EXPERIENCES OF DEMAND RESPONSE IN YOKOHAMA DEMONSTRATION PROJECT

Kazumasa HONDA
Toshiba Corporation – Japan
kazumasa.honda@toshiba.co.jp

Kazuaki KUSAKIYO
Toshiba Corporation – Japan
kazuaki.kusakiyo@toshiba.co.jp

Shigeo MATSUZAWA
Toshiba Corporation – Japan
shigeo.matsuzawa@toshiba.co.jp

Masayuki KOSAKADA
Toshiba Corporation – Japan
masa.kosakada@toshiba.co.jp

Yasuyuki MIYAZAKI
Toshiba Corporation – Japan
yasuyuki.miyazaki@toshiba.co.jp

ABSTRACT

Many experiments are being carried out through demonstration to establish the negawatt/demand response (DR) market, in Japan.
A demonstration project of DR among residential households, buildings, factories, and electric vehicles (EV) has been conducted from 2012 to 2014, in Yokohama Smart City Project (YSCP), which is one of the largest-scale smart city projects in Japan, and 2014 to 2016 in successive projects.
In the DR demonstration experiments for buildings and factories, the target amount of reduction of power consumption had been allocated for each customer according to its capability to reduce electricity demand, in order to provide the stable amount of negawatt(aggregated DR capacity) for the power utility as an "negawatt aggregator".
In this paper, we report the demonstration experiment result and the difference between consumers in capability to reduce electricity demand in terms of the characteristics of consumers. In order to compare each consumer, the analysis was based on several key factors such as; DR response time (speed of response), equipment and control process, and capability of reduction of power consumption.

INTRODUCTION

In the electricity system reform process promoted by METI (the Ministry of Economy, Trade and Industry), the negawatt trading system is under discussion for establishment in Japan. Negawatt refers to the amount of power load capacity reduced as a result of consumers refraining from their original intended power consumption levels, in response to the requirement by the power utility and/or market. Since the Great East Japan Earthquake occurred on March 11, 2011, more attentions were drawn to the "negawatt power" as one of the measures to stabilize the balance of demand and supply.
Toshiba has conducted demonstration project of DR among residential households, buildings, factories, and EV from 2012 to 2014, in YSCP, which is one of largest-scale smart city projects in Japan, and 2014 to 2016 in successive projects. Figure 1 shows an overview of YSCP. In these demonstration projects electricity consumers reduced their electricity demand by energy saving and utilization of energy storage facilities and equipment control by building energy management system (BEMS) and so on. The demonstration has been proven each customer had enough capability to shave or shift its peak electricity demand.
In the DR demonstration for buildings and factories, the target amount of reduction of power consumption had been allocated for each customer according to its capability to reduce electricity demand, in order to provide the stable amount of negawatt for the power utility.

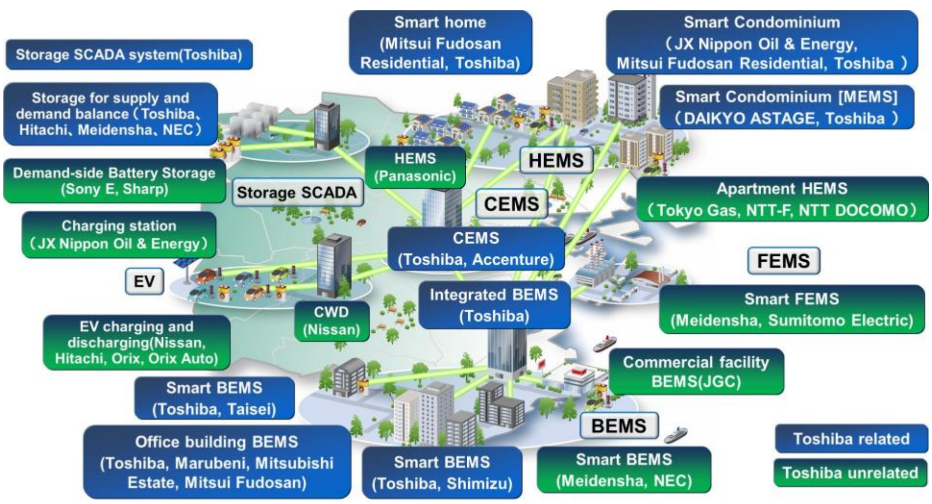

Fig.1 Overview of YSCP

In the advanced countries and/or region such Europe and North America [1]~[7], negawatt trading market is established and revealing by utilizing energy management/control of factory load mainly. In order to further expand negawatt trading market volume, it would be necessary for DR players to include industries that utilize other types of DR capacities in addition to factory load. Considering these points, we tried to clarify the characteristics of participants of more than 10 industries participating in the demonstration projects and utilize them for future negawatt trading market expansion.

DEMONSTRATION SYSTEM OF EXPERIMENT

Figure2 shows demonstration system diagram of experiment. In this experiment, Integrated-BEMS operates as DR aggregation system.

Integrated-BEMS receives the DR request signals from CEMS (Community Energy Management System, which manages local power grid) in YSCP demonstration project and DRAS (Demand Response Automation Server, which owned by the power utility) in successive projects. Then, Integrated-BEMS dispatches DR requests to customers in order to reduce electricity demand. Finally, Integrated-BEMS provides the requested amount of negawatt to grid, and send the result of DR to CEMS and DRAS.

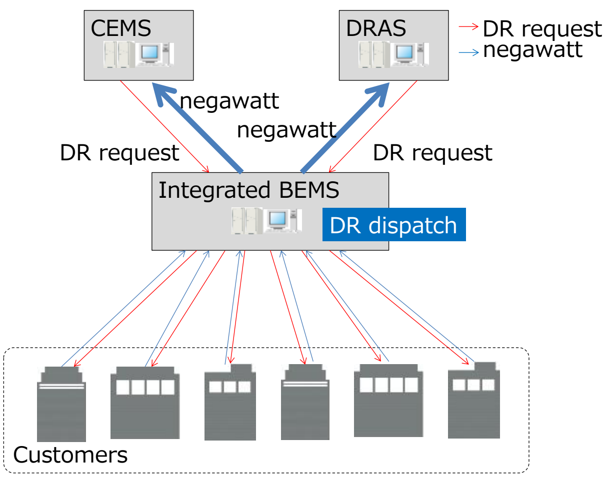

Fig2. Demonstration system diagram for experiment

DEMONSTRATION EXPERIMENT OF DEMAND RESPONSE

The demonstration experiment was carried out in three stages.

In the first stage, the capability to shave or shift customer's peak electricity demand was evaluated [8]. It was reported that more than 20% of the maximum reduction of customer's peak electricity demand was achieved and about 15% of the average reduction was achieved. Furthermore, DR capability was significantly different for each customer. Customers, who installed cogeneration system or storage battery, could reduce more than 15% of peak electricity demand. On the other hand, customers, who takes power conserving measures (e.g. turn off the lighting and weaken the heating or cooling), could reduce 3~6% of peak electricity demand.

This result is due to the fact that the participating buildings taking power conserving measures were commercial buildings which were occupied by many tenants. In order to avoid disrupting the comfort level of residents, DR was only performed for common areas, which only consume approximately 30% of the power consumed by the whole of building. Even if the power of the common areas were reduced by 20% as a whole the effective reduction was only 6% (30%*20%=6%). Tenant participation is critical for DR in commercial buildings. However, it was found that many problems remain in the incentive scheme for tenants and the DR performance measurement of each tenant.

In the second stage, the accuracy of the amount of adjustment in accordance with the each customer's target was evaluated.

Since in the first stage of the demonstration, we were able to demonstrate the capability to shave or shift customer's peak electricity, but we couldn't verify and control the amount of adjustment in accordance with the each customer's target.

Six of the ten customers reduced electricity demand more than target amount of electricity reduction. As a whole, the average achievement rate of all customers reached to 98%. On the other hand, two customers were not able to reduce their electricity demand successfully. This is due to temperature of DR event date was higher than temperature of that of the baseline calculation date in this experiment and amount of decrease in baseline is larger than amount of customer's power reduction. This result shows that temperature condition have an influence on the accuracy of the baseline. In order to reduce effect of temperature and enhance accuracy in baseline calculation, the Fast-DR such as 1 hour-ahead DR or fifteen minutes-ahead DR is needed.

In the third stage, to solve the issues identified in previous experiments became the obvious next step, hence the capability of Fast-DR (15 minutes-ahead DR and 1 hour-ahead DR) was evaluated. There were mainly two purposes. One is to quantify the potential to reduce electricity demand through the Fast-DR and the other is to evaluate the difference in the potential between consumers.

In this paper, the result of the Fast-DR demonstration experiment result and the difference between customers in capability to reduce electricity demand in terms of the characteristics of customers, are reported.

Fast-DR demonstration experiment

Prior the experiment, each customer had made a contract about DR program such as commitments to the DR response time and the duration and amount of electricity reduction.

Table.1 shows the condition of the DR demonstration experiment.

Table.1 The condition of the DR demonstration experiment

period	7/2014~1/2015
The number of participated customers	14
The number of the DR events	51
DR event time period	8:00~11:00 / 13:00~16:00 (7/2014~9/2014) 8:00~11:00 / 17:00~20:00 (10/2014~1/2015)
Condition of the DR requests	At the request from the power utility
DR request timing	15 minutes-ahead 1 hour-ahead Day-ahead
Baseline calculation method	Mean electricity consumption during DR event time period of the 3-highest-days among last 5 weekdays (High 3 of 5 method)

The experiment results were evaluated with an average success rate of all DR events and an average achievement rate of all DR events. The formula is shown as below.

$R_{s,t} = N_{s,t} / N_{e,t}$,where

$R_{s,t}$: Success rate

$N_{s,t}$: The number of successful reductions

$N_{e,t}$: The number of the DR events

$R_{a,t} = (E_{base,t} - E_{cons,t}) / E_{target,t}$,where

$R_{a,t}$: Achievement rate

$E_{base,t}$: Electric energy of base-line

$E_{cons,t}$: Electricity consumption

$E_{target,t}$: Electricity reduction target

The higher success rate means that the electricity consumption has been stably reduced. If achievement rate is close to 100%, it can be said that the customer has reduced electricity demand with high accuracy. The customers were evaluated in terms of following characteristics.

In this experiment, various types of customers such as factories, commercial facilities, water purifying plants, sewage treatment plants and district heating and cooling company have participated.

The customers were evaluated in terms of following characteristics.

- DR response time (speed of response)
- Equipment and control process
- Capability of electricity reduction

Table.2 shows the number of customers by characteristics.

Table.2 The number of customers by characteristics

DR request timing	15 minutes-ahead DR	3
	1 hour-ahead DR	5
	Day-ahead DR	6
Category of business	District heating and cooling company	1
	Event venue	1
	Commercial facility	2
	Factory	2
	Laboratory	1
	Waterworks department	7
Equipment and control process	Distributed power generator	1
	Distributed co-generator	3
	Battery storage	2
	Control air-conditioner	4
	Shifting production process	4

Results and evaluations

Evaluation of DR response time

DR response time was evaluated. Table 3 shows the results of the average success rate and the average achievement rate of the Fast-DR customers and the Day-ahead-DR customers.

Table.3 Result of DR response time

	success rate [%]	achievement rate [%]
Fast-DR	79.4	167.6
Day-ahead-DR	73.7	266.3

The success rate of Fast-DR customers was higher than Day-ahead DR customers and the achievement rate was closer to 100% than Day-ahead DR customers. The result indicates that the Fast-DR is more accurate than Day-ahead DR. However, the achievement rate of Fast-DR customers also exceeded 100%. From these results following factors can be considered.

- Customer who participated in DR program for the first time has set the contract volume for reduction of electricity demand conservatively.
- Customers avoid declining target because the incentive is paid only if customers achieve the contract volume for reduction of electricity demand

We need to adjust the contracted volume for reduction of electricity demand according to each customer's potential.

Evaluation of taking power generating vs. power conserving measures

We classified the customers into two groups; those taking power generating measures (distributed generator, distributed co-generator and battery storage) vs. those taking power conserving measures (control air-conditioner and shifting production process). Table 4 shows the results of those two different approaches.

Table.4 Results of taking power generating vs. power conserving measures

	success rate [%]	achievement rate [%]
power generating measures	84.8	145.6
power conserving measures	70.6	318.2

As a result, the success rate of the group taking power generating measures was higher than the group taking power conserving measures, and the achievement rate closer to 100% than the other group. This is because customers equipped with distributed generator are able to adjust the output to the target amount of electricity consumption.

Evaluation of contract volume

We evaluated result for different DR contracted volumes by classifying into large (100[kW] or more) and small (less than 100[kW]) customers. Table 5 shows the results by contract amount of reduction of power consumption.

Table.5 Results difference of the contracted volume

	success rate [%]	achievement rate [%]
Large Customer	81.3	158.2
Small Customer	63.2	440.4

The success rate of Large Customer was higher than Small Customer and the large customer's achievement rate was closer to 100% than Small Customer. Stable reductions are expected beyond a certain level of contracted volume. In contrast, if the contracted volume is small, there is a possibility that the DR performance is absorbed by fluctuation of the baseline.

Characteristics of customers

Up to 2015, more than ten types of the industries of customers participated. As a result, the characteristics of each industry and resource were grasped. Table 6 shows the characteristics of customers.

In order to provide the stable amount of negawatt/DR for the power utility, it is necessary to utilize the reduction characteristics of each industry and each customer and to dispatch DR request according to their characteristics.

Table.6 The characteristics of each industry and resource

Industry	DR resource	Characteristics
District heating and cooling company	Shifting production process (Switching operation of refrigerator)	・ The volume for reduction of electricity demand is large ・ Operational structure is in place, power reduction is stable
Event venue	Operating distributed power generator	・ The volume for reduction of electricity demand is large ・ Power reduction is stable
Waterworks department	Shifting production process (Stopping the pump) Control air-conditioner	・ Power reduction is stable in fine weather, but is not stable in rainy weather ・ A certain amount of reduction is required for stable power reduction
	Shifting production process (Changing quantity of water intake)	・ Power reduction is not stable ,because it can correspond only the day-ahead DR
	Discharge of battery storage (NaS battery)	・ The volume for reduction of electricity demand is large ・ Power reduction is stable
Recycling plant	Stopping scrap equipment	・ Power reduction is stable , because it is only equipment stop
Office building	Control air-conditioner and lighting adjustment	・ Automatic control is possible ・ Power reduction is not stable ,because the volume for reduction of electricity demand is small
	Operating distributed co-generator	・ The volume for reduction of electricity demand is large ・ Power reduction is stable
Factory (Manufacturing industry)	Control air-conditioner	・ Power reduction is not stable ,because the volume for reduction of electricity demand is small
	Operating distributed co-generator	・ The volume for reduction of electricity demand is large ・ Power reduction is stable
Laboratory	Operating distributed co-generator and Discharge of battery storage etc.	・ The operation of research facilities varies from day to day, the baseline is not stable ・ Power reduction is not stable
Commercial facility	Control air-conditioner and lighting adjustment	・ Power reduction is not stable ,because the volume for reduction of electricity demand is small
	Operating distributed co-generator	・ The volume for reduction of electricity demand is large ・ Power reduction is stable

Approach to the high-accuracy DR

The accuracy of the amount of negawatt/DR is improved by enhancing our understanding of the characteristics of each DR participant and selecting the participants who dispatch DR requests according to the situation (e.g. weather forecast, expected temperature, power usage situation etc.).

Figure3 shows the approach to generate high-accuracy DR. The histograms of DR potential (DR capacity) for participants with different behavioural patterns were created. Then, the customer's optimal portfolio could be found by repeating simulation and analysis.

Demonstration experiments will continue to be conducted throughout FY 2016 (Japanese FY 2016 ends in March 2017) to target error rate within ± 10% of the aggregator's contracted volume with the power utility.

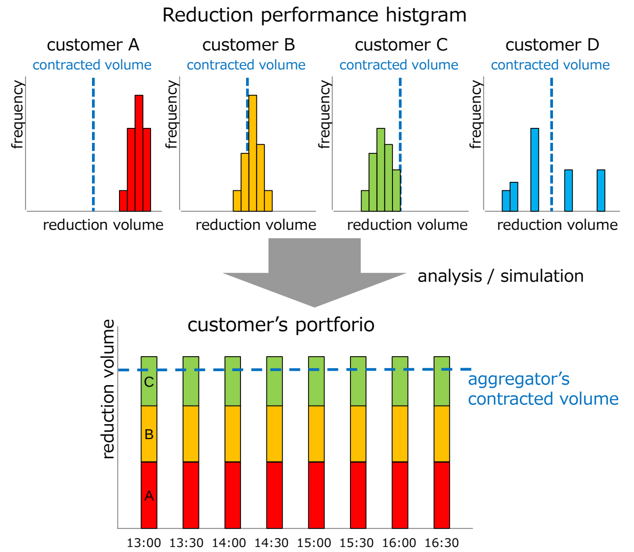

Fig.3 The approach to generate high-accuracy DR

CONCLUSIONS

Demonstration experiments of DR have been conducted. It has been proven that each customer had capability to shave or shift its peak electricity demand. In addition, the customer's potential about Fast-DR and the difference of each customer's characteristics were verified.

In the future, we will evaluate aggregator potential and continue to enhance DR performance (e.g. dispatch method to each customer, the contracted volume for reduction of power consumption according to each customer's potential, etc.).

REFERENCES

[1] Smart Energy Demand Coalition (SEDC), "Mapping-Demand-Response-in-Europe-Today-2015"

[2] Nomura Research Institute, "Survey on economic efficiency of negawatt trading (in Japanese)", (2015) http://www.meti.go.jp/meti_lib/report/2016fy/000283.pdf

[3] B. GUÉDOU, A. RIGARD-CERISON, "Comparison of market designs enabling DSR participation in the energy market", *CIGRE2016* C5-304

[4] M. LOMBARDI, S. DI CARLO, S. DE FRANCISCI, S. BRAMBILLA, "The impact of active demand on the electrical system and its actors estimated within the ADVANCED project", *CIGRE2016* C5-305

[5] M. SOBCZAK, K. KULA, M. KRUPA, "Project SMART – lessons learned from the emergency DSR programmes involving residential consumers and the aggregator", *CIGRE2016* C5-306

[6] dr. D. PARAVAN, R. MARKOČIČ, L. PRISLAN, "The importance of market regulation in exploiting demand response on balancing market: Slovenian and Austrian case", *CIGRE2016* C5-308

[7] N. DELANEY, D. STEVENS, S. POWER, "Facilitating Demand Side Response in the Single Electricity Market", *CIGRE2014* C5-205

[8] Ted Leopkey, Brad Rideouty, Tugcan Sahin, "Enabling new business models by utilizing flexibility in customer load - Addressing NB Power's winter peak demand challenge by using customer thermal storage flexibility", *CIRED2016* 0092

[9] Kazuaki Kusakiyo, Koichi Shimaoka, "Yokohama Smart City Project(YSCP) The effect of Demand Response(DR)", *International Conference on Integration of Renewable and Distributed Energy Resources* 3051_poster, (2014)