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Smart Meter Use Cases for New Energy Services

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ABSTRACT

The introduction of advanced metering infrastructure (AMI) is imminent in Korea as it is expected to demonstrate the next generation AMI in 2021. In addition, several countries around the world such as Italy, Germany have already deployed and operating AMIs or are planning. They also show a trend to utilize various functions of AMI to use new energy services for reasons of energy efficiency. In order to reflect this trend in recent years, specific use cases and related procedures should be defined. Thus, in this paper, we classify and structure the business cases of AMI that are required to support new energy services. Furthermore, we will summarize the lower business use cases and present the information exchange sequences of the business use cases in class and sequence unified modeling language diagrams. 5 use cases are found, we carefully selected which new energy service to support beyond the structural and functional limitations of the existing infrastructure in Korea. We hope that through such work, the foundation for implementing and operating various functions of AMI can be laid.

Keywords: Service providers, demand management, integrated meter reading, unified modeling language diagram, business cases and business use cases, information exchange sequence

1. INTRODUCTION

The Korea government has been planning to expand advanced metering infrastructure (AMI) that can implement functions such as supporting demand side management, managing small-scale distributed energy resources (DER), and supporting service providers (third parties) in various national plans such as Energy Master Plan [1], Smart Grid Master Plan [2], and Distributed Energy Activation Roadmap [3]. Globally, for energy efficiency reasons, AMIs have already been deployed and operating or planning, and study to implement and operate various functions by using this infrastructure is being conducted [4].

AMI refers to an infrastructure composed of a management system and a communication system including a smart meter that supports bi-directional communication [5]. Compared with automated meter reading of single-way remote meter reading, the main difference is that data exchange between consumers and utilities or system operators is possible by using the bi-directional communication. Furthermore, in Germany, there has been a study on AMI in which various functions can be implemented depend on applications without structural and functional limitations of smart meters, and in Korea, platform-based AMI, a similar concept, will be introduced as a next-generation AMI [4]. Considering that enormous amount of investment is required when deploying an AMI, it is necessary to utilize various use cases by platform-based AMI capable of bi-directional communication, application use, real-time measurement and customer-specific measurement.

In Korea, the next-generation AMI is expected to be introduced on a large scale after the demonstration in 2021. In such a situation where the introduction of AMI is imminent, aside from the problem of installing the AMI, a problem emerges regarding the implementation and operation of a use case using the application.

In terms of AMI operation, it can be classified into business cases such as DER and system control, demand management, and integrated meter reading, and various use cases can support for each business case. Meanwhile, we discuss the use cases for new energy

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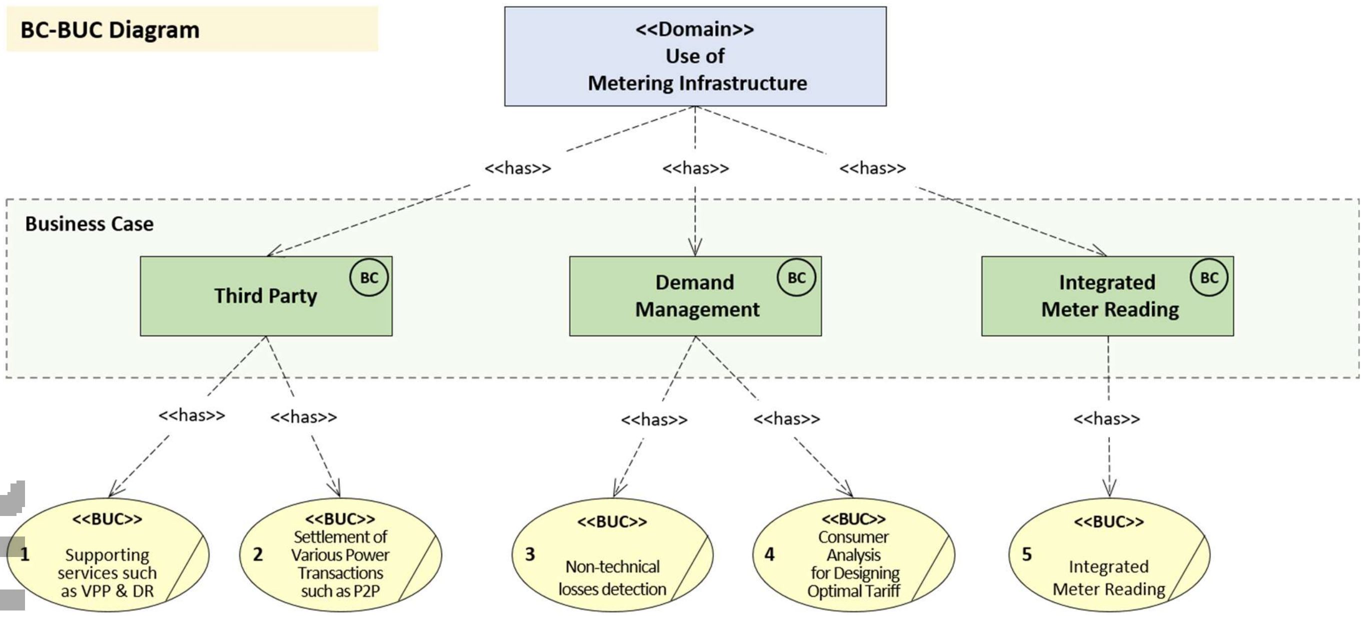

Fig 1 Domain model diagram as class diagram of use cases

services among several use cases. Business cases of AMI can be broadly divided into support for operating distribution system and providing new energy service depending on whether it contributes to a part that has been being carried out in the previous transmission system operation but is difficult to perform for reasons such as visibility in the distribution system.

It is found that 5 use cases to support providing new energy service are supporting services such as virtual power plant (VPP) and demand response (DR) [6], settlement of power transactions in various forms such as peer-to-peer (P2P) [7-9], non-technical losses detection [10], consumer analysis for designing optimal tariff [10], integrated meter reading in the non-power sector [11]. In the literatures, these use cases are presented individually, but no specific classification or procedure is defined in terms of business use cases.

Therefore, in this paper, a structural class unified modeling language (UML) diagram and information exchange sequence classified into business cases and business use cases (hereinafter referred to as use cases) for new energy services are presented, and it is expected to be helpful for implementing and operating AMI use cases by establishing the relationship between actors participating in the corresponding use case.

The remaining sections of this paper are organized as follows: Section 2 introduces class of use cases and concept of AMI for new energy services. Section 3 presents sequence UML diagram for each Use case of AMI. Finally, Section 4 concludes.

2. USE CASE OF THE AMI FOR NEW ENERGY SERVICES

In this section, we classify and summarize the use cases of AMI. Fig. 1 describes a class diagram of a new energy service of *Use of Metering Infrastructure* as a domain. Prior to classifying business use cases, business cases, which are higher-level concepts, were classified into *Third Party*, *Demand Management* and *Integrated Meter Reading*. *Third Party* is a business case that supports power trading platforms such as P2P electricity market, and aggregator to operate VPP except for power generation operators, Korea Electric Power Corporation (KEPCO) and Korea Power Exchange (KPX), which are participants in the current power trading market in Korea. *Demand Management* supports non-technical losses detection and designing optimal tariff with real-time data and meter data for individual customers that cannot be done with previous infrastructure. *Integrated Meter Reading* is intended for efficiency and economic feasibility by integrating access to meter reading data without deploying a separate infrastructure for energy in the non-power sector.

In the following, we look into the concept of business use cases for each business case.

2.1 Supporting services such as VPP, DR

Supporting services such as VPP, DR analyzes the effects of distributed resources on the systems by using the system status and market information that distribution system operator (DSO) has before using distributed resources and supports the procedure of adjusting the bid volume of service providers such as VPP and DR depending on the effects of distributed resources. This makes full use of bi-directional communication of AMI, and enables operation in consideration of the variability when distributed resources are connected to the system.

2.2 Settlement of power transactions in various forms

Settlement of power transactions in various forms supports various forms of power transaction settlement so that customers in the power grid can trade each other's assets or information to achieve individual energy targets. and it allows to settle P2P transaction by measuring the amount of power generation or consumption through a smart meter after bidding the volume for the power transaction between customers on the power trading platform.

2.3 Non-technical losses detection

Non-technical losses detection can minimize profit loss by detecting losses more accurately. In addition to technical losses, non-technical losses are detected through anomaly detection after collecting smart meter data.

The technical loss refers to the power loss naturally occurring in the transmission line and the transformer in the system, and the non-technical loss means loss due to certain actions such as theft of energy by the customer, a third party or consumed without payment from the customer. It is quite difficult to distinguish whether the non-technical loss is a loss unless the system is systematically monitored compared to the technical loss.

2.4 Consumer analysis for designing optimal tariff

Consumer analysis for designing optimal tariff analyzes the consumer group through the analysis of smart meter data such as billing data and load pattern analysis results, and designs a tariff based on it. It allows to design and provide better tariff and services to consumers compared to existing tariff system, and it enables power utilities to optimize profits.

2.5 Integrated meter reading in the non-power sector

Integrated meter reading in the non-power sector integrates and monitors public services such as gas, heat, hot water, and water in addition to electricity through AMI. Efficiency and economic feasibility can be secured by integrating access to meter reading data without deploying a separate infrastructure.

3. SEQUENCE OF INFORMATION EXCHANGE FOR EACH USE CASE OF THE AMI

In this section, we present a sequence diagram of information exchange between actors for each business use case, and through this, it is intended to be helpful in understanding the specific operation process of each business use case and implementing the function of AMI. Each use case requires some assumptions because there are some things that need to be improved after the deployment of the AMI in Korea or in the future, and a prerequisite will be presented as a trigger for each use case. First of all, the common assumption of the following use cases is that platform-based AMI has been deployed and its functions has been implemented for each application. Because it enables AMI to freely implement and operate use cases without any structural or functional restrictions. Other individual assumptions and prerequisites are discussed in each use case.

3.1 Supporting services such as VPP, DR

Assumption of the use case is:

- System of services such as VPP, DR have been established institutionally.

and perquisite is:

- The connection should be established to communicate between AMI and VPP, DSO and transmission system operator (TSO).

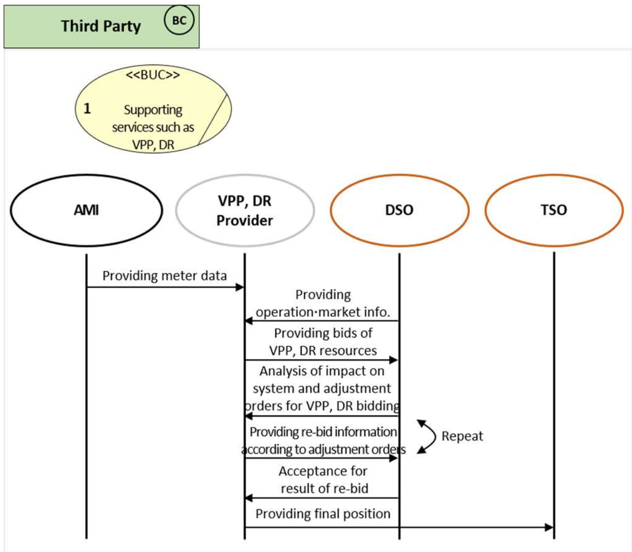

Fig 2 Information exchange sequence of BUC 1

Fig. 2 shows the information exchange sequence of this use case. As actors, AMI, DSO, TSO and service providers such as VPP, and DR appear. AMI supports bi-directional communication between DSO and service providers such as VPP and DR (hereinafter referred to as service providers). DSO provides system information to service providers, and based on this information, service providers bid on the wholesale market considering the system status. In order to use distributed resources without adverse effects on the system, DSO analyzes the effects of the bids of service providers on the voltage and current of the distribution system, and orders service providers to adjust the bid volume based on result of analysis. and then service provider accepts the bid adjustment and transmits the information to the TSO, it leads for TSO to plan for system operation that reflects the status.

3.2 *Settlement of power transactions in various forms*

Assumption of the use case is:

- Various types of power transactions are institutionally possible, and users are free to trade electricity with each other.

and perquisites are:

- Communication to obtain the volume of bidding regarding purchase, sale in the power trading platform should be available.
- The AMI should be established for detailed measurement of individual customers' power generation and consumption.
- The connection should be established to communicate between AMI and retailer.

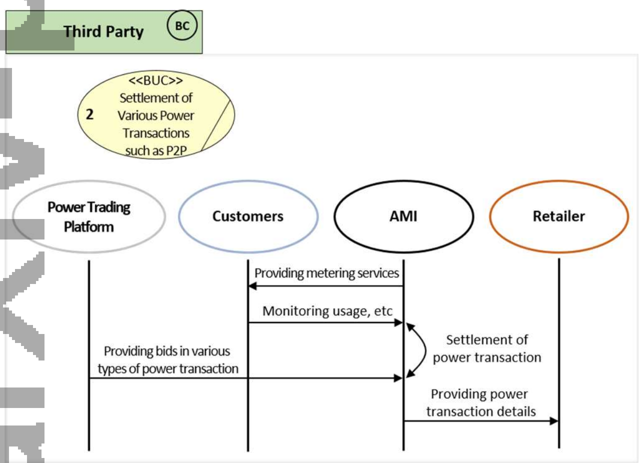

Fig 3 Information exchange sequence of BUC 2

In Fig. 3, power trading platform, customers, AMI and retailer appear as actors. After trading electricity between customers in the local market, they individually bid on the electricity trading platform. This bid volume is provided to AMI, and smart meter measures their power generation and consumption individually. Based on the volume of bids and actual measurements collected in this way, the settlement of power transactions is made, and the details of power transactions are delivered to the server of the retailer. The part already settled will be excluded from the existing tariff considering the delivered transaction details on the electric power trading platform.

3.3 *Non-technical losses detection*

Assumption of the use case is:

- The retailer is willing to use this use case as part of a demand management method.

and perquisites are:

- AMI database (DB) should be established for measurement data utilization and analysis.
- The connection should be established to communicate between AMI and retailer.
- Related function needs to use historical DB and real-time data.

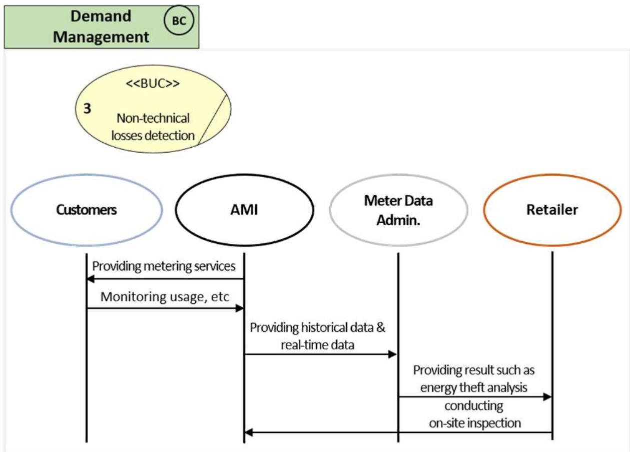

Fig 4 Information exchange sequence of BUC 3

In Fig. 4, customers, AMI, meter data administrator and retailer appear as actors. The smart meters collect the power usage of individual customers. These customer-specific and hourly data are stored in the meter DB of AMI and delivered to the meter data administrator. The meter data administrator is an entity who has the authority to process and manage such data. In this use case, the administrator sets a reference value of anomaly detection through data analysis, and then detects anomaly values based on the reference value when non-technical losses such as energy theft occur. This is called theft analysis, and the result of the theft analysis is provided to the retailer. The retailer conducts on-site inspection as a follow-up action to prevent non-technical losses such as energy theft.

3.4 *Consumer analysis for designing optimal tariff*

Assumption of the use case is:

- The retailer is willing to use this use case as part of a demand management method.

and perquisites are:

- AMI DB should be established for measurement data utilization and analysis.
- The connection should be established to communicate between AMI and retailer.
- Related function needs to use historical DB and real-time data.

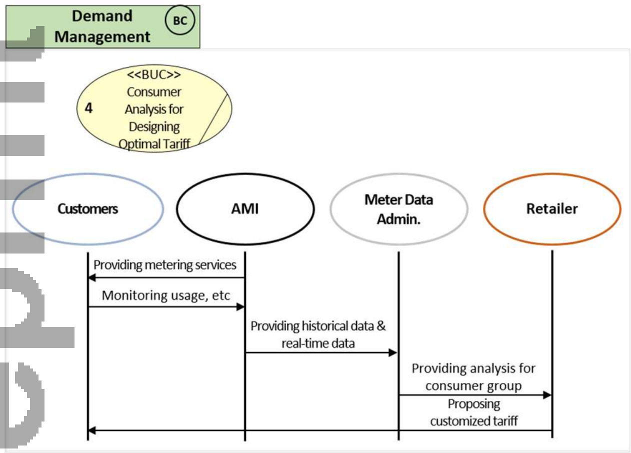

Fig 5 Information exchange sequence of BUC 4

In Fig. 5, as section 3.4, customers, AMI, meter data administrator and retailer appear as actors. The customer-specific and hourly meter data is transmitted to the metering data administrator as in section 3.4, but the difference is that the administrator uses the meter data to distinguish between consumer groups. The administrator classifies the electricity tariff level and load usage pattern for each customer by a clustering method, and extracts consumers who show abnormally different level of tariff and usage patterns from the classified cluster. When the results of this analysis are delivered to the retailer, the retailer designs a tariff system for each consumer type and proposes a customized tariff to them.

3.5 *Integrated meter reading in the non-power sector*

Assumptions of the use case are:

- Meter readers have been installed in consideration of laws and regulations for each service.
- It is assumed that the privacy problem for each utility's meter reading data has been resolved.

and perquisites are:

- AMI should be deployed to collect meter reading data.
- The connection should be established to communicate between AMI and other utilities such as gas, water.
- The connection should be established to communicate between AMI and retailer.

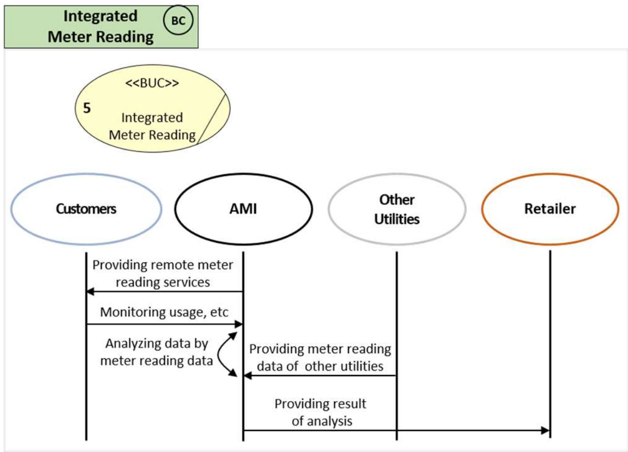

Fig 6 Information exchange sequence of BUC 5

In Fig. 6, customers, AMI, other utilities and retailer appear as actors. The key sequence of this use case is that the meter reading data of other utilities in the non-power sector is provided to the AMI. Other utilities deliver meter reading data from installed meters to AMI, and AMI can collect meter reading data from the power sector as an extension of remote meter reading service. The integrated meter reading data that integrates the power sector and the non-power sector can be linked to designing optimal tariff that considers each customer's usage pattern by providing raw data itself or the analyzed result to the retailer. Thus, It ensures efficiency and economic feasibility by integrating access to meter reading data without deploying a separate infrastructure for energy in the non-power sector.

4. CONCLUSION

In this paper, we have learned the principle by examining the concept of use cases required to support new energy services when operating AMI after introduction. In addition, we have investigated the relationship between the actors participating in the use case operation and the procedure between them in more detail. As a result, it seems that the foundation for implementing and operating these functions has been laid.

However, in the proposed procedure of the business use cases, each has a core process. These should be structured more specifically by selecting them as system use cases, and it is necessary to design an information exchange sequence for them. Furthermore, assumptions in this paper such as legal issues for meter data including privacy and information security issues related to communication and data storage should be resolved, and more elaborate discussions on how to design from a structural or functional point of view should be continued.

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REFERENCES

[1] Korea Ministry of Trade, Industry and Energy. The Third Energy Master Plan; 2019.
[2] Korea Ministry of Trade, Industry and Energy. The Second Smart Grid Master Plan; 2018.
[3] Korea Energy Economics Institute. The First Distributed Energy Activation Roadmap; 2020.
[4] Meister J, Ihle N, Lehnhoff S, Uslar M, Smart grid digitalization in Germany by standardized advanced metering infrastructure and green button. Application of Smart Grid Technologies 2018;347-371.
[5] Garcia FD, Marafão FP, Wesley Angelino de Souza, Luiz Carlos Pereira da Silva. Power Metering: History and Future Trends. In: 2017 Ninth Annual IEEE Green Technologies Conference (GreenTech), Denver, CO, USA, 29-31 March 2017.
[6] CAISO. Coordination of Transmission and Distribution Operations in a High Distributed Energy Resource Electric Grid; 2017.
[7] Sousa T, Soares T, Pinson P, Moret F, Baroche T, Sorin E. Peer-to-peer and community-based markets: A comprehensive review. Renewable and Sustainable Energy Reviews 2019;104;367-378.
[8] Tushar W, Saha TK, Yuen C, Morstyn T, McCulloch MD, Poor HV, et al. A motivational game-theoretic approach for peer-to-peer energy trading in the smart grid. Applied Energy 2019;243;10-20.
[9] Zhang C, Wu J, Long C, Cheng M. Review of Existing Peer-to-Peer Energy Trading Projects. Energy Procedia May 2017;105;2563-2568.
[10] World Bank Group. Data Analytics for Advanced Metering Infrastructure - A Guidance Note for South Asian Power Utilities; 2018.
[11] U.S. Department of Energy. Advanced Metering Infrastructure and Customer Systems - Results From the Smart Grid Investment Grant Program; 2016.