

The Model of User Responses to Time-of-Use Price Based on MAS

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Abstract. Based on the multi-agent technology, this paper presents the optimization process of power agent, user agent and government agent in detail. Combined with the principles of consumer psychology, this paper simulates the user response to the electricity price, outputting response curve and obtaining a more excellent time-of-use price, taking into account the rate of electricity revenue change of power company, user demands and the requirements of grid stability. Simulation results show that the response curve obtained by taking all interests into attention can reflect the user response to different time-of-use prices.

Introduction

Demand side management can effectively alleviate the problem, and time-of-use price^[1] is one of the leading demand side management strategies^[2]. The implementation of time-of-use price has achieved initial success, but time-of-use price is not reasonable. Therefore we should quantify the user response to time-of-use price, providing a reliable basis to develop a reasonable price.

[3] establishes the price elasticity matrix of electricity demand to reflect the user response to the time-of-use prices, and it establishes the time-of-use prices decision model. [4] studies the user response to the time-of-use prices by multi-agent technology, but the article is only for the big users, and the results are only given the optimized time-of-use prices. [5] depicts the diagram of multi-agent system, and the optimal time-of-use prices is drawn through the simulation analysis. [6] establishes response model under time-of-use prices, accurately grasping the response needs of the user, and solves the problem that processing the response curve inflection point.

Based on multi-agent system, combining with the principle of consumer psychology, this paper analyzes the user response to different time-of-use prices, and the simulation obtains user response curve to time-of-use price, and further revises the inflection point, obtaining the optimum time-of-use price.

User response curve

According to consumer psychology principle^[7].The response curve is shown in Fig.1.

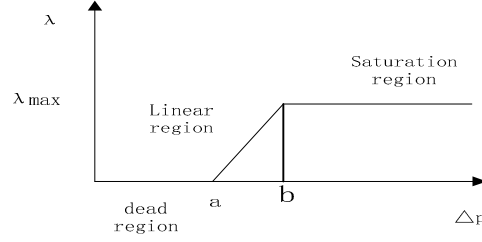


Fig.1.Responsiveness graph

λ is the rate of load transfer, ΔP is the price difference, a is the dead zone threshold, b is the saturated region threshold, λ_{\max} is the maximum rate of load transfer, K is the slope of the response area.

The limit to inflection point

This paper assumes that they are in a certain range. The range is shown in the following:

$$I_{\max} \in (I_{\max} - f, I_{\max} + f) \quad (1)$$

$$\Delta P_{\min} \in (\Delta P_{\min} - y, \Delta P_{\min} + y) \quad (2)$$

The design of multi-agent system

Power Agent: Compute the rate of electricity revenue change, and adjusts the price of electricity after comparing the rate with the expected rate δ_{EXP} . Before implementing time-of-use price, the electricity price is P_0 . After implementation, the price of peak period is $P_f = (1 + a) P_0$; the price of float period is $P_p = (1 + b) P_0$; the price of valley period is $P_g = (1 + c) P_0$. The role of power agent is to reasonably adjust the value of P_f, P_p, P_g . The electricity revenue M is shown in the following :

$$M = Q_f P_f + Q_p P_p + Q_g P_g \quad (3)$$

The rate of electricity revenue change δ is shown in the following :

$$d = \frac{\Delta M}{M} = \frac{M_{t+1} - M_t}{M_t} \quad (4)$$

If $\delta_{\text{EXP}} - \delta < 0$, then turn down P_f, P_p, P_g . If $0 < \delta_{\text{EXP}} - \delta < \mu$ (μ is the difference between the rate of electricity revenue change and the expected rate), it is considered that the price is optimal. If $\delta_{\text{EXP}} - \delta \geq \mu$, then turn up P_f, P_p, P_g , according to certain step length.

User Agent: User responds to the change and adjusts the load, controlling the rate of load change and the rate of electricity charge change within a certain range.

The rate of load change is shown in the following :

$$q = \frac{|q0 - q1|}{q0} \quad (5)$$

The rate of electricity charge change is shown in the following :

$$e = \frac{c(p_f, p_p, p_g) - c(p_0)}{c(p_0)} \quad (6)$$

Government Agent: If power agent ensures that user load condition meets the rate of electricity revenue change, government agent computes difference between peak and valley and the load rate of load curve that adjusted by user, and then guides power agent to adjust the price, so that between peak and valley and the load rate of load curve can reach a certain requirement.

The difference between peak and valley ω is shown in the following :

$$w = (\max q1) - (\min q1) \quad (7)$$

The load rate ζ is shown in the following :

$$x = \frac{\text{avg}(q1)}{\max(q1)} \quad (8)$$

Simulation process

Specific process is shown in Fig. 2:

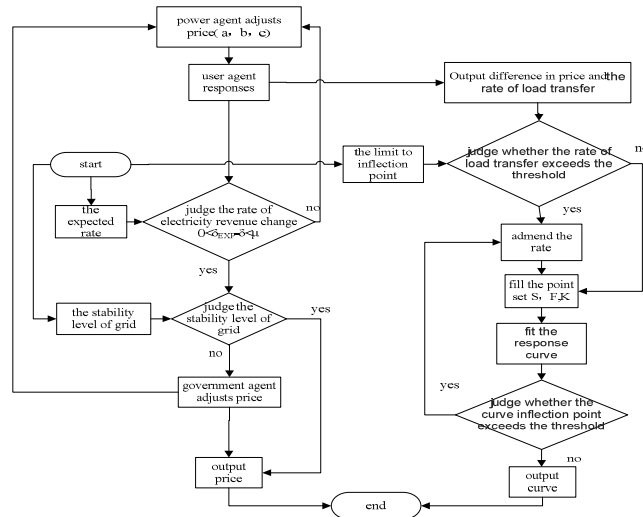


Fig.2. Diagram of simulation flow

Analysis of examples

This paper takes a user in a certain region as an example to verify the validity of the model, before implementation of time-of-use price, the electricity price is 0.4 yuan /kw.h. The load data before implementation of time-of-use price is shown in Table 1.

Table 1. Table of actual load data

time interval	load /MW	time interval	load/MW
1	24	13	32.9
2	25	14	32.3
3	24.7	15	32.4
4	23.9	16	32.8
5	22.1	17	33.1
6	24.7	18	33.2
7	23.5	19	34.1
8	32	20	40.0
9	37.9	21	35.2
10	39.3	22	33.9
11	38.4	23	32.3
12	32	24	29.1

The range of expected rate δ_{EXP} is 0.1% -0.15%, the maximum peak to valley difference is 8MW, and the minimum load factor is 0.90. The rate of peak period to float period is 0.3%, the rate of peak period to valley period is 0.6%, and the rate of float period to valley period is 0.4%.

The excellent time-of-use price is $P_f=0.61$, $P_p=0.39$, $P_g=0.2$. The user response curves is shown in Fig.3, Fig.4 and Fig.5.

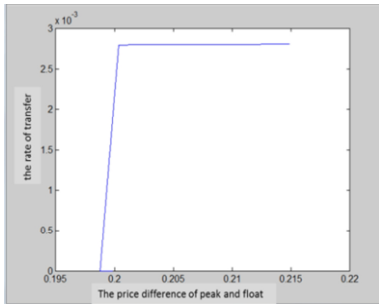


Fig.3. The response curve of peak period to float period

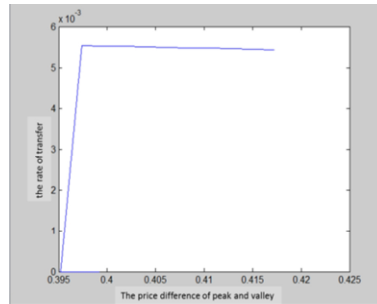


Fig.4. The response curve of peak period to valley period

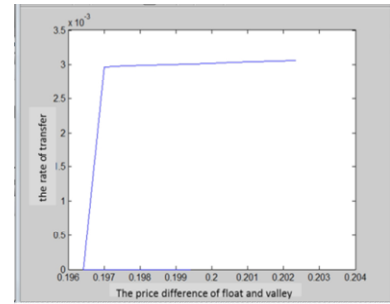


Fig.5. The response curve of float period to valley period

Conclusions

Through the interaction of multi-agent system, it obtains the response curve that user response to time-of-use price, laying a foundation for the study of user behavior, meanwhile, it obtains a more excellent time-of-use price, basing on the user normal electricity, ensuring enterprise obtaining a certain profit, and ensuring the stability of grid meeting the requirements, Government agent plays a crucial role in the development of long-term grid. In the next step study, considering other factors such as economic impact on user load transfer, to enhance the practicability of model.

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