Research on Pricing of Power Retail Package Based on User's Choice Behaviours

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Abstract. Since the implementation of the new electricity reform in China, the electricity sales market has been liberalized orderly, and the electricity retail market has also developed rapidly. The electricity retail package plays a key role in the development of the electricity retail market. This paper considers the willingness and choice of users to purchase electricity price package in the electricity market, and constructs a pricing model of electricity price package considering user's independent choice. The example analysis proves that the pricing model based on user choice strategy is more accurate. This research has practical guiding significance for the electricity sales companies to implement scientific and quantitative electricity price package design and marketing.

Keywords: user's choice，power retail package，pricing model

1. Introduction

The "No.9 Document" of the electricity reform and the supporting documents clearly put forward that the electricity sales business should be liberalized to social capital, the types of competition entities in the electricity sales market should be increased, and the power users should be given the right to purchase electricity independently. [1] At present, the mainstream profit model of power sales companies is to "grab low-cost electricity" and "grab large customers", relying on the function of com technical content". [2]

The mainstream format of China's electricity sales market is quite different from the mature electricity sales market in developed countries. One of the important manifestations is that the pricing structure of China's electricity sales companies is too rigid, and the pricing level lacks a scientific generation mechanism and model.[3] This is determined by the status quo of the construction of supporting links such as China's electricity spot wholesale market and medium-and long-term trading with curves. Spot trials have been rolled out in various places, and the new edition of Basic Rules for Medium-and Long-Term Trading of Electric Power has also been published. Under this background, the package pricing method of power sales companies needs to be iteratively upgraded. [4]

Firstly, this paper analyzes the related problems of electricity retail package pricing optimization, then establishes the electricity retail package pricing model based on user's choice behavior, and finally simulates and verifies the optimization process of electricity retail package pricing based on user's choice behavior based on actual market data and reasonable assumptions.

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2. Issues related to optimal pricing of electric retail packages

In the electricity sales market, through market research and analysis of existing user's own load characteristics, we can determine which electricity price package users prefer, and understand the specific situation of the electricity sales market. Based on the investigation of electric power users' preferences and market conditions, the research of electricity price package optimization is to take enterprise income, total profit, user utility and other objectives as the optimization criteria, and then analyze the dimensions of electricity price package design and the values of attributes of each dimension to select the package that is most beneficial to enterprises or users. The package includes the main information and the determination of dimension attribute values.[5]

Similar to users' comparison and selection when purchasing products in the market, users will have different preferences when purchasing electricity price packages. Users will compare the basic attributes of different electricity price packages according to their own electricity demand, such as whether users need reliable power supply, whether to avoid peak electricity consumption, etc., and determine whether the basic attributes of purchased electricity price packages include reliable electricity price, peak-valley electricity price and other attributes. [6] The user's choice behavior will affect the market share of packages, which determines the profit level of each package in the market. Therefore, when setting the package price, the power sales company needs to consider the market share that the package can occupy as a function aiming at the maximum profit, so that the determined electricity price level will get the established income. The power sales company can meet the user's needs by designing different package dimensions and price levels, thus increasing the market share and overall income.

3. Pricing model of electricity retail package considering users' choice behaviours

3.1 Determine the electricity cost of electric retail users.

Time-divided electricity retail package (divide the time period into three time periods) User's electricity cost function:

$$U_{pv}^{i} = \left(\sum_{j=1}^{n} \left(\vec{p}_{pv}^{\,\mathrm{i}}\right)^{T} * \vec{Q}_{ij}\right) \tag{1}$$

Type, is the monthly electricity cost paid by the subscription users in the “I” month. J is the number of days in a month, and n is the number of days in the “I” month; Is the time-of-use electricity price vector of the “i” month; It is the electricity consumption on the j day of the “i” month.$U_{pv}^{i}\vec{p}_{pv}^{\,\mathrm{i}}\vec{Q}_{ij}$

$$\left(\vec{p}_{pv}^{\,\mathrm{i}}\right)^{T} = \left[p_{pv}^{N,1}, p_{pv}^{N,2}, p_{pv}^{N,3}\right] \tag{2}$$

$p_{pv}^{N,1}p_{pv}^{N,3}$is the retail electricity price of each period of the day.

3.2 Analyse the power purchase cost of the power selling company.

By signing contracts with power generation companies in the medium and long-term market, power sales companies can purchase different types of power in different periods (peak period, normal period and valley period). The cost of purchasing power is:

$$C_{tA} = \sum_{a\in A} \sum_{i=1}^{N_a} P_{aiA}\lambda_{aiA}d_t , \quad \forall t \tag{3}$$

$$P_{aA} = \sum_{i=1}^{N_a} P_{aiA} \tag{4}$$

$$0 \le P_{atA} \le \vec{P}_{aiA}\forall a, \forall i \tag{5}$$

Where, it represents the total cost of electricity purchase that the electricity sales company needs to pay during T period, A represents the total number of different types of electricity purchase contracts signed by the electricity sales company, A represents one of many types of electricity purchase contracts divided according to the type of electric energy, the number of available contracts in a certain type of contract set, the maximum output value of the "i" contract in the category A contract set, that is, the upper limit of unit treatment that the power generation company can sell when signing the contract, and the electricity that the company purchased from the "i" contract. It indicates the purchase price of electric energy of the "i" valid contract in Class A contract, the total output that the company can purchase through Class A contract in T period, and the duration of the T period.$C_{tA}N_a\vec{P}_{aiA}P_{aiA}\lambda_{aiA}P_{aA}d_t$

The cost per unit day of the electricity sales company is:

$$C = \frac{C_{tA}}{T_{IA}} \tag{6}$$

Type, said the long-term power purchase cycle, said the long-term power purchase cost.$T_{IA}C_{tA}$

3.3 Analysis of power retail users' independent choice behaviours

Multi-logit selection model is applied to predict the behavior of power users in choosing electricity price package. Assume that the utility of electric power users consists of two parts, including the utility of electricity price level attribute and package structure attribute to users.

$$U_{ij} = w_1u_{ij} + w_2u'_{ij} \tag{7}$$

$$u_{ij} = B_i - B_{ij}(i = 1,2,\cdots,I; j = 1,2,\cdots,J) \tag{8}$$

$$u'_{ij} = 1 - \frac{\sum_{t=1}^{24}|Q'_t - Q_t|}{\sum_{t=1}^{24} Q_t} \tag{9}$$

$$w_k = \frac{\left[max(f_{i_2,k,s}) - \frac{n}{l_k}\right]}{\sum_{k=1}^{m}\left[max(f_{i,k,s}) - \frac{n}{l_k}\right]} \tag{10}$$

Type, said the comprehensive utility of electricity retail package to users; Indicates the proportion of electricity price level of electricity retail package to user utility to comprehensive utility; It indicates the proportion of structural attributes of electric retail package to users' utility in comprehensive utility. Indicates the utility of the electricity price level of the "j" electricity retail package to the "i" target user, the electricity consumption budget, the consumption cost of purchasing the electricity retail package, the total number of users and the total number of

electricity retail packages. Indicates the utility of the structural attribute of the “j” electric retail package to the “i” target user; Said the electricity consumption in the period t before the implementation of the electricity retail package; Indicates the electricity consumption of time period T after the implementation of the electricity retail package. The weight that affects utility, the number of times the attribute value of attribute K appears, the average frequency of the attribute value, and M the total number of attributes of electric retail package.$U_{ij} w_1 w_2 u_{ij} B_i B_{ij} I J u'_{ij} Q_t Q'_t w_k f_{i,k,s} \frac{n}{l_k}$

Assuming that "the S package is selected" as a reference, based on the package comprehensive utility computing formula, the probability of rational power user I choosing package J is determined as follows:

$$P_{ij} = e^{U_{ij}} / \sum_j e^{U_{is}} \tag{11}$$

Where, the utility obtained by user I selecting power package J, the utility obtained by user I selecting power package S, and the probability of user selecting electricity price package J are represented.$U_{ij} U_{is} P_{ij}$

3.4 Design time-sharing electricity retail package and pricing model.

(1) Time division and package pricing

Constructing the price level optimization model of time-sharing package;

$$maxR = \sum_{i=1}^{I} ms\left(f_{\text{avg}}\right) C_i - C \tag{12}$$

$$C_i = [Q_i(t) \cdot E^{avg} \cdot \Delta P + Q_i(t)] \cdot p_j(t) \tag{13}$$

Where, it means the profit of the power sales company, the number of users, the average electricity charge of users in each period, the market share of the power sales company, the fees paid by users, the daily cost of the power sales company, the electricity consumption of users in T period, the difference between the new electricity price and the original electricity price, and the newly set electricity price in T period.$RI f_{\text{avg}}\, ms\left(f_{\text{avg}}\right) C_i C Q_i(t) \Delta P p_j(t)$

Peak-valley difference constraint is expressed as:

$$L_f - L_g \leq L'_f - L'_g \tag{14}$$

Where, and respectively represent the peak value and valley value of the user load curve before the electricity price package is implemented, and respectively represent the peak value and valley value of the user load curve after the electricity price package is implemented.$L_f L_g L'_f L'_g$

(2) Price constraints

The pricing of power sales companies will be restricted by the price limit of government regulatory authorities, and the average price will be lower than the price limit to protect consumers' rights and interests, namely:

$$p_{\text{avg}} \leq p_{\text{reg}} \tag{15}$$

Type, the average price ceiling set by the regulatory authorities.p_{reg}

(3) the user selects constraints.

Determine the market share of each package and the probability of users choosing packages based on the discrete choice model;

$$P_{ij} \geq Pth \tag{16}$$

Where, the probability of the user choosing a set meal is the probability threshold.$P_{ij}Pth$

4. Example analysis

Selecting the time-sharing package pricing process of a power sales company as an example to illustrate the rationality and effectiveness of the invention, and selecting the typical load curves of 140 large industrial users in a certain area, as shown in Figure 1, the users are divided into three categories through clustering: daily peak users, night peak users and stable users, which are used as the pricing basis of time-sharing power retail packages.

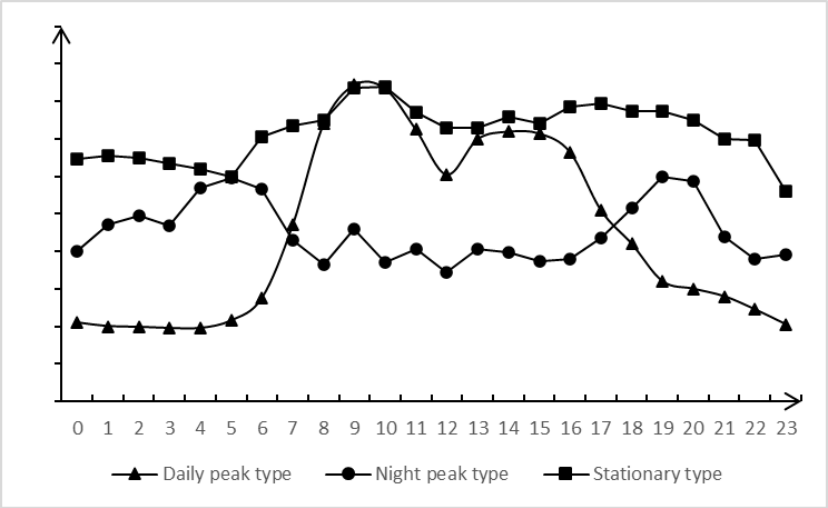

Figure 1. Typical user load curve

The medium-and long-term market transaction price of power sales companies is shown in Table 1.

Table 1. Medium- and Long-Term Market Transaction Electricity Price

Contract type	Electric energy delivery period	Electric energy delivered (within 1h)	Electricity price for delivery (RMB /kWh)	Contract period
one	10:00~22:00	380,000 kWh	0.29	365
2	2: 00 ~ 10: 00 the next day	380,000 kWh	0.27	365

Parameter data and percentage of different categories of users are shown in Table 2.

Table 2. Parameter data and proportion of different categories of users

users' category	Daily electricity consumption (10,000 Kwh)	Peak value (ten thousand kWh)	Account for users/%
Daily peak type	1.89	0.13	18.58
Night peak type	3.51	0.35	7.97
Stable type	7.59	1.01	27.43

Assume that there are two power sales companies in this area participating in the market competition, with 40% of the sticky users of each power sales company. The fixed investment cost of each power sales company is 1.8 million yuan per year, and the recovery period is one year. The critical value of user selection probability is set at 0.9, and the government regulatory department sets the peak price limit at 1.5 yuan /kWh. According to the basic optimization model, the electricity price level of electricity retail package in different time periods has changed on the basis of the original electricity price, and the same package level has increased and decreased in different time periods, which ensures that the utility of electricity retail package in different time periods to users is greater than the original electricity price, increases user stickiness and maintains the market share of electricity sales companies. When considering users' independent choice, the price level of the price package during peak hours is the lowest compared with the other three types of packages, which brings the greatest benefit to the daily peak users. For night peak users, the electricity price of electricity retail package in valley hours is the lowest among several packages, which reduces the electricity cost of night peak users. The average rate of electricity retail packages designed for stable users is the lowest among these packages, and it has the greatest utility for stable users. The utility of the three electricity price packages to users is higher than the initial electricity price, which can well motivate users to buy packages. Compared with the situation without considering users' independent choice, the estimated market share of power sales companies is more accurate, and the measured package price level is more accurate.

The electricity price package brings the profit of 673,000 yuan to the electricity sales company, which is higher than the daily profit of 622,400 yuan generated by the initial electricity price, indicating that the electricity price package is conducive to increasing the profit of the electricity sales company; At the same time, the average electricity prices of the packages designed for the three types of users, namely, steady, day peak and night peak, are 0.548, 0.549 and 0.546, respectively, all of which are lower than the average of the original electricity prices of users, which indicates that the electricity price packages bring higher benefits to users at the same time.

5. Conclusion

This paper studies the optimal pricing model of electric retail package. Firstly, the user's choice behavior is analyzed, and the probability model of user's choice of package based on the utility of electricity price package is constructed. Then, the cost model of electricity purchase in the medium and long-term market is constructed, and the risk brought by randomness of users' electricity consumption to the electricity sales company is analyzed. On this basis, the pricing

model of basic electricity price package with maximizing the profit of power sales companies as the objective function is constructed. Finally, an example is given with the actual data of typical provinces. By comparing the profits of the electricity sales companies before and after the implementation of the electricity price package, the profits of the electricity sales companies are larger after the implementation of the electricity price package, and the average price level of the electricity price package is lower than the original electricity price level of the users. After the implementation of the electricity retail package based on users' choice behavior, the load curve of the total users appears obvious peak cutting and valley filling.

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