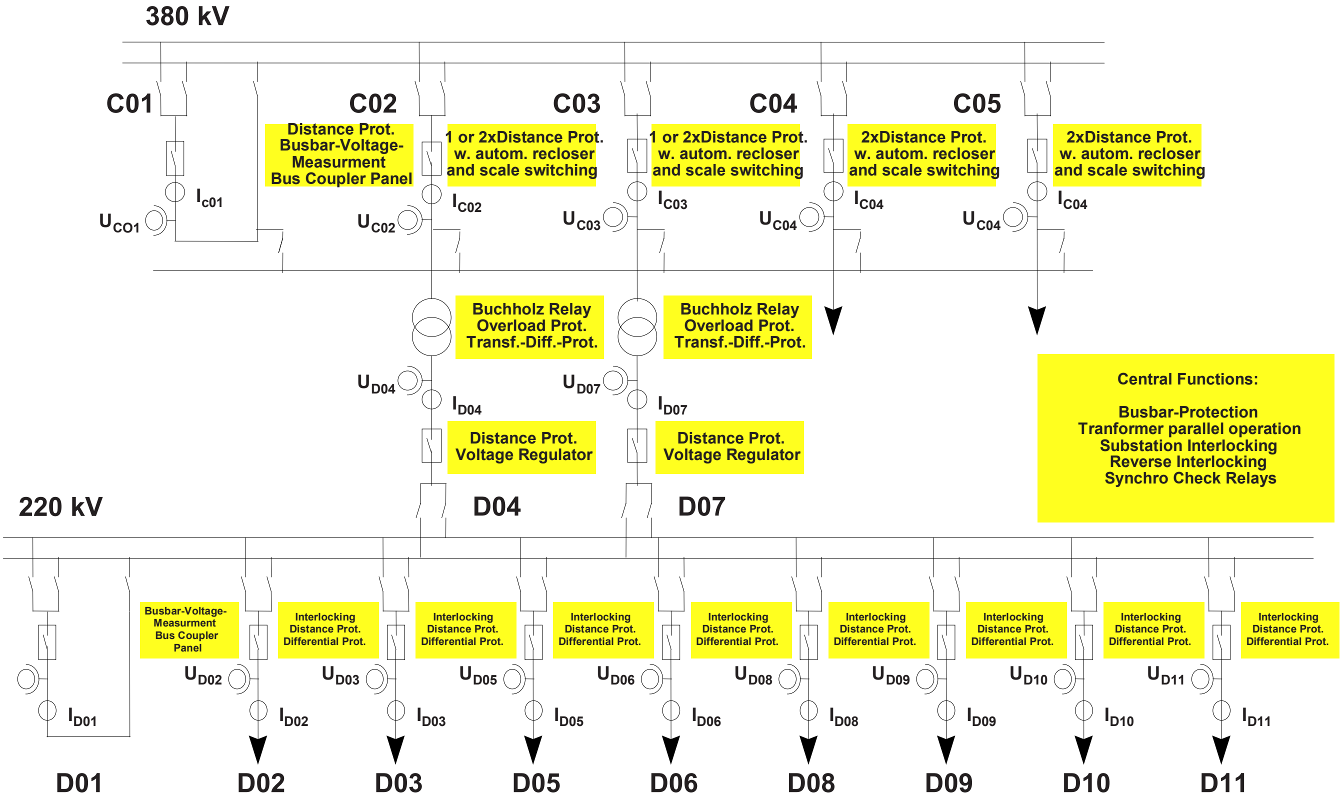


IEC 2401/12

Figure H.7 – Substation of type T1-2
(functions allocated same as for T2-2 in Figure H.8)

### H.2.5 Substation T2-2

The protection scheme and associated control functions of this large size transmission substation are shown in Figure H.8:



*IEC 2402/12*

**Figure H.8 – Substation of type T2-2 with allocated functions**

# Annex I

(informative)

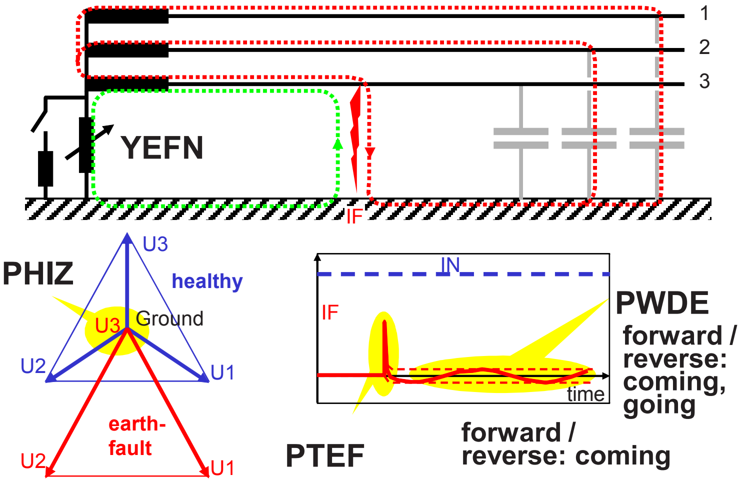
# Examples for protection functions in compensated networks

## I.1 The Transient Earth Fault (PTEF)

PTEF (Protection Transient Earth Fault) and PDEF (Protection Directional Earth Fault) are typically used functions to detect the location of an earth fault in a compensated network. The PTEF detects the transient charging current related with the network capacitance. Therefore the PTEF can only detect the beginning of an earth fault. The PSDE (directional earth fault protection for compensated networks based on watt-metric principle) detects the residual phase to earth current. Therefore the PSDE is able to notify the beginning and the end of an earth fault (see Figure I.1).

The feeders of the faulty line will indicate a forward earth fault while the other feeders may indicate a reverse earth fault.

At the beginning of the earth fault PTEF or/and PSDE provides information about the transient earth fault, at the end of the earth fault PSDE informs about.

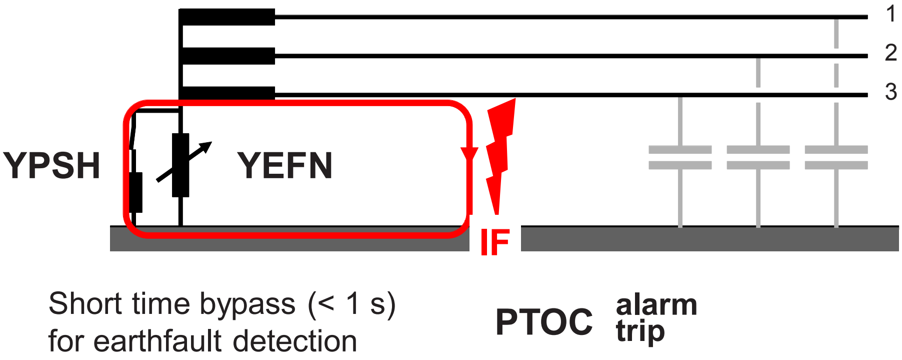


IEC 2403/12

Figure I.1 – The transient earth fault in a compensated network

## I.2 Short term bypass (YPSH)

For a clear detection of an earth fault in a compensated network the Pedersen coil in the star point of the transformer is bypassed by a shunt (see Figure I.2).

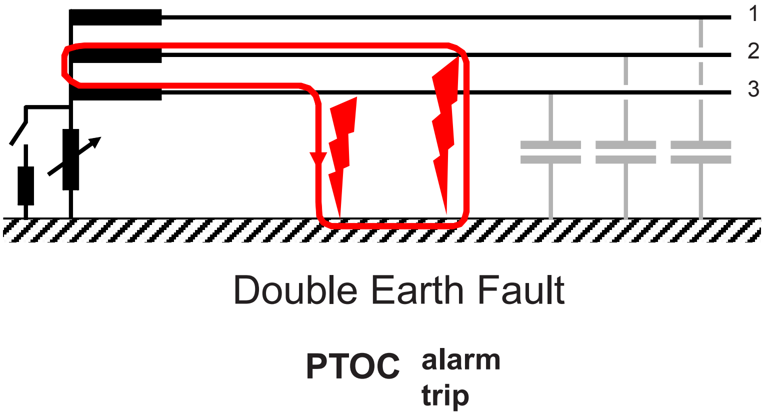


IEC 2404/12

**Figure I.2 – Short term bypass for single earth fault in compensated networks**

## I.3 The double earth fault (PTOC)

In compensated networks in case of a double earth fault (two phase earth fault) no reasonable fault current is flowing through the star point to ground (see Figure I.3).



IEC 2405/12

**Figure I.3 – Double earth fault in compensated networks**

## Bibliography

IEC 60617, *Graphical symbols for diagrams*

IEC 60834, *Teleprotection equipment of power systems – Performance and testing*

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, *Telecontrol equipment and systems – Part 4: Performance requirements*

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

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

IEC/TR 61850-1, *Communication networks and systems in substations – Part 1: Introduction and overview*

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

IEC 61850-7 (all parts), *Communication networks and systems for power utility automation – Part 7: Basic communication structure*

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

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

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

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

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

IEC 61850-8 (all parts), *Communication networks and systems for power utility automation – Part 8: Specific communication service mapping (SCSM)*

IEC 61850-9 (all parts), *Communication networks and systems for power utility automation – Part 9: Specific communication service mapping (SCSM)*

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

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

Cigré Report 34.03 published in Electra – K.P. Brand et al., *Communication requirements in terms of data flow within substations,* Electra 173, August 1997, 73-85

K.P. Brand et al., *Communication requirements in terms of data flow within substations,* December 1996 – published 2001, Ref. No. 180

IEEE Std C37.2-2008: *Electrical Power System Device Function Numbers and Contact Designation*

---

*This page deliberately left blank*

*This page deliberately left blank*

# British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

## About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

## Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

## Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

## Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

**PLUS** is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

## Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

## Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

## Useful Contacts:

**Customer Services**
**Tel:** +44 845 086 9001
**Email (orders):** orders@bsigroup.com
**Email (enquiries):** cservices@bsigroup.com

**Subscriptions**
**Tel:** +44 845 086 9001
**Email:** subscriptions@bsigroup.com

**Knowledge Centre**
**Tel:** +44 20 8996 7004
**Email:** knowledgecentre@bsigroup.com

**Copyright & Licensing**
**Tel:** +44 20 8996 7070
**Email:** copyright@bsigroup.com

**BSI Group Headquarters**

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™