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Information technology — Sensor Networks: Sensor Network and its interfaces for smart grid system

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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Introduction

Transitioning the existing Power Grid to Smart Grid is a challenging task over a lengthy period, and all power needs should be satisfied during the period that this transition takes place. This transition will likely affect a broad set of stakeholders, e.g., individuals and businesses, and the stakeholders should properly be informed of the changes taking place and to come. Smart Grid is a large, complex system which operates at various operation modes ranging from fully automated to handle time critical and instantaneous responses (sensing and actuation) to human-in-the-loop for response and interaction (command and control). The transition to Smart Grid will be a gradual migration with the coexistence of diverse technologies, systems and equipment from the past, today, and the future. To ensure the interoperability of the diverse technologies, systems, and equipment without compromising the performance (e.g., reliability, safety, cyber security, etc.), Smart Grid will require effective standards. These standards should not be static, but evolve over the transitional time period. These standards should maintain their integrity to support all technologies, systems, and equipment that are and will be involved during the transition.

This standard, *Sensor Network and its Interfaces to Smart Grid System*, does not address standards for Smart Grid (e.g., electrical power system). This standard addresses sensor network and its interfaces to Smart Grid, e.g., various applications of the sensor network to Smart Grid. The sensor network and its processing algorithms provide intelligent services to the user, e.g., operators in various domains of Smart Grid including power utilities and consumers.

The sensor network plays many critical roles in all areas of Smart Grid because: (1) sensors with processing capability are smart devices and sensor nodes can include actuators, (2) sensor data/information are transmitted via wired/wireless communication systems and data links, and sensor nodes typically include communication devices that formulate protocols for the data/information streams, and (3) sensors monitor and measure their designated environments, collect data from the environments, analyze the data if they have processing capability, formats the data, and stores them at their local memory devices; thus, within sensor network, some level of data management is necessary.

Sensor data from Smart Grid in many cases should be secured and cyber security should be in place to prevent from unauthorized access of sensors and related devices on the sensor network. Certain types of sensor data, e.g., customer data and information, should be protected from the information security and privacy point of view.

The sensor network can provide various applications and services during the transitional road to Smart Grid. The sensor network is expected to become one of the essential and critical players in migrating the legacy power grid system to Smart Grid. This includes adding and integrating sensor-related and network-related technologies with power systems and devices from the past, today and the future. From the sensor network point of view, the information technology (IT) network is considered as the information highway or IT backbone providing the pathways for Smart Grid data and information. Therefore, a study of existing sensor network and power system related standards is necessary to leverage these standards for the sensor network standard development unique for Smart Grid, smart grid services and applications during the transitional period and afterward.

Information technology — Sensor Networks: Sensor Network and its Interfaces for Smart Grid System

1 Scope

This International Standard (IS) is for sensor networks in order to support smart grid technologies for power generation, distribution, networks, energy storage, load efficiency, control and communications and associated environmental challenges. This standard characterizes the requirements for sensor networks to support the aforementioned applications and challenges. Data from sensors in smart grid systems is collected, transmitted, published and acted upon to ensure efficient coordination of the various systems and subsystems. The intelligence derived through the sensor networks supports synchronization, monitoring and responding, command and control, data/information processing, security, information routing, and human-grid display/graphical interfaces.

This International standard (IS) specifies:

- Interfaces between the sensor networks and other networks for smart grid system applications
- Sensor network architecture to support smart grid systems
- Interface between sensor networks with smart grid systems
- Sensor network based emerging applications and services to support smart grid systems

2 Normative References

The following referenced documents are indispensable for the application 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.

ISO/IEC 29182-1, *Information technology – Sensor Networks: Sensor Network Reference Architecture (SNRA) – Part 1: General Overview and Requirements.*

ISO/IEC 29182-2, *Information technology – Sensor Networks: Sensor Network Reference Architecture (SNRA) – Part 2: Vocabulary and Terminology.*

ISO/IEC 29182-3, *Information technology – Sensor Networks: Sensor Network Reference Architecture (SNRA) – Part 3: Architecture Views.*

ISO/IEC 29182-4, *Information technology – Sensor Networks: Sensor Network Reference Architecture (SNRA) – Part 4: Entity Models.*

ISO/IEC 29182-5, *Information technology – Sensor Networks: Sensor Network Reference Architecture (SNRA) – Part 5: Interfaces.*

IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads.

3 Terms and Definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 29182-2 apply.

4 Symbols (and abbreviated terms)

AMI	Advanced Metering Infrastructure
BAN	Business area Network
CB	Circuit Breaker
CMOS	Complementary Metal–Oxide–Semiconductor
CNT	Carbon Nanotube
CPN	Customer premises network
CT-IAP	Communication Technology Interoperability Architecture Perspective
DSM	Demand-Side Management
DER	Distributed Energy Resource
EPS	Electric Power System
ESI	Energy Services Interfaces
FAN	Field area networks
GIS	Gas Insulated Switchgear
GPS	Global Positioning System
HAN	Home Area Network
HV	High Voltage
IAN	Industrial Area Network
IAP	Interoperability Architecture Perspective
IED	Intelligent Electric Device
IEEE	Institute of Electrical and Electronics Engineers
IS	International Standards
ISP	Internet Service Providers
IT-IAP	Information Technology Interoperability Architecture Perspective
LAN	Local Area Network
LTC	On-Load Tap-Changer
LV	Low Voltage
MV	Medium Voltage
OHTL	Overhead Transmission Line
PD	Partial Discharge
PEV	Plug-in Electric Vehicle
PMU	Phase Measurement Unit
PS#	Power System # (Interface Designation in PS-IAP)
PS-IAP	Power System Interoperability Architecture Perspective
RH	Relative Humidity
RF	Radio Frequency
RTO	Regional Transmission Organization
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SDOs	Standard Developing Organizations
SG	Smart Grid
SGRM	Smart Grid Reference Model
SGRA	Smart Grid Reference Architecture
SN&I	Sensor Network and its Interface
SNRA	Sensor Network Reference Architecture
UGC	Underground Cables
UHF	Ultra High Frequency
UTP	Unshielded Twisted Pair
UV	Ultraviolet
WAN	Wide Area Network

5 Smart Grid Reference Models and Architectures

5.1 General

Smart Grid (SG) reference models and architectures are being developed by various standard developing organizations (SDOs) and industrial consortia/organizations. Sensor network and its interfaces standard for SG need to be consistent with the reference model and architecture to be useful and realizable. The sensor network and its interfaces for smart grid system standards should be applicable, adoptable, and adaptable to varying architectural differences among smart grid architectures to be effective. For this reason, a number of available SG Reference Models and Architectures (SGRMs and SGRAs) are referenced, and these SG reference models and architectures are included in Annex A of this standard document. Understanding and leveraging the existing SGRMs and SGRAs is crucial for developing the sensor network and its interfaces for smart grid system for compatibility and acceptance.

5.2 Smart Grid Architectures Adopted for Developing Sensor Network & its Interfaces for Smart Grid System

For developing the sensor network and its interfaces for smart grid system, IEEE P2030 Power System Interoperability Architecture Perspective (PS-IAP) is adopted because this architecture perspective provides the entities/devices that are physical or logical in the power system for a typical implementation. Additionally, from the sensor network point of view, the sensors in sensor networks interface with the power systems in the seven SG domains, namely, Operations, Service Providers, Customer, Distribution, Transmission, Bulk Generation, and Market domains (See Annex A.2, NIST Smart Grid Conceptual Model).

Networking and communication allowing sensors and sensor networks within in each domain and also between the domains is described in IEEE P2030 Communication Technology Interoperability Architecture Perspective (CT-IAP), and this architecture perspective is adopted for any discussion of sensor networks and data/information communication routing.

From the data/information contents perspective, IEEE P2030 Information Technology Interoperability Architecture Perspective (IT-IAP) is adopted for this standard work to describe the data/information that will be passed between the entities in the same domain and also between the domains.

IEEE P2030 PS-IAP is mainly used for developing this standard because sensors are physically attached to power systems (e.g., physical interfaces), and these sensor nodes form a sensor network or sensor networks in a domain communicating data/information from one domain to another domain. The communication perspective is described in the CT-IAP. From data/information stand point, the IT-IAP is utilized to describe the data/information contents and context mapping to the physical interfaces in the PS-IAP.

5.3 IEEE P2030 Smart Grid Interoperability Guideline Standard

IEEE P2030 developed Smart Grid Interoperability Guideline Standards. In this standard, smart grid's interoperability is categorized by Power System Technology, Communications Technology, and Information Technology. In each technology, top-level reference architecture is developed, which is called Interoperability Architecture Perspective (IAP).

IEEE P2030 Power System IAP (PS-IAP) represents a view of the Electric Power System (EPS) that not only represents Smart Grid but also emphasizes the production, delivery, and consumption of electrical energy. The CT-IAP emphasizes the communication connectivity among systems, devices, and applications in the smart grid. The IT-IAP emphasizes the control of processes and data management flow in the smart grid.

The domains in IEEE P2030 are the same as those in the NIST Conceptual Model. The description of each domain in IEEE P2030 is comprehensive. Table 1 shows the description of each domain in the IEEE P2030 Interoperability Guideline standard document.

Table 1. IEEE P2030 descriptions of the SG domains.

Domain	**Descriptions**
Bulk Generation	The bulk generation domain contains any generation and storage that is connected directly to the transmission system (with no distribution system interface). The generation and storage can be any size such as large power generation stations, small peaking generation, and small storage connected to the electrical transmission system. These facilities may be owned by electric utilities or by independent entities. The bulk generation domain's primary interfaces are with transmission domain entities, generation and transmission operations control entity, and markets domain. The interface to the markets domain is focused on the operation of the generation and storage in order to provide economic operation. The rest of the interfaces displayed in Figure 1 (PS-IAP) are focused on efficient and reliable operation.
Transmission	The transmission domain includes entities that represent equipment associated with the electrical transmission system. This equipment is represented by three entities. The transmission substation entity represents many pieces of equipment in substations that cannot be classified as transmission protection and control devices nor sensors and measurement devices. The transmission domain's primary interfaces are with the bulk generation domain and operations/control domain. The interfaces with the bulk generation domain are focused on reliable operation. The interconnection with the transmission operation/control entity in the operations/control domain is the focal point of the centralized control of the transmission system. This is often under the control of an independent system operator, Regional Transmission Organization (RTO), or local utility. In addition, there may be interfaces with the customer domain where the customer may have a transmission-level connection to the power system, as may be the case with IPP's, large industrial facilities, or large commercial facilities.
Distribution	The distribution system domain includes entities located throughout the electrical distribution system. The distribution substation entity represents many components that cannot be assigned to the distribution protection and control devices entity nor the sensors and measurement devices entity. In addition, the distributed energy resource (DER) entity represents generation and storage of all kinds that are connected to the electric distribution system except those at customers' facilities. The distribution domain's primary interface is with the distribution operation and control entity in the control and operations domain. This interface reflects the centralized control of the distribution system from the distribution control center. The distribution domain may also have an interface to the transmission substation entity in the transmission domain. This interface usually reflects only protection and control systems. The distribution domain may also have an interface with the generation operation and control entity in the control domain in order to provide direct dispatch of distribution connected DER.
Customer	The customer domain includes many types of customers that are connected to the electrical distribution system or electrical transmission system. These customers could be residential, commercial, or industrial. The customer domain may include customers with only loads and customers with any combination of loads, generation, and storage. The customer domain includes all loads whether they are connected at the transmission or distribution level, but it does not consider generation and storage connected at the transmission level. If generation and storage is connected at the transmission level, that generation or storage is considered part of the bulk generation domain. Each type of customer may have several different entities employed in its application. These entities are dependent on the size and type of customer as well as its connections to the EPS. The DER entity includes all distribution system-connected generation and storage and may require an interface with the market domain. A plug-in electric vehicle may have the characteristics of a load or customer DER.

Domain	Descriptions
	The customer domain can have interfaces to the distribution domain, markets domain, and the distribution operations/control entity of the operations/control domain. These interfaces handle the customer requirements with the exception of facilities that have a substation connected to the electrical transmission system. In this case, the substation has interfaces to the transmission domain and to the transmission operations/control entity of the operations/control domain. Transmission operations will often have control over customer substations since customer substations may have direct influence on operations of the transmission system. In some instances, customer DER will be directly dispatched by the generation or transmission operation and control entities.
Control and Operations	The control and operations domain includes three distinctive operation and control entities. These entities are control generation, transmission, and distribution. They are the controlling mechanisms that, from an EPS viewpoint, keep the grid up and running. The primary interface of each entity in the control and operations domain is to its appropriate domain in the electrical power system. These primary interfaces include the distribution operation and control entity to the distribution domain, the transmission operation and control entity to the transmission domain, and the generation operation and control entity to the bulk generation domain. In addition, the distribution operation/control entity has some interface to the customer domain for applications where the customer has controllable loads, generation, and/or storage. The transmission operation and control entity has an interface with the customer substation entity in the customer domain for those circumstances where a customer connects directly to the transmission system instead of through the distribution system. In some instances, customer DER will be directly dispatched by the generation or transmission operation and control entities.
Market	The markets domain reflects market operations associated with electric utilities and regional entities. The markets domain is logically connected with any of the generation, load control, and storage entities. Control by markets can be done directly at generation, load control, and storage, but it can also be done via the operations/control domain. Additionally, as new markets emerge, the customer may seek to interact directly with the marketplace.
Service Provider	The service provider domain contains third-parties and utilities that provide electrical power-related services. . The service provider domain is the connection between the electric energy markets and the end users. There are many models for potential electric service providers, but the most common model in use today is that of the electric utility as service provider. Some locations have third-party service providers who aggregate electric power for consumption by end users. Electric service providers may also provide additional electric power-related services. These services may include additional power supply options, such as discounts for less consumption during peak hours. They may also include demand-side management and services such as protection against lightning and voltage excursions. Some electric service providers may also provide services such as monitoring electrical equipment for maintenance and troubleshooting purposes. The equipment monitored could include generation, storage, substation equipment, and equipment located on electric distribution or transmission lines.

5.3.1 Power System Interoperability Architecture Perspective (PS-IAP)

The Power System Interoperability Architecture Perspective (PS-IAP) shown in Figure 1is a logical representation of the major entities that describe the functions of the EPS. Figure 1 displays domains, entities, and interfaces from the power system perspective. The PS-IAP domains (common to all perspectives) provide a division of efforts close to those of existing electric utilities.

These PS-IAP domains are: