Demonstration of Demand Response with Fuel Cell Units in a Condominium

Takuto. Isshiki[1], Yosuke. Watanabe[1], Hideyuki. Hosono[1] and Takao. Shinji[1]
[1] Tokyo Gas Co., Ltd.

SUMMARY: Tokyo Gas Co., Ltd. initiated a demonstration that combined fuel cells with demand response in a residential setting at a time when considerable attention is being paid to demand response in Japan. It was the first test that combined demand response with fuel cell units. We constructed an integrated control system to manage fuel cell units and battery output and power supply to a condominium during demand response events. To maximize fuel cell unit efficiency, we captured and stored waste heat in an accumulator tank. This allowed exhaust heat to be recovered regardless of whether the fuel cell unit was generating power and helped fuel cell units operate during a demand response event without sacrificing energy efficiency. Demonstration test results show that our system can scale back supply during a demand response event. Fuel cell unit can support both energy conservation and contribute to the stability of the electric power system.

Keywords: Demand Response, Fuel Cells

1. INTRODUCTION

Since the Great Japan Earthquake on March 11, 2011, we have faced electric power supply shortages which has caused rolling outages and has become a major social problem. Considerable attention is being paid to demand response [1] as a way to manage this problem and numerous tests are being performed in industrial sector, commercial sector and residential sector.

In demand response market of Japan, residential sector is expected to play an important role as well as industrial sector and commercial sector. Demand response of residential sector is mainly performed by curtailment of loads controlled by HEMS. Inhabitants have to change the life pattern when performing demand response of curtailment, meanwhile they don't have to change the life pattern when performing demand response with generators. But demand response demonstration tests with combined heat and power (CHP) in the residential sector, such as in a condominium, had never been performed. Tokyo Gas Co., Ltd. took the initiative with a demonstration that combined fuel cells with demand response in a residential setting. It was a first test that combined demand response with fuel cell units. The results show that fuel cell units can scale back supply during a demand response event without sacrificing energy efficiency.

2. DEMONSTRATION FACILITIES

Our test installation was housed in a 20-apartment condominium[※1] and included 10 fuel cell units (0.75 kW output each) and a 40 kWh battery with 10 kW output (Figure 1, 2). We have constructed the integrated control system to control the output of each fuel cell unit and the battery, so that the power supply from grid to the condominium could be reduced during demand response events.

The outline of this system is shown in Figure 3. This system reduces the power demand of the condominium by running fuel cell units and increasing output of the battery during demand response time, when the system receives a request of demand response from community energy management system (CEMS[※2]).

Figure 1. Fuel cell units

Figure 2. Battery

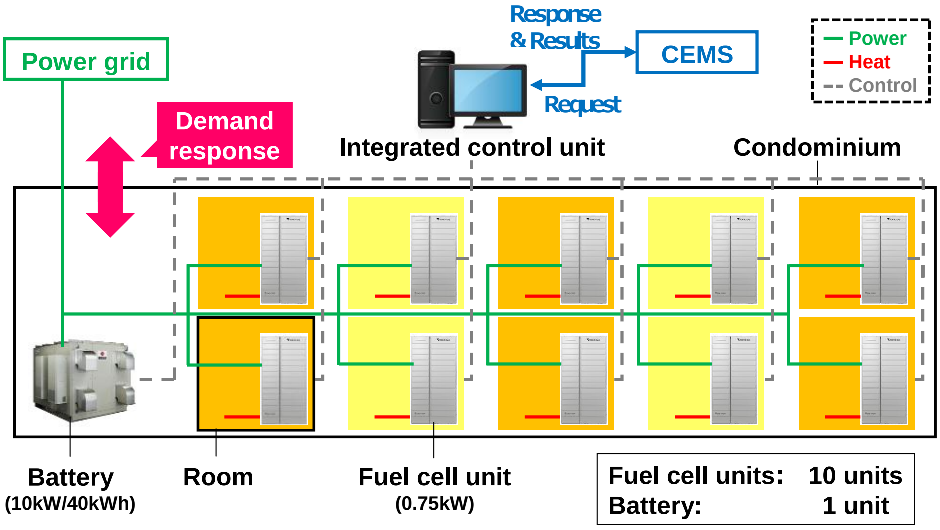

Figure 3. Outline of demand response system

A fuel cell unit is a micro-CHP system. The rated output of electricity and heat from a fuel cell unit is 0.75kW and 0.94kW, respectively. And electricity efficiency is 40% LHV and heat recovery efficiency is 50% LHV.

A fuel cell unit has an accumulator tank, and the waste heat of the fuel cell unit is accumulated in it as hot-water, while the fuel cell units is generating. This hot water will be used mainly for bathing.

Figure 4 shows the example of operation of fuel cell unit. The fuel cell unit predicts the residents' bath time and the demand of hot water, and it generates before the bath time and reserves the hot water in an accumulator tank for bathing. When there is a request of demand response, the fuel cell units could be easy to generate during the demand response time intensively without lowering energy efficiency.

The fuel cell unit can be used as a means to demand response without sacrificing energy efficiency.

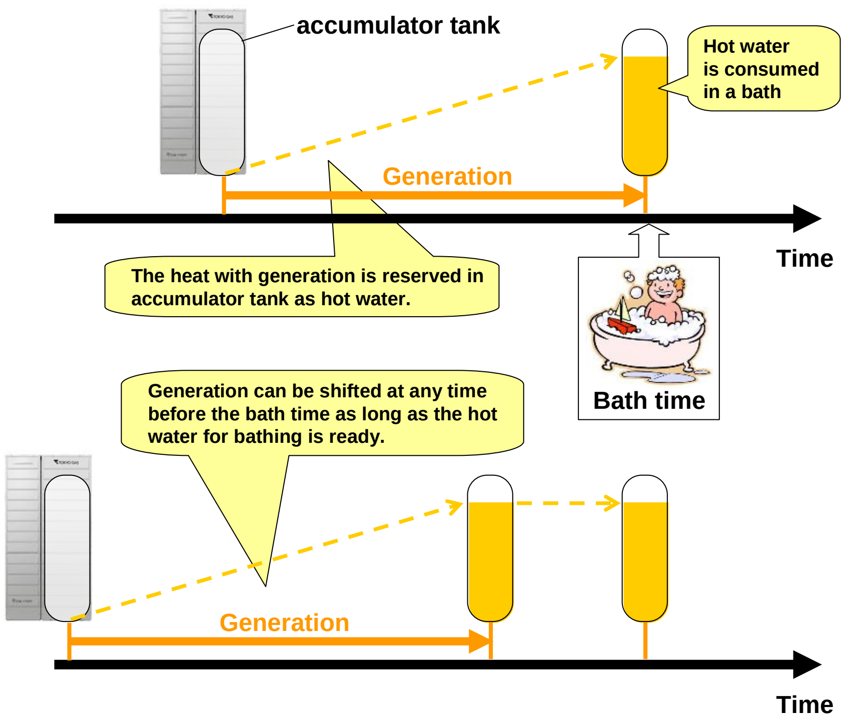

Figure 4. Example of operation of fuel cell unit

3. RESULTS OF DEMONSTRATION

Eight separate demand response demonstrations were performed between July and September 2013. Three separate demand response demonstrations are performed in January 2014.

Demand response time in summer was 13:00 to 16:00, and demand response time in winter was 17:00 to 20:00.

3.1. Electricity demand reduction

Example of electricity demand with and without demand response request and output of fuel cell units with and without demand response request are shown in Figure 5.

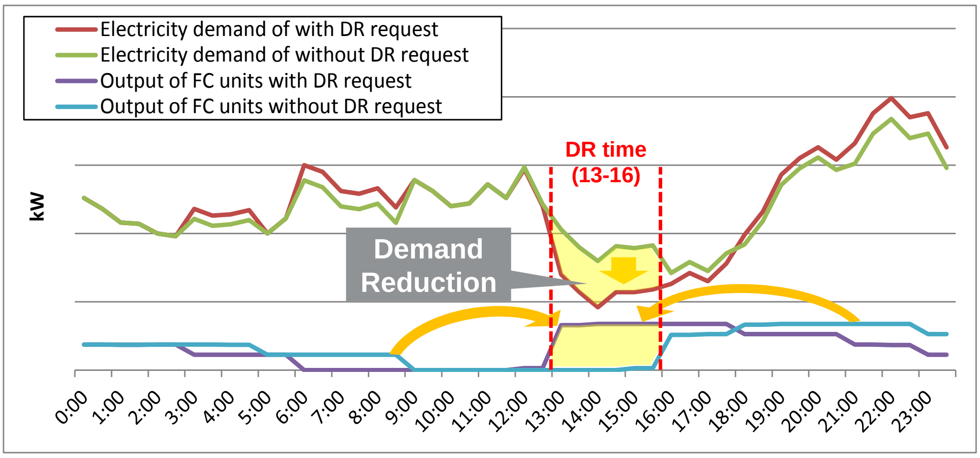

Figure 5. Example of electricity demand with/without demand response (DR) request

Fuel cell unit's power generation and discharge of the battery without demand response request is shown in blue line. At this time, the power demand is the green line. If there is a demand response request, integrated control system changes the operation plan of fuel cell unit's power generation and discharge of the battery in purple line. At this time, the power demand is the red line. The difference between the red line and the green line of demand response time is demand reduction.

3.2. Evaluation methods of demand response

Green line of Figure 5 can't be measured, so demand response is verified by reduced electricity demand from base line. Base line is electricity demand assuming the customer doesn't participate in the demand response. The evaluation method is shown in Figure 6. In demonstration, the effect of demand response is evaluated by demand reduction rate that to be calculated according to the following equation; (Base line – Demand reduction) ÷Base line.

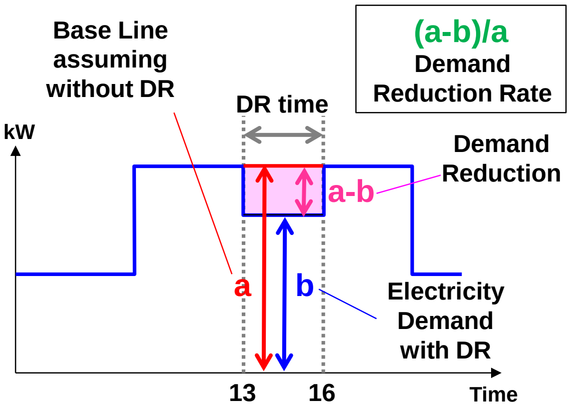

Figure 6. Evaluation method

3.3. Results of demand response

The summer test results show that we reduced supply by an average 58% with a maximum reduction of 84%. These results are shown in Table 1.

The winter test results show that we reduced supply by an average 49%. These results are shown in Table 2.

Date	Time	Base Line a	Electricity Demand b	Demand Reduction a-b	Demand Reduction Rate (a-b)/a
7/19	13:00-16:00	17.1kW	6.3kW	10.8kW	63%
7/25	13:00-16:00	14.7kW	2.4kW	12.3kW	84%
7/30	13:00-16:00	14.9kW	5.8kW	9.1kW	61%
8/8	13:00-16:00	17.0kW	4.3kW	12.7kW	75%
8/9	13:00-16:00	16.3kW	7.4kW	8.9kW	55%
8/30	13:00-16:00	16.6kW	12.7kW	4.0kW	24%
9/3	13:00-16:00	15.7kW	9.2kW	6.6kW	42%
9/5	13:00-16:00	16.8kW	7.1kW	9.8kW	58%
				Average	58%

Table 1. Results of the summer demand response tests

Date	Time	Base Line a	Electricity Demand b	Demand Reduction a-b	Demand Reduction Rate (a-b)/a
1/15	17:00-17:30	19.4kW	8.9kW	10.5kW	54%
	17:30-18:00	19.6kW	8.7kW	10.9kW	56%
	18:00-18:30	20.2kW	10.5kW	9.7kW	48%
	18:30-19:00	20.4kW	10.5kW	9.8kW	48%
	19:00-19:30	19.7kW	11.4kW	8.3kW	42%
	19:30-20:00	19.1kW	11.7kW	7.4kW	39%
1/16	17:00-17:30	19.4kW	7.4kW	12.0kW	62%
	17:30-18:00	19.6kW	7.5kW	12.1kW	62%
	18:00-18:30	20.2kW	10.0kW	10.2kW	51%
1/29	17:00-17:30	16.8kW	6.1kW	10.7kW	64%
	17:30-18:00	18.0kW	7.4kW	10.6kW	59%
	18:00-18:30	17.5kW	8.1kW	9.4kW	54%
	18:30-19:00	16.3kW	9.6kW	6.7kW	41%
	19:00-19:30	14.9kW	10.5kW	4.4kW	29%
	19:30-20:00	15.3kW	10.3kW	4.9kW	32%
				Average	49%

Table 2. Results of the winter demand response tests

These results show that fuel cell units can be utilized for demand response in residential sector.

Demand reduction rate of our demonstration and average of demand reduction rate of all demonstration sites are shown in figure 7.

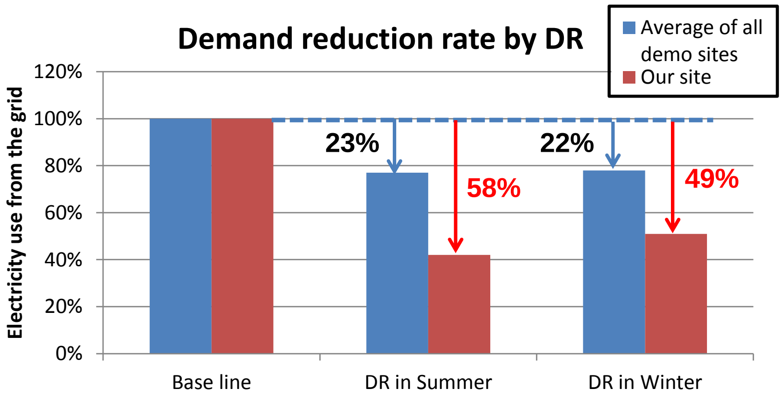

Figure 7. Demand reduction rate of our demo and average of all demo sites

Electricity demand reduction of average of all demonstration sites is 23% in summer and 22% in winter. These results of all demonstration sites include curtailment demand response. So, demand response by generators can reduce more electricity demand than demand response by curtailment.

4. CONCLUSIONS

We have confirmed the three things by the demonstration;

1) Generators in residential sector that is to say fuel cell units can be utilized for demand response.
2) Generator DR can reduce electricity demand more than curtailment DR.
3) Demand response with generators can reduce electricity demand without changing the life pattern of inhabitants.

Twenty five thousand fuel cell units are installed in 2013 and we expect this number to increase [2]. Though a single fuel cell unit is small at 0.75 kW, when integrated, the overall effect of fuel cell units can be substantial. To integrate fuel cell units, we are developing an ICT (Information and Communication Technology) with a standard protocol such as OpenADR.

5. ANNOTATION

※1 Details of the condominium

Concept:
Zero energy house in apartment type

Total floor space:
3,400m^2

Room:
24 living units, about 75m^2/room

Figure 8.　The exterior of our site

※2 CEMS (Community Energy Management System)

CEMS controls the electric demand and supply retaining high efficiency of energy. Integrate control units in condominium receives a request of demand response from CEMS. CEMS in our demonstration has role as a demand response aggregator. Demand response aggregator collects negawatt the local electric power company that managed for the electric power grid. In our demonstration, CEMS requests demand response to customers that are registered as demand response aggregator, and collects negawatt.

6. REFERENCES

[1] DOE, “Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them”, U.S. Department of Energy,　2006
[2] Advanced Cogeneration and Energy Utilization Center Japan (A.C.E.J) Home Page, 22 Jan. 2014. A.C.E.J. 30 Sept. 2013 < http://www.ace.or.jp/web/works/works_0090.html>.