IEC/TR 61850-7-510

Edition 1.0 2012-03

TECHNICAL REPORT

colour inside

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

IEC/TR 61850-7-510:2012(E)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRICE CODE XC

ICS 33.200

ISBN 978-2-8322-0046-9

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-510: Basic communication structure – Hydroelectric power plants – Modelling concepts and guidelines

FOREWORD

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IEC 61850-7-510, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/1143/DTR	57/1203/RVC

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

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

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

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

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- withdrawn,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

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A bilingual version of this technical report may be issued at a later date.

INTRODUCTION

This Technical Report is connected with IEC 61850-7-410, as well as IEC 61850-7-4:2010, explaining how the control system and other functions in a hydropower plant can use logical nodes and information exchange services within the complete IEC 61850 package to specify the information needed and generated by, and exchanged between functions.

The dynamic exchange of values by using polling, GOOSE, Reporting or Sampled Values is beyond the scope of this report. This data flow is specified in the engineering work flow defined in IEC 61850-5; this part of IEC 61850 applies also to applications in hydro power plants.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 7-510: Basic communication structure – Hydroelectric power plants – Modelling concepts and guidelines

1 Scope

This part of IEC 61850 is intended to provide explanations on how to use the Logical Nodes defined in IEC 61850-7-410 as well as other documents in the IEC 61850 series to model complex control functions in power plants, including variable speed pumped storage power plants.

IEC 61850-7-410 introduced the general modelling concepts of IEC 61850 to hydroelectric power plants. It is however not obvious from the standard how the modelling concepts can be implemented in actual power plants.

2 Normative references

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

IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*

IEC 61850-5:2003, *Communication networks and systems in substations – Part 5: Communication requirements for functions and device models*

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

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

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

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

IEC 61850-7-410, *Communication networks and systems for power utility automation – Part 7-410: Hydroelectric power plants – Communication for monitoring and control*

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

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

ISO/TS 16952-10, *Technical product documentation – Reference designation system – Part 10: Power plants*

3 Overall communication structure in a hydropower plant

3.1 Abstract communication structure

Figure 1 is based on the substation structure described in IEC 61850-6. A typical power plant will include a "substation" part that will be identical to what is described in the IEC 61850 series. The generating units with their related equipment are added to the basic structure.

A generating unit consists of a turbine-generator set with auxiliary equipment and supporting functions. Generator transformers can be referenced as normal substation transformers; there is not always any one-to-one connection between generating units and transformers.

The dam is a different case. There is always at least one dam associated with a hydropower plant. There are however reservoirs that are not related to any specific power plant, equally there are power plants from which more than one dam is being controlled. There can also be dams with more than one hydropower plant. While all other objects can be addressed through a specific power plant, dams might have to be addressed directly.

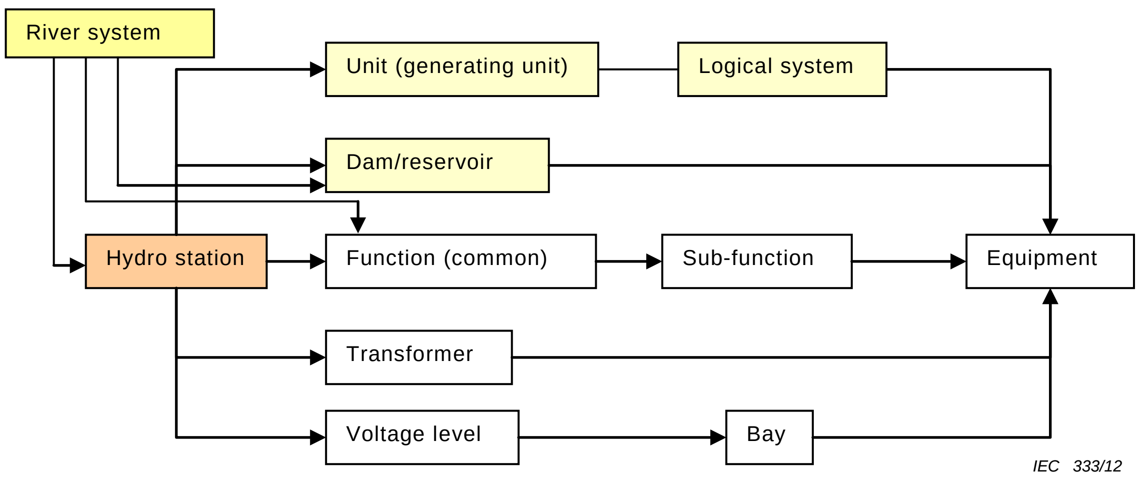


Figure 1 – Structure of a hydropower plant

There is however no standardised way of arranging overall control functions, the structure will depend on whether the plant is manned or remote operated, as well as traditions within the utility that owns the plant. In order to cover most arrangements, some of the Logical Nodes defined in this document are more or less overlapping. This will allow the user to arrange Logical Devices by selecting the most appropriate Logical Nodes that suits the actual design and methods of operation of the plant. Other Logical Nodes are very small, in order to provide simple building blocks that will allow as much freedom as possible in arranging the control system.

3.2 Communication network

Defining a station communication network is one of the primary steps for defining how the logical devices will be distributed among IEDs. The decision of where to nest the logical device is relative to the physical connection of an IED and the field instrumentation. Table 1 lists an example of physical devices used for control of a small hydropower plant.

Table 1 – IED within a simplified single unit power plant

Intelligent electronic device	Description	Example of types of logical Devices nested in an IED
IED1	Intake valve controller	Valve {A, B}
IED2	Turbine controller and speed governor	Actuators, Controllers, Turbine information
IED3	High pressure oil system controller	Tank, Pump A, Pump B
IED4	Generator monitoring system	Phase Windings{A,B,C}, Eccentricity
IED5	Excitation system	Logical device group reference: Regulation, Controls, Field Breaker, Protection
IED6	Bearing monitoring system	Thrust bearing, guide bearing, and generator bearing
IED7	Dam monitoring system	Spillway gate{1,2} and dam
Unit IED	Unit acquisition and control	Logical device group reference: sequences and Alarm grouping
Common IED	Remote terminal unit	Nil
Merging unit 1	Current- and voltage measurements at generator	Merging Unit
Merging unit 2	Current- and voltage measurements in MV	Merging Unit
Merging unit 3	Current- and voltage measurements in HV	Merging Unit
PROT1 T	Primary transformer protection	Protection, measurement
PROT2 T	Secondary transformer protection	Protection, measurement
PROT1 G	Primary generator protection	Protection, measurement
PROT2 G	Secondary generator protection	Protection, measurement

The following example in Figure 2 shows a simplified network of a single unit power plant. The IEDs exchange information and control commands using MMS (IEC 61850-8-1), send trip commands via GOOSE messaging (IEC 61850-9-2) and get information instantaneous current and voltage reading via sample value (IEC 61850-9-2). The logical devices are distributed among IEDs along functional groupings. The information is pushed to the dispatch centre via a data concentrator which is the remote terminal unit using IEC 60870-5-104.

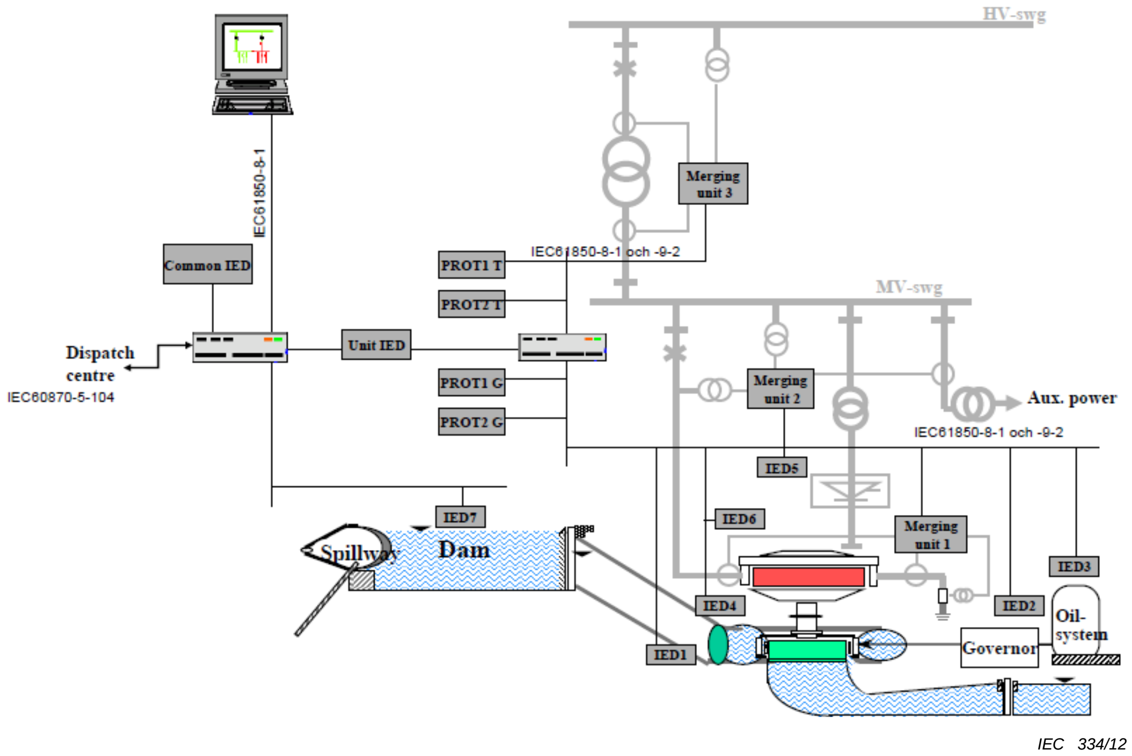


Figure 2 – Simplified network of a hydropower plant

3.3 Operational modes

A power plant can be operated in different modes: active power production mode or condenser mode. The generator can be used as a pure synchronous condenser, without any active power production and with the runner spinning in air.

In a pumped storage plant, there is a motor mode for the generator. A generator in a pumped storage plant can also be used for voltage control in a synchronous condenser mode, in this case normally with an empty turbine chamber.

The following steady states are defined for the unit:

Stopped – Unit is at standstill

Speed no load, not excited – No field current is applied, no voltage is generated; the generator is running at rated speed but not connected to any external load.

Speed no load, excited – Field current is applied and a voltage is generated, the generator is however not connected to any external load, there is no significant stator current.

Synchronised – The generator is synchronised to an external network. This is the normal status of an operating generator.

Synchronised in condenser mode – The generator is synchronised. However it does not primarily produce active power. In condenser mode, it will produce or consume reactive power.

Island operation mode – The external network has been separated and the power plant shall control the frequency.

Local supply mode – In case of a larger disturbance of the external network, one or more generators in a power plant can be set at a minimum production to provide power for local supply only. This type of operation is common in thermal power plants to shorten the start-up time once the network is restored, but can also be used in hydropower plants for practical reasons.

3.4 Fundamental control strategies

The control of hydropower plants can follow different strategies, depending on the external requirements put on the operation of the system.

Speed control in isolated mode:

The purpose of the speed control basically is to maintain constant frequency. For more detailed description, see IEC 61362.

Active power control:

The active power output control with a separate power controller is applied with the unit connected to the grid. For more detailed description, see IEC 61362.

Reactive power control:

Reactive power control includes voltage and power factor control. This can include synchronous condenser mode without active power output, but also added to active power production.

Water flow control:

In this type of control, the power production is roughly adapted to the water flow that is available at the moment. The rate of flow is controlled while the water level is allowed to vary between high and low alarm levels in the dams. The dams are classified after the time over which the inflow and outflow shall add up (daily, weekly, etc.).

Water level control:

In some locations, there are strict limits imposed on the allowed variation of the water level of the dam. This might be due to maritime shipping or by other environmental requirements. In this case, the upper water level of the dam is the overriding concern; power production is adjusted by the water level control function to provide correct flow to maintain the water level.

Cascade control:

In rivers with more than one power plant, the overall water flow in the river is coordinated between plants to ensure an optimal use of the water. Each individual plant can be operated according to the water level model or the water flow model as best suited, depending on the capacity of the local dam and allowed variation in water levels. The coordination is normally done at dispatch centre level, but power plants often have feed-forward functions that automatically will notify the next plant downstream if there is a sudden change of water flow.

Power plants with more than one generating unit and/or more than one dam gate can be provided with a joint control function that controls the total water flow through the plant as well as the water level control.

3.5 Hydro power plant specific information

Different devices handle active and reactive power control. The turbine governor provides the active power control by regulating the water flow through the turbine and thus the pole angle between the rotating magnetic flux and the rotor. The excitation system provides the reactive power control by regulating the voltage of the generator. The magnetic flux shall correspond to the shaft torque to keep the generator synchronised to the grid.

Figure 3 shows an example of an arrangement including a joint control function. The set-points will be issued from a dispatch centre and could be one of three optional values. Therefore, the type of set-point that will be used depends on the water control mode that is used for the plant.

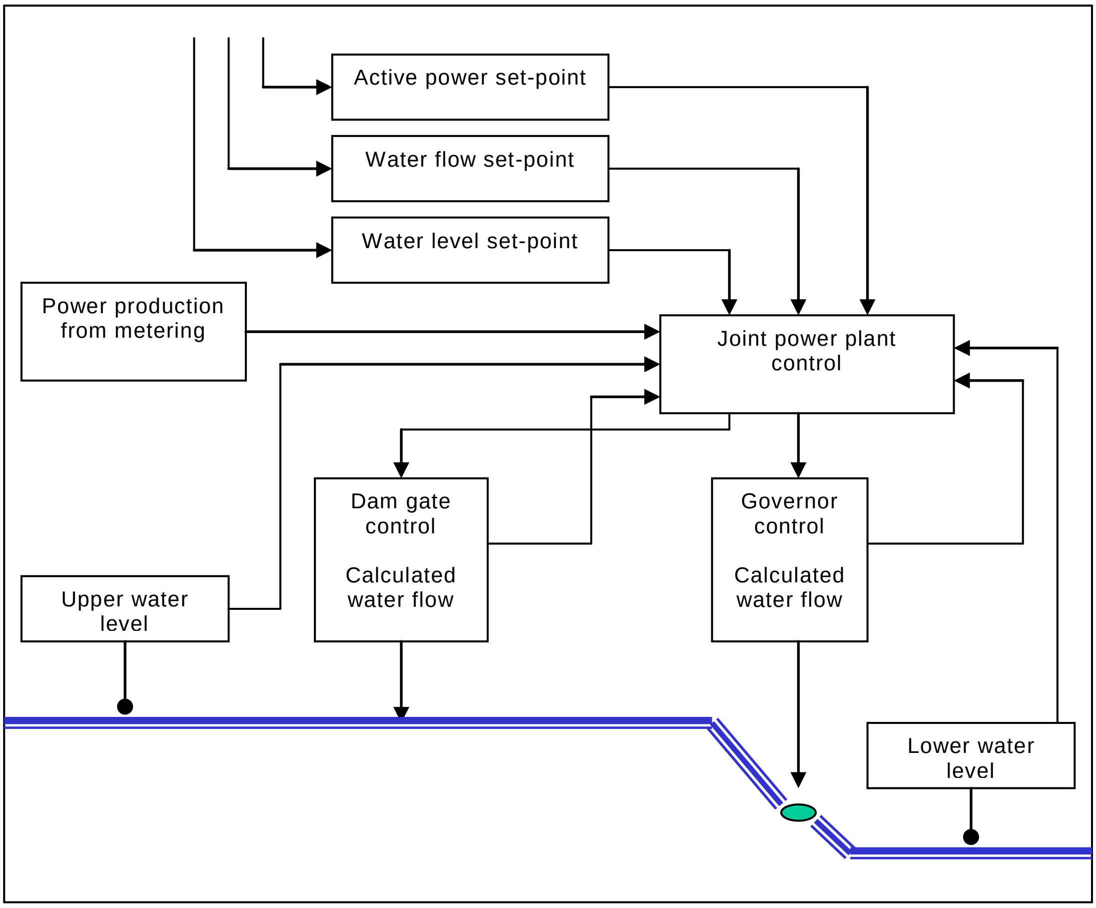


Figure 3 – Principles for the joint control function

In case of a reservoir without any power production, the water control function will get the water control set-points from a dispatch centre; in case of a power plant, it will be normally the joint control function that sets the values. The set-point will be either water level or water flow set-points.

The total water flow is the sum of flow through turbines and gates. The turbine control system can, due to this, be provided with different set-points for the control.

- Water flow set-point. The control system will base the regulation on the given water flow level and try to optimise the production.
- Active power set-point. The control system will try to meet the active power, the water flow will be reported back to the overall water control system.

- Active power control with speed droop. This is the mode when the unit is contributing to the network frequency control. The active power set-point is balanced over the speed droop setting to obtain the desired power/frequency amplification.
- Frequency set-point. In case of an islanded system or a power plant in peak load duty, the active power will be controlled to exactly meet the demand. This control mode is also used during start-up of the unit, up to the point when the generator is synchronised. Water flow will be reported.

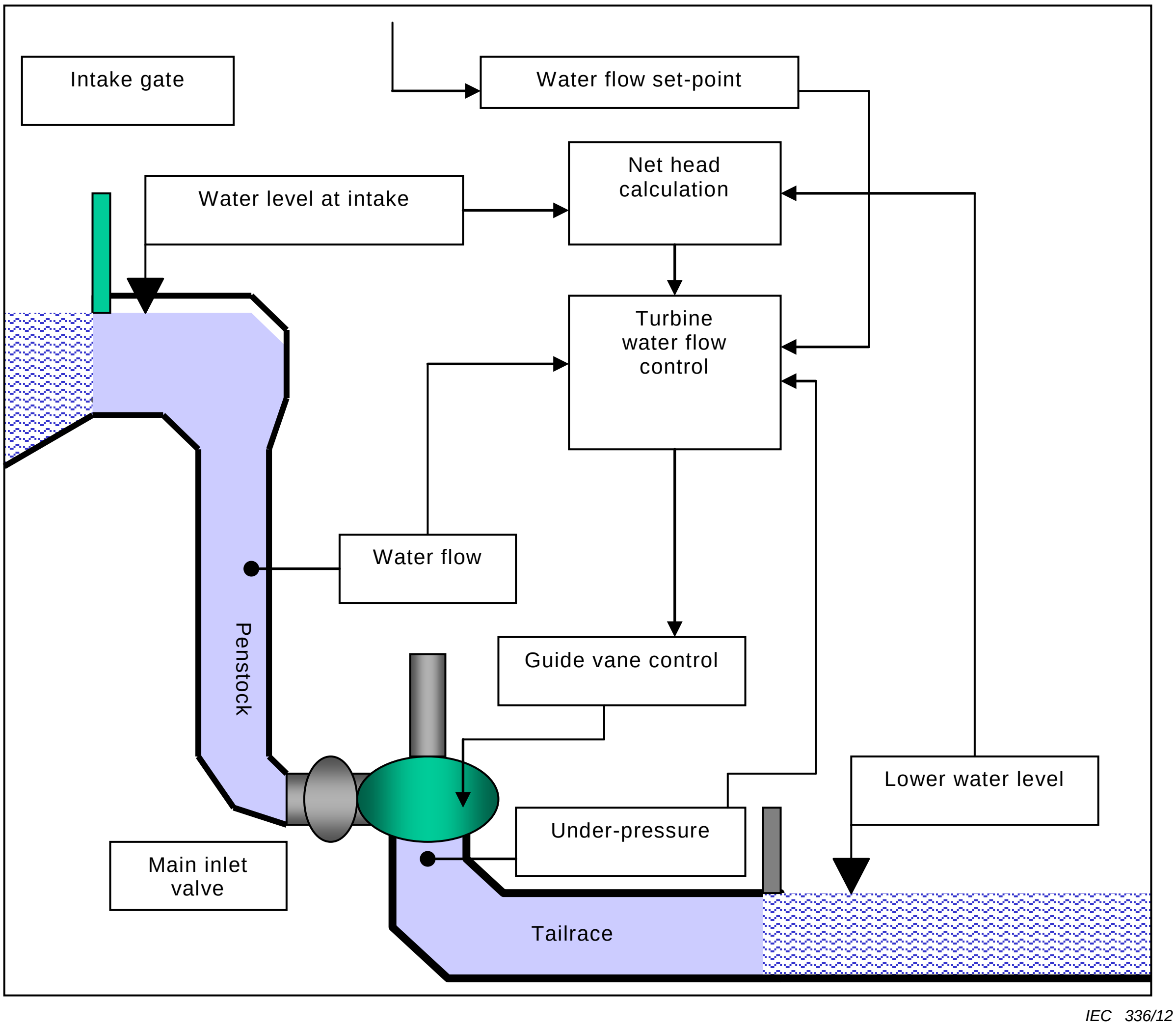


Figure 4 – Water flow control of a turbine

Figure 4 shows an example of water flow control for a turbine. Direct measurement of the water flow, as indicated in the figure, is less common. The flow is normally calculated, using the net head, the opening angle of the guide vanes and a correlation curve.

Main inlet valves to shut off the turbine chamber are used for pumped storage plants and power plants with high penstocks.

It is important to differentiate between the water levels of the dam and at the intake. Due to the intake design or if the turbine is running close to rated power, the water level at the intake might be considerably lower than the average for the dam.

The measurement of under-pressure below the turbine chamber is a safety measure, to ensure that the operation of the guide vanes does not cause any dangerous conditions in the tail-race part.

4 Structuring control systems

4.1 Basic use of logical nodes

To fulfil all the requirements, functions are decomposed into logical nodes. Refer to Clause 9 of IEC 61850-5 for more information about the logical node concept.

The introduction of additional structures such as logical devices which are composed of logical nodes is not an application requirement, but may be helpful for the modelling.

In order to identify the purpose of a Logical Node with a more general name, a suffix for identification can be added. The limitation is that the sum of characters for prefix and suffix shall not be more than 7. For use in hydropower plants, the recommended logical node prefixes are listed in Table 2.

Table 2 – Recommended LN prefixes

Name / description of function	Recommended LN prefix
Active power	W_
Actuator	Act_
Current	A_
Close	C_
Deflector	Dfl_
Droop	Drp_
Flow	Flw_
Frequency	Hz_
Guide vane	Gv_
Level	Lvl_
Limiter	Lim_
Needle	Ndl_
Open	O
Position	Pos_
Power factor	Pf_
Pressure	Pa_
Reactive power	VAr_
Runner blade	Rb_
Speed	Spd_
Temperature	Tmp_
Unit	Unt_
Voltage	V_

The prefixes in Table 2 are only recommendations, the user may decide on another method to identify the purpose of logical nodes for control functions. If a more specific definition is required, e.g. if a flow control function is intended for water flow or oil flow, this should be identified by the logical device name-string.

4.2 Logical device modelling

The basic standard of IEC 61850 does specify the Logical Node as the highest-level object that has a formal structure given by the standard. However, Logical Nodes shall be assembled in Logical Devices. The formal definition of a Logical Device is given in the standard; the user is though free to select any combination of Logical Nodes that suits the purpose.

As a simple example, we can start by looking at e.g. a pressurised oil system group reference, used to provide initial lifting power to a vertical turbine-generator shaft.

Typically, the system would include an oil tank, a pump, various valves and oil filters. It would also include the thrust bearing, maybe an oil sump and a number of sensors for temperature, pressure, level and other things.

First we define a logical device group reference, or higher-level Logical Device with a LPHD and LLN0 logical node to form a container for addition of logical devices.

Logical device group reference <plant>_<unit>_PresOil
LPHD
LLN0

Looking at the complete name-string, the device name would start with the power plant name, the generating unit name, followed by the system name; in this case “PresOil”.

This shall then be filled with the various logical devices that are required in order to create the oil system.

The first device may be the oil tank. There is a Logical Node KTNK (in IEC 61850-7-4:2010) that covers part of the functionality. KTNK only returns information about the level, we might also be interested in the temperature and the pressure, so we create a logical device that covers, beside the tank, also two pressure sensors, one temperature sensor and one additional level sensor. A logical device shall also include Logical Nodes for common functions e.g. LPHD and LLN0. The logical device would then be:

Logical Device Suffix Tnk

LLN0
KTNK
TPRS1
TPRS2
TTMP
TLVL

Since there are two temperature sensors, they shall be differentiated by use of instance numbers.

An alternative naming could be to use a prefix in front of the logical node name. The complete name-string could now be e.g. <Plant>_<Unit>PresOil_Tnk_TPRS1 for the first pressure sensor.

The same method should be used for the pressure pump. The Logical Node for a pump, KPMP, does only report the rotational speed. For control, we might also add a motor, a flow sensor as well as an oil filter and at least one temperature sensor.

LLN0
KPMP
ZMOT
KFIL
TTMP
TFLW

In an actual application, there could be more temperature sensors, e.g. one for the motor, one for the pump and one for the oil.

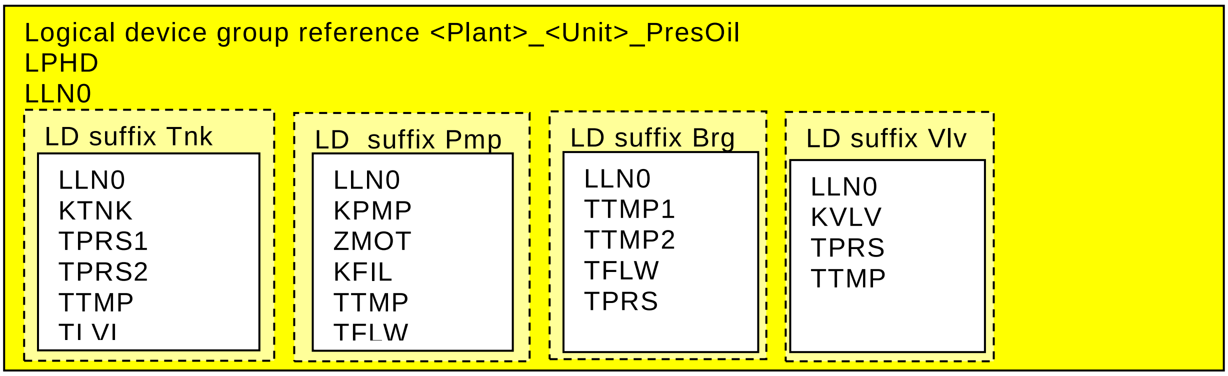
The filter Logical Node includes a measurement of differential pressure over itself. If it is important, pressure sensors could be added before and after, otherwise the basic information is available.

A more tricky issue is the thrust bearing. IEC 61850-7-410 includes a logical node for the bearing, however this could be seen as either part of the oil system or as part of the generator shaft system.

Since any specific instance of a Logical Node only can have one address string, we shall select one Logical Device where it should belong. In this case, we assume that HBRG belongs to the shaft system and not the oil system.

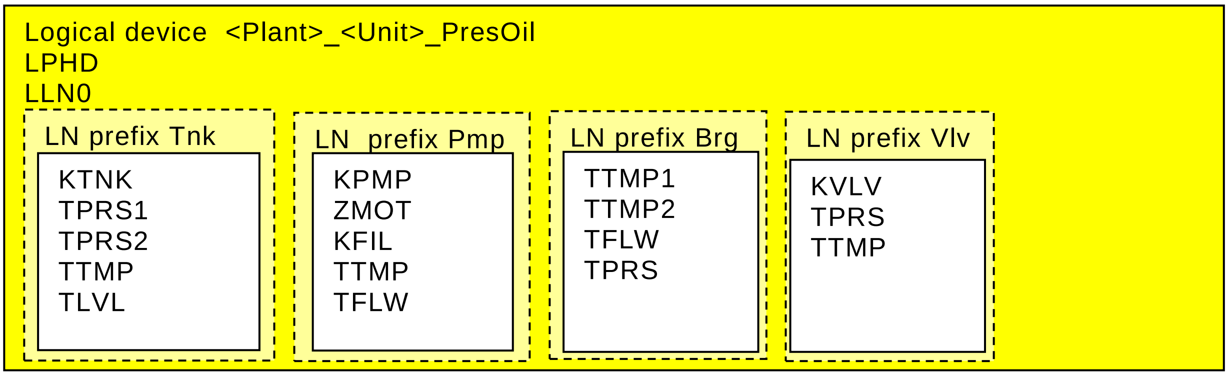
We may though still create a Logical Device within the oil system that represents the bearing, but includes only the related sensors, e.g. temperature in and out, flow and pressure but not the bearing itself. If we also add a Logical Device for a control valve, the oil system would get this final form (see Figure 5a).

Since the logical devices names size does not exceed 5 characters, then it is preferable to use a LN prefix naming structure to reduce the complexity of the logical device. See Figure 5b.



IEC 337/12

Figure 5a – Pressurised oil system with LD suffix



IEC 338/12

Figure 5b – Pressurised oil system with LN prefix

Figure 5 – Pressurised oil systems with LD suffix and with LN prefix

4.3 Example of application for an excitation system

4.3.1 General

Figure 6 shows an example of functional blocks of an excitation system, with typical logical nodes that can be used within each functional element.

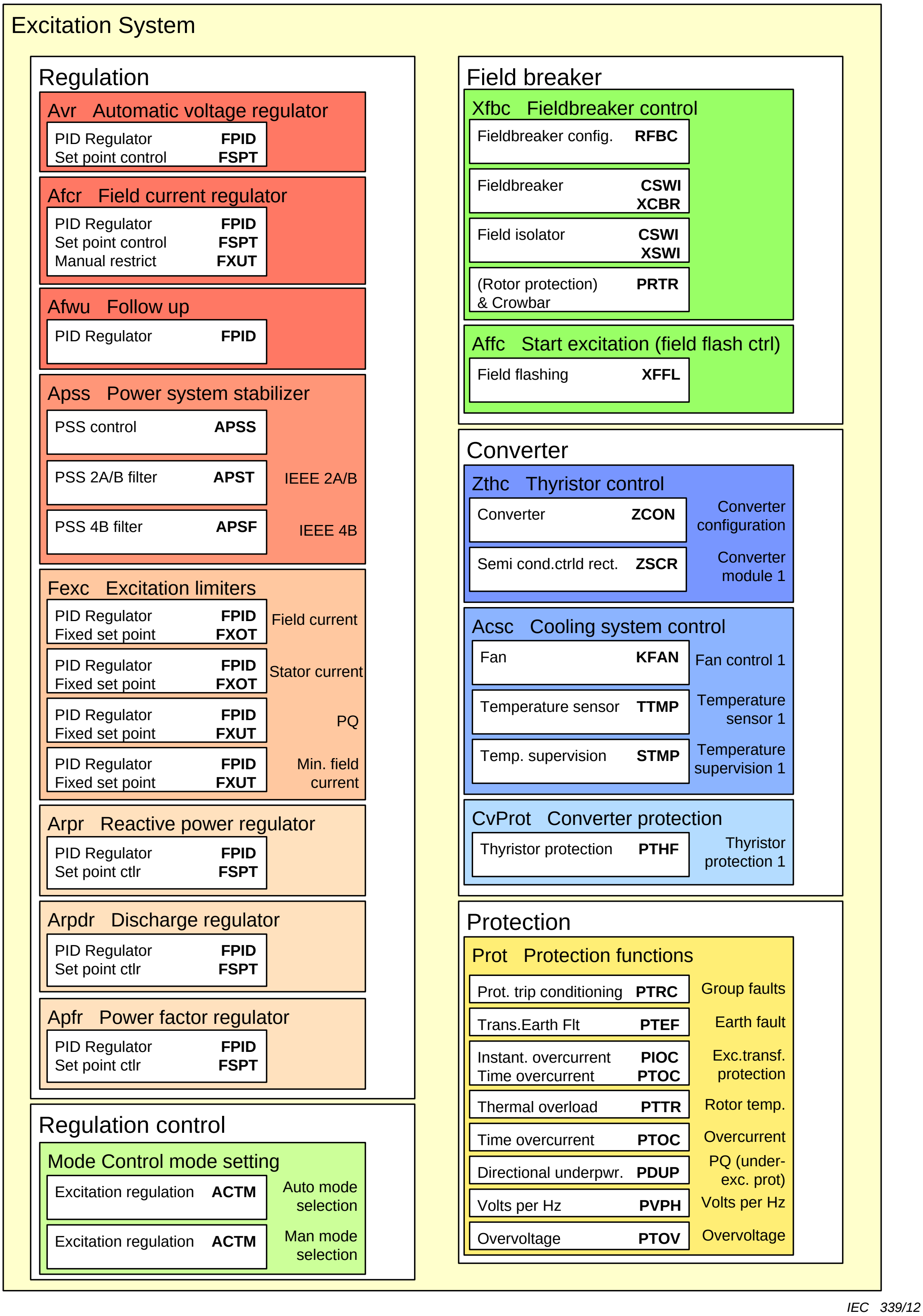


Figure 6 – Examples of logical nodes used in an excitation system

For practical purposes, the excitation system will be divided in a number of Logical Devices that can be addressed and handled separately.

The division into functional blocks (Regulation, Field breaker, Converter and Protection), as well as in Logical Devices (Avr, Afcr,...) as represented on Figure 6 is only informative and may be interpreted in different ways. The following alternatives may be considered:

- Different assignment of Logical Devices to the functional blocks, e.g. Affc may be part of Converter instead of Field breaker.
- Different division between the Logical Devices, depending on different regulation models, e.g. automatic mode LD and manual mode LD, each covering regulation loops and their limitations.
- Different scaling of the LD's, e.g. the functional blocks may be used as LD's itself.

Table 3 gives a non-exhaustive example of how this can be done for a larger excitation system. The notation {inst} means that there might be more than one logical device of a certain type. A number shall replace the {inst} if instantiation is used.

Table 3 – Logical device structure

Logical device name	Functionality
Avr{inst}	Automatic voltage regulator
Arpr{inst}	Reactive power regulator
Apfr{inst}	Power factor regulator
Afcr{inst}	Field current regulator
Apss{inst}	PSS
Aut{inst}	Automatic control mode
Man{inst}	Manual control mode
Boost{inst}	Boosting function
Fexcl{inst}	Excitation limiter
Flux{inst}	Flux limiter (volt /hertz limiter)
Fstcl{inst}	Stator current limiter
Arpdr{inst}	Discharge regulator
Affc{inst}	Start excitation (field flash control)
Xfbc{inst}	Field breaker control
Zthc{inst}	Thyristor control
Acsc{inst}	Cooling system control
CvProt{inst}	Converter protections
Prot{inst}	Protection functions (general)
Ialm{inst}	Alarm handling
Meas{inst}	Electric measurements
Texc{inst}	Excitation transformer
Aseq{inst}	Start-stop sequence
Irec{inst}	Fault and event recording
Ggio{inst}	I/O cards

Figure 7 is an example for the functional structure of the regulation part of an excitation system. The coloured parts represent logical devices.

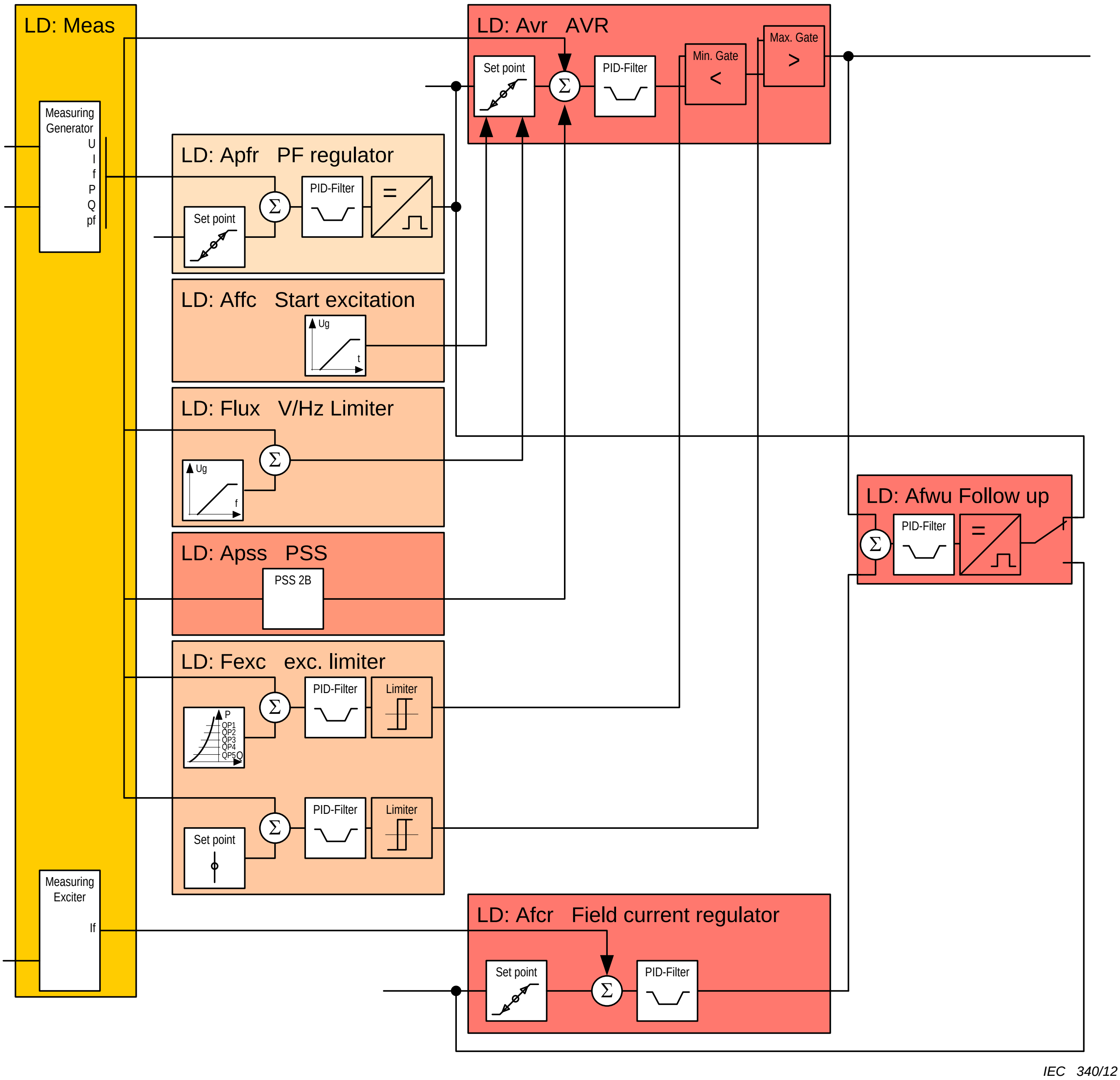


Figure 7 – Example of logical devices of the regulation part of an excitation system

NOTE Standard IEC 61850 generally allows reading and writing parameter settings using the IEC 61850 interface. From practical point of view, writing parameters using the IEC 61850 interface will not be allowed. Therefore, the following examples show settings as read only signals.

4.3.2 Voltage regulation example

Figure 8 shows an automatic voltage regulator.

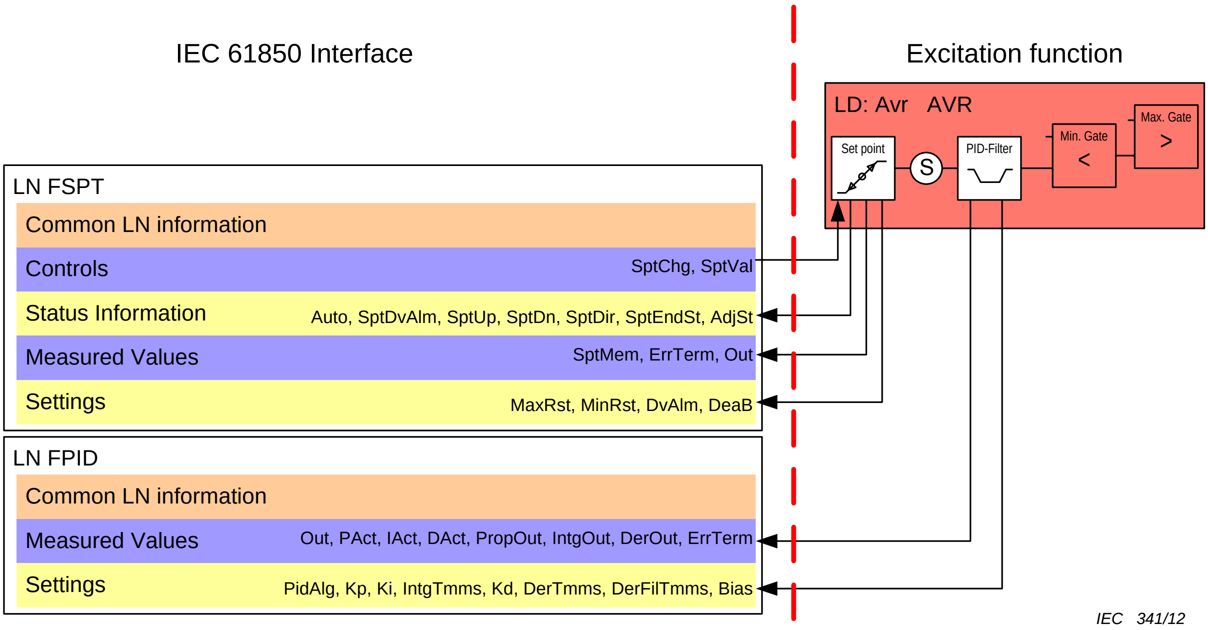


Figure 8 – AVR basic regulator

Figure 9 shows a power factor regulator.

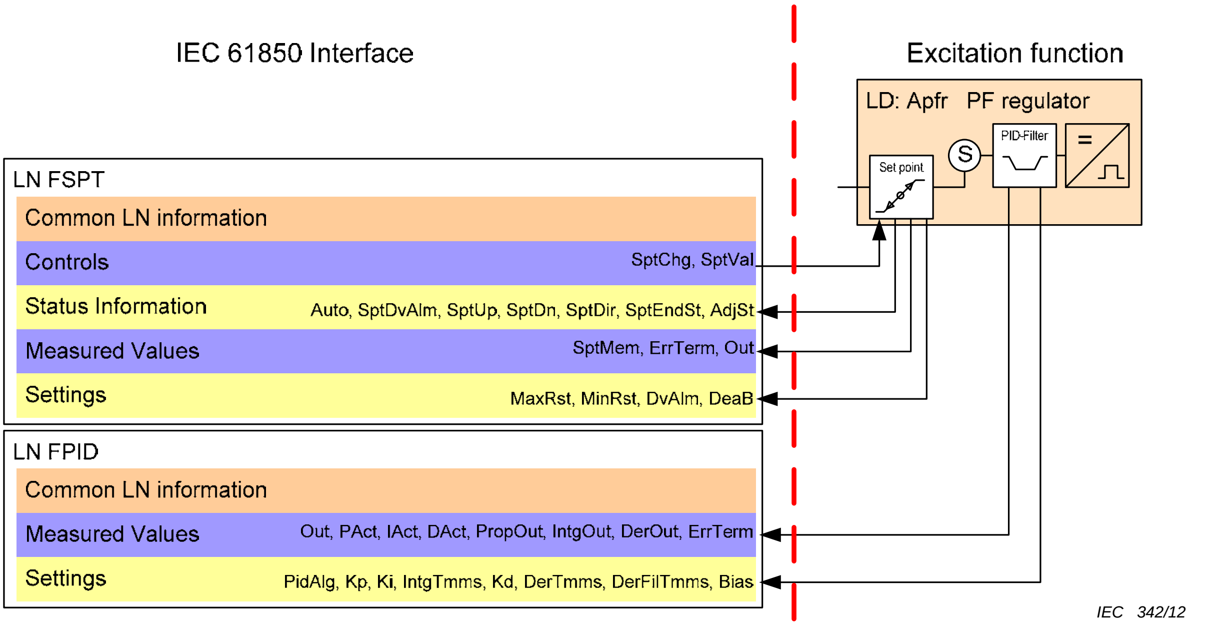


Figure 9 – Superimposed regulators, power factor regulator

Figure 10 shows an over-excitation limiter.

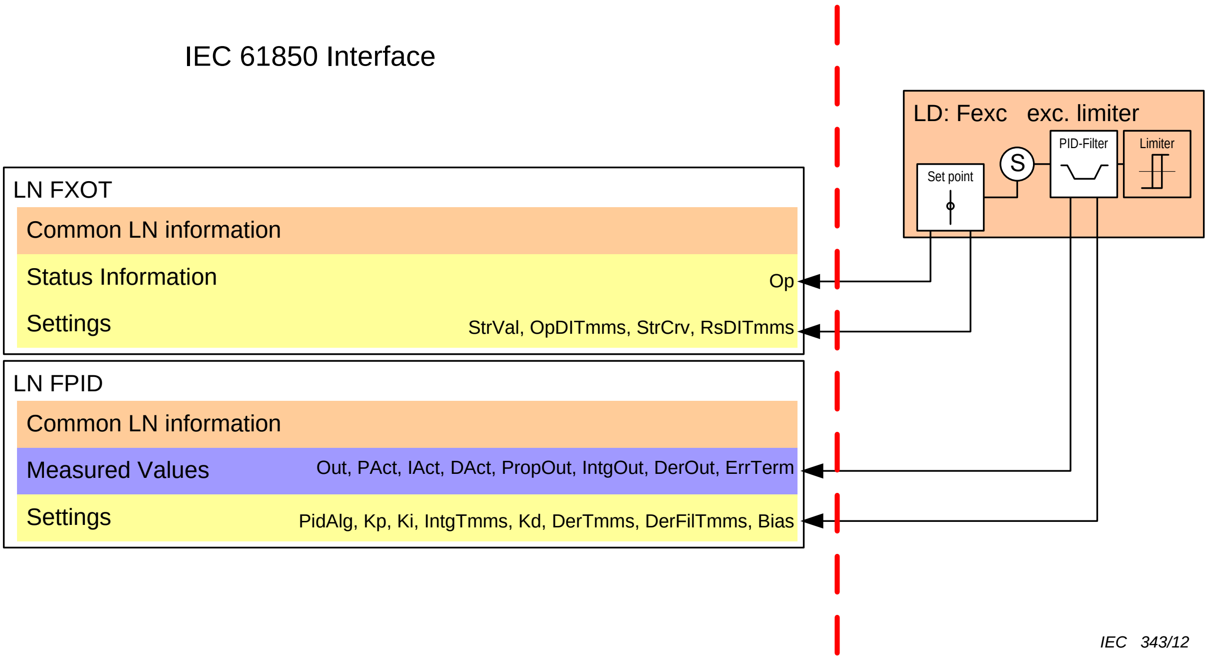


Figure 10 – Superimposed regulators, over-excitation limiter

Figure 11 shows an under-excitation limiter.

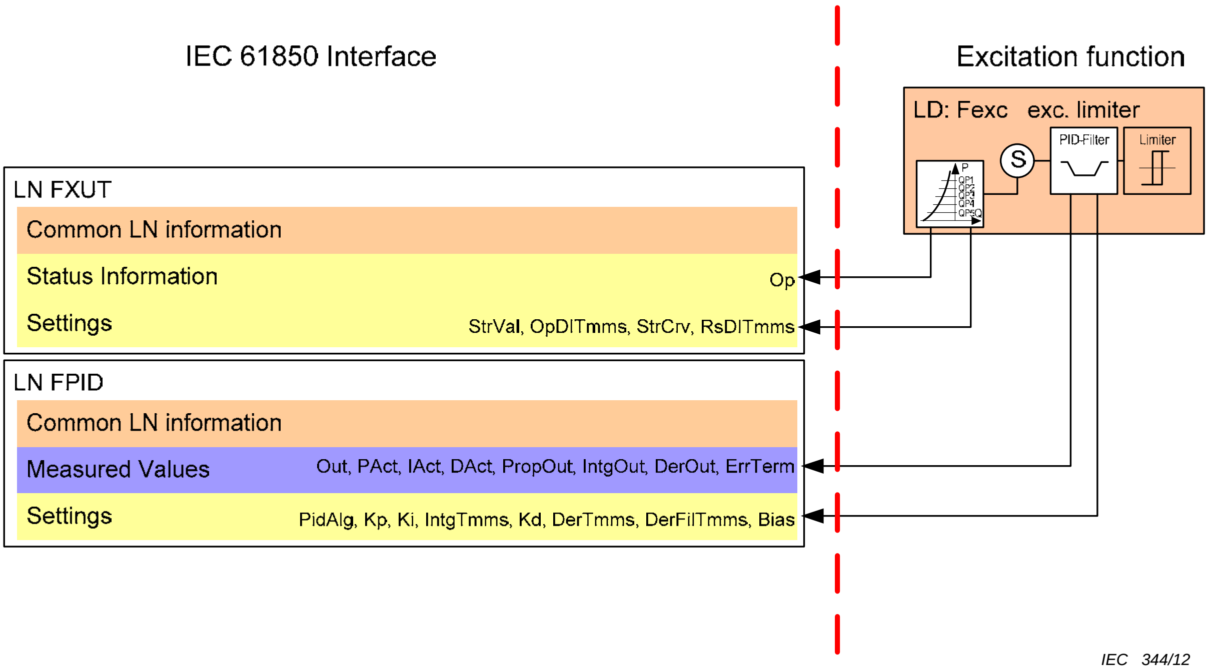


Figure 11 – Superimposed regulators, under-excitation limiter

Figure 12 shows a follow up.

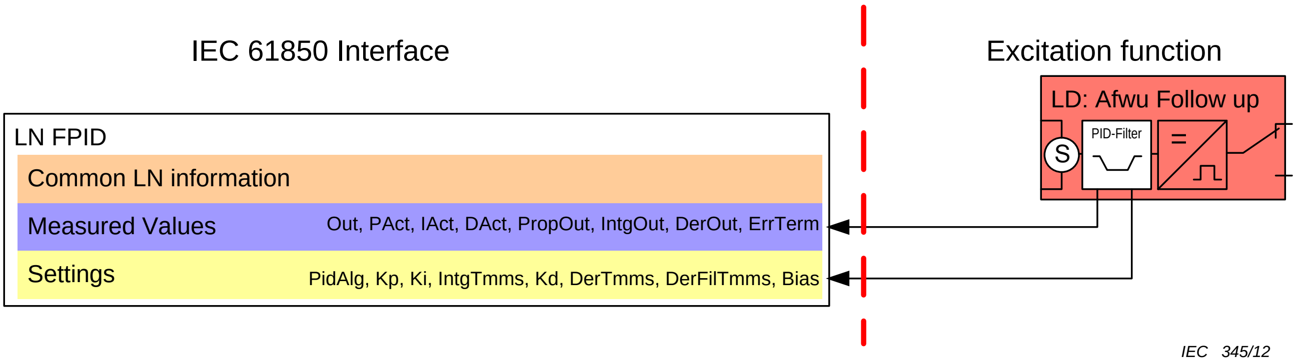


Figure 12 – Superimposed regulators, follow up

4.3.3 PSS example

Figure 13 shows a power system stabilizer function.

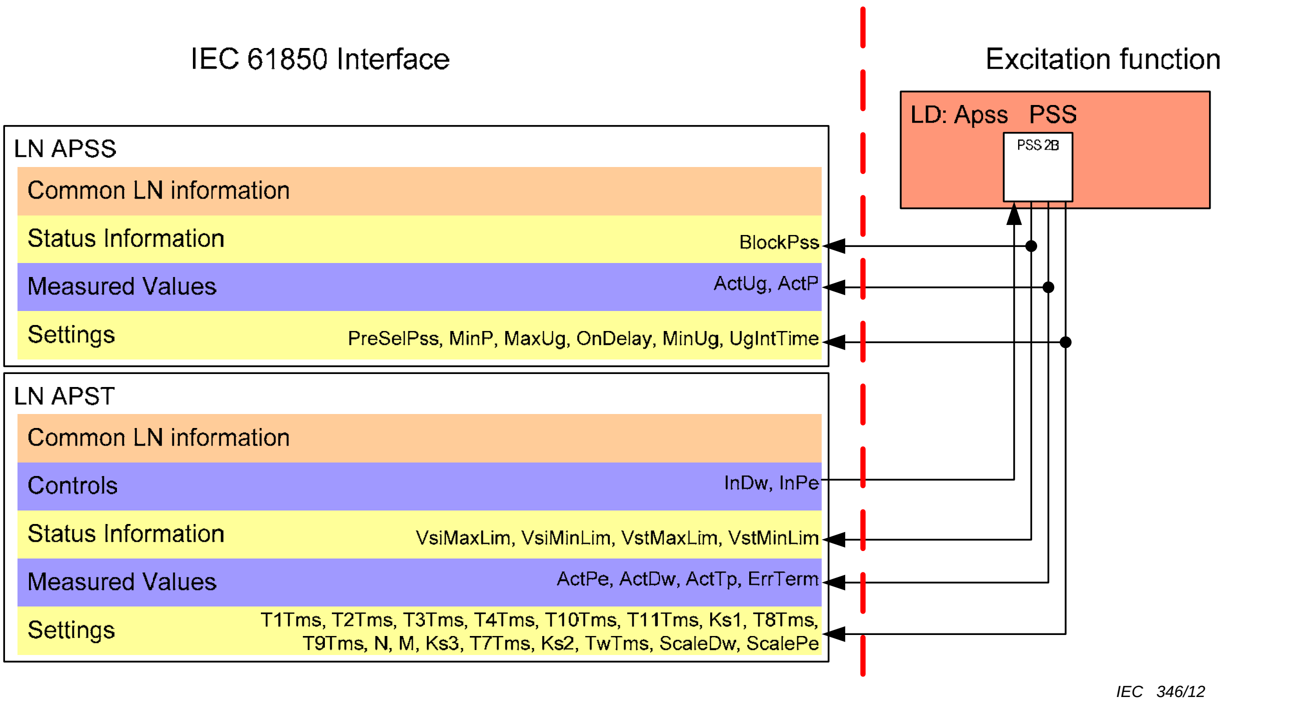


Figure 13 – Power system stabilizer function

The standard includes three logical nodes that can be combined to represent a PSS function: RPSS that provides general information, RPST that represents a IEEE 2A/B filter and RPSF that represents a IEEE 4A filter. In Figure 13 above, only the 2A/B filter is shown.

4.4 Example of application for a turbine governor system

4.4.1 Conditions of this example

The example is based on a minimum signal list on which everyone can agree, consisting of datapoints that are absolutely necessary for operating a turbine governor. In addition, consideration has been made to enable extension to other projects:

- no fixed definition of used controllers,
- clear separation of the control algorithm from the operation conditions and the data acquisition.

The following assumptions have been made.

- Francis turbine with one single actuator (only one position indication). In case of individual wicket gate control, individual position can be added and threshold associated to the actuators are being managed by internal data of the turbine governor;
- single turbine governor (no redundant signal or system);
- communication with a HMI (Human-Machine Interface) is not included.

4.4.2 Signal hierarchy

Figure 14 shows a signal hierarchy.

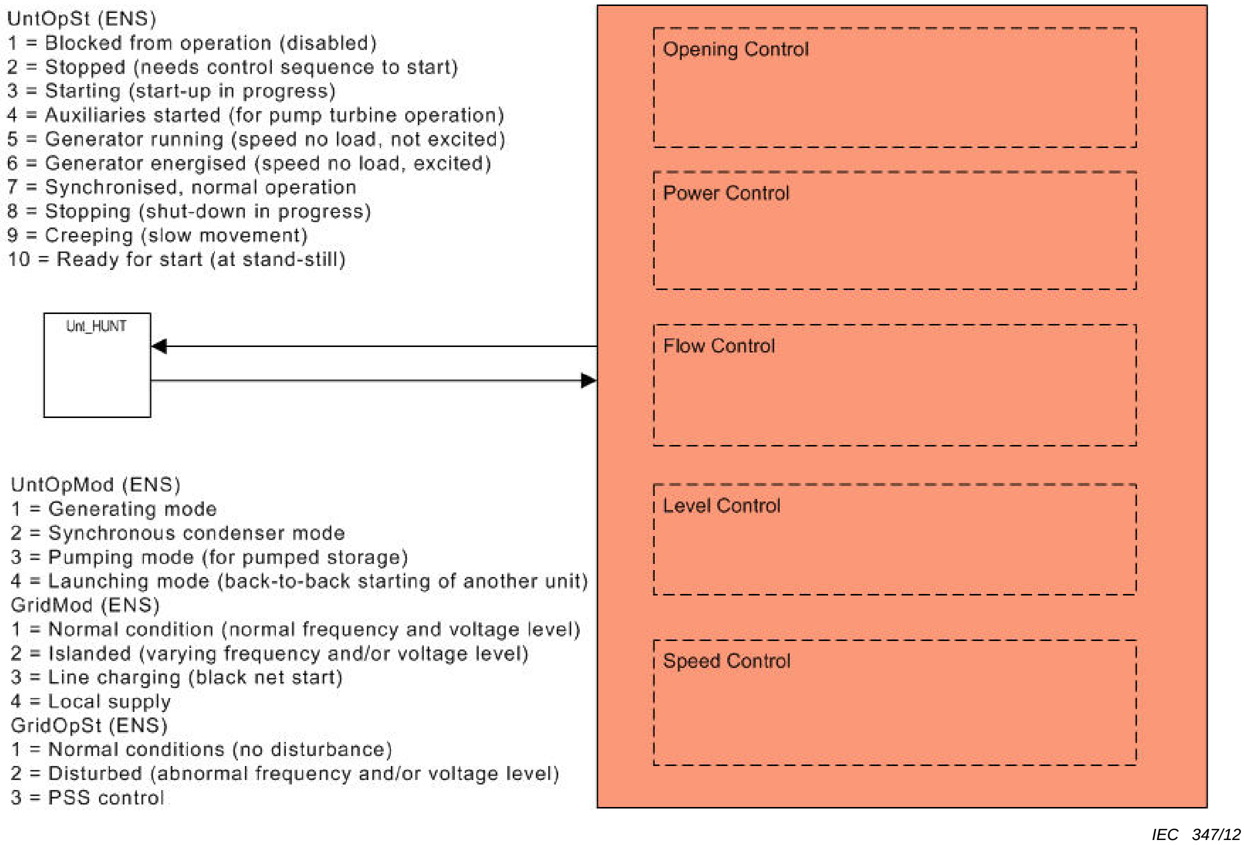


Figure 14 – Signal hierarchy

The HUNT LN communicates the actual state of the grid and the desired operation mode to the turbine control. In dependency on these states the actual governor (power, opening, flow, level or speed) and the correspondent parameter set are selected.

4.4.3 Basic overview

Figure 15 shows the typical functional blocks of a turbine governing system, from the communication point of view, and by considering the example of a Francis turbine.

Detailed block descriptions of the used logical nodes will be given in 4.4.4.

As mentioned in 4.4.2, the general structure is based on the allocation of the different signals to be exchanged, among 3 main logical devices, which are interacting:

1) Logical Device "Actuators": it mainly concerns the position of the wicket gate, and the corresponding failures of the positioning circuit.
2) Logical Device "Turbine information": it mainly concerns the different operating modes of the turbine (e.g. start / stop, synchronous condenser mode,…) and the different hydraulic variables (e.g. water levels and flow, penstock pressure,...).
3) Logical Device "Controllers": it mainly includes a large block made up of a combination of different single controllers (speed controller, power controller), which are interacting; the output signal of this combination is then limited by the block "Limitation", and is finally acting as a command signal for the actuators.

Table 4 gives a non-exhaustive example of how logical device names can be defined for a turbine control system. The notation {inst} means that there might be more than one logical device of a certain type. A number shall replace the {inst} if instantiation is used.

Table 4 – Logical device names for functions

Logical device name	Functionality
Act{inst}	Actuators
Contr{inst}	Controllers
TrbInf{inst}	Turbine information

Concerning the controllers block (in red colour), and according to IEC 61362, some controllers can be made inoperative: for example, the level controller will be made inoperative when the water level control is not required, or operated by the joint power plant control. Furthermore, the global control structure using a combination of such controllers can be either a series or a parallel structure: for example, the power controller and the speed controller, linked by the frequency power droop.

Finally and generally speaking, the logical node HGOV, as shown in the following figure, activates all these controllers.

Figure 15 shows the use of Logical Node HGOV.

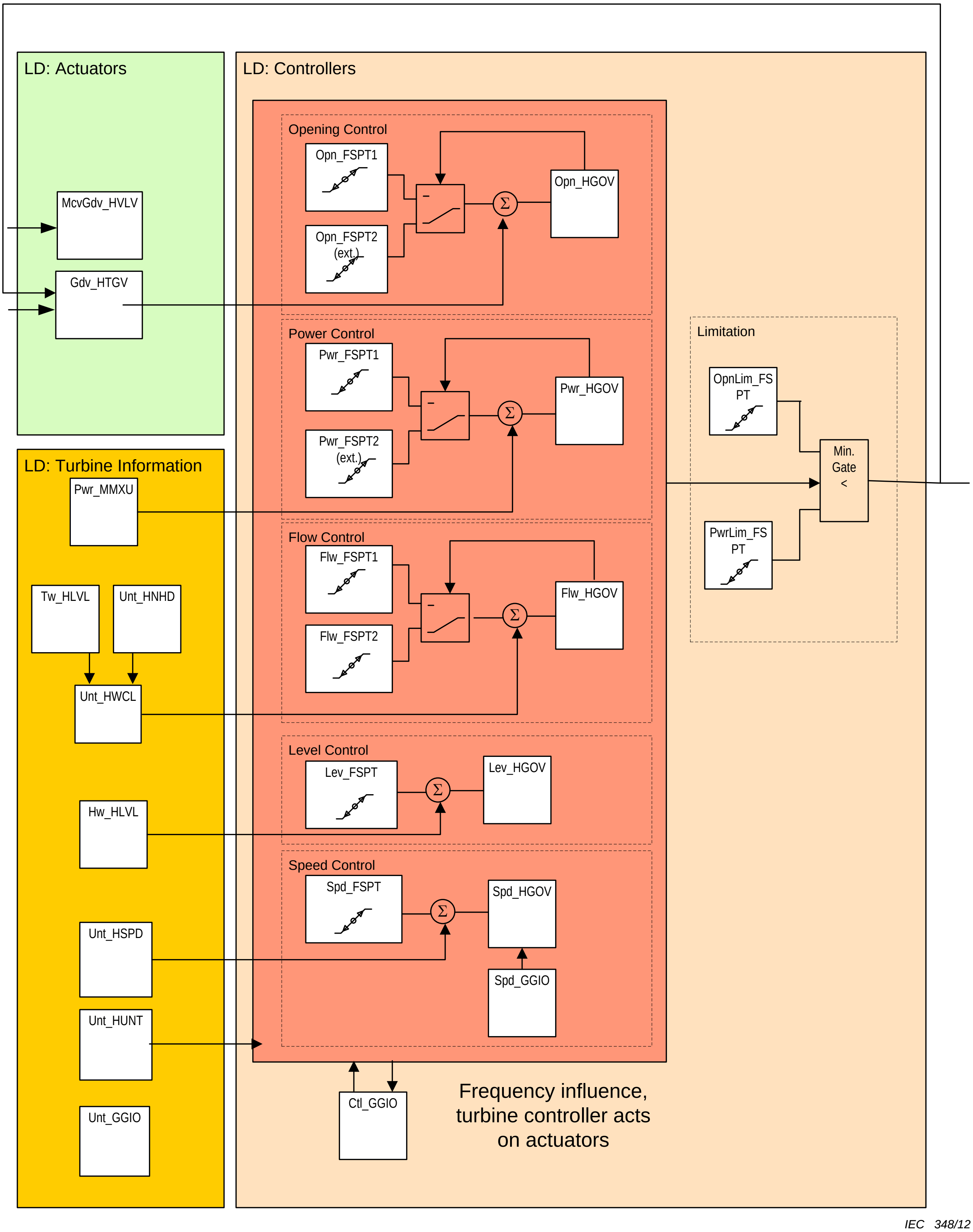


Figure 15 – Use of Logical Node HGOV

4.4.4 Detailed description of used structure

The following is a detailed block description and ideas behind the used LNs.

Use of quality information (xxx.q) for indication of fault in the device, control loop errors is handled separately.

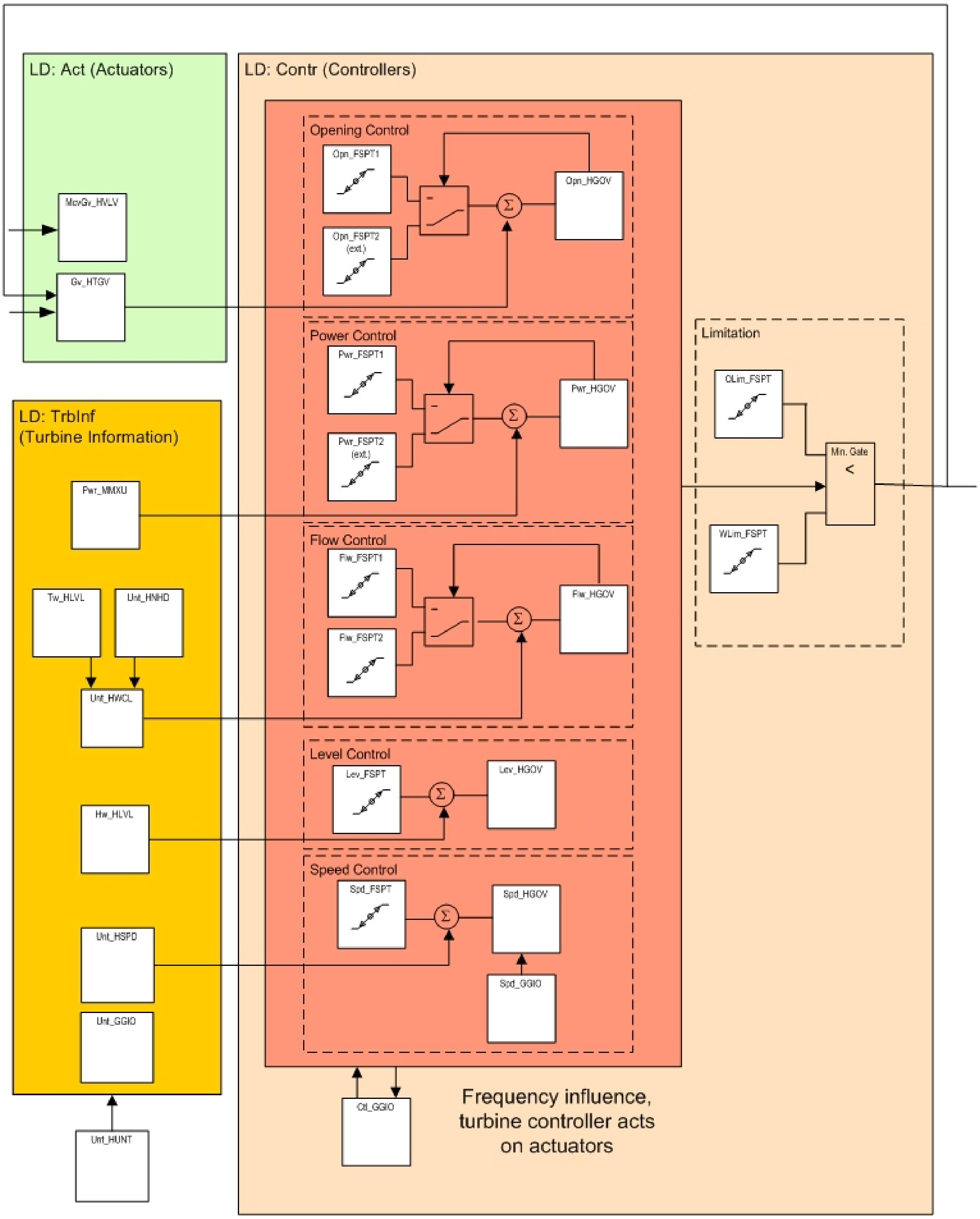
Some controllable settings are only set internally.

In the three Logical Devices, the Logical Nodes model the data exchange via IEC 61850 to any communication partner. Only the information, which is relevant for external devices, is available at the Logical Nodes and can be used to monitor and control the governor.

Any kind of information that describes the state (quality), like “good”, “invalid”, “questionable”, etc., is mapped to the attribute of the information it belongs to. For example, the information “failure signal” is mapped to the DataObjectName “q” of the type “Quality” in the used CommonDataClass. This is done only for the CDC’s MV and APC. All analogue information in these CDC’s are based on floating point values and not on integer values. Please see the detailed information on the quality information in IEC 61850-7-3.

The Logical Nodes are identified and selected by their main functionality. To describe the advised function of a LN, the prefix is used. The use of general LN’s like GGIO should be reduced to its minimum. This general LN type represents only some not assignable information.

At the Logical Device “Turbine Information” the prefix “Unt” or “Pwr” is used to point out that the LN is unit related. To describe a plant related LN, the prefix “Hw” or “Tw” is used, see Table 2 above. Governor wide information or control is done by the LN HUNT located in this LD. For example, this includes the local/remote control location. For serving the water flow and penstock pressure information, the LN HWCL is used. All required electrical information (active power, frequency) are inside the integrated LN MMXU. The used GGIO only displays the summary information of secondary signal failures. Figure 16 shows a governor control.



IEC 349/12

Figure 16 – Governor control

The behaviour of the Governor is controlled by the LN's inside the LD "Controllers". Except the "activation of the frequency influence" and the "information of acting on actuators", the LD contains all of the control modes and the output limitation. All process related information used in the LD "Controllers" is provided by the LD "Turbine Information" and the feedback information of the guide vane by the LD "Actuators". The control modes are structured all in the same way, to ensure that each control mode can act independent of all others. Generally each control mode consists of up to two set points. The selection of the actual used set point is done via the LN HGOV. The actual used set point at this LN FSPT is forwarded to the DataName "Out" and "SptMem". The LN HGOV is also used for specifying the Droop, activating a control mode and serving the unlimited output of each control mode. Figure 17 shows a flow control, Figure 18 shows a level control, Figure 19 shows a speed control.

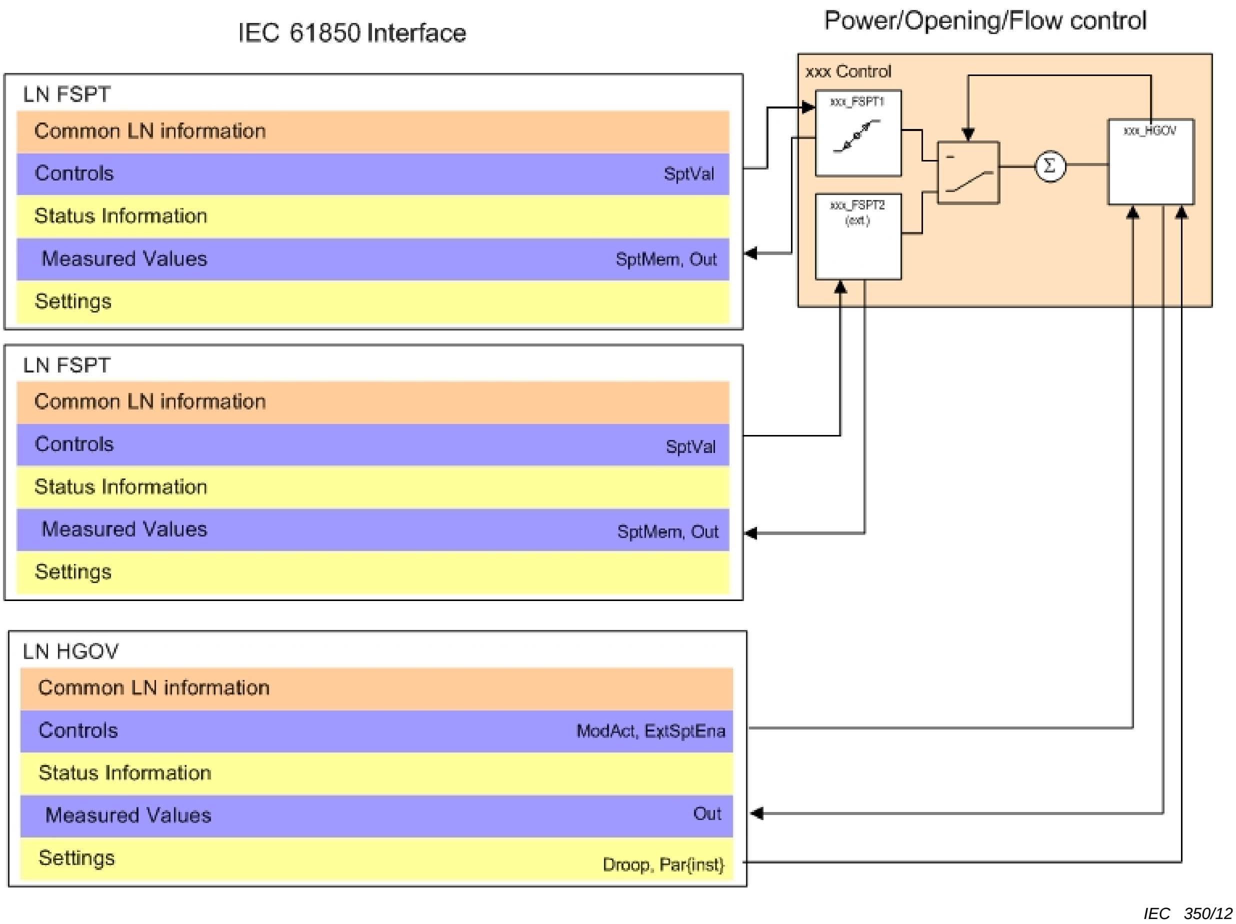


Figure 17 – Flow control

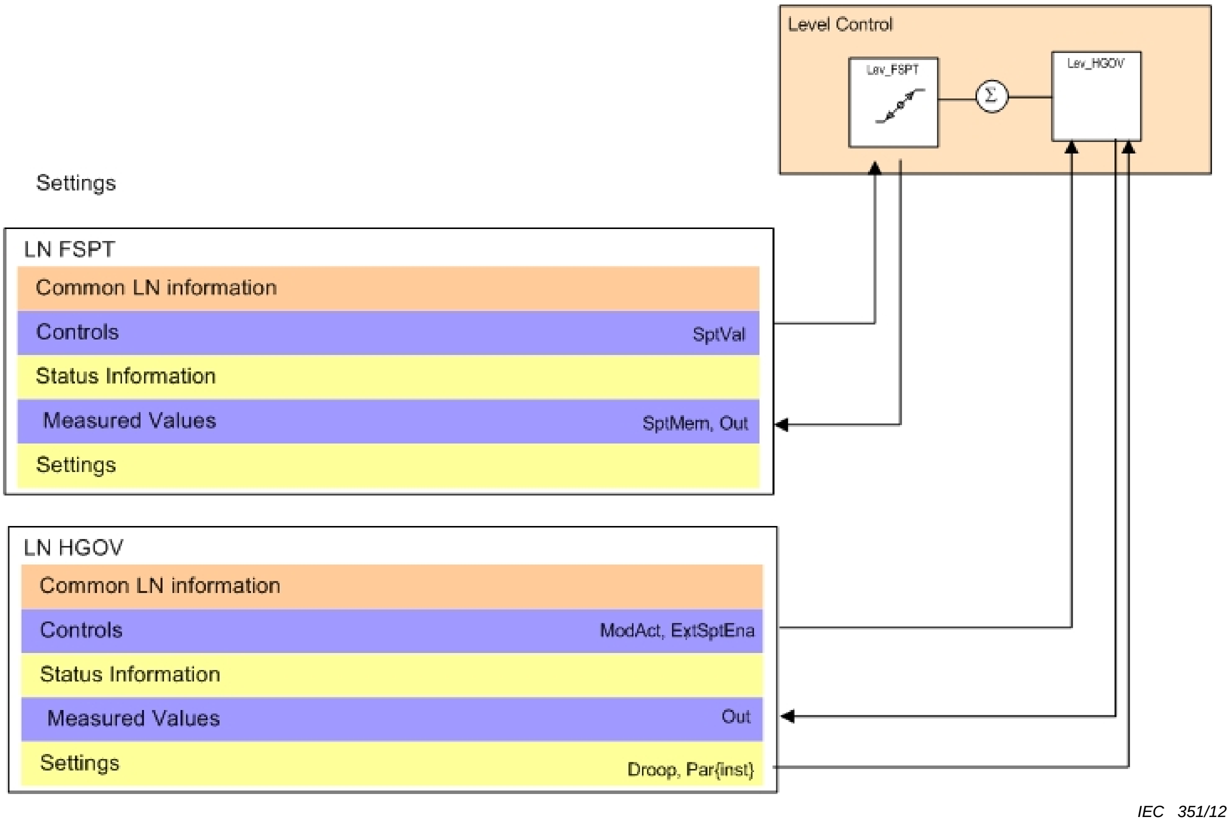


Figure 18 – Level control

At the speed controller, the control mode can be extended by the option to activate the insensitivity mode via the LN “Spd_GGIO”. The LN “Ctl_GGIO” takes care about the “activation of the frequency influence” and the “information of acting on actuators” for all control modes.

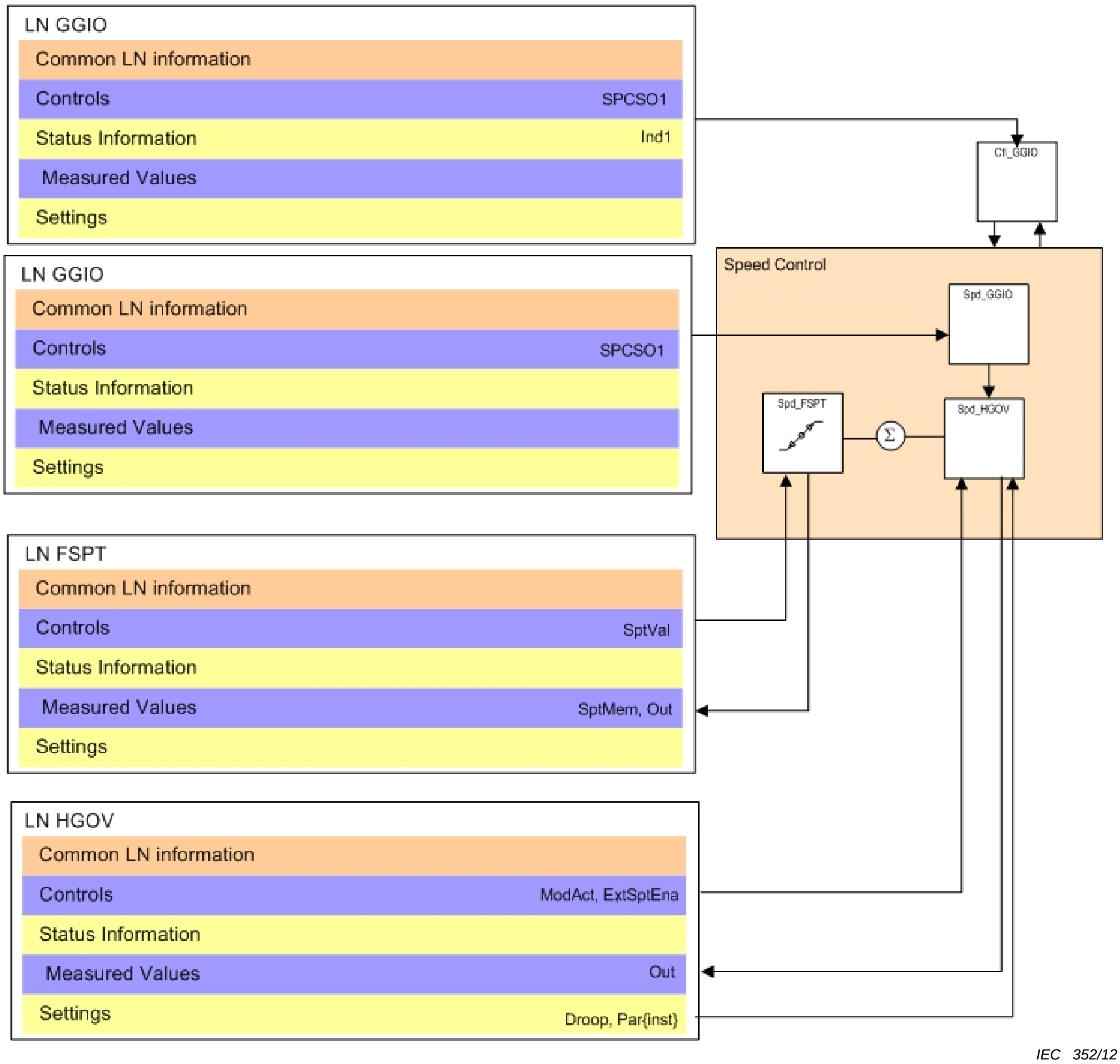


Figure 19 – Speed control

The output of any individual controller can be used as an input for another control loop or as final output signal of the selected control mode. This resulting output is forwarded to an output limitation to ensure neither the opening or power limit is exceeded. Both limitation set points can either be set via the LN FSPT at the DataName "SptVal" or with an internal calculated value. At the DataName "SptMem", the internal calculated set point is displayed. The DataName "Out" indicates the actual used set point. Figure 20 shows limitations.

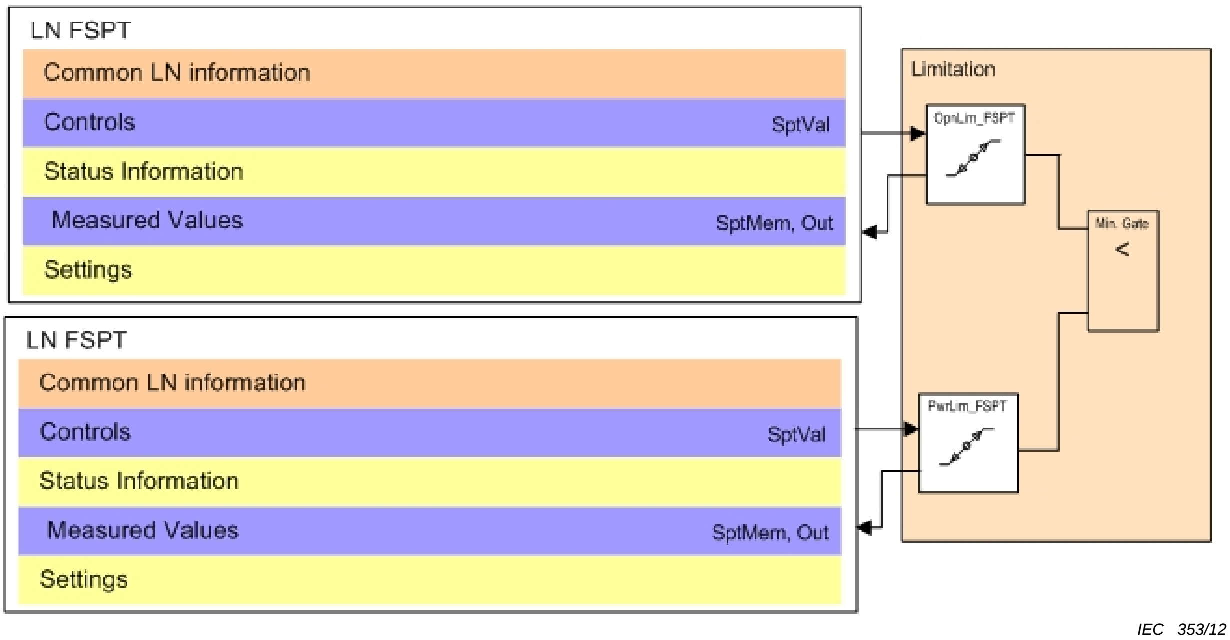


Figure 20 – Limitations

The set point "PosSpt" for the guide vane control LN HTGV in the LD "Actuators" is provided by the LD "Controllers". From the main control valve only status information are available at the LN HVLV. Figure 21 shows an actuator control.

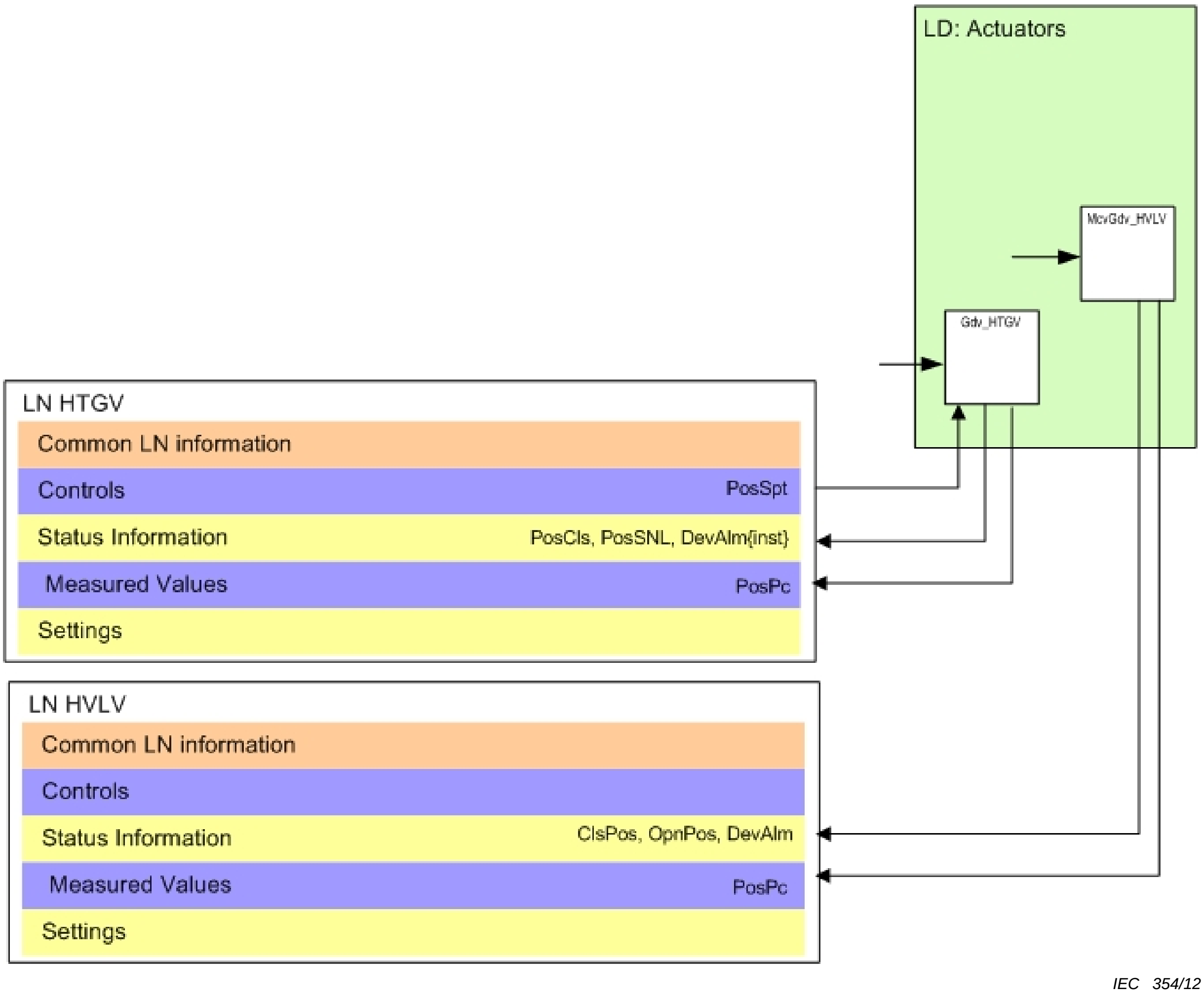


Figure 21 – Actuator control

4.5 Examples of how to reference a start / stop sequencer of a unit

4.5.1 General

The examples are for a simple turbine generator unit with an intake gates and no inlet valve. The guide vanes are equipped with servomotor locks and the unit is supplied with a lubrification unit and brakes. The generator is cooled by a cooling fan.

There are several different tripping strategies widely used as common practice today depending on a combination of different tripping criteria, different servomotor shutdown initiating devices and the corresponding sequence of tripping actions.

The example below is widely used in the hydro community (see Table C.2 of IEC 61362:2012); a second widely used strategy is described in Table C.1 of IEC 61362:2012.

4.5.2 Unit sequences definition with IEC 61850

Each unit sequence is defined by a “HSEQ” LN and it is included in a dedicated LD. All of them are grouped together in a group reference LD called “SEQ” (unit start-stop sequencer). Only the “SEQ” group reference logical device will have the LLN0 and LPHD logical nodes. Figure 22 shows a sequencer overview.

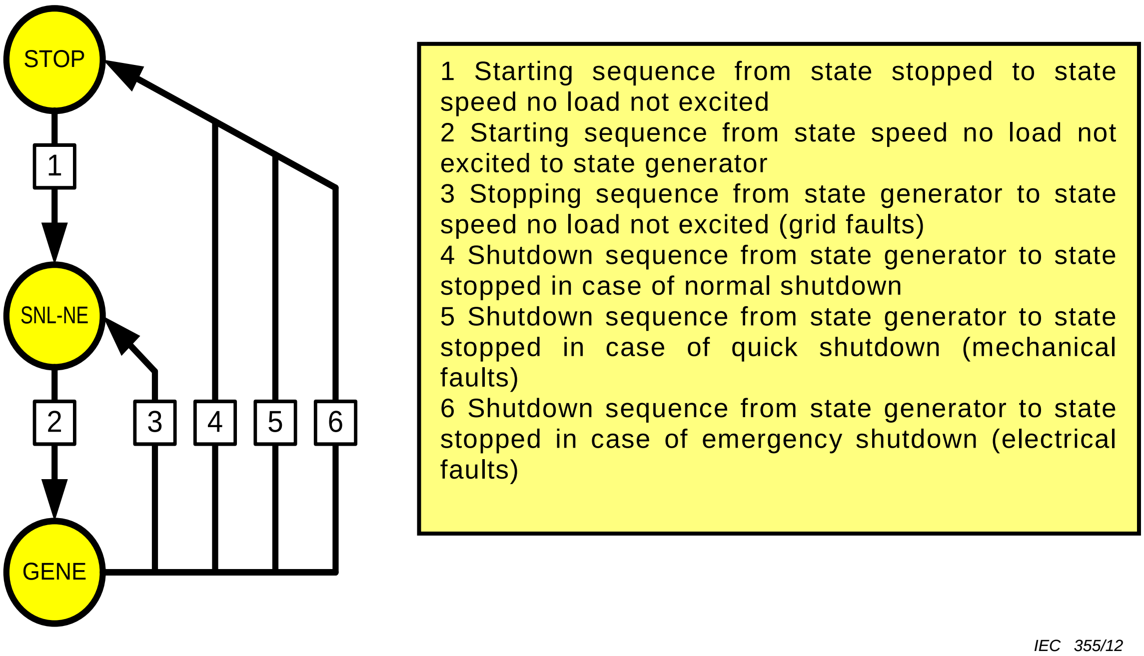


Figure 22 – Sequencer overview

Table 5 summarizes the most common specified names for the LDs which are including the “HSEQ” LNs.

Table 5 – Typical sequences

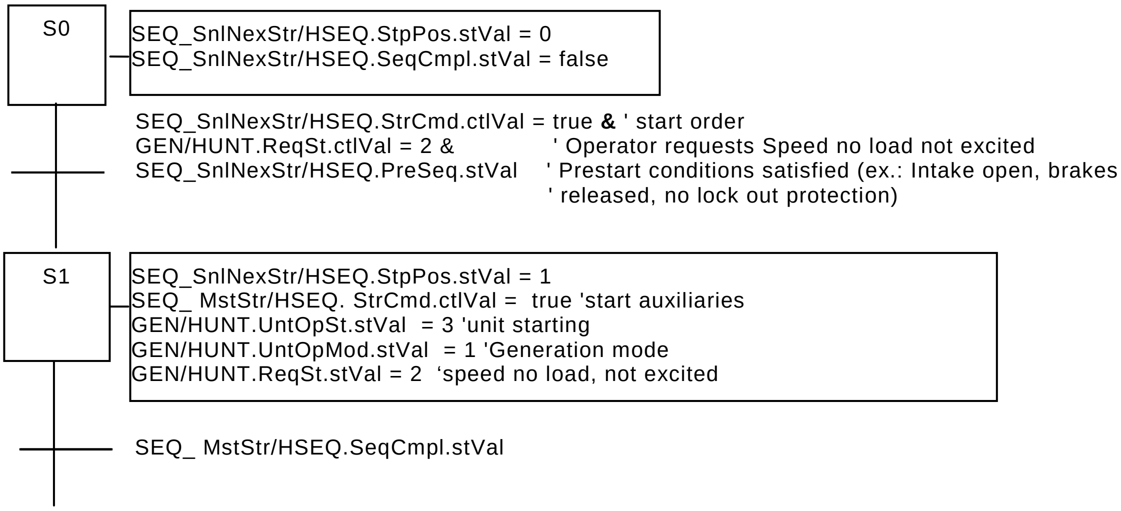
Logical Device	Function
MstStr	Master start relay (starts necessary auxiliary equipment)
EmgStop	Fast (emergency) shutdown Sequence
FastLdStop	Fast offloaded shutdown Sequence
Gen	Generator
GenStr	Generator start Sequence
GenCndStr	Generator condenser mode start Sequence
GridFaultStop	Grid fault stop Sequence
LinChaStr	Line charging start Sequence
NormalStop	Normal Shutdown Sequence
PmpBtbStr	Pump mode start with back to back Sequence
PmpSfcStr	Pump mode start with SFC Sequence
PmpCndBtbStr	Pump condenser mode start with back to back Sequence
PmpCndSfcStr	Pump condenser mode start with SFC Sequence
SftStr	Soft start Sequence(raising voltage slowly connected to transformer)
SnlExcStr	Speed no load excited Sequence (running at normal speed with excitation on)
SnlNexStr	Speed no load not excited Sequence (running at normal speed without excitation)
QuickStop	Quick Stop Sequence
LocSrvStop	Offload to local service operation Sequence

4.5.3 Start sequence from a state “stopped” to a state "speed no load not excited” (included in LD named “SEQ_SnlNexStr”)

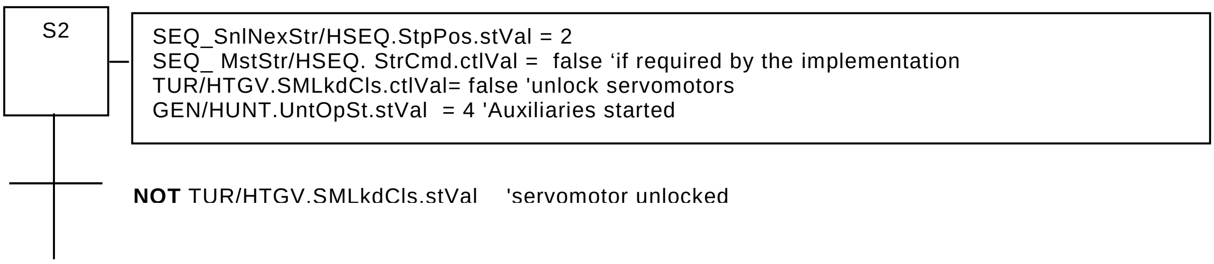
The starting sequence from a state “stopped” to a state "speed no load not excited” is activated from an operator order only if the unit is in the state stopped and if the starting initial conditions are present. At the end of each step and if the step by step mode is selected, an operator validation is necessary to activate the step N+1.

The sequence (start sequence up to "speed no load not excited" state) may be broken down into the following steps:

- Step 1: Starting of the unit auxiliaries (cooling system, oil station, …). Step 1 is valid while the feedback of the unit auxiliaries started is not present. A timer is necessary to control the length of step 1. In case of step 1 too long length, the quick shutdown sequence is automatically activated.

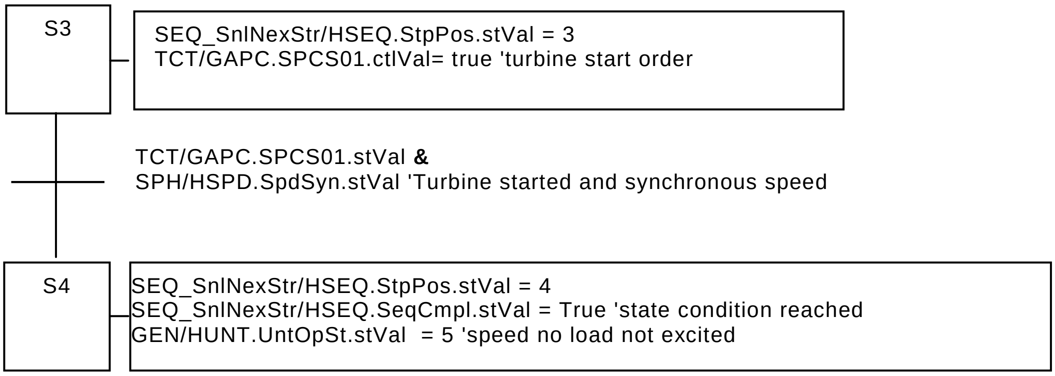


- Step 2: Releasing of the unit locks (locks on the wicket gates). Step 2 is valid while the feedback of the unit locks released is not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the quick shutdown sequence is automatically activated.



- Step 3: Running of the unit (managed by the speed regulator). Step 3 is valid while the feedback of the start excitation unit speed is not present. A timer is necessary to control the length of step 3. In case of step 3 too long length, the quick shutdown sequence (sequence 5) is automatically activated.

  At the end of step 3, the state "speed no load not excited" is reached.



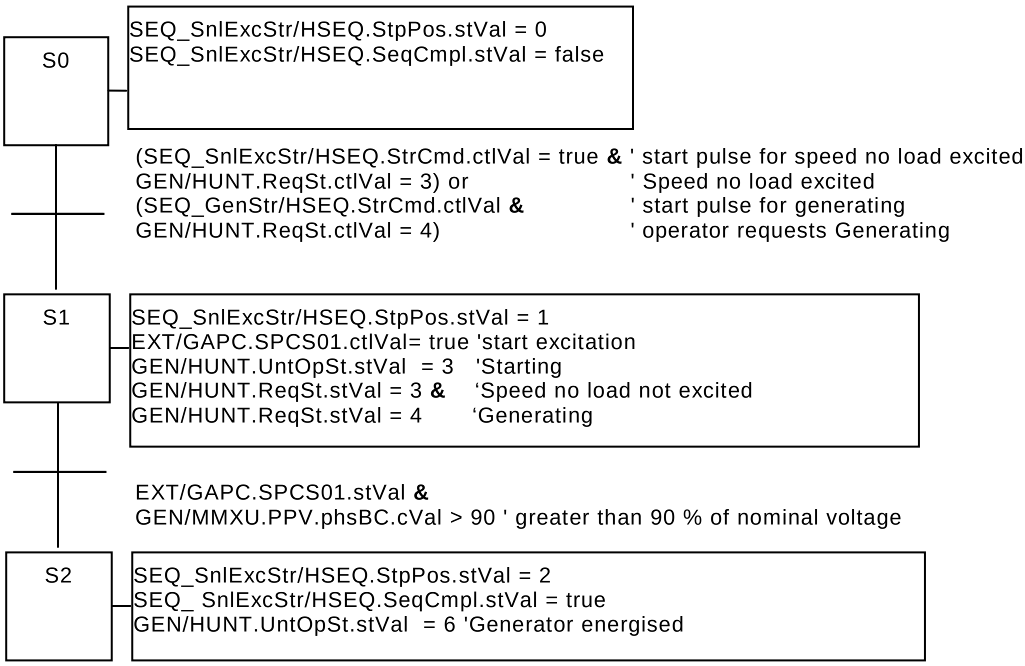
4.5.4 Start sequence from state “speed no load not excited” to state “generation” (included in LD named “SEQ_SnlExcStr” and “SEQ_GenStr”)

The start sequence from state “speed no load not excited” to “state generation” is automatically activated if an operator from the state requested the state generator stopped. After a grid fault and an automatic return from the state generation to the state "speed no load not excited", the present starting sequence is also activated from an operator order if the grid fault is acknowledged and not present any more. At the end of each step and if the step by step mode is selected, an operator validation is necessary to activate the step N+1.

The sequence (starting sequence up to "generation" state) may be broken down into the following steps:

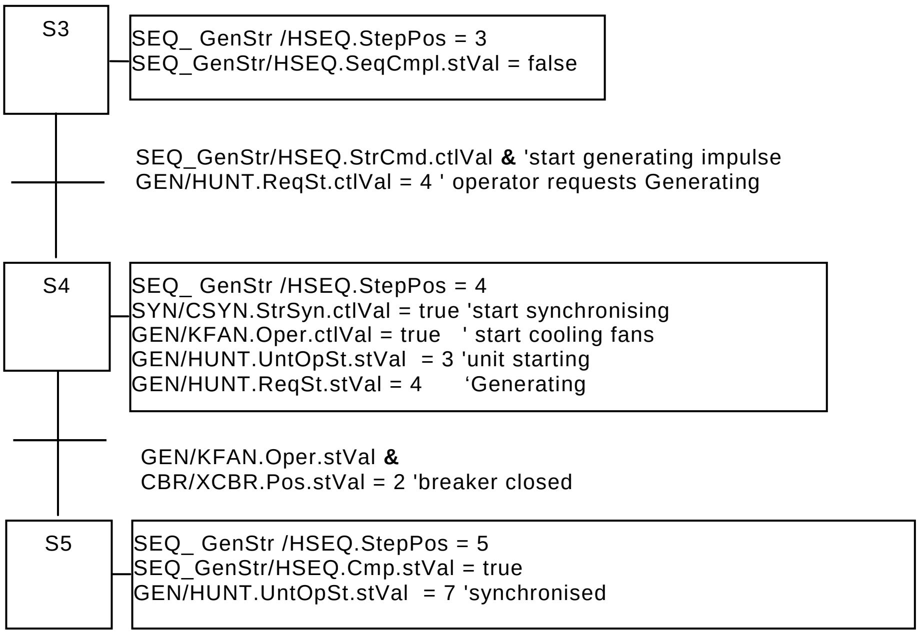
- Step 1: Starting of the excitation system. Step 1 is valid while the feedback of the unit voltage equal to 90 % of the nominal voltage is not present. A timer is necessary to control the length of step 1. In case of step 1 too long length, the quick shutdown sequence (sequence 5) is automatically activated.

  At the end of step 1, the state "speed no load excited" is reached.



- Step 2: Starting of the generator cooling fans and unit synchronization to the grid. Step 2 is valid while the feedback of the generator cooling fans started and the feedback of the unit circuit breaker closed are not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the quick shutdown sequence is automatically activated.

  At the end of the sequence, the state generation is reached.

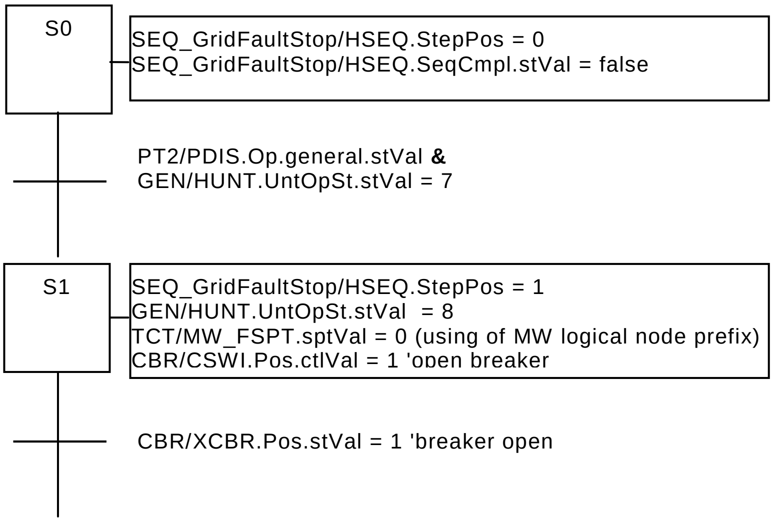


4.5.5 Stop sequence from state “generator” to state “speed no load not excited” (included in LD named “SEQ_GridFaultStop”)

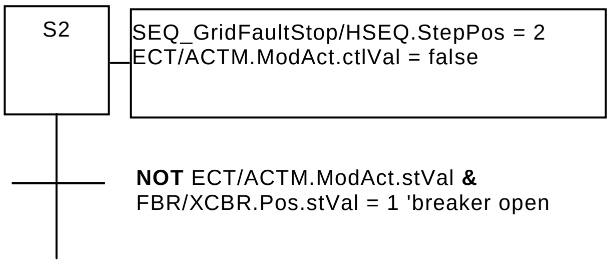
The grid fault stopping sequence from state “generator” to state “speed no load not excited” is automatically activated if a grid fault occurs and the state of the unit is generator. If the step-by-step mode was selected, it is automatically changed to the automatic mode when the sequence is activated.

The sequence (stopping sequence up to "speed no load not excited" state) may be broken down into the following steps:

- Step 1: Opening of the unit circuit breaker and updating of the active power set point with the value 0. Step 1 is valid while the feedback of the unit circuit breaker open is not present. A timer is necessary to control the length of step 1. In case of step 1 too long length, the quick shutdown sequence is automatically activated.

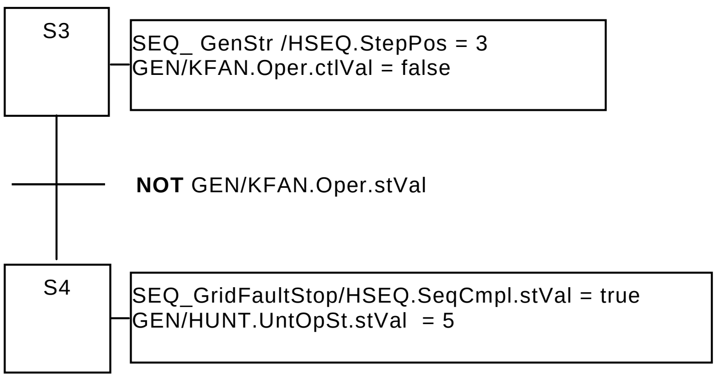


- Step 2: Stopping of the excitation system. Step 2 is valid while the feedback of the unit excitation stopped is not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the quick shutdown sequence is automatically activated.



- Step 3: Stopping of the generator cooling fans. Step 3 is valid while the feedback of the generator cooling fans stopped is not present. A timer is necessary to control the length of step 3. In case of step 3 too long length, the quick shutdown sequence is automatically activated.

  At the end of the sequence, the state "speed no load not excited" is reached.

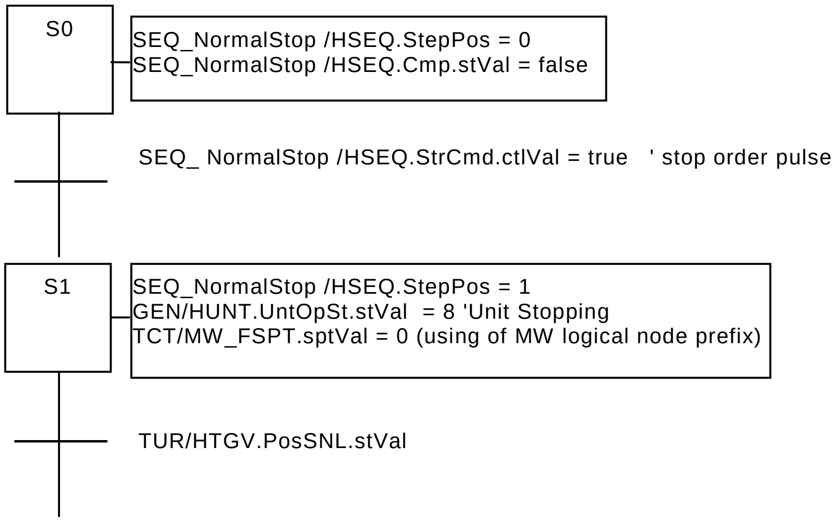


4.5.6 Shutdown sequence from state “generator” to state “stopped” (SEQ_NormalStop)

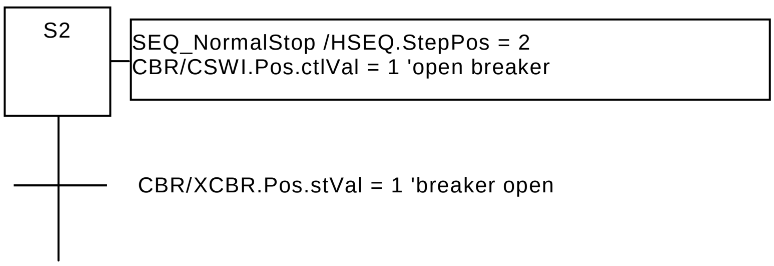
The normal shutdown sequence is activated from an operator order if the state of the unit is different from the state stopped or blocked and if the higher priority shutdown sequences are not already activated (quick or emergency shutdown sequences). At the end of each step and if the step by step mode is selected, an operator validation is necessary to activate the step N+1.

The sequence (shutdown sequence up to stopped state) may be broken down into the following steps:

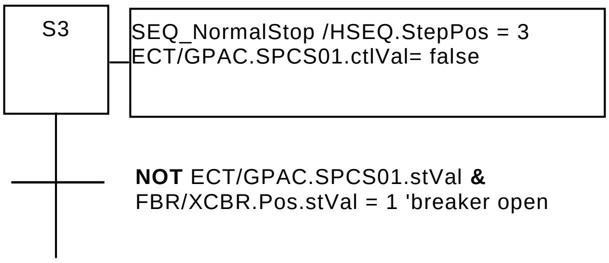
- Step 1: Updating of the active power set point with the value 0. Step 1 is valid while the feedback of the unit speed no load position on the wicket gates is not present. A timer is necessary to control the length of step 1. In case of step 1 too long length, the quick shutdown sequence is automatically activated.



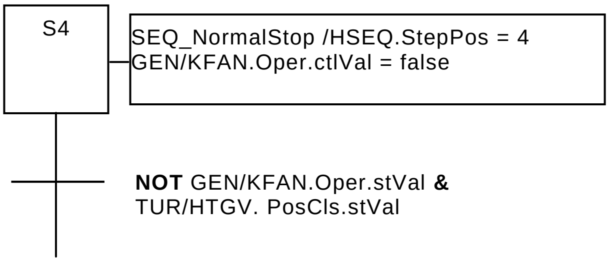
- Step 2: Opening of the unit circuit breaker. Step 2 is valid while the feedback of the unit circuit breaker open is not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the quick shutdown sequence is automatically activated.



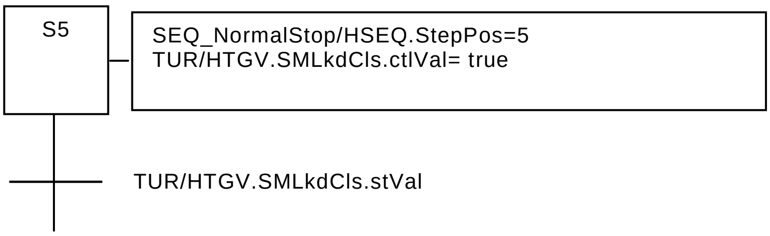
- Step 3: Stopping of the excitation system. Step 3 is valid while the feedback of the unit excitation stopped is not present. A timer is necessary to control the length of step 3. In case of step 3 too long length, the quick shutdown sequence is automatically activated.



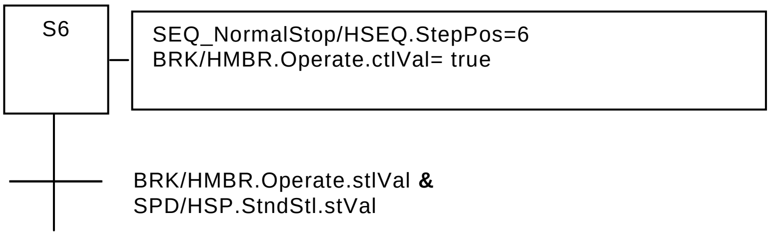
- Step 4: Stopping of the generator cooling fans and complete closing of the wicket gates. Step 4 is valid while the feedback of the generator cooling fans stopped and the feedback of the wicket gates closed are not present. A timer is necessary to control the length of step 4. In case of step 4 too long length, the quick shutdown sequence is automatically activated.



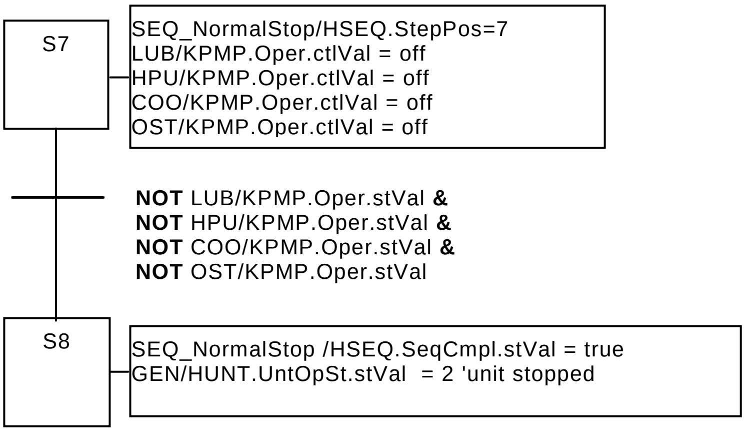
- Step 5: Applying of the unit locks (locks on the wicket gates). Step 5 is valid while the feedback of the unit locks applied and the feedback of the unit braking speed are not present. A timer is necessary to control the length of step 5. In case of step 5 too long length, the quick shutdown sequence is automatically activated.



- Step 6: Applying of the unit brakes. Step 6 is valid while the feedback of the unit speed equal to 0 is not present. A timer is necessary to control the length of step 6. In case of step 6 too long length, the quick shutdown sequence (sequence 5) is automatically activated.



- Step 7: Stopping of the unit auxiliaries (cooling system, oil station, ...). Step 7 is valid while the feedback of the unit auxiliaries stopped is not present. A timer is necessary to control the length of step 7. In case of step 7 too long length, the quick shutdown sequence is automatically activated. At the end of the sequence 4, the state stopped is reached.

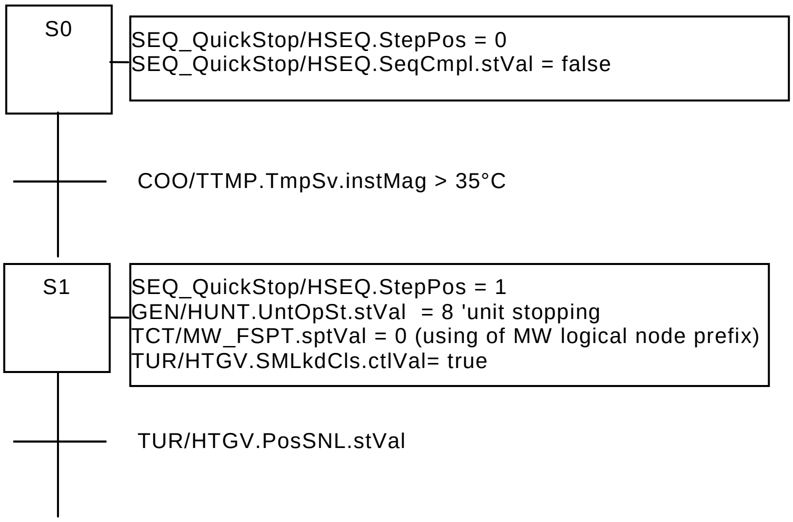


4.5.7 Quick shutdown sequence from state "generator" to state "stopped" (SEQ_QuickStop)

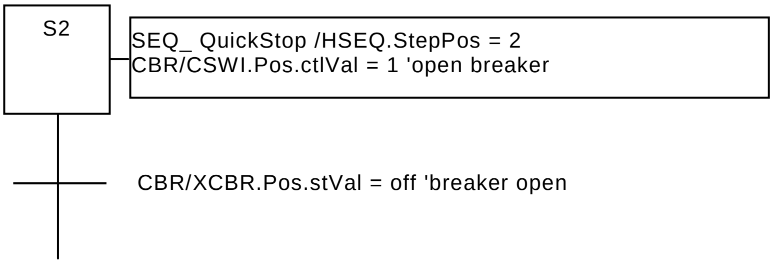
The quick shutdown sequence from state "generator" to state "stopped" is automatically activated if a mechanical fault occurs, a loss of the permanent running conditions occurs when the unit is in the mode generator, a sequence step too long length occurs, if the state of the unit is different from the state stopped or blocked and if the highest priority shutdown sequence is not already activated (emergency shutdown sequence). If the step by step mode was selected, it is automatically changed to the automatic mode when the sequence is activated.

The sequence (shutdown sequence up to stopped state in case of mechanical fault) may be broken down into the following steps:

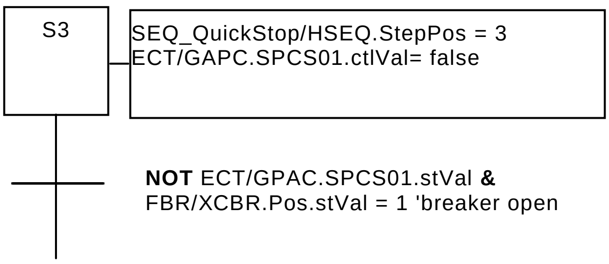
- Step 1: Complete closing of the wicket gates and updating of the active power set point with the value 0. Step 1 is valid while the feedback of the unit speed no load position on the wicket gates is not present. A timer is necessary to control the length of step 1. In case of step 1 too long length, the emergency shutdown sequence is automatically activated.



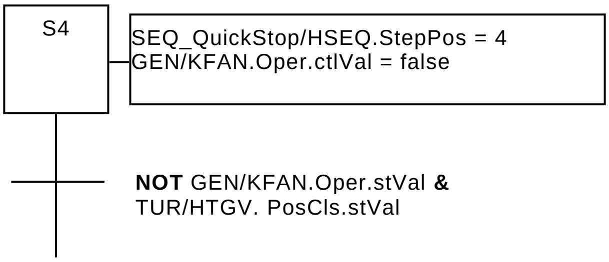
- <u>Step 2</u>: Opening of the unit circuit breaker. Step 2 is valid while the feedback of the unit circuit breaker open is not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the emergency shutdown sequence is automatically activated.



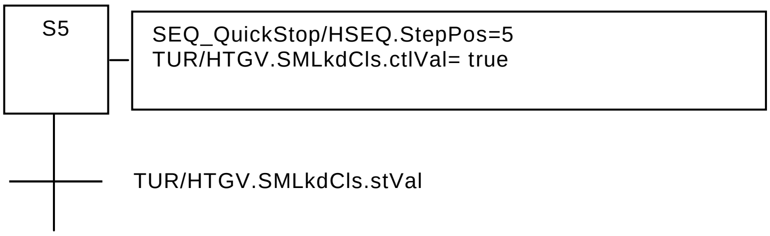
- <u>Step 3</u>: Stopping of the excitation system. Step 3 is valid while the feedback of the unit excitation stopped is not present. A timer is necessary to control the length of step 3. In case of step 3 too long length, the emergency shutdown sequence is automatically activated.



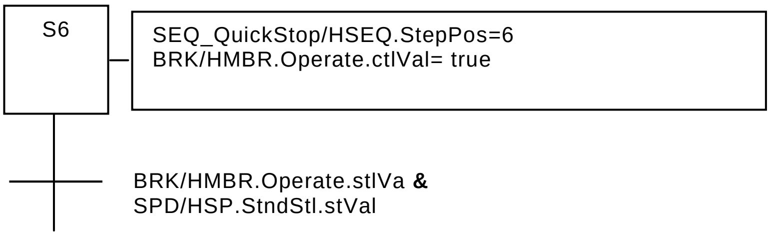
- <u>Step 4</u>: Stopping of the generator cooling fans. Step 4 is valid while the feedback of the generator cooling fans stopped and the feedback of the wicket gates closed are not present. A timer is necessary to control the length of step 4. In case of step 4 too long length, the emergency shutdown sequence is automatically activated.



- Step 5: Applying of the unit locks (locks on the wicket gates). Step 5 is valid while the feedback of the unit locks applied and the feedback of the unit braking speed are not present. A timer is necessary to control the length of step 5. In case of step 5 too long length, the emergency shutdown sequence is automatically activated.

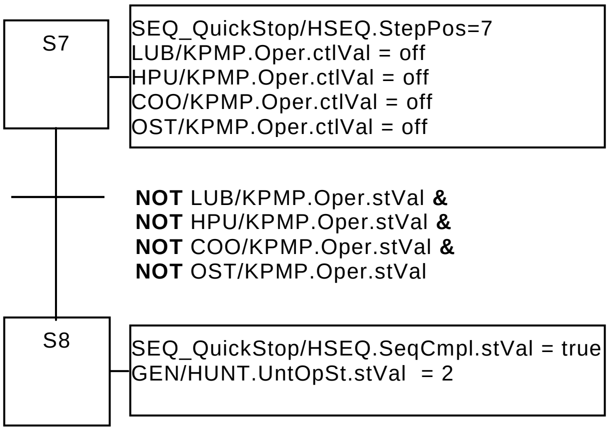


- Step 6: Applying of the unit brakes. Step 6 is valid while the feedback of the unit speed equal to 0 is not present. A timer is necessary to control the length of step 6. In case of step 6 too long length, the emergency shutdown sequence is automatically activated.



- Step 7: Stopping of the unit auxiliaries (cooling system, oil station, ...). Step 7 is valid while the feedback of the unit auxiliaries stopped is not present. A timer is necessary to control the length of step 7. In case of step 7 too long length, the emergency shutdown sequence is automatically activated.

  At the end of the sequence, the state stopped is reached.

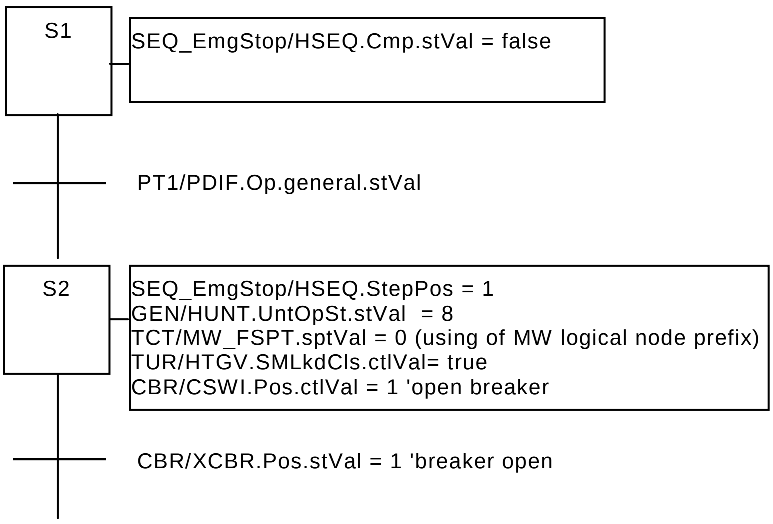


4.5.8 Emergency shutdown sequence from state “generator” to state “stopped” (SEQ_EmgStop)

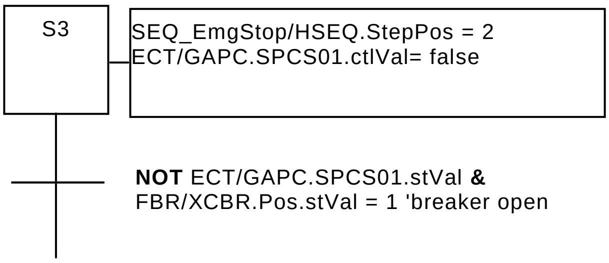
The emergency shutdown sequence from state “generator” to state “stopped” is automatically activated if either an electrical fault occurs or an operator order is given. If the step by step mode was selected, it is automatically changed to the automatic mode when the sequence is activated.

The sequence may be broken down into the following steps:

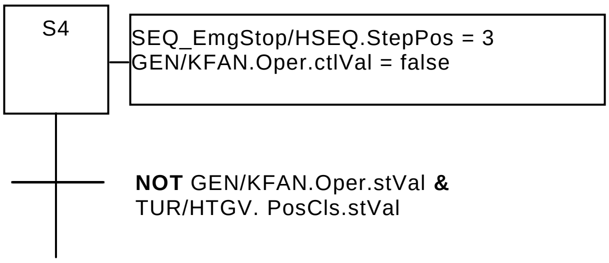
- Step 1: Complete closing of the wicket gates, opening of the unit circuit breaker and updating of the active power set point with the value 0. Step 1 is valid while the feedback of the unit circuit breaker open is not present. A timer is necessary to control the length of the step 1. In case of step 1 too long length, the unit state blocked is automatically activated.



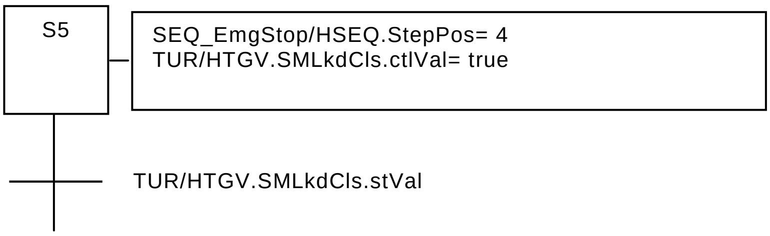
- Step 2: Stopping of the excitation system. Step 2 is valid while the feedback of the unit excitation stopped is not present. A timer is necessary to control the length of step 2. In case of step 2 too long length, the unit state blocked is automatically activated.



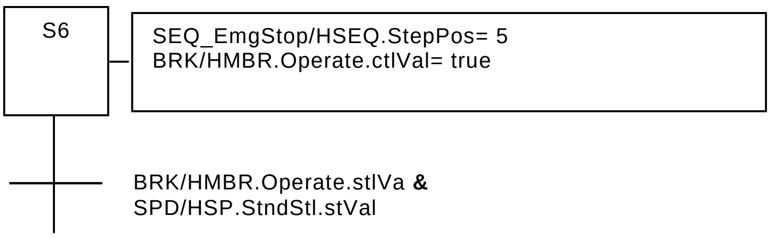
- Step 3: Stopping of the generator cooling fans. Step 3 is valid while the feedback of the generator cooling fans stopped and the feedback of the wicket gates closed are not present. A timer is necessary to control the length of step 3. In case of step 3 too long length, the unit state blocked is automatically activated.



- Step 4: Applying of the unit locks (locks on the wicket gates). Step 4 is valid while the feedback of the unit locks applied and the feedback of the unit braking speed are not present. A timer is necessary to control the length of step 4. In case of step 4 too long length, the unit state blocked is automatically activated.

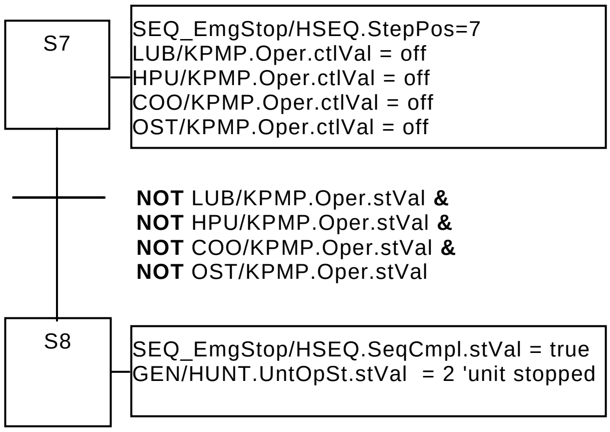


- Step 5: Applying of the unit brakes. Step 5 is valid while the feedback of the unit speed equal to 0 is not present. A timer is necessary to control the length of step 5. In case of step 5 too long length, the unit state blocked is automatically activated.



- Step 6: Stopping of the unit auxiliaries (cooling system, oil station, ...). Step 6 is valid while the feedback of the unit auxiliaries stopped is not present. A timer is necessary to control the length of step 6. In case of step 6 too long length, the unit state blocked is automatically activated.

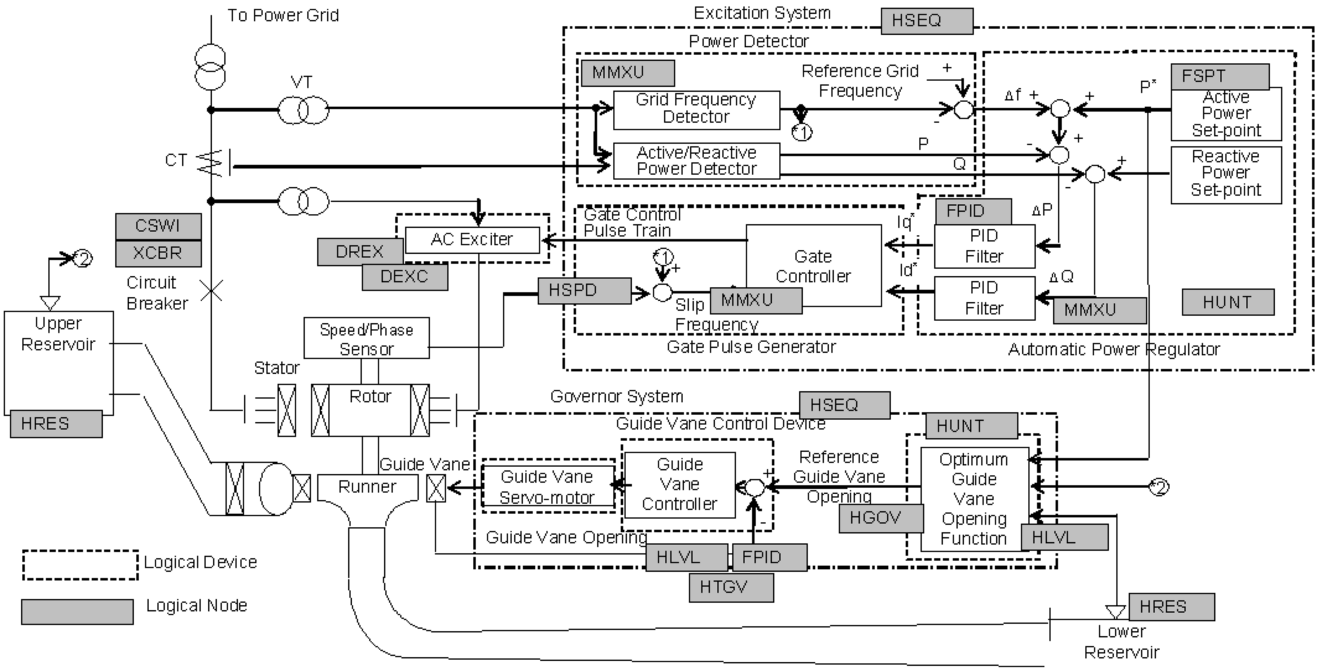
  At the end of the sequence, the state stopped is reached.



5 Variable speed system example

5.1 Example of block diagrams and logical nodes of variable speed pumped storage system

Figure 23, Figure 24 and Figure 25 show the typical block diagrams describing the overall system of the variable speed pumped storage system and mapping of the related logical nodes.



IEC 356/12

Figure 23 – Typical block diagram in pumping operation

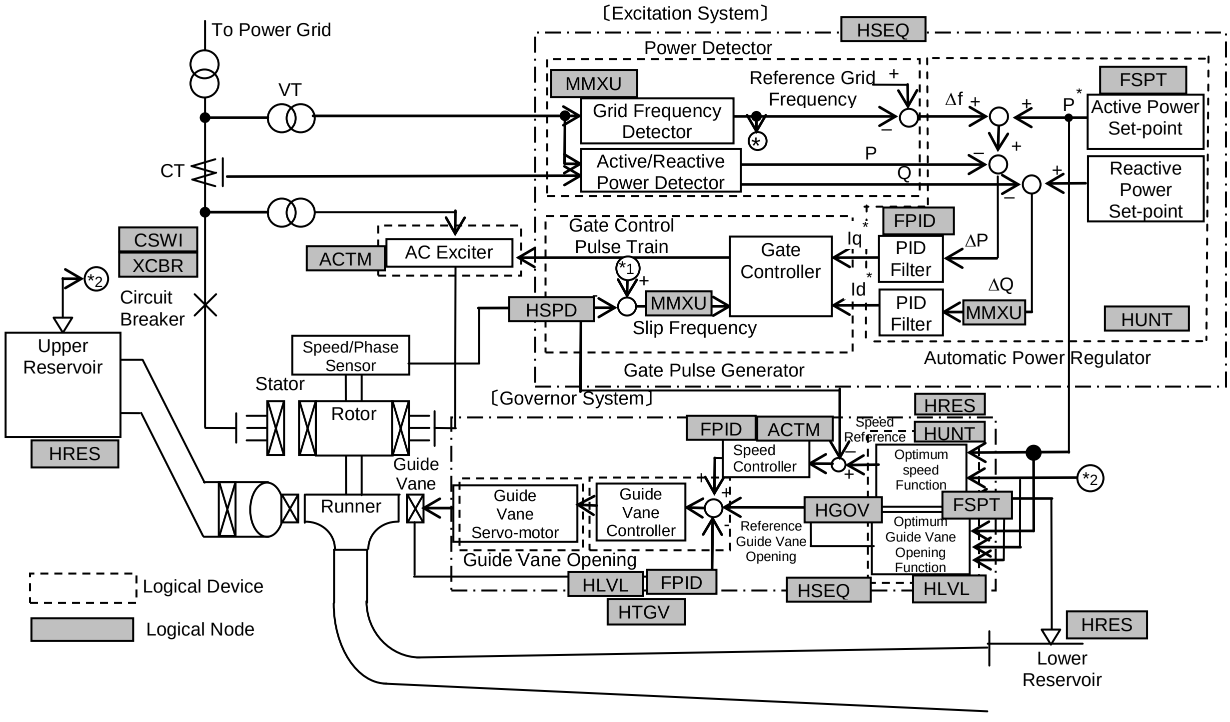


Figure 24 – Typical block diagram in generating operation

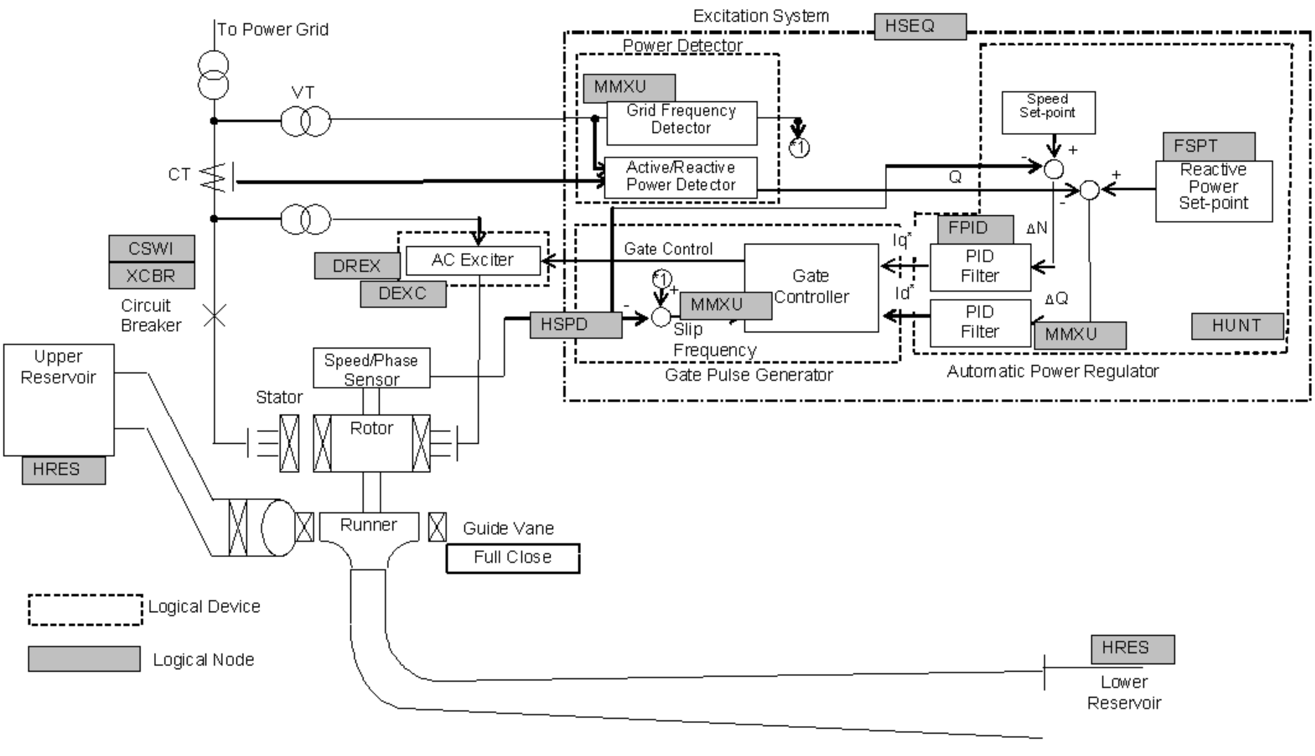


Figure 25 – Typical block diagram in synchronous condenser mode

5.2 Example of application for an excitation system of variable speed pumped storage

5.2.1 General

Typical logical nodes of an excitation system for variable speed pumped storage system are mapped to the block diagrams described in 5.1.

For practical purposes, the excitation system will be divided in a number of Logical Devices that can be addressed and handled separately.

The division into functional blocks, as well as in Logical Devices as represented on Figure 23, 24 and 25 are only informative and may be interpreted in different ways.

5.2.2 Automatic power regulator example

Figure 26 shows an automatic power regulator.

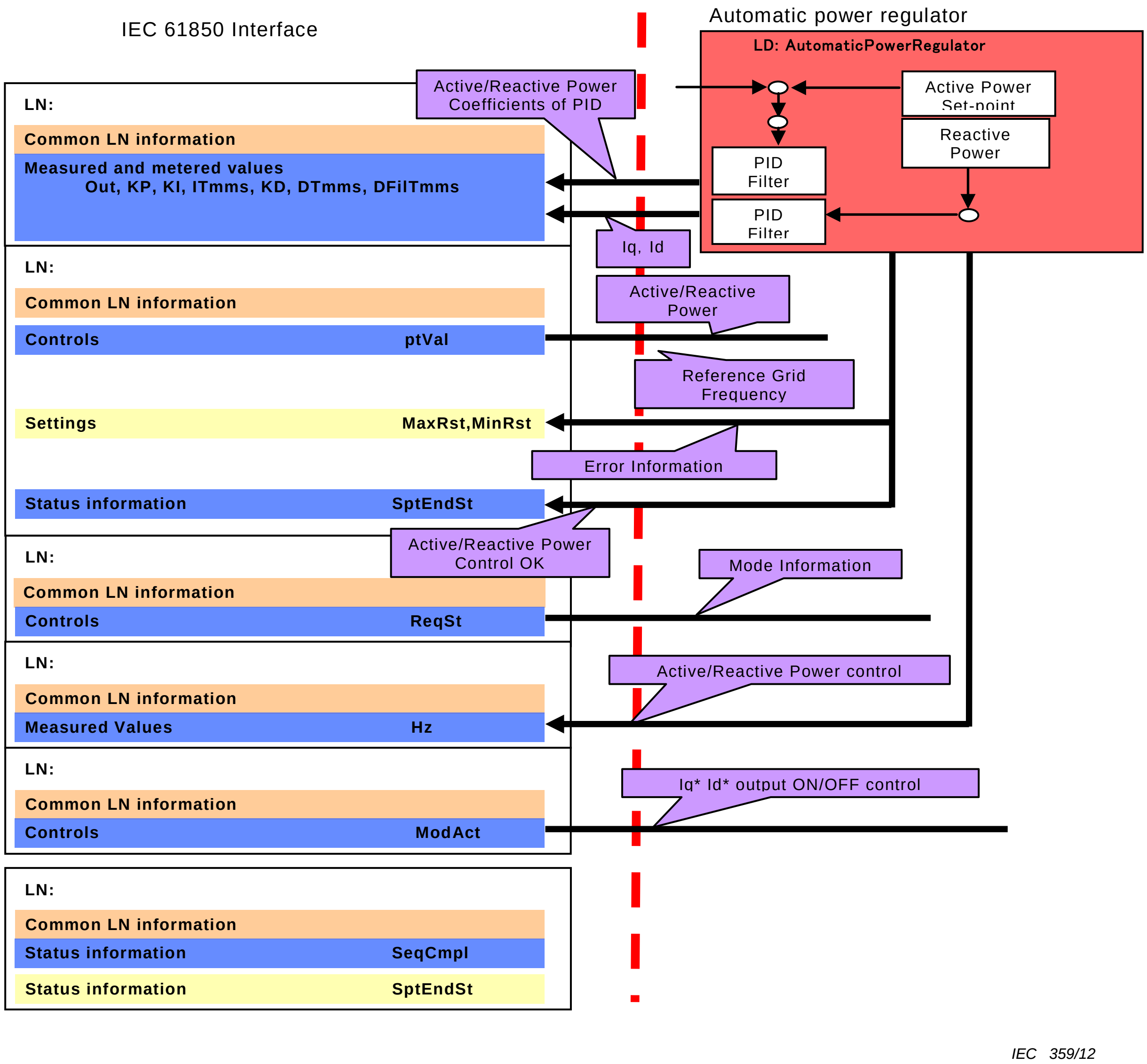


Figure 26 – Automatic power regulator

5.2.3 Power detector example

Figure 27 shows a power detector.

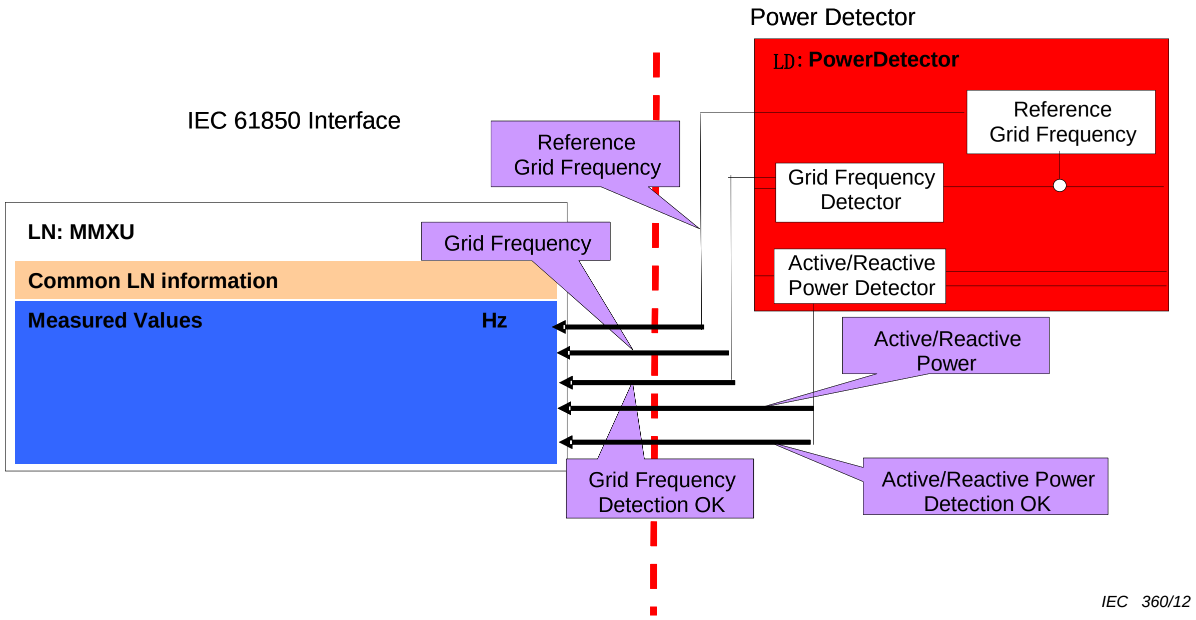


Figure 27 – Power detector

5.2.4 Gate pulse generator example

Figure 28 shows a gate pulse generator.

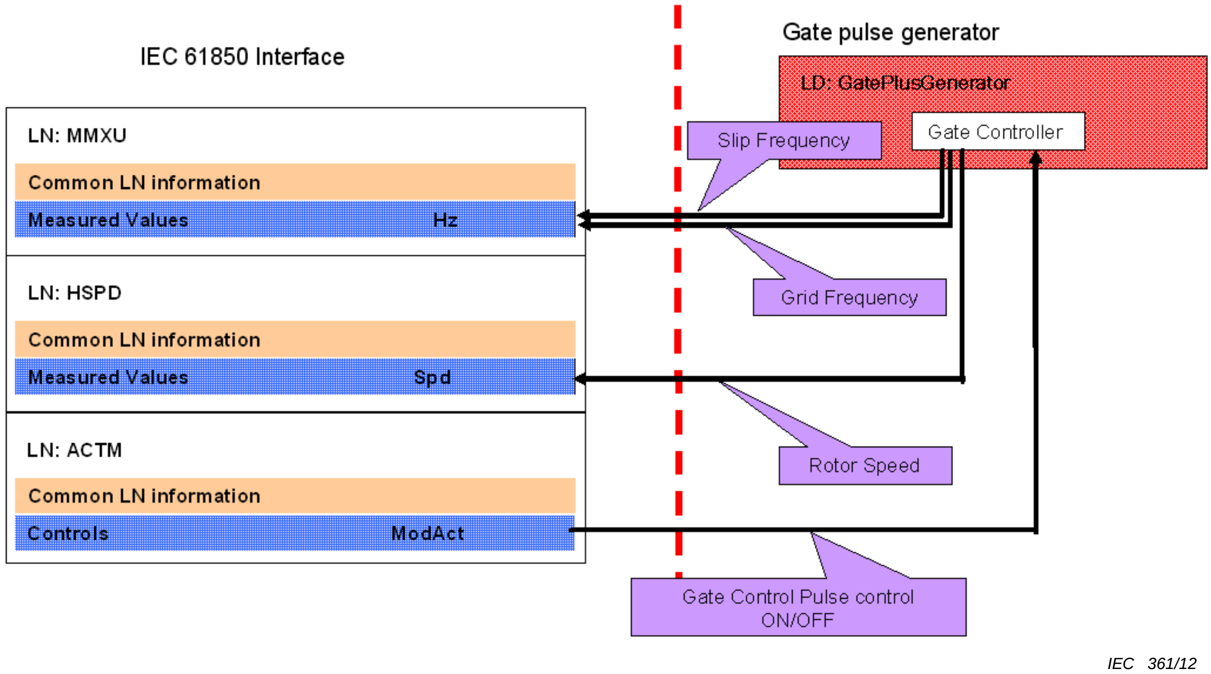


Figure 28 – Gate pulse generator

5.3 Example of governor system

5.3.1 Guide vane opening function example

Figure 29 shows a guide vane opening function.

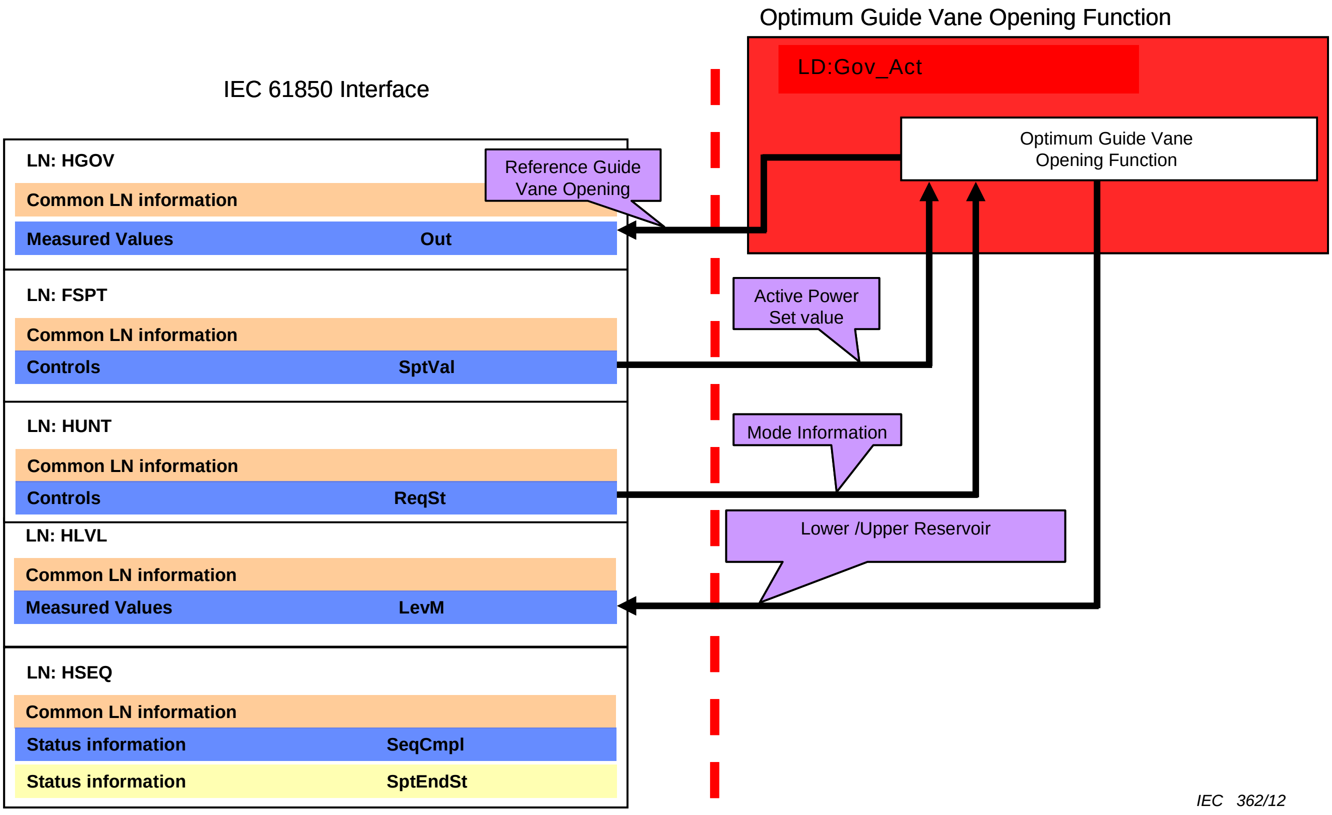


Figure 29 – Guide vane opening function

5.3.2 Guide vane controller example

Figure 30 shows a guide vane controller.

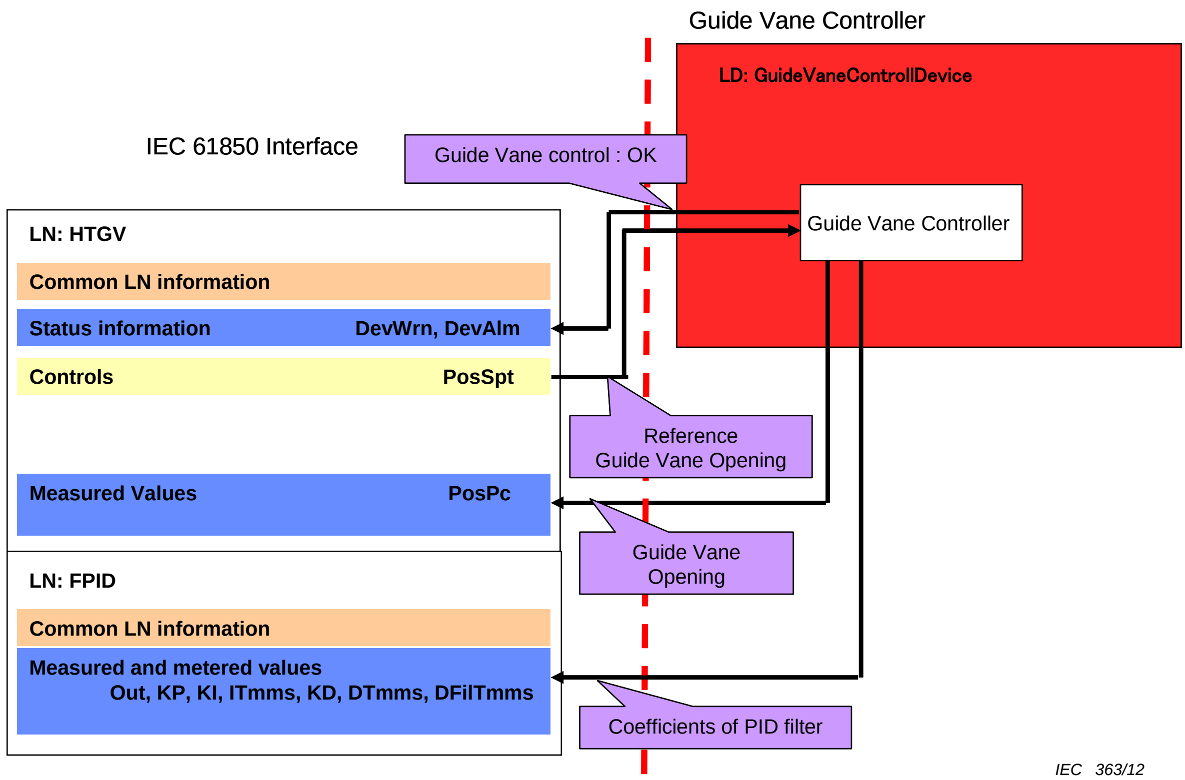


Figure 30 – Guide vane controller

5.3.3 Speed controller example

Figure 31 shows a speed controller.

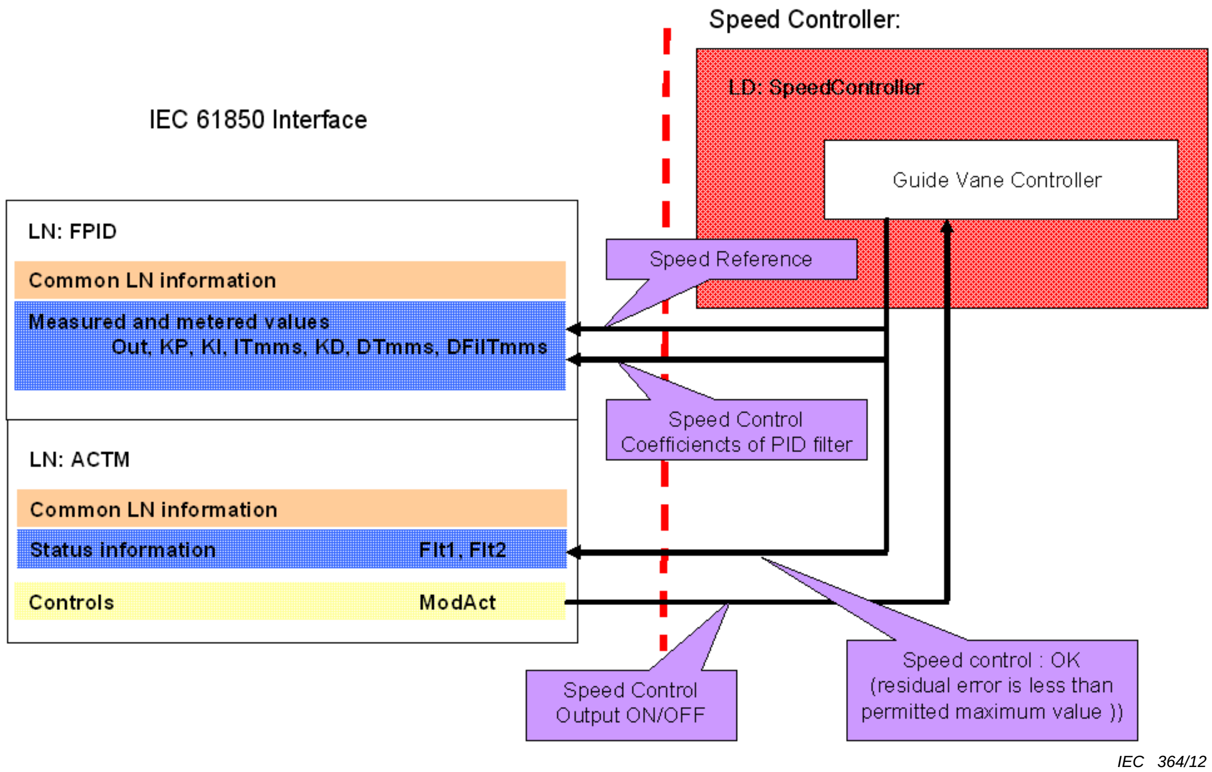


Figure 31 – Speed controller

5.3.4 Optimum speed function example

Figure 32 shows an optimum speed function.

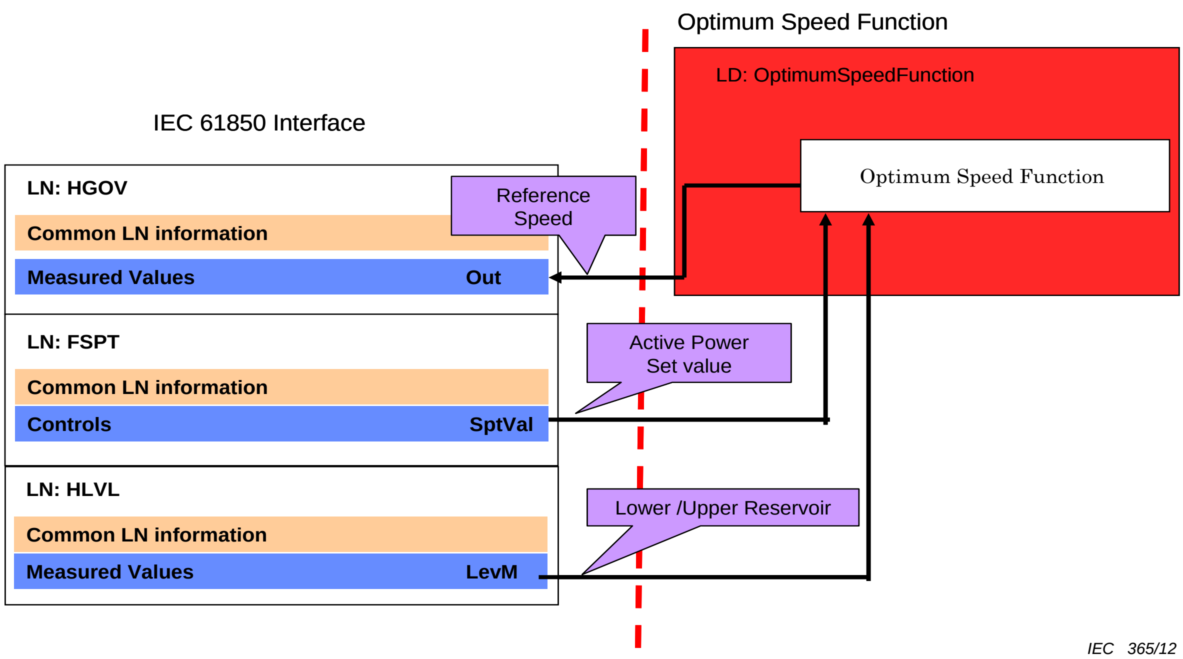


Figure 32 – Optimum speed function

5.4 Example of how to reference a start / stop sequencer for variable speed pumped storage system

5.4.1 Unit sequences definition for conventional and variable speed pumped storage

Each unit sequence is defined by a “HSEQ” LN and it is included in a dedicated LD. All of them are grouped together in a group reference LD called “Seq” (unit start-stop sequencer). Basically, the sequences of generating mode are the same as for turbine generator. Figure 33 shows a sequencer overview.

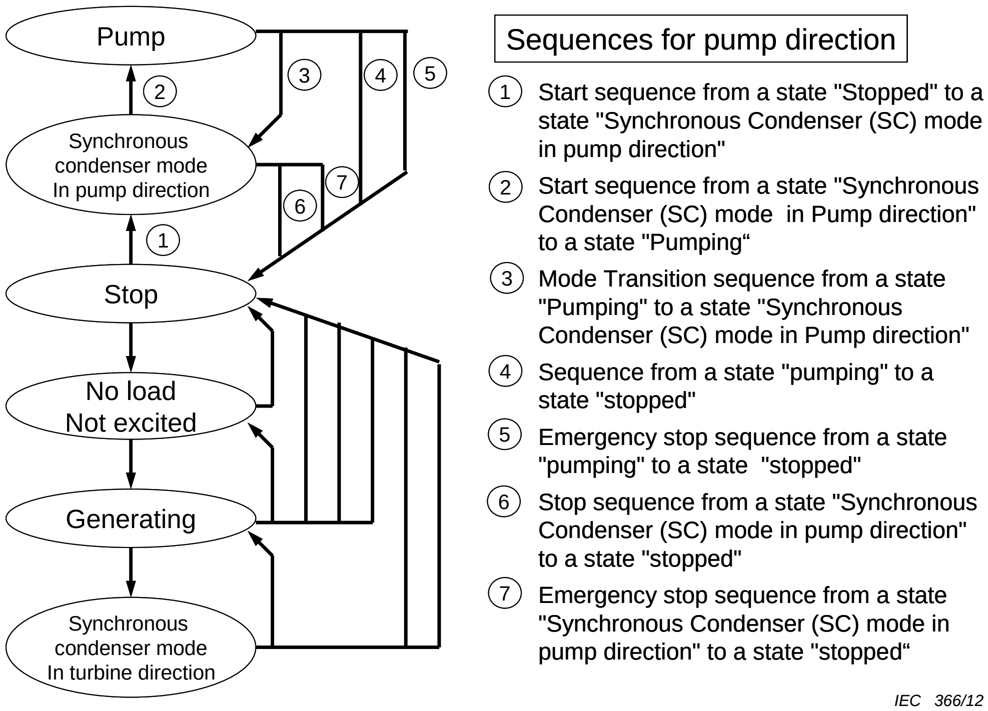


Figure 33 – Sequencer overview

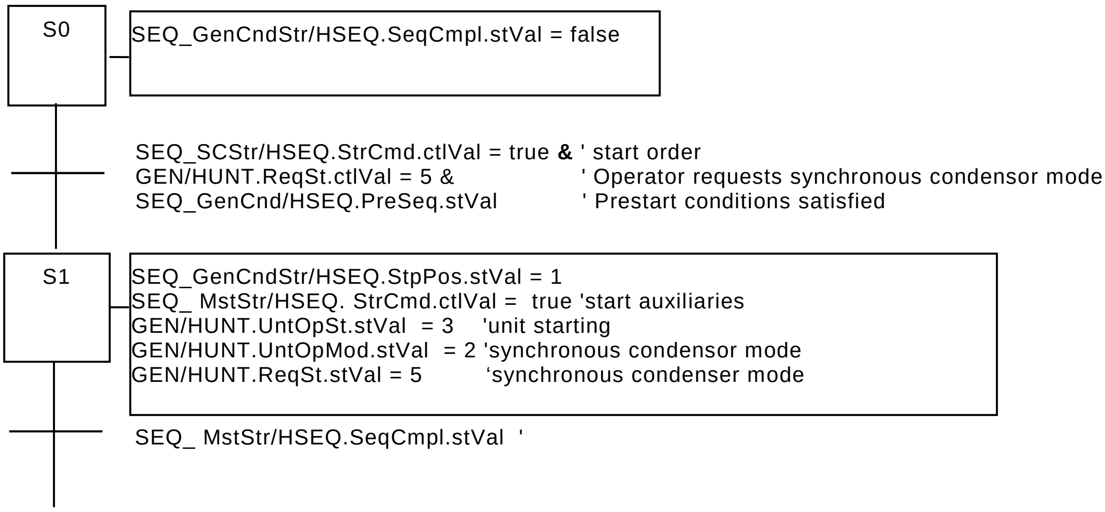
Table 6 summarizes typical sequences used by start / stop sequencer functions.

Table 6 – Logical device names for sequence function groups

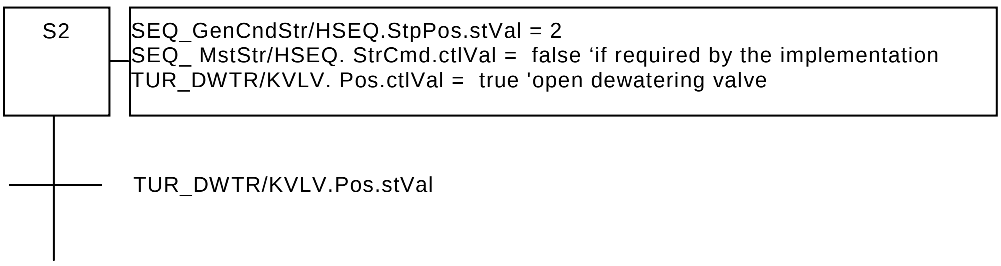
Logical Device	Function
MstStr	Master start relay (starts necessary auxiliary equipment)
CndEmgStop	Generator condenser fast (emergency) shut down sequence
GenCndStr	Generator condenser mode start sequence
GenCndPmp	Generator condenser to pump sequence
PmpGenCnd	Pump to generator condenser sequence
PmpStop	Pump shutdown sequence
PmpEmgStop	Pump emergency shutdown sequence

5.4.2 Start sequence from a state "Stopped" to a state "Synchronous Condenser (SC) mode in pump direction"

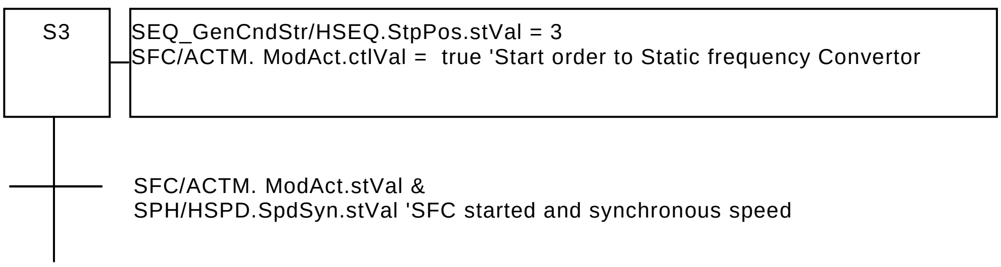
- Step 1: Starting of the unit auxiliaries (cooling system, pressed oil system, compressed air system, etc.).



- Step 2: Dewatering of Draft tube water level (controlled by compressed air supply system)

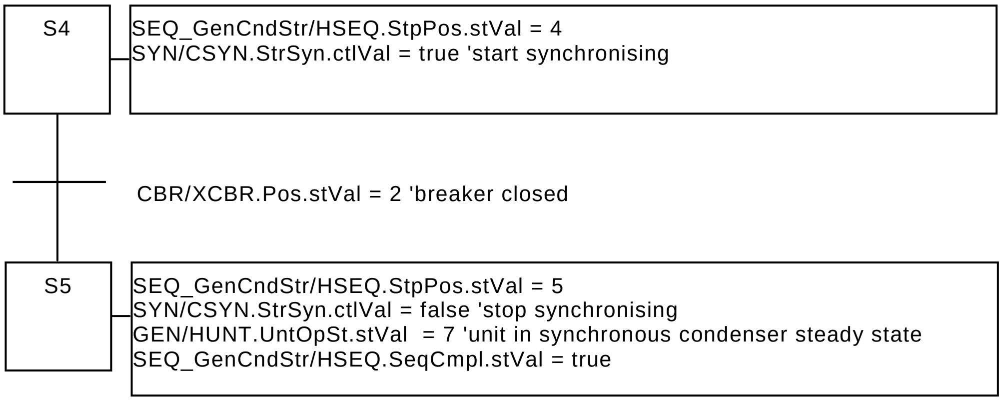


- Step 3: Running of unit (managed by the Static Frequency Converter)



- Step 4: Unit synchronization to the grid (managed by the synchronizer)

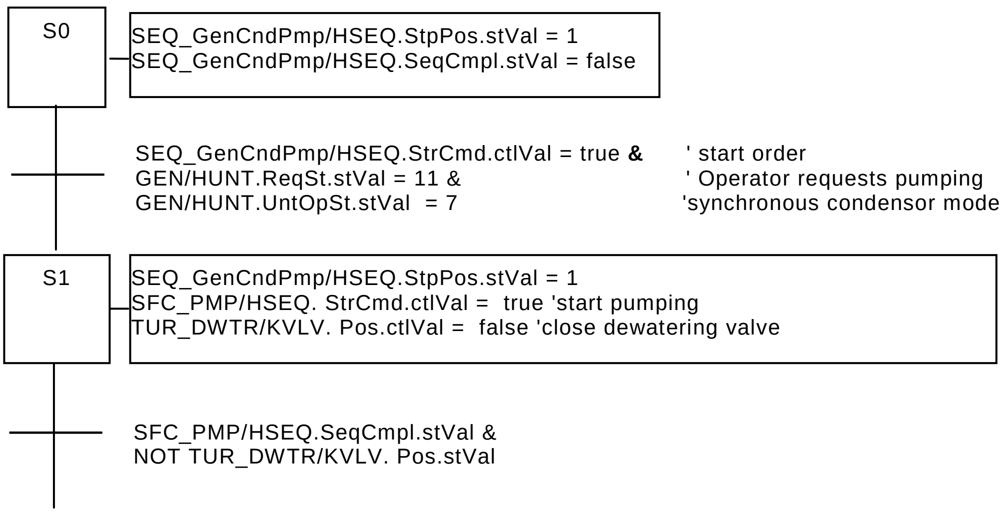
At the end of the sequence, the state Synchronous Condenser (SC) mode in pump direction is reached.



5.4.3 Start sequence from a state "Synchronous Condenser (SC) mode in Pump direction" to a state "Pumping"

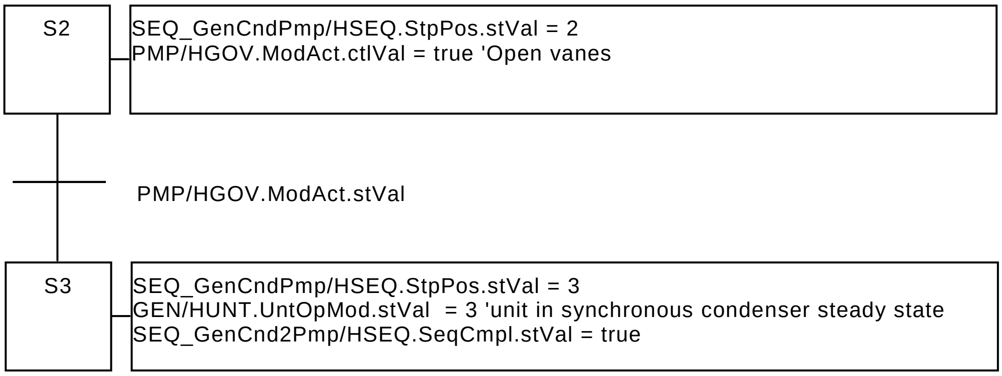
The start sequence from a state "Synchronous Condenser" to a state "Pumping" is activated if an operator from the state requested the state SC in pump direction. In addition, the start sequence is automatically activated if an operator from the state requested the state unit stopped.

- Step 1: Starting of pump priming operation.



- Step 2: Starting of the guide vane opening

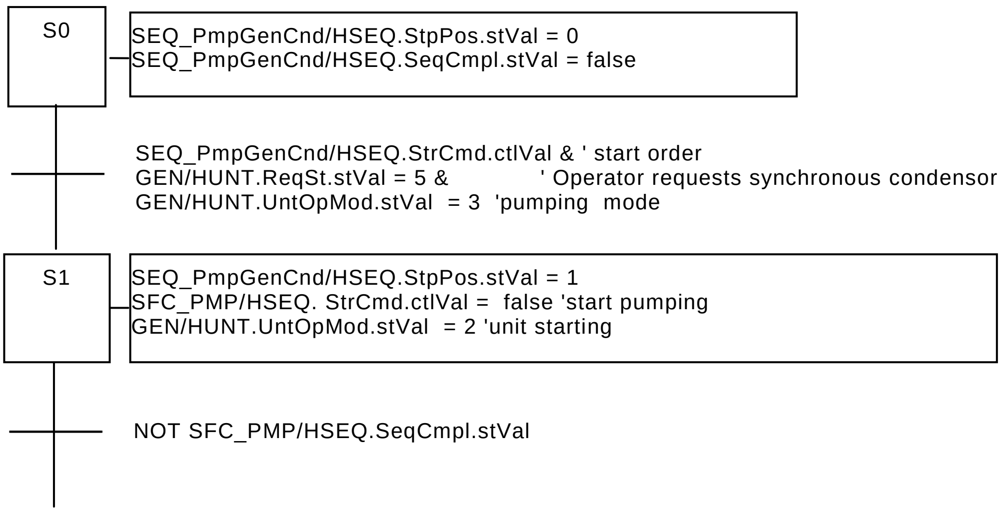
At the end of the sequence, the state pumping is reached.



5.4.4 Mode Transition sequence from a state "Pumping" to a state "Synchronous Condenser (SC) mode in Pump direction"

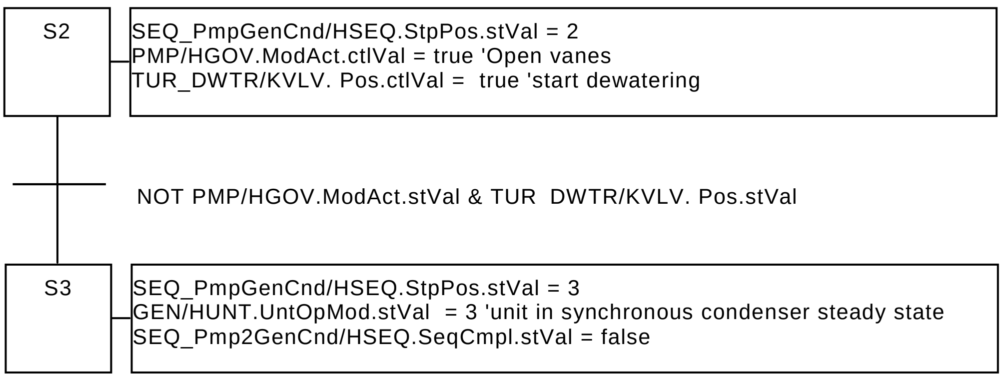
The Mode Transition sequence from a state "Pumping" to a state "Synchronous Condenser" is activated if an operator from the state requested the state pumping.

- Step 1: Starting of guide vane closing



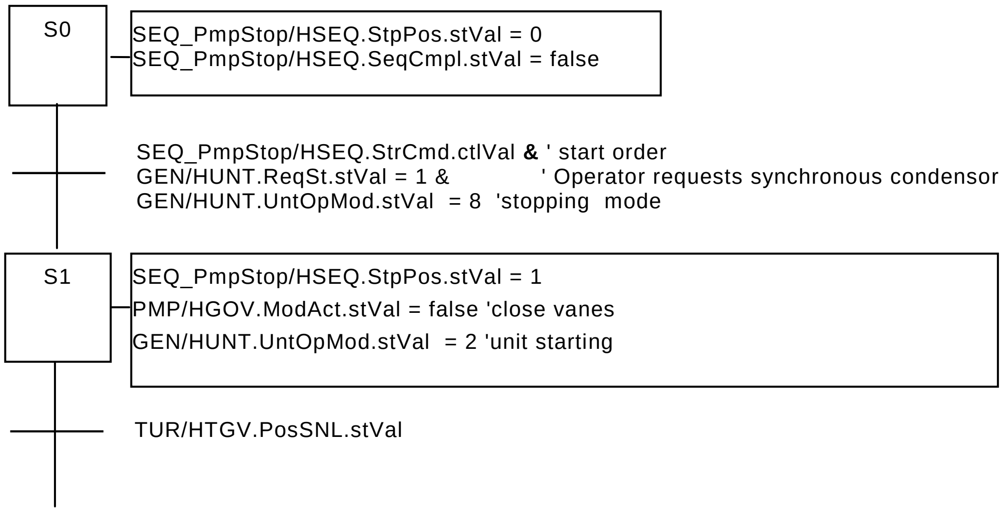
- Step 2: Dewatering of Draft tube water level (controlled by compressed air supply system)

At the end of the sequence, the state Synchronous Condenser (SC) mode in pump direction is reached.

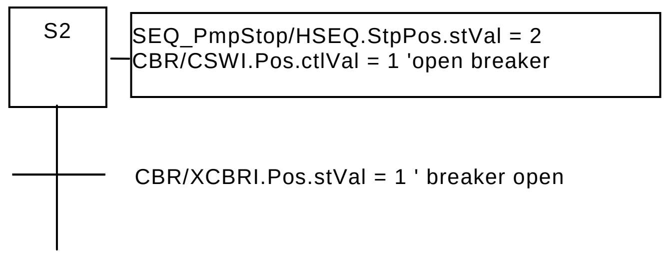


5.4.5 Sequence from a state "pumping" to a state "stopped"

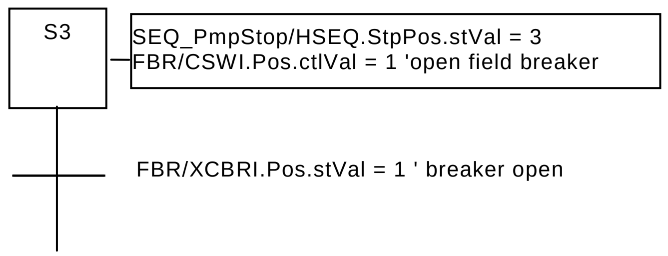
- Step 1: When Stop command is turned "ON", the input power to the generator/motor will be decreased and the guide vane will be closed gradually.



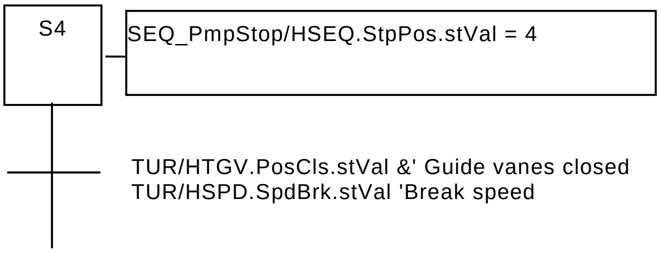
- Step 2: When the position of the guide vane has reached the setting value, the main circuit breaker should be opened.



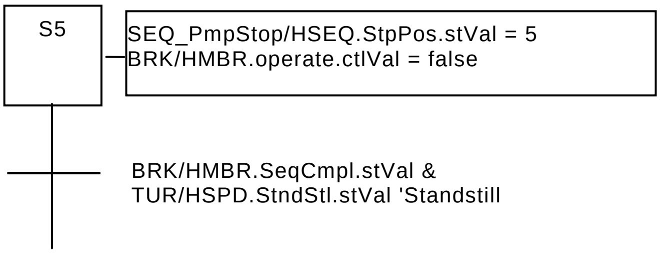
- Step 3: Turn off the excitation.



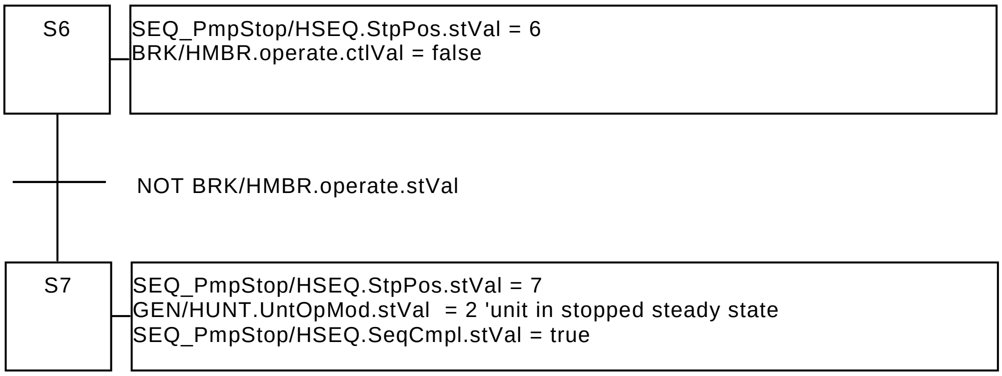
- Step 4: The guide vane should be fully closed.



- Step 5: When the speed of the rotor is under the setting value, the mechanical break should be done.

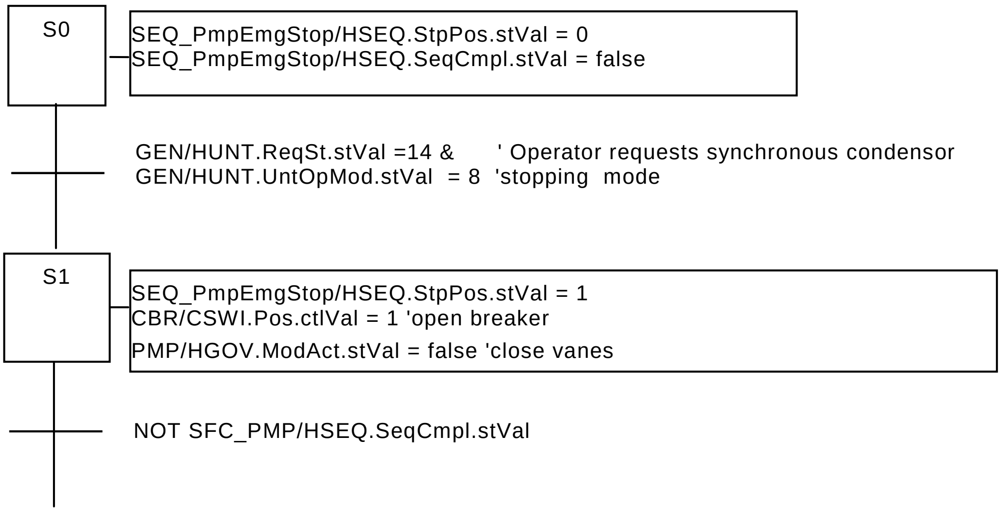


- Step 6: When the main generator/motor is stopped, the mechanical break will be released.

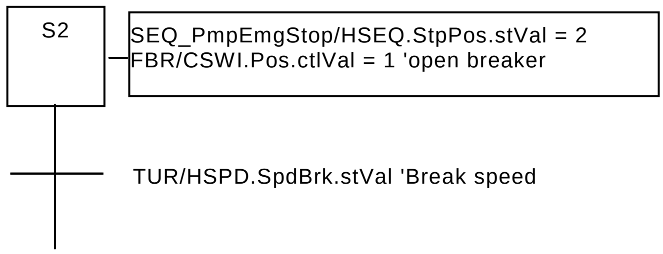


5.4.6 Emergency shutdown sequence from a state "pumping" to a state "stopped"

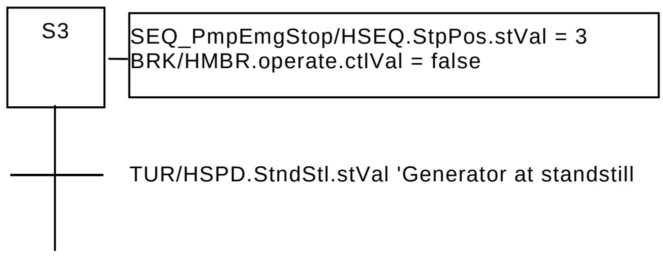
- Step 1: When emergency protection relay is operated, main circuit breaker should be opened. Then the guide vane should be fully closed.



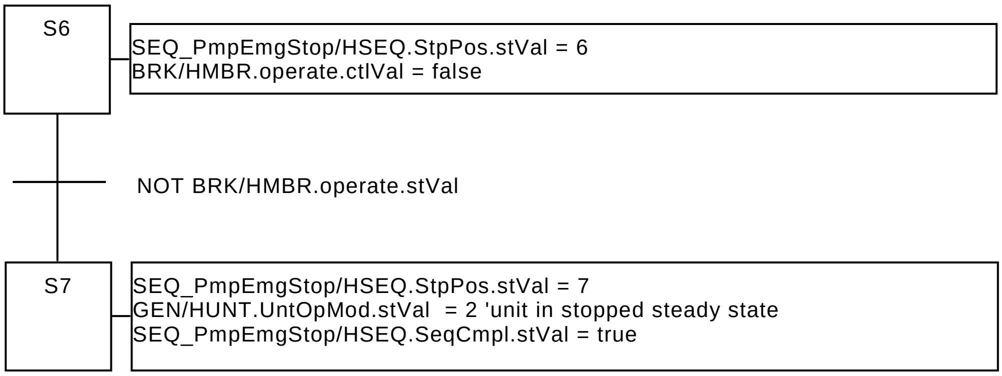
- Step 2: Turn off the excitation.



- Step 3: When the speed of the rotor is under the setting value, the mechanical break should be done.

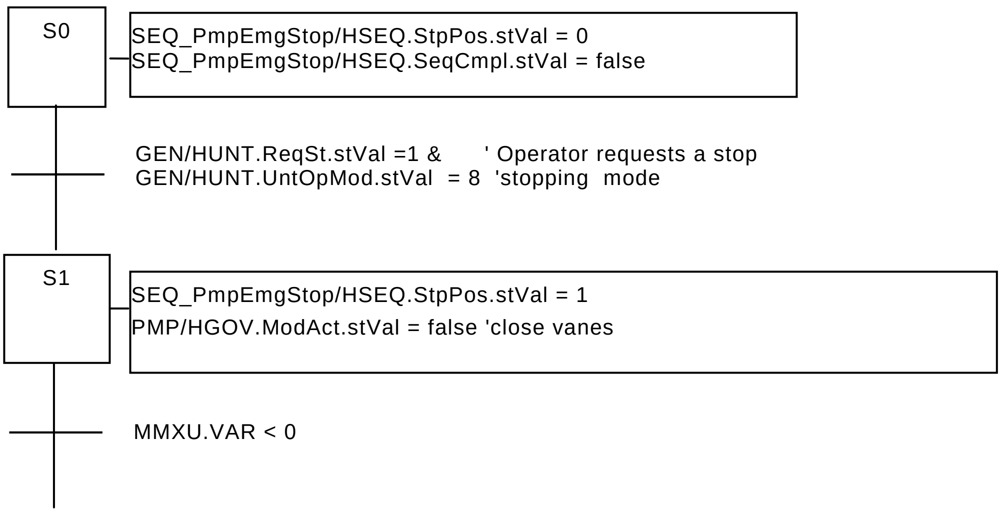


- Step 4: When the main generator/motor is stopped, the mechanical break will be released.

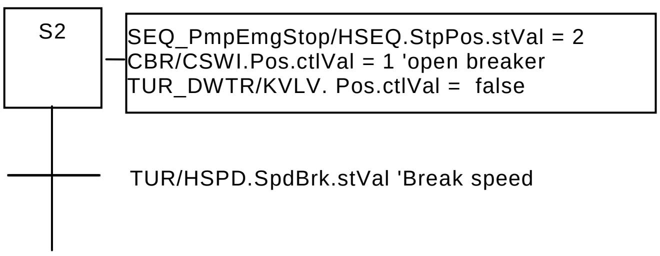


5.4.7 Shutdown sequence from a state "Synchronous Condenser (SC) mode in pump direction" to a state "stopped"

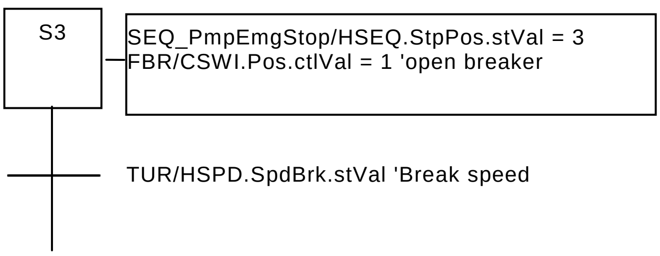
- Step 1: When Stop command is turned "ON", reactive power should be controlled to zero.



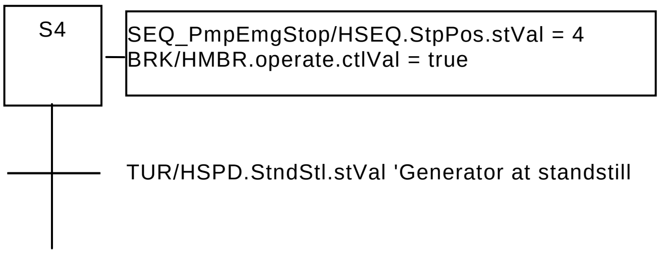
- Step 2: Main circuit breaker should be open. Water depression should be stopped.



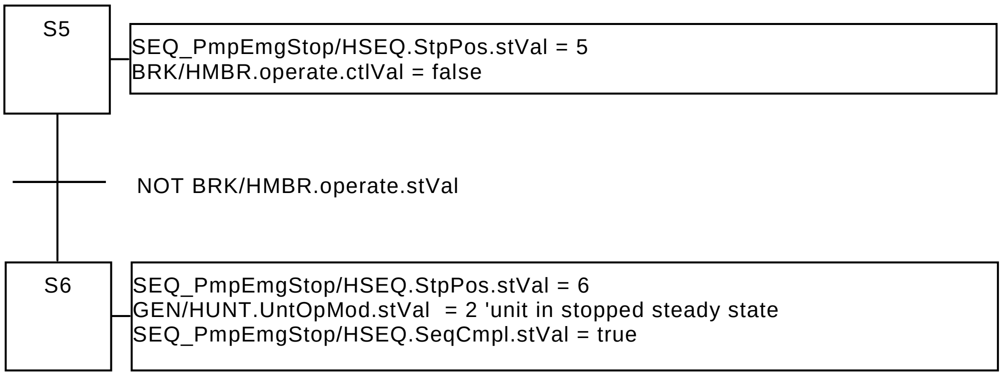
- Step 3: Turn off the excitation.



- Step 4: When the speed of the rotor is under the setting value, the mechanical break should be done.

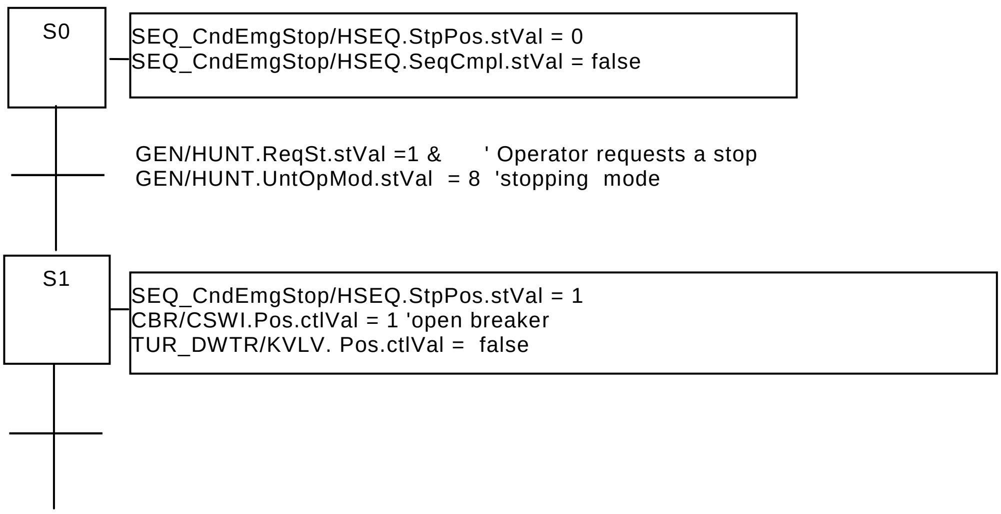


- Step 5: When the main generator/motor is stopped, the mechanical break will be released.

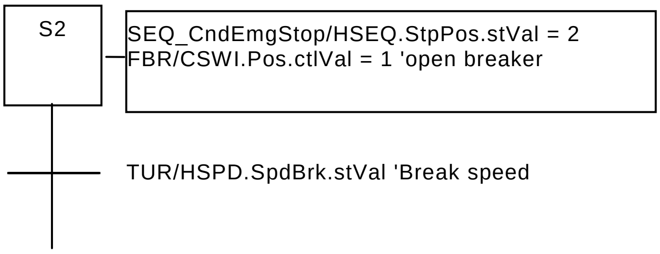


5.4.8 Emergency shutdown sequence from a state "Synchronous Condenser (SC) mode in pump direction" to a state "stopped"

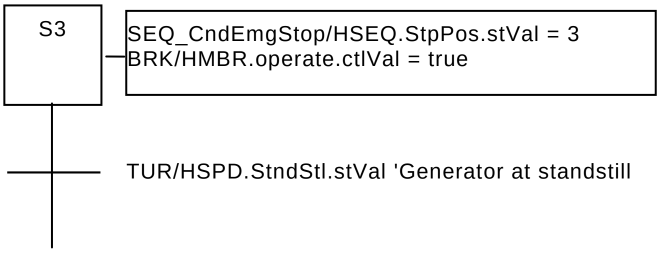
- Step 1: When emergency protection relay is operated, Main circuit breaker should be open. Water depression should be stopped.



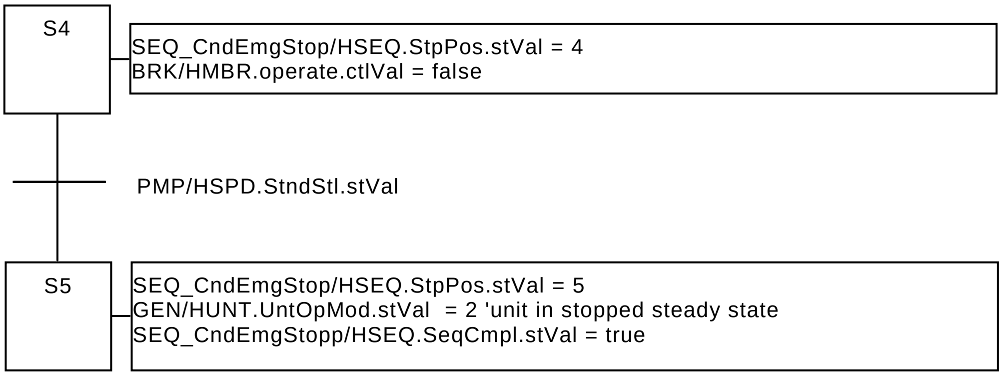
- Step 2: Turn off the excitation.



- Step 3: When the speed of the rotor is under the setting value, the mechanical break should be done.



- Step 4: When the main generator/motor is stopped, the mechanical break will be released.



6 Pump start priorities of a high pressure oil system

6.1 Example of a pump start priority for high pressure oil system

6.1.1 General

This example will demonstrate how to use IEC 61850 logical nodes to program a start-stop sequence for pumps using the FXPS logical node to manage the pump start priorities of a high pressure oil system. The high pressure oil system is composed of two pumps and a tank. Two oil level markers show the threshold points for the low level indicators. Figure 34 shows a graphical representation of the high pressure oil pumping unit.

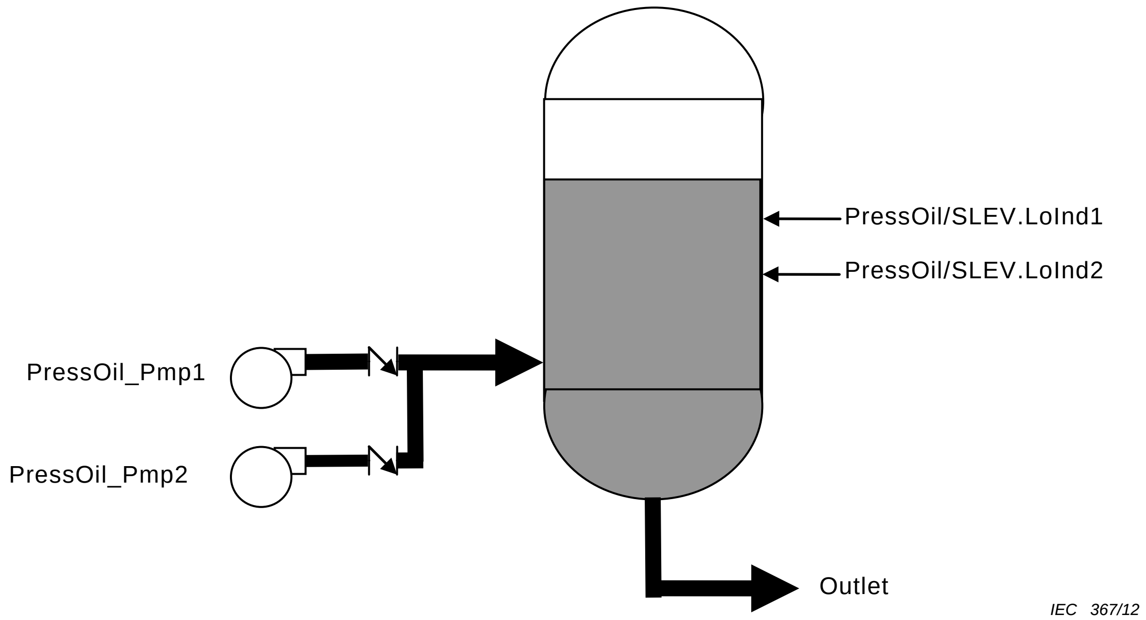


Figure 34 – Graphical representation of the high pressure oil pumping unit

6.1.2 Sequence to manage a pump start priorities

The goal of this sequence is to manage the pump start priorities. This sequence can be used to start other types of equipment such as fans or heaters. Note that when a Boolean ctlVal is set true or false, its return value and readable value is stVal for the same data object instance.

The logical node template used for FXPS is shown in the following incomplete ICD file. FXPS was modified so to have the ability to manage 2 pumps.

---file: PresOil.ICD---


```xml
<?xml version="1.0" encoding="UTF-8" ?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
<IED name="PresOil">
<AccessPoint name="S1">
<Server>
<Authentication />
<LDevice inst="PresOil">
 <LN0 lnType="LN0" lnClass="LLN0" inst="">
<DataSet name="Status">
  <FCDA ldInst="PresOil" prefix="" lnInst="1" lnClass="FXPS" doName="CtlMod" fc="ST" />
  <FCDA ldInst="PresOil" prefix="" lnInst="1" lnClass="FXPS" doName="StrPrt1" fc="ST" />
  <FCDA ldInst="PresOil" prefix="" lnInst="1" lnClass="FXPS" doName="StrPrt2" fc="ST" />
  <FCDA ldInst="PresOil" prefix="" lnInst="1" lnClass="FXPS" doName="QuSts1" fc="ST" />
  <FCDA ldInst="PresOil" prefix="" lnInst="1" lnClass="FXPS" doName="QuSts2" fc="ST" />
  </DataSet>
  </LN0>
  <LN inst="1" lnClass="FCSD" lnType="FCSDa" />
  </LDevice>
  </Server>
  </AccessPoint>
  </IED>
<DataTypeTemplates>
 <LNodeType id="FXPS1" lnClass="FXPS">
  <DO name="Beh" type="myBeh" />
  <DO name="CtlMod" type="myCtlMod" />
  <DO name="StrPrt1" type="myStrPrt" />
  <DO name="StrPrt2" type="myStrPrt" />
  <DO name="QuSts1" type="myQuSts" />
  <DO name="QuSts2" type="myQuSts" />
  </LNodeType>
</DataTypeTemplates>
</SCL>
```


--- EOF ---

The sequence may be broken down into the following steps:

- Step 0: This is the initial step. In this case, the step is active only when the program is initiated (after a soft reset, a reboot, or a forced re-initiation of the sequencer). In this step, the following data attributes of logical node "PressOil/FXPS1" are set:
  - CtlMod.stVal, set at 6 (Alternate + First In First Out),
  - QuSts1.stVal which is the queue order in which pump 1 is located,
  - QuSts2.stVal which is the queue order in which pump 2 is located.
- Step 1: This step stops all pumps, synchronises the pump start priority with respect to pumps location in the Queue, and waits for a low oil level.
- Step 2: This step awaits a selection confirmation for the pump that has the priority to start.
- Step 3 or 4: If "PresOil/FXPS1.StrPrt1.stVal = 1" then step 3 will become active and Pump 1 will receive an order to start. The Queue order for the priority start will then be inverted. If "PresOil/FXPS1.StrPrt2.stVal = 1" then step 4 will become active and Pump 2 will receive an order to start. The Queue order for the priority start will then be inverted.
- Step 5: This step selects branch according two conditions. If the low oil level condition disappears, the next active step will be step 1 and thus the pumps will receive a stop order. If a lower oil level condition appears, the sequence will branch to the next active step depending on the start priority of each pump.

- Step 6 or 8: These steps will send a start order to Pump 1 when in step 6 or a start order to Pump 2 when in step 8. These steps wait for the lower level condition to disappear before being inactivated.
- Step 7 or 9: These steps will send a stop order to Pump 1 when in step 6 or a stop order to Pump 2 when in step 8 and the sequence will go to back to step 5.

A logic scheme of these steps is shown in Figure 35.

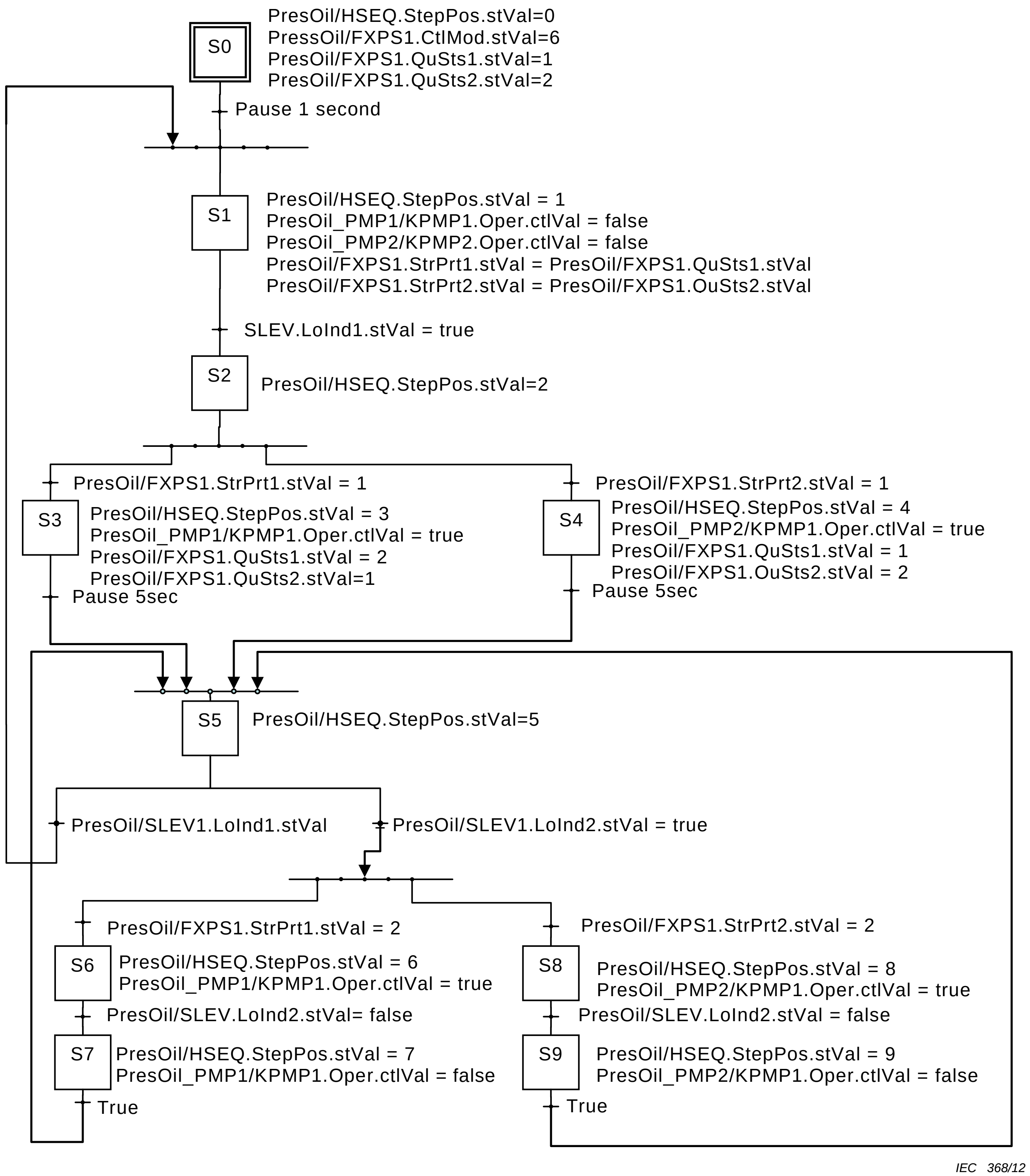


Figure 35 – Example of pump priority start logic sequence

6.1.3 Sequence to manage a pump

The goal of this sequence is to manage the pump. This sequence can be used to start other types of equipment such as fans or heaters.

The logical node template used for KPMP is shown in the following ICD file.

---file: PresOil.ICD---

```
<?xml version="1.0" encoding="UTF-8" ?>
<SCL                                    xmlns="http://www.iec.ch/61850/2003/SCL"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
<IED name="PresOil">
<AccessPoint name="S1">
<Server>
<Authentication />
<LDevice inst="PresOil_Pmp">
 <LN0 lnType="LN0" lnClass="LLN0" inst="">
<DataSet name="Status">
   <FCDA ldInst="PresOi_Pmp" prefix="" lnInst="1" lnClass="KPMP" doName="Beh" fc="ST"
/>
    <FCDA ldInst="PresOil_Pmp" prefix="" lnInst="1" lnClass="KPMP" doName="EEHealth"
fc="ST" />
   <FCDA ldInst="PresOil_Pmp" prefix="" lnInst="1" lnClass="KPMP" doName="Oper" fc="ST"
/>
  </DataSet>
  </LN0>
  <LN inst="1" lnClass="FCSD" lnType="FCSDa" />
  </LDevice>
  </Server>
  </AccessPoint>
  </IED>
<DataTypeTemplates>
 <LNodeType id="KPMP1" lnClass="KPMP">
  <DO name="Beh" type="myBeh" />
  <DO name="EEHealth" type="myEEHealth" />
  <DO name="Oper" type="myOper" />
  </LNodeType>
</DataTypeTemplates>
</SCL>
```

--- EOF ---

The sequence may be broken down into the following steps:

- Step 0: This is the initial step. In this case, the step is active only when the program is initiated (after a soft reset, a reboot, or a forced re-initiation of the sequencer. The value of PresOil_Pmp1/KPMP1.Oper.stVal is set equal to the position of the pump starter coming from the discrete input PresOil_Pmp1/GGIO1.Ind01.stVal.
- Step 1: When the system is not in local and the sequence receives a stop order, the discrete output PresOil_Pmp1/GGIO1.SPCSO1.ctlVal is set to true for 0,5 s to stop the pump.
- Step 2: When the system is not in local and the sequence receives a start order, the discrete output PresOil_Pmp1/GGIO2.SPCSO1.ctlVal is set to true for 0,5 s to start the pump.

Figure 36 shows an example of pump start logic sequence.

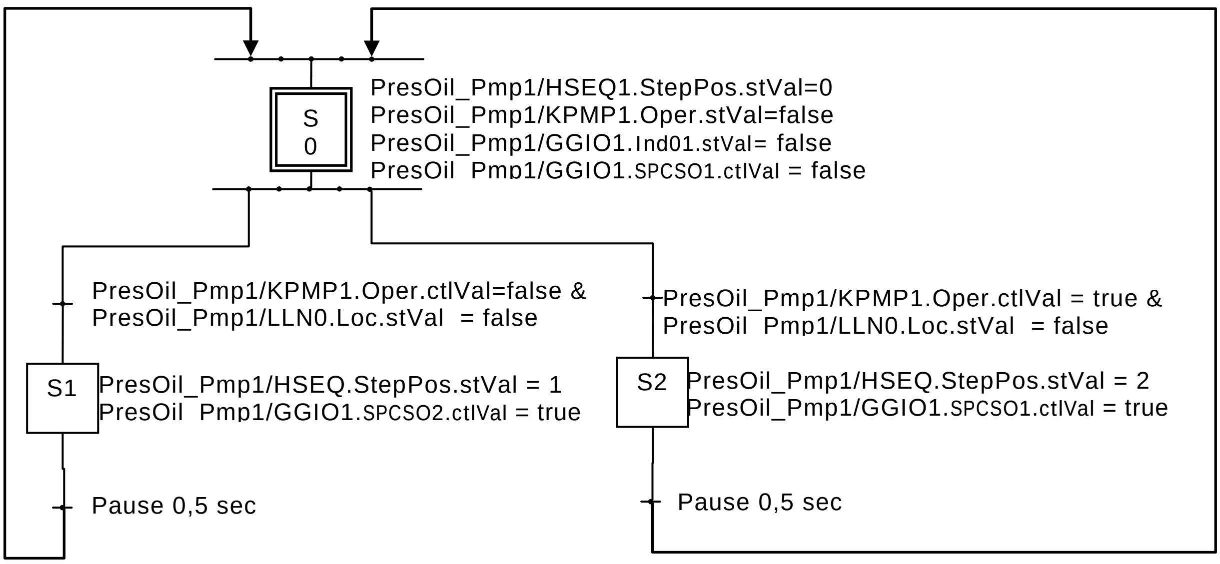


Figure 36 – Example of pump start logic sequence

7 Addressing structures, examples of mapping

7.1 Basic principles (IEC 61850-6)

IEC 61850-6 specifies a file format for describing communication related IED configurations and parameters. The main purpose of this format is to exchange IED capability descriptions.

IEC 61850-6 does not specify individual implementations or products using the language, nor does it constrain the implementation of entities and interfaces within a computer system. This part of the standard does not specify the download format of configuration data to an IED, although it could be used for part of the configuration data. For small extensions either by a manufacturer or for a specific project, the private parts can be used. The advantage of private parts is that the data content is preserved at data exchange between tools.

The IED configuration tools are proprietary software packages. The functions of an IED configuration tool include:

- creation of an ICD file;
- export of ICD file;
- import of an SCD file;
- download of a CID file into the IED.

7.2 Decentralised ICD file management

Each IED produces a self-description IED capability description file (ICD or CID) with information available for data exchange.

The importation ICD files generated by system configuration tool shall be imported in the other IED configuration tool to enable GSSE/GOOSE, or SV subscriptions or Client/Server dataset access points. Each IED configuration tool will generate a download file (normally a CID file) to download into the IED.

The drawback of such an import and export method from every configuration is the difficulty to management logical connections. Accountability of a forgotten connection is difficult to query prior to servicing the field IED. Figure 37 shows an exchange of ICD files between system configurators.

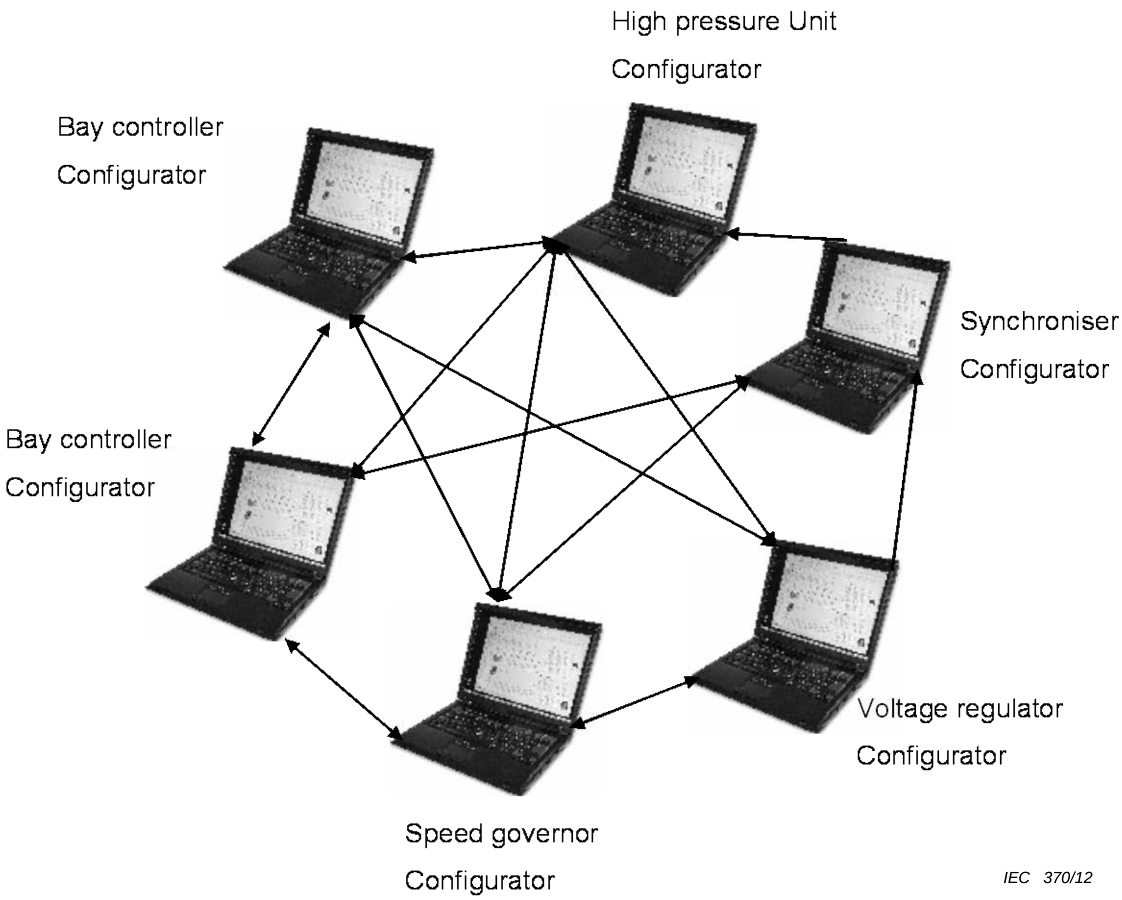


Figure 37 – Exchange of ICD files between system configurators

7.3 Centralised ICD file management

In the case of a centralised system configuration tool, the ICD files are managed in a centralised database which can produce a system configuration description (SCD) file.

The SCD can then be imported in each IED configuration. Then IED configuration tool downloads a file into the IED.

Ideally, a system configuration should have the ability of managing the private parts of the different IED manufacturers. Then the CID file would download directly into IED.

The private part would map the necessary 61850-7-x data attribute to the data in a logic controller.

Figure 38 shows a static data exchange with vendor's configuration tool.

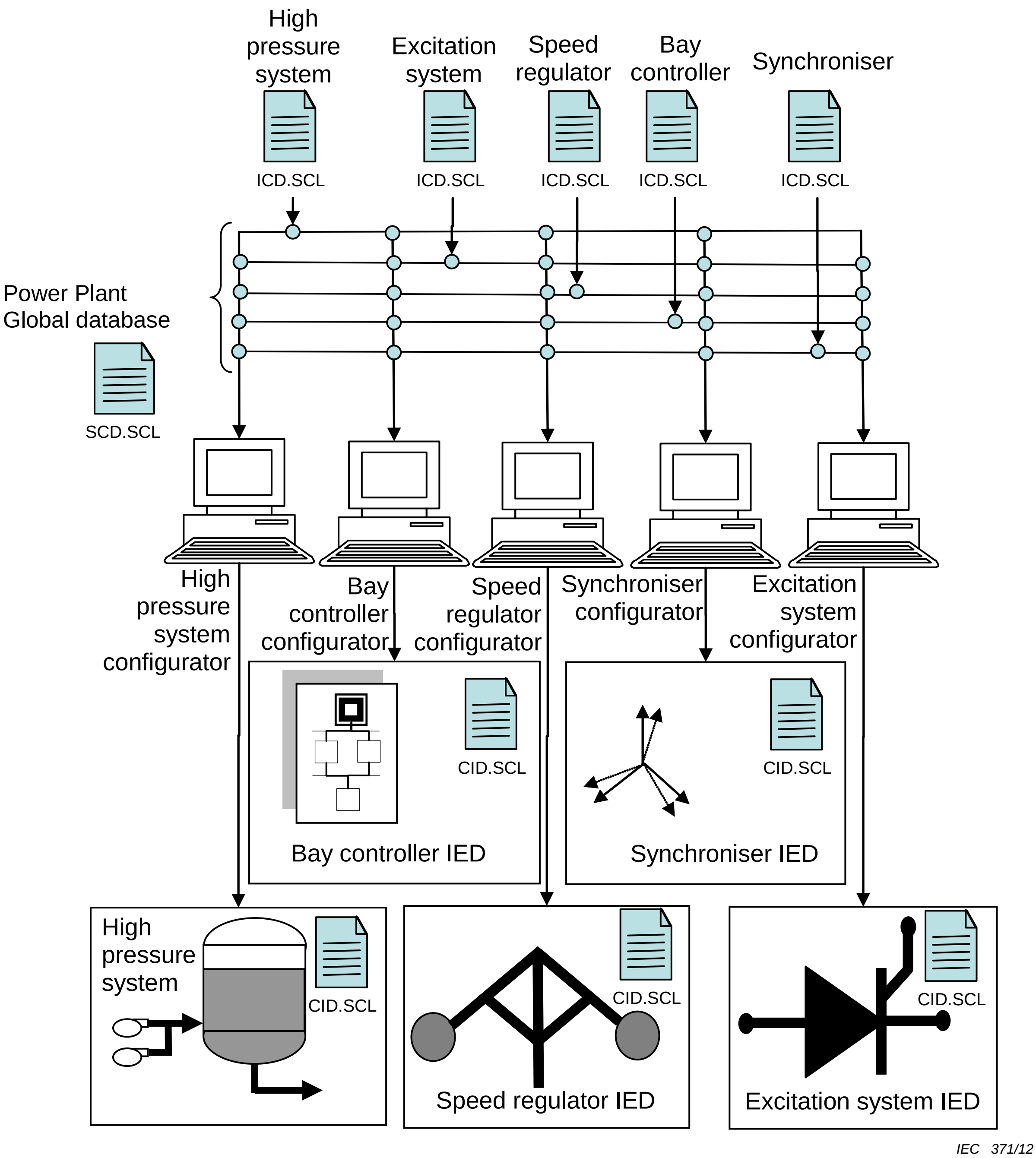


Figure 38 – Static Data exchange with vendor's configuration tool

7.4 Power plant structure – ISO/TS 16952-10 (Reference Designation System – Power Plants)

7.4.1 ISO/TS 16952-10 (Reference Designation System – Power Plants)

The current IEC 61850-7-2 naming scheme may be extended using naming designations from other standards. The Reference Designation System for Power Plants – RDS-PP for short – is one such naming designation which results from an effort to ensure conformity among power plant operators wanting to avail themselves of a standardized equipment designation system for their power plants.

RDS-PP has the following features of a proven identification system:

- applicability to all power plant types,
- consistency throughout the entire life cycle,
- identity in sense for all technical disciplines,
- language independence.

Table 7 lists codes taken from RDS-PP that may be applied in a logical device prefix.

Table 7 – RDS-PP designation codes for Hydropower use

Code	Intended purpose or task of object
B	Converting an input variable (physical property, condition or event) into a signal for further processing
C	Storing of energy, information or material
F	Direct protection (self-acting) of a flow of energy, signals, personnel or equipment from dangerous or unwanted conditions
G	Buffer, battery, Capacitor, Event recorder (mainly for storing purposes), Hard disk, Magnetic tape recorder (mainly for storing purposes), Memory, RAM, Storage battery Video recorder (mainly for storing purposes), Voltage recorder (mainly for storing purposes)
K	Processing (receiving, treating and providing) signals or information (excluding objects for protective purposes, see Class F)
M	Providing mechanical energy (rotational or linear mechanical motion) for driving purposes
P	Presenting information
Q	Controlled switching or varying a flow of energy, of signals (for signals in control circuits, see Classes K and S) or of material
R	Restricting or stabilizing motion or a flow of energy, information or material
S	Converting a manual operation into a signal for further processing
T	Conversion of energy maintaining the kind of energy Conversion of an established signal maintaining the content of information Conversion of the form or shape of a material
U	Keeping objects in a defined position
V	Processing (treating) of material or products (including preparatory and post-treatment)
W	Guiding or transporting energy, signals, material or products from one place to another
X	Connecting objects

The prefix signs used in RDS-PP to indicate the type of aspect in a reference designation are the following:

Prefix	Designation	Description
#	Number	Conjoint designation
=	Equals	when relating to the function aspect of the object
-	Minus	when relating to the product aspect of the object
;	Semi colon	signal designation

The unambiguous designation of signals is achieved by combining the reference designations and the signal name according to the following structure:

Reference designation	; Signal name

The signal name is shown in the following structure.

Prefix	Signal	Name
;	AA	(N)NN

Figure 39 shows the signalling tree structure using RDS-PP naming structure for a Hydro Turbine.

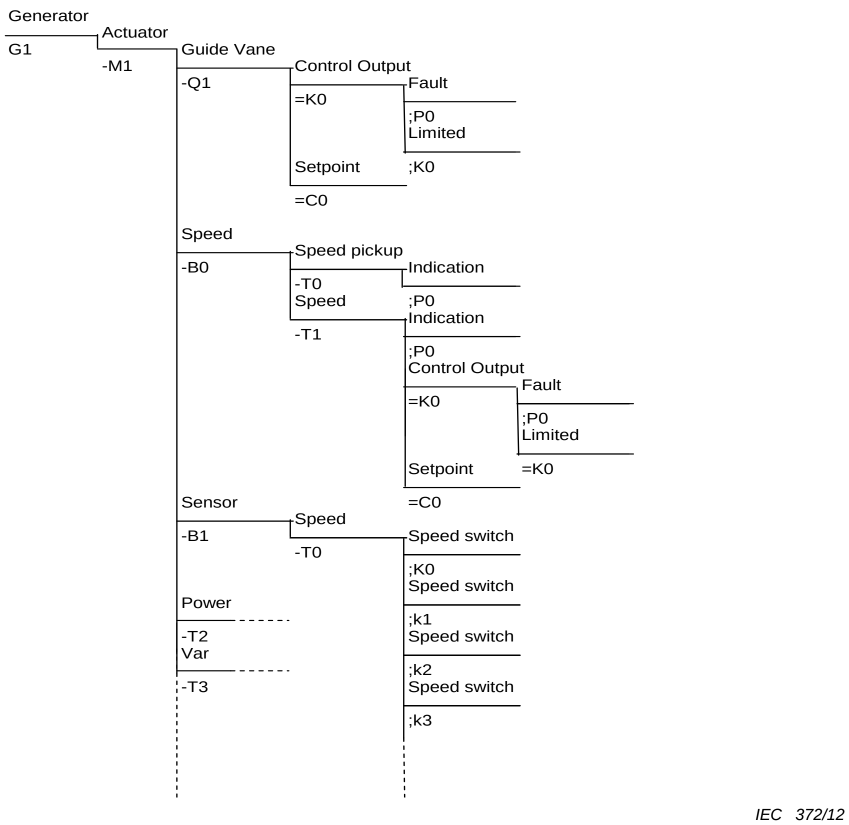


Figure 39 – Tree structure of a system using RDS-PP

The RDS-PP designation of a signal can reside in the data attribute instance of a data Object as shown in the file below.

--File Governor.ICD--------------------------------------


```
<?xml version="1.0" encoding="UTF-8" ?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd">
<IED name="G1-GOV">
<AccessPoint name="S1">
<Server>
<Authentication />
<LDevice inst="A1_M1">
<LN0 lnType="LN0" lnClass="LLN0" inst="" />
<LN inst="1" lnClass="MMXU" lnType="MMXU">
<DOI name="TotW">
<DAI name="d">
<Val>G1-T1</Val>
</DAI>
</DOI>
<DOI name="Hz">
<DAI name="d">
<Val>G1-T3</Val>
</DAI>
</DOI>
</LN>
</LDevice>
</Server>
</AccessPoint>
</IED>
</SCL>
```


--EOF--------------------------------------

The following are some examples using a RDS-PP designation scheme for a speed governing system. A similar approach can be used with a proprietary naming scheme.

7.4.2 Example 1: Wicket gate indications

This example uses RDS-PP as a naming designation to describe the signal list a Wicket Gate. The RDS-PP designation can be easily split between the reference designation and the signal name. The third column shows an IEC 61850 equivalence.

The following considerations were taken to achieve a signal correspondence between a RDS-PP signal list and IEC 61850 for a wicket gate:

- RDS-PP product designation (where G1 represents the Generator, M1 represents the actuator assembly with Q1 representing the wicket gates) can be used to generate the name of the logical device. The product designation was replaced by underscores.
- The signals names are replaced by the data object of a logical node.
- Signal G1-M1-Q1;P5: In ISO/TS 16952-10, signals are not assigned any description fields (such as the data attribute instance in 61850).
- The health of the G1_M1_Q1 logical is indicated in the logical node LLN0.

Signal	RDS-PP	IEC 61850 possible solution
Wicket Gate Pos.	G1-M1-Q1;P1	G1_M1_Q1/HTGV01.PosPc.mag.f
	G1-M1-Q1;B1	G1_M1_Q1/TPOS01.PosPctSv.instMag.f
Wicket Gate Pos. Open	G1-M1-Q1;P2	G1_M1_Q1/HTGV01.PosOpn.stVal
Wicket Gate Pos. Closed	G1-M1-Q1;P3	G1_M1_Q1/HTGV01.PosCls.stVal
Wicket Gate Pos. Closed (hardwired contact)	G1-M1-Q1;P4	G1_M1_Q1/HTGV01.PosCls.stVal
Wicket Gate Pos. Broken wire	G1-M1-Q1;P5	G1_M1_Q1/HTGV01.PosPc.q [out of range]
Wicket Gate Pos. Circuit failure	G1-M1-Q1;P6	G1_M1_Q1/HTGV01.DevAlm.stVal
Wicket Gate Pos. Feedback Failure	G1-M1-Q1;P0	G1_M1_Q1/HTGV01.PosPc.q [inaccurate]
Wicket Gate Pos. Feedback Failure 2 out of 3	G1-M1-Q1;P7	G1_M1_Q1/HTGV01.PosPc.q [inconsistent]

7.4.3 Example 2: 3 Phase Measurement

This example uses RDS-PP as a naming designation to describe the signal list for phase measurement.

The following considerations were taken to achieve a signal correspondence between a RDS-PP signal list and IEC 61850 for phase measurement within a governing system:

- The reference designation G1-M1 was renamed G1_M1 to create the logical device.
- The logical node MMXU grouped signals provided by different physical transducers.
- The health of the transducer is thus linked to the quality of the signal.
- The logical device G1_M1 is also the group reference and thus inherits the LPHD logical node. Its health is indicated in PhyHealth of LPHD.

Signal	RDS-PP	IEC 61850 possible solution
Power	G1-M1;T1	G1_M1/MMXU01.TotW.mag.f
Frequency	G1-M1;T3	G1_M1/MMXU01.Hz.mag.f

7.4.4 Example 3: Speed Controller

This example uses RDS-PP as a naming designation to describe the signal list for a speed controller.

The following considerations were taken to achieve a signal correspondence between a RDS-PP signal list and IEC 61850 of a speed controller:

- G1-M1-B0 was kept to create the logical device under group reference G1_M1.
- The logical node MMXU grouped signals provided by different physical transducers.
- The health of the speed controller G1_M1_B0 is thus linked to the health of logical node LLN0.

Signal	RDS-PP	IEC 61850 possible solution
Speed set-point internal	G1-M1-B0;C0	G1_M1_B0/FSPT02.SptVal.ctlVal
Speed set-point external	G1-M1-B0;C1	G1_M1-B0/FSPT03.SptVal.ctlVal
Actual Speed	G1-M1-B0;P0	G1_M1_B0/HSPD.Spd.mag.f
Isolated network cmd on	G1-M1-B0;P1	G1_M1_B0/HGOV.ModAct.ctlVal
Isolated network is on	G1-M1-B0;P2	G1_M1_B0/HUNT.GridMod.stVal
Permanent Droop	G1-M1-B0;P3	G1_M1_B0/HGOV.Drp.ctlVal
Speed controller is on	G1-M1-B0;P4	G1_M1_B0/HGOV.ModAct.stVal
Speed controller output	G1-M1-B0;K0	G1_M1_B0/HGOV.Out.mag.f
Speed higher	G1-M1-B0;K1	G1_M1_B0/FSPT02.SptChg.ctlVal [2]
Speed lower	G1-M1-B0;K2	G1_M1_B0/FSPT02.SptChg.ctlVal [3]

7.4.5 Example 4: Speed measurement with some thresholds

This example uses RDS-PP as a naming designation to describe the signal list for Speed measurement with some threshold (speed switches). The RDS-PP designation can be easily split between the reference designation and the signal name.

The following considerations were taken to achieve a signal correspondence between a RDS-PP signal list and IEC 61850 for the speed thresholds:

- G1-M1-B1 was kept to create the logical device under group reference G1_M1.
- The logical node HSPD grouped signals provided by different physical signals.
- The health of the physical signals is thus linked to the quality of the signal.
- The health of the speed controller G1-M1-B1 is thus linked to the health of logical node HSPD and LLN0.

Signal	RDS-PP	IEC 61850 possible solution
Speed Standstill	G1-M1-B1;P0	G1_M1_B1/HSPD.StndStl
Speed Creeping	G1-M1-B1;P1	G1_M1_B1/HSPD.SpdCrp
Speed less than 30 %	G1-M1-B1;P2	G1_M1_B1/HSPD.SpdBrk1
Speed more than 90 %	G1-M1-B1;P3	G1_M1_B1/HSPD.SpdExt
Speed between 99 % and 101 %	G1-M1-B1;P4	G1_M1_B1/HSPD.SpdSyn
Overspeed limit 1	G1-M1-B1;P5	G1_M1_B1/HSPD.SpdOvr1
Overspeed limit 2	G1-M1-B1;P6	G1_M1_B1/HSPD.SpdOvr2

7.4.6 Example 5: Common turbine information

This example uses RDS-PP as a naming designation to describe the signal list for the common turbine information. The RDS-PP designation can be easily split between the reference designation and the signal name.

The following considerations were taken to achieve a signal correspondence between a RDS-PP signal list and IEC 61850:

- G1-M1 was kept to create the logical device under group reference G1_M1.
- The HUNT information was forwarded to the Governor by the generator bay controller (G1_K1). This is to maintain a client (bay controller) server (governor) architecture.
- The Quick Shutdown uses a private enumeration to indicate the requested state.
- The NetHead and Tail Water level are retrieved by the generator bay controller from the governor.

Signal	RDS-PP	IEC 61850 possible solution
Turbine limited	G1-M1;P101	G1_M1/HUNT.LimAct.stVal
Condenser Mode	G1-M1;P102	G1_M1/HUNT.UntOpMod.StVal [2]
Quick ShutDown	G1-M1;P103	G1_M1/HUNT.ReqSt [21]
Unit in NoLoad Operation	G1-M1;P104	G1_M1/HUNT.ReqSt [2,3]
NetHead	G1-C0;P0	G1_M1/HNHD.Nhd.mag.f
Tail water level	G1-C0;P1	G1_M1/TW_HLVL.LevM.mag.f

8 Examples of how to use various types of curves and curve shape descriptions

Example: Water flow based on gate position

In Figure 40, we can see an example of a 2 dimensional curve used for shaping a Flow Value based on the gate position. The values entered in the table are based on statistical data obtained following a series of index tests.

FILE: FlowCalculation.ICD


```
<?xml version="1.0" encoding="UTF-8"?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL
SCL.xsd">
<IED name="GOV">
 <AccessPoint name="S1">
  <Server>
    <Authentication/>
    <LDevice inst="A1_GOV">
      <LN0 lnType="LN0" lnClass="LLN0" inst="">
        <DataSet name="Curves">
          <FCDA ldInst="A1_GOV" prefix="" lnInst="1" lnClass="FCSD" doName="Out" fc="MX"/>
        </DataSet>
     </LN0>
     <LN inst="1" lnClass="FCSD" lnType="FCSDa">
       <DOI name="Crv">
          <SDI name="numPts">
            <Val>5</Val>
          </SDI>
          <SDI name="crvPts">
            <DAI name="xVal">
             <Val>0</Val>
             <Val>1</Val>
             <Val>3</Val>
             <Val>5</Val>
             <Val>10</Val>
            </DAI>
            <DAI name="yVal">
             <Val>1</Val>
             <Val>2</Val>
             <Val>3</Val>
             <Val>5</Val>
             <Val>10</Val>
            </DAI>
          </SDI>
       </DOI>
     </LN>
</LDevice>
</Server>
</AccessPoint>
</IED>
</SCL>
```

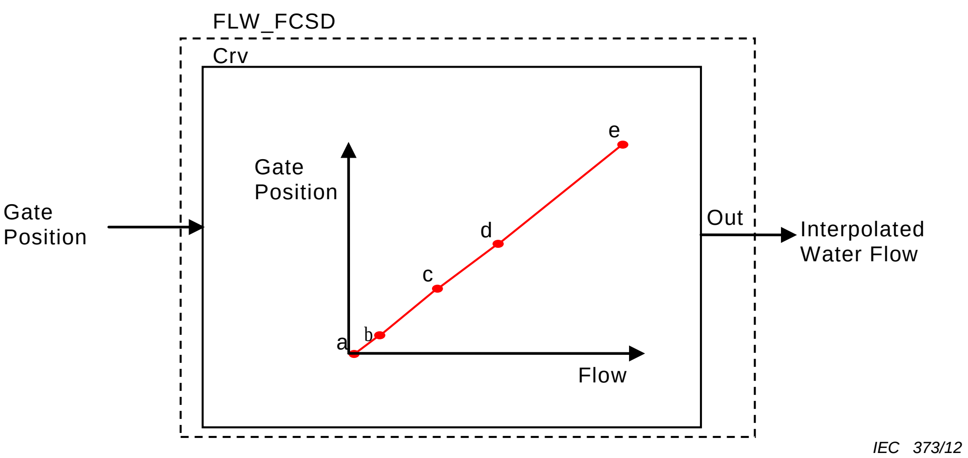



Figure 40 – Hydraulic correlation curve

In Figure 41, we can see an example of a 3 dimensional curve used for shaping a runner blade position based on two variables, the net head and the gate position. To achieve such a function, the HCOM logical node is used. The following TurbineCorelationCurve.ICD file provides 15 XYZ coordinate points to define the curve. The values entered in the table are based on statistical data obtained following a series of index tests.

FILE: TurbineCorelationCurve.ICD


```
<?xml version="1.0" encoding="UTF-8"?>
<SCL xmlns="http://www.iec.ch/61850/2003/SCL" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL
SCL.xsd">
<IED name="GOV">
 <AccessPoint name="S1">
  <Server>
    <Authentication/>
    <LDevice inst="A1_GOV">
      <LN0 lnType="LN0" lnClass="LLN0" inst="">
        <DataSet name="Measurement">
          <FCDA ldInst="A1_GOV" prefix="" lnInst="1" lnClass="HCOM" doName="RbPos" fc="MX"/>
        </DataSet>
        <DataSet name="Status">
          <FCDA ldInst="A1_GOV" prefix="" lnInst="1" lnClass="HCOM" doName="Out" fc="ST"/>
       </DataSet>
     </LN0>
     <LN inst="1" lnClass="HCOM" lnType="HCOMa">
       <DOI name="CrvSet">
          <DAI name="numPts">
            <Val>15</Val>
          </DAI>
          <SDI name="crvPts">
            <DAI name="xVal">
             <Val>5</Val>
             <Val>10</Val>
             <Val>15</Val>
             <Val>20</Val>
             <Val>25</Val>
             <Val>5</Val>
             <Val>10</Val>
             <Val>15</Val>
             <Val>20</Val>
             <Val>25</Val>
             <Val>5</Val>
             <Val>10</Val>
             <Val>15</Val>
             <Val>20</Val>
             <Val>25</Val>
            </DAI>
            <DAI name="yVal">
             <Val>0</Val>
             <Val>0</Val>
             <Val>0</Val>
             <Val>0</Val>
             <Val>0</Val>
             <Val>6</Val>
             <Val>6</Val>
             <Val>6</Val>
             <Val>6</Val>
             <Val>6</Val>
             <Val>9</Val>
             <Val>9</Val>
             <Val>9</Val>
             <Val>9</Val>
             <Val>9</Val>
            </DAI>
            <DAI name="zVal">
             <Val>23</Val>
             <Val>15</Val>
             <Val>10</Val>
             <Val>4</Val>
```

```
        <Val>0</Val>
        <Val>23</Val>
        <Val>15</Val>
        <Val>10</Val>
        <Val>4</Val>
        <Val>0</Val>
        <Val>23</Val>
        <Val>15</Val>
        <Val>10</Val>
        <Val>4</Val>
        <Val>0</Val>
       </DAI>
      </SDI>
  <DAI name="xUnit" fc="CF" bType="VisString255" dchg="true"/>
        <Val>M</Val>
  </DAI>
  <DAI name="yUnit" fc="CF" bType="VisString255" dchg="true"/>
        <Val>%</Val>
  </DAI>
  <DAI name="zUnit" fc="CF" bType="VisString255" dchg="true"/>
        <Val>%</Val>
   </DAI>
   <DAI name="xD" fc="CF" bType="VisString255" dchg="true"/>
        <Val>NetHead</Val>
    </DAI>
    <DAI name="yD" fc="CF" bType="VisString255" dchg="true"/>
        <Val>Wicket Gate or Guide Vane Opening</Val>
    </DAI>
    <DAI name="zD" fc="CF" bType="VisString255" dchg="true"/>
        <Val>Turbine pitch</Val>
    </DAI>
    <DAI name="D" fc="CF" bType="VisString255" dchg="true"/>
        <Val>Hydraulic Corelation Curve</Val>
    </DAI>
   </DOI>
  </LN>
</LDevice>
</Server>
</AccessPoint>
</IED>
 <DataTypeTemplates>
  <LNodeType id="FCSDa" lnClass="FCSD">
  <DO name="Beh" type="myBeh"/>
  <DO name="Out" type="myOut"/>
  <DO name="Crv" type="myCrv"/>
  </LNodeType>
 <DOType id="myCrv" cdc="CSG">
  <DA name="numPts" fc="SP" bType="INT16" dchg="true"/>
  <DA name="crvPts" fc="SP" bType="ARRAY" dchg="true"/>
  <DA name="xUnit" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="yUnit" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="zUnit" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="xD" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="yD" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="zD" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="D" fc="CF" bType="VisString255" dchg="true"/>
  <DA name="ldNs" fc="EX" bType="VisString255">
    <Val>IEC61850-7-4 Ed2</Val>
 </DOType>
 </DataTypeTemplates>
</SCL>
```

Figure 41 shows a turbine correlation curve.

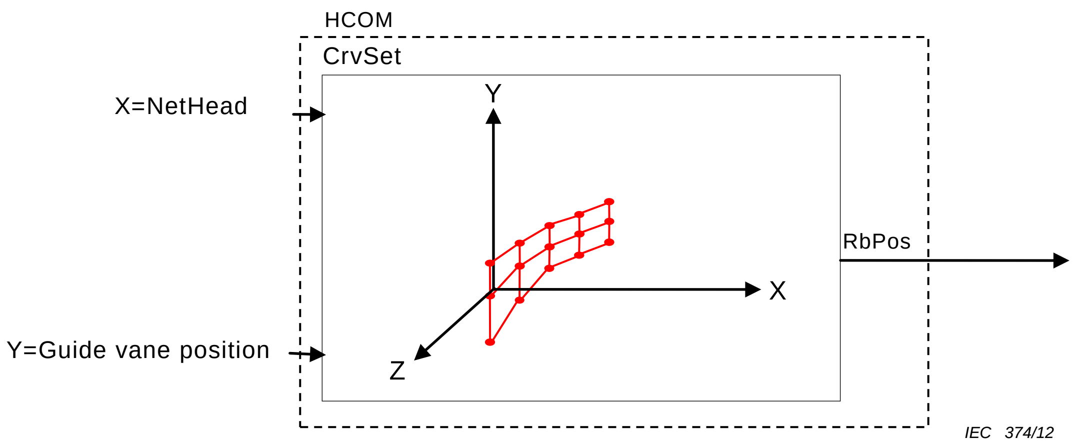


Figure 41 – Turbine correlation curve

9 Examples of voltage matching function

Traditionally, voltage matching pulses are sent from the synchroniser to the AVR. The length of the pulse is proportional to the actual voltage difference ΔU. Figure 42 shows an example of traditional voltage adjusting pulses.

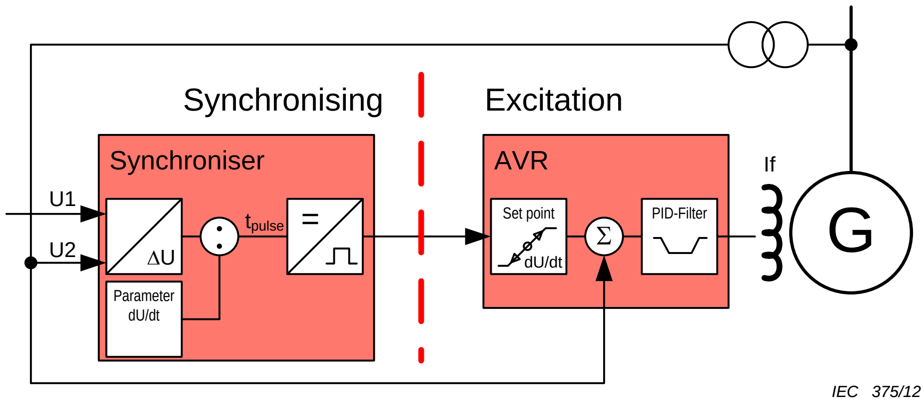


Figure 42 – Example of traditional voltage adjusting pulses

The voltage adjusting pulses may be mapped as follows (see Figure 43):

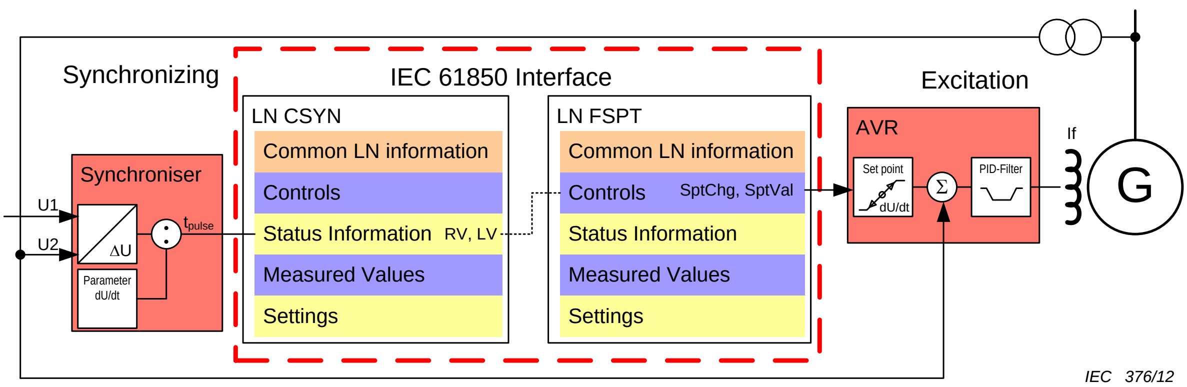


Figure 43 – Example of mapping of the pulse time in IEC 61850

Alternatively, the adjusting command may be used directly, e.g., without using the pulse time calculation (see Figure 44):

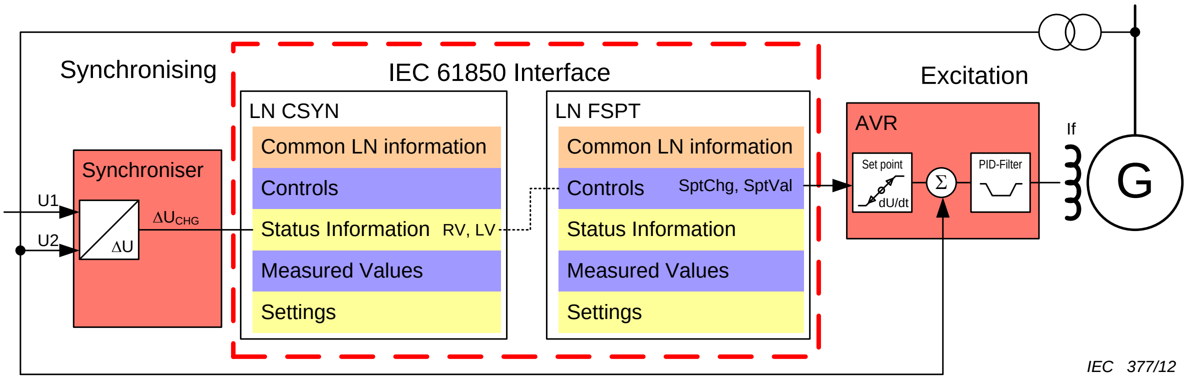


Figure 44 – Example of an IEC 61850 voltage adjusting command

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