Study for Designing Power Trading System in High Voltage Power Receiving Apartment Complex Considering Economy and CO_2 Emission

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***Abstract*—Because of recent trend of realizing a low carbon society, fuel cell in residential sector has been attracting much attention. Nevertheless, many Fuel Cells have installed in detached house, installation Fuel Cells into apartment complex have not progressing well. In order to promote introduction of Fuel Cell in apartment complex, a system that each house in an apartment complex may accommodate surplus electricity which is made from fuel cells to other houses in the apartment complex is suggested. Apartment complex which installs this system contracts a power company to receive bulk high pressure power, so we can design Electricity rate system in the apartment complex. In this paper we calculate energy flow in an apartment complex which adopt the system using Mixed-Integer Linier Problem in order to promote this system. We evaluate profitability and CO_2 emission of an apartment complex. Also we optimize electricity rate so that all houses in an apartment complex have profit.**

***Index Terms*—component, fuel cell, apartment complex, electricity trade, mix-interger linear problem**

I. Introduction

According to the fourth report of IPCC [1], the numbers of disasters that seem to be caused by global warming tend to be increasing. Since Japan emit 4% of CO_2 of the world CO_2 emission; 5th most CO_2 emitting country, Japan must play an important role in reducing CO_2 emission. Fig. 1 shows Japanese energy consumption in each sector. While energy consumption of industrial sector is not much increasing, Energy consumption of commercial sector and household sector are increasing, so it would be need to reduce energy consumption in these sectors.

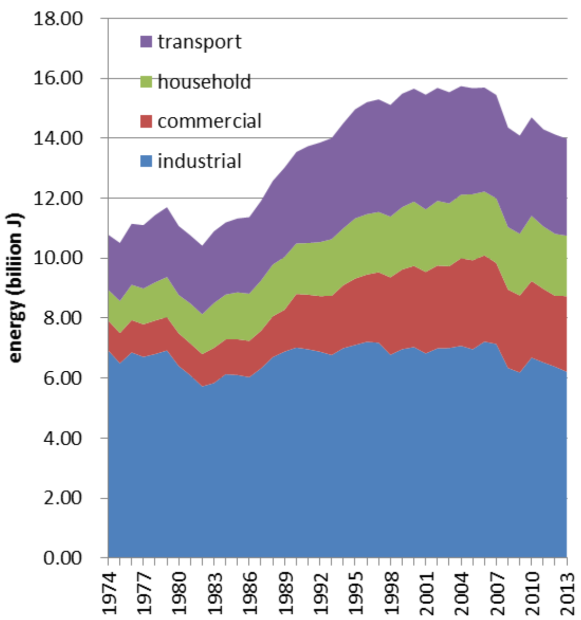

Figure 1. Energy consumption of each sector in Japan

In order to reduce energy consumption in Japan, Fuel Cell has been paid attention because of its high energy efficient. Japanese government aim to install Fuel Cells to 5.3 million families until 2030 [2], but Fuel Cell installation into residential sector is not going smoothly. However installation of fuel cell is mainly advancing in detached houses, installation into apartment complex which count for 40% of Japanese house is not progressing well [3]. One of the reason why installation of Fuel Cell into apartment complex is not going smoothly is an operation rate of Fuel Cell in an apartment complex is tend to be smaller than that in detached house.

In this paper, we introduce systems, which install Fuel Cell in all houses in an apartment complex and increase operation rate of Fuel Cell by trading electricity made by Fuel Cell. We simulate the flow of electricity in the

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apartment complex which installed trading system, design electricity rate in the apartment complex, and we evaluate the economy and energy saving, of the system in order to show the system play a role in energy saving society.

II. About System

Fig. 2 shows overview of an apartment complex which adopted the proposed system [4]. This system allows residents of apartment complex to trade electricity made by Fuel Cell. In this system, we can increase operation rate of Fuel Cell in small demand houses, and depress total electricity demand of apartment complex. In the apartment applying this system, we can design electricity rate by ourselves because the apartment complex receives high voltage electricity from Electricity Company.

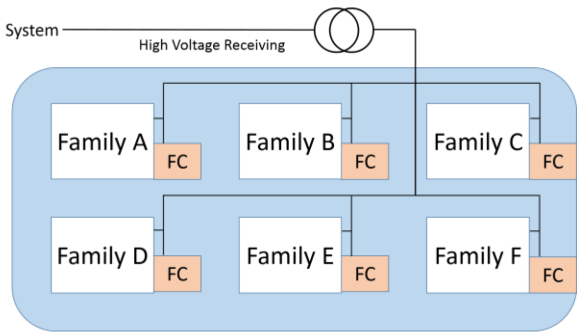

Figure 2. Overview of the proposed system.

Fig. 3 shows flow of electricity in an apartment complex which installed the proposed system. In traditional system, a large demand house (House A) operate fuel cell in max output and buy electricity shortage from electric company, but in proposed system, House A buy electricity from a small demand house (House B). In House B, they can operate Fuel Cell longer than in conventional system, and sell surplus electricity.

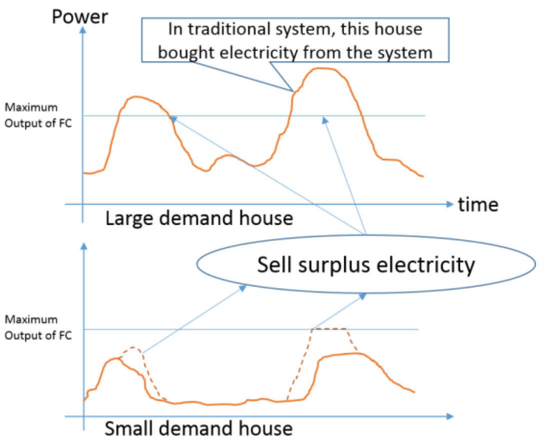

Figure 3. Flow of Electricity in proposed system

III. About Simulation

For the simulation, we made the hypothetical electricity and heat demands of 38 houses in apartment complex from actual demand data. We calculate 6 patterns of demands for each seasons; summer, middle term, winter and weekday or holiday.

We simulated energy flow in apartment complex by using mixed integer problem. Objective function is the outgoings of the whole apartment complex. We minimize this objective function as variables in amount of electricity made by Fuel Cells, amount of electricity purchased from the system, and amount of electricity traded among houses in the apartment complex. Moreover, we use these data and try to find the most rational electricity price in the apartment complex because small energy demand houses in the apartment complex doesn't gain many benefit than large demand houses in conventional electricity prices. Fig. 4 shows the flow of the simulation in this paper.

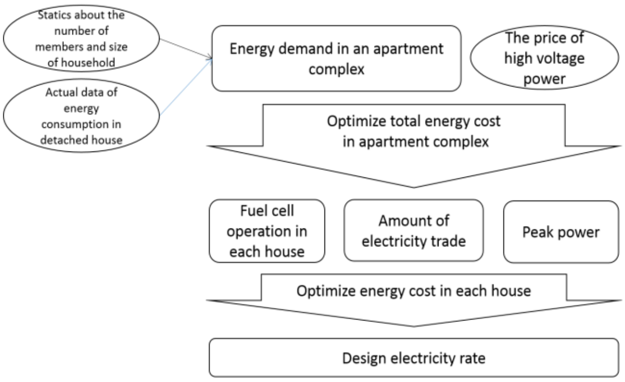

Figure 4. The flow of simulation

IV. Result of Optimizing Total Energy Cost of Apartment Complex

We can reduce peak power demand of the apartment complex by trading electricity especially in winter (Fig. 5). Because Peak power demand is inhibited, contract power charge is reduced. Average running time of fuel cell is increased in especially winter because small demand houses can sell unnecessary electricity to big large demand houses (Fig. 6). In summer, there is a little heat demand, so each family operate Fuel Cell in maximum output, in which Fuel Cell works most efficiently, and trade electricity each other. CO_2 emission of apartment complex is 20% reduced from a conventional apartment complex (Fig. 7).

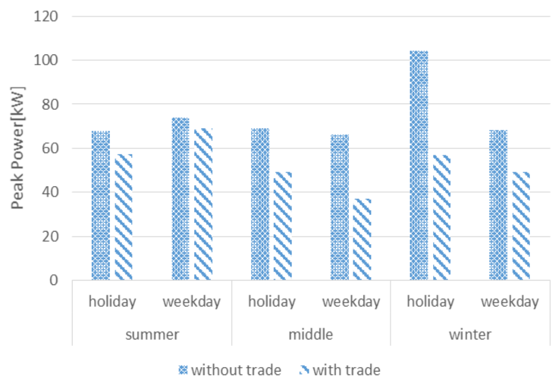

Figure 5. Peak power of the apartment complex in each season

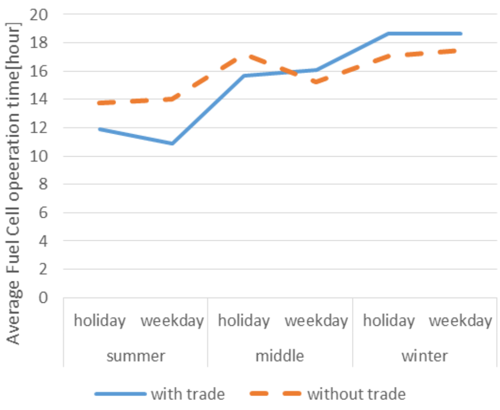

Figure 6. Average fuel cell running time in each season

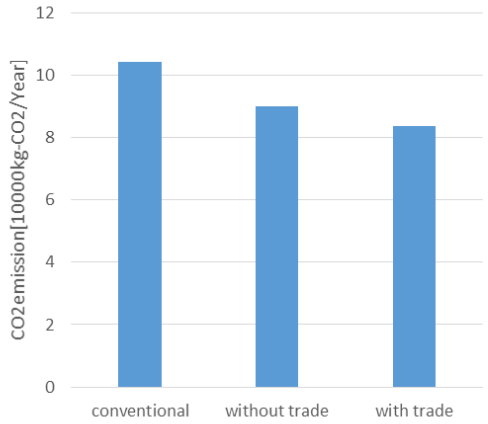

Figure 7. CO_2 emission of whole the apartment complex

V. Result of Optimizing Energy Cost of Residents

We optimize energy cost of each house in the apartment complex. We adopted a concept of nucleolus [5] into optimization, in the other word, we maximize profit of the family with smallest profit. In this paper, Profit means "the difference from the energy cost in ordinary apartment complex". We calculated about three electricity rate cases (Table I). In case 1, electricity rate in the apartment complex is same as TEPCO (Tokyo Electric power Company Holdings, Inc.) meter-rate lighting plan B (Table II) [6], and amount of traded electricity is deducted from used electricity. In case 2, electricity rate is same as case 1, but electricity is traded in certain price, and we calculate the fairest trading price. In case 3, Basic electricity rate, Meter electricity rate, and trading electricity rate. In case 4, there is no electricity trading in the apartment complex.

Fig. 8 shows reduction of energy cost of each house in each case. Electricity rate in case 2 and case 3 are calculated as Table III and Table IV. In case 1, families with large energy expense get larger profit than families with small energy expense, because in this case, large electricity demand houses can sell electricity at 3rd stage meter price, but small demand house sell electricity at 1st stage meter price. In case 2, we calculate the fairest electricity trading price, but there is no big difference in energy cost reduction of each house from case1. In case 3, we calculate meter price and basic price in addition to trading price, which is fair in all families. In this case small demand houses can gain larger profit than case 1, 2.

TABLE I. Features of 4 Cases

Case	
1	Basic electricity rate is same as TEPCO meter-rate lighting plan. Trading electricity is deducted from used electricity.
2	Basic electricity rate is same as TEPCO meter-rate lighting plan. Trading electricity rate is variable.
3	Basic electricity rate is variable. Meter electricity rate is variable. Trading electricity rate is variable
4	No electricity trading.

TABLE II. Electricity Rate of TEPCO Meter-Rate Lighting Plan B

Basic price [yen]	Meter price [yen/kWh]		
	1st stage	2nd stage	3rd stage
1123.2	19.43	25.91	29.33

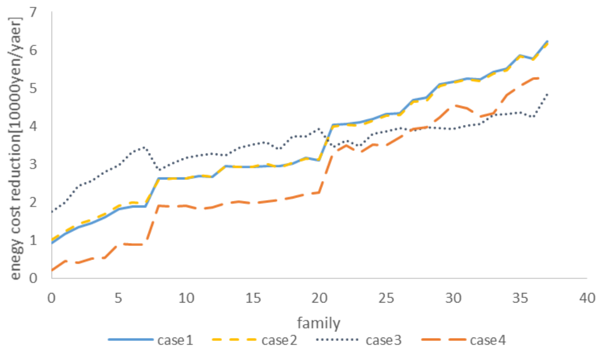

Figure 8. Reduction of energy cost in each case

TABLE III. Result of Optimizing Trading Price in Case 2

Basic Price [yen]	Meter Price[yen/kWh]			Trading price [yen/kWh]
	1st stage	2nd stage	3rd stage	
1123.2	19.43	25.91	29.33	20.43

TABLE IV. Result of Optimizing Electricity Rate Price in Case 3

Basic Price [yen]	Meter Price [yen/kWh]	Trading Price [yen/kWh]
0	32.55	34.18

Fig. 9 shows energy cost reduction rate of apartment complex in each case. In case 3, there are 2 big change in energy cost reduction rate, one is between family No 8 and 9, and the other is between family 21 and 22. There is border of single-member household and two-member household between family 8 and 9, and border of two-member household and three or more-member household between family 21 and 22. It is important to grasp family composition of apartment complex in order to introduce this system.

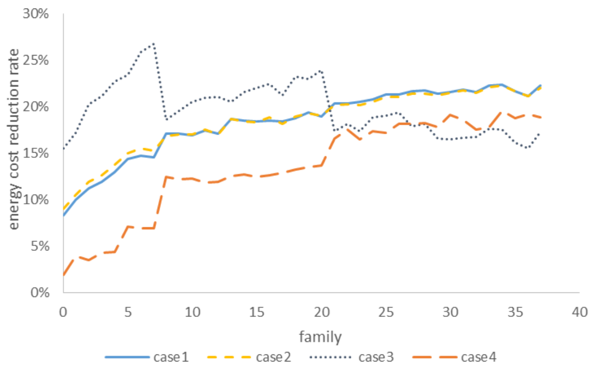

Figure 9. Energy cost reduction rate in each case

VI. Conclusion

In this paper, we introduce the system that install Fuel Cell in all households in an apartment complex and trade electricity that generated from Fuel Cell between houses. We show electricity trading system in an apartment complex environment-friendly, and economical for residents of the apartment complex. In this paper, we used invariant demand data in this simulation, but actual demand in apartment complex varies in day to day, so we need to do simulation using various demand data. Furthermore, we would like to make algorithm of Fuel Cell operation of all houses in an apartment complex.

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