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# INTERNATIONAL STANDARD

colour inside

## Internet of things (IOT) – Wireless sensor network system supporting electrical power substation



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CONTENTS

# INTERNET OF THINGS (IOT) – WIRELESS SENSOR NETWORK SYSTEM SUPPORTING ELECTRICAL POWER SUBSTATION

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

| FDIS | Report on voting |
|---|---|
| JTC1-SC41/163/FDIS | JTC1-SC41/176/RVD |

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

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# INTRODUCTION

The data collected from various types of electrical equipment is sparsely located, and on-line transmission of the data helps to collaboratively aggregate and analyse them in real-time. Transitioning to the smart electrical power substation using wireless communication among the sensor nodes – i.e. wireless sensor network (WSN) – requires systems architecture provisioning automated data collection from the electrical equipment, which allows collaborative data processing, sends automatic alerts, provides preventive actions, and potentially takes corrective actions for certain situations.

Electrical power substation communications should be designed to support scalability, interoperability, autonomous fault correction, and other key attributes. The intelligent wireless sensor network (iWSN) is inherently flexible and scalable in its capabilities and in operations including in the size of its converge areas; however, depending on the geographical (e.g. urban, suburban, remote location) and structural (both natural and man-made) situations, the installation architecture should ensure the fidelity of all sensor nodes' wireless connectivity. Furthermore, the WSNs can support either distributed or decentralized network architecture. The wired substation network typically uses high-availability seamless ring (HSR) and parallel redundancy protocol (PRP) protocols (see IEC 62439-3, IEC 61850-8-1 and IEC 61850-9-2) to provide seamless failover against failure of any network component. For the iWSN, it is also important to have the key iWSN network components (e.g. sensor nodes) from data communication failure. Therefore it is important to select wireless sensor network architecture for a substation which overcomes the potential issue of a single point of failure in the wireless sensor network, for example, by installation architecture, the use of PRP to improve packet loss and timing behaviour in wireless network, or a combination of these.



This document introduces iWSN as a system which helps to make the power substation smarter, which is compatible with IEC 61850. In the past, wireless communication was thought to be unreliable and ineffective over long distances. With the advancements in communication technologies in the last decade, the wireless communications have given rise not only to wireless meshed systems, multi-hop and self-healing networks, but also to various low-power protocols having high network/communication security standards. Additionally, different network topologies with effective wireless signal routing algorithms have improved range and reduced power consumption while minimizing frequency of communication channel error. These improvements can be leveraged to form a highly reliable communication network for the electrical power substation.



The existing applications of the WSNs in smart grid include, but are not limited to, automatic meter reading, remote system monitoring and control, equipment fault diagnostics, distribution automation, outage detection, line fault and electronic fault detection, underground cable system monitoring, towers and poles monitoring, conductor temperature and dynamic thermal rating. However, the realization of these existing and envisioned WSN-based smart grid applications is hindered by not having uniform sensing data formats, data interfaces, etc. Although some sensor communication systems are not compatible with the devices from different equipment manufacturers, most intelligent electronic devices used in electrical power substations are interoperable, through the use of standard protocols, for example, IEC 61850 GOOSE, TCP, UDP, etc., and standards related to the common information model (CIM) defined by IEC 61970 and IEC 61968. For cases where new types of sensors (either existing or newly developed) have not adopted IEC 61850, they may be used with an intelligent wireless sensor network (iWSN) system[1][2] because the iWSN system interfaces can act as an adaptor for the sensors and the rest of the systems.

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1 Wireless technology in general is not suitable for the transmission of mission critical data such as sampled measured values according to IEC 61850-9-2 or trip signals for circuit breakers due to the possible interference of electromagnetic radiation caused by arc-flashes (e.g. in case of an internal fault or switching operations inside a substation) with the radio signals of wireless sensors.

2 Any data commonly sent over layer 2 broadcast (e.g. GOOSE) are not suitable for transmission over wireless networks due to the unavailability of corresponding broadcast features.

The main purpose of wireless sensor network applications for electrical power substations is to improve the capability of acquiring, monitoring, processing, and maintaining the data and information from the power equipment. A wireless sensor network (WSN) is characterized by flexible deployment, device collaboration and low-cost implementation, and WSN realizes efficient monitoring of the smart grid systems and subsystems. By enabling the monitoring and controlling capabilities by installing wireless sensor nodes on critical power grid equipment, reliable and real-time online management of this equipment can be accomplished.

Electrical power substation is one of the most important building blocks of the smart grid. The monitoring and control systems in electrical power substations acquire current, voltage, status and other parameters from their primary equipment, and also data from their environment. The information from the measurement systems provides the basis for integrated applications, enabling the transformation of a conventional electrical power substation to a smart electrical power substation, especially when considering the use of the IEC 61850 series, iWSN and other information technologies. In addition to the substation equipment's (wired) connectivity, which is likely based on the IEC 61850 series, the iWSN system will provide additional benefits to collect, process, and transmit data/information about power substation equipment and its environment. An effective and efficient sensing system can be achieved by an iWSN system which takes the role of a data/information measurement and collection system. The concept of the iWSN system provides functions, such as automatic data collection and aggregation, collaborative information processing (e.g. data/information fusion), data analysis, and alarming, and other functional applications that enable the intelligence or smartness of the system that the iWSN system is monitoring.

The information collected in an electrical power substation about the equipment state and the flow of electricity provides the electricity providers with a clearer view and better control over the electrical power substation. Among the many add-values that the iWSN brings compared to the wired installation, one of them is the migration to the no-wire installation as all the sensor nodes are powered by batteries and the data is transmitted via the wireless communication links of the iWSN. A wireless sensor network that is able to communicate with the utility provider's control system by sharing the collected information with the existing networks becomes an attractive technology to deploy in an electrical power substation in order to collect required and critical information.



This document is built upon ISO/IEC 29182 (Sensor Network Reference Architecture) and ISO/IEC 30101 (sensor network and its interfaces for smart grid systems), IEC 61850 (communication networks and systems for power utility automation), and ETSI's and NIST's work in smart grid, and extends ISO/IEC 29182 and ISO/IEC 30101 to the application standard of the sensor network that supports the electrical power substations.

The iWSN system uses wireless sensor networks for power substations including substation, equipment, facility, environment, etc. The existing communication protocols specified in IEC 61850-8-1 and IEC 61850-9-2 can be used within power substation, or IEC 61850-8-2 can be used over public network. This document provides the iWSN system's infrastructure from System and Communications Views and also specifies the iWSN system's technical requirements to realize and support the smart electrical power substation. Electrical power substations with sensor networks use advanced information and communication technologies in order to improve the efficiency, reliability, and security of their components and services.

# INTERNET OF THINGS (IOT) – WIRELESS SENSOR NETWORK SYSTEM SUPPORTING ELECTRICAL POWER SUBSTATION

## 1 Scope

This document specifies

– intelligent wireless sensor network (iWSN) from the perspectives of iWSN's system infrastructure and communications internal and external to the infrastructure, and

– technical requirements for iWSN to realize smart electrical power substations.

## 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 61000-4-39, *Electromagnetic compatibility (EMC) – Part 4-39: Testing and measurement techniques – Radiated fields in close proximity – Immunity test*

IEC 61326-1, *Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements*



IEC 61850-3, *Communication networks and systems for power utility automation – Part 3: General requirements*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

**3.1**
**control subsystem for sensor network**
**CSSN**
platform together with all the sensor nodes communicated to it with networks, including the rules for control, for communication and for management among application processes of sensor network

[SOURCE: IEC 60050-732:2014, 732-10-02, modified – In the definition, "home network", "devices" and "attached to it" have been replaced by "platform", "sensor nodes" and "communicated to it with networks", respectively, and "of sensor network" has been added at the end.]

**3.2**
**control subsystem for power substation**
**CSPS**
infrastructure together with all the equipment attached to it, including the rules for control, for communication and for management among application processes of a power substation

[SOURCE: IEC 60050-732:2014, 732-10-02, modified – In the definition, "home network" and "devices" have been replaced by "infrastructure" and "equipment", respectively, and "of a power substation" has been added at the end.]

**3.3**
**data acquisition functional subsystem**
**DAFS**
subsystem for gathering required data from a group of sensors, and assembling them into messages for delivery to another component

[SOURCE: IEC 60050-721:1991, 721-18-64, modified – In the definition, "a facility", "small quantities of" and "a nominated group of addresses" have been replaced by "subsystem", "required" and "a group of sensors", respectively, and "a single message" and "nominated address" have been changed to "messages" and "component", respectively.]

**3.4**
**intelligent wireless sensor network**
**iWSN**

system of spatially distributed sensor nodes interacting with each other using wireless communication technology and, depending on applications, possibly with other infrastructure in order to acquire, process, transfer, and provide information extracted from its environment with a primary function of information gathering, analysing, fusing, and possible control capability to support the intelligent services based on the application scenarios and users



[SOURCE: ISO/IEC 29182-2:2013, 2.1.6, modified – In the definition, "using wireless communication technology" and "analysing, fusing," have been added, and "to support the intelligent services based on the application scenarios and users" has been added at the end.]

**3.5**
**sensor network for electrical power substation**
system of spatially distributed sensor nodes interacting with each other and, depending on electrical power substation applications, possibly with other infrastructure in order to acquire, process, transfer, and provide information extracted from electrical power substation's equipment and environment with a primary function of information gathering and possible control capability

[SOURCE: ISO/IEC 29182-2:2013, 2.1.6, modified – In the definition, "electrical power substation" has been added in front of applications, and "its environment" has been replaced by "electrical power substation's equipment and environment".]

**3.6**
**smart electrical power substation**
part of an electrical system, confined to a given area, mainly including ends of transmission or distribution lines, electrical switchgear and control gear, buildings and transformers, and generally including safety or control devices (for example protection), with the infrastructures and technologies of digital information, network communication and shared information to collect data, measure, detect and protect the electrical system, possibly support online analysis, decision-making, collaborative interaction, and real-time control

[SOURCE: IEC 60050-601:1985, 601-03-02, modified – "a" has been removed from the beginning, and "A. substation generally includes" is replaced by "and generally including". "network communication and shared information to collect data, measure, detect and protect the electrical system, possibly support online analysis, decision-making, collaborative interaction, and real-time control" is added in the end of the definition.]

**3.7**
**reliability**
ability to perform as required, without failure, for a given time interval, under given conditions

[SOURCE: IEC 60050-192:2015, 192-01-24]

**3.8**
**availability**
property of being accessible and usable on demand by an authorized entity

Note 1 to entry: IoT systems can include both human users and service components as "authorized entities".

[SOURCE: ISO/IEC 27000:2018, 3.7]

## 4 Symbols and abbreviated terms

| | |
|---|---|
| ASD | Application and Service Domain |
| CAN | controller area network |
| CIP | collaborative information process |
| CSPS | control subsystem for power substation |
| CSSN | control subsystem for sensor network |
| CT | current transformer |
| DAFS | data acquisition functional subsystem |
| DER | distributed energy resource |
| EMF | electromagnetic field |
| GIS | gas isolated switchgear |
| GOOSE | generic object oriented substation event |
| HMI | human–machine interface |
| IED | intelligent electronic device |
| iWSN | intelligent wireless sensor network |
| LoRaWAN™ | long range wide area network |
| OLTC | on load tap changer |
| MMS | manufacture message service |
| MTBF | mean time between failures |
| MTTF | mean operating time to failure |
| MTTFF | mean operating time to first failure |
| NB-IoT | narrow band Internet of Things |
| ONVIF | open network video interface forum |
| OTA | over the air |
| PD | partial discharge |
| PED | Physical Entity Domain |

| | |
|---|---|
| PSIA | Physical Security Interoperability Alliance |
| RTU | remote terminal unit |
| SCADA | supervisory control and data acquisition |
| SCD | Sensing and Controlling Domain |
| $SF_6$ | sulfur hexafluoride |
| SNRA | Sensor Network Reference Architecture |
| SV | sample value |
| UD | User Domain |
| VT | voltage transformer |
| XML | extensible markup language |

# 5 Intelligent wireless sensor network system supporting electrical power substation

## 5.1 System View

### 5.1.1 System overview

The iWSN system for electrical power substation is composed of subsystems which include sensor nodes, meters, cameras, and gateways, communication network, and control subsystem for sensor network (CSSN). The iWSN system collects data (system operation status, etc.) from electrical equipment and substation environment, and transmits the data wirelessly to be processed, aggregated and/or analysed for effective and efficient monitoring of the electrical power substation in real-time. The iWSN system contributes to the automation of the operation and management of the substation especially by feeding it with appropriate data, but also provides the electricity providers with a clearer operating picture of the substation and better automated control through supervisory control and data acquisition (SCADA). In addition, with consideration for sensor and actuator interoperable communication interfaces and common sensor and actuator data for sharing and exchanges between networks and systems, interoperability in electrical power substation operations should be achieved. Consequently, the application of the iWSN system results in a smart electrical power substation through interactive operations, self-healing, safer and securer environment, and so on. The system overview of the iWSN system supporting electrical power substation is depicted in Figure 1. In Figure 1, SCADA, control centre and control subsystem for power substation (CSPS) are only shown to provide the relationship with iWSN, but SCADA, control centre and CSPS are neither in the scope nor discussed in this document.

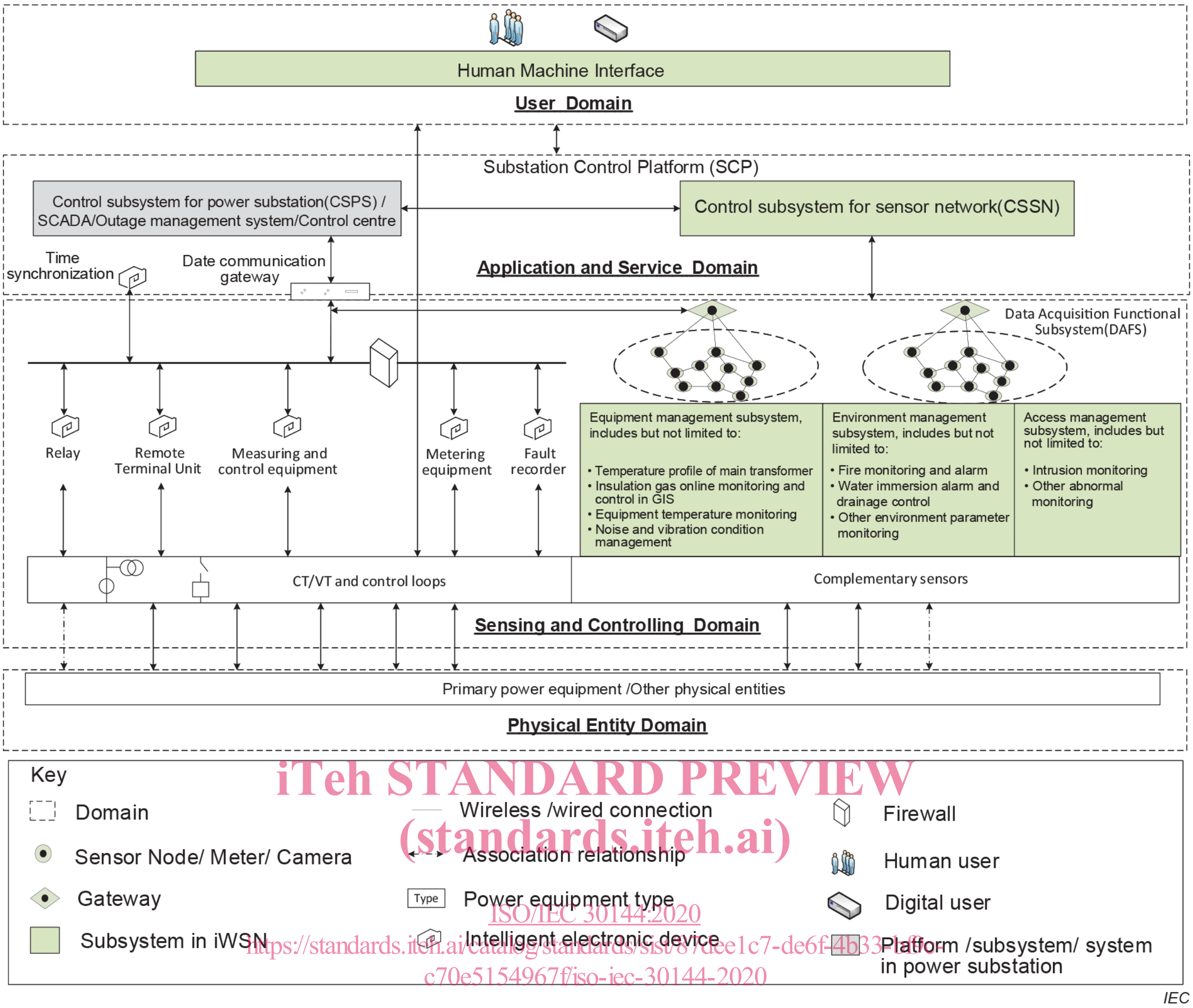




**Figure 1 – System overview of the iWSN system supporting electrical power substation**

As shown in Figure 1, in principle, the iWSN system's System View supporting electrical power substation follows the Sensor Network Reference Architecture (SNRA) described in ISO/IEC 29182. Figure 1 resulted from applying and tailoring the SNRA (see Figure A.1) supporting electrical power substation monitoring. Figure 1 shows the entire sensor network system that is used to improve the substation's intelligence and automated system performance. Sensor nodes (see Figure A.3) in Figure 1 are attached to power equipment or placed in the substation to monitor the equipment and environmental status. The sensor nodes with different type of sensors and communication modules are used for electrical power substations, and they are listed in this document. The entire functional models of the iWSN system comply with those of the SNRA (see Figure A.4). Interfaces of SNRA, layer focus model, sensor node physical reference architecture and functional models of the sensor network are shown in Annex A.

The iWSN systems are used for monitoring the electrical equipment, environment, access management, and other parameters in electrical power substations, and also provide numerous other services depending on the needs of specific users. An iWSN system consists of sensor nodes, gateways, and various types of the iWSN system's subsystems. It also includes a platform for managing the iWSN system that has a graphical user interface.

Since the iWSN system supporting electrical power substations is one of the application scenarios of Internet of Things, it also follows the Internet of Things Reference Architecture (IoT RA, ISO/IEC 30141). The mapping relationship between the entities in the iWSN system's System View (see Figure 1) and the domains of the IoT RA is shown in Table 1.