

TECHNICAL REPORT



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



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2012 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
Fax: +41 22 919 03 00
info@iec.ch
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 corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you 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It also gives information on projects, replaced and withdrawn publications.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

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

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - 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: csc@iec.ch.

TECHNICAL REPORT



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE

ICS 33.200

ISBN 978-2-88912-007-9

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

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	9
3 Overall communication structure in a hydropower plant	10
3.1 Abstract communication structure.....	10
3.2 Communication network	10
3.3 Operational modes	12
3.4 Fundamental control strategies	13
3.5 Hydro power plant specific information	14
4 Structuring control systems	16
4.1 Basic use of logical nodes	16
4.2 Logical device modelling	16
4.3 Example of application for an excitation system	19
4.3.1 General	19
4.3.2 Voltage regulation example	22
4.3.3 PSS example.....	24
4.4 Example of application for a turbine governor system	25
4.4.1 Conditions of this example.....	25
4.4.2 Signal hierarchy	25
4.4.3 Basic overview	26
4.4.4 Detailed description of used structure.....	28
4.5 Examples of how to reference a start / stop sequencer of a unit	34
4.5.1 General	34
4.5.2 Unit sequences definition with IEC 61850.....	34
4.5.3 Start sequence from a state “stopped” to a state “speed no load not excited” (included in LD named “SEQ_SnINexStr”)	35
4.5.4 Start sequence from state “speed no load not excited” to state “generation” (included in LD named “SEQ_SnIExcStr” and “SEQ_GenStr”)	37
4.5.5 Stop sequence from state “generator” to state “speed no load not excited” (included in LD named “SEQ_GridFaultStop”)	38
4.5.6 Shutdown sequence from state “generator” to state “stopped” (SEQ_NormalStop)	40
4.5.7 Quick shutdown sequence from state “generator” to state “stopped” (SEQ_QuickStop)	42
4.5.8 Emergency shutdown sequence from state “generator” to state “stopped” (SEQ_EmgStop)	45
5 Variable speed system example	47
5.1 Example of block diagrams and logical nodes of variable speed pumped storage system.....	47
5.2 Example of application for an excitation system of variable speed pumped storage.....	49
5.2.1 General	49
5.2.2 Automatic power regulator example	49

5.2.3	Power detector example	50
5.2.4	Gate pulse generator example	50
5.3	Example of governor system	51
5.3.1	Guide vane opening function example	51
5.3.2	Guide vane controller example	52
5.3.3	Speed controller example	53
5.3.4	Optimum speed function example	53
5.4	Example of how to reference a start / stop sequencer for variable speed pumped storage system	54
5.4.1	Unit sequences definition for conventional and variable speed pumped storage	54
5.4.2	Start sequence from a state "Stopped" to a state "Synchronous Condenser (SC) mode in pump direction"	55
5.4.3	Start sequence from a state "Synchronous Condenser (SC) mode in Pump direction" to a state "Pumping"	56
5.4.4	Mode Transition sequence from a state "Pumping" to a state "Synchronous Condenser (SC) mode in Pump direction"	57
5.4.5	Sequence from a state "pumping" to a state "stopped"	58
5.4.6	Emergency shutdown sequence from a state "pumping" to a state "stopped"	60
5.4.7	Shutdown sequence from a state "Synchronous Condenser (SC) mode in pump direction" to a state "stopped"	61
5.4.8	Emergency shutdown sequence from a state "Synchronous Condenser (SC) mode in pump direction" to a state "stopped"	62
6	Pump start priorities of a high pressure oil system	64
6.1	Example of a pump start priority for high pressure oil system	64
6.1.1	General	64
6.1.2	Sequence to manage a pump start priorities	64
6.1.3	Sequence to manage a pump	67
7	Addressing structures, examples of mapping	68
7.1	Basic principles (IEC 61850-6)	68
7.2	Decentralised ICD file management	68
7.3	Centralised ICD file management	69
7.4	Power plant structure – ISO/TS 16952-10 (Reference Designation System – Power Plants)	70
7.4.1	ISO/TS 16952-10 (Reference Designation System – Power Plants)	70
7.4.2	Example 1: Wicket gate indications	73
7.4.3	Example 2: 3 Phase Measurement	74
7.4.4	Example 3: Speed Controller	74
7.4.5	Example 4: Speed measurement with some thresholds	75
7.4.6	Example 5: Common turbine information	76
8	Examples of how to use various types of curves and curve shape descriptions	76
9	Examples of voltage matching function	80
	Bibliography	82
	Figure 1 – Structure of a hydropower plant	10
	Figure 2 – Simplified network of a hydropower plant	12
	Figure 3 – Principles for the joint control function	14
	Figure 4 – Water flow control of a turbine	15

Figure 5 – Pressurised oil systems with LD suffix and with LN prefix.....	18
Figure 6 – Examples of logical nodes used in an excitation system.....	19
Figure 7 – Example of logical devices of the regulation part of an excitation system	21
Figure 8 – AVR basic regulator	22
Figure 9 – Superimposed regulators, power factor regulator	22
Figure 10 – Superimposed regulators, over-excitation limiter	23
Figure 11 – Superimposed regulators, under-excitation limiter	23
Figure 12 – Superimposed regulators, follow up.....	24
Figure 13 – Power system stabilizer function	24
Figure 14 – Signal hierarchy	25
Figure 15 – Use of Logical Node HGOV	27
Figure 16 – Governor control	29
Figure 17 – Flow control	30
Figure 18 – Level control	31
Figure 19 – Speed control.....	32
Figure 20 – Limitations	33
Figure 21 – Actuator control.....	33
Figure 22 – Sequencer overview	34
Figure 23 – Typical block diagram in pumping operation	47
Figure 24 – Typical block diagram in generating operation.....	48
Figure 25 – Typical block diagram in synchronous condenser mode	48
Figure 26 – Automatic power regulator.....	49
Figure 27 – Power detector.....	50
Figure 28 – Gate pulse generator	50
Figure 29 – Guide vane opening function	51
Figure 30 – Guide vane controller	52
Figure 31 – Speed controller.....	53
Figure 32 – Optimum speed function.....	53
Figure 33 – Sequencer overview	54
Figure 34 – Graphical representation of the high pressure oil pumping unit.....	64
Figure 35 – Example of pump priority start logic sequence.....	66
Figure 36 – Example of pump start logic sequence	68
Figure 37 – Exchange of ICD files between system configurators	69
Figure 38 – Static Data exchange with vendor's configuration tool	70
Figure 39 – Tree structure of a system using RDS-PP	72
Figure 40 – Hydraulic correlation curve.....	77
Figure 41 – Turbine correlation curve	80
Figure 42 – Example of traditional voltage adjusting pulses	80
Figure 43 – Example of mapping of the pulse time in IEC 61850.....	80
Figure 44 – Example of an IEC 61850 voltage adjusting command	81
Table 1 – IED within a simplified single unit power plant	11
Table 2 – Recommended LN prefixes	16

Table 3 – Logical device structure.....	20
Table 4 – Logical device names for functions.....	26
Table 5 – Typical sequences.....	35
Table 6 – Logical device names for sequence function groups	54
Table 7 – RDS-PP designation codes for Hydropower use	71

This document is a preview generated by EVS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**COMMUNICATION NETWORKS AND SYSTEMS
FOR POWER UTILITY AUTOMATION –****Part 7-510: Basic communication structure –
Hydroelectric power plants –
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.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

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

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

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

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

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

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

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.

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

INTRODUCTION

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

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

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

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

1 Scope

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

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

3 Overall communication structure in a hydropower plant

3.1 Abstract communication structure

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

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

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

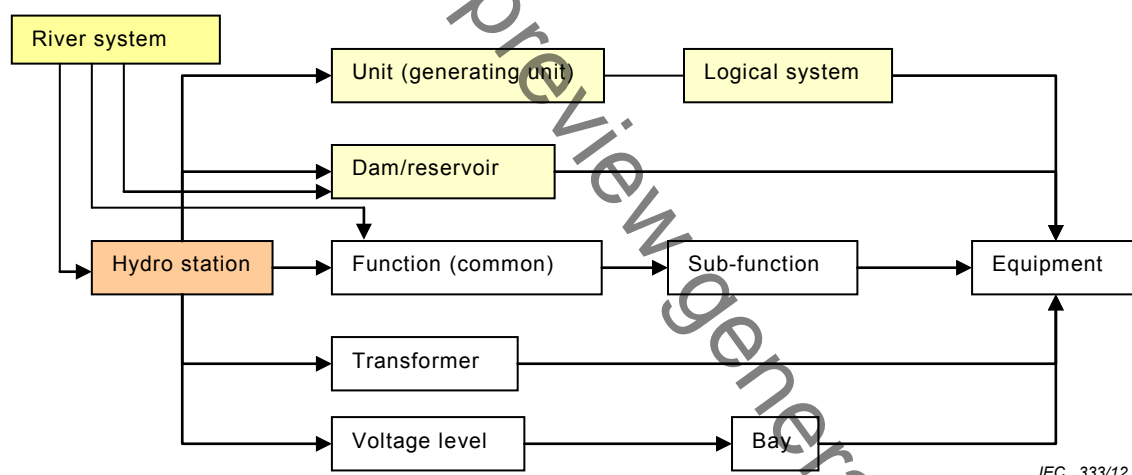


Figure 1 – Structure of a hydropower plant

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

3.2 Communication network

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