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The Cost performance of Dynamic Pricing and Storage Battery Technology in a Residential House

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Abstract. This paper tries to investigate the effect of dynamic pricing system on the residential house use and also tries to analyze the influence of introducing the storage battery technology into the dynamic pricing system. Through the calculation, get the conclusion that it has little economic benefit for residents by using dynamic price. Meanwhile, this study proposed two different situations to solve the contradiction between the improvement of grid and the residential consumers' benefit.

Keywords: Dynamic pricing, Electric system, Economic performance, Storage battery.

1. Introduction

With the incessant development of the world economy and the improvement of people's living standards, the power grid's operating system has stepped into a new historical stage. The idea of moving from time-invariant electricity prices to dynamic pricing, where price are more closely tied to variations in the marginal cost of generating electricity, has been around for at least fifty years. Because of the marginal cost of electricity varies widely over time what caused by the demand for electricity varies widely, so it is uneconomical to store electricity in most applications and all hours given [1]. In order to lead users to the rational use of electricity and guarantee the optimal power resource allocation, dynamic pricing system has quickly emerged [2].

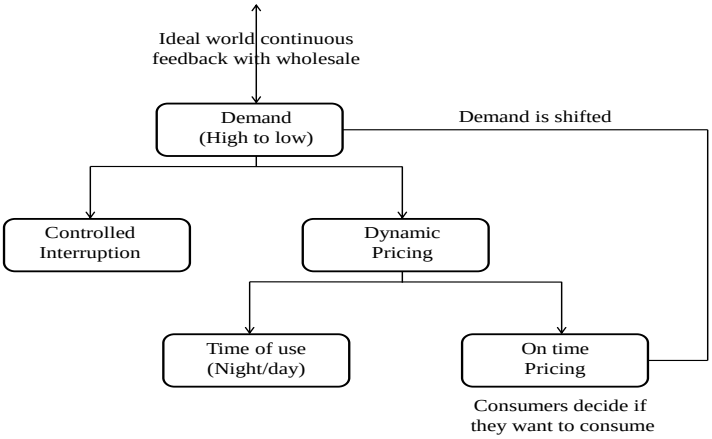

Fig. 1: The way that dynamic pricing shift demand

As is shown in Fig.1, dynamic electricity price is a demand response method which needs the participation of both consumers and the power supply enterprises. Usually, electricity dynamic price has

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three main pricing methods: forecast and actual system demand, day-ahead price and real-time price [3]. Taking the consumers as a whole, it can shift the peak load, decrease electricity cost to some extent [4]. However, for the residential consumers, dynamic pricing is not necessarily a good thing. Based on the habits of the residents and due to the climate in winter and summer, a period of time of peak demand will always appear in order to ensure normal living standards of the people. But this load is different from the whole consumers' peak load area. So whether using the dynamic price can brings benefit to residential users is still need to be discussed [5]. This paper tries to investigate the effect of dynamic pricing system on the residential house use and also to analyze the influence of introducing the storage battery in the dynamic pricing system.

2. Case Setting

2.1. Data base

2.1.1. Electricity load data

In this study, a two-story detached house with floor area 183m2 has been selected as case study. Fig.2-4 reflects the situation of residents' electricity load in different month.

In January, as Fig. 2 shows, the electricity load of residential consumers decreased slowly from 1:00 to 4:00. Then it began to rise slowly from 5:00 to 7:00, owing to the residents' daily activities in the morning. About 8:00, the load reached at morning peak period, after that the load has fallen slightly. In the period from 16:00 to 19:00, the load curve continued its rise, reached an evening peak at 19:00 o'clock and continued until 21:00 o'clock. Then it began to fall, fell to a low point at 5:00 o'clock. In the January, the maximum load is 4.74kW, the minimum load is 0.69kW, and the peak-vale difference is 4.05kW.

In August, residents' electricity load has increased shown in Fig.3. From morning 8:00, some of household appliances opened what resulted in the load reached at 1.23kW. After that, due to the high temperature in summer, cooling load began to increase what made the load rise to a higher level. From 18:00, most people went off work, household appliances' opening rate increased, load continued to climb. At 20:00, night lighting gradually open, the electricity load reached maximum at 21:00.

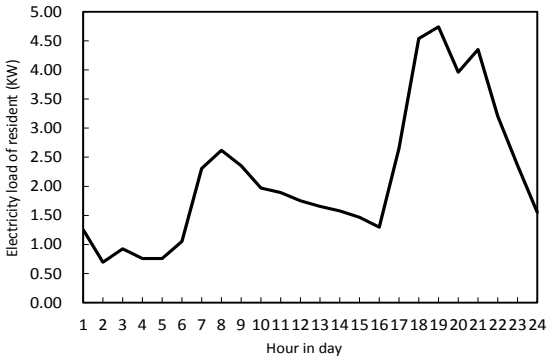

Fig.2: Weekday Electricity load of residential consumers in January

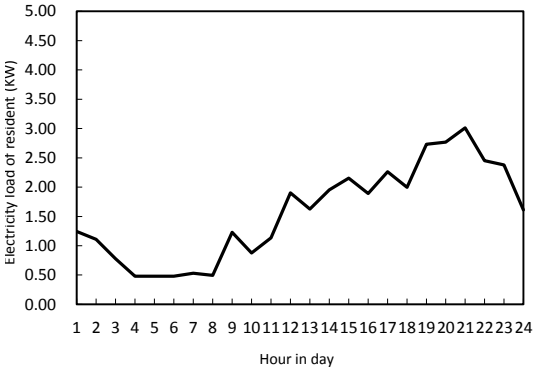

Fig.3: Weekday Electricity load of residential consumers in August

2.1.2. Electricity price data

Here, we choose time-of-use electricity price as the research target. There are two primary ways of pricing, one is regular price (RP), and another one is dynamic price (DP). For RP, the price is 8JPY/kWh for 1:00 to 7:00 and 22:00 to 24:00, and 25JPY/kWh for 8:00 to 21:00. For DP the price is 6JPY/kWh for 1:00 to 7:00 and 22:00 to 24:00, 18.75JPY/kWh for 8:00 to 12:00 and 16:00 to 21:00, and 150JPY/kWh for 12:00 to 15:00. Compared with regular price, dynamic price in the period of 1:00-7:00, 22:00-24:00, 8:00-12:00 and 16:00-21:00 is declined in the proportion of 25%. In Fig.4, Dynamic price from 12:00 to 15:00 is 6 times higher than the price in other time period [6].

2.1.3. Storage battery data

Storage battery is an electrochemical device storing the chemical energy and releasing energy when necessary. It is usually charged the batteries in the case of low peak and electricity consumption at night, and using them in the on-peak period of the day [7]. Table 1 is the related information of storage battery; the charge-discharge efficiency is 0.8. In this study, we assume that storage battery is charged from 22:00 to 8:00 and discharged from 8:00 to 22:00 continuously. In which, the output power of storage battery is 0.45 in the period from 8:00 to 12:00, 1 in the period from 12:00 to 15:00.The capacity of storage battery which we have selected is 10kW according to the maximum load in the whole 12:00-15:00 period. The initial cost of storage battery is 300000JPY/kWh. In this paper, we assumed that the initial cost will fall on some level as the technology development. The useful life of storage battery is 15 years. Fig.5 shows the charge-discharge curve of storage battery.

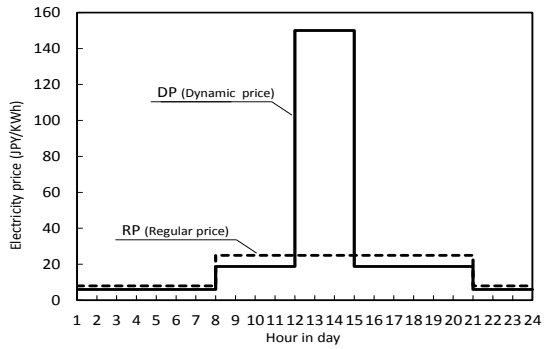

Fig.4: Electricity price in a day

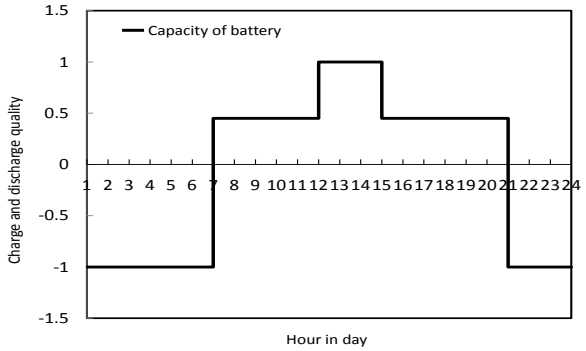

Fig.5: Charge-discharge mode of battery

2.2. Case setting

Three different pricing ways were planned for the cases. The related information was shown in table 2. We let case 1 only use the regular price as shown in Fig.4. Case 2 use the dynamic price as shown on Fig.5. Both case 1 and case 2 are not equips with storage battery. Through the comparison between case 1 and case 2, we can draw a conclusion about whether the residents can benefit from using dynamic price. Case 3 using the dynamic price, meanwhile, storage battery was introduced into it. As table 2 shown, the output power of storage battery is 0.45kWh for 8:00-12:00, 1kWh for 12:00-15:00. In case 2, we supposed that dynamic price will gradually increase from 100JPY/kWh to 250JPY/kWh as time goes on. In case 3, we supposed that the initial cost of storage battery will gradually decrease from 300,000JPY/kWh to 100,000JPY/kWh.

Table 1: Storage battery information

Charge-discharge efficiency	0.8
Initial cost(JPY/KWh)	300000
Charge time	22:00-8:00
Discharge time	8:00-22:00
Life time(year)	15

Table 2: Three different cases

	Electricity mode	Storage battery		
Case 1	Regular price	Not have		
Case 2	Dynamic price	Not have		
Case 3	Dynamic price	have		
		Output power(kWh)	8:00-12:00	0.45
			12:00-15:00	1
		Capacity of battery(kWh)	10	

3. Case Analysis

3.1. The effect of dynamic pricing on the cost performance in a residential house

In a general way, it has the difference of peak load period between residential consumers and whole consumers which contained commercial and industry sectors. Due to time delay, it will cause a bad influence on residential consumers when using dynamic pricing at high load period. In order to get a clear conclusion, this paper compared the cost effects caused by using regular pricing and using dynamic price, take an analysis between case 1 and case 2. As shown in Fig.6, every month of all spending on electricity using dynamic price is higher than that using regular price. In July, August and September, the cost of using dynamic price is about 67% higher than that using regular price.

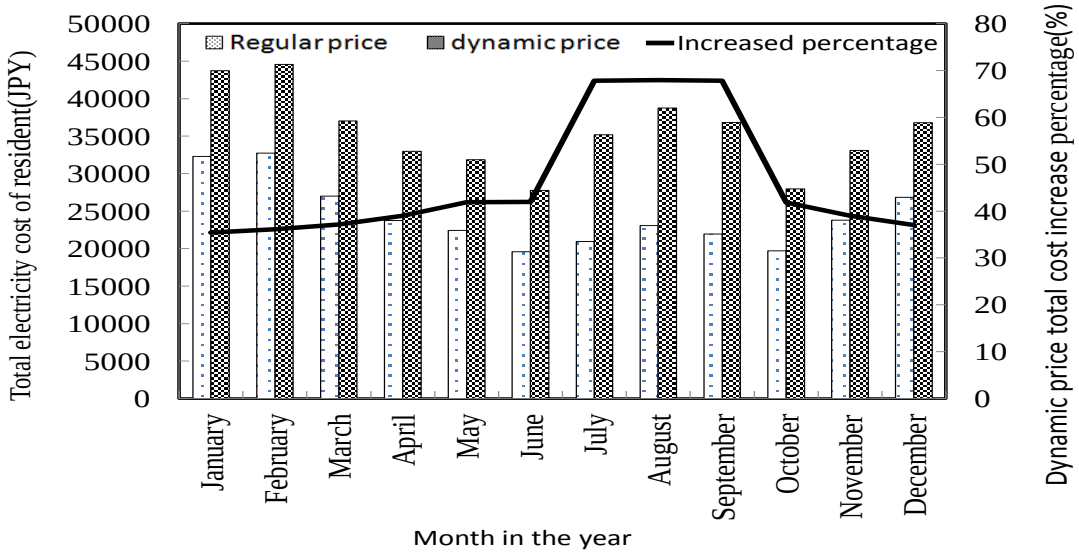

Fig. 6: Total cost comparison between regular price and dynamic price in residential house

3.2. The effect of storage battery on the cost performance in a residential house

3.2.1. The effect of storage battery on the cost performance in a residential house as the change of dynamic price of peak period

From the above, we can kown that residents who use dynamic price is expensive than that use regular price. However, dynamic price is an essential way of improving power grid, so it is important for us to make a balance between residential consumers' benefit and the whole grid's improvement. Here, we make an assumption that the dynamic price is changed in the range from 100JPY/kWh to 250JPY/kWh to see its cost performance in a residential house. As shown in Fig.7, the total cost of introducing storage battery into residential side is gradually decreased as the increase of electricity price which during 12:00 to 15:00 period. We can evidently see that when the dynamic price of 12:00 to 15:00 period reached at 174.61JPY/kWh, the costs of using dynamic price only and that using both dynamic price and strorage battery are equivalent. So we can draw the conclusion that when the dynamic price of 12:00 to 15:00 period reached at 174.61JPY/kWh, the costs of case 2 and case 3 are equivalent.. Introducing storage battery into residential side can take cost effect only in the condition that the price for 12:00-15:00 period is higher than 174.61JPY/kWh.

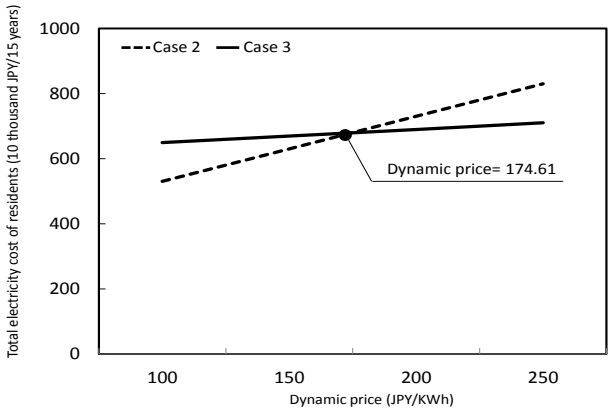

Fig. 7: Total cost changes with the dynamic price

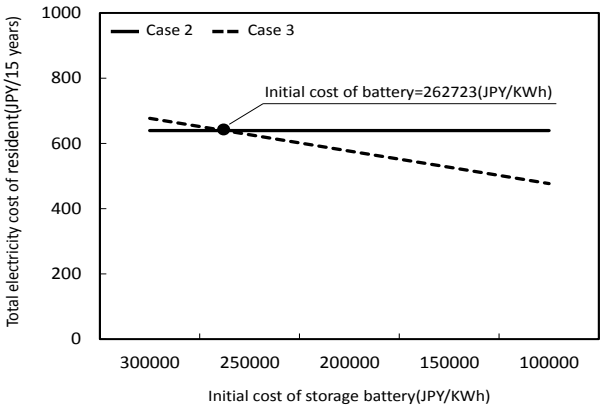

Fig. 8: Total cost changes with the initial cost of battery

3.2.2. The effect of storage battery on the cost performance in a residential house as the change of the initial cost of battery

Introducing storage battery into residents' house is conductive to decrease the additional fee caused by dynamic pricing compared to the cost of using regular price. It is a good way to solve the contradiction between consumers' benefit and the improvement of power grid [8]. But high initial cost of battery restricts

its development [9]. As time goes on, it provides many possibilities for cutting the price of battery which also provide us an opportunity to try to introduce storage battery into the power system [10].

The storage battery which we selected in this paper is ordinary household battery. As shown in Fig.8, when the initial cost of storage battery is 300,000JPY/kWh, the total electricity cost of residents is much higher than the cost using dynamic price. But as the decrease of storage battery' s initial cost, the cost gap between case 2 and case 3 is narrowing. When the initial cost of battery reduced to 87% of the present price, reached at about 262,700JPY/kWh, the cost of case 2 that using dynamic price and the cost of case 3 that using both dynamic price and storage battery are equivalent. If the initial cost of storage battery continued to decrease, using battery to eliminate extra fee began to have feasibility.

4. Conclusion

This paper explores the effects of dynamic pricing and storage battery technology on the cost performance in a Residential House. It was found that it has little economic benefit for residents by using dynamic price. It also has the feasibility to introduce storage battery into power system in residential house. The specific conclusions can be drawn as follows:

(1) Every month of all spending on electricity using dynamic price is higher than that using regular price. In July, August and September, the cost of using dynamic price is about 67% higher than that using regular price.

(2) If dynamic price of the period from 12:00 to 15:00 is changed from 100-250JPY/kWh, residential consumers can not benefit from using dynamic price if the price in that period is lower than 174.61JPY/kWh. Introducing dynamic price into residential side can take effect only in the condition that the price for 12:00-15:00 period is higher than 174.61JPY/kWh.

(3) When the initial cost of battery reduced to 87% of the present price (300,000JPY/kWh), reached at about 262,700 JPY/kWh, the cost of using dynamic price and the cost of that using both dynamic price and storage battery are equivalent. If the initial cost of storage battery continued to decrease until it lower than about 262,700JPY/kWh, using battery to eliminate extra fee which caused by using dynamic price began to have feasibility.

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