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NORME INTERNATIONALE

Technical guidelines for smart hydroelectric power plant

Lignes directrices techniques d'une centrale hydroélectrique intelligente

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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TECHNICAL GUIDELINES FOR SMART HYDROELECTRIC POWER PLANT

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The text of this International Standard is based on the following IEC documents:

Draft	Report on voting
4/448/FDIS	4/451/RVD

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 International Standard is English.

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- withdrawn,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

INTRODUCTION

In the past few decades, the widespread use of automatic control systems in hydroelectric power plants, including computer-based control systems, brought a number of benefits including improved work efficiency, enhanced reliability and real-time capability, as well as optimized Operating Expense (OPEX).

Nowadays, tremendous changes occur in hydroelectric power plants and their external environment, thereby posing challenges in operation, maintenance, scheduling and management.

The evolution of power grid codes and electricity markets, the growing sensibility of the public about the environmental impact and such risks generated by operating hydroelectric power plants as control of flow variation downstream, and the increasing demand for multi-purpose utilization of water resources lead to the increasing difficulty in generation scheduling decision-making. Giant unit/plant capacity enhances the role of hydroelectric power plants in maintaining grid stability. The rationale for developing cascade hydroelectric power plants has been widely recognized, as integrated operation and maintenance requirements have become increasingly prominent. The latest technologies such as cloud computing, Artificial Intelligence (AI), big data, Internet of Things (IoT), mobile terminal, and Virtual Reality (VR) are triggering a revolution in hydroelectric power plant automation systems.

Newly installed, renovated and partially refurbished hydroelectric power plants and remote control centers need innovative technologies to strengthen information sharing and coordination among equipment and applications. With the goal to realize multi-dimensional information sensing, comprehensive data display, interactive applications and intelligent warnings and decisions, and to cope with the challenges of operation, maintenance, dispatching and management, innovation involving multiple elements regarding system architecture, information model, integrated standards, software structures, business procedure, applications, optimized models, etc., should be conducted. The innovation based on such elements is multi-dimensional, flexible and open to different demands, rather than a mere improvement of certain technologies, so that hydroelectric power plants and remote control centers where those innovations are put into use can be called a smart hydroelectric power plant.

In the present document, open architecture has been proposed for a smart hydroelectric power plant and technical requirements for each part have been specified, thus improving the safe, reliable, efficient and economic operation of hydroelectric power plants/remote control centers, enhancing the interaction with the smart grid and facilitating ecological and environmental responsibility. The overall system structure and functionality are mainly determined by the scales, types, importance and complexity of specific smart hydroelectric power plants. The document describes a representative set of architectures, components and functionalities. The appropriate selection, extension or modification tailored to the needs of a specific power plant shall be chosen in a specific project. The document can be used as a reference for engineers of hydroelectric power plants/remote control centers, consultants or automation system vendors in helping the design of smart hydroelectric power plants, development of hardware and software products, implementation of projects, and compilation of related documents.

TECHNICAL GUIDELINES FOR SMART HYDROELECTRIC POWER PLANT

1 Scope

This document describes the integrated control and management of smart hydroelectric power plants and groups of plants using the latest proven and widely accepted digital equipment. The descriptions are applicable to all types of hydroelectric power plants except tidal and ocean power plants.

Based on internationally standardized communication models, this document incorporates guidelines for communication networks, sensors, local monitoring and control equipment, Integrated Control and Management Platform (ICAMP) as well as intelligent applications. In addition, special attention is also given to cyber security.

This document considers the future structure of completely digitalized power plants equipped with digitalized sensors and actuators as well as the intelligent control and management of power plants with existing instrumentation.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. ISO, IEC, and IEEE 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
- IEEE Standards Dictionary Online: available at: http://dictionary.ieee.org

3.1
smart hydroelectric power plant
hydroelectric power plant or group of plants which is featuring digitalized information, networked communication, standardized integration, interactive applications, optimized operation, and intelligent decision

Note 1 to entry: Smart hydroelectric power plant uses Intelligent Electronic Devices (IEDs) and intelligent equipment for the automatic acquisition, measurement, control, protection and other basic functions, and possesses economic operation, analysis evaluation & decision support, security and safety interaction and other intelligent applications based on the Integrated Control and Management Platform (ICAMP) in compliance with grid and regulatory requirements.

3.2
process level
level of the architectural model which realizes data acquisition and command execution throughout the power generation process, typically consists of transducers/smart transducers, intelligent terminal, intelligent equipment, etc.

3.3
unit level
level of the architectural model which realizes monitoring, control and protection of equipment related to different units according to the pre-set strategy, typically consists of various IEDs

3.4
plant level
level of the architectural model which realizes monitoring, control, analysis, etc. for a plant, typically consists of computers, network equipment, ICAMP, and various intelligent applications, whose equipment is deployed in different physical locations such as a central control room and server room

3.5
group-of-plants level
level of the architectural model which realizes monitoring, control, analysis, evaluation, decision-support etc. for a group of plants, typically consists of computers, network devices, ICAMP, and various intelligent applications including economic operation, condition-based maintenance of a generation fleet, emergency command support, etc. whose devices are distributed in different physical locations of a remote control center such as a control room, reservoir scheduling duty office and server room

3.6
process bus
communication network which connects process-level and unit-level devices

3.7
plant bus
communication network which connects devices within the unit level and plant level, and connects unit-level to plant-level devices

3.8
group-of-plants bus
communication network which connects devices within the group-of-plants level and connects plant level to group-of-plants level devices

3.9
system
collection of parts and relationships among these parts that may be organized to accomplish some purposes

[SOURCE: IEC 62357-1:2016, 3.1.3]

3.10
control zone
zone with applications of real-time monitoring and control functions

3.11
non-control zone
zone with applications which are potentially required for the generation process, but not involved in control directly.

3.12
production control zone
zone consisting of control zone and non-control zone

3.13
management information zone
collection of management information systems outside the production control zone for power generation utilities

3.14
Intelligent Electronic Device
IED
device within the unit level or process level incorporating one or more processors with the capability of receiving or sending data/controls from or to an external source (for example, electronic multi-function meters, digital relays, controllers)

3.15
smart transducer
analog or digital sensor or actuator combined with a microprocessor, a signal conditioning unit and a communication interface

3.16
intelligent terminal
IED which realizes data acquisition or command output, supports unified information model, has capabilities of self-diagnosis and self-recovery within the process level, connecting various sensors of pressure, flow, temperature, position, status, etc. or actuators through cables, as well as connecting other IEDs within the unit level through process bus, usually deployed near terminal boxes or equipment

3.17
merging unit
interface unit that accepts multiple analogue CT/VT and produces multiple time synchronised IEC 61850-9-2 compliant frames to provide data communication via the logical interface 4

[SOURCE: IEC TS 61850-2:2019, 3.109]

3.18
intelligent equipment
integration of electromechanical equipment or hydraulic facilities with electronic devices and transducers, featured with digital measurement, networked communication, unified information model, self-diagnosis and interactive information, and supports functions like monitoring, control and protection

3.19
data management
function which realizes uniform storage and management of models and data, and provides uniform data access service interfaces

3.20
basic service
technologies realizing background functionalities, for example, data communication, data processing, data access, chart service, log management, authority management, task management, workflow management, process management, Geographic Information System (GIS), alarms, expert system etc.

3.21
basic application
software realizing basic business functionalities of hydroelectric power plants, for example, supervision and control, reservoir scheduling automation, plant condition monitoring, dam safety monitoring, comprehensive information display and analysis, mobile application, etc.

3.22
Integrated Control and Management Platform
ICAMP
software platform which consists of data management, basic services and basic applications, deployed separately in the control zone, non-control zone and management information zone, supporting the unified modeling of devices and other resources in hydroelectric power plants, providing standard interfaces and services for the integration of equipment, systems and intelligent applications, realizing data sharing, centralized control & management and collaborative interaction

3.23
intelligent application
application serving decision support of hydroelectric power plants, such as economic operation, Condition-based Maintenance (CBM), emergency command support, dam safety analysis and evaluation, intelligent alarm, etc., which is accomplished by modules deployed on the ICAMP or individual decision support system

3.24
Automatic Generation Control
AGC
capability to control the power output of selectable units in response to total plant/group-of-plants output, tie-line power flow, and power system frequency

3.25
Automatic Voltage Control
AVC
capability to control a specific power system voltage, via adjustment of unit excitation within the limits of unit terminal voltage and reactive power (VAR) capability

3.26
joint control
functions that enable the automatic control to coordinate the power/water across the system, e.g. AGC, AVC, water control of power plants or reservoirs

4 General principles

The general principles of smart hydroelectric power plants are as follows:

1) With the process bus, plant bus and group-of-plants bus as backbone network, a smart hydroelectric power plant should adopt a "level and zone" architecture. Furthermore, it should be based on smart transducers and IEDs within the process and unit levels, ICAMP within the plant level or group-of-plants level as the software platform, and intelligent applications deployed in correspondent zones as business requirements, promoting the safe and reliable operation of hydroelectric power plants. Before defining the final system architecture in a power plant, a careful risk analysis should be conducted on the dependencies and consequences of failures, etc. An analysis should also be conducted on maintenance needs, costs, effectiveness, etc., to meet the requirements in practical operations and those of the supervisory authorities.
2) An information model with the capability of self-description should be adopted. Such an information model enables IEDs and ICAMP to identify measured data correctly. The information model makes application functions independent of communication protocols. International standards described in 5.3 should be adopted in the model definition for electrical and mechanical equipment, hydraulic facilities, and functions, thus realizing object-oriented data management and enhancing the capability of fulfilling data sharing, application collaborations and intelligent data analysis.

3) Network communication should be adopted for information transmission. From the perspective of project practice and cost-effectiveness, smart transducers or "traditional transducer plus intelligent terminals" should be considered while highly efficient process, plant and group-of-plants buses should be used. Wireless networking (e.g. cellular data, Zigbee, LORA) can also be considered to increase system flexibility and reduce system installation and commissioning.

4) IEDs should embody interoperability. Interoperability is the ability of two or more devices either from the same vendor or from different vendors to exchange information for the correct execution of specified functions; it is the ability to operate in the same network or the same communication path sharing information and commands.

5) Smart hydroelectric power plants should realize integrated operation and management. Based on the ICAMP, it should facilitate integrated monitoring and data sharing for such basic applications as supervision and control, reservoir scheduling automation, plant condition monitoring, dam safety monitoring, protection information management and basic support systems like Closed Circuit Television (CCTV) and firefighting. Comprehensive data analysis and interactions among applications should be realized to promote the operation reliability and efficiency of a single power plant or group-of-plants. Integrated operation and management should meet demands such as unattended operation, coordinated dispatching of water resources and electricity, and remote fault diagnosis.

6) Smart hydroelectric power plants should provide intelligent decision support. Based on the features of a specific plant or group-of-plants, intelligent applications like condition-based maintenance decision support, emergency command support, dam safety analysis and evaluation, and intelligent alarm should be deployed selectively. Expert knowledge bases should be established and expanded continuously. Various models of analysis, evaluation and optimization should be built to improve the optimized decision-making capability.

7) Smart hydroelectric power plants should be featured with openness and flexibility. An open and flexible architecture conforming to well-established international standards and compatible with conventional automation devices and IEDs should be adopted and be able to meet the need for thorough or partial refurbishment of smart hydroelectric power plants. ICAMP should be equipped with standard and open interfaces, thereby providing data and service access to third-party intelligent applications under the condition of cyber security.

5 System architecture

5.1 Architecture model

IEC 62357 proposes the Smart Grid Architecture Model (SGAM). According to SGAM, the domains are divided into generation, transmission, distribution, Distributed Energy Resources (DER) and customer premises. The smart hydroelectric power plant is an important part of the smart grid and belongs to the generation domain. The smart hydroelectric power plant architecture model is shown in Figure 1.

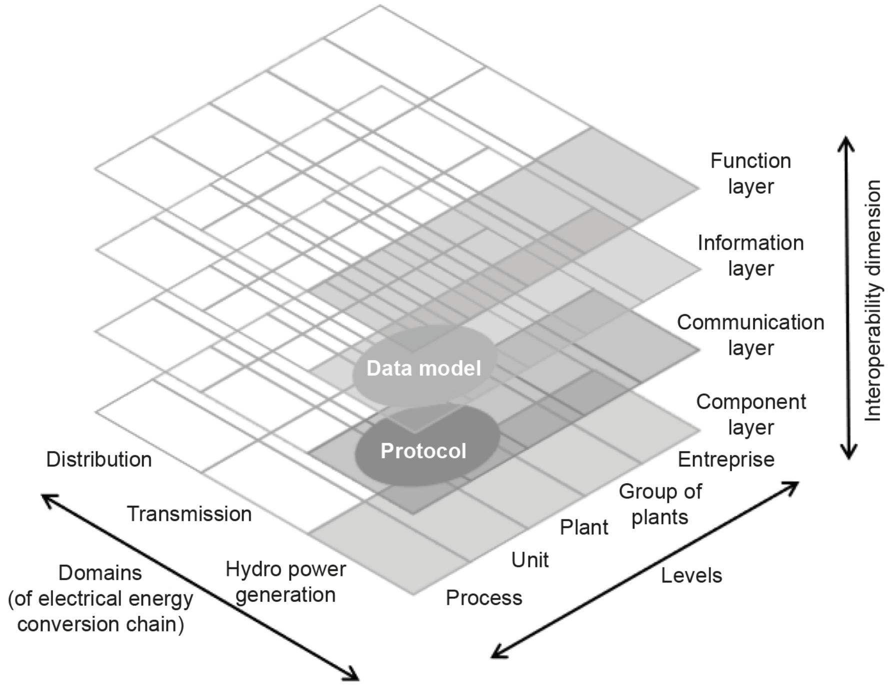

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Figure 1 – System architecture model of a smart hydroelectric power plant

NOTE "Levels", "Unit", "Plant", "Group-of-plants" in this document correspond to "Zones", "Field", "Station" and "Operation" in IEC 62357 individually. The control center of the group is included in "Group-of-plants".

This document	IEC 62357
Levels	Zones
Unit	Field
Plant	Station
Group-of-plants	Operation

In the context of Clause 5, a system is a boundary which includes all layers of the architecture model of a smart hydroelectric power plant. Besides the domains of the electric energy conversion chain, the system architecture model of a smart hydroelectric power plant, as shown in Figure 1, is divided into two additional dimensions: for the first dimension based on the hierarchy of operation and management, the architecture model is divided into process level, unit level, plant level, and group-of-plants level, and each level is described in 5.2.2. The enterprise level is not included in the scope of this document. The process and the unit levels realize local control, the plant level realizes centralized control, and the group-of-plants level realizes off-site control. For the second dimension based on interoperability, the architecture model is divided into component layer, communication layer, information layer and function layer. The four layers are described below.

The component layer specifies the physical components involved in a smart hydroelectric power plant. It includes primary equipment, smart transducers, intelligent terminals, IEDs (generally located within the process and unit levels), network infrastructure (wired and wireless communication connections, routers, switches and firewalls), and any kinds of computers.

The communication layer describes mechanisms and protocols for the interoperable exchange of information between components in the context of the underlying functions, services and related information objects or data models.