



BSI Standards Publication

Communication networks and systems for power utility automation

Part 90-14: Using IEC 61850 for FACTS (flexible alternate current transmission systems), HVDC (high voltage direct current) transmission and power conversion data modelling

National foreword

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

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TECHNICAL REPORT



**Communication networks and systems for power utility automation –
Part 90-14: Using IEC 61850 for FACTS (flexible alternate current transmission
systems), HVDC (high voltage direct current) transmission and power
conversion data modelling**

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-14: Using IEC 61850 for FACTS (flexible alternate current transmission systems), HVDC (high voltage direct current) transmission and power conversion data modelling

FOREWORD

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IEC TR 61850-90-14 has been prepared by working group 10: Power system IED communication and associated data models, 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:

Draft	Report on voting
57/2232/DTR	57/2273/RVDTR

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

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.

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

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- withdrawn,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

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INTRODUCTION

The IEC 61850 series was established to focus on the main primary equipment and functionality of conventional AC substations. By now it has been widely deployed and has become state of the art in that area.

Soon after, ambitions emerged to make IEC 61850 applicable to a largely widened range of equipment and functionality. Even completely new domains, like wind or hydro power generation, have created extensions to the series in order to match their applications.

Thanks to the very generic basic information and communication structures of IEC 61850 and the integrated services provided, most domain requirements can be easily adopted and fulfilled with IEC 61850 core functionality. Most of the extension work thus just needs to focus on creating a domain specific data modelling, which allows the semantic description of domain specific signals.

Due to the latest boom in deploying an exponentially increasing number of power electronics and semiconductor based equipment directly in the area of medium, high and ultra-high voltage transmission networks, the call for integrating those direct current related processes and control systems into IEC 61850 is only logical and consecutive.

Two main groups of DC based types of applications exist: FACTS devices (shunt and series connected) that mainly influence the network at a definite point of connection and Power Converters (e.g. HVDC, SFC) that additionally allow the transmission of active power between two different points of connection.

The benefits of those technologies are clear: as methods to influence conventional AC networks are limited, DC based technologies provide the possibility to actively adjust power flow and network parameters like frequency and voltage within just milliseconds. They help to support network stability, performance and quality, increase transmission capacity. They enable transmission tasks that would otherwise be technically borderline or impossible, moreover doing so mostly with unprecedented efficiency respectively low losses.

FACTS and Power Conversion are thus indispensable to secure power supply and represent a vital component within the backbone of efficient, reliable and resilient future smart grids. This technical report finally enables those technologies to also become an integral part of the IEC 61850 world.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-14: Using IEC 61850 for FACTS (flexible alternate current transmission systems), HVDC (high voltage direct current) transmission and power conversion data modelling

1 Scope

This part of IEC 61850, which is a technical report, specifies the information model of devices and functions related to systems of power utility automation, specifically related to FACTS (Flexible AC Transmission Systems) and Power Conversion applications.

The IEC 61850-90-14 information model standard utilizes existing IEC 61850-7-4 logical nodes where possible, but also defines specific logical nodes where needed.

Specifically, the scope of this document:

- Covers communication between control system of FACTS, HVDC and Power Conversion and SCADA and HMI systems
- Includes the data model for FACTS, HVDC and Power conversion devices
- Does not cover Protection relays
- Does not cover process bus
- Does not cover valve communication

1.1 Namespace name and version

This new subclause is mandatory for any IEC 61850 namespace (as defined by IEC 61850-7-1:2011).

Table 1 shows all attributes of (Tr)IEC 61850-90-14:2020A namespace.

Table 1 – Attributes of (Tr)IEC 61850-90-14:2020A namespace

Attribute	Content
Namespace nameplate	
Namespace Identifier	(Tr)IEC 61850-90-14
Version	2020
Revision	A
Release	3
Full Namespace Name	(Tr)IEC 61850-90-14:2020A
Namespace Type	transitional
Namespace dependencies	
extends	IEC 61850-7-4:2007B version:2007 revision:B
Namespace transitional status	
Future handling of namespace content	The name space (Tr)IEC 61850-90-14:2020A is considered as "transitional" since the models are expected to be included in further editions of IEC 61850-7-4xx. Potential extensions/modifications may happen if/when the models are moved to the International Standard status

The table below provides an overview of all published versions of this namespace.

Edition	Publication date	Webstore	Namespace
Edition 1.0	2020-xx	IEC TR 61850-90-14:2020	(Tr)IEC 61850-90-14:2020

Table 2 shows all tracking information of (Tr)IEC 61850-90-14:2020A namespace building-up.

Table 2 – Tracking information of (Tr)IEC 61850-90-14:2020A namespace building-up

Attribute	Content
Namespace IEC specific information	
Version of the UML model used for generating the document (informative)	wg10built7-wg18built5-wg17built6-jwg25built2-tc17built1-tc38built1_20210122.eap
Date of the UML model used for generating the document (informative)	2021-01-22
Autogeneration software name and version(informative)	j61850DocBuilder 01v12 based on jCleanCim 02v02-NS beta5

1.2 Code Component distribution

The Code Components are in light and full version:

- The full version is named: *IEC_TR_61850-90-14.NSD.2020A.Full*. It contains definition of the whole data model defined in this standard with the documentation associated and access is restricted to purchaser of this part

- The light version is named: *IEC_TR_61850-90-14.NSD.2020A3.Light*. It does not contain any documentations but contains the whole data model as per full version, and this light version is freely accessible on the IEC website for download at: <http://www.iec.ch/tc57/supportdocuments>, but the usage remains under the licensing conditions.

The Code Components for IEC 61850 data models are formatted in compliance with the NSD format defined by the standard IEC 61850-7-7. Each Code Component is a ZIP package containing:

- the electronic representation of the Code Component itself (possibly multiple files),
- the grammar files (XSD) enabling to check the consistency of the associated files against the defined version of NSD, but as well against the IEC 61850 flexibility rules in case of private extensions
- a file describing the content of the package (IECManifest.xml)

The IECManifest file contains different sections giving information on:

- The copyright notice
- The identification of the code component
- The publication related to the code component
- The list of the electronic files which compose the code component
- An optional list of history files to track changes during the evolution process of the code component

The life cycle of a code component is not restricted to the life cycle of the related publication. The publication life cycle goes through two stages, Version (corresponding to an edition) and Revision (corresponding to an amendment). A third publication stage (Release) allows publication of Code Component in case of urgent fixes of InterOp Tissues, thus without need to publish an amendment.

Consequently new release(s) of the Code Component may be released, which supersede(s) the previous release, and will be distributed through the IEC TC57 web site at: <http://www.iec.ch/tc57/supportdocuments>.

The latest version/release of the document will be found by selecting the file named *IEC_TR_61850-90-14.NSD.{VersionStateInfo}.Light* with the filed VersionStateInfo of the highest value.

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 61850-5:2013, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*
IEC 61850-5:2013/AMD1:2021

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

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

IEC 61850-7-2:2010/AMD1:2020

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

IEC 61850-7-3:2010/AMD1:2020

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

IEC 61850-7-4:2010/AMD1:2020

IEC 60633:2019, *High-voltage direct current (HVDC) transmission – Vocabulary*

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

3 Terms, definitions, variable symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 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 <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.2 Variable symbols

Symbol	Description
$B_{\max}$	Upper susceptance limit of the regulator output
$B_{\min}$	Lower susceptance limit of the regulator output
$B_{\text{REGREF_LOWER}}$	Slow Susceptance regulator lower reference limit
$B_{\text{REGREF_UPPER}}$	Slow Susceptance regulator upper reference limit
B_{ref}	Reference susceptance set by the operator in manual control mode
B_{SVC}	Output susceptance from the voltage regulator
f	Frequency
f_{ac}	AC network frequency
f_1	Nominal frequency
I	Current
I_{d}	Direct current
$I_{\text{SVC,max}}$	Maximum SVC primary current
Q	Reactive power
q_{uc}	TSC capacitor peak voltage quota, used in TSC Symmetrical Blocking

Symbol	Description
S	Apparent power
P	Active power
P_d	DC power order
T_{Breg}	Integrator time constant of Slow Susceptance regulator
U_{ac}	AC voltage
U_{bus}	Bus voltage
$\hat{u}_c$	TSC capacitor peak voltage
U_d	Direct Voltage
U_{di0}	Idealized DC voltage
U_{sec}	Secondary voltage
V	Voltage
ΔV_{POD}	Additional voltage reference signal from the Power Oscillation Damper
$\Delta V_{REG,NLVL}$	Negative voltage limit for the Slow Susceptance regulator operation range
$\Delta V_{REG,PLVL}$	Positive voltage limit for the Slow Susceptance regulator range
ΔV_{ref}	Additional voltage reference signal from the Slow Susceptance regulator
$V_{neg.seq}$	The negative sequence voltage signal, named V2RESP in TFR
V_{PODmax}	Upper voltage limit of the POD regulator
V_{PODmin}	Lower voltage limit of the POD regulator
V_{ref}	Voltage reference signal, set by the operator in automatic control mode
V_{resp}	Voltage response signal, positive sequence
V_{RMAX}	Maximum voltage reference
V_{RMIN}	Minimum voltage reference
X_{sa}	short circuit capacity
X_{sb}	short circuit capacity

3.3 Abbreviated terms

Abbreviated term	Term
CCC	Capacitor Commutated Converter
COVP	Capacitor Over-Voltage Protection
C&P	Control and Protection
DC	Direct Current
DCLFRS	DC Line Fault Recovery Sequence
DER	Distributed energy resource
DMR	Dedicated Metallic Return
EMS	Energy Management System
EPC	Emergency Power Control

Abbreviated term	Term
FSC	Fixed Series Capacitor
GC	Grid Controller
GWS	Gateway Work Station
HMI	Human Machine Interface
HV	High Voltage
HVDC	High Voltage Direct Current
HSR	High-Availability Seamless Redundancy
IGBT	Insulated Gate Bipolar Transistor
LCC	Line Commutated Converter
LV	Low Voltage
MR	Metallic Return
MOV	Metal Oxide Varistor
MSC	Mechanically Switched Capacitor
MSR	Mechanically Switched Reactor
NCC	Network Control Center
OHL	Overhead Line
OLC	Overhead Line Control
OLT	Open Line Test
OLTC	On-Load Tap Changer
OWS	Operator Work Station
PCC	Point of Common Coupling
PLL	Phase Locked Loop
POC	Point of Connection
POD	Power Oscillation Damping
PRP	Parallel Redundancy Protocol
PSS	Power System Stabilizer
RCI	Remote Control Interface
RPC	Reactive Power Control
RTU	Remote Terminal Unit
RUB	Run-Up/Run-Back Module
SCADA	Supervisory Control And Data Acquisition
SFC	Static Frequency Converter
SSSC	Static Synchronous Series Compensator
SVC	Static Var Compensator
TCR	Thyristor Controlled Reactor
TCSC	Thyristor Controlled Series Compensator
TSC	Thyristor Switched Capacitor
TFR	Transient Fault Recorder
U _{di0}	Ideal no-load direct voltage
U _{sec}	Voltage Secondary side

Abbreviated term	Term
UHVDC	Ultra High Voltage Direct Current
UPFC	Unified Power Flow Controller
VBO	Voltage Break-Over
VCU	Valve Control Unit
VOVP	Valve Over-Voltage Protection
VSC	Voltage Source Commutated Converter

4 FACTS Controllers and power conversion definition and specific requirements – Definitions of FACTS and power conversions

4.1 Flexible AC transmission system

4.1.1 General

A flexible AC transmission system (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system.

FACTS Controller is defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."¹

In this document FACTS Controller is classified to Shunt and Series compensation by the configuration type.

- Mechanically switched type FACTS
- Thyristor switched or controlled type FACTS
- Voltage source converter type FACTS

4.1.2 Examples of FACTS for shunt compensation

For shunt compensation, reactive current is injected into the line to maintain voltage magnitude. Transmittable active power is increased but more reactive power is to be provided. Common technologies include:

- Static synchronous compensator (STATCOM); previously known as a static condenser (STATCON)
- Static VAR compensator (SVC).
- Mechanically switched capacitor (MSC) or reactor (MSR): capacitor or reactor is switched by circuit-breaker. It aims at compensating steady state reactive power.

The above-mentioned variants are further described in Clause 6

4.1.3 Examples of series compensation

FACTS series compensation devices modify line impedance to increase the transmittable active power. Solutions for series compensation include:

- Fixed Series compensation (FSC)

¹ Proposed terms and definitions for flexible AC transmission system (FACTS), IEEE Transactions on Power Delivery, Volume 12, Issue 4, October 1997, pp. 1848 to 1853.

- Thyristor-controlled series capacitor (TCSC): a series capacitor bank is shunted by a thyristor-controlled reactor
- Static synchronous series compensator (SSSC)
- Thyristor-controlled series reactor (TCSR): a series reactor bank is shunted by a thyristor-controlled reactor
- Thyristor-switched series capacitor (TSSC): a series capacitor bank is shunted by a thyristor-switched reactor
- Thyristor-switched series reactor (TSSR): a series reactor bank is shunted by a thyristor-switched reactor

The above-mentioned variants are further described in Clause 6

4.2 Power conversions systems

By definition, "power conversion is converting electric energy from one dimension to another such as converting between AC and DC; or just changing the voltage or frequency; or some combination of these. A power converter is an electrical or electro-mechanical device for converting electrical energy."

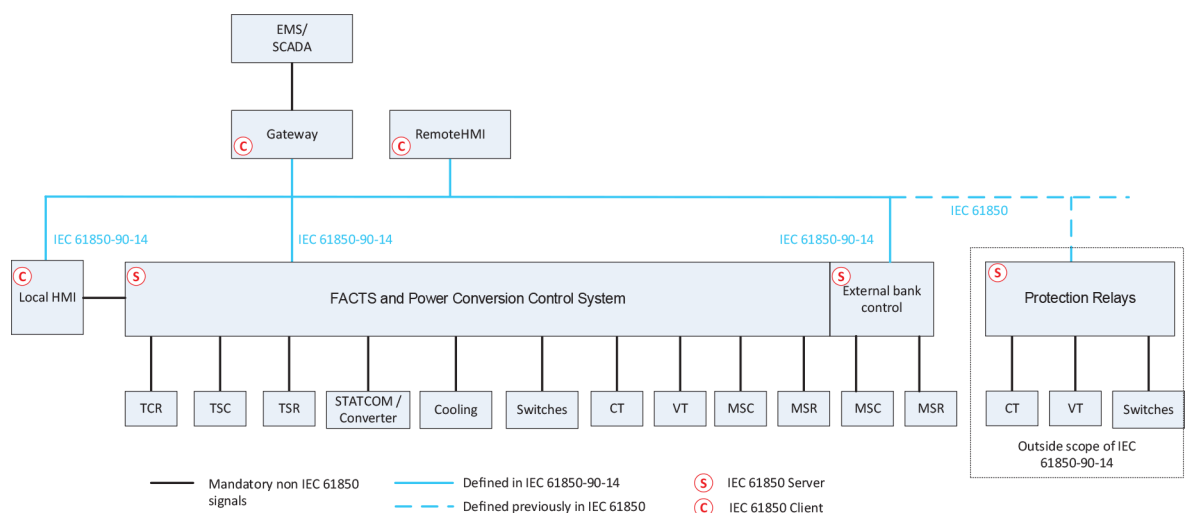
A power conversion system always considers and modifies the current flow between the converter as such and a connected electrical grid at a defined POC.

Examples of specific power conversion applications elaborated in more detail in this document:

- HVDC (LCC): HVDC power transmission with Line Commutated Converters.
- HVDC (VSC): HVDC power transmission with Voltage Source Converters.
- SFC: Static Frequency Converter for coupling power networks of different frequencies.

5 Scope clarification and definition

5.1 General



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Figure 1 – Conceptual view of communication paths considered in this report

This document will consider communication between FACTS/Power Conversion control system and control centre and Remote HMI. Figure 1 shows this document's communication path scope in solid blue line. Additionally, the scope also includes communication paths between the FACTS/Power conversion control system and external devices controlled by the control system.

FACTS and Power Conversion Control System – A multi device control system, used for FACTS, HVDC or Power Conversion regulation, control and protection of valve or converter. It also includes operation components like cooling, auxiliary power control, etc. It also includes engineering workstations, disturbance recording, sequence of event recorder, etc.

EMS/SCADA and Remote HMI – An interface used by substation or network control centre. The interface can control and supervise the FACTS/Power Conversion device, by direct orders or change of control values.

Local HMI – In this report the local HMI of the FACTS/Power conversion control system represents operator and engineering interface for control and supervision of the FACTS/Power Conversion device. The local HMI can be extended with an IEC 61850 client for control and supervision of IEDs outside or for parts of the FACTS/Power Conversion control system.

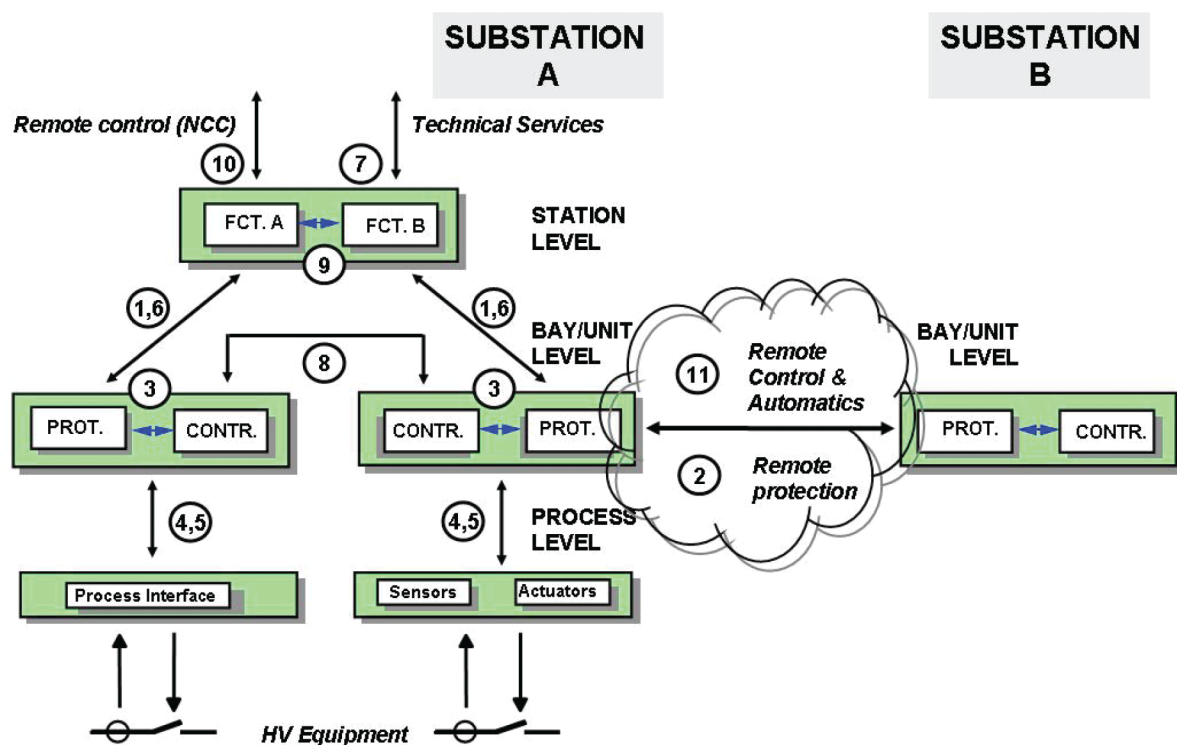
External bank control – describes a conceptual configuration about external bank control of a FACTS/Power Conversion device.

Protection Relays – Configuration of protection relays are not included in the scope of this document as it is already defined in other parts of IEC 61850.

5.2 Communication requirements and data flow

5.2.1 General

This document adheres to the requirements for the interfaces defined in IEC 61850-5, and does not add any additional requirement. For reference the definition is included in Figure 2 and a mapping of defined interfaces in Figure 3.



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Figure 2 – Levels and logical interfaces in substation automation systems

The meaning of the interfaces (as defined in IEC 61850-5):

- 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

5.2.2 Mapping to interfaces defined in IEC 61850-5

The information flow shown in Figure 3 describes a general view of the flow of data and control commands to and from a FACTS / Power Conversion controller and also the information flow within a FACTS / Power Conversion controller. The scope of the report is shown in the area "IEC TR 61850-90-14" and corresponds to the station level communication in a substation with one or more FACTS controllers.

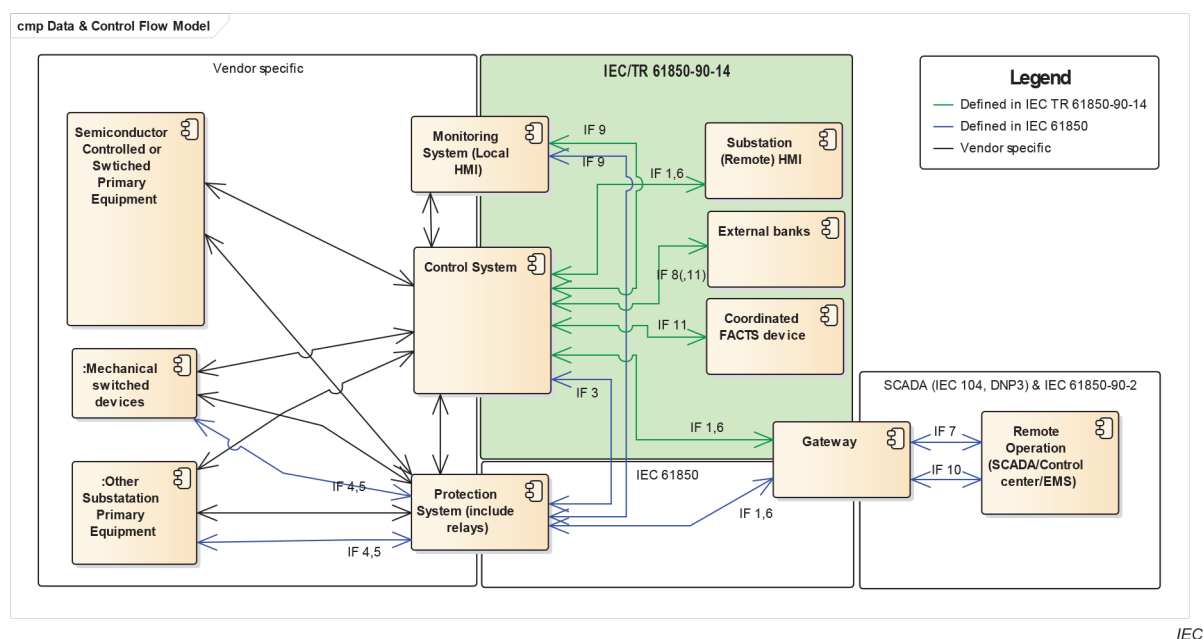


Figure 3 – Data flow of a FACTS / Power Conversion controller

Performance requirements of "Vendor Specific" area, data flow indicated with black lines are out of scope for this report.

Performance requirements of the "IEC TR 61850-90-14"-area in Figure 3 matches the station level of Figure 2 (IF 1, IF 6, IF 9, IF 8, and IF 11). The data flow indicated with green lines is defined in this report.

The data flows indicated with blue lines are previously defined in different parts of IEC 61850. This includes bay level interfaces IF 3, IF 4 and IF 5, station level interfaces IF 1, IF 6 and IF 9. Also defined previously is the communication interfaces Gateway and remote operation or remote engineer. It is mapped to IF 7 and IF 10 in Figure 3, which is control-data exchange between the substation and remote-control centre.

5.3 SCL modelling requirements

Postponed for later editions.

6 Shared use cases for FACTS controllers and Power Conversion

This clause contains use cases shared by the three application types covered in this document.

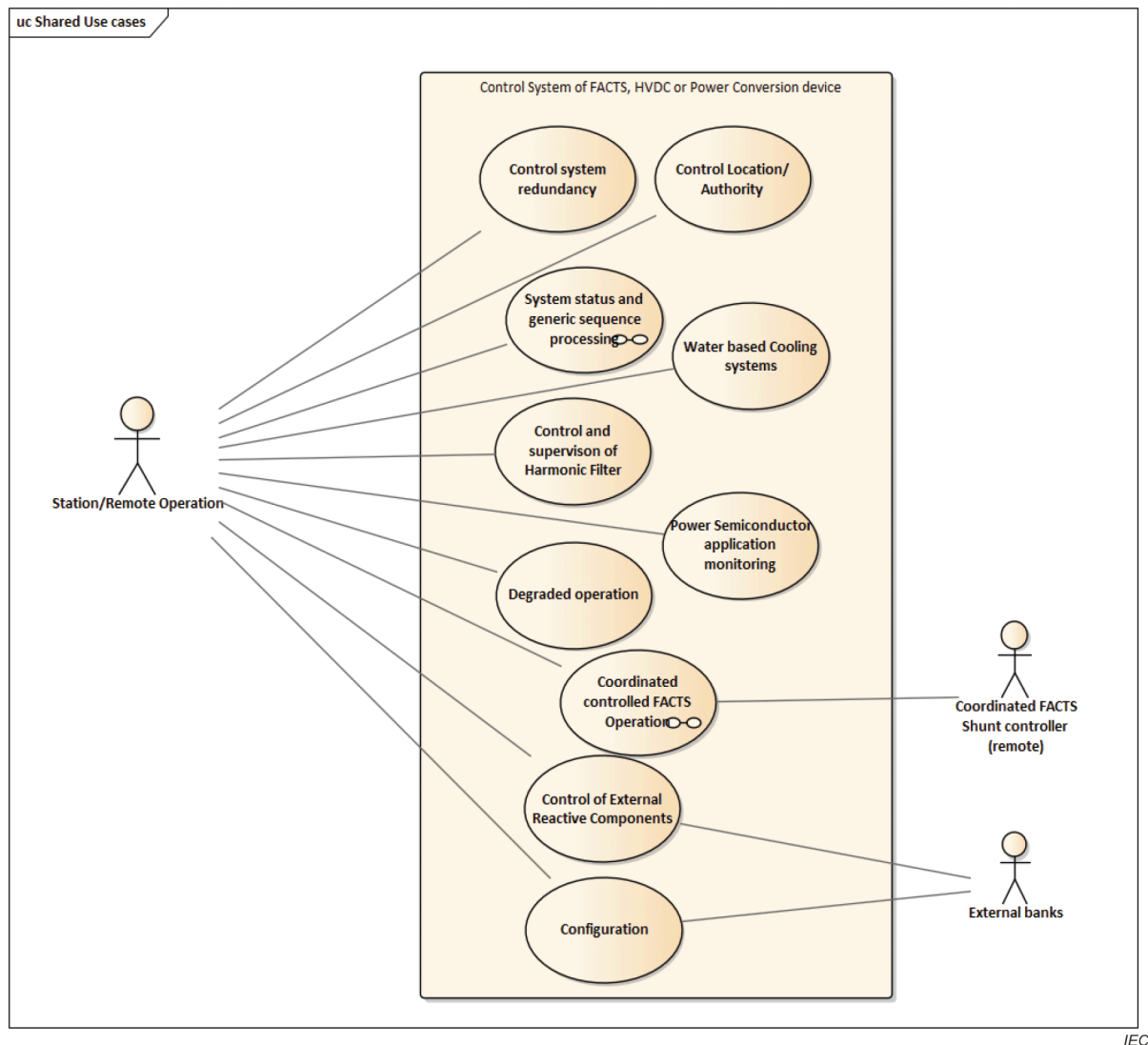


Figure 4 – Shared use cases for FACTS controllers and Power Conversion

Further description and elaboration of these use cases, as illustrated in Figure 4, is found in subsequent subclauses. Some use cases include a guideline to how they can be modelled. A definition of a proposed data model is presented in Clause 9 together with the proposed application specific modelling.

6.1 Commonly used actors

This document uses several roles in the use case descriptions. The roles have been divided in to three main categories or kinds, human roles, power system equipment and control system. The roles are described in Table 3 and illustrated in Figure 5.

Table 3 – Actors used in use cases

Actor name	General kind of actor	Description
Human Roles		A generic human actor
Station Operator	Human	Actor representing an operator acting locally on a station (FACTS or Power conversion). The operator acts through an HMI defined as the local HMI of the station, a system that displays or acquires values and issues commands using IEC 61850 in a client role.
Remote Operator	Human	Actor representing an operator acting remotely on a station (FACTS or Power conversion). The operator acts through a remote connection passing through a gateway to the local control system.
Station/Remote Operator	Human	Local or remote operator interacts through SCADA, HMI, EMS or NCC system that displays or acquires values and issues operator or automatic commands using IEC 61850 in a client role.
Station/Remote Engineer	Human	Local or remote engineer who can perform changes to configurable options.
Power System Equipment		Generic role representing Power System Equipment
Coordinated FACTS Shunt controller (remote)	Equipment	One or more remote FACTS controller capable of exchanging control commands and status information using IEC 61850
External banks	Equipment	One or more MSC or MSR capable of exchanging control commands and status information using IEC 61850
Control System		Generic actor representing the main regulating process of a FACTS device.
Converter	Control System	Power converter or FACTS device control. Power electronic switching device comprising semiconductor and firing circuits (thyristor, IGBT, etc.). Additionally, the power electronic switching devices provides measured values as input to the control system.
Sequence State Machine	Control System	Application control sequence
Protection	Control System	Protection functions with the capability to trip or block equipment
Valve Cooling System	Control System	Actor representing the Valve Cooling System of the control system

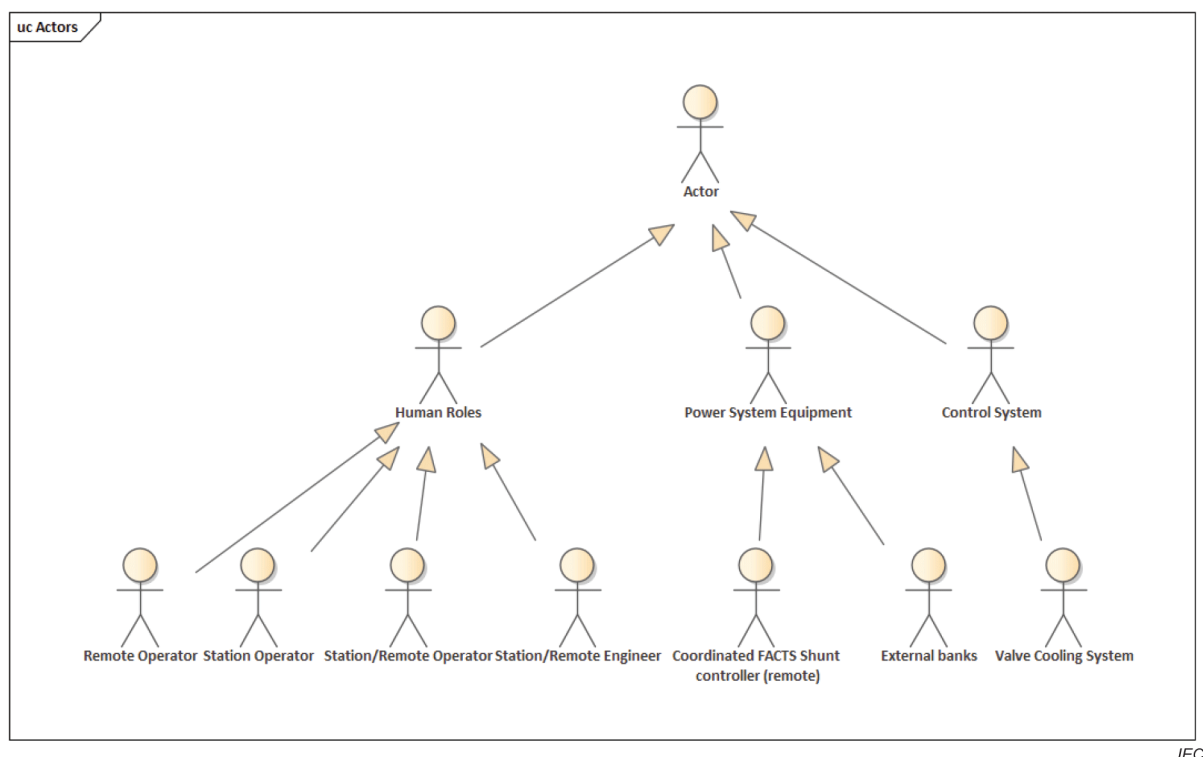


Figure 5 – Hierarchical view of commonly used actors

6.2 Use case: Control system redundancy

6.2.1 Communication redundancy

Communication redundancy with-in FACTS or Power Conversion control systems is a common requirement, e.g. PRP and HSR², is covered by other standards. For reference see IEC 61850-90-4 and IEC 61850-90-12.

6.2.2 Functional application redundancy

Figure 6 describes a typical example of how a control and protection redundancy schema can be set up. To be able to distinguish between IED1 C&P and IED2 C&P, which provide identical functionality, the servers needs to provide a redundancy concept for the clients to be able to determine which IED that is e.g. active and which is standby (given an active-standby relationship).

The functional application redundancy is or will be covered by IEC TR 61850-90-20.

² IEC 62439-3:2016

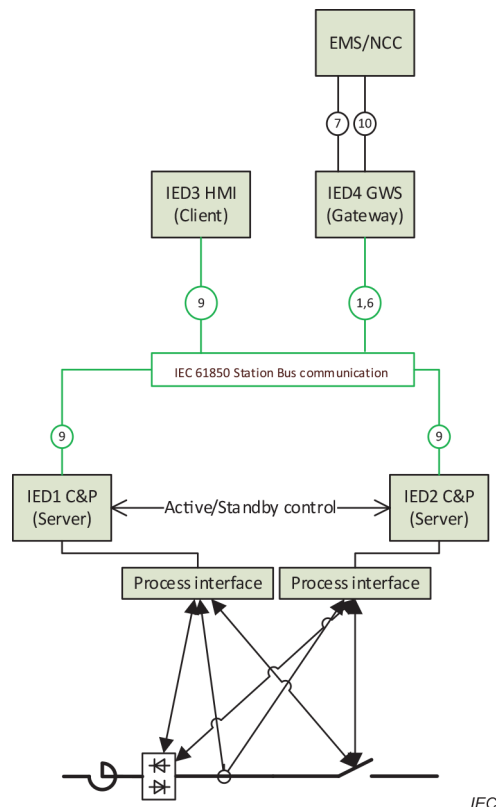


Figure 6 – Typical redundant FACTS/Power Conversion control system setup

6.3 Use case: Control location and authority

The FACTS device or power converter application, as any substation equipment, can be operated from different control locations and levels. The levels are usually identified as Local Mode (Loc), where the operation is done in front of the equipment, Local at Station Level (LocSta), where the operation is done from a local HMI in a substation control room and finally remote from a control centre. For safety reasons substation equipment can be locked, by key or logic, to only allow local operation. Indication of control location is important process data for the operators, regardless whether they work locally or remotely.

This potentially affects all logical nodes with data objects of a CDC type to which the control service (see IEC 61850-7-2) can be applied.

IEC TR 61850-7-500 already covers the principle and practical application of control authority management as a generic and domain independent guideline. The same principles apply for FACTS and power conversion.

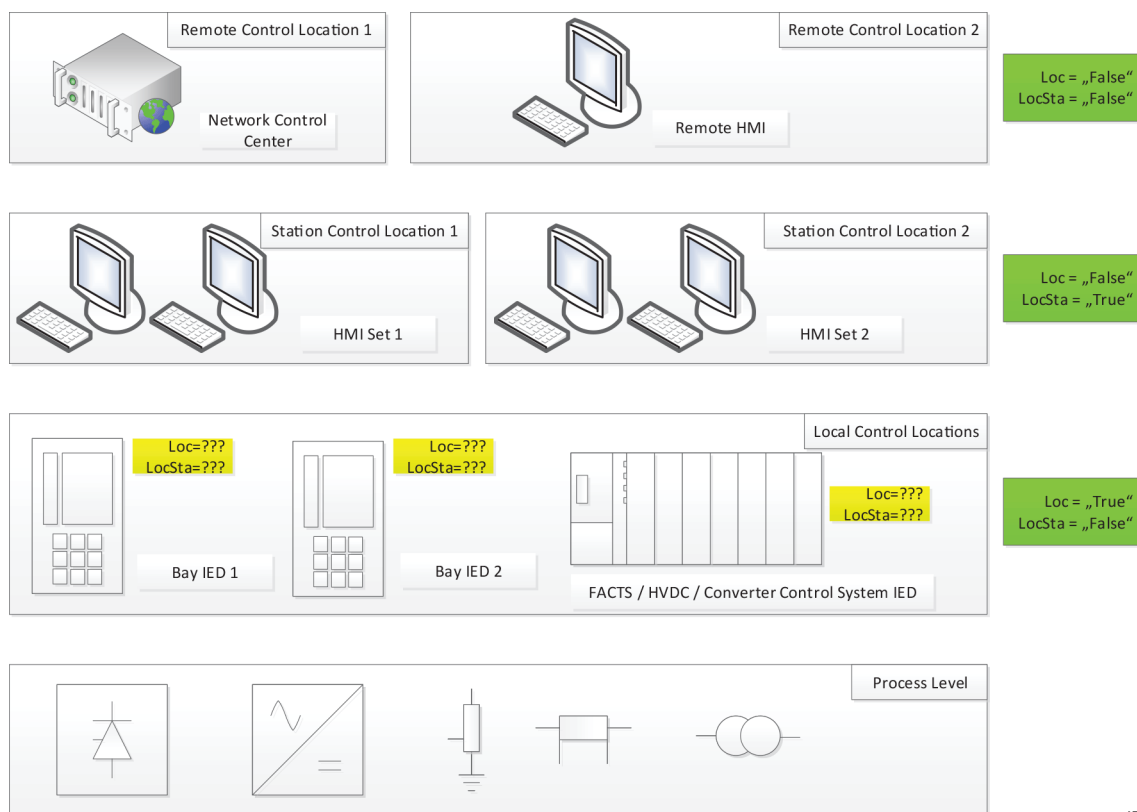
However, there are special requirements regarding control authority management, that as of today cannot be fully implemented and modelled in the IEC 61850 context and have to be realized by application specific implementations. Hence, they are explicitly not considered to be within the scope of this TR (marked with question marks in Figure 7).

Nevertheless, the requirements are mentioned and further explained below, in order to raise awareness and consider those for future IEC 61850 general standard development.

The requirements for extended control authority management originate mainly from the operation environment of FACTS and power conversion applications in interconnected transmission networks:

- transmission schemes consist of 2 or multiple terminals that are geographically distributed independent stations, often connected to completely independent AC networks, but are coupled with integrated control systems
- due to inter-country connections or coupling of different voltage levels and network frequencies, FACTS and power conversion control often has to enable seamless collaboration and coordination between players in different legislative, regulatory and operative domains
- there are system, station, area and network specific control functions within one scheme, whose specific responsibility needs to be coordinated between multiple entities (e.g. TSOs, DSOs, NCCs, IPPs) at the same time
- control authority for those control function needs to be freely assigned and securely shifted between different parties and control levels, if there is operative demand
- for redundancy and workforce reasons, control authority may be shifted between different control locations on a scheduled basis.

For e.g. HVDC schemes it is very common that there are multiple control locations existing on the same hierarchical level (e.g. multiple sets of HMIs at the local station or multiple remote NCCs or a remote NCC in parallel with a remote HMI). Differentiation between control locations on the same hierarchical level cannot be established via native existing 61850 means. This logical switchover has to be established and arranged on application level.



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Figure 7 – Authority for control of devices from different control levels and locations

Usually, all purely software related control functions within the same FACTS and power conversion IED will have the same control location definition, however they may also be split into different groups of functions with independent definition, which can all be operated from a specific control location. Those software functions of associated areas are often called "function groups", exemplified in Figure 8.

In extended schemes, function groups can also be spread across multiple IEDs at the same physical station or even at distributed geographical stations belonging to the same power transmission system.

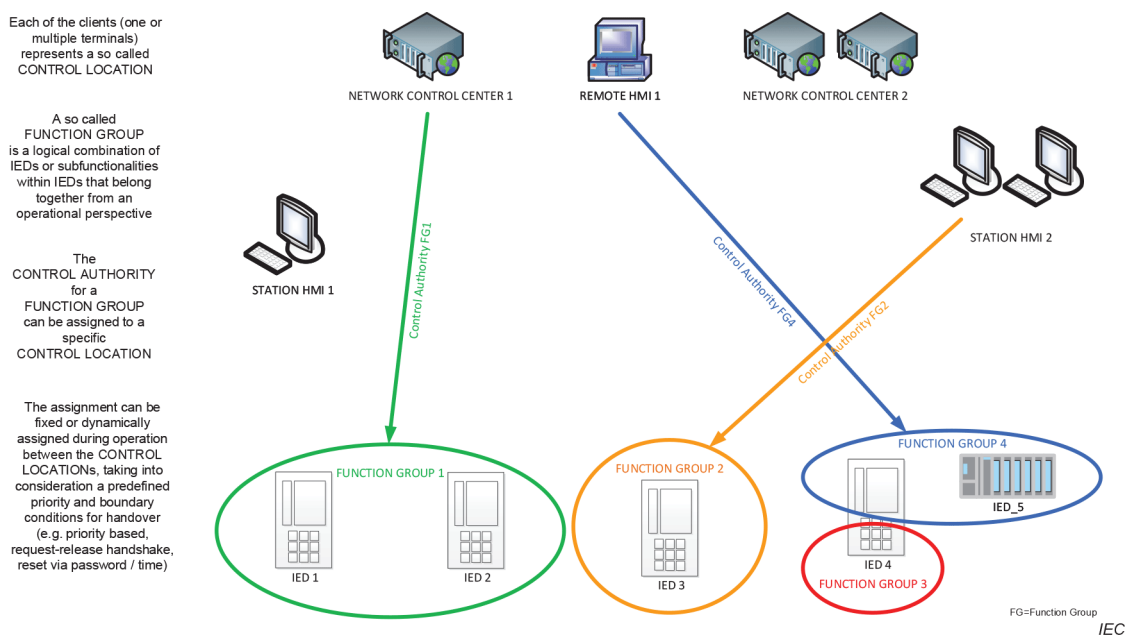


Figure 8 – Typical scheme for implementation of control authority for function groups

A logical representation of affiliation to a certain function group or even logical representation within the 61850 data model is also not possible with native 61850 means and has to be handled by the application.

6.4 Use case: System status and generic sequence processing

6.4.1 General

A FACTS device or power converter application has different defined states of operation, that are based on various status conditions and operation steps of converter and substation related equipment. An operator can usually perform those actions manually, but in order to simplify operation state-of-the-art control systems usually comprise a state machine that can be triggered to perform step-by-step or automatic complete transitions between different states.

In order to control this state machine several distinct converter target states need to be controlled and displayed, as well as the status of any ongoing control sequence itself. As state transitions may take a very long time, the operator must be able to manually cancel an ongoing sequence in its current state. An emergency shutdown may bring the FACTS device or power converter to a tripped state in a controlled manner as fast as possible.

Additionally, based on the current status and further conditions, not all target states can always be selected, which needs to be displayed for operator guidance. A converter may be blocked for operation, e.g. due to missing fault clearing or preconditions, as well as any sequence fault or trip needs to be acknowledged.

Besides the main operation controlling sequence, various other operational issues (e.g. switchgear reconfigurations) may also be implemented with a similarly acting but generic state sequencer.

Application specific target steps need to be selectable for control and displayed directly.

In addition, all basic sequence steps are usually assigned defined step numbers and defined transitions in a start and stop direction manner. Control of this sequencer can also be performed by means of selecting the specific step number.

Explicit start and stop orders allow to easily operate simple bidirectional sequences, whilst in combination with a dedicated step order sequencer transitions can be performed automatically or step by step in both directions.

To cover this functionality, the new Logical node **ASEQ** "FACTS and HVDC Automatic Sequencer" is intended, providing the required data objects as described in Figure 9 and listed in Table 4.

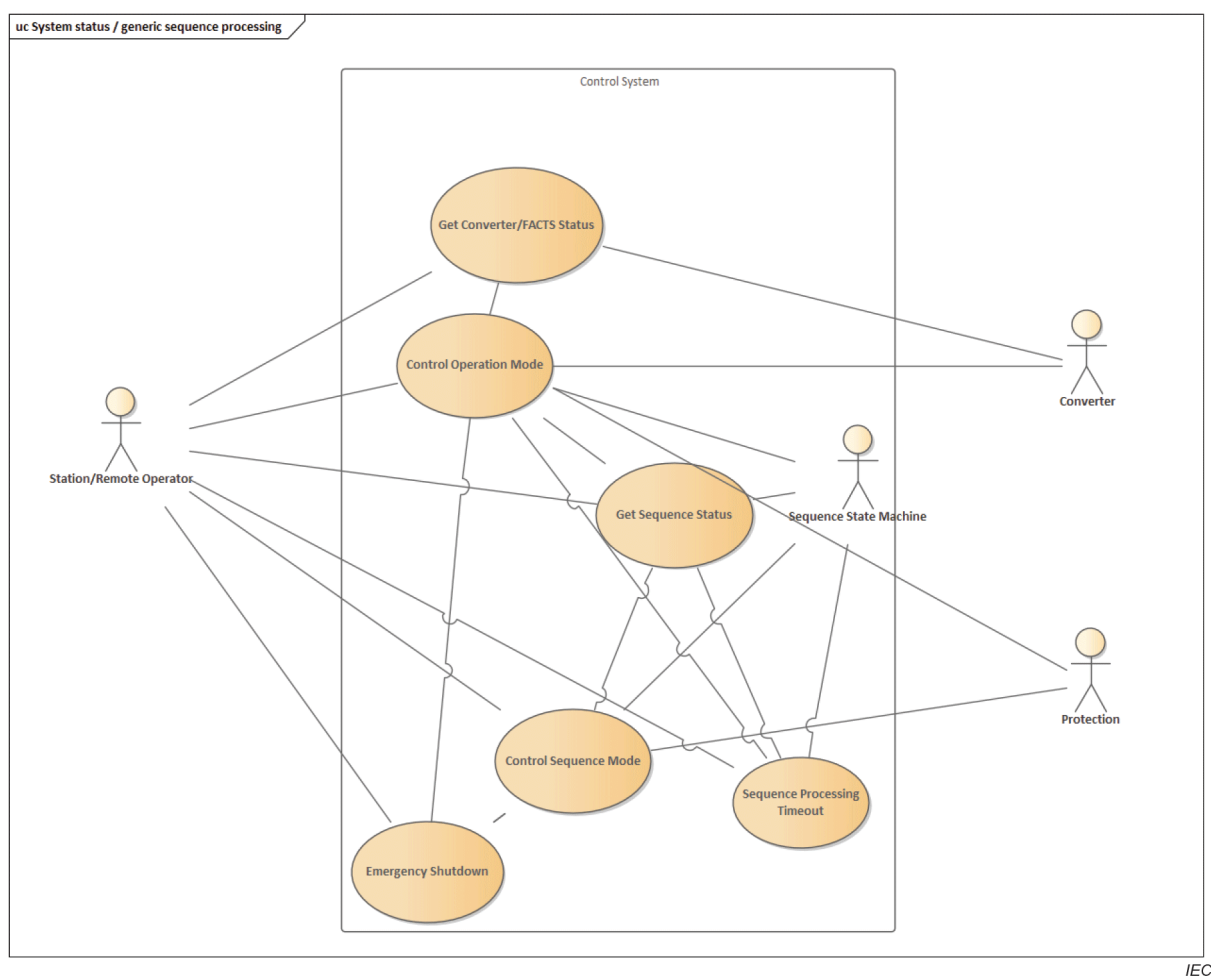


Figure 9 – System status / generic sequence processing

Table 4 – Use case: System status and generic sequence processing

Use case(s):

Name	Service or information provided
Get Converter/FACTS Status	Display of the application's operation mode
Control Operation Mode	Change the application's operation mode
Get Sequence Status	Display of the application's sequence status
Sequence Processing Timeout	Display a sequence or step timeout
Control Sequence Mode	Change the application's sequence mode
Emergency Shutdown	Immediately shut down the converter / FACTS device in case of emergency

Basic flow:

Get Converter/FACTS Status

Use Case step	Description
Step 1	Get the current converter / FACTS device operation mode
Step 2	Provide the status to the Station/Remote Operation

Basic flow:

Control Operation Mode

Use Case step	Description
Step 1	Station/Remote Operation sends converter operation mode change request command
Step 2	Application's operation mode status is checked
Step 3	Mode change is triggered accordingly if possible, by means of a control sequence logic; status of control sequence is changed transiently and provided to the Station/Remote Operation
Step 4	An ongoing mode change can be stopped by cancelling the ongoing sequence by Station/Remote Operation, which forces the state machine to remain in its current status and changes the sequence status to aborted
Step 5	If converter / FACTS device is tripped or shut down via emergency shutdown change of operation mode is not possible until acknowledgement from Station/Remote Operation
Step 6	Provide the new operation mode to the Station/Remote Operation

Basic flow:

Get Sequence Status

Use Case step	Description
Step 1	Get the current application's sequence status
Step 2	Provide the application's sequence status to the Station/Remote Operation

Basic flow:

Sequence Processing Timeout

Use Case step	Description
Step 1	An ongoing sequence times out as either its processing time as a whole or the processing time for a dedicated step takes longer than a predefined time limit
Step 2	The timeout indication is provided to the Station/Remote Operation

Basic flow:

Control Sequence Mode

Use Case step	Description
Step 1	Station/Remote Operation sends automatic / manual sequence mode change request command and decides whether step by step mode shall be used
Step 2	Sequence status is checked, and sequence mode is changed accordingly if possible
Step 3	New sequence mode is provided to the Station/Remote Operation

Basic flow:

Emergency Shutdown

Use Case step	Description
Step 1	Station/Remote Operation sends emergency shutdown command
Step 2	Converter/FACTS device is shut down quickly, operation mode is set to tripped and will remain in that mode until acknowledgement from Station/Remote Operation
Step 3	Any ongoing sequence is set to aborted

Basic flow:

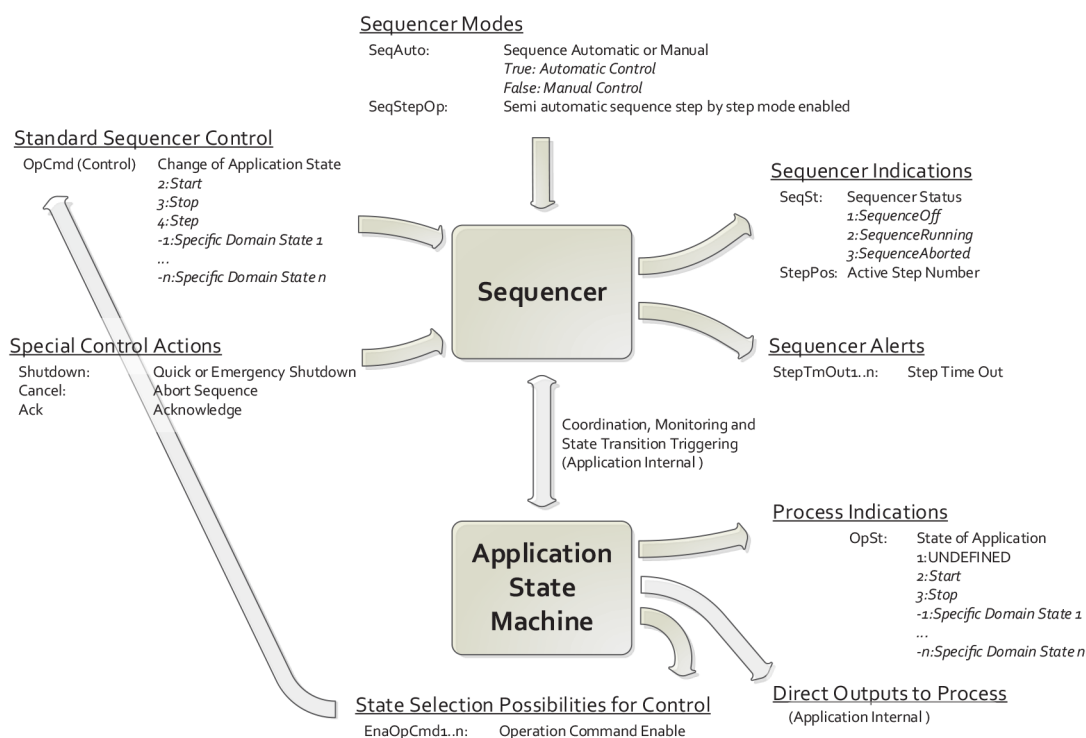
Change Control Location

Use case step	Description
Step 1	The actor sends the command to set the FACTS Controller in desired control location.

6.4.2 ASEQ Application Overview

A schematic overview of how the various Data Objects within the ASEQ correlate to each other in order to establish a generic sequence processing can be found in Figure 10. It should be noted that the ASEQ contains two interdependent units:

- the sequencer itself, i.e. the functionality that triggers and monitors the state transitions and provides the necessary control and indication interface.
- the application state machine that is controlled by the sequencer. It influences the actual underlying process and has the necessary internal knowledge about which state the application currently has, which application states exist and which transitions between states are possible – in general and specific for further control in the current state of application.



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Figure 10 – ASEQ Application Overview (using the most important Data Objects)

6.4.3 Application example HVDC

In order to support the understanding of how sequence control utilizing the LN ASEQ (see LN definition in Clause 8) could be realized, a simple practical example is given below. Please note that the example in this clause is only an example. Figure 11 visualise the example states of the sequence.

A power converter has an implemented operational sequence software function comprising the major status conditions EARTHED, ISOLATED, OFF and ON. A status transition from one major step to the other contains a combination of several smaller steps, which either just check the presence of operational conditions (e.g. "check door and key interlocking fulfilled") or actively trigger actions and wait for the feedback of those actions before continuation (e.g. "open AC-side earthing/grounding switches"). Status transitions can be performed in any direction (start and stop) along the predefined routes; ongoing steps can be reversed or cancelled.

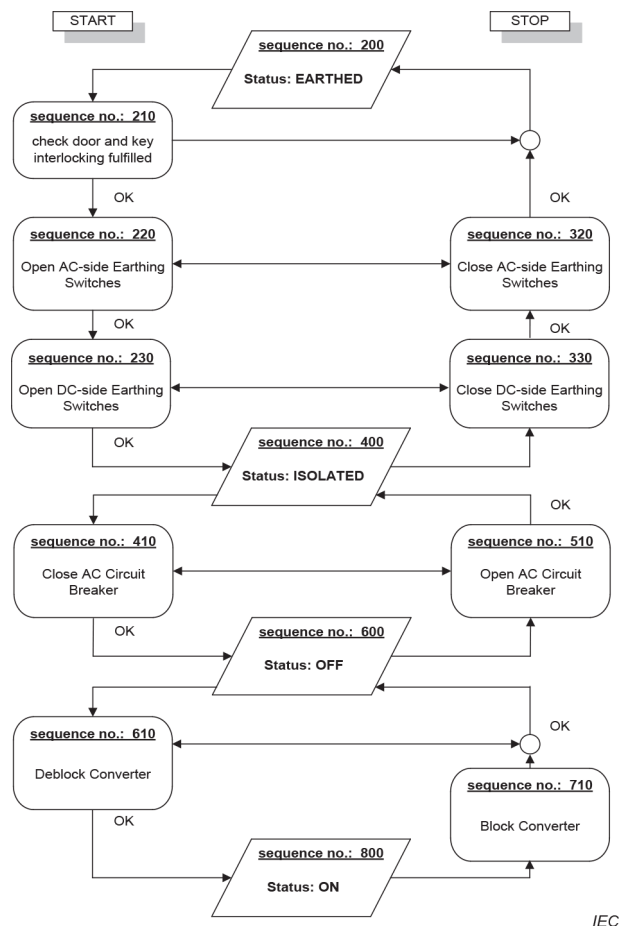


Figure 11 – Exemplary sequence diagram, not applicable to all use cases

Two DOs within the LN ASEQ represent the state machine itself: OpSt (status direction, dedicated for indication) and OpCmd (command direction, dedicated for control). Two separate DOs are foreseen in order to be able to decouple the status indication from the command triggering, the correlation of which might be subject to internal application logic. Note: OpCmd allows control services (OpCmd.ctlVal) to select the desired command, and an indication of the currently active selected command request (OpCmd.stVal).

An application specific SCL-representation of those DOs OpSt and OpCmd could look like the following:

OpSt:

```

<EnumType id="Operation_States">
  <EnumVal ord="3">Stop</EnumVal>
  <EnumVal ord="2">Start</EnumVal>
  <EnumVal ord="1">UNDEFINED</EnumVal>
  <EnumVal ord="-1">EARTHED</EnumVal>
  <EnumVal ord="-2">ISOLATED</EnumVal>
  <EnumVal ord="-3">OFF</EnumVal>
  <EnumVal ord="-4">ON</EnumVal>
</EnumType>

```

OpCmd:

```
<EnumType id="Operation_Commands">
  <EnumVal ord="4">Step</EnumVal>
  <EnumVal ord="3">Stop</EnumVal>
  <EnumVal ord="2">Start</EnumVal>
  <EnumVal ord="1">UNDEFINED</EnumVal>
  <EnumVal ord="-1">EARTHED</EnumVal>
  <EnumVal ord="-2">ISOLATED</EnumVal>
  <EnumVal ord="-3">OFF</EnumVal>
  <EnumVal ord="-4">ON</EnumVal>
</EnumType>
```

Please note that application specific profiles of ENC commands have to be made in the negative number range in order to comply with SCL modelling and 61850 standard series definitions.

Precondition: the initial state is EARTHED (OpSt.stVal=-1/EARTHED; StepPos.stVal=200) and the sequence is not running (SeqSt.stVal=0/SequenceOff).

With the sequencer set to automatic mode (Auto.stVal=True whilst SeqStepOp.stVal=False) a client could in principle trigger a fully automated transition to the neighbour step ISOLATED (by control value OpCmd.ctlVal=-2/ISOLATED) or directly to one of the distant steps OFF (by control value OpCmd.ctlVal=-3/OFF) or ON (by control value OpCmd.ctlVal=-4/ON). Thus, it is also possible to directly select steps that are not neighbour steps.

However, due to process restrictions (e.g. a cooling system is not ready yet) it is not possible to go directly from EARTHED to the target status ON. This is indicated to the client by the DO value EnaOpCmd4.stVal=False and is forbidden accordingly for selection within the client. ISOLATED and OFF can be selected, which is represented by EnaOpCmd2.stVal=True and EnaOpCmd3.stVal=True.

The client now selects OpCmd.ctlVal=-3/OFF, which leads to OpCmd.stVal=-3/OFF and the sequencer starts working by setting SeqSt.stVal=2/SequenceRunning. However, a door contact is not closed and the sequence times out and aborts itself during intermediate step 210; which triggers the abnormal condition SeqSt.stVal=3/SequenceAborted and resets the selected target step indication to OpCmd.stVal=1/UNDEFINED. A failure indication to the client is possible using the combined information StepPos.stVal=210 and StepTmOut.stVal=True.

The above-mentioned door contact is then closed by operator personnel. The client afterwards acknowledges the abnormal condition (Ack.ctlVal=True), which brings the sequencer back to SeqSt.stVal=1/SequenceOff and resets the step timeout (StepTmOut.stVal=False).

The client now selects again OpCmd.ctlVal=-3/OFF (OpCmd.stVal=-3/OFF), the sequence starts running (SeqSt.stVal=2/SequenceRunning), steps 210, 220, 230, 400, 410, 600 are processed with the indications changing in the meantime (StepPos.stVal=210,..., 600), OpSt.stVal=UNDEFINED, ISOLATED, OFF). After the desired target step has been reached the command is reset to OpCmd.stVal=1/UNDEFINED.

The sequence is now in state OFF and the process restrictions have disappeared (e.g. the cooling system is now ready), EnaOpCmd4.stVal=True. The client selects OpCmd.ctlVal=-4/ON and the sequence starts running again. However, deblocking takes a longer time in this case as the intermediate circuit has to be slowly charged. In the meantime, the operator decides to stop the process due to other reasons and actively cancels the ongoing sequence (Can.ctlVal=True). This brings the sequencer to SeqSt.stVal=3/SequenceAborted and the sequence state directly back to OpSt.stVal=-3/OFF. An acknowledge Ack.ctlVal=True brings the sequencer back to SeqSt=1/Sequence Off.

An alternative possible option for operating the sequence is the step by step mode, which is a semi-automated sequence processing. When enabled (SeqStepOp.stVal=True whilst Auto.stVal=true) a single step transition to the next step in the desired direction can be performed.

Depending on the required operational behaviour, this control itself can be performed using a directional step request for bidirectional implementations (i.e. OpCmd.ctlVal=2/Start or OpCmd.ctlVal=3/Stop), an unidirectional step request for cases where sequence direction is not required/available (i.e. OpCmd.ctlVal=4/Step) or triggering the sequence transitions towards the target step by repeatedly selecting the final distant target step (e.g. OpCmd.ctlVal=-4/ON) within the sequencer state transition definition.

A command acceptance consecutively leads to OpCmd.stVal=1/Start or OpCmd.stVal=2/Stop, OpCmd.stVal=3/Step or OpCmd.ctlVal=-4/ON. Indication of the sequencer, the sequence status, step number, cancel etc. is the same as for the fully automated sequence. When the very next step has been reached the command is reset to OpCmd.stVal=1/UNDEFINED.

6.4.4 Application example Shunt connected FACTS device

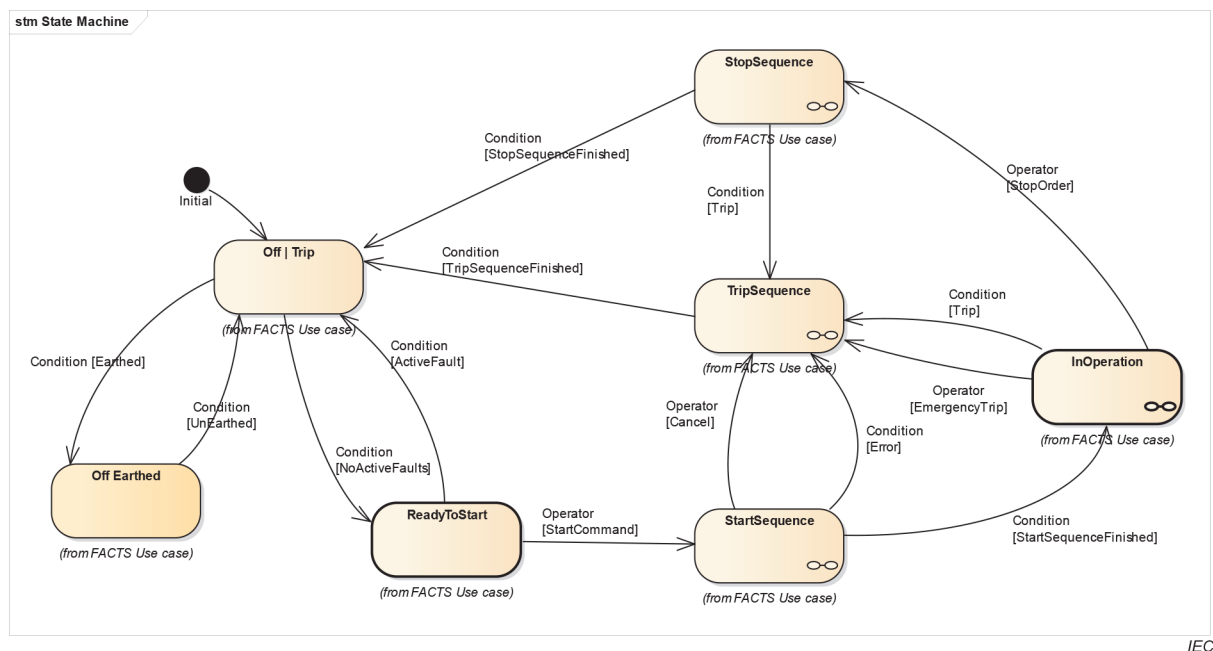


Figure 12 – Operating states of a FACTS shunt device

A FACTS shunt device has different states of operation which affects the grid in different ways. A general view of states can be seen in Figure 12. The figure does describe the state machine of an SVC/STATCOM, it does not describe the status of the IED used for controlling the SVC/STATCOM. Nor does it describe the control modes of the shunt connected FACTS device. The steady states can be described as follows:

- **Off | Trip:** The FACTS device is not active and in the current state, conditions are preventing the device to be put in to service.
- **Off Earthed:** The FACTS device is not active, and the FACTS device is earthed. In the current state a transition to **OFF | Trip** is prohibited as long as the device is earthed.
- **ReadyToStart:** The conditions needed to put the FACTS device into operation is fulfilled. This conditions include for instance that no major alarm is activated, all target and lock-out relays are reset, grounding switches at SVC/STATCOM bus are open, SVC/STATCOM disconnector switch is closed, grounding switches in each available SVC/STATCOM branch are open, disconnector switches in each available SVC/STATCOM branch are closed and valve cooling system is ready for start. The conditions needed can be both vendor and site specific.
- **InOperation:** the SVC/STATCOM is started and running with given parameters and connected to grid.

The state machine also includes transition states or sequences of actions. They can be described as follows:

- **StartSequence:** By order from operator or initiated by an automatic start request, the SVC/STATCOM is taking predefined actions to start the SVC/STATCOM and connect to the grid. When the sequence is finished the SVC/STATCOM will be in state InOperation.
- **StopSequence:** By order from operator or an automatic stop request, the SVC/STATCOM is taking predefined actions to make a controlled stop of the SVC/STATCOM. When the sequence is finished the SVC/STATCOM will be in state Off.
- **TripSequence:** In case of a non-recoverable fault the SVC/STATCOM is taking predefined actions to make an immediate disconnection from the grid by opening the related circuit breaker and a stop of the SVC/STATCOM. When the sequence is finished the SVC/STATCOM will be in state Off.

An SCL-representation of the operation states in the above example could be as follows (example):

OpSt:

```
<EnumType id="Operation_States">
  <EnumVal ord="3">Stop</EnumVal>
  <EnumVal ord="2">Start</EnumVal>
  <EnumVal ord="1">UNDEFINED</EnumVal>
  <EnumVal ord="-1">OFFTRIP </EnumVal>
  <EnumVal ord="-2">OFFEARTHED</EnumVal>
  <EnumVal ord="-3">READYTOSTART</EnumVal>
  <EnumVal ord="-4">INOPERATION</EnumVal>
  <EnumVal ord="-5">STARTSEQUENCE</EnumVal>
  <EnumVal ord="-6">STOPSEQUENCE</EnumVal>
  <EnumVal ord="-7">TRIPSEQUENCE</EnumVal>
</EnumType>
```

OpCmd:

```
<EnumType id="Operation_Commands">
  <EnumVal ord="4">Step</EnumVal>
  <EnumVal ord="3">Stop</EnumVal>
  <EnumVal ord="2">Start</EnumVal>
  <EnumVal ord="1">UNDEFINED</EnumVal>
  <EnumVal ord="-1">OFFTRIP </EnumVal>
  <EnumVal ord="-2">OFFEARTHED</EnumVal>
  <EnumVal ord="-3">READYTOSTART</EnumVal>
  <EnumVal ord="-4">INOPERATION</EnumVal>
  <EnumVal ord="-5">STARTSEQUENCE</EnumVal>
  <EnumVal ord="-6">STOPSEQUENCE</EnumVal>
  <EnumVal ord="-7">TRIPSEQUENCE</EnumVal>
</EnumType>
```

Section 7.2.3 describes the different operation modes of a FACTS Shunt device. This example sub-use case describes the actions performed to change the operation mode of a FACTS controller, using the general model described in 6.4.2.

Figure 13 and Table 5 describes states in the example.

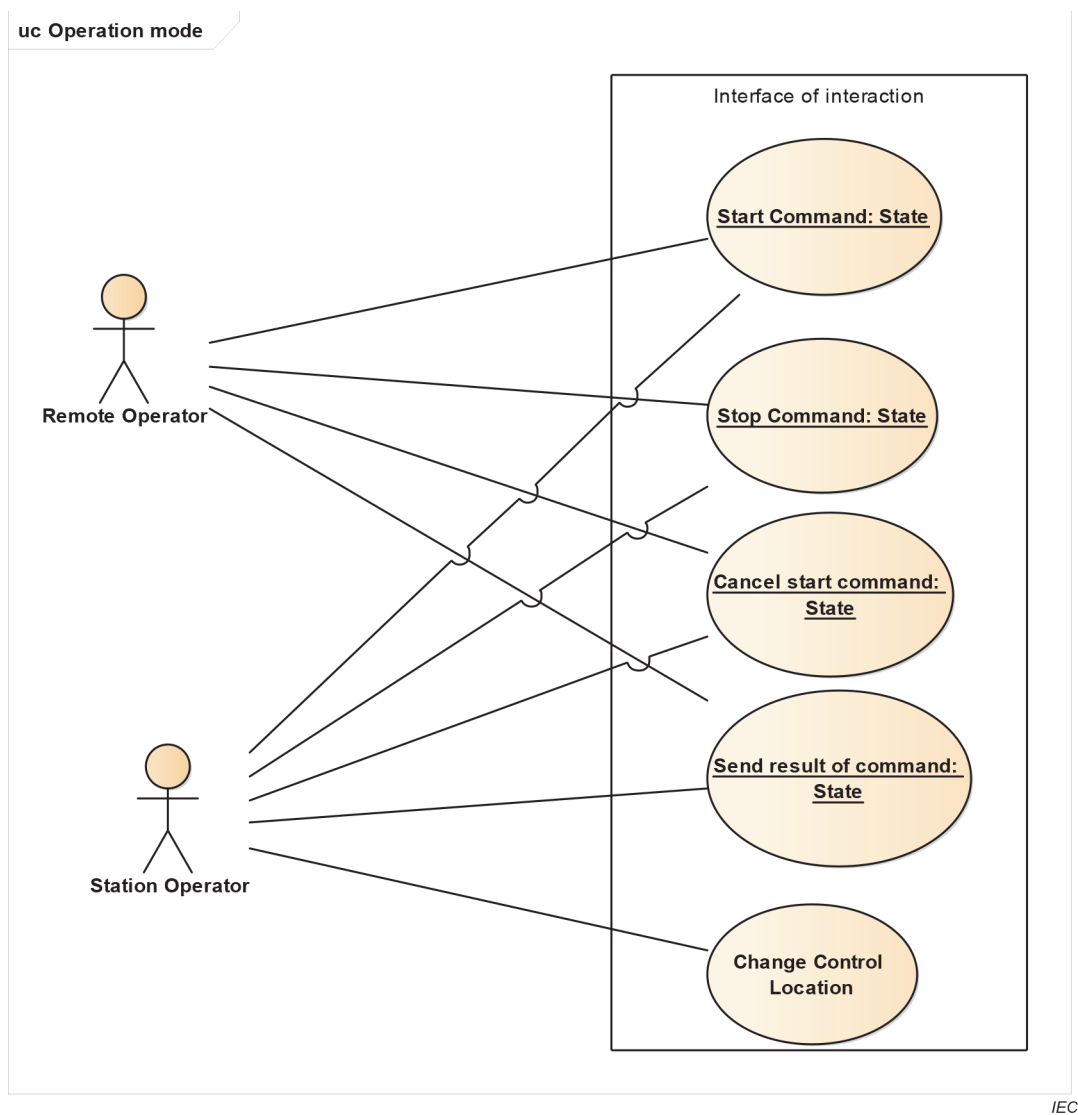


Figure 13 – Use case diagrams of State use case

Table 5 – Use case: State

Use case(s):	
Name	Service or information provided
Start Command	Available in the state ReadyToStart (see application example in Section 6.4.4). Triggers a transition to the StartSequence-state.
Stop Command	Available in the state InOperation (see application example in Section 6.4.4). Triggers a transition to the StopSequence-state.
Cancel Start Command	During the StartSequence, the actor remote/station operator issues a cancel start command.
Send Result of the Command	Sends Operation Results to USER
Change Control Location	User configures the FACTS Controller to be in. Changing the Control location from local to remote is only available for the local operator. This use case is described in Section 6.3.
Basic flows:	
Start Command	
Use case step	Description
Step 1	The actor sends Start command to FACTS Control System
Stop Command	
Use case step	Description
Step 1	The actor sends Stop command to FACTS Control System
Cancel Start Command	
Use case step	Description
Step 1	The actor sends Cancel start command to FACTS Control System
Send Result of the Command	
Use case step	Description
Step 1	FACTS Control System sends the result of the previous command to the station/remote operator
Change Control Location	
Use Case step	Description
Step 1	Get the current converter / FACTS device operation mode
Step 2	Provide the status to the Station/Remote Operation

6.5 Use case: Cooling system

6.5.1 General

The converter or valve cooling system is an essential an auxiliary system of the FACTS and HVDC device, present in many configurations of HVDC, SVC, STATCOM and TCSC. Malfunction of the cooling system can degrade the transmission or compensation possibilities of a FACTS or power conversion device and eventually cause a trip of the device. Figure 14 describes a cooling system use case, and Table 6 describes it further.

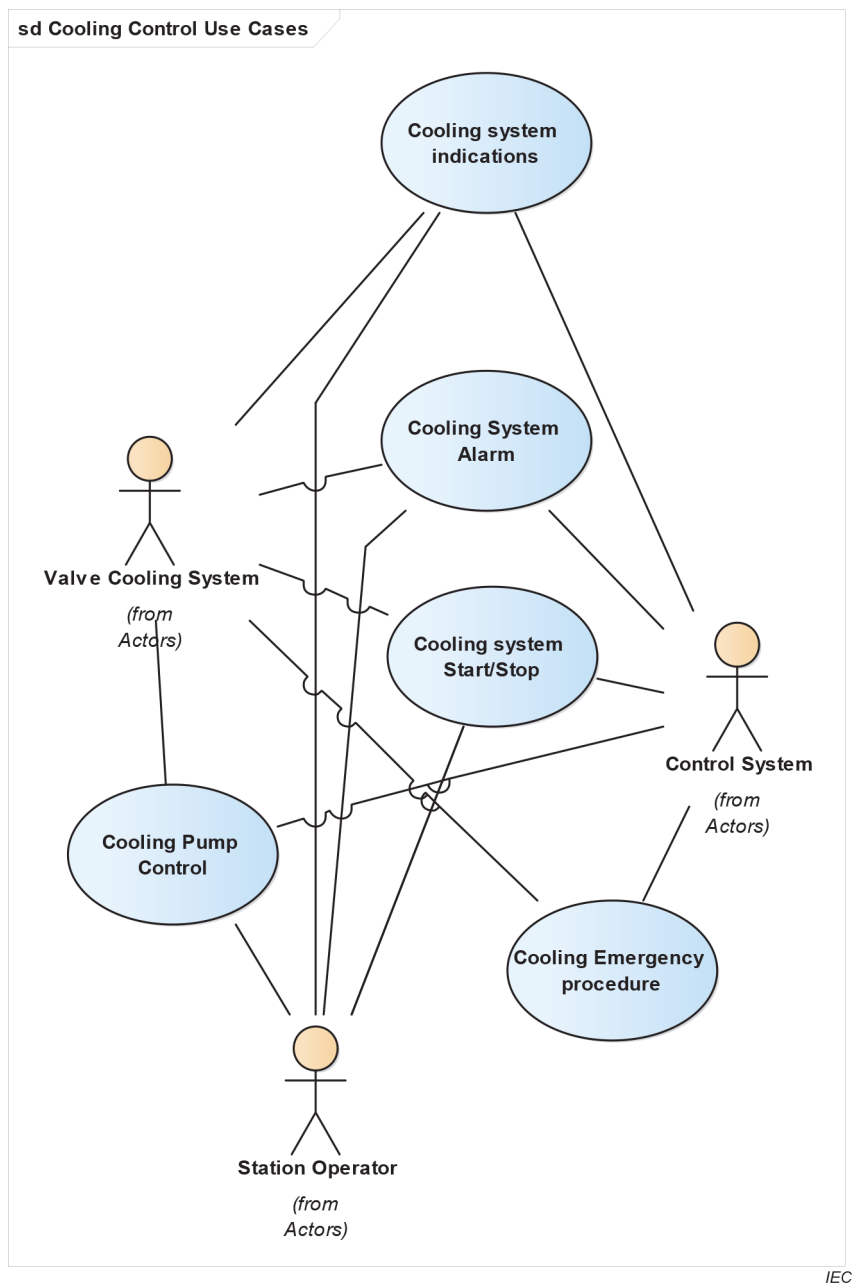


Figure 14 – Cooling control use cases

Table 6 – Use case: Cooling system

Use Case(s):	
Name	Services or Information provided
Cooling System Indications	Status indications from cooling system
Cooling System Alarm	Alarm Indication from cooling system
Cooling System Start	Start-order of cooling system
Cooling System Stop	Stop-order of cooling system
Cooling Pump Control	Control of shifting between pumps
Activate protective function	Indications from cooling system requires protection actions from the control system

Basic flows:

– Cooling System Indications

Use case step	Description
Step 1	Measured values from cooling system to be processed by control system or/and shown to operator. Measured values are shown in Table below,
Step 2	Control system process measured values and takes appropriate actions.

– Cooling System Alarms

Use case step	Description
Step 1	Alarm from any part of valve cooling system. Could be flow, temperature, conductivity, pressure or mechanical mal function of pump or fan.
Step 2	Alarm is shown to operator for appropriate action and/or control system for predefined actions depending on type of alarm.

– Cooling System Start

Use case step	Description
Step 1	Substation Operator manually sends control command to start the cooling system Or start order is sent from automatic start up sequence in control system
Step 2	On successful start, cooling system reports Cooling system started, or If cooling system fail to start, cooling system sends indication of failed start and respective indication or alarm according to above flow for "Cooling system Indications" or "Cooling system alarms".
Step 3	When cooling system reports cooling system ready, the FACTS or HVDC device is ready for energization.

– Cooling system Stop

Use case step	Description
Step 1	If function is not interlocked by ongoing operation, Substation Operator manually sends control command to stop the cooling system Or stop order is sent from automatic stop sequence in Control System
Step 2	On successful stop of cooling system, it reports cooling system stopped

– Cooling Pump Control

Use case step	Description
Step 1	Substation Operator manually or Control System sends control command to shift running cooling pump
Step 2	Cooling System starts the standby pump
Step 3	When the standby pump is confirmed running, the Cooling system stops the active pump. Alternatively, the standby pump is started instantly after the active pump is shut down.
Step 4	Control system updates indications according to the new status

– Cooling Emergency Procedure

Use case step	Description
Step 1	Indication from sensors in the cooling system requires protective actions.
Step 2	Depending on internal logic, specific measures are taken, such as block, trip, reduce power flow, etc.

6.5.2 List of logical nodes for modelling of a Water based cooling system

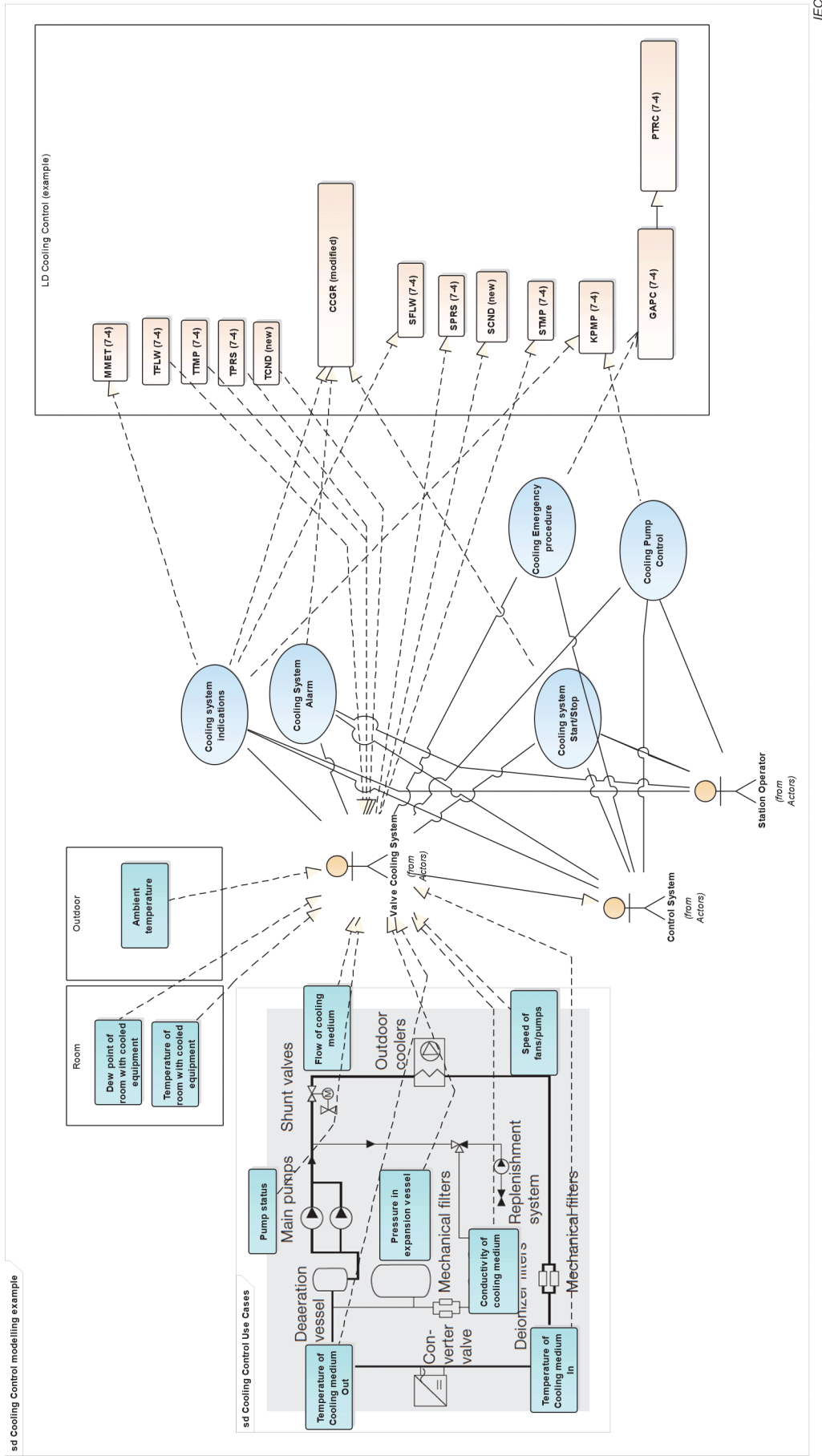
Useful logical nodes for modelling of water-based cooling system are listed in Table 7.

Table 7 – Logical nodes for modelling a water-based cooling system

Logical Node	Description
CCGR (updated)	This logical node is used to control the cooling equipment, one instance per cooling group.
SFLW	This logical node is used to represent various devices that supervise the flow of a medium. If more than one sensor is connected, the SFLW shall be instantiated for each sensor.
SCND (new)	This logical node is used to represent various devices that supervise the conductivity of a medium. If more than one sensor is connected, the SCND shall be instantiated for each sensor.
TTMP	Logical node used to represent a single temperature measurement.
TCND (new)	Logical node used to represent a single conductivity measurement.
TPRS	Logical node used to represent the absolute pressure of a medium
TFLW	Logical node used to represent a measurement of media flow rate through the device where it is located.
STMP	Logical node is used to represent various devices that supervise the temperature. It provides alarm and trip/shutdown functions. If more than one sensor is connected, the STMP shall be instantiated for each sensor.
SPRS	This logical node is used to represent various devices that supervise the pressure. If more than one sensor is connected, the SPRS shall be instantiated for each sensor.
KPMP	Logical node represents a pump, to allow for temporary setting of data object.
MMET	This logical node represents meteorological information, which can come from a meteorological station information or be a collection of meteorological information from many sources, that is, from sensors located at different places such as dew point, room temperature and ambient temperature
PTRC	This logical node is used to connect the operate outputs of one or more protection functions to a common trip of PTRC to be transmitted to XCBR. The operate signal to PTRC could in this case come from a Cooling Emergency procedure in the Valve Control System.

6.5.3 Example of modelling a cooling system

Figure 15 gives a guidance on how to model a cooling system for a converter based solution like FACTS or HVDC.



IEC

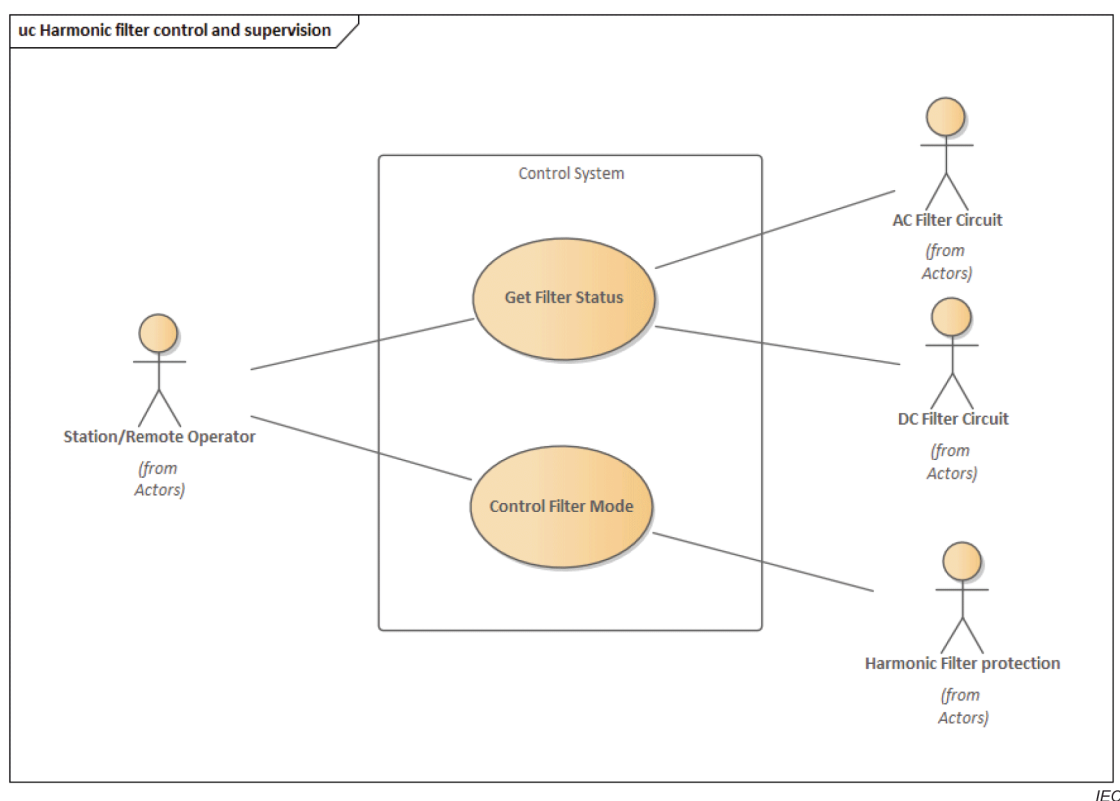
6.6 Use case: Control and supervision of Harmonic filter

A FACTS and Power Conversion device may use one or more mechanically switched harmonic filters to influence reactive power exchange. The related status of this equipment, usually AC harmonic filters, measurements and corresponding control modes need to be handled.

Each filter circuit can be considered as a separately handled unit. Filter switching either is done automatically by a control system function, manually by an operator or in a mixed configuration, based on general filter availability and operational discharge waiting times before re-energization.

The same applies to DC harmonic filter circuits, which are usually installed in HVDC OHL transmission schemes. The harmonic filters are represented by a fixed var-rating, rated voltage and discharge timer. Figure 16 and Table 8 describe the identified use case.

To cover this functionality, the new Logical node ZHAF "Harmonic Filter" is intended, providing the required data items as listed below directly after the corresponding use cases.



IEC

Figure 16 – Harmonic filter control and supervision

Table 8 – Use case: Control and supervision of Harmonic filter

Actor(s):											
	<table> <tr> <th>Name</th><th>Role description</th></tr> <tr> <td>AC Filter Circuit</td><td>Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to an AC system</td></tr> <tr> <td>DC Filter Circuit</td><td>Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to a DC system</td></tr> <tr> <td>Harmonic Filter protection</td><td>Harmonic Filter protection functions with the capability to trip or block equipment</td></tr> </table>	Name	Role description	AC Filter Circuit	Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to an AC system	DC Filter Circuit	Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to a DC system	Harmonic Filter protection	Harmonic Filter protection functions with the capability to trip or block equipment		
Name	Role description										
AC Filter Circuit	Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to an AC system										
DC Filter Circuit	Harmonic filter circuit, consisting of several components (e.g. resistors, capacitors, inductors) connected to a DC system										
Harmonic Filter protection	Harmonic Filter protection functions with the capability to trip or block equipment										
Use case(s):											
	<table> <tr> <th>Name</th><th>Service or information provided</th></tr> <tr> <td>Get Filter Status</td><td>Display filter circuit related information (e.g. availability, interlocking, reactive power, discharge status/timer, unbalance counter, selected for next switching)</td></tr> <tr> <td>Control Filter Mode</td><td>Control filter circuit mode (e.g. Auto/Manual, On/Off)</td></tr> </table>	Name	Service or information provided	Get Filter Status	Display filter circuit related information (e.g. availability, interlocking, reactive power, discharge status/timer, unbalance counter, selected for next switching)	Control Filter Mode	Control filter circuit mode (e.g. Auto/Manual, On/Off)				
Name	Service or information provided										
Get Filter Status	Display filter circuit related information (e.g. availability, interlocking, reactive power, discharge status/timer, unbalance counter, selected for next switching)										
Control Filter Mode	Control filter circuit mode (e.g. Auto/Manual, On/Off)										
Basic flow:											
Get Filter Status											
	<table> <tr> <th>Use Case step</th><th>Description</th></tr> <tr> <td>Step 1</td><td>Get the current filter circuit information</td></tr> <tr> <td>Step 2</td><td>Provide the status information to the Station/Remote Operation</td></tr> </table>	Use Case step	Description	Step 1	Get the current filter circuit information	Step 2	Provide the status information to the Station/Remote Operation				
Use Case step	Description										
Step 1	Get the current filter circuit information										
Step 2	Provide the status information to the Station/Remote Operation										
Basic flow:											
Control Filter Mode											
	<table> <tr> <th>Use Case step</th><th>Description</th></tr> <tr> <td>Step 1</td><td>Get and provide the current filter circuit mode information to the Station/Remote Operation</td></tr> <tr> <td>Step 2</td><td>Station/Remote Operation sends filter circuit mode toggle command</td></tr> <tr> <td>Step 3</td><td>If filter circuit is tripped, mode is changed to tripped until acknowledgement from Station/Remote Operation</td></tr> <tr> <td>Step 4</td><td>Provide the new mode information to the Station/Remote Operation</td></tr> </table>	Use Case step	Description	Step 1	Get and provide the current filter circuit mode information to the Station/Remote Operation	Step 2	Station/Remote Operation sends filter circuit mode toggle command	Step 3	If filter circuit is tripped, mode is changed to tripped until acknowledgement from Station/Remote Operation	Step 4	Provide the new mode information to the Station/Remote Operation
Use Case step	Description										
Step 1	Get and provide the current filter circuit mode information to the Station/Remote Operation										
Step 2	Station/Remote Operation sends filter circuit mode toggle command										
Step 3	If filter circuit is tripped, mode is changed to tripped until acknowledgement from Station/Remote Operation										
Step 4	Provide the new mode information to the Station/Remote Operation										
NOTE If switching of the Harmonic Filter is subject to a more complex process, an assigned sequence processing may be implemented using the ASEQ functionality.											

6.7 Use case: Control of external devices as part of automatic reactive power control

6.7.1 General

The Mechanical Switched Capacitor (MSC) and the Mechanical Switched Reactor (MSR) incorporates only passive components such as capacitors and reactors and can be connected directly to the high voltage busbar system or via a coupling transformer.

The control of the device can be in cooperation with a FACTS device. This coordinated control extends the dynamic range of the FACTS device. The coordination requires specific parameters, and the coordination can be turned off or on by operator. Use cases are shown in Figure 17 and described in Table 9 and Table 10.

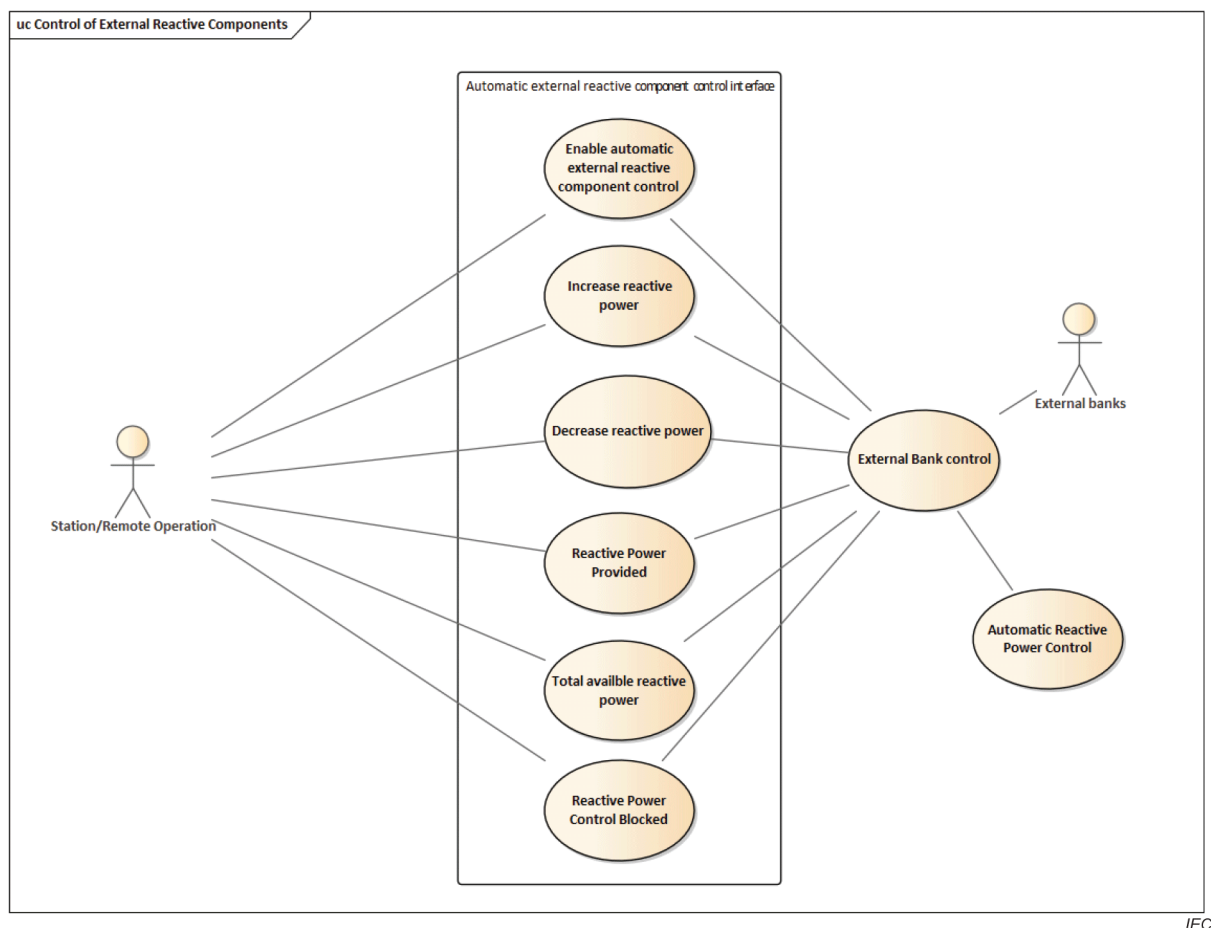


Figure 17 – Use case Control of external reactive components

Besides the above use cases set points, settings, other configuration parameters as control strategies are local issues and vendor specific, therefore not elaborated further.

Table 9 – Use case: Control of external banks mode

Use case(s):	
Name	Service or information provided
Enable automatic external reactive component control	The reactive power control is configured to use external reactive components to optimize the dynamic range of the shunt connected FACTS device
Increase reactive power	The control is asked to increase the reactive power by the reactive power control mode of the FACTS controller
Decrease reactive power	The control is asked to decrease the reactive power by the reactive power control mode of the FACTS controller
Reactive power provided	The momentary amount of reactive power provided by the external reactive power control
Total available reactive power	The total amount of reactive power available to the external reactive component control
Reactive Power Control Blocked	The external reactive power control is blocked due to discharging
Basic flows	
– Enable automatic external reactive component control	
Use case step	Description
Step 1	Station/Remote Operation enables automatic control function
– Increase/ Decrease reactive power	
Use case step	Description
Step 1	Station/Remote operation or Automatic Reactive Power Control sends increase or decrease command to the Reactive Power Control for the object to be control.
Step 2	After checking procedure, Reactive Power Control sends an acknowledge
Step 3	Reactive Power Control issues the command
– Total available reactive power	
Use case step	Description
Step 1	Reactive Power Control acquires status from devices
Step 2	If the status changed, the status with time stamp, is sent to the Station/Remote operation
– Reactive Power Control Blocked	
Use case step	Description
Step 1	Reactive Power Control disconnects the external bank from the bus
Step 2	Reactive Power sets the status discharging=TRUE to the external bank. The external bank is now blocked for operation
Step 3	Depending on variables of line current and capacitance the status changes to discharging=FALSE after a certain time