Developing Scalable Smart Grid Infrastructure to Enable Secure Transmission

System Control

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Abstract	Power system applications responsible for operational energy management, planning, asset and market management all require interoperability to support smart grid functionality. With the goal of achieving an integrated and interoperable smart grid, a number of organisations all over the world started uncoordinated standardisation activities, which caused the emergence of a large number of incompatible architectures and standards. Consequently, there are now new standardisation activities that have the goal of organising existing standards. In this regard, employing standards such as Common Information Model (CIM) and unified Application Programming Interface (API) provides integration of various applications in the power system and sharing the models and operating data.			
Keywords	CIM, IEC 61850, smart grid, standardisation			

Contents

Abbreviations

API	Application Programming Interface
CIM	Common Information Model
DMS	Distribution Management System
EMS	Energy Management System
EPRI	Electric Power Research Institute
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
MMS	Market Management System
OO	Object Oriented
PMU	Phasor Measurement Unit
SAS	Substation Automation System
TC	Technical Committee
UML	Unified Modeling Language
WAMS	Wide Area Monitoring System

1. Introduction

Smart grids have an essential role in transforming the functionality of the electricity supply system to provide a user-oriented service, high security, quality, and economic efficiency in an open market environment. In this regard, a Wide Area Monitoring System (WAMS) is vital in order to detect problems and react to them as quickly as possible. The high number of different manufacturers active in the power system and WAMS markets, each implementing proprietary protocols and applications, could result in systems that cannot be interconnected. Therefore, standardisation is a key for the advancement of connectivity and interoperability within systems. In the past, utilities used to employ proprietary protocols, which were specified by the product vendors. Gradually, it was decided to move towards open standards to provide an interoperable environment and improve modelling capabilities. Apart from Phasor Measurement Unit (PMU) standards, in a typical power system, several communication protocols exist and are required for transferring data, and each of them cover certain domains and specific groups of data. The objective of this report is to investigate the adoption and development of the most common open standards to enable interoperable power systems [1][2].

2. Synchrophasor Standards

The primary purpose of synchrophasor standards is to ensure PMU interoperability. The first standard for synchrophasors, IEEE 1344, was introduced in 1995 and reaffirmed in 2001. It defined the basic concepts for the measurement and method of data handling. However, technology is constantly evolving and standards should be updated in order to accommodate new requirements. Thus, the new standard, IEEE C37.118, was published in 2005. This significantly improved the previous standard, while still maintaining basic compatibility [3]. The IEEE C37.118-2005 open standard specified a set of fundamental characteristics, including time reference (UTC - Coordinated Universal Time), rate of measurement, phase reference (cosine), accuracy metrics (Total Vector Error), and communication model (format of messages). By defining these specifications, the real-time and off-line processing of synchrophasor data from different measuring systems can be performed more easily [4]. Although the publication of IEEE C37.118-2005 was an important step in the standardisation of phasor measurements, this standard does not cover all aspects. For example, it does not specify PMU performance requirements under dynamic conditions, which could lead to PMUs using the same standard to show different results under transient situations. Moreover, it does not address frequency measurement requirements, and does not specify a communication protocol; it only defines the data format with basic methods for data transfer [3].

Due to the above issues, further work was done to revise the standard in 2008. In addition, IEC 61850 was proposed to be employed as a communication standard for transferring measured synchrophasors [5]. However, there were some problems in merging C37.118 into IEC 61850. As a solution to these issues, it was proposed to split the C37.118 standard into two parts. In fact, the revision separates the measurement and communication sub-clauses into individual standards. This facilitates widespread adoption and deployment of this standard by allowing freer use of other standards for synchrophasor communication. The two new revised standards were completed and published in December 2011. The first part, C37.118.1-2011, includes the synchrophasor measurement definitions and requirements, and the second part, C37.118.2-2011, includes a new standard for synchrophasor data transfer, which is designed to be compatible with IEC 61850. Both standards have maintained features from the previous version, but with updates and additional provisions [6][7].

3. IEC 61850 Standard

IEC 61850 is a communication standard released by the Technical Committee (TC) 57 of International Electrotechnical Commission (IEC). The goal of this standard is to provide interoperability between the Intelligent Electronic Devices (IEDs) from different suppliers or, more precisely, between functions to be performed for power utility automation. It was originally introduced for the design of Substation Automation Systems (SASs). It defines communication between IEDs in substations and related system requirements. As a consequence of employing advanced and fast devices, such as protection and control IEDs, the efficient and high-speed communication infrastructure has become an important issue in substations [8]. The IEC 61850 standard has enabled IEDs and devices in a substation to be integrated on a high-speed peer-to-peer communication network as well as client/server. In this standard, the application is independent from the communication protocol by specifying a set of abstract services and objects. IEC 61850 applies Object Oriented (OO) data and service models to support all substation functions. This provides more flexibility to the developer and users, as well as simplifying engineering tasks [9]. The IEC 61850 set of documents is comprised of 10 parts, where each part defines a specific aspect of the standard.

4. Common Information Model

Power systems have become enormous and complex and a large number of relevant supporting systems have been developed or established. Among them most of the auxiliary systems cooperate together or need to be interoperated. This means the data which can describe the power system status are shared among different applications. This can cause problems as the description of the same data needs to be unified for avoiding misunderstandings in various systems. Therefore, the management of smart grid is challenged by the increase in data volume and the requirement for interoperability. In this regard, Common Information Model (CIM) has been developed for power system in the recent years. It is gaining worldwide recognition and acceptance as a standard for power system domain. CIM can model the required aspects of power system using defined properties, protocols and parameters, which results in clarifying the definitions of data [10][11].

The CIM was first developed by Electric Power Research Institute (EPRI) more than a decade ago, aimed to provide application programs with a platform-independent view of the power system. Since then, the IEC TC 57 has been actively engaged in standardising CIM for the electric power industry. The CIM is an abstract model that defines all the major objects in an electric utility enterprise included in Energy Management System (EMS) information model as well as other software applications' models. It facilitates the integration of information and data sharing between different applications developed by different vendors independently [12][13]. The initial CIM model was created to allow EMS-to-EMS import and export of network models and to avoid the proprietary data formats that complicated data exchange between EMS systems. However, it was then discovered that this model could also be used to exchange power system data used in network analysis such as power flows, topology processing, and state estimation [14].

The IEC 61970 and IEC 61968 standard series define the CIM and the representation of physical entities in the software model and the IEC 62325 standard completes the CIM by defining the data exchange protocols for energy markets. With CIM as core, these IEC standards provide a common language and protocols among heterogeneous power system applications, and enable development and use of plug-in applications. CIM applications range from CIM-based model exchange to CIM-based information management, in the areas of EMS, Distribution Management System (DMS), Market Management System (MMS) and Substation Automation. The CIM includes a large data model maintained in the Unified Modeling Language (UML) [12]. This model contains hundreds of classes that include thousands of attributes and are connected by many associations. In fact, CIM is an OO information model that provides a semantic framework to facilitate enterprise application integration in the power industry [15][16].

It should be noted that although CIM represents almost all applications in EMS, CIM will not always be mature and perfect for the reason that power system is a developing system. Therefore, CIM needs to be extended following the pace of the development of power system. In this regard, WAMS is a newly developed technology and is more flexible and reliable than the existing SCADA. But a uniform model on WAMS has not been completely established yet. Therefore, CIM should be extended to fulfil the data and information exchange between the two systems [13]. Extension of the CIM to facilitate the modelling of IEDs such as PMUs is desirable from the perspective of data integration and wider uses of situational awareness. Such use cases could include near real-time update of the EMS and advanced visualization of network status [17][18]. Furthermore, one of the main interoperability issues in electric power systems concerns the interactions between IEC 61850 and CIM standards. This includes solutions to facilitate the exchange of configuration files between the two standards [15][19].

5. Conclusion

Various applications such as WAMS, SCADA, EMS, DMS etc. are used in a typical power system for the reliable and efficient operation. These applications have different modelling methods, communication protocols and data formats that are not compatible. In addition, the high number of different manufacturers active in the power system, each implementing proprietary protocols, could result in systems that cannot be interconnected. Therefore, standardisation is a key for the advancement of connectivity and interoperability within such systems. In this regard, IEC 61850 and CIM are core standards in the electrical power domain. They are the most widely accepted standard series that promote interoperability in electric power systems. CIM standards include a data model that defines the semantics to achieve interoperability in a broad range of energy management functionalities, such as network operations, asset management and electricity markets. Meanwhile, IEC 61850 standards facilitate the interoperability within the automation systems of electric facilities. On this basis, the interoperability between the substation domain of IEC 61850 and the power management domain of CIM is a key success factor for the implementation of smart grids.

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