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Smart Meter Use Case for Low Voltage Distribution System Operation

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ABSTRACT

Recently, with the introduction of DER (Distributed Energy Resources) such as wind, solar, energy storage systems, and electric vehicles, distribution systems have also started to produce and trade electricity. In order to cope with the changing system environment, countries around the world recognize that new functions for distribution system operation are needed, and application research based on AMI (Advanced Metering Infrastructure) is underway. However, it is still in the research stage and there is no specific functional design. In this paper, in line with the spread of AMI in Korea, four business use cases that can be implemented using AMI are defined. These are related to the distribution system and DER control, and the information exchange sequence was designed and represented as a Unified Modeling Language diagram. DSO (Distribution System Operator) can establish a foundation for improving distribution system operation and secure LV (Low Voltage) distribution system visibility through the implementation of this business use case.

Keywords: AMI, DER and power system control, business case, business use case, sequence of information exchange

1. INTRODUCTION

Recently, variable and inflexible DERs such as wind power, solar energy, energy storage systems, and electric vehicles are increasing in distribution systems [1], [2]. Accordingly, in order to efficiently manage and control DER, many countries around the world recognize that other new distribution system operation functions are needed in addition to grid maintenance, planning, outage management, billing, and distributed energy connection. Accordingly, related research has been conducted to improve the distribution system operation based on AMI. However, it is still in the research stage, and no specific implementation method has been suggested. In Korea, as DER is rapidly spreading through national plans such as Energy Master Plan [3], Smart Grid Master Plan [4], and Distributed Energy Activation Roadmap [5], improvement of distribution system operation capability is becoming more important.

In Korea, platform-based AMI will be introduced soon and will support various applications through two-way communication between the system operator and the end-device. Research on functions that can be implemented based on AMI has been conducted. However, until now, it has remained at the level of billing, remote meter reading, and consumption data analysis, and research on functions related to distribution operation for utilities is poor. Therefore, in order to effectively manage and control the increasing DER and distribution system, a new function related to distribution system operation must be defined, and an information exchange sequence for how the function should operate for implementation must be designed. In this paper, based on studies conducted abroad, LV distribution system state estimation [6], [7], LV distribution system topology estimation [8], BTM (Behind-The-Meter) resource output measurement and control [9], low voltage distribution system power flow/load prediction. [10] business use cases were defined. In order to actually implement this, we designed function elements that AMI should have, actors and sequences that exchange information, and presented them in Unified Modeling Language diagram. The use cases and sequences presented in this paper will be of great help in actual implementation in the future.

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Function	Use Case			
	LV distribution system state estimation	LV distribution system topology estimation	LV distribution system power flow/load prediction	BTM output measurement and control
Measurement equipment asset management	∨	∨	∨	∨
Measurement data storage and efficient management	∨	∨	∨	-
Pre-processing and processing of measurement data	∨	∨	∨	-
External communication network management/security	-	-	-	∨
Support for internal/external users of measurement data	-	-	-	Third party
Distribution operation function module and system connection	∨	∨	∨	∨

Table 1 Functional elements of AMI for use case implementation

2. FUNCTION OF AMI FOR IMPLEMENTING USE CASES

Table 1 shows the AMI functional elements required for implementation for each use case. Since all business use cases are based on smart meter measurement data, measurement equipment asset management functions are needed to manage measurement equipment and assets so that data can be transmitted without problems. State estimation, topology estimation, and flow/load prediction business use cases are implemented based on metering data in a database. Therefore, the measured smart meter data must be managed so that the metering data can be efficiently used through pre-processing and processing of measurement data and measurement data storage and efficient management functions. In the BTM resource output measurement and control use case, support for internal/external users of measurement data and external communication network management/security function is required to prevent for external network attacks, as well as the central communication network to communication with the BTM side and a third party managing BTM resources. In addition, in order to accurately control the output, the measured value must be provided to a third party. In common, the four use cases described in this paper should be operated in conjunction with one function in the process of the distribution system operation of DSO. Therefore, distribution operation function module and system connection function must be supported.

3. SEQUENCE FOR EACH USE CASE OF AMI

Fig 1 is a class diagram showing business cases for distribution system and DER control and business use cases supporting it. Various business cases such as Third Party, Demand Management, and Integrated Meter Reading are classified, but only the distribution & DER control business cases directly related to the distribution system operation are covered in this paper. In the

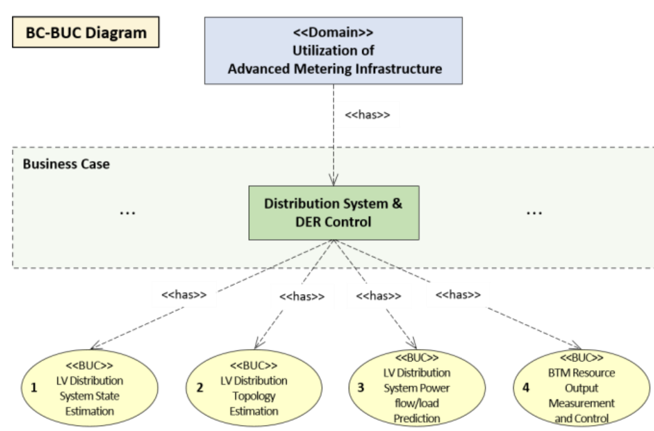

Fig 1 Domain model diagram as class diagram of use cases

following, each business use case is defined and the information exchange sequence between actors is presented.

3.1 LV distribution system state estimation

LV distribution system state estimation is a business use case that estimates the state of LV lines by using real-time measurement values of smart meters to improve reliability of distribution system operation and control. Fig 2 is a diagram showing the information exchange sequence for the business use case. As actors performing this function, there are AMI, which is a measurement infrastructure, the metering data administrator, and DSO. AMI collects real-time smart meter measurements in all areas of the distribution system and delivers them to the central cloud server. In the central cloud server, the metering data administrator pre-processes and processes the data, and then independently performs state estimation for each LV distribution system, and the result is stored in the central cloud server and transmitted to the DSO. The metering data administrator performs state estimation for the entire distribution system using the state estimation result for each region and the smart meter measurement value, and then stores it in the central cloud server. DSO can increase the reliability of distribution system operation and control by securing distribution system visibility through state estimation results provided from the central cloud server.

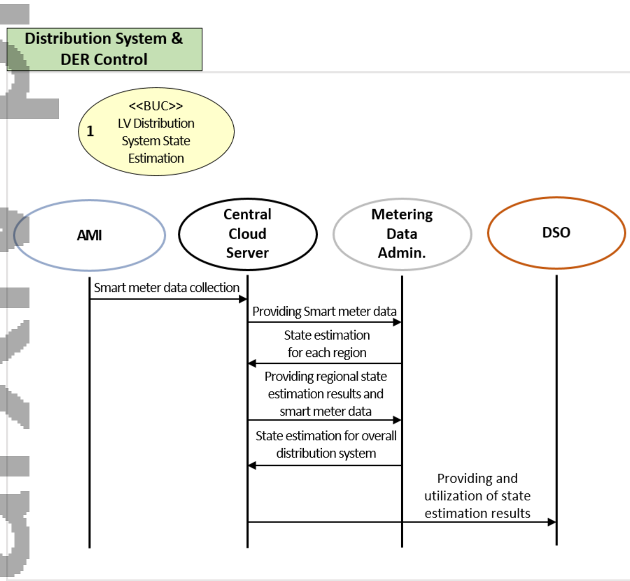

Fig 2 Business use case 1 information exchange sequence

3.2 LV distribution system topology estimation

LV distribution system topology estimation uses smart meter data collected from DER and AMI, historical metering data provided from MDMS (Metering Data Management System), and system state data of SCADA (Supervisory Control And Data Acquisition) to estimate LV distribution system components connectivity. The actors include AMI, MDMS, SCADA, GIS (Geographic Information System) server, the metering data administrator that performs topology functions, and DSO. Fig. 3 shows the information exchange sequence for this use case. AMI collects smart meter measurement values in real time and delivers them to the metering data administrator. GIS, SCADA and MDMS servers deliver historical metering data, GIS data, and system state data to the metering data administrator through the platform provided by AMI. The metering data administrator estimates the system topology configuration through SCADA and MDMS data and smart meter readings, and compares the results with existing GIS data. If the result of the comparison is different from the previous one, it performs a function of updating the new topology estimation result in the GIS server after verifying whether the estimation result is appropriate. By monitoring in real time through this use case, visibility of the distribution system can be secured by grasping the connection status of distribution system components.

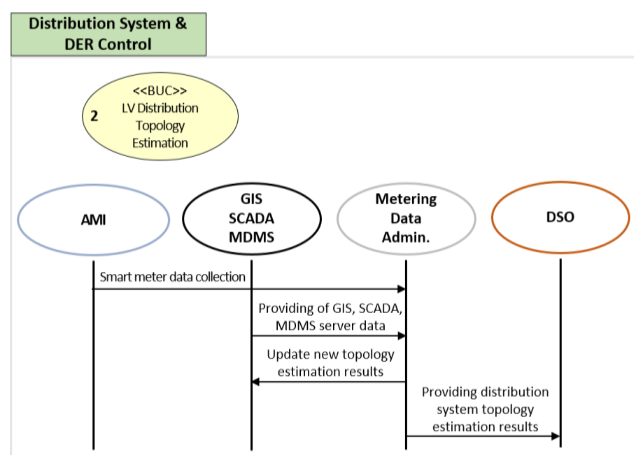

Fig 3 Business use case 2 information exchange sequence

3.3 LV distribution system power flow/load prediction

LV distribution system power flow/load prediction is a business use case that predicts the power flow and the energy consumption of the load at the time of prediction using weather forecast data and past energy consumption data. Short-term forecasts in minutes and long-term forecasts in annual units are performed. The AMI that collects individual consumer meter data, DSO, the metering data administrator that performs data-related functions, and the subordinate power flow/load

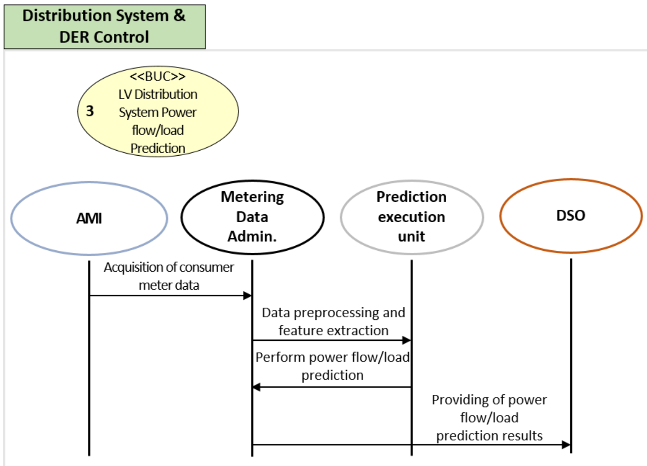

Fig 4 Business use case 3 information exchange sequence

prediction execution unit are actors that perform this function. Fig. 4 shows the information exchange sequence of BUC 3. AMI collects individual consumer meter data and delivers it to the metering data administrator. The metering data administrator pre-processes the received individual consumer data and then extracts the features of the data using a technique such as clustering. The power flow/load prediction execution unit predicts power flow and load at a desired time point through a predictive model designed using the extracted data features. The results are communicated to the DSO by the metering data administrator. This use case can help a lot in terms of grid investment by predicting currents and loads at a desired point in time.

3.4 BTM resource output measurement and control

BTM resource output measurement and control is a use case that measures the output of BTM resource and controls in case of system constraints and failures. The AMI, the BTM resource, the DSO, and a third party are

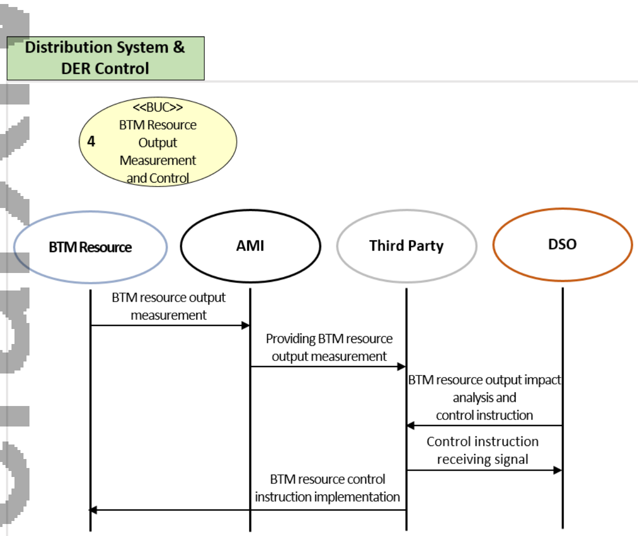

Fig 5 Business use case 4 information exchange sequence

the actors of this use case. When the BTM resource output is delivered to the DSO via the AMI, the DSO monitors the output in real time using the delivered information. In the event of a system constraint or failure, the DSO transmits the BTM resource output control instruction to a third party managing the BTM resource. The third party communicates the success of receiving the instruction to the DSO and regulates the output. Through this use case, the situation can be alleviated in case of system constraints or failures.

4. CONCLUSION

In this paper, we have listed the functional elements necessary to implement each use case. In addition, business use cases and actors related to distribution system and DER control were defined, and information exchange sequence was designed. Through this process, we were able to find out what functions and information exchange systems should be equipped to implement AMI-based business use cases. However, some core processes of the information exchange sequence require further elaboration in the future.

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