IEC TR 61850-7-5

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TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 7-5: IEC 61850 Modelling concepts

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-5: IEC 61850 Modelling concepts

FOREWORD

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IEC TR 61850-7-5 has been prepared by Working Group 10 of IEC Technical Committee 57: Power systems management and associated information exchange. It is a Technical Report.

The text of this Technical Report is based on the following documents:

DTR	Report on voting
57/2253/DTR	57/2322/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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INTRODUCTION

The IEC 61850 standard series provides a very broad range of data models covering as much as possible all application functions in the range of power utility automation. The modelling both in the domains and between the domains show differences which may impact interoperability. Therefore, some informative guidelines are helpful to reach a common approach in application function modelling. A lot of basic functionality is based on the concept of IEC 61850 and is, therefore, the same for all application domains. As result, a basic cross-domain part in the form of a Technical Report is useful. Domain specific issues are addressed in the Technical Reports IEC TR 61850-7-5xx (e.g. IEC TR 61850-7-500 for substation automation).

To cover all domains in a comprehensive way would not come to a result in a reasonable time. This may be a task for future editions of this document. Therefore, this document describes in selected examples the use of logical nodes for modelling application functions and related concepts and guidelines in general independently from any application domain respectively valid for all application domains in the utility automation (substation automation, distributed energy resources, hydro power, wind power, etc.). It also includes some tutorial material where helpful.

The modelling of the use cases given in this document is based on the class model introduced in IEC 61850-7-1. The logical node and data names used in this document are defined in IEC 61850-7-4 and IEC 61850-7-3, the services applied in IEC 61850-7-2. If needed for the understanding of modelling these use cases, the application of services is also described. If different options cannot be excluded, all options may be mentioned.

If extensions are needed in the use cases, the normative naming rules for multiple instances and private, compatible extensions of Logical Node (LN) Classes and Data Object (DO) Names defined in IEC 61850-7-1 are considered.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-5: IEC 61850 Modelling concepts

1 Scope

This part of IEC 61850, which is a technical report, establishes modelling concepts that help the user to understand how to apply the models defined in IEC 61850-7-4 and IEC 61850-7-3 to implement practical applications.

This document provides the basic concepts that are valid for all application domains using IEC 61850. Domain specific concepts are defined in other technical reports as in the document range of IEC 61850-7-5xx; as an example, IEC 61850-7-500 describes modelling concepts for functions related to substation automation.

On one side the number of potential topics for cross-domain modelling may be very high but on the other side it may be limited by domain specific restrictions often created by the historical evolution of IEC 61850 in the domains.

The first topic selected is the common control of power utility primary objects by means of the power utility automation systems based mainly on the long experience in substation automation systems. Common attributes for reliable power utility automation systems in all domains are quality and health. A special function having a broad application range in power utility automation systems is the scheduling of services as provided by the domain distributed energy resources (DER) used in smart grids, especially also for electric mobility. Not yet so much discussed in the context of IEC 61850 but very important for all IEDs is the impact of restart (power cycle) on the data model parameters. Non-agreed behaviour will raise problems for interoperability in multi-vendor systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

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

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

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

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

IEC TR 61850-90-8, *Communication networks and systems for power utility automation - Part 90-8: Object model for E-mobility*

IEC 62351, *Power systems management and associated information exchange – Data and communications security* (all parts)

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document the terms and definitions given in IEC 61850-2 and IEC 61850-7-2 apply.

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

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp/ui

3.2 Abbreviated terms

EV Electric vehicle

IL Checking Interlocking

NCC Network Control Centre

CS Checking Synchronism

4 Control

4.1 Control authorization

4.1.1 Basics

Control (control commands) crosses various layers and may require authentication and authorization before it arrives at the controllable object. Figure 1 shows the various layers.

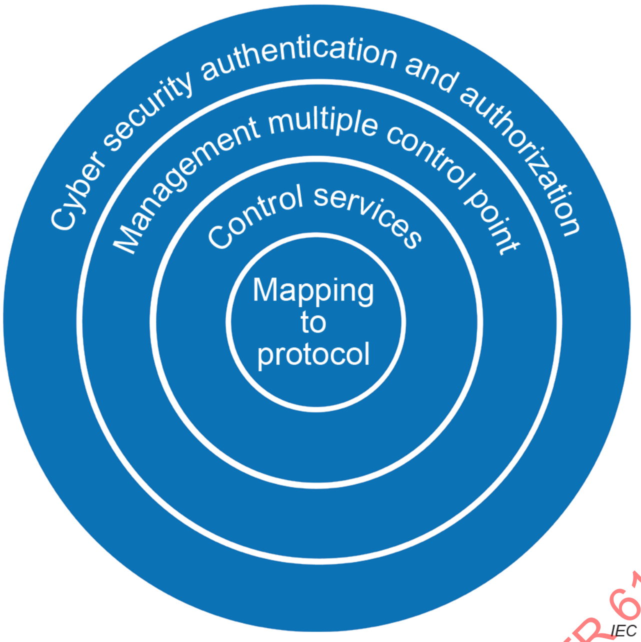


Figure 1 – Communication vs. application layer model for controls

- Mapping to protocol

  To pass a control command from a client (which issues the control) to a server (which executes the control command) both located in two different IEDs, the command needs to be mapped to a protocol. For exchanges within substations and for tunnelling through external communication systems to other substations and to the NCC a mapping to Manufacturing Message Specification (MMS) above Ethernet according to IEC 61850-8-1 is preferred. In addition, also mapping to GOOSE according to IEC 61850-8-1 may be used. For the usage outside substations beside the message tunnelling and message conversion for non-IEC 61850 communication networks especially at distribution level a mapping to web technology protocol as described in IEC 61850-8-2 may be more appropriate.

- Control services

  The flexibility of being able to choose a protocol to map to is granted thanks to the fact that controls are defined in IEC 61850-7-2 as control services of an Abstract Communication Service Interface (ACSI). These control services are tailored to the applications of the power utility automation domain.

- Management of multiple control points

  Where a control is an exclusive exchange of requests and responses between two peers, network automation systems need to also allow for applications where more than one control point may issue controls to a controllable object. The management of parallel accesses is performed on the basis of user specific rules depending on operational philosophy.

- Authentication and authorization

  The means and methods provided by the IEC 62351 series on communication network and system security will ensure that only authenticated clients may have defined access to given parts of a power utility automation system. It is furthermore up to the roles and to the permissions granted to this client whether its control request to a given controllable object is accepted.

4.1.2 Validating a control request

4.1.2.1 General

Before a control is executed, the command shall pass several steps in approval, reflecting different aspects of validation.

4.1.2.2 Validation against the LN behaviour

The control request is forwarded to the function in charge of the controllable data object addressed in the control service. When reaching a function for control, the LN behaviour (e.g. represented by the actual value of the DO CSWI.Beh) shall decide whether the control can be processed or not, following IEC 61850-7-2. Since functions are accessible via communication in all the five states of their functional behaviour DO LN.Beh, a response has always given.

4.1.2.3 Validation against the control model

Depending on the control model which is set for the controllable object, the IED shall perform various checks against the command. The explicit order is out of the scope of the standard IEC 61850. Since the use of SBO control with enhanced security according to IEC 61850-7-2 is the common model for switchgear control, the current clause delves neither into direct operate, nor into SBO with normal security.

4.1.2.4 Test whether the conditions are met

4.1.2.4.1 General

Two kinds of tests may be performed: ‘operative test’ depending on the operative condition of the object and its process environment, and ‘dynamic test’, e.g. checking the moment of allowance for the command to the object. In its control request the client shall specify whether synchrocheck and interlocking check are to be performed. If the addressed function respectively the data object does not support these checks (not implemented, not configured), the appropriate check bits of the control request are ignored and the command is performed directly, see IEC 61850-7-2:2010, Table 110.

4.1.2.4.2 Operative test

The control hierarchy function has to be configured according to the operations requirement of the user. The control authority shall be checked by comparing the state (XXXX.Loc) of control hierarchy active in the function hosting the controllable object against the order category submitted in the actual command. Plausibility checking shall run to see whether the intended operation does not contradict to the actual position of the switchgear. To validate the switchgear control against the conditions of interlocking (IL) with the positions of other switchgear, the release output of the interlocking function CILO is taken as criteria for approval (see Table 1). The control of the switchgear shall be validated against the readiness of the equipment for an operation (consideration of EEHealth, BlkCls, supervisions through SCBR, etc.).

Table 1 – Dependence of checking Interlocking (IL) conditions on the control command and on the server configuration

LN, DO configuration → ↓ Control context		No IL check	IL check	No IL check	IL check
		SwModKey = F		SwModKey = T	
from client (NCC, station HMI)	no CheckCondition	N	N	N	N
	IL CheckCondition set	N	Y	N	N
from IED level	not specified	N	Y	N	N

Then, upon SelectWithValue, the object is reserved for this actor, unless associated checks (1-out-of-n, client reservation e.g.) would lead to a rejection of the control, documented with the appropriate AddCauses. All other objects are deselected.

4.1.2.4.3 Dynamic test

In a second step, upon receipt of the Operate, the synchrocheck release (RSYN.Rel) shall be checked (see Table 2). The synchrocheck is only applicable for circuit breakers which may connect separated parts of the power grid.

Table 2 – Dependence of checking synchronism (CS) conditions on the control command and on the server configuration

LN, DO configuration → ↓ Control context		No CS check	CS check
from client (NCC, station HMI)	no CheckCondition	N	N
	CS CheckCondition set	N	Y
from IED level	not specified	N	Y

As soon as the control passed the approval for execution on the switch controller level, the function which is modelling the controllable data object (here: XCBR.Pos, XSWI.Pos) is triggered. Depending on the device layout and on the functional distribution, similar checks shall be performed in the new function and on the new object before the control finally leads to an action of a contact at the device periphery. Figure 2 outlines the individual steps of a command approval; the sequence of the steps is a local issue.

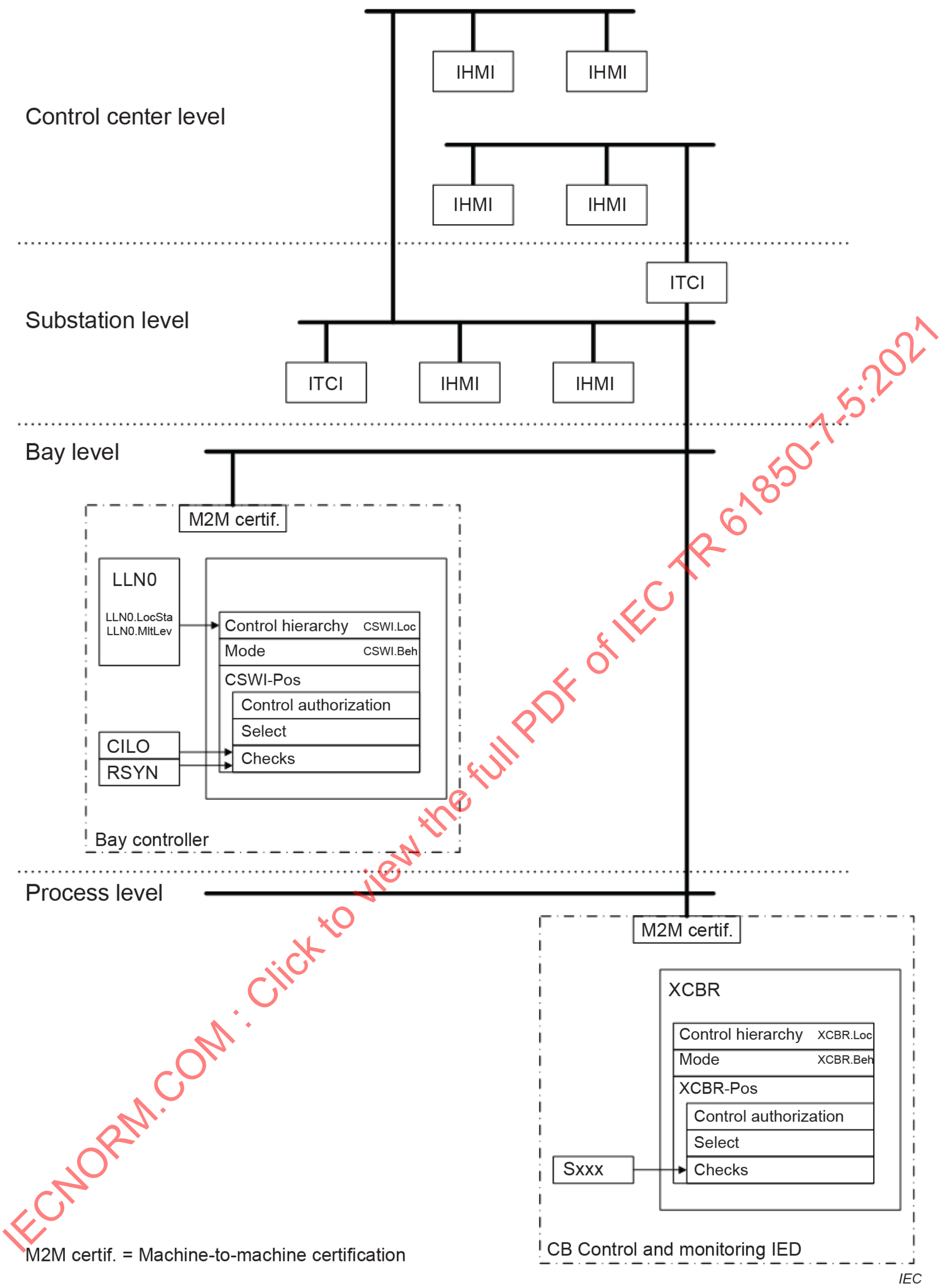


Figure 2 – Different levels of control authority (example)

4.1.3 Exclusive control authorization for one out of multiple actors of the same level of control hierarchy

Operational constraints may restrict the number of active control sources to one control level (in effect the one which is closer regarding the control circuits with respect to the controllable object). For this, LLN0.MltLev is set to 'False'. But still, more than one operator workstation may exist at the same level of hierarchy, and more than one gateway computer could request control access to the substation at the same time.

In addition, to ensure that only one control command at a time is executed in a system, the 1-out-of-n control principle shall be applied. The first actor claims for an exclusive right to issue controls in the system. As soon as it is granted to them, controls from all other instances of IHMI or ITCI are rejected on all servers in charge of controllable objects. After the control execution is finished, the system-wide blocking is released. This so-called 1-out-of-n control principle may be restricted to limited areas (subsystems) where in each of the subsystems one object out of these different areas may be operated independently at the same time. Regarding the common use of SBO the first set "selected" attribute is very convenient to be distributed and block any second control approach.

4.1.4 Different control permissions for different actors of the same level of control hierarchy

MltLev='True' specifies that control from multiple levels is allowed at the same time, some topologies require different rights for different actors, even on the same level of control hierarchy.

Example: Assumed a substation automation system is connected to two network control centres e.g. to a local control centre and to a regional control centre. Both control centres (NCC) receive the feedback information from the controllable objects of the substation, but their permissions to control these objects are different:

– The local control centre is not allowed to control the earthing switch of the overhead line, since this control centre has normally no visibility onto the remote switchgears connected to the overhead line.
– The regional control centre is not allowed to control the incomer circuit breaker, since the transformer is owned by the local utility.
– During the night shift, where the local control centre is unmanned, the permission to control the incomer circuit breaker is granted to the regional control centre.
– In emergency situations the permissions may be given to the other control centre.

The application needs behind the above scenarios are not limited to controls from network control centres; they are applicable to multiple HMIs at substation level as well.

Since the scheme of control authorities reflects the individual organization of the user and varies from project to project, no common rule can be proposed. There is today no means in IEC 61850 to configure the control authority to support such scenarios. Therefore, these applications shall be configured/engineered in proprietary ways to reach reliable controllability.

NOTE Ongoing modelling activities as in IEC TR 61850-90-19 and AoR in IEC 62351-8 may resolve this issue.

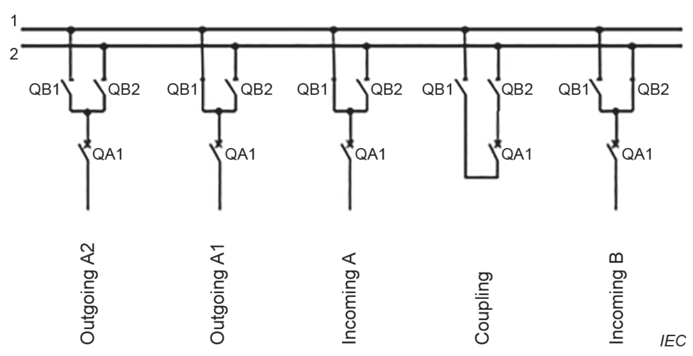
4.2 Control authority for process equipment

4.2.1 Control commands for process equipment from automations instead of HMI

4.2.1.1 Use case 1 – Busbar change-over

This use case defined in Table 3 is related to the issuing of switchgear controls (control commands), especially a sequence of controls, as outputs of logics, i.e. out of the domain substation automation. Nevertheless, this approach is valid for all domains, when commands may be issued not only by a client but also by some automatics (logics).

Table 3 – Use case 1 definition

Use case description	An outgoing line is supplied from busbar 1 of a double busbar scheme. This line shall be changed over to busbar 2 without interrupting the supply.
Initiator Actor	Network operator initiating the change-over
Primary Actors	None
Secondary Actors	None
Trigger	Operational reasons
Assumption list	Busbar 2 is connected to incoming line B, switchgears are available for switching, i.e. no blockings
Precondition list	Outgoing bay A1: QB1 closed, QB2 open, QA1 closed Coupling bay: QB1 open, QB2 open, QA1 open
Postcondition list	Outgoing bay A1: QB1 open, QB2 closed, QA1 closed Coupling bay: QB1 open, QB2 open, QA1 open
Flow	Control to close QB1 of the coupling bay If desired end position is reached, then Control to close QB2 of the coupling bay If desired end position is reached, then Control to close QA1 of the coupling bay If desired end position is reached, then Control to close QB2 of the outgoing bay If desired end position is reached, then Control to open QB1 of the outgoing bay If desired end position is reached, then Control to open QA1 of the coupling bay If desired end position is reached, then Control to open QB1 of the coupling bay If desired end position is reached, then Control to open QB2 of the coupling bay If desired end position is reached, then end
Illustration	
Additional Requirements list	In case of trips or user interactions during run time the sequence has to be terminated immediately.

Notes & Outstanding Issues	The sequence of controls is continued on the conditions – that the previous step is successfully terminated, – that the next equipment is not blocked, – that the next step is permitted checking all conditions applicable otherwise the sequence is terminated. As an option, the opening of the coupling bay may be bypassed, if another outgoing bay shall be changed-over as well. Then, for the second run, also the closing of the coupling can me bypassed. For the last run, the opening of the coupling cannot be bypassed.

4.2.1.2 Solution variant A: Control commands using control services on CSWI.Pos

Since logic outputs are Boolean, each output to control a switchgear must be converted to trigger control services (typically select-before-operate) using an external function. The implementation of this function is a local issue. To issue controls via CSWI needs the verification of the controls against the interlocking conditions, against the uniqueness of control (1-out-of-n) and against the synchrocheck release as applicable.

4.2.1.3 Solution variant B: Control commands using GOOSE messages to XSWI/XCBR

When using GOOSE messages to initiate a control directly at XSWI/XCBR, the GAPC instance will provide a similar output interface which is provided by CSWI: SelOpn, SelCls (SPS) and OpOpn, OpCls (ACT). Based on Ed.2.1 the LN class GAPC offers only one output of common data class ACT. Therefore, multiple instances of GAPC are needed. The full control capability in one instance of GAPC will be addressed in future standardization.

4.2.1.4 Solution variant C: Control commands using GOOSE messages to CSWI

To issue controls via CSWI needs the verification of the controls against the interlocking conditions, against the uniqueness of control (1-out-of-n) and against the synchrocheck release if applicable. If the CSWI instance implements the subscription of GOOSE to initiate a control, then this variant is already possible today.

5 Quality and its propagation

5.1 Standard processing principle

5.1.1 General

Regardless from the further processing of the received information in the receiving LN (respecting the Beh and LN specific calculations), the following functionality shall be provided:

– output.q.validity shall follow input.q.validity unless specified differently by the function.

– input.q.detailQual is not propagated.

– input.q.source is not propagated.

– output.q.test shall follow the rules laid down in IEC 61850-7-4:2010, Clause A.2.

– input.q.operatorBlocked is not propagated.

5.1.2 Respecting behaviour

The functional behaviour of the receiving LN is expressed by its XXXX.Beh. The data quality of its outputs is assigned in accordance with the rules laid down in IEC 61850-7-4:2010, Clause A.2.

5.1.3 LN specific calculations

The receiving application function uses the received information to perform its function. The specific need of the application defines how the input status value is consumed and how the input data quality influences the acceptance of the input status value in that function.

Application dependent rules shall be implemented in the function how to deal with questionable or invalid inputs to always come to a useful/save result. Then the function output may be of quality.validity ‘good’, although the input was of a worse validity.

5.1.4 detailQual is not propagated

Since the output data of an application function is based on calculations considering the data quality of all input data, the detail quality of the input data is not directly transferred into the output data detail quality. It is the application function itself which defines the detailQual of its output data.

5.1.5 Configurable propagation of the value of the element ‘source’

If an information is substituted (status value and/or data quality) the element ‘source’ of the data quality is set to ‘substituted’.

The user may want to bring to the operator’s attention the fact that a signal is being substituted. For cases where a substituted signal is processed by another function, the input data quality information ‘source’ must be propagated through that function to show in the resulting data quality that input data is substituted. Typically, output data which is calculated from substituted input data is not marked as substituted, for the substitution was not made on the output data. As an option the propagation may be configured.

5.1.6 operatorBlocked is not propagated

If an input data to a function is operatorBlocked, the function will not receive process updates from this input, but it continues processing using this input data as a static value. The function may still receive updates from other inputs, contributing to a change of the output data, therefore the output data is not ‘operatorBlocked’.

‘operatorBlocked’ is only to be found at the data which was subject to a user intervention.

5.2 Special processing principle for (single phase) XCBR mapping to CSWI

5.2.1 General

The principle is valid for both XCBR and XSWI mapping to CSWI.

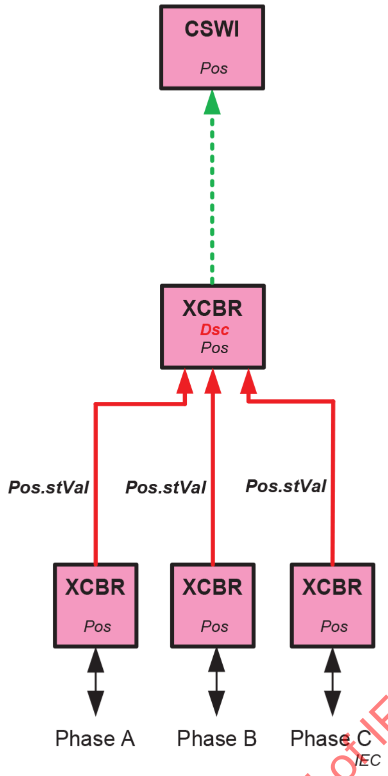


Figure 3 – Single-phase monitoring of the CB position

Today, IEC TR 61850-7-500 describes which Logical Node is in charge to combine the three single phase XCBR.Pos into a consolidated common single three phase XCBR.Pos. CSWI could directly subscribe to the individual single phase XCBR.Pos, but more often the common XCBR instance is seen to be used for consolidating the three phase XCBR.Pos, together with creating the XCBR.Dsc signal if applicable (Figure 3). The single-phase modelling option of CSWI is not considered here.

Regardless of the processing of the received information in CSWI/common XCBR afterwards (respecting the Beh and LN specific calculations), the following treatment shall be provided for both the Pos.stVal and the Pos.q:

a) If the information of the single phase XCBR.Pos are of the same value (closed resp. open), then the common XCBR.Pos shall be this value.

b) If the information of the single phase XCBR.Pos are of different values, then the common
   - XCBR.Pos.stVal shall be ‘bad’
   - XCBR.Pos.q.validity shall be
     - ‘invalid’ if at least one contributing Pos.q.validity is ‘invalid’
     - ‘questionable’ if at least one contributing Pos.q.validity is ‘questionable’ and the others are ‘good’
     - ‘good’ if all contributing Pos.q.validity are ‘good’
   - XCBR.Pos.q.detailQual information shall follow detailQual of the dominating validity information.
   - XCBR.Pos.q.source shall be
     - ‘substituted’ if at least one contributing Pos.q.source is ‘substituted’
     - ‘process’ if all contributing Pos.q.source are ‘process’

– XCBR.Pos.q.test shall follow the rules laid down in IEC 61850-7-4:2010, Clause A.2.
  • If the common XCBR is not in ‘test’ and one or more of the contributing XCBRs are in ‘test’, the three phase XCBR.Pos.stVal shall be ’bad’.
– XCBR.Pos.q.operatorBlocked is not propagated from the contributing Pos.

5.2.2 Respecting the Behaviour

The functional behaviour of the common XCBR depends on its Beh. The data quality of its outputs is assigned in accordance with the rules defined in IEC 61850-7-4:2010, Clause A.2.

5.2.3 LN specific calculations

If CSWI/common XCBR do not contribute to the processing of the position output by internal evaluations, the source stVal and the q shall be forwarded according to the above principle.

Internal evaluations can be:

– Switchgear movement supervision: If the switchgear started to move from one position to the other – its Pos.stVal is set to ‘intermediate’ – but the final position is not reached, Pos.stVal ‘bad’ can be set in place of ‘intermediate’ after the expiration of a supervision time.
– Suppression of the intermediate position information: Some users prefer to suppress the intermediate position signal (stay with the prior state) until the final position is reached. If the above movement supervision is used and active, ‘bad’ state is transferred in case of defects after the expiration of a supervision time.

5.2.4 Propagation of detailQual

The cascading of CSWI, common XCBR and single phase XCBR shall not lead to a deprecation of the detailed quality information provided by an XCBR. Unless contributed by a specific functionality, CSWI does not provide an add-on (internal evaluation) to the data validity of position information. Receiving functions like IHMI or automations might be interested in receiving the information ‘oscillatory’ of XCBR.Pos to act upon this in a specific way.

5.2.5 Substitution of switchgear position signals

Before coming to forwarding of substituted values, the object of a substitution shall be discussed.

Once a user intends to substitute a switchgear position, then the user needs to decide on the intended purpose of this substitution:

– If the substituted position shall become visible on an operator screen and automations shall use this substituted value as well, then he substitutes XCBR.Pos.
– If the substituted position shall become visible on an operator screen, but automations like switchgear interlocking shall perform on the process value, then the user substitutes only CSWI.Pos.

For information consistency between XCBR.Pos.stVal and CSWI.Pos.stVal, the first option is preferred.

A substituted XCBR.Pos.stVal is transferred into CSWI.Pos and gets visible on the operator screen. Besides the substituted position, the user may also want to bring to the operator’s attention the fact that a position is being substituted. To allow this, the resulting CSWI.Pos.q.source must reflect XCBR.Pos being substituted and therefore XCBR.Pos.q.source must be propagated through CSWI.

5.2.6 operatorBlocked is not propagated

If an input data to a function is operatorBlocked, the function will not receive process updates from this input, but it continues processing using the input data as a static value. The function may still receive updates from other inputs, contributing to a change of the output data, therefore the output data is not ‘operatorBlocked’.

‘operatorBlocked’ is only to be found at the data which was object to a user intervention.

5.3 Conclusion

Finally, it depends on the application (a processing chain of individual functions) which information details are needed at the different levels. There are some use cases (information consumed by automations e.g.) where it can be fixed in rules (see Table 4) whether quality details are propagated or not, whereas there are other use cases (e.g. information consumed by the operator) where it must be configurable.

Table 4 – Example of fixed rules: Boolean OR out of two input signals

in_SPS1		in_SPS2		out_SPS	
stVal	**q.validity**	**stVal**	**q.validity**	**stVal**	**q.validity**
0	good	0	good	0	good
1	good	1	good	1	good
0	invalid	0	good	0	invalid
1	invalid	0	good	1	invalid
1	invalid	1	good	1	good
0	good	0	invalid	0	invalid
0	good	1	invalid	1	invalid
1	good	1	invalid	1	good
0	invalid	0	invalid	0	invalid
1	invalid	1	invalid	1	invalid

As long as a receiving function is healthy (cf. the following chapter), this function may output valid data, although not all of its input data is valid. It is always a matter of the functionality implemented whether a function propagates the validity of the inputs or processes them as per application needs and outputs valid signals.

Example:

HV line is in service, but VT fuse is blown: earthing switch must not be released for closing

TVTR.FuFail.stVal=true, q.validity='good'

→ Measurement acquisition MMXU.PhV=[zero], q.validity=’invalid’

→ Release for earthing switch FLIM.LoLim=false, q.validity=’good’

6 Health and its application

6.1 General

There are different types of health but with the same encoded enumeration of three values.

The data object “Health“ provides information about the status of a certain functionality modelled by logical nodes. It is a result of the self-supervision of the corresponding logical node.

Data object Health is assigned to the CDC ENS (enumerated status). Health, as an enumeration object, can have three enumerated values. The literals are “Ok”, “Warning” and “Alarm”.

<EnumType id="HealthKind">
<EnumVal ord="1">Ok</EnumVal> →No problems, normal operation ("green").
<EnumVal ord="2">Warning</EnumVal> →Minor problems, but in safe operating mode ("yellow"). The exact meaning is a local issue, depending on the dedicated function/device.
<EnumVal ord="3">Alarm</EnumVal> →Severe problem, no operation possible ("red").
</EnumType>

There are four data object classes, where HealthKind is assigned:

– LPHD.PhyHealth – Health of the physical device (IED)
– LLN0.Health – Health of the logical device
– LN.Health – Health of domain LNs
– LN.EEHealth – Health of the external equipment.

The semantic of the state of health “Ok” (green) is quite simple. The state of the object is active, and the LN performs its designated functionality. Self-supervision does not detect any functional nor other failure.

State of health “Warning” (yellow) depends on the supervised function. Supervision detects failures which may result in limited functionality. An example is the supervision SCBR for the switchgear XCBR. It detects a deviation from a normal operative state which results in some restrictions on the circuit breaker function.

State of health “Alarm” (red) provides the information that the functionality is not anymore active or shall be blocked due to failures detected by the self-supervision.

Example 1: SCBR.OpCntWrn is true, if the number of operations 'OpCnt' exceeded the warning level for the operations. There are still operations possible but the remaining number of operations is near to the absolute limit for operations. Reaching this limit results in an operation counter alarm (SCBR.OpCntAlm) and will block any further breaker operation.

Example 2: The DO Health for a function represented by an LN XXXX shows the “Warning” (yellow) state. This means that the function is neither “Ok” (green) nor “Alarm” (red). One reason may be that the function is starting up after a power down. The “Warning” (yellow) state is not persistent i.e. refreshed if the reason for the “Warning” (yellow) is still existing after the power up.

There are many examples where the Health is both outside the “Ok” (green) state and the “Alarm” (red) state. These both states are easily to be defined. For the meaning of the state “Warning” (yellow) the user has to consult the manual.

6.2 The use of LPHD.PhyHealth, LLN0.Health, LN.Health and LN.EEHealth

The class mode of the object Health is shown in Table 5.

Table 5 – Health in IEC 61850-7-4

DOname	LNclass/ abstractLN	Presence condition	Description in IEC 61850-7-4	Sub-package in IEC 61850-7-4 UML	How related to Function/ Equipment/ IED	Semantical remarks
PhyHealth	LPHD	Mandatory	State of the physical device related hardware and software.	LNGroupL	Physical IED Health	HW: State of electronic components of a complete IED from HW supervision SW: internal supervision
Health	LLN0	MO rootLD (Mandatory in rootLD, optional in others)	State of the logical device related to hardware and software. It is derived from the worst (most critical) value of the health attribute of all the domain logical nodes contained in the logical device: 'Health' = max('DomainLN[i].Health').	LNGroupL	LD Health (most critical LN Health within specific LD)	HW/SW Functional supervision
Health	Domain LN	Optional	State of the logical node related hardware and software. More detailed information related to the source of the problem may be provided by specific attribute of the logical node.	AbstractLNs Common	All function/ equipment LNs e.g. P-LN, C-LNs etc.	HW/SW Functional supervision of Domain LN
EEHealth	Equipment Interface LN	Optional	State of external (electrical, mechanical or communication) equipment to which the logical node is associated.	AbstractLNs Common	LN related to external process equipment e.g. YPTR, T-LN	External signal shows external component (HW) failure (e.g. circuit breaker mechanism, power equipment failure)
EEHealth	Non Process Interface LN	Optional			LN related to external equipment, but not with process interface e.g. IHMI, ITCI	External signal shows external component (HW) failure (e.g. display is out of operation)
EEHealth	Control Equipment Interface LN	Optional			LN related to external process, controllable equipment e.g. GGIO, K-LN, X-LN, Z-LN, Y-LN with controls	External signal shows external component (HW) failure (e.g. circuit breaker contact abrasion)

The states of Health will be calculated based on HW, SW and functional supervisions.

EEHealth is related to external equipment and provided by Equipment Interface LN, based on inputs of health-related signals.

Examples for HW supervision are:

– Communication-module failure
– Measuring-transducer module failure
– Integrated Ethernet interface
– Real-time clock building block
– A/D converter
– Memory error (flash)
– CPU/Controller/FPGA error
– 3 consecutive unsuccessful restarts
– Battery voltage
– Supervision of hardware configuration (Missing hardware module)

Examples for SW supervision are:

– Supervisions of the data and version consistency
– Supervision of the undisturbed sequential activity of the device firmware
– Supervision of the available processor performance

Examples for functional supervision are:

– Voltage or current supervision (sequence, balance, sum, rotating field)
– Broken conductor

Examples for external equipment supervision are:

– Gas insulation supervision
– Trip circuit supervision
– Drive supervision

6.3 Health in Proxy-IEDs, in LNs of type Mirror and in a LD hierarchy

The concept of LD hierarchy is described in IEC 61850-7-1. Proxy LDs are treated in the same document but also in IEC 61850-90-2.

In Figure 4 some theoretical examples are shown of how Health and EEHealth may be utilized.

IED1 contains three logical devices (LD1, LD2, LD3). All LDs are on root level, i.e. their LN LLN0 does not contain DO GrRef.

In LD2 the data object LPHD.Proxy = true. By that DO, LD2 shows that it is a proxy of another LD in another IED (in the example IED3 LD5). LD3 of IED1 contains a LN with data object mirror Mir = true, i.e. this LN instance is a mirror of another LN (here in IED2 LD4.LN3).

LPHD.PhyHealth represents HW/SW status information about the complete IED1. LLN0.Health is the value of LD.Health summarizing the worst value of all domainLN.Health.

Health of domainLN provides LN specific information. The meaning of enumerated value Health.stVal=Warning cannot be specified for the domain LN in the standard because it is LN specific and depends on the implementation in the IEDs.

The value of Health of the proxy LD/LN or that of the mirrorLN comes from their source LD or LN.

IED4 shows an example of a LD hierarchy. The root LD LD1 contains a LD11 that contains itself the LD111. Therefore the Health of the root LD1 summarizes also the LD11.LLN0.Health and LD111.LLN0.Health.

LD11 has a domainLN1 with the data object EEHealth, i.e. there is the information available that represents HW/SW status information of the external equipment.

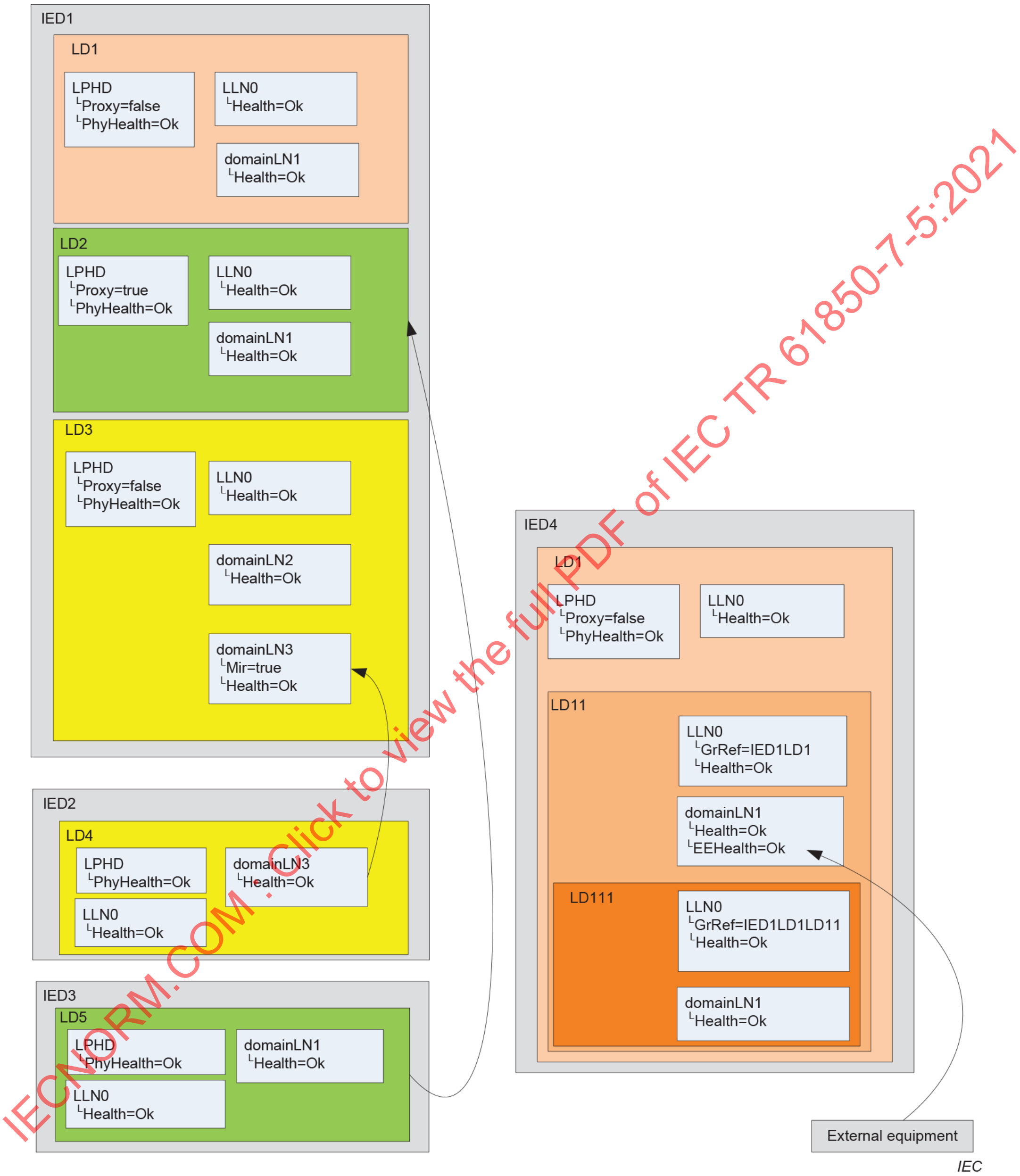


Figure 4 – Examples of use of Health and EEHealth in models

7 Special functions

7.1 Use of cross domain schedules and scheduler

7.1.1 Introduction

This clause illustrates possible usage of the schedule LNs as proposed in IEC TR 61850-90-10, but now integrated into IEC 61850-7-4. It proposes two examples. Example 1 is an instance of possible usage of schedules in EV charging as described in IEC TR 61850-90-8 illustrating the prioritization among schedules. Example 2 is a more generic one and illustrates the switching between periodic schedules of similar priorities.

As a reminder, and extracted from IEC 61850-7-4, schedules are supported by the association of at least two LN class instances aiming at modifying the value of a single controllable scheduled entity (as defined in IEC 61850-7-4:2010, Subclause K.2.8):

An instance of LN FSCH (Schedule) describes the content of a single schedule composed of a set of values of the same CDC (i.e. SPG, ING or ENG, or ASG, depending whether the expected scheduled entity is respectively of CDC SPC, INC, ENC or APC) at given intervals of time. The FSCH LN class content is shown in Figure 5 (extract from IEC 61850-7-4).

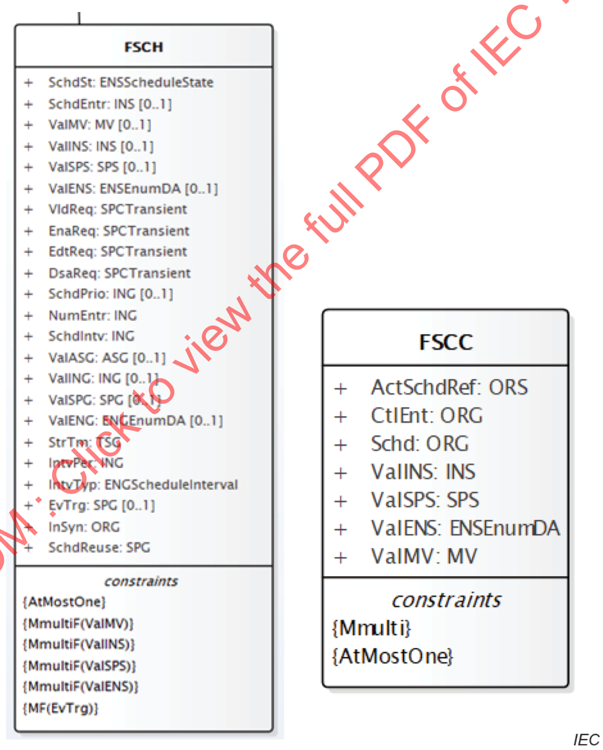


Figure 5 – FSCH and FSCC LN class

The LN FSCH has various states and can be started at a given time or triggered by an external trigger. Due to the CDC of starting time (TSG), such start time can be one or multiple UTC times (e.g. 2016-06-10 06:00), one or multiple calendar times (e.g. every Monday at 08:00 h).

The LN FSCH can be assigned a processing priority and is governed by the standard state machine defined in IEC 61850-7-4:2010, Subclause K.2.6.2 as shown in Figure 6.

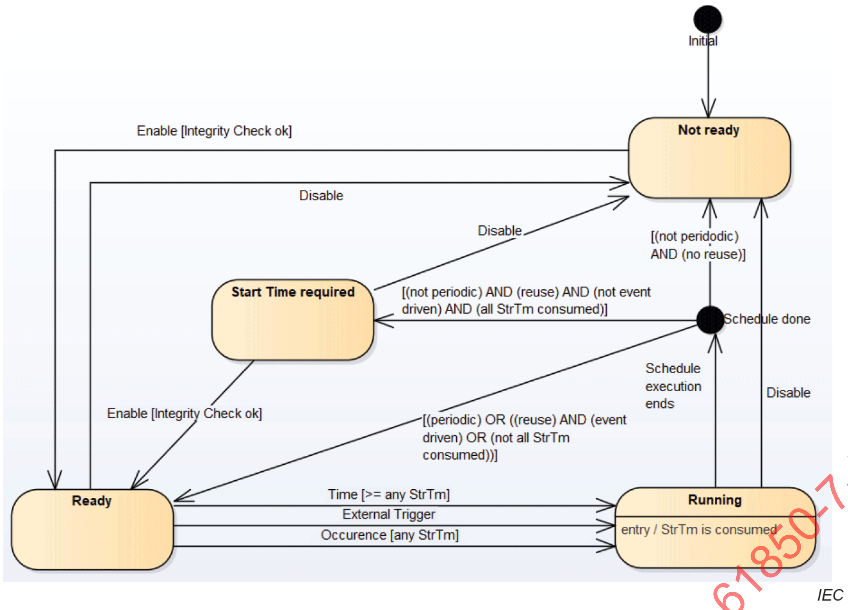


Figure 6 – State Machine

An instance of LN FSCC (Schedule Controller), formally associated to the targeted scheduled entity (through an ORG reference DO), is in charge of evaluating the value of an entity according to the current value of a running schedule FSCH. The LN FSCC class content is shown in Figure 5.

The running instance of LN FSCH is the one referenced by the FSCC which has the highest priority or the first to start (in case of identical priorities). The exact set of detailed rules is provided in in IEC 61850-7-4:2010, Annex K.

This global functioning may be illustrated in Figure 7.

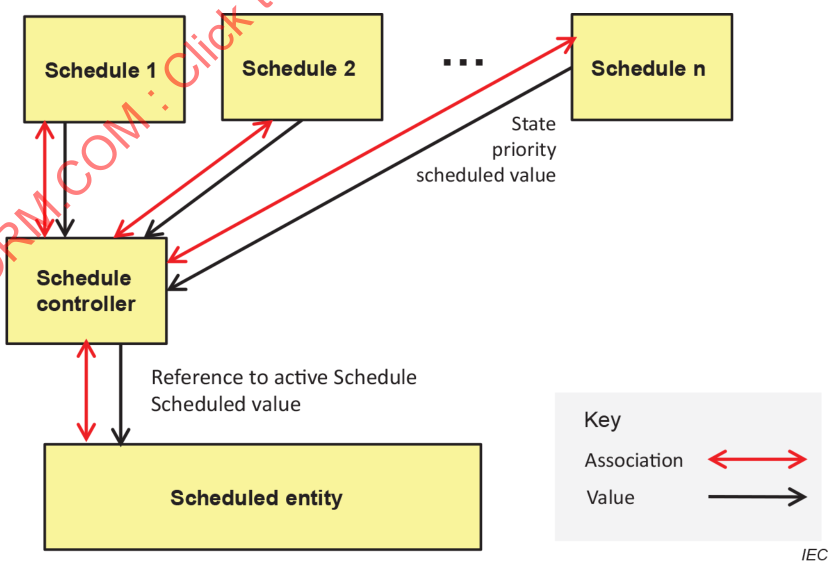


Figure 7 – Relation between schedule controller, schedules and entity scheduled

7.1.2 Example 1

This example shown in Figure 8 illustrates a possible use case for EV charging according to IEC TR 61850-90-8.

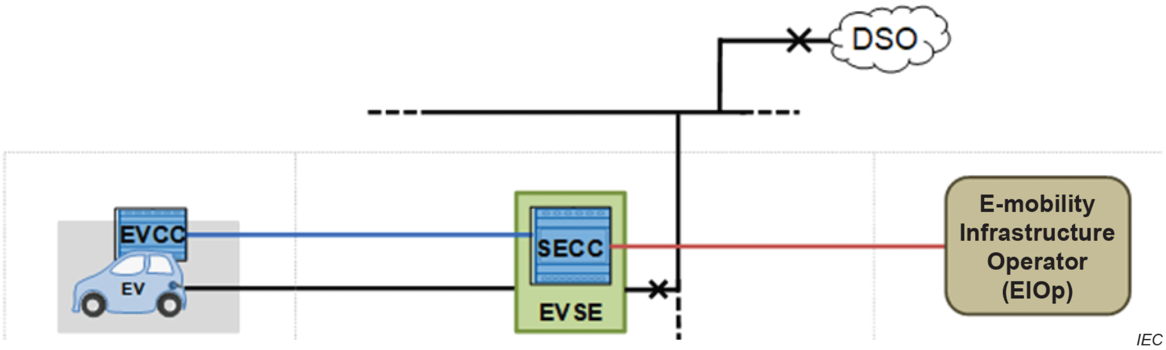


Figure 8 – Use case charging architecture

In this possible use case the Local Energy Management (LEM) system – not shown in Figure 8 – imposes an "envelope schedule" for the maximum power deliverable by the connection point of the network, when one or more EVs require energy from charging stations (EVSE, Electric Vehicle Supply Equipment). The maximum power schedule for the charging point is calculated according to local issues (energy balancing) of the charging stations. This schedule will then allow the EV to calculate a charging profile monitored by the EV. The charging process will be started by the EV. The communication between the EV and the EVSE is provided by the related communication controllers i.e. by the EVCC (Electric Vehicle Communication Controller) and by the SECC (Supply Equipment Communication Controller).

The example shown in Figure 9 and Figure 10 is a simplified view of settings and data exchange between the two schedules, one schedule controller and a controllable entity of CDC ASG.

Schedule_1 is handled by FSCH1. This schedule is considered as a recurrent default Pmax envelope. It is assumed to have been enabled and is periodic everyday with 12 points (2h or 7 200 000ms between each point) and 5 changing value points:

Hour (h)	0	2	4	6	8	10	12	14	16	18	20	22
Pmax (kW)	6	6	6	4	4	6	6	6	6	4	4	6

This could be a normal/peak hour kind of behavior.

Schedule_2, handled by FSCH2 is supposed enabled (at 4h00), and triggered at 4h30 for a one shot schedule. This schedule is the charging envelope Pmax capacity for a charging session between 4h30 and 8h30. There are 9 points separated by 30mn (1 800 000ms) and 2 changing value points: 4h30 (3 kW), 6h00 (2kW).

Hour (h:mn)	4:30	5:00	5:30	6:00	6:30	7:00	7:30	8:00	8:30
Pmax (kW)	3	3	3	2	2	2	2	2	2

Schedule_1 has priority 1, Schedule_2 has priority 2 (highest) and gets precedence when running. The triggering LN is DEEV1 (E-mobility electric vehicle LN instance).

Schedule_1 and Schedule_2 are enabled respectively by LEM1 (Local Energy Management instance) and EVSE1 (Electric Vehicle Supply Equipment instance).

The controller is handled by the FSCC1 LN instance.

The controlled entity (ChaPwrLim (Pmax) of APC or ASG CDC) is hosted in the LN DESE1 (LN instance which contains information related to monitoring and controlling the features of an EVSE).

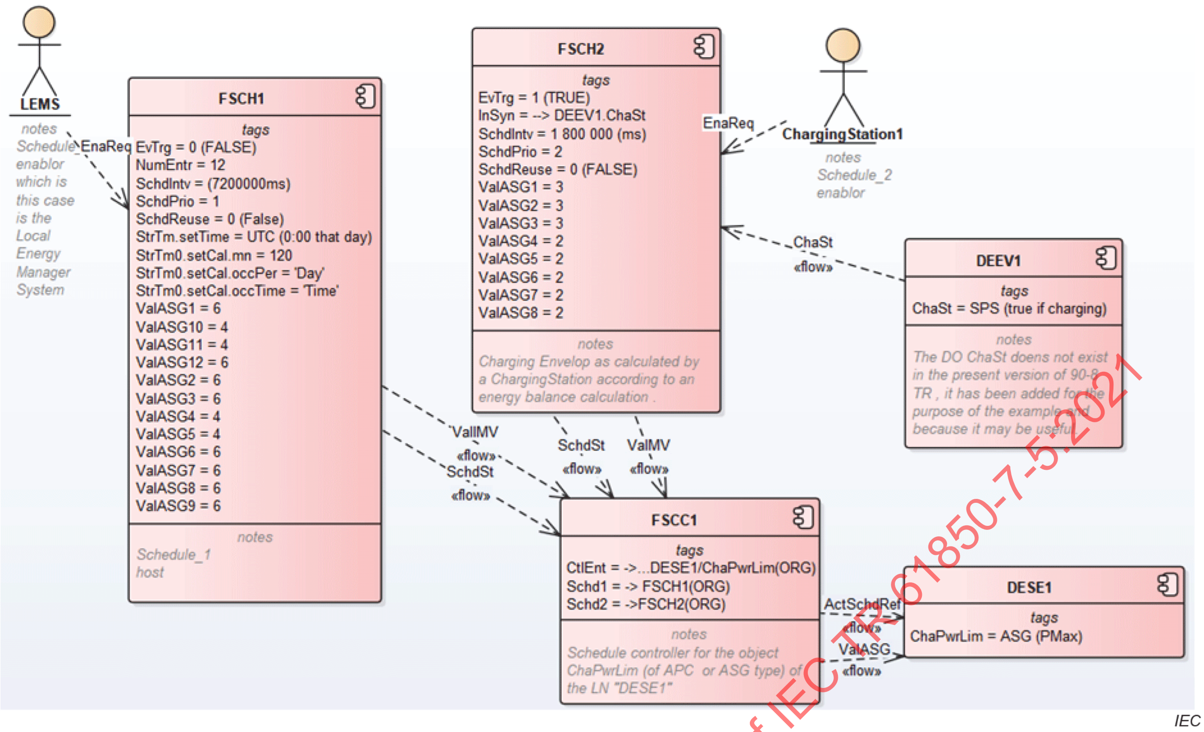


Figure 9 – LN instances and relationships in example 1

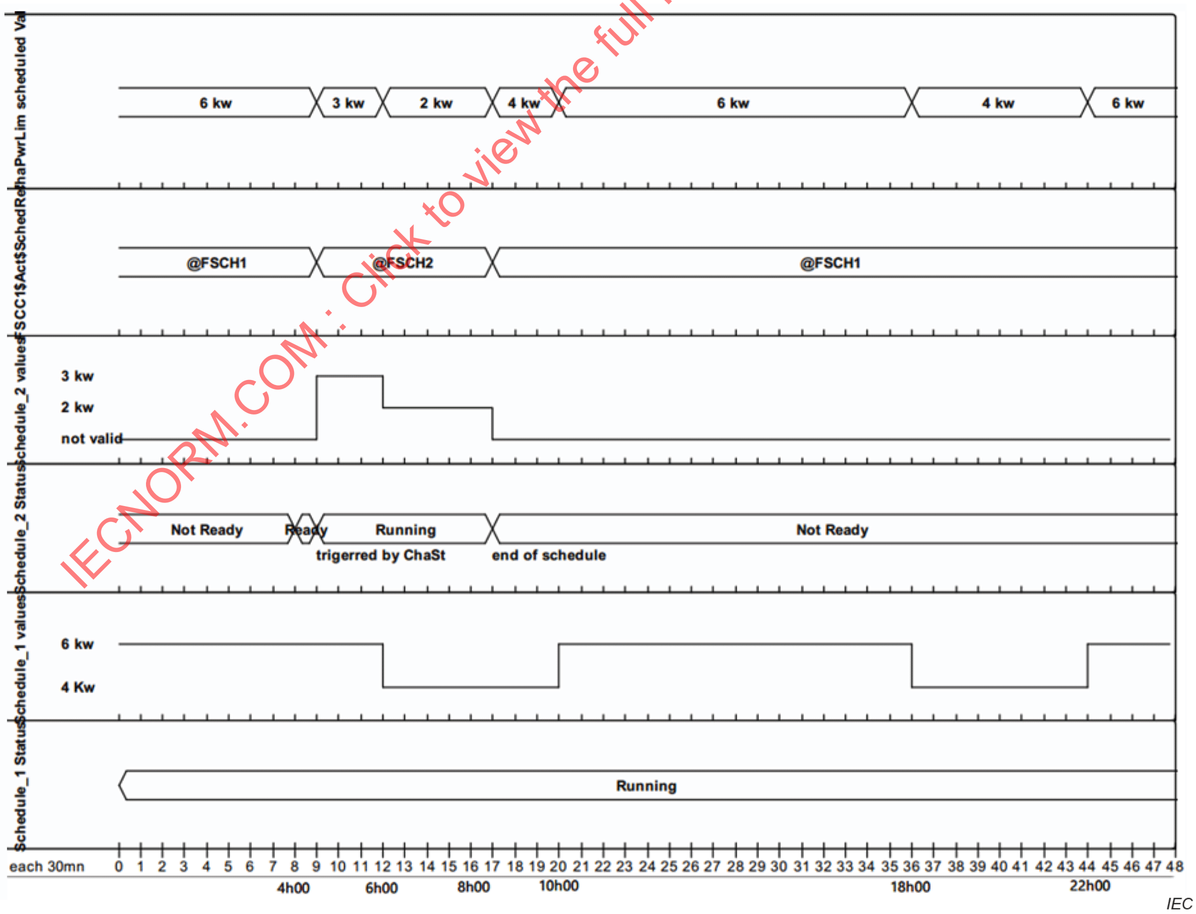


Figure 10 – Timelines associated to the example 1

7.1.3 Example 2

The example shown in Figure 11 and Figure 12 is a simplified view of settings and data exchange between two schedules, one schedule controller and a controllable entity of CDC INC.

Figure 11 shows the LN instances and relationship in the Example 2 described below.

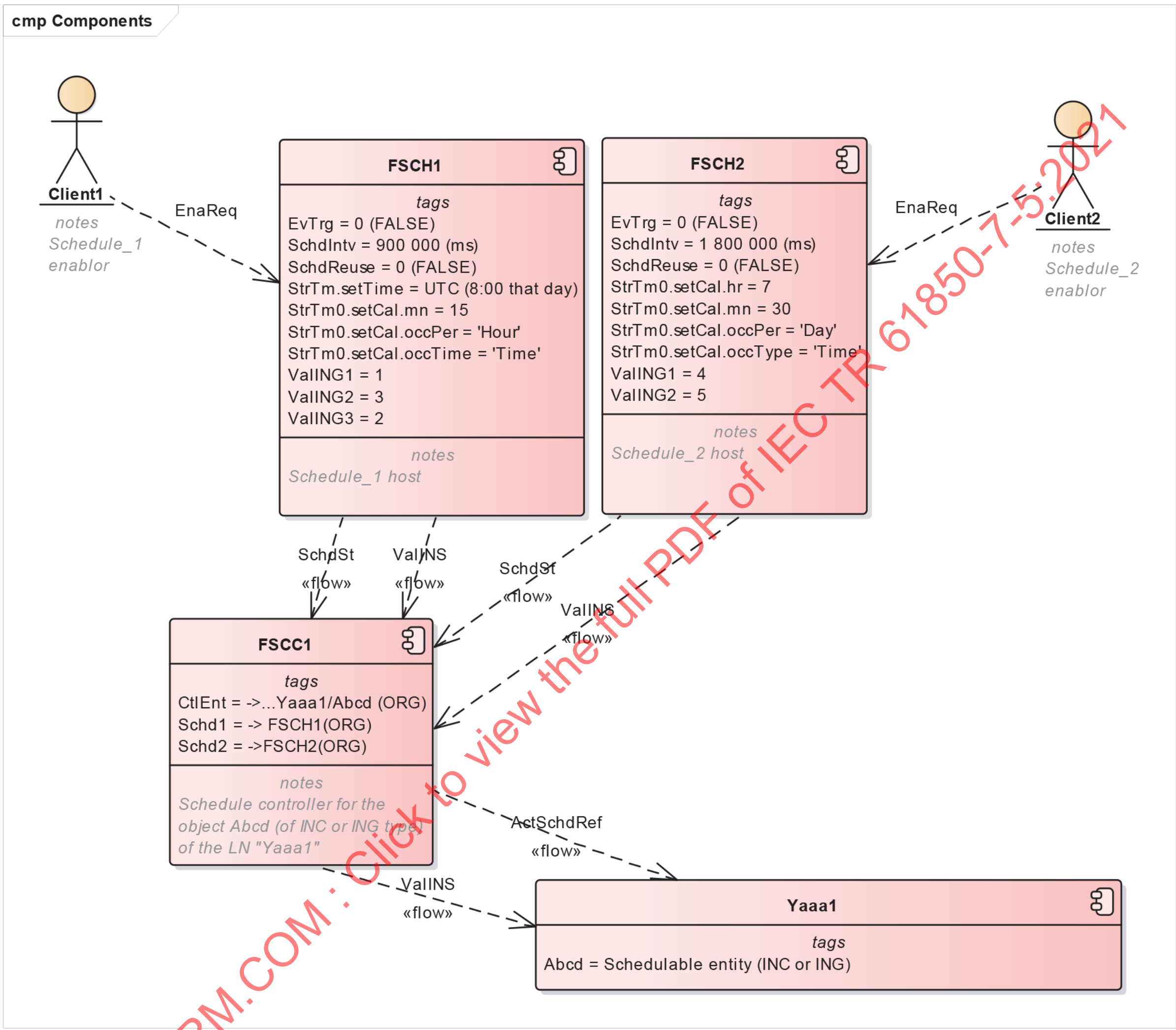


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Figure 11 – LN instances and relationships in example 2

Schedule_1, handled by FSCH1, main assumptions are: enabled (at 6:45), periodic after 8:00 that day, periodic every hour starting 15 mn after the beginning of the hour, with 3 values separated each by 15 minutes (900,000 ms), respectively 1, 3, 2.

Hour (h:mn)	n:00	n:15	n:30	n:45
value		1	3	2

Schedule_2, handled by FSCH2 is supposed, enabled (at 6:30), periodic every day at 7:30, with 2 values separated each by 30 minutes (1 800 000 ms), respectively 4, 5.