

# TECHNICAL REPORT



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



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2021 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC online collection - [oc.iec.ch](http://oc.iec.ch)

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Preview generated by EVS

## TECHNICAL REPORT



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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 33.200

ISBN 978-2-8322-1062-2

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references .....	10
3 Terms and definitions .....	11
4 Overview .....	11
4.1 General.....	11
4.2 Target group .....	11
4.3 Hydro power domain .....	11
4.3.1 General .....	11
4.3.2 Hydropower plant specific information .....	11
4.4 Thermal power domain.....	14
4.4.1 General .....	14
4.4.2 Steam turbine power plant specific information .....	14
4.4.3 Gas turbine specific information.....	15
4.4.4 Combined cycle power plants .....	16
4.4.5 Coal-fired power plant specific information .....	17
5 Process modelling .....	18
5.1 Reference designation system .....	18
5.1.1 General .....	18
5.1.2 Structuring principles and reference designation system.....	18
5.1.3 Object ownership principle.....	18
5.1.4 The concept of aspects.....	19
5.1.5 The RDS-structure and classification .....	20
5.1.6 Example: Unit 2 main inlet valve with a bypass system .....	21
5.1.7 The top node .....	21
5.2 SCL modelling of the functional structure of a hydropower plant .....	23
5.3 Mapping the SCL Process structure to the reference designation system	
RDS.....	24
5.3.1 General .....	24
5.3.2 Hierarchical mapping of information .....	25
5.3.3 Process object reference design considerations .....	27
5.3.4 Choice of logical node classes.....	27
5.4 The Alpha Valley River System examples .....	27
5.4.1 Introduction .....	27
5.4.2 The Reservoirs .....	29
5.4.3 Hydrometric .....	31
6 SCL:DataType template modelling.....	34
6.1 General.....	34
6.2 LNodeType definition .....	34
6.3 DOType definition .....	35
6.4 DAType and EnumType definition .....	36
6.5 Example using SLVL.....	37
7 SCL:IED modelling .....	37
7.1 General.....	37
7.2 Linking the SCL:IED model to the SCL:process model .....	37

7.3	Referencing the Logical Device.....	37
7.4	SCL:Function element.....	39
8	Communication Modelling.....	39
8.1	General.....	39
8.2	Communication structure in hydro power plants .....	41
8.2.1	General .....	41
8.2.2	Process bus level .....	41
8.2.3	Station Bus.....	42
8.2.4	Enterprise Bus.....	42
8.3	Communication structure in thermal power plants .....	42
9	Modelling of controls .....	46
9.1	General.....	46
9.2	Operational modes for hydropower plants .....	46
9.3	Operational modes for thermal power plants .....	47
9.4	Fundamental control strategies for hydropower plants.....	47
9.5	Joint control modelling examples .....	48
9.5.1	General .....	48
9.5.2	Joint control of active power .....	48
9.5.3	Joint Control of Reactive Power.....	50
9.5.4	Joint Control of Water.....	52
9.6	Scheduling Example .....	53
9.7	Example of application for an excitation system .....	54
9.7.1	General .....	54
9.7.2	Voltage regulation example .....	59
9.7.3	PSS example.....	61
9.8	Example of application for a turbine governor system .....	62
9.8.1	General .....	62
9.8.2	Signal hierarchy.....	62
9.8.3	Basic overview .....	62
9.8.4	Detailed description of used IED structure .....	64
9.9	Example of a braking system .....	71
9.9.1	General .....	71
9.9.2	Brake control with mandatory data objects in LN: HMBR.....	71
9.9.3	Brake control with process indications .....	72
9.10	Example of a heater system.....	72
9.10.1	General .....	72
9.10.2	Example of a LN: KHTR usage .....	73
9.11	Examples of how to reference a start / stop sequencer of a hydropower unit.....	73
9.11.1	General .....	73
9.11.2	Unit sequences definition with IEC 61850 .....	74
9.11.3	Start sequence from a state "stopped" to a state "speed no load not excited" (Sequence 1).....	75
9.11.4	Start sequence from state "speed no load not excited" to state "synchronised" (Sequence 2).....	76
9.11.5	Stop sequence from state "synchronised" to state "speed no load not excited" (sequence 3) .....	78
9.11.6	Shutdown sequence from state " synchronised " to state "stopped" (Sequence 4).....	79
9.11.7	Fast shutdown sequence from state " synchronised " to state "stopped" (Sequence 5).....	82

9.11.8	Emergency shutdown sequence from state " synchronised " to state "stopped" (sequence 6).....	84
9.12	Example of a capability chart representation .....	86
9.12.1	General .....	86
9.12.2	Example of a capability curve .....	86
9.12.3	Example of a Hill chart.....	88
9.12.4	Example of a multi-layer capability chart.....	89
9.13	Pump start priorities of a high-pressure oil system .....	91
9.13.1	General .....	91
9.13.2	Sequence to manage a pump start priorities .....	92
9.13.3	Sequence to manage a pump .....	94
9.14	Examples of how to use various types of curves and curve shape descriptions .....	95
9.15	Examples of voltage matching function .....	96
Annex A (informative)	Electrical single line diagrams of thermal power plants.....	97
Annex B (informative)	System Specification Description for the Alpha 2 power plant.....	100
Annex C (informative)	RDS schema for the Alpha 2 power plant .....	163
Bibliography	.....	169
Figure 1	– Principles for the joint control function.....	12
Figure 2	– Water flow control of a turbine.....	13
Figure 3	– Example of a large steam turbine.....	14
Figure 4	– Simplified example of a large steam turbine power plant with typical control system.....	15
Figure 5	– Example of a gas turbine.....	16
Figure 6	– Example of a combined cycle power plant with one GT and one ST in a multi-shaft configuration.....	16
Figure 7	– Example of a combined cycle power plant with one GT and one ST in a single shaft configuration .....	17
Figure 8	– Example of heat flow diagram of a coal-fired power plant.....	18
Figure 9	– IEC/ISO 81346 ownership principle .....	19
Figure 10	– A system breakdown structure showing the recursive phenomenon of system elements also being systems .....	20
Figure 11	– Three levels of classes within RDS .....	20
Figure 12	– A system breakdown structure for a system of interest.....	21
Figure 13	– Example of an RDS top node implementation.....	22
Figure 14	– SCL process elements are structured according to the RDS Power Supply system designations .....	24
Figure 15	– SCL process elements are structured according to the RDS Construction Works designations.....	24
Figure 16	– IED model (LNs) linked to the SCL Process structure with the Power Supply system profile .....	25
Figure 17	– IED model (LNs) linked to the SCL Process structure with the Construction works profile .....	25
Figure 18	– The Alpha Valley River System example .....	28
Figure 19	– Primary and supporting system to SCL overview .....	29
Figure 20	– Mapping between IEC/ISO 81346 (RDS) and IEC 61850 (SCL) .....	29
Figure 21	– Reservoir locations.....	30

Figure 22 – Mapping of water levels with logical node TLVL .....	31
Figure 23 – Mapping of water levels with logical HLVL .....	32
Figure 24 – Mapping of water levels with logical MHYD .....	32
Figure 25 – Mapping of the rate of discharge with logical node TFLW .....	33
Figure 26 – Mapping of the rate of discharge with logical node HWCL .....	33
Figure 27 – Mapping of the rate of discharge with logical node MHYD .....	34
Figure 28 – The structure of LN SLVL .....	37
Figure 29 – Schematic mapping of the process element to IED .....	38
Figure 30 – Mapping the process element to IED and DataTemplate .....	39
Figure 31 – Bus and services example .....	40
Figure 32 – Hydro bus and services .....	41
Figure 33 – Typical communication structure with two GTs and one ST, with the use of IEC 61850 interface controller .....	43
Figure 34 – Typical communication structure with two GTs and one ST, with IEC 61850 interface of process controllers .....	44
Figure 35 – Typical communication structure with two GTs and one ST, with IEC 61850 interface of process controllers from different manufacturers .....	45
Figure 36 – Typical communication structure with one ST, with IEC 61850 interface of process controllers .....	46
Figure 37 – Joint Control of active power .....	50
Figure 38 – Joint control of reactive power (SCL:Function:Fct2) .....	51
Figure 39 – Example of joint control of water .....	53
Figure 40 – An example of scheduling of active power output .....	54
Figure 41 – Examples of logical nodes used in an excitation system .....	55
Figure 42 – Example of an excitation a functional breakdown .....	57
Figure 43 – Example of logical devices of the regulation part of an excitation system .....	58
Figure 44 – AVR basic regulator .....	59
Figure 45 – Superimposed regulators, power factor regulator .....	59
Figure 46 – Superimposed regulators, over-excitation limiter .....	60
Figure 47 – Superimposed regulators, under-excitation limiter .....	60
Figure 48 – Superimposed regulators, follow up .....	61
Figure 49 – Power system stabilizer function .....	61
Figure 50 – Signal hierarchy .....	62
Figure 51 – Use of Logical Node HGOV with RDS-PS .....	63
Figure 52 – Governor control .....	66
Figure 53 – Flow control .....	67
Figure 54 – Level control .....	68
Figure 55 – Speed control .....	69
Figure 56 – Limitations .....	70
Figure 57 – Actuator control .....	71
Figure 58 – Brake control with mandatory data objects .....	72
Figure 59 – Brake control with indications .....	72
Figure 60 – Oil tank heater using a step controller .....	73
Figure 61 – Sequencer overview .....	74

Figure 62 – An example of a capability curve .....	87
Figure 63 – An example of a Hill chart (five variables) .....	88
Figure 64 – An example of a multi layered capability chart (five dimensions) .....	89
Figure 65 – Graphical representation of the high-pressure oil pumping unit .....	91
Figure 66 – Example of pump priority start logic sequence.....	93
Figure 67 – Example of pump start logic sequence .....	94
Figure 68 – Gate flow correlation .....	95
Figure 69 – Turbine correlation curve.....	95
Figure 70 – Example of traditional voltage adjusting pulses .....	96
Figure 71 – Example of mapping of the pulse time in IEC 61850 .....	96
Figure 72 – Example of an IEC 61850 voltage adjusting command .....	96
Figure A.1 – Typical Single Line Diagram of a steam turbine power plant .....	97
Figure A.2 – Typical Single Line Diagram of a gas turbine power plant or a combined cycle power plant in single shaft configuration .....	98
Figure A.3 – Typical Single Line Diagram of a combined cycle power plant in multi- shaft configuration with separate step-up transformers .....	99
Figure A.4 – Typical Single Line Diagram of a combined cycle power plant in multi- shaft configuration with 3-winding step-up transformers .....	99
Table 1 – IEC/ISO 81346 aspects .....	19
Table 2 – Mapping SCL to RDS-PS.....	26
Table 3 – Reservoir descriptions.....	30
Table 4 – Examples of water level measurements.....	31
Table 5 – Examples of the rate of discharge measurements.....	33
Table 6 – Functional breakdown of an RDS component with functions for joint control.....	48
Table 7 – Joint Control active power setpoints data flow .....	50
Table 8 – Joint Control reactive power setpoints data flow .....	52
Table 9 – Joint Control flow setpoints data flow .....	53
Table 10 – Functional breakdown of a Process child RDS component with functions .....	56
Table 11 – Functional breakdown of a Process child RDS component with functions .....	64
Table 12 – Alpha2 Typical sequences .....	74
Table 13 – Capability table .....	87
Table 14 – Mapping of Hill charts.....	88
Table 15 – Five-dimensional capability chart.....	90
Table 16 – Alpha2 Typical pump sequences .....	91



## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**COMMUNICATION NETWORKS AND SYSTEMS  
FOR POWER UTILITY AUTOMATION –****Part 7-510: Basic communication structure – Hydroelectric power plants,  
steam and gas turbines – Modelling concepts and guidelines**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 61850-7-510 has been prepared by IEC technical committee 57: Power systems management and associated information exchange. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Process modelling according to IEC 61850-6:2009, including IEC 61850-6:2009/AMD1:2018.
- b) Examples of application of Reference Designation System together with the process modelling, in particular application of IEC/ISO 81346.
- c) Description of modelling related to Steam- and Gas turbines.
- d) Annexes with examples of application of SCL according to the examples in the Technical Report.

- e) The dynamic exchange of values by using polling, GOOSE, Reporting or Sampled Values is no longer included in the Technical Report.
- f) Updated examples of application of SCL:Process and IED modelling applying the Logical Nodes defined in IEC 61850-7-410:2012, including IEC 61850-7-410:2012/AMD1:2015.

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

DTR	Report on voting
57/2391/DTR	57/2432/RVDTR

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

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

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

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 document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

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

**IMPORTANT** – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

## 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, steam or gas turbine 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 document.

This document applies the SCL Process element structure for modelling of the processes.

Examples of application of SCL Code according to the modelling examples in this document are presented in Annex B and Annex C.

## COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

### **Part 7-510: Basic communication structure – Hydroelectric power plants, steam and gas turbines – Modelling concepts and guidelines**

#### **1 Scope**

This part of IEC 61850, which is a technical report, 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 for power plants. It is however not obvious from the standard how the modelling concepts can be implemented in actual power plants.

This document explains how the data model and the concepts defined in the IEC 61850 standard can be applied in Hydro; both directly at the process control level, but also for data structuring and data exchange at a higher level. Application of the data model for Thermal is limited to power evacuation (in principle the extraction of the generated electrical power) and the prime mover shaft and bearing system. The interfaces of the fuel and steam valves are modelled for the purpose of process control.

Communication services, and description of the use of mappings of the IEC 61850 data model to different communication protocols, are outside the scope of this document.

#### **2 Normative references**

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

IEC 61362:2012, *Guide to specification of hydraulic turbine governing systems*

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

IEC 61850-7-3:2010, *Communication networks and systems for power utility automation – Part 7-3: Basic communication structure – Common data classes*  
IEC 61850-7-3:2010/AMD1:2020

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

IEC 61850-7-410:2012, *Communication networks and systems for power utility automation – Part 7-410: Basic communication structure – Hydroelectric power plants – Communication for monitoring and control*  
IEC 61850-7-410:2012/AMD1:2015

ISO 81346-10:—<sup>1</sup>, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 10: Power Supply systems*

### 3 Terms and definitions

No terms and definitions are listed in this document.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

## 4 Overview

### 4.1 General

This clause describes the target group of the document and introduces the modelled power plant domain.

### 4.2 Target group

This document targets engineers and system integrators working with control and modelling of Hydro Power and Thermal Power plant processes.

The document gives an overview of the process control in the different contexts and provides examples on how to structure and name the systems in a model, and how to use the DataObjects in control and supervision of the power plant processes. The document provides guidance on how to apply the IEC 61850 data model defined in IEC 61850-7-410.

### 4.3 Hydro power domain

#### 4.3.1 General

In hydro power, the power is derived from the potential energy difference of water transferred from a higher to a lower level through a rotating turbine. The turbine transfers the power from the flowing water to a rotating shaft, and a generator transforms the mechanical power into electrical power. To handle the water level and the flow of water several types of gates are used.

#### 4.3.2 Hydropower 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 corresponds to the shaft torque to keep the generator synchronised to the grid.

Figure 1 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.

---

<sup>1</sup> Under preparation. Stage at the time of publication: ISO/DIS 81346-10:2021.