EVALUATION AND ANALYSIS OF THE UTILIZATION OF DATA FROM SMART METER SYSTEM

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ABSTRACT

Smart meters have been installed worldwide, of which data represents actual condition of energy usage on customer side. Thus it has big potential for providing valuable information for power grid management and operation, and also additional values for our society.
The survey about the smart meter deployment and use cases of data utilization had been carried out. The evaluation of collected use cases indicated us some characteristics, and also through the technological evaluation, we could derive technological requirements for data processing. Then, we picked up applicable candidate technologies and drew the whole system architecture for utilization of data from smart meter systems.

INTRODUCTION

CIGRE Study Committee C6 and D2 had realized the potential and importance of data from smart meter system, and approved to launch joint working group (JWG) working on this subject.
The aim of this JWG was to provide an overview of utilization of data from smart meter systems, to integrate and organize the values, tasks, and approaches to be taken and to make a proposal to the electric power utilities and associated market participants.

SURVEY

JWG conducted the questionnaire survey to address the following points.
* General outlines of the smart meter system in each country, area or company.
* Summary of examples on how the data from smart meter systems have been already utilized or could be utilized.
For later matter, which is about use case, questionnaires covered questions to clarify use cases and ideas of utilization of data from smart meter system, necessary technologies, and future works.
The questionnaire was distributed all over the world, and 35 responses were collected which contains 37 use cases.
Table 1 on the next page shows all of collected use cases, and Table 2 shows the number of respondents and use cases by countries.

Table 2: Result of questionnaire

Country	No. of Responses	No. of Use Cases
Austria	1	5
Bosnia & Herzegovina	3	2
Brazil	1	1
China	2	4
Germany	1	1
Italy	1	1
Japan	18	12
Poland	1	1
Romania	1	0
Russia	1	1
South Africa	2	3
South Korea	1	2
Spain	1	2
Sweden	1	2
TOTAL	35	37

DEPLOYMENT STATUS OF SMART METER SYSTEM

Deployment of smart meter system would be completed in several years in most of the countries, though there were some countries that their deployment plans had not been yet confirmed. There were various purposes for deploying smart meters; DSOs seemed to be motivated more on DSO side usages such as reducing labor cost or optimizing operation & maintenance. On the other hand, governments seemed to be motivated more on customer-side usage such as demand side integration.
Typical systems consisted of smart meters, concentrators for collecting data from several tens to several hundreds of smart meters, and central systems (HES/MDMS) for storing and managing metered data shown in Fig. 1.

Table 1: Collected use cases

No.	Title of Use Case	Status	Plan/Schedule
AT01	Power Snap Shot Analysis	Operational	Completed
AT02	Voltage Guard	Operational	Completed
AT03	Express Grid Access / EGDA	PoC	Completed
AT04	Topology Assignment	Tested in field	By 2016 - 17
AT05	Validation of Inverter Voltage Control Characteristic	Studying	Not yet confirmed
BA01	Prediction of consumers' electricity consumption by electrical load curve modeling	In service	Completed
BA02	Master data synchronization: meter readings, events collection and processing	Tested in field	By 2017
BR01	Reduce technical and commercial losses	Not yet installed	By 2017
CN01	Billing management	In service	Completed
CN02	DMS advanced applications	In service	Completed
CN03	Big data analysis	PoC	N/A
CN04	Ningxia electric power information collection system	In service	Completed
DE01	Prediction of consumers' electricity consumption behavior	In service	By 2020
ES01	Power control actuation	In service	Completed
ES02	Billing	In service	Completed
IT01	Collection and processing of load profiles for LV smart meters	In service	Completed
JP01	Detection of broken wires in distribution system	Not yet installed	Not yet confirmed
JP02	Prediction of consumers' electricity consumption behavior	Studying	Not yet confirmed
JP03	Load Forecast using SM systems	In Service	Not yet confirmed
JP04	Outage detection in distribution system	Tested in field	By 2016
JP05	Demand response baseline calculation system	PoC	Not yet confirmed
JP06	Demand prediction feed back system	Studying	Not yet confirmed
JP07	Outage detection using communication between meters	Studying	Not yet confirmed
JP08	Monitoring system for elderly people living alone	Studying	By 2020
JP09	Revising design standard of distribution facilities	In service	Completed
JP10	Efficient use of heat storage connected with Weather forecast system	Studying	Not yet confirmed
JP11	Inquiry of consumers' electricity consumption	In service	Completed
JP12	Accuracy enhancement of load management in distribution system by utilizing smart meter data	Studying	By 2020
KR01	"Load limitation" and "Power steal"	In service	By 2020
KR02	Power management system function in Smart Meters in order to control a customer DERs	Studying	Not yet confirmed
PL01	UPGRID Project	Not yet installed	By 2017
RU01	Smart Metering	In service	Completed
SE01	Outage management, manual solution today	In service	Completed
SE02	Outage management future	Not yet installed	By 2017
ZA01	Pilot: To install 3000 AMI meters	In service	Completed
ZA02	To install 33000 Smart Prepayment meters (AMI) meters	Not yet installed	By 2017
ZA03	Supply load profile data to customer	In service	Completed

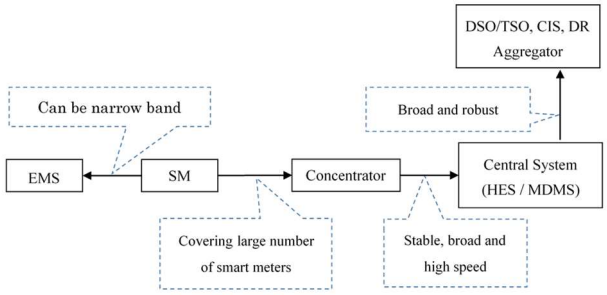

Fig. 1: Typical architecture of smart meter system

It was supposed that suitable communication media would be selected depending on the environment. The communication between smart meters and concentrator typically has to cover large number of smart meters and be cost effective for both initial deployment and operation. On the other hand, the communication between concentrator and central system needs to be stable, broad and high speed. Therefore, many of smart meter systems adopted different kinds of communication systems respectively.

EVALUATION OF COLLECTED USE CASES

For the evaluation of collected 37 use cases, it seemed to be plausible to categorize some similar use cases. Use cases were about the utilization of data from smart meter system, but there were differences among use cases whether they use data as it is or with processing and/or analyzing. So we set up two items for the categorization, which consisted matrix for categorization.

One item was what to be utilized or provided. The other was who utilize data, that is to say, the customer of use cases.

The former item consisted of four elements:

* Data as it is
* Processed data
* Analyzed data
* Event or something detected by data

Here, we defined “process” and “analyze”. “Process” means calculation, “analyze” means statistical process. For example, to draw a load curve based on the data from smart meter system is just calculation, which is defined as “process”. In addition to drawing load curve, to read its historical data and to make some calculation to predict future consumption is defined as “analyze”. These definitions were not general ones, only for this paper.

The latter item consisted of five elements:

* Customers/Consumers
* DSO
* Power entities including DSO
* Retailers
* Anybody

These elements would create a matrix which has 20 cells, and we sorted 37 collected use cases there.

Because the functions and/or the contents of some use cases had broad meanings to some extent, some use cases were defined in more than one cell. After sorting the 37 collected use cases, it was found that only 14 cells were valid.

Table 3 shows the outcome matrix. The contents of matrix represent use cases; the first two alphabet characters mean the country and the latter two number mean the serial number of use cases submitted from that country, which can be seen in Table 1.

Table 3: Matrix of use cases sorted out

	Data as it is	Processed data	Analyzed data	Event detected by data
To customers/ consumers	JP10, ZA03	JP05, KR01, ZA03		KR01
To DSO	AT01, JP06, PL01, RU01, ZA01, ZA02	AT02, AT03, AT04, BA02, BR01, JP12, KR01	BA02, BR01, CN02, CN04, JP03, JP09	ES01, JP01, JP04, JP07, KR01, SE01, SE02
To power entities including DSO			BA01, CN03	
To retailers	ES02, JP06, JP11	BA02, BR01, CN01, IT01, JP05	BR01, CN04, DE01, JP02	ES01
To anybody		AT05, KR02		JP08, KR02

For example, use case ZA03 is “Supply load profile data to the customer”. So, this use case “process” data from smart meter, draw load profile and provide this load profile to the customer, or just provide data itself to the customer. Another example, use case JP07 is “Outage detection using communication between meters”. This use case “process” and “analyze” data from smart meter, and with certain criteria, it detects power outage on certain smart meters and notify it to DSO.

Through this sorting, 37 use cases had been evaluated their similarities and categorized into 14 groups. These 14 occupied cells had their own certain function, which to be called “Function” representing a general outline of each cell. Named Functions are shown in Table 4. The numbers for occupied cells are counted from left to right, row by row, from top to bottom of the above matrix.

As Table 5 shows, all of the sorted use cases were 51, and more than half, 26 use cases were sorted as the group of which object was DSO. So, the utilization of data from smart meters could be said as mainly for network operators’ sake.

Table 4: 14 Functions

1	Data provision to customers
2	Load profile data for customers
3	Event detection to customers such as over load
4	Provision of metered data to DSO
5	Provision of processed data to DSO
6	Analysis of metered data for DSO
7	Power outage detection for DSO
8	Provision of data analysis
9	Data process to get consumption and/or billing data for retailer
10	Data process for retailer such as load profile
11	Analysis of metered data for retailer such as load forecast
12	Event detection to retailer such as over load
13	Data process for DER operation
14	Event detection for new business/services

Table 5: The number of use cases sorted out

	Data as it is	Processed data	Analyzed data	Event detected by data	No. of use cases
To customers/ consumers	2	3		1	6
To DSO	6	7	6	7	26
To power entities including DSO			2		2
To retailers	3	5	4	1	13
To anybody		2		2	4
No. of use cases	11	17	12	11	51

On the other hand, the numbers of use cases sorted into four items of what to be utilized or provided were almost same. It was understood that 37 collected use cases would cover all kinds of data calculation, processing and analysis. For these 14 functions, we evaluated and picked up technological requirements. Each use case, each function had its own characteristics, the number of smart meters required for its objective and data processing time acceptable for its objective.

Table 6 shows the evaluated technological requirements. The contents on upper cells mean the required number of smart meters, and ones on lower cells mean the required time for data handling.

For example, function 4 located on the second top and leftmost cell, which is “Provision of metered data to DSO”. This is the data provision to DSO, typical use case is the data provision for billing. So, required number of smart meters are all of them and required time for data handling is not critical, it can be offline.

Table 6: Technological requirements for 14 functions

	Data as it is	Processed data	Analyzed data	Event detected by data
To customers/consumers	One	One		One
	Hours to 1 day	Daily		In minutes
To DSO	All	All	All	Several to many
	Offline	1 minute to offline	Offline	Several minutes
To power entities including DSO			One or many	
			Offline	
To retailers	Many	Many	Many	One
	1 day to month	Days until month	Offline	In minutes
To anybody		One		One
		In minutes		In minutes

For another example, function 12 located on the second bottom and rightmost cell, which is “Event detection to retailer such as over load”. This use case detects over load of a customer with certain processing and analyzing, then system transmits a signal to open circuit breaker on the customer side in order to prevent over load. Required number of smart meters is just one, and required time for data handling is critical, should be within minutes.

TECHNOLOGICAL EVALUATION: EVALUATION PLANE

The quantity of smart meters and data processing time period would be the keys to technologically evaluate use cases. In order to effectively analyze the technological matters, the use case would be categorized based on the response time and a minimum number of smart meters required in the use case.

Based on the Table 6, we set up the evaluation plane created by the number of smart meters and data processing time, shown as Fig. 2.

X-axis of the plane represents the required response time, and Y-axis represents the minimum number of smart meters required as input for the use case. Boundary lines were put as references without clear definition, creating 4 categories. One use case might be mapped into 2 categories, but this would not affect technological evaluation.

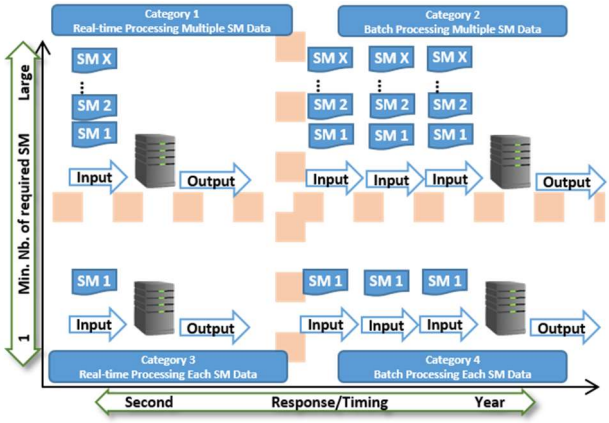

Fig. 2: Evaluation plane

Four categories are as follows:
Category 1: Real-Time Processing, Multiple Smart Meters
Use cases in this category need fast output based on input from multiple smart meters.
Category 2: Batch Processing, Multiple Smart Meters
Use cases in this category do not need fast output but input from multiple smart meters is required.
Category 3: Real-Time Processing, Each Smart Meter
Use cases in this category need fast output from the individual smart meter.
Category 4: Batch Processing, Each Smart Meter
Use cases in this category do not need fast output and can be carried out independently for individual smart meter.
The response time depends on the characteristics of use cases. For example, use cases based on historical evaluation utilize a group of data collected over a period of time, and use cases of instant action utilize real time data processing with a continuous data input.
Similarly, the needed amount of smart meters depends on the objective. The use case for individual consumer mostly needs input only from one smart meter. In contrast, the application for operation and maintenance of distribution network would need input from plural smart meters.

TECHNOLOGICAL EVALUATION: CANDIDATE TECHNOLOGIES

From the system's points of view, data are measured at smart meters, collected through communication network, stored into certain storage system at the central servers, then extracted with specific purpose, analyzed for such purpose, and finally put out with appropriate style. This is a process for utilization, and there are appropriate technologies for realizing each process. We derived four technological fields for each process; "Communication Technology", "Storage & Search Technology", "Computing Technology" and "Analysis Technology".
Fig. 3 shows the data processing flow and related technological field.
We surveyed related technologies and among them, we picked up candidate technologies for each technological field as shown below.

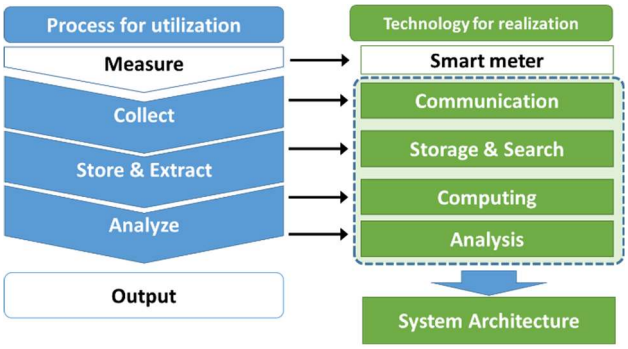

Fig. 3: Data processing flow and technological field

* Communication
Wired: fibre optics, twisted pair cable, coaxial cable
Wireless: multi-hop, 1-N/Mobile Phone
Power Line Communication
* Storage & Search
RDBMS
Key-Value type DB (NoSQL)
NewSQL
* Computing
Batch Processing
Ad-hoc Processing
Streaming Processing
* Analysis
Machine Learning (Supervised/Unsupervised learning)
Data Mining
Optimization
The appropriate system architecture would be different depending on how to implement applications; whether applications would be implemented as one of the internal functions of smart meter system or as the independent external functions of smart meter system. Applications, which realize the functions and/or services of data utilization, would be connected to MDMS for either system for accessing data. The most suitable system architecture for each category would be individually specified. System architecture for data utilization would be looked into thoroughly as well as picked up candidate technologies.

CONCLUSION

JWG conducted a questionnaire survey on smart meter system in the world. The evaluation of collected use cases showed that use cases tended to be for DSO's sake at least under current situation. JWG also derived technological requirements in terms of the required number of smart meters and the required time period for data handling. These two values would be keys to specify and design the system of data utilization.
JWG picked up the candidate technologies and drew the rough picture of whole system architecture. JWG would work on this matter and finalize this task.