Signal modelling

principles and requirements

-Based on IEC 81346 and IEC 61850

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**CHANGE LOG**

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# Purpose and Scope

This document describes general signal modelling principles used in Statkraft. The modelling principles are applicable for all new systems treating process signals and data (process control, atomisation, data collection, communication, analysis and more). Retrofitting existing systems is encouraged whenever possible.

Regarding technology, these principles aim primarily at Hydro Power systems, but can be extrapolated to other technologies (wind, PV, district heating, etc..).

Extract from IEC 81346-1:2022, annex L:

*“The rules defined in IEC 81346-1 and the other parts of the 81346 standard series offer a degree of flexibility in the development of a reference designation system. This necessitates that any organization applying any part of the standard series documents its application for the benefit of stakeholders.*

*Some rules of IEC 81346-1 require information on the application of the rules to be documented. Table L.1 list all the rules of this publication and provides further recommendations for supplementary information to be provided that may aid the use of a reference designation system in an organization.”*

One of the main goals of this document is to address the needs for documentation addressed in the quotation above.

The reader of the document should have a good understanding of the following standards series:

IEC/ISO 81346 Industrial systems, installations and equipment and industrial products – structuring principles and reference designations

IEC 61850-7 Communication networks and systems for power utility automation - Part 7: Basic communication structure

General coursing in IEC/ISO 81346 (hereby referred to as “RDS-PS”) is available to all through a dedicated Statkraft Motimate course.

# Abbreviations

IED Intelligent Electronic Device

IT Information Technology

RD Reference Designations

RDS Reference Designations System

PV Photovoltaic

# Terms and definitions

**RDS compatibility**

RDS-compliance / compatibility refers to an IT-systems capability of:

1. Structuring its information according to a hierarchical view of a full system (e.g. powerplant), following one of the aspects of the RDS.
2. Associating information to systems nodes (e.g. power plant sub-systems such as turbines or transformers), in particular other Reference Designations to the object of interest in other aspects (e.g. location or product tag)

# Deviations from international Standards

## IEC/ISO 81346

1. **Ambiguous Reference Designation Semantics**

Horizontal ellipsis (…) should be used for ambiguous RD, which is commonly the case in the ++ site of location aspect (where a space generally will contain multiple objects). Because this is more common than not, in this aspect, the horizontal ellipsis will not be required.

1. **Meaningless instantiation**

In accordance with IEC 81346-1, every reference designation (RD) shall be instantiated regardless of the relevance or not (e.g. =A1, is “unit 1” and must be so, even if the powerplant only has one unit). The instantiation (numbering) must bear no meaningful information. It is strictly to identify potential multiple systems of the same nature within the structure, such as a gate system (e.g. =C1.KA1) composed of two actual gates (e.g. =C1.KA1.KA1 and =C1.KA1.KA2)

There are some exceptions to this rule, including -but not limited to- the following:

* Within the location aspect (site of installation, “++”), the floor lever will be visible in the RD. See 8.1.
* With the functional aspect the numbering will be used to reflect if a sub-system is on/in the upstream or downstream part of the larger system. See 7.3

## IEC 61850

Although not a deviation as such, it is worth pointing out that Statkraft will employ a set of logical nodes and general extensions to the standard, described in this document.

# General Modelling principles

## Two standards

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| **Requirement** | **Description** |
| **GeMoPr-M-001** | Signal modelling and naming SHALL be done in accordance with IEC 81346 and IEC 61850, in accordance with the rules and guidelines in this document. |

Two international standards are used for Signal modelling:

* The IEC/ISO 81346 – series[[1]](#footnote-2) (referred to as the RDS from this point on) is used to provide the user with a reference designation (RD), an identification of the occurrence of an individual within a larger system. It is, in fact a Tagging system.
* The IEC 61850, part 7 specifically provides a system to model the nature of any signal or dataset.

A signal shall be modelled by combining the **RD of the signal source** and the **signal description** using IEC 61850.

*Example:*

**<Alta1.PS1>=A1.KA1/KVLV1.OpnPos.stVal**

**Main inlet valve, unit 1, Alta powerplant** **/ Open position status**

Note that the naming can be simplified to match system technical requirements (e.g. “Alta1A1KA1KVLV1OpnPosstVal”).

## System naming

To all systems identifiable by a RD, a physical name (“Driftsbetegnelse” in Norwegian) should be attributed. The term “system description”

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| **Requirement** | **Description** |
| **GeMoPr-M-002** | To all systems identifiable with a reference designation, in accordance with IEC 81346, there SHALL exist a system description.  The description SHALL be:   * In English (also in local language when required) * Humanly readable and understandable * Following an international standard whenever possible * Labelled using 61850 signal name: LPHD1.PhyNam.name |
| **GeMoPr-O-003** | Names SHOULD be intuitive names, not necessarily the class names given by the RDS system.  Example: =A1.KA1 is the “Main Inlet Valve”, not a “Flow Control System”. |

## Deviations from Signal Modelling Principles

# RDS, General Modelling principles

## Maximum depth of a structure

**Product aspect:** Lowest level of interest for maintenance.

Objects of a simple nature such as common screws and bolts should not be included unless of particular interest (e.g. for maintenance purposes, such as turbine cover housing bolts who could potentially even be instrumented).

**Functional aspect:** Lowest level of interest for automation: requirements according to signal modelling

As a rule of thumb, the leaves (outer edges) of a model in the functional aspect, should all have data/signals attached to them (e.g. sensors producing data, or systems receiving/creating signals).

## Sub-system or sibling system

1. If a systems BB1 only serves one system =A1.AA1, then BB1 is a sub-system of =A1.AA1 (=A1.AA1.BB1)

1. If a system BB1 serves more than one system (e.g. =A1.AA1 and =A1.AA2) then one should elevate the system BB1 to a higher level (e.g. =A1.BB1)

1. If a system BB1 only serves one system =A1.AA1, but often serves more than system in other power plants (e.g. it is often a common system to =A1.AA1 and =A1.AA2) then one should consider elevating the system BB1 to a higher level (e.g. =A1.BB1)

## System Numbering / instantiation

In general terms, numbering should not carry any meaning. IEC 81346-1 allows for certain deviations 1 if documented, which is the purpose of this document.

Rules:

* Numbering shall not carry meaning regarding the system characteristics (size, type, affinity, etc…). **Exceptions** to this rule are listed in this chapter.
* No system shall be numbered zero “0”

Guiding principles:

* IT-systems collecting data should strive to be independent of system numbering
* When instantiating, one should follow the flow of energy

**Exceptions to the numbering rules:**

* When instantiating measurements performed before/after a system the following guiding principles should be used:
* Upstream/before the system core, all measurement numbering should be “1” or the instantiation should be preceded by a leading “1”
* Downstream/after the system core, all measurement numbering should be “2” or the instantiation should be preceded by a leading “2”

A diagram of a valve

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## RDS and 61850 where one ends and the other begins

For signal modelling one should apply the RDS to the final object, the component in question.

*Example*

=A1.KA1/KVLV1.OpenPos.StVal

Where =A1.KA1 identifies the unit main inlet valve, and the KVLV.OpenPos.StVal indicates the binary value of the valve open-state signal.

The example above shows an unsatisfying duplication of perceived information:  the notion of a valve is present in both the RDS- and 61850-part of the signal designation (KA1 is the main inlet valve, and KVLV is a logical node for valve control).

 This principle should still be upheld to harmonize the use of the combined standards and to cater for a potential need to attach more than one logical node to a certain object (e.g. =A1.KA1/CALH for alarm handling).

## RDS and Signals: Functional aspect only

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| **Requirement** | **Description** |
| **GeMoPr-M-004** | For signal structuring the reference designations according to IEC/ISO 81346 SHALL always be in the functional aspect. |

## Signal simplification

RDS and 61850 tags must still be readable if the signal is simplified (e.g. if all punctuation is removed)**.**

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| **Requirement** | **Description** |
| **GeMoPr-M-006** | Disregarding prefixes (“=”) and level separators (“.” and “/”), all levels in the (functional) RDS-part of a signal description, as well as the *logical node* (see IEC 61850-7) SHALL start with a letter and end with a number.  Example: =**A1**.**KA1**.**KA1**/***KVLV1***.OpenPos.StVal |

# RDS - Specific Modelling Principles

## Location aspect

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| **Requirement** | **Description** |
| **GeMoPr-M-007** | Floor numbering in the *site of installation aspect* (RD with the prefix “++”, see IEC 81346-1) will be done in accordance with ISO 4157. |

This requirement implies a deviation from the proposed principles of IEC 81346-1, as numbers in a RD will be given a meaning (the floor numbering).

It is proposed that the floor should be added to a (++) site of installation RD by using a dedicated level containing only the floor number.

e.g. ++C1.CA1**.3.**CAA2

## Prime Systems

### A systems

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| --- | --- | --- |
| **Definition** | **Boundaries** | **Typical examples** |
| Functional system transforming energy or energy carrier. | On the hydraulic/waterway side the A system starts with the main inlet valve (=A1.KA1 - **including**) and ends with the draft tube gate (=H1.KA1 **excluding**).  On the electrical side the A system starts with the generator system and ends with the unit transformer system switchgear (including) | Wind turbine  Hydro unit  Steam turbine  Gass turbine |

**Notable sub-systems:**

**A1.RA1 - Generator**

**A1.RA1.RJ1 Rotor**

**A1.RA1.RK1 Stator**

Notable systems:

* A1.RA1.RK1.FEC1 - Stator Core
* A1.RA1.RK1.FEC1.UAA1 - Stator Tooth
* A1.RA1.RK1.WBB# – Stator winding L#

**A1.RA1.LD1 - Excitation system**

Notable systems:

* A1.RA1.LD1.XZA1 – Slip ring
* A1.RA1.LD1.TAA1 – Excitation system core
* A1.RA1.LD1.TAA1.WBB# – Excitation system winding L#
* A1.RA1.LD1.QAB1 – Excitation trigger

**A1.RA1.HE1 - Cooling system**

Notable systems:

* A1.RA1.HE1.HE1.EQC# – Air cooling system #
* A1.RA1.HE1.HE1.EQD# – Water cooling system #

**A1.RB1 - Turbine**

**A1.RB.AE - Turbine housing**

**A1.RB.LD - Turbine governing system**

**A1.RB.KA - Flow control system**

Notable systems:

* A1.RB1.KA1.WPA1 - Distributor

**A1.JF1 - Shaft System**

The unit **bearings (KJ)** are constituents of the shaft system.

For the FUNCTIONAL aspect:

For vertical units with three bearings (one a combined guide and thrust bearing), four systems should be created – one for each function:

* =A1.JF1.KJ1 is the upper guide bearing
* =A1.JF1.KJ2 is the lower guide bearing
* =A1.JF1.KJ3 is the turbine guide bearing
* =A1.JF1.KJ4 is the thrust bearing

For horizontal units (and other configuration), the same principles apply:

1. Numbering follows the shaft from generator side to turbine
2. All combined bearings (guide- and thrust in combination) perform two functions. In the functional aspect these should be separated into two different systems (e.g. functions =A1.JF1.KJ2 and =A1.JF1.KJ4 are in fact performed by the same bearing)

For the PRODUCT aspect:

Vertical units usually have three bearings:

* -A1.JF1.KJ1 is the upper generator bearing
* -A1.JF1.KJ2 is the lower generator bearing
* -A1.JF1.KJ3 is the turbine bearing

One of these is usually a combined guide and thrust bearing.

**A1.JF1.KJ# - Bearing system**

Notable systems:

* A1.JF1.KJ#.HB1 – High pressure oil system
* A1.JF1.KJ#.EQD1 – Water cooling system

**A1.JF.LE - Speed monitoring system**

**A1.JF.KA - Mechanical brake system**

**A1.KA1 - Main Inlet Valve**

**A1.KA1.KA - Flow control system**

**A1.KA1.JB - Bypass system**

**A1.KA1.KK - Positioning system**

**A1.KA1.KB - Seal system**

**A1.JE - Switch gear**

**A1.JE.KF - Transformer**

Notable systems:

* A1.JE1.KF1.HE1 – Transformer cooling system
* A1.JE1.KF1.HB1 – Oil supply system
* A1.JE1.KF1.WBB# – Winding L#

**A1.LA - Local control**

### B systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system transporting electric power. | Starts with unit transformer switchgear (excluding) and ends at:   * grid connections * D-systems, auxiliary/local system switchgears (excluding). | - Plant produced power collecting system.  - Substations |

**Typical sub-systems:**

**JE - Switch gear**

**JE.KF - Transformer**

Notable systems:

* JE1.KF1.HE1 – Transformer cooling system
* JE1.KF1.HB1 – Oil supply system
* JE1.KF1.WBB# – Winding L#

### C systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system transporting energy or energy carrier, excluding electric energy. | For Hydro (Waterway):  **Starts** with the inlet **trash rack** system (including) and **ends** with the **Main Inlet Valve** (excluding)  In general the system should start with the connecting system (including) to an energy storage system and end with the connecting system to the system exploiting the energy (excluding)l | - Waterway  - Coal belt conveyer system  - Gass distribution system |

**Waterway boundaries, general guidelines:**

A diagram of a electrical system

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* Waterways will be **segmented** into sections (JB-class). For powerplants with tunnel systems there is expected a minimum of two JB systems: one to represent the inlet **tunnel**, and one to represent the **penstock**.
* **If a powerplant has no Main Inlet Valve (MIV)**, only the inlet gate as closing system, the C-system should still exist, the power plant will have no =A1.KA1 system.
* **Numbering** should follow the following rules (for both functional and product aspect – See 4.5:
* Tunnel system leading to the penstock should be instantiated using a leading “1” (e.g. =C1.JB11, =C1.JB12, =C1.JB13)
* Penstock systems should be instantiated using a leading “2” (e.g. =C1.JB21, =C1.JB22 for penstocks 1 and 2)
* If the pressure shafts are dedicated to specific units, then the shafts instantiation should reflect the unit numbering (i.e. shaft “-C1.JB24” supplies water to unit 4).
* If the powerplant only has one tunnel- and/or penstock technical system, only the leading instantiation is necessary (e.g. =C1.JB1 and C1.JB21 and C1.JB22 for a powerplant with one short tunnel and two pressure shafts)
* If there are more than one reservoir connected to the main water course (Skjomen?) the respective intake systems will be called =C1.KA11 and =C1.KA12 for reservoirs =E1 and =E2.
* Reminder: As a general guide, numbering should strive to follow the flow of energy/water

### D systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system supporting the energy production process. | D-systems are varied. Boundaries, if unclear, should follow the *receiver principle* (see below) | - Common cooling supply systems  - Common hydraulic oil distribution systems  - Cleaning systems |

**Receiver principle**

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A lesser system constituting the connecting system between two higher systems will hierarchically belong to the receiving system.

**Numbered typical sub-systems**

Note that the following sub-system suggestions also have a numbering proposed. These are proposals to harmonize the systems throughout the machine park.

**D1 – Cooling Supply System**

**Starts** at the connection to the different sources of cooling water (including since the D1 system is the receiver of cooling medium), such as turbine leakage water system and/or sump.

**Ends** at the heat exchangers to the different recipient systems (excluding)

Includes (amongst other):

* Cooling water pool/tank
* Feeding systems (Feedwater system from sump, leakage water from turbine, and more
* Distribution systems
* Liquid treatment systems such as filters and coolers/heaters.

**D2 – Common hydraulic oil supply system**

Includes (amongst other):

* Tank
* Distribution systems
* Liquid treatment systems such as filters and coolers/heaters.

**D40 – Peripheral Systems**

By definition, all peripheral systems should be identified under another top node (they are not part of the modelled powerplant, i.e. they are peripheral). However, in certain cases it makes no sense to have a separate system, or the Peripheral system in question may have a certain effect/dependency which makes it useful to model within the power plant structure.

Examples:

* The local grid (the local frequency can be measured and influence the power plant).
* Local atmospheric pressure

### E systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system for collecting and storing energy for subsequent retrieval. | **Boundaries for (Hydro)**  E systems should be instantiated for each large body of water considered a reservoir  E-systems include:  - All systems functionally related to reservoir (water) handling (e.g. bypass system, reservoir drainage systems, weirs, flood gates etc…)  - All systems related to inflow to the reservoir in question (metering stations, …)  - All systems included in a water transport system adding water to the reservoir including its inlet (Gate, trash rack, … ) | Water reservoirs  Coal mine/depo  Gass storage |

**Numbering proposal: E1 should be the powerplant main reservoir.**

Bratsberg main reservoir is Selbusjøen (=E1), see figure below. Østrungen (=E4), Sørungen (=E5), Store-Slindvann (E2) and Dragstsjøen (=E3) also belong to the powerplant. Apart from E1, the numbering of the reservoirs is not bound to any rules or principles but could be done in accordance to importance to the powerplant production (often according to size).

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If a measurement station is detached from a reservoir (general weather station etc…) it should be a subsystem of a support system (D40 Peripheral Measurement Systems)

### F systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system managing energy supply and generation. | F-systems will vary greatly in size and purpose. Boundaries should follow general rules such as the receivers principle. | - SCADA  - Plant automation system |

**Cubicles**

Cubicles and general housing systems for electronic components (UCA), fully committed to one particular system (such as the local control cubicle for a gate system =H1.KA1), is likely to be considered a subsystem of said system (=H1.KA1.UCA1).

However, more generic housing systems that contain equipment for multiples systems also need a designation. These should be found under =F1.AA#.

When helpful, different cubicles (classified as a UCA) can be grouped under different =F1.AA# levels.

*Example:*

=F1.AA1.UCA# could be all cubicles related to the production of unit 1

=F1.AA20.UCA# could be all cubicles related to protection systems

**Numbering**

=F1.AA40 to =F1.AA49 is reserved for “peripheral” equipment (i.e. equipment that is not part of the power plant system, but still housed in a powerplant cubicle. This could be e.g. a monitoring system owned by a third part (governmental or TSO).

=F1.AA50 is reserved for Stand alone monitoring and data acquisition systems

### H systems

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| **Definition** | **Boundaries** | **Typical examples** |
| Functional system disposing residues or waste. | **Start** at the point where waste is created (excluding) or waste is stored/collected (including) for subsequent extraction.  The H system end point will often be outside of the scope of the larger system. (e.g. a river outside of what is considered part of the hydro power plant system). | - Water bypass system  - Sump |

**H1** should be the designation for the **power plant outlet system**. Including all systems concerning the water outflow from the draft tube gate (including) to the outlet river (including /excluding depending on the needs of the users).

Note that for pump-storage plants, when in pump mode, the outlet is the source of water (“input”) of the powerplant. To harmonize the application of the standard on all components, pump-storage plants is first and foremost a power production facility. I.e. it is the turbine state that dominates the classification principles (GENERATOR/motor, TURBINE/pump). The outlet H1 is therefore classified as such (an H system) even when the powerplant uses this system as reservoir.

**H2** should be the designation for the power plant **leakage water extraction system**, the system extracting water from the collecting basin (“sump”) below the turbine floor. This includes the sump/basin/collecting chamber itself, all extraction systems such as pumps and all related equipment.

**H3** should be reserved for **turbine bypass systems**. Note that this annotation is reserved for bypasses with an outlet to the same body of water as the turbine outlet. It should include energy reduction systems, gates and valves dedicated to the governing and monitoring of the bypass system.

A diagram of a diagram

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**H4** should be reserved for **downstream rivers to which the outlet is connected**. This is to be used only in case where additional instrumentation exists in the river, monitoring more than the discharge of the powerplant.

Note that systems related to reservoirs (drainage systems, overflow systems, weirs and floodgates) should generally be considered as subsystems to the reservoir system (e.g. =E1.KA1 for a floodgate system).

## Technical Systems

### A\_ Structural Systems

In the functional aspect, the A\_ systems are expected to exist only if signals or measurements are applied to them (monitoring such as vibration, heat, etc… or signals such as positioning or manoeuvring).

The **AE Housing System class can be used to** represent cabinets and cubicles.

The **AA Support Frame System can be used to** represent dams.

Functional Aspect: For dams, measurements directly applicable to the dam as a function (leakage flow, pore pressure etc…) should be added directly under the dam (e.g. =E1.AA1.BFA1 is dam leakage measurement).

Note that it is unambiguous that =E1.AA1.BFA1 is dam leakage measurement, as flow through gates would be attributed to the gate systems, and other flows out of the reservoir should be attributed to the reservoir, not the dam (even if the overtopping system is physically a art of the dam).

### HE Cooling/heating systems

Cooling or heating system will usually consist of some of the following systems:

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| **Code** | **Description** |
| HE | Supply system for heating/cooling system |
| HB | Supply system for liquid matter |
| HA | Supply system for gaseous matter |
| LE | Monitoring system |
| LA | Automation system |

**Functional aspect:**

1. Group all components under one or more HE systems (more if there is redundancy or parallel stand-alone systems). This includes coolers that are physically part of the system being cooled/heated (from a product point of view).
2. Second level should consist of the actual coolers/heater (component systems, often E \_ \_) and the supply system of heating/cooling medium HA or HB.
3. Cooling/heating of the energy carrier (liquid or gas) is a sub-system of the medium supply system HA or HB. This supply system should contain storage and treatment systems when relevant (generally for liquid medium).
4. The flow of the cooling/heating medium might be surveyed by a BFA/BFB system, which is a subsystem of the medium supply system (…HE1.HA1.BFA1).

A diagram of a system

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Figure 1 - Example of a cooling system in the functional aspect

A diagram of a temperature control system

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Figure 2 - Example 2 of a cooling system in the functional aspect

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Figure 3 - Example 3 of a cooling system in the functional aspect, Stator cooling system

**Product aspect:**

1. The individual coolers are often part of the assembly of the system being cooled. *Example: generator stator coolers are part of the stator system (=A1.RA1.RK1.ECA1).* Complex implementation may warrant the use of a technical system HE to group them (=A1.RA1.RK1.HE1.ECA1).
2. The system supplying the cooling medium is a separate system. It includes storage, treatment and distribution of the medium.

A diagram of a fan

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Figure 2 - Example of a cooling system in the product aspect

**Numbering/instantiation:**

With the general terms that “1” is upstream and “2” is downstream:

* A cooling system cold side should be instantiated “1”
* A heating system warm side should be instantiated “1”

Note that oil in bearings are considered friction reduction systems, not cooling systems (even though it does that too).

### KA Gate/valve systems

The following chapters show the different types of gates and valves

Most gate systems include a trash rack (grating). This is a subsystem to the gate systems

e.g. =A1.KA1.HQB1

### An.KA Main Inlet Valve (MIV)

**On the bypass system -A1.KA1.JB1 / =A1.KA1.JB1**

* Usually the bypass system will be equipped with a manual closing valve (for maintenance purposes). This valve should be assigned the number 2 (i.e. =A1.KA1.JB1.QMA2 / =A1.KA1.JB1.QMA2).
* There are multiple pressure measurements required for operation of the bypass system. Notably pressure measurements upstream and downstream the bypass valve =A1.KA1.JB1.QMA1, as well as pressure sensors for operational pressure measurements (hydraulics) related to the valve itself. The former are part of the bypass systems (e.g. =A1.KA1.JB1.BPA1), while the latter are subsystems of the valve. See the figure below.

A diagram of a system

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### An.JF1.KJn Bearings

**Thrust bearings**

Thrust bearings usually have an internal cooling system and a dedicated oil chamber part of the bearing itself.

General rules:

* Monitoring of the cooling medium for the oil (air/water) will be subsystems of the heat exchanger.EXAMPLE =An.JF1.KJ2.EQD1.BTA2 is outlet (hot) cooling water temp. measurement.
* To distinguish temp. measurements on the mechanical components and the oil, a separate level for the oil (class: FRA) should be created.
* To simplify the monitoring system, all measurement related to the oil should be subsystems of the oil (i.e. pressure, circulation and level) EXAMPLE =An.JF1.KJ2.FRA.BLA1 oil level in lower guide bearing

### En.KAn Reservoir gates

Preferred instantiation for gates related to a reservoir,

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| --- | --- | --- |
| **Pref.** | **Description** | **Note** |
| KA1 | Bypass/flood gate system |  |
| KA2 | Maintenance gate system |  |
| KA3 | Drainage gate system | “tappeluke” “drenering” |
| KB1 | Reservoir threshold/overflow system | KB is not an error, it is not a KA system |

Each gate system may include one or more physical gates. To model multiple gates, create a substructure (e.g. =E1.KA1.KA2 is the second flood gate)

Multiple arrays of gates may exist, e.g. to bypass the power production system into different bypass riverbeds. To instantiate this a second number should be added to the numbering system (e.g. =E1.KA12 is a second set of flood gates related to the reservoir in question)

Note 1: Gate systems leading to the main waterway (C1.KA1) are not part of the reservoir system.

Note 2: Although gates tend to be incorporated into dams (=E1.AAn) this is not reflected in the functional aspect. That is not the case for the product aspect, where the numbering convention should also be applied. E.g. -E1.AA3.KA2.KA1 is the first maintenance gate in the third dam of the reservoir.

### Cn.PF1 Surge Chamber/shaft

### Cn.KAn Waterway gates

C1.KA1 Is the mail inlet.

### RK Stator

Stator system cooling system is handled in section 7.3.2.

**Functional aspect:**

Subsystems to the stator

=A1.RA1.RK1 Stator core

=A1.RA1.RK1.RK**2** Stator core, phase **2**

=A1.RA1.RK1.RK**2**.BTA1 Stator core, phase **2,** temp measurement (laminate sheets)

=A1.RA1.RK1.RK**2**.TDA**45**.BTA1 Stator core, phase **2,** winding **45**, temp.

=A1.RA1.RK1.RK**2**.UNA**2324**.BTA1 Stator core, phase **2**, tooth between tracks/windings **23** and **24**, temp

A diagram of a circular object with text

Description automatically generated

## Component system

### EGC\*, EQD,EQC Heat exchangers

To harmonize better between powerplants and technologies used, it is **preferred to use EQC** (heat exchanger) rather than detail what cooling/heating agent have been used.

### BPA/BTA Ambient pressure sensors

It should allways be presumed that pressure sensors are measuring pressures or temperatures related to the production process. There might however be sensors dedicated to atmospheric measurements, relevant for determining characteristics (e.g. fluid viscosity), safety systems, etc...

Ambient measurements should be instantiated using numbers between 40 and 50.

Example:

=E1.BLA1 Measurment of reservoir water level

=E1.BTA1 Measurement of reservoir water temperature

=E1.BTA40 Measurment of ambient air temperature

### MMA Piston / linear motor

Pressure monitoring should be done with the numbering system:

1: closing (pressure)

2: opening (pressure)

A blue and black symbol

Description automatically generated

### Heaters and coolers

EGC

Heat exchanger is the most generic system for heating and cooling. It should always be used for individual component systems that provide heating or cooling (depending on the temperature of the receiving system). If possible, one should strive to use the system classes described below.

EQB

“Cooling Panel” Should be used as default cooling system when more information about the workings of the system is unavailable.

EQC

“Cold air blower” should be used when air is used for cooling. Typical example: air-coolers in

a stator. Beware of potential misunderstandings caused by the class name: EQC should not be used for fans, this is the heat exchanging system, not the circulation system.

EQD

“Cooler” should be used when liquid matter is used for cooling, typically in a heat-exchanger system.

EB\_

Used for electric heat transfer. Power supply is included in these systems for both functional and product aspects.

If applied, this system will tend to be seen in cooling/heating matter treatment, rather than directly for process heating or cooling.

[FYLL UT MER]

# Principles for 61850

## General Principles

### logical node hierarchy

Hydropower plants vary in size, age, complexity. Some values gathered, such as a bearing temperature are standard, but could vary in implementation from plant to plant – especially in the number of sensors/measurements. There could exist multiple instances of alarm/warning functions for a single system (bearing in the example below).

To standardize and harmonize the data exploitation system it is suggested to add a (single) data object representing one averaged/representative value to the higher up logical node (HBRG in the case of the example below). This value should exist no matter how many measurement/sensors exist or if it is calculated, estimated, or measured. There should always exist a logical node hierarchically below this upper node (generally an S-node), representing the source of the data.

A screenshot of a computer

Description automatically generated

- For a specific measurement T-nodes and an S-nodes will exist. The instantiation of the T-nodes is however optional – it should be created if the raw data (sample values) are collected/useful.

- All T-nodes must have an equivalent S-node. If an S-node isn't defined in part 4 or 410, it should be created in the Statkraft namespace.

- Multiple S-nodes (i.e., multiple instantiation such as /STMP1 /STMP2 ….) will exist if there are multiple alarm signals based on multiple sensors for the same attribute

Example: multiple temp sensors on a tank with each their own alarm signal). In these cases, there will often be one aggregated alarm - based on these values (I.e. one tank alarm triggered by any of the three smart sensors attached to it). That aggregated signal should be added to the higher-level system (logical node) representing the overall system (e.g. KTNK1.TmpAlm.stVal in the case of our example.

This principle is valuable for processes of data surveillance and condition monitoring. Different power plants will have different implementations and set-ups for the same major functions. But surveillance, and PLC’s will require some aggregated data sets regardless of the implementation.

Example:

An overview system “Park view” of waterways will require the state of gates (e.g. the inlet gate =C1.KA1) in the waterway. In “Powerplant Alpha”, the gate system (=C1.KA1) may be highly complex and consist of an array of gates (=C1.KA1.KA1, =C1.KA1.KA2,… =C1.KA1.Kan). In “Powerplant Beta”, the gate system might be one single gate.

“Park View” only works shows the aggregated state value: Open/Closed/Error, which is the aggregated value <Alpha>=C1.KA1/HGTE.PosDn.stVal and <Beta>=C1.KA1/HGTE.PosDn.stVal

Because of this principle, the signals will have the same designation for both powerplants, regardless of the complexity of the method used to provide the value (state).

### Prefix/suffix

Prefixes and suffixes should be avoided.

* Additional data can be added as metadata when required, depending on the systems/tools used.
* The RDS-part of a signal tag replaced the *logical device identification* (see IEC 61850-7-1). It is not considered a prefix.
* To add more information about a measurement type (averaged, predicted value, max/min), see chapter 8.2.

### Alarms and trips

For S-nodes in particular many varied sorts of data objects are available dependent on the S-node, we wish to use these:

* Hi2  (Trip)
* Hi1  (warning)
* HiAlm  (warning)
* LoAlm  (warning)
* Lo1  (warning)
* Lo2  (Trip)

Hi# and Lo# are alarms (warnings) of different levels. The lower the number the higher the criticality, with Hi2 and Lo2 trip alarms.

### Sequences

Sequencing is proposed not to affect the naming of the different signals involved in the sequenced process.

E.g. signals from different processes during start-up should not actually reflect that they are a part of the start-up sequence, as the same signals may be used in other processes or circumstances.

## Logical Nodes

K-nodes should be used on “bottom-level” equipment, i.e. components that are not divisible. For higher systems H-nodes are generally used.

EXAMPLE

=E1.KA1/HGTE is the node for the general reservoir(=E1) gate(=E1.KA1) control.

=E1.KA1.KA1/KGTE is the control node specific to gate 1

## Collected data

Data produced at site is generally named in its raw form using a T-logical node (e.g. /**T**TMP1.TmpSv.instMag). This raw data is however generally not the ones which are collected remotely. Generally raw data is collected by an IED and then pre-processed and conditioned to perform data preparation (filtering, cleaning, deadband spontanisation, etc..). It is this data that is then forwarded, stored and used for future analysis. Those data points will usually be modelled using a S-logical node.

### LN Instance numbering conventions

In general, multiple LN instances are not needed because the multiplicity of data and / or systems must be managed at RDS level. Differentiation of instances at LN level must be done in the following circumstances:

* in the case of implementation of statistical calculations, or
* when the same information is published to multiple clients that require different information handling (for example, the need for differentiated alarm acknowledgement, forcing of values and differentiated testing).

### Mathematical Statistical operations

For analogue measurements it is possible to provide additional information, which are calculated as statistical values over time. In particular, several kinds of statistically calculated values may be provided for an individual “source” time series. For each statistical calculation an additional instance of LN is defined, using the same LN class and DO of its source LN instance. The following calculations can be made on it (specified in clcMth) within a given time interval:

• min, max, average, standard deviation

• peak, rms, other electrical quantities

• extensions with custom calculations

The a.m. statistical calculations concern only the time axis, that is, they only take into account the changes over time and do not combine multiple signal sources.

It is through the ~~enumeration~~ number of the logical node instance that the ~~mathematical~~ statistical operation will be identified.

Most commonly a single ~~data stream~~time series will be collected and stored for any specific measurement at site. In case no statistical calculation is applied to that collected data, it is defined as the current values for that specific measurement and its logical node instance number will be normally “1”. This applies also when the collected data are related to a statistical calculation, but it’s either not relevant, or known. ~~What mathematical operations (Such as averaging over a certain period, RMS value, etc…) may either not be relevant, or known. In these cases the enumeration of the logical node will be “1”, i.e. unspecified.~~

*Example: : D45.LE1.BTA1/STMP****1****.Tmp.mag*

*This is the current temperature measurement ~~is unspecified. It could be an averaged value over an hour or an RMS value calculated over a 1 second time period~~.*

~~Data produced at site is generally named in its raw form using a T-logical node (e.g. /~~**~~T~~**~~TMP1.TmpSv.instMag). This raw data is however generally not the data collected. In most cases raw data is collected by an IED where a mathematical operation is performed to compress the data (average, max value over a period, etc..). It is this data that is then forwarded, stored and used for future analysis. Those data points will usually be named using a S-logical node.~~

To ~~differentiate~~ identify the different ~~operations~~ statistical calculations and relevant datapoints (as in some cases multiple of these values will be collected), different logical node instance numbers shall be used. The following numbering convention (derived from IEC 61850-7-4 enumerated calculation method) ~~it~~ is proposed ~~to use logical node instantiation~~ to differentiate the different ~~operations~~statistical calculation.

~~This should be done according to the following table:~~

|  |  |  |
| --- | --- | --- |
| Name | Instance number~~Value~~  nn | Description |
| CURRENT OR UNSPECIFIED | 01 | Either current value or ~~C~~calculation of the analogue value~~s~~ is unspecified. |
| TRUE\_RMS | 1~~0~~2 | All analogue values are true rms values. |
| PEAK\_FUNDAMENTAL | 1~~0~~3 | All analogue values are peak fundamental values. |
| RMS\_FUNDAMENTAL | 1~~0~~4 | All analogue values are rms fundamental values. |
| MIN | 1~~0~~5 | All analogue and counter values are minimum values. |
| MAX | 1~~0~~6 | All analogue and counter values are maximum values. |
| AVG | 1~~0~~7 | All analogue and counter values are average values. |
| SDV | 1~~0~~8 | All analogue and counter values are standard deviation values. |
| PREDICTION | 1~~0~~9 | All analogue values are long term changes over time. |
| RATE | 2~~1~~0 | (use 'DIFF' instead) All analogue values are actual changes over time calculated with the actual and previous value. |
| P-CLASS | 2~~1~~1 | All analogue values (i.e., all common attributes 'i' and 'f') meet the sampling and filtering characteristics specified in IEEE C37.118.1 for P-CLASS. |
| M-CLASS | 2~~1~~2 | All analogue values (i.e., all common attributes 'i' and 'f') meet the sampling and filtering characteristics specified in IEEE C37.118.1 for M-CLASS. |
| DIFF | 2~~1~~3 | All analogue values are [F(t+T)-F(t)] for a calculation interval T (in the same unit as the original entity). Note: The client can still calculate rate so: RATE = DIFF/T. |
| MEDIAN | 2~~1~~4 | All values and counters are median values. |
| SAMPLE | 2~~1~~5 | Randomly sampled value |

*Example:* D45.LE1.BTA1/STMP**1~~0~~5**.Tmp.mag

The **minimum values** of the raw temperature values collected by system D45.LE1.BTA1. Please note that the time interval where the minimum is calculated is undefined or not specified.

1. **Calculation t~~T~~ime ~~period~~interval**

Unless stated otherwise, the ~~mathematical~~ statistical calculations ~~operations~~ are done over a past time period ~~given by the data collecting frequency~~which might be specified by means of a bunch of DO’s (“ClcIntvTyp”, “ClcIntvPer”) in the statistical LN instance. When this is sufficient, the time period information may not be specified, and the tag is designated with the calculation method only. However, when this information is necessary, it is possible to decorate the tag naming with that time interval information. In this case, the LN instance number is further enriched with additional digits in the “more significant digits” position (left side of the number). The instance numeric pattern to be used in this case is as following:

xxxtnn

where, from less to most significant digits:

* **nn** is the LN instance number indicating the calculation method as explained in the paragraph above and better detailed in the Table above; due to pattern recognition, leading zeros might be necessary when **nn**<10;
* **t** identifies the time unit to consider in defining the calculation interval duration (similarly to IEC 61850-7-4 enumerated options in “ClcIntvTyp”):
* 1: Milliseconds
* 2: Seconds
* 3: minute
* 4: hour
* 5: day
* 6: week
* 7: month
* 8: year
* **xxx** indicates the number of time units (as per digit **t**) to consider for the calculation time interval. Leading zeros are not necessary.

*Example:*

A diagram of a medical procedure

Description automatically generated

*Examples:*

D45.LE1.BTA1/STMP**415**.Tmp.mag

**Hourly** Temperature measurement, **minimum value**

D45.LE1.BTA1/STMP**2415**.Tmp.mag

Temperature measurement, **minimum value** over a period of **2** hours

D45.LE1.BTA1/STMP**30517**.Tmp.mag

Temperature measurement, **average value** over a period of **30** **days**

D45.LE1.BTA1/STMP**6607**.Tmp.mag

Temperature measurement, **average value** over a period of **6** **months**

## Special cases

### Dam measurements

=E1.AA1 Dam

=E1.AA1/HDLS Total dam leakage (sum of individual leakage measurements)[[2]](#footnote-3)

=E1.AA1.BFA1/SFLW Individual leakage measurements

=E1.AA1.LE40 Surveillance of atmospheric/ground characteristics related to the dam, such as ground water pressure/level.

### Meteorological measurements

Measurement systems not directly related to the water in the reservoir should be grouped under a generic monitoring system =Cn.LE40 (40 to indicate it is a monitoring system not directly related to the process).

A diagram of a diagram

Description automatically generated with medium confidence

Measurements/monitoring included in this system:

* Atmospheric Pressure
* Air temp. measurement
* Rain (flow)
* Snow depth

and more…

Note that the logical node (see IEC 61850) MMET should be used for all atmospheric related measurements when applicable.

### Setpoints and return- (measured) values

The setpoint value is a controlled setting to a system. This setting value is then measured by a local system and returned. A discrepancy between these two values could indicate local malfunction.

A close-up of a sign

Description automatically generated

Below are some notable cases of setpoint and equivalent return value. Note that some return signals will originate from dedicated measuring systems, not the receiver of the set-point.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Logical Node** | **Description** | **DO** | **DA** | **Setpoint or returned** |
| HSPC | Turbine frequency set-point by operator | SpdSpt | MxVal.f | Setpoint |
| HSPC | Turbine frequency set-point (measured) | SpdEsp | mag.f | Returned |
| HWGC | Turbine load set-point by operator | FlwSpt | MxVal.f | Setpoint |
| HFLC | Turbine load set-point (measured) | ReqFlw | mag.f | Returned |
| HWGC | Turbine power set-point by operator | WSpt | MxVal.f | Setpoint |
| HWGC | Turbine power set-point (measured) | ReqW | mag.f | Returned |

Note that these logical nodes follow the IEC 61850 ruleset, but are from the Statkraft Namespace.

### Bearing measurements – Orbit plot

Distance measurements between the bearing and the shaft are typically done within the bearing systems. The logical nodes relevant to this is SAXD which represents the measurements of axial displacement of the sensors (X, Y or Z direction)

* Measurement values in the three directions shall be modelled with SAXD1.Dsp.mag.f. This includes all settings for the measurements, e.g. TDST.SmpRte (sample rate)
* Instantiation for the different directions is done in the RDS (i.e. BGA1 for X, BGA2 for Y and BGA3 for Z – even if Z is the only TDST within the thrust bearing =A1.JF1.KJ4)
* Note that the value may be the maximum value averaged over a given time (it is often referred to SMAX), this measurement shall be modelled using HBRG16.RdlDsp.mag.f
* Because supervision of the measurements (alarms etc..) is done in accordance with the distance (in mm), the supervision shall be modelled using the SDST (Statkraft Namespace as of now).
* Since the supervision functions trigger mostly on max values from X and Y distance measurements only one instantiation is expected for each bearing.

# Statkraft Extensions

## Signal modelling extensions to IEC 61850-7

The extensions shall, as far as possible, follow the naming conventions and existing short-names. The structure of the Statkraft specific Logical Nodes (LN) shall follow the same rules as the LN in 61850-7.

The Statkraft Namespace, containing all Statkraft-specific logical nodes shall be made available in xml-format to all users, both internal and external.

## Signal modelling extensions to IEC/ISO 81346

Extentions shall be kept to a strict minimum and should only be created with the intent of the new classes being officially added to the 81346 series in a future update of the relevant sub-part. If the new class is rejected during the update, the class should not be used.

The extensions can be found in the attached annex.

# Appendix A - Fabulous signals and where to find them

**Distance**

* Shaft displacement (“origo”) in **x(1)**/y(2)/z(3) direction: =A1.JF1.KJ#/TDST**1** with # the bearing in question (1: Upper Guide Bearing, 2: Lower G. Bearing, 3: Turbine G. Bearing, 4: Thrust bearing)

**Flow**

* Turbine Leakage flow (through turbine cover) =A1.RB1.AE1.JB1/TFLW1.Flw.mag
* Turbine flow through Pelton needle position =A1.RB1.KA1/HNDL.PosPct.mag.f
* Turbine flow through Francis guide vanes position =A1.RB1.KA1/HTGV.PosPct.mag.f

**Frequency**

* Grid =D40.LE1/MMXU1.Hz.mag

**Power**

**Speed**

* Speed of sound in water =A1.RB1/sosTSPD1.Spd.mag

**Pressure**

* Turbine Pressure (upstream), =A1.RB1.BPA1 is the same as valve pressure (downstream) **=A1.KA1.BPA2**. The latter is the preferred term because pressure upstream and downstream the main inlet valve is usually minitored, while draft tube pressure often doesn’t.

A diagram of a valve

Description automatically generated

* The inlet pressure of the Main Inlet valve is also the outlet pressure of the pressure shaft/penstock.

**=A1.KA1.BPA1\* |same function| =C1.JB2.BPA2**

From a functional point of view, the pressure upstream the MIV could be considered more relevant (i.e. it is more likely that this function is what you would be looking for) than the outlet pressure of the penstock. This is why MIV inlet is the preferred RD for this function.

**Miscellaneous**

* Internfeil LPHD.PhyHealth.stVal
* Spenningstilførsel LPHD.PwrSupAlm.stVal
* Bruker mag og ikke instMag pga dødbånd

1. All parts of the standard must be considered in their latest edition. E.g. IEC 81346-1:2009 is not applicable, nor are standards and principles based on outdated edition, such as VGB RDS-pp. [↑](#footnote-ref-2)
2. Can be done in after data aquisition [↑](#footnote-ref-3)