An Architecture of Layered Systems for Providing Services on the Distribution Systems

Min-Soo Kim
Electrical engineering
Myongji University, Korea
kms5410@gmail.com

Tae-Wan Kim
Electrical engineering
Myongji University, Korea
twkim@mju.ac.kr

Sang-Hee Kang
Electrical engineering
Myongji University, Korea
shkang@mju.ac.kr

SugWon Hong
Computer engineering
Myongji University, Korea
swhong@mju.ac.kr

Abstract

The current power system has several management & operating systems based on different standards, and each system uses a variety of communication protocols and data models, causing the lack of interoperability of data. To support new services on the distribution domain such as peer-to-peer energy trading in distribution systems, all the data should be considered in an integrated way. We propose the layered architecture which has the management & operation system platform in the middle, through which all management and operation data can be shared between the physical power system and the cyber physical system and utilized to derive necessary control functions for the application. The platform also has an integrated data model and provides layered services to ensure the interoperability.

Keywords

Distribution system architecture, Management & operation Platform, Integrated data model, Layered services

1. INTRODUCTION

For the electrical power industry, the necessity for data management in the physical power systems is continuously increasing. North America, Europe, and China are making an effort to develop the platforms which are able to collect, process, and manage data of physical power systems efficiently [1-4]. The platform is intended to provide the physical power system data to new services at the application domain.

In the conventional electrical power system, each system component maintains its own communication protocol and data model for management and operation of data according to each purpose. For example, the substation automation system (SAS) is based on IEC 61850 as a communication protocol and a data model. The IEC 61850 is an international standard defining communication protocols for intelligent electronic devices (IED) at substation automation systems (SAS) [5]. The energy management system (EMS) is based on IEC 61970 as a communication protocol. The 61970 series define communication protocols in order to deal with the application program interfaces for energy management systems [6]. All the protocols mentioned above have different data models and services. Different communication protocols and data models raise the problem of interoperability of data usage in light of meeting the challenge of new services on the distribution system domain such as peer-to-peer energy trading. To overcome the limitations described above, an integrated way of handling various data of different systems is required.

The paper proposes an approach of using the platform to overcome limitations of using different communication protocols and data models and enabling new services on the distribution system domain to utilize data necessary for processing in an integrated way. The paper, based on an architecture of layered systems, focuses on the data communication method between the management & operating system level and the CPS level. The interoperability is the most important issue for the data communication. To ensure the interoperability of the data communication, an integrated data model and layered services are required. The layered services are not only focusing on communication per se; it should focus on the functions required by the power system.

2. ARCHITECTURE OF LAYERED SYSTEMS

The proposed architecture is a model of system layers which consists of four layers. Fig. 1 shows the layered system architecture for the power system suggested in the paper.

The physical system collects all data related to devices and operation of the distribution power system. The cyber physical system (CPS) is designed to mirror the real-world physical system to contain all relevant data in order to simulate the physical system. The application layer can perform a variety of applications with the data from the CPS such as state estimation, prediction, long-term planning and so on. The application level can make operational and control decisions that take into account peer-to-peer energy trading and system monitoring/analysis, then transmits the control decision to the physical system after performing prediction and virtual control at the cyber system.

The management & operation system collects data at the physical system level and then transmits the data to the CPS level. The management & operation system platform must be able to handle data from both systems at the physical system level and the CPS level, and provide necessary information required by the services at the application layer on-demand.

The power system has some management & operating systems such as EMS (Energy Management System), DMS (Distribution Management system), DERMS (Distributed Energy Resources Management System), SAS and so on. Each management & operating system use a variety of communication protocols such as IEC 61970, IEC 61968, MODBUS, and IEC 61850 [5-8]. In addition, the IEC 60870 is used as a communication protocol for the distribution power system in Europe and the DNP is used for the same purpose in North America [9-10]. The IEC 62325 is related to deregulated energy market communications [11]. The data from the indivisual system must be collected into the management & operating system platform.

Fig.1 Architecture of layered systems

Fig. 2 shows the detailed structure of the proposed platform. There is a data bus and an engine in the platform. The gateways are for converting the data models of other communication protocols to an integrated data model. The data are collected from the management & operating systems with different communication protocols such as MODBUS, IEC 61968, IEC 61970, IEC 61850, and the like. Then those data models are converted to transmit to the CPS through a gateway of the platform. The protocols of IEC 61968, IEC 61970, and IEC 62325 are using the common information model (CIM) for the data model. The CIM is an open standard which defines how managed elements in an IT environment are represented as a common set of objects and relationships between them based on UML (Undefined Modeling Language). For the data from the distribution power system, the protocols used in distribution power system must be considered.

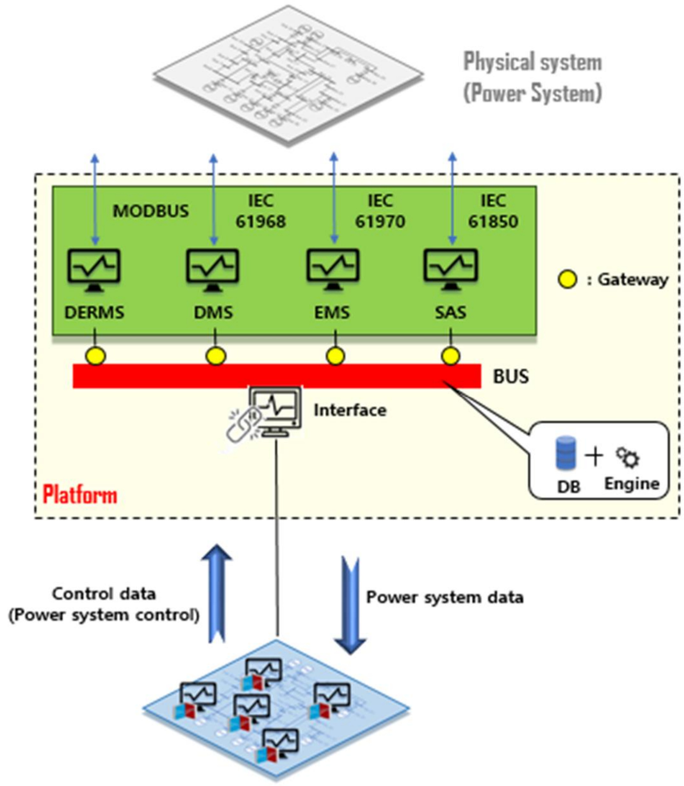

Fig.2 Detailed architecture of the proposed platform

3. INTEGRATED DATA MODEL

For the interoperability of data, the integrated data model must be considered. The integrated data model should allow multiple parties to exchange data. However, the integrated data model not only represents the data of managed elements and of the distribution power system, but also provides means to actively control and manage these elements. By using an integrated data model, management software of the management & operating system platform can be written once and work with many implementations of the data models without complex and costly conversion operations or loss of data information.

The CIM is suggested as the integrated data model in this paper. The CIM infrastructure specification defines the architecture and concepts of CIM, including a language by which the CIM schema including any extension schema is defined, and a method for mapping CIM to other information models, such as the simple network management protocol (SNMP). The CIM architecture is based upon UML and object-oriented. The managed elements are represented as CIM classes and any relationships between them are represented as CIM associations. Table 1 shows the protocols used mainly in the power systems, and the types of the data models used by protocol types. The protocols of IEC 61968, IEC 61970, and IEC 62325 are using CIM for the data model.

Protocol	Data model
IEC 61968	CIM
IEC 61970	CIM
IEC 62325	CIM
IEC 61850	LN (Logical Node)
IEC 60870	Index base
DNP	Index base
MODBUS	Object types

Table 1 Types of the data model used by protocols

As shown in Table 1, CIM is mainly used by the protocols for the distribution power system. CIM is modeled using an object-oriented language based on UML, and a lot of research is being conducted on a method of converting the data models used in other protocols to the CIM structure with a gateway [12, 13]. Furthermore, because CIM is modeled as an object-oriented language based on UML, it is easy to develop and manage from an engineer's perspective. Therefore, the CIM is proposed as the integrated data model in this paper.

4. THE ROLES OF THE LAYERED SERVICE

To ensure the interoperability of the data communications, an integrated data model and layered services are required. The layered services are not focusing on communication; it should focus on the functions required by the power system.

The platform for the distribution power system is required to transmit data not only to the CPS but also from the CPS to the platform. At first, the CPS requires distribution power system data to simulate the physical system in the cyber system. Then the CPS do simulation for the functions of the application such as generation/load prediction, operating planning, power trading, and the like. Each function provides a variety of services and control indications. Therefore, the platform must be designed to provide the services to process the bi-directional data to the CPS and also from the CPS to the management & operating system platform. In addition, the layered services must serve two purposes such as facility monitoring and control indications. The facility monitoring service provides the services of request/response methods and the services of publish/subscribe method, and the control indication service provides the services of request/response methods.

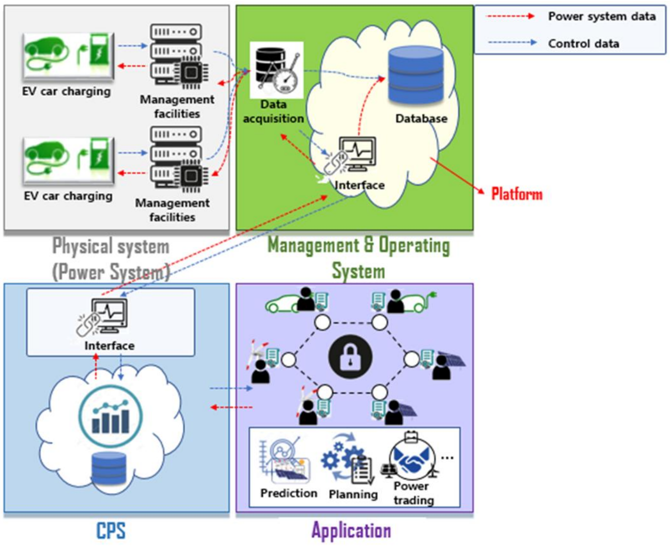

Fig.3 The diagram of data flow

Fig. 3 shows the diagram of data flow. As shown in the figure, the data from the physical system is collected into the management & operating system platform, then transmitted to the CPS after being converted to the integrated data model. The CPS simulates the required functions from the application layer, and also conversely delivers the control data from the application level for the power system. The CPS determines which control is to be performed according to the simulation results.

One example of this operation on the model can be explained for the application of EV charging system to peer-to-peer electric power trading. The management & operating system platform collects the data of distribution power system from the distribution energy system (DES) and then delivers the data to the CPS. The application layer acquires the data of distribution power system through the CPS. Then the CPS do the simulation with the data of the distribution power system and generate the results for the control of the application layer. After performing prediction and virtual control, the CPS transmits the control data for the EV charging system through the management & operating system platform. A series of operations through the platform proceeds like these procedures.

5. CONCLUSION

The power system has several data management & operating systems. However, since those systems use a variety of communication protocols, the interoperability of the data models becomes the problem. A conceptual approach of using the platform is suggested for coping with this problem. This paper focuses on the data communication method between the physical power system and the platform, and between the CPS and the platform. To ensure the interoperability of the data communications, an integrated data model and layered services are also suggested. In particular, the paper focuses on suggesting how to use the integrated data model and identifying the roles of the layered services.

Acknowledgements
This research was supported by Korea Electric Power Corporation. (Grant number:R18XA01)

References
[1] Pirre Mallet, Per-Olof Granstrom, Per Hallberg, Gunnar Lorenz, Pavla Mandatova, "Power to the People!: European Perspectives on the Future of Electric Distribution", IEEE Power and Energy Magazine, 12, 2014, 51-64.

[2] Martin Sarnovsky, "Big data processing and analytics for process industries", IEEE World Symposium on Applied Intelligence and Informatics(SAMI), Kosice, Slovakia, 2018, 1-4.

[3] Dunwen Song, Boying Wen, Xuetao Yang, Yubao Gu, Shiquan Wei, Shiying Ma, "A New Method for Processing and Application of Wide Area Measurement Big Data in a Power System", International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery, Xian, China, 2015, 137-140.

[4] Di Cao, Jian Li, Dongsheng Cai, Qi Huang, Yufei Teng, Weihao Hu, "Design and Application of Big Data Platform Architecture for Typical Scenarios of Power System", IEEE Power & Energy Society General Meeting (PESGM), Portland, USA, 2018, 1-5.

[5] IEC 61850-1 TR Ed.2 Communication networks and systems for power utility automation Part 1: Introduction and overview, IEC INTERNATIONAL STANDARD, April 2012.

[6] IEC 61970-1 Energy management system application program interface (EMS-API) - Part 1: Guidelines and general requirements, IEC INTERNATIONAL STANDARD, December, 2005.

[7] IEC 61968-1 Application integration at electric utilities - System interfaces for distribution management - Part 1: Interface architecture and general recommendations, October, 2012.

[8] MODBUS APPLICATION PROTOCOL SPECIFICATION V1.1b3, Modbus Organization, August, 2013.

[9] IEC 60870-1-1 Telecontrol equipment and systems. Part 1: General considerations. Section One: General principles, IEC INTERNATIONAL STANDARD, December, 1988.

[10] IEEE Standard for Electric Power Systems Communications-Distributed Network Protocol (DNP3), IEEE std 1815-2012, October 2012.

[11] IEC TR 62325-102 Framework for energy market communications - Part 102: Energy market model example, IEC INTERNATIONAL STANDARD, February, 2005.

[12] Byunghun Lee, Dae-Kyoo Kim, Hyosik Yang, Hyuksoo Jang, Daeseung Hong, Herber Falk, "Unifying Data Types of IEC 61850 and CIM", IEEE Transactions on Power Systems, 30, 2015, 448-456.

[13] Yoseba K. Penya, Aitor Peña, Oihane Kamara Esteban, "Semantic integration of IEC 60870 into CIM", IEEE International Conference on Smart Grid Communications (SmartGridComm), Brussels, Belguim, 2011, 428-433.