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CHP-based Demand Response for controlling Electricity Load Profile

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I. INTRODUCTION

Japan has decided to open its retail electricity market by 2016. Within the institutional design of electric power market, Negawatt power, the use of Demand Response (DR) is expected to play a new role in electric power on the demand side. In this paper, we propose a Combined Heat and Power (CHP)-based DR mechanism for controlling the electricity load profiles of apartment houses, each of which is equipped with a micro-CHP and a smart meter.

II. A MODEL APARTMENT HOUSE EQUIPPED WITH CHPS

In Japan, residential fuel cells (FCs), which work as CHPs, have been commercialized since June 2009 and installed as household facilities in apartments since April 2014. Here we propose a model apartment house equipped with an FC in each dwelling. The apartment block has less than one hundred units and is connected to the power grid in a bundle. In general, each FC works for the electricity and heat demand of its own dwelling and monitors the total electricity load of the apartment building via the Internet.

III. ELECTRICITY LOAD PROFILE CONTROL

In the normal mode, the electricity load profile of the apartment building ($LOAD_{POI}$) is equal to the sum of the dwellings, subtracting FC power (DER_{NORMAL}) from electricity demand (DEMAND) for each unit, expressed by (1),

$$LOAD_{POI}(t) = \sum_{i=1}^{N}(DEMAND_i(t) - DER_{NORMALi}(t)) \quad , \qquad (1)$$

where N is the total number of dwellings in the apartment building.

When an aggregator or a power grid requests the Negawatt power of the apartment, the residents, to whom FCs belong, agree to the Negawatt request shift to a DR mode and boost their electric power (DER_{DR}) for the electricity demand. As a result of the power boosting, the electricity load profile appears to decrease, as shown in Eq. (2). The amount of Negawatt power ($NEGAWATT_{EP}$) for 30 min is displayed in Eq. (3),

$$LOAD_{POI-DR}(t) = \sum_{i=1}^{N}(DEMAND_i(t) - DER_{NORMALi}(t)) - \sum_{j=1}^{M} DER_{DRj}(t) \quad , \qquad (2)$$

$$NEGAWATT_{EP}(30min) = \sum_{j=1}^{M} \int_{30\,\min} DER_{DRj}(t)dt \quad , \qquad (3)$$

where M is the number of residents who agree to the Negawatt request in the apartment building.

IV. AUTOMATIC HEAT CONSUMPTION AND CONCLUSION

To meet the Negawatt request, FCs in the DR mode need to ensure the capacity and the duration of electric power generation. Automatic heat consumption, such as filling the bath with hot water, removes the operational constraints from residential FCs. Consuming heat from exhaust heat recovery tanks, the FCs are guaranteed to operate for at least four hours in a summer day. Therefore, CHP-based DR mechanism comprises the electricity load profile control by FCs and the automatic process of heat consumption by exhaust heat recovery tanks.

APPENDIX

A configuration of energy networks in a model apartment building equipped with CHPs and a procedure table for the processes of CHP-based DR mechanism are shown below.

A. Energy networks of an apartment building equipped with CHPs

In the model apartment building equipped with FCs and exhaust heat recovery tanks, the energy networks composed of electricity, city gas, and hot water are configured as seen in Figure 1.

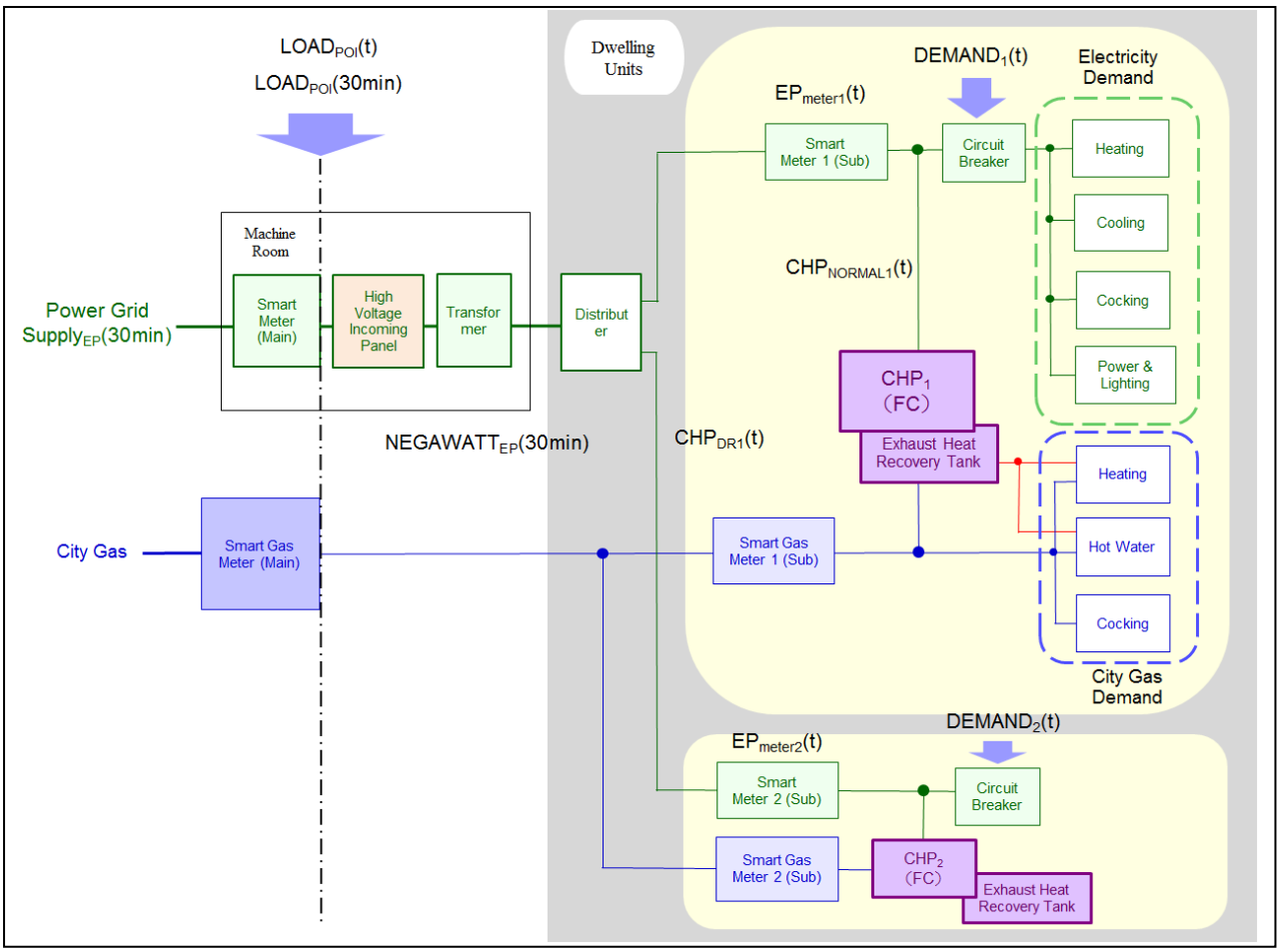

Figure 1. Energy networks of the model apartment building equipped with FCs and exhaust heat recovery tanks

B. Processes of CHP-based DR mechanism

Residential FCs install exhaust heat recovery tanks; if the tanks are full of hot water, FCs stop generating electricity. FCs have to ensure the operational circumstances before boosting the electric power in the DR mode. FCs and exhaust heat recovery tanks work on two procedures in parallel, the electricity load profile control and the automatic heat consumption, as shown in Table 1.

Table 1. Processes of the electricity load profile control and the automatic heat consumption

Electricity Load Profile Control	Automatic Heat Consumption
1) Each FC starts boosting its electric power by autonomous group control monitoring the total electricity load. 2) The aggregator or the power grid adjusts the Negawatt power of the apartment building modifying the value of Negawatt request via the Internet. 3) It also manages the duration of Negawatt power time.	a) Each FC searches the vacant capacity of its exhaust heat recovery tank. b) Unless the vacant capacity is enough, the FC activates its tank by filling the bath with hot water. c) This process consumes more than 75 % of storage heat in the tank.