



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. The main document types developed by IEC are described in greater detail at 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 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:—¹, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 10: Power Supply systems*

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