Evaluation of Demand Response Programs

Background and Objective

The electric utility in Japan has been tackling with various load leveling measures such as time-of-use (TOU) rates or contracts for adjustment to peak demand using thermal storage air conditioners. On the other hand, the "Demand Response (DR) program," which encourages voluntary energy conservation or load leveling on the demand side by using the Energy Management Systems (EMS), has been operated recently in the U.S., and its further expansion is expected to be the main service of the smart grid.

In this project, we clarified the effects of applying the DR program in Japan on peak demand saving of each customer and utility-wide load and supply cost. Also, a prototype of energy management system to verify the effects of DR program will be developed.

Main results

1. Issues in assessing the benefit of smart meters in Japan based on the analysis of the U.S. case

To find issues in assessing the social benefits of smart meters in Japan, we surveyed and analyzed literatures on the smart meters and smart grid in the U.S. According to our analysis, the smart meters in the U.S. are expected not only to dissolve lack of supply capability and improve supply reliability, but also to enable the grid connection of renewable energy resources and improve energy conservation (Table 1). These social benefits might be important for Japan as well; however the effectiveness of smart meters to the objectives has not been clarified in Japan. Benefits of demand response (DR) programs using the smart meter in Japan are to be demonstrated by field tests. In addition, alternatives to the smart meter should be also assessed in order to achieve proper control of surplus electricity from photovoltaic (PV) power in the future and in visualization of electricity usage for customers [Y09028].

2. Preliminary field experiment of demand response control in a Japanese office space

Customer acceptance is an important factor to determine the market potential of demand response program. To study the acceptance, we conducted a preliminary field experiment of peak-cutting demand response control of air conditioning and lighting in an office space located in Tokyo during 2009 summer. The target equipments were controlled on event days when forecasted daily highest temperature exceeded 30 degrees Celsius. Electricity consumption of the controlled equipment, thermal environment of the controlled space and worker comfort were surveyed to investigate the DR control effect.

We adopted two kinds of DR control strategies in the experiment, named event-U and event-K. In the latter, some lights in the office space were turned off and air conditioners were stopped for a longer time than the former. In these two DR control strategies, the experiment results showed a reduction of about 10% and 23% of peak demand of office space during DR period (Table 2, Fig. 1), respectively; however, the adopted DR control strategies affected worker comfort and their subjective working efficiency (Table 2) [Y09014].

Table 1 Current situations and issues in social benefits of smart meters, which are expected in the U.S. and Japan

Social benefit	Expectations for smart metering in the U.S.	Current situations and issues associated with smart metering in Japan
①Eliminate lack of supply capability	Reducing peak demand can be achieved by introduction of DR program, visualization systems of power usage and distributed generators, as a result, which makes it possible to postpone a new power plant construction.	Although lack of supply capability will not occur in the long term, there might exist inhibition risks of stable power supply (e.g. deterioration of energy situation). In addition, further improvement of load factor might be possible. Therefore load management would be needed in Japan. Although load management by use of smart meters is possible, its effectiveness has not been clarified in Japan.
②Improvement of power supply reliability	If a power blackouts occurs, grid operators can detect abnormality quickly from monitoring information of smart meters and restore the failure. It is also possible to avoid rolling blackout by reducing peak demand.	High supply reliability and high power quality have been maintained with distribution automation systems in Japan. Although introduction of smart meters might contribute to detect and restore the low-voltage power line failures quickly, its effectiveness should be measured quantitatively.
③Enabling the grid connection of renewable energy resources and EVs/ PHEVs	Introduction of smart meters makes it possible that a large amount of renewable energy resources and EVs/PHEVs interconnect with the power grid.	If a large amount of PV generators connect with grid, a few damages to grid stability are suspected. In particular, surplus electricity from the PV generators is concerned. There exist that a method which utility send inhibitory signals to power conditioning subsystems of PV generator via smart meter to avoid the surplus electricity, but there also exit alternatives to the smart meter should be assessed.
④Energy conservation	It is possible to visualize power usage and control intelligent devices by use of smart meters, as a result, which is expected to encourage consumers to use energy more efficiently.	Efforts to achieve energy-conservation are absolutely imperative for Japan where natural resources are scarce. Although achieving energy-conservation by visualization of electricity usage using smart meter is possible, alternatives to the smart meter should also be assessed.

Table 2 Summary of DR Control Experiment

The shorter the running period of air conditioners, the larger the amount of shaved peak demand, and the worse the subjective working efficiency of office workers.

Name of DR event			Proxy-event	Event-U	Event-K
DR control strategy	Control targets*1	Air Conditioner *2	No control (All air conditioner turned on)	All of air conditioners turn off for 5 minutes and then turn on for 10 minutes	All of air conditioners turn off for 5 minutes and then turn on for 5 minutes
		Light	No control	No control	A part of lights in the perimeter turn off
	Number of event days		6 days	6 days	4 days
Results	Peak cut ratio		-	10%	23%
	PMV *4		0.48	0.7	0.86
	Subjective working efficiency *3		81%	73%	49%

*1: DR period on event day is 13:00-16:00
*2: Preset temperature is fixed to 26 degrees C when air conditioners turn on
*3: Percent of workers who stated that thermal environment of controlled space does not affect their working efficiency
*4: Predicted Mean Vote

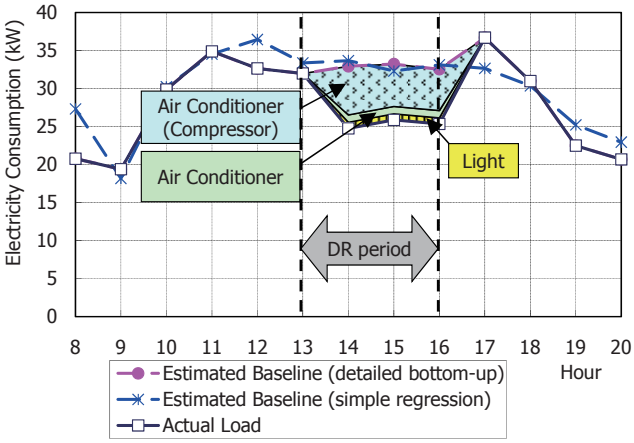

Fig. 1 Estimated shaved peak demand on an event day with Event-K

The contribution of air conditioning appliances to electricity demand reduction is prevalent during the controlled time.