PROPOSAL OF LOAD MANAGEMENT IN DISTRIBUTION SYSTEM BY UTILIZING SMART METER DATA

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ABSTRACT

KANSAI Electric Power Co. reports that we developed the new load management scheme of the meter and the transformer by utilizing smart meter data in order to optimize construction of distribution facilities. Moreover we propose further sophisticated management method of distribution facilities based on each facility's characteristic in this report.

1. INTRODUCTION

In recent years, more and more dispersed energy resources have penetrated power systems, and the interest in "smart grid" has been enhanced worldwide. Especially, smart meters with which we can communicate remotely have been introduced in many countries, and they are expected to be utilized in improving efficiency of both consumers' energy usage and electric power companies' operation.

KANSAI Electric Power Co. had developed smart meters since 1999, and started to install them in 2008. We have already implemented about 5 million smart meters of 13 million meters as of the end of 2015, and we will complete to implement smart meters by 2023. Previously we had got customers' power consumption data only once a month as monthly total consumption, but by introducing smart meters, we can get every 30 minutes' consumption data.

The purpose of this study was to improve the load management methods of distribution facilities by analysing the installed smart meter data statistically.

2. GENERAL OUTLINE OF SMART METER

2.1 Smart meter

Fig.1 and Fig.2 show the outlook of our smart meter which has plug-in module structure composed of metering unit, communication unit, and optional unit. The metering unit measures customer's power consumption. The communication unit records every 30 minutes' consumption data and transmit them to our MDMS (Meter Data Management System). The advantage of this structure is that we can replace only the metering unit, when we have to replace meters every 10 years according to Measurement Act in Japan. Besides, we can replace only the communication unit when we change communication media according to field's condition. Moreover, we can install a switch unit or a voltage measurement unit as optional unit if necessary. These replacement and installation can be done without live-line work.

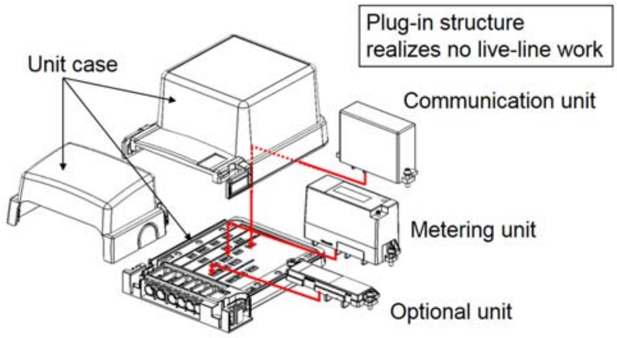

Fig.1 Structure of smart meter

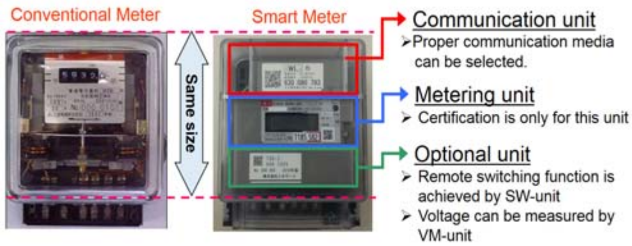

Fig.2 Comparison of conventional meter and smart meter

2.2 Communication system for smart meter

Fig.3 shows the overview of communication system applied for our smart meter. We apply wireless multi-hop method as the communication system of smart meters for individual houses. Smart meter data is transmitted from meter to meter and reach the concentrator by this way. On the other hands, we apply wired PLC (Power Line Communication) method as the communication system of meters for large multi dwelling buildings because it is difficult to transmit data from meters enclosed space by wireless system. Smart meter data collected in the concentrator is transmitted to our MDMS with fiber optics. Thus we can get 30 minutes' consumption data which is composed of 48 points per day per customer at MDMS. The data is stored and only connected with the billing system at present. However they will be expected to connect various systems and enable to improve efficiency of operating and maintaining distribution facility. In this paper, we introduce examples of improvement of managing distribution facilities by utilizing smart meter data.

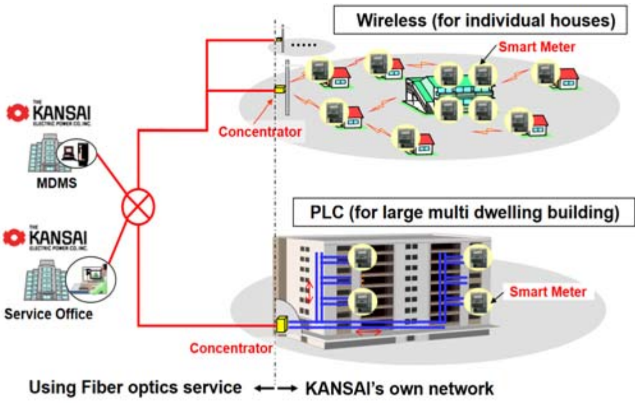

Fig.3 Communication system for smart meter

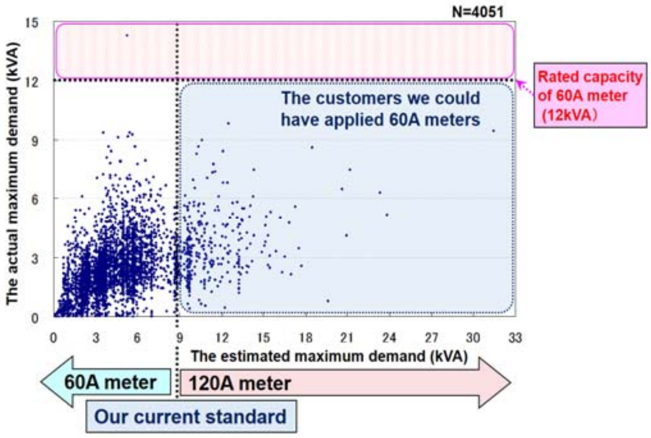

Fig.4 The estimated demand and actual demand

3. OPTIMIZATION OF METER SELECTION

3.1 Improving the standard of meter selection for new customers

We estimated the maximum demand from customer's facility and selected the type of meter capacity, either 60A or 120A, when a customer applied for new contract. According to our previous standard, in case of general contract type of customers which occupied around 70% of all customers, we applied 120A meter when the maximum demand of the customer exceeded 9kVA, otherwise we applied 60A meter. However, when we plotted the correlation between the estimated maximum demand and the actual maximum one collected by smart meters, we confirmed that almost all of the actual demand of customers did not exceed 12kVA, which is the rated capacity of 60A meter, though their estimated maximum demand was more than 9kVA(shown in Fig.4). Therefore we considered whether we could apply 60A meter to all customers and revise our standard. These led to reduce the cost, because 60A meter was cheaper than 120A meter.

We analyzed the distribution of the actual maximum demand by using Gumbel distribution and evaluate the risk whether the actual maximum demand exceeds the rated capacity accurately. Gumbel distribution is known to be applied for analyzing the distribution of maximum wind speed or highest wave. The distribution function is shown as (1) and (2).

$$F(x)=P[X \leqq x]=\exp(-\exp(-(x-\alpha)/\beta)) \quad \cdots (1)$$

$$f(x)=(1/\beta)\exp(-(x-\alpha)/\beta-\exp(-(x-\alpha)/\beta)) \quad \cdots (2)$$

{Average : $\mu=\alpha+\beta\gamma$ ($\gamma=0.5772$: Euler constant) , Dispersion : $\sigma^2=\beta^2\pi^2/6$}

Fig.5 shows Gunbel distribution of the actual demand. The risk was calculated as 0.0082% which is quite low. Therefore we decided to apply 60A meter to all customers with general contract type and revised our standard.

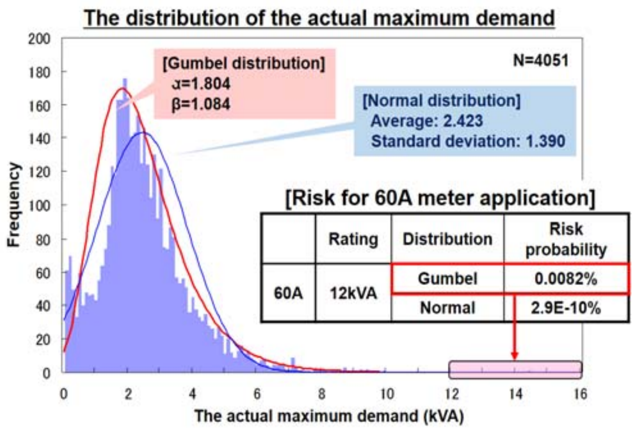

Fig.5 Gumbel distribution analysis

3.2 Replacement by expiration of certification

When we replaced meters every 10 years according to Measurement Act in Japan, we selected the type of meter by estimating maximum demand from monthly amount of consumption. According to our previous standard, we applied 120A meter when the monthly amount of consumption exceeded 1909 kWh, otherwise we applied 60A meter. Because we became able to estimate customers' consumption more precisely by smart meter data, we considered to revise the standard regarding replacement at the expiration of certification in a way of statistical approach.

Fig.6 shows the result of analyzing correlation of monthly power consumption and monthly peak load from smart meter data. As a result, we confirmed that the standard could be changed from over 1,909kWh to 2,528kWh as monthly power consumption.

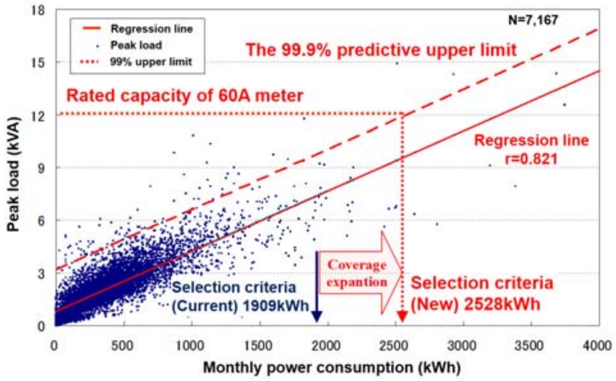

Fig.6 Correlation between monthly power consumption and peak load of customer

4. OPTIMIZATION OF TRANSFORMER SELECTION

When some customers built new houses and applied for electricity, if we estimated the maximum load based on just summation of each customers' demand, the transformer capacity was calculated much larger than actual maximum load because load curve depends on each customer's life style (shown in Fig.7). So we estimated the maximum load by multiplying the summation of each demand by compression coefficient which was derived by our previous research as the following formula.

$$[Max.load] = \frac{2n+1}{3n} \times \sum [each.demand]$$

n : number of customers connected to the transformer

Recently customers' life style has changed, and the compression coefficient has become obsolete.

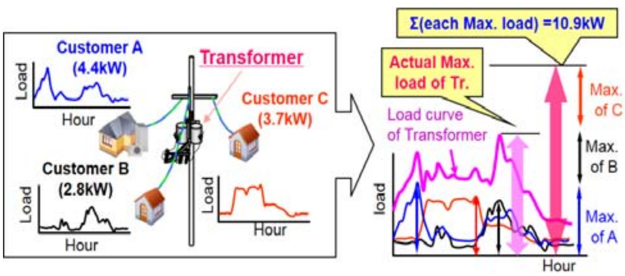

Fig.7 Image of conventional transformer selection

In this paper, we considered to revise the compression coefficient by analyzing the actual load from smart meter data. We sampled customers' load from smart meter data at random and created 280 virtual transformers in which all of the smart meters was installed because there were few such transformers. We compared the correlation between the number of customers of each transformer and the actual compression coefficient. We found two values had the liner correlation with plotting on logarithmic axes. So we applied the simple liner regression analysis and derived the approximate function, $y=0.96/n^{0.155}$, with the 95% forecast upper limit (shown in Fig.8).

We checked and confirmed the adequacy of this compression coefficient by winter and summer peak load data of real 42 transformers (shown in Fig.9). We concluded that new compression coefficient ($0.96/n^{0.155}$) is feasible and revised compression coefficient from (2n+1)/3n to $0.96/n^{0.155}$.

It is expected that we can reduce the asset investment for transformers with the revision.

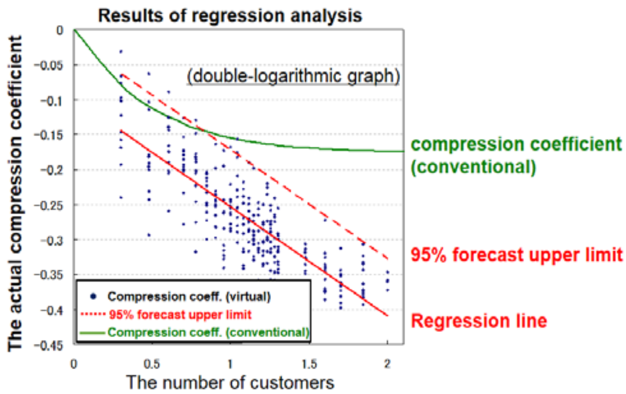

Fig.8 Examination of new compression coefficient

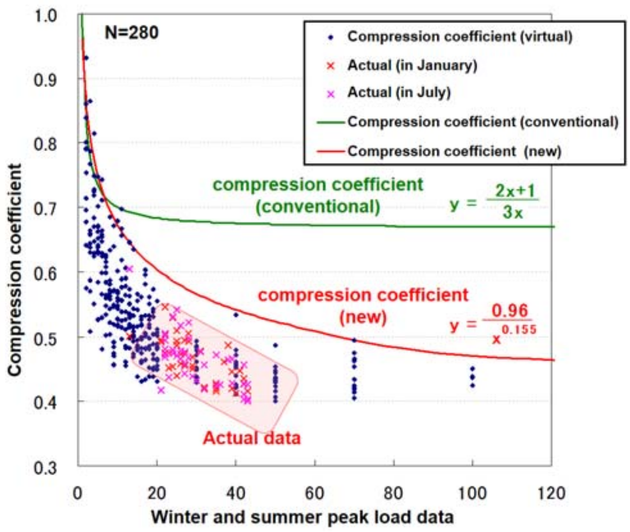

Fig.9 The adequacy of new compression coefficient

5. MANAGEMENT METHOD BASED ON CHARACTERISTICS OF FACILITY

We will be able to improve the load management by grasping the electricity usage of all customers when we will complete to implement smart meters. For example, we still estimate the maximum load of transformers statistically by using monthly power consumption data and selected necessary capacity of each transformer in case of replacing them due to aging. However, in the future we will be able to select more appropriate transformer capacity by actual load from smart meter data. In addition, by setting some threshold for various distribution facilities based on load characteristics and each equipment's specification, we can notice the time to replace them more precisely. So we are investigating each equipment's load characteristics from smart meter data and other related data (shown in table 1), and preparing to standardize.

Furthermore, it is expected to improve the customer service by utilizing smart meter data, and to create multiple effect by combining smart meter data and other sensors data. We will continue to research technology to create added value.

Table 1 Characteristic of facility

Facility	Threshold value	Threshold time
Meter	Rated capacity of meter	Instant
Transformer	1.4 times rated load of transformer	1 consecutive hour
Low-voltage electric wire	Short time allowable current	Instant
	Allowable current	10 cumulative hours in a month

6. CONCLUSION

We developed the load management scheme of the meter and the transformer by analyzing 30 minute's consumption data from smart meter, and revised selection standard of them. In order to optimize the investment for other distribution facilities, we continue to research further smart meter data utilization.