Research on the Operation Measurement and Evaluation Method of Retail Packages under the Background of Electricity Market

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Abstract. With the liberalization of the electricity market, building a diversified and open competitive electricity retail market has become the focus of market reform and development. In the initial stage of the retail market, the operating status of retail companies is an important evidence for the analysis of the current development of the retail market and the formulation of relevant rules. This paper designs a retail allocation method and proposes different business calculation and analysis methods based on 9 different types of retail packages in Yunnan electricity retail market. Based on a two-tier evaluation index system for retail packages and the electricity sales company, the FCE method combined with the AHP is used to evaluate the operating states of the electricity sales company and the retail packages.

1. Introduction
As the focus of the new round of power system reform, forming competition on the power sales side and encouraging social capital to enter the retail market to form a diversified and open competitive retail market has become an irreversible trend in the power sales side reform[1]. With the continuous advancement of market construction, the retail market has begun to take shape, but it is still in the groping and learning stage. The mechanism system in all aspects is unsound, which makes it difficult to estimate the operating conditions of the retail market entities.

At present, most of the research on the retail market focuses on the retail electricity price package system and regulatory mechanism. Literature [2-4] investigates the retail electricity price package systems in countries such as Texas, the United Kingdom, and Australia, and gives a detailed introduction to typical power retail packages. Literature [5] studies the principles of power retail package design and common methods of power user grouping, and designs a variety of standard retail package models based on user grouping, which provide a useful reference for the decision-making of market entities in the power spot market. Literature [6-8] discusses the information disclosure mechanism framework and related content of the electricity retail market, and provides feasible suggestions for relevant departments. Literature [9] studies the challenges faced by the electricity retail market and retail package pricing methods. Literature [10] analyzes how electricity sales companies can optimize their operations by formulating reasonable pricing strategies for purchasing and selling electricity.

In order to more effectively and accurately reflect income and investment income of electricity sales companies, this article conducts business calculation and analysis for 9 different retail packages in Yunnan. A two-tier index system is established, and the AHP (Analytic Hierarchy Process) method
is used to determine the index weight. According to the results of operating calculations, the FCE (Fuzzy Comprehensive Evaluation) method is used to evaluate the operating conditions of the electricity sales companies and retail packages. The calculation and evaluation of retail packages and the retail company can not only reflect the overall income and expenditure of the retail company, but also provide specific analysis for different packages, providing a basis for the subsequent improvement of the package contents of the retail company.

2. Operation Measurement method of retail packages

2.1. The retail allocation of the prices and volumes

After the wholesale market transaction, the retail company needs to perform electricity and price allocation under the premise of satisfying the distribution constraints. Each retail user will be allocated a transaction volume and a transaction price. Then the electricity bills of retail users is settled according to the actual power consumption and the settlement algorithm.

\[
\begin{align*}
\sum_{i=1}^{N} \min(Q_i,\text{month} - \sum_{j=1}^{T} Q_{i,\text{day}} \times P_{i,\text{final}}) \times P_{i,\text{final}} &= \min\left(\sum_{i=1}^{N} Q_{i,\text{month}} - \sum_{j=1}^{T} Q_{i,\text{day}} \times Q_{\text{retail}}\right) \times P_{S} \\
\sum_{i=1}^{N} Q_{i,\text{final}} &= Q_{\text{contract}} \\
P_{\min} \leq P_{i,\text{final}} \leq P_{\max}
\end{align*}
\]

Where \( N \) is the number of users; \( T \) is the number of days in the month; \( Q_{i,\text{month}} \) is monthly electricity consumption of user \( i \); \( Q_{i,\text{day}} \) is the amount of electricity purchased by user \( i \) in day-ahead market transactions; \( Q_{\text{retail}} \) is the monthly transaction volume of the electricity sales company; \( P_{S} \) is the price at which the electricity sales company buys electricity in the wholesale market; \( Q_{i,\text{final}} \) and \( P_{i,\text{final}} \) are the allocated power volume and price of user \( i \), which are decision variables; \( Q_{\text{contract}} \) is the monthly contract electricity volume of the electricity sales company; \( P_{\max} \) and \( P_{\min} \) are the maximum and minimum values of the allocated price respectively.

2.2. Types of retail packages

This article conducts business calculations for nine types of retail packages in the Yunnan power retail market (As shown in Table 1), and calculates their costs and incomes. According to the correlation between the income of the electricity sales company and the transaction price in the wholesale market, retail packages can be divided into three categories: risk-return, stable- return and free. Electricity sales companies can provide different types of retail package services according to customer needs and their own needs.

| Types       | Codes | Names                              | Features                                                                                       |
|-------------|-------|------------------------------------|------------------------------------------------------------------------------------------------|
| Risk-return | 1     | Spread income                      |                                                                                               |
|             | 2     | Spread income + proportional share |                                                                                               |
|             | 3     | Contract energy management         |                                                                                               |
|             | 4     | Agency service type-1 (constrained, per kWh) | The income of the electricity sales company is related to the transaction price and the agreed electricity price in the wholesale market, and the income is greatly affected by market d risks. |
|             | 5     | Agency service type-2 (constrained, per time month) |                                                                                               |
2.3. Electricity sales company operation measurement

The business calculations of market entities on the electricity sales side are mainly analyzed from the service modes of the electricity sales company. Each electricity sales company may have multiple service modes, and their profitability is equal to the sum of the income from various users and various service models.

For the electricity sales company, the total income $NR_{ps}$ from electricity retail business is equal to the sum of the net income of each retail package. $NR_{i,l}$ is the income from the user $i$ of the package $l$, then the specific calculation method is as follows:

$$NR_{ps} = \sum_{l=1}^{n} \left( \sum_{i} NR_{i,l} \right)$$ (2)

### 2.4. Operation measurement of Retail packages

#### 2.4.1. Spread income type

The feature of this package is that it is charged in full according to the difference between the transaction price and the contract price. In the service of Spread return type, it is assumed that the sales company and the customer agree in the entrustment agreement to sell electricity at the price $P_{1,l}$, the final distribution and settlement electricity price is $P_{2,l}$. Part $P_{2,l} = P_{1,l} - P_{3,l}$ of the price difference is (100%) recognized as the income (or loss) of the electricity sales company. At the same time, in accordance with the final distribution of the electricity sales company agreed in the entrustment agreement, the sales company’s income settlement will be carried out.

In the spread income type, the income of the electricity sales company can be expressed as:

$$NR_{i,l} = Q_{i,l} \times P_{1,l} - \alpha \Delta F_{i,l}$$ (3)

Where $\alpha$ is the proportion of deviation electricity charges borne by the retail company. $\Delta F_{i,l}$ is the deviation electricity charge of user $i$ in package $k$.

#### 2.4.2. Spread return + proportional share type

The income method of this type of service is basically the same as the first (spread income type) method. The difference is that the electricity sales company obtains the spread income $P_{2,l} = P_{2,l} - P_{3,l}$, according to the agreed ratio $\omega$. The income of the electricity sales company can be expressed as:

$$NR_{2,l} = Q_{2,l} \times P_{1,l} \times \omega - \alpha \Delta F_{2,l}$$ (4)

#### 2.4.3. Contract energy management

Under this type of service, the electricity sales company signs a contract with the customer to confirm the commission relationship, and the difference between the user’s marketized electricity price $P_{3,l}$ and the catalog electricity price $P_{0}$ is used as the charging basis, and the income of the electricity sales company is determined according to the ratio $\lambda$ agreed in the commission agreement:
\[ NR_{3i} = Q_{3i} \times \Delta P_{3i} \times \lambda - \alpha \Delta F_{3i} \]  

(5)

Where \( \Delta P_{3i} = P_0 - P_{3i} \) represents the difference in electricity price.

2.4.4. Agency service type-1 (constrained, per kWh)

The feature of this package is that as long as the transaction price reaches the target, it will be charged according to the charging standard agreed by both parties. \( P_{4i}^t \) is the target price agreed in the entrustment agreement between the retail company and the customer. When the transaction price \( P_{4i}^2 \) is lower than the target price, the revenue of the retail company is calculated according to the agreed revenue standard. When the transaction price is higher than the target price, the sales company's income is zero. Then the electricity sales company's income can be expressed as:

\[ NR_{4i} = \begin{cases}  -\alpha \Delta F_{4i}, & P_{4i}^2 > P_{4i}^t \\ Q_{4i} \times P_{4i}^t - \alpha \Delta F_{4i}, & P_{4i}^2 < P_{4i}^t \end{cases} \]

(6)

where \( Q_{4i} \) is the final transaction electricity volume, \( P_{4i}^t \) is the revenue standard agreed by both parties.

2.4.5. Agency service type-2 (constrained, per time-month)

The income of the electricity sales company in this service type is a fixed service fee, which is charged with a restriction clause. When the final transaction price \( P_{5i}^2 \) is less than or equal to the target price \( P_{5i}^t \), the expected goal is achieved, and the electricity sales company will charge customers a service fee according to the income standard \( F_{5i} \) (yuan/time-month) agreed by both parties. Otherwise, there is no charge. Thus, the income of the electricity sales company can be expressed as:

\[ NR_{5i} = \begin{cases}  -\alpha \Delta F_{5i}, & P_{5i}^2 > P_{5i}^t \\ F_{5i} - \alpha \Delta F_{5i}, & P_{5i}^2 < P_{5i}^t \end{cases} \]

(7)

2.4.6. Agency service type-3 (free service)

Electricity sales companies make declarations for electricity customers free of charge. For this type of contract, only a proportional deviation assessment fee borne by the electricity sales company is collected.

\[ NR_{6i} = -\Delta F_{6i} \]

(8)

2.4.7. Agency service type-4 (unconstrained, per kWh)

This type is a derivative of the constrained package 4. The service fee standard \( P_{7i}^c \) is specified in the commission agreement without setting the target price. After the electricity sales company declares the transaction on behalf of the user in the month, the benefits is calculated according to the final transaction electricity \( Q_{7i} \) and the service fee standard:

\[ NR_{7i} = Q_{7i} \times P_{7i}^c - \alpha \Delta F_{7i} \]

(9)

2.4.8. Agency service type-5 (unconstrained, per time-month)

Package 8 charges the service fee directly according to the income standard \( F_{8i} \) (yuan/time-month) agreed by both parties, and does not set the target price. The income of the electricity sales company can be expressed as:

\[ NR_{8i} = F_{8i} - \alpha \Delta F_{8i} \]

(10)
2.4.9. Tiered billing type
In this type of service, the agency service price is determined based on the actual power consumption, and the electricity sales revenue is determined by multiplying the actual power consumption by the agency service price.

\[ NR_{ij} = Q_{ij} \times P_{y,j,k} - \alpha F_{y,j} \quad (11) \]

\[ P_{y,j,k} = \begin{cases} P_{y,j,1} & 0 \leq Q_{y,j} \leq Q_1 \\ P_{y,j,2} & Q_1 < Q_{y,j} \leq Q_2 \\ \vdots \end{cases} \quad (12) \]

where, \( Q_{ij} \) represents the actual power consumption of user \( i \), and \( P_{y,j,k} \) represents the \( k \)-th stepped proxy service price corresponding to the actual power consumption of user \( i \).

3. Operation Evaluation for the electricity sales company and retail packages

3.1. Evaluation index system and weight
The evaluation index system for the electricity sales company and its retail packages can be divided into two levels, as shown in Fig. 1. The first level is for different retail package categories, and the second level is for indicators designed for the operation of retail packages, including deviation expenditure per kWh (\( DEp \)), net income per kWh (\( NIp \)), profit margin compared to final transaction price (\( PM \)), etc. The return on investment is obtained by dividing the net income by the investment cost.

![Evaluation index system of the retail company and its retail packages](image)

Figure 1. Evaluation index system of the retail company and its retail packages

Assuming that the industry’s average \( DEp \) is 0.3 yuan/MWh, the average \( NIp \) is 0.001 yuan, and the average \( PM \) is 0.15%. The evaluation criteria of each index are formulated accordingly, as shown in Table 2.

| Rating          | Terrible | Bad     | Ordinary | Good    | Great   |
|-----------------|----------|---------|----------|---------|---------|
| Scoring scale   | 0~60     | 60~70   | 70~80    | 80~90   | 90~100  |
| \( DEp \) (yuan/MWh) | >0.4     | 0.35-0.4 | 0.3-0.35 | 0.25-0.3| <0.25   |
| \( NIp \) (yuan/kWh) | <0.0005  | 0.0005-0.001 | 0.001-0.0015 | 0.0015-0.002 | >0.002  |
| \( PM \)         | <0.05%   | 0.05%-0.15% | 0.15%-0.3% | 0.3%-0.5% | >0.5%   |

Use AHP to determine the weight of each indicator. The weights of the packages in the first layer are equal, set to 1/9. The importance of each index in second layer is compared in pairs to determine the judgment matrix \( J \).
$$J = \begin{pmatrix} 1 & 1/2 & 1/3 \\ 2 & 1 & 1/2 \\ 3 & 2 & 1 \end{pmatrix}$$  \hspace{1cm} (13)

Then, the weights of each indicator can be obtained \((\text{DEp}: 0.0182, \text{NIp}: 0.0330, \text{PM}: 0.0600)\). Then the overall fuzzy comprehensive evaluation can be formed through the weight and the fuzzy evaluation of each index.

3.2. Fuzzy Comprehensive Evaluation

The fuzzy comprehensive evaluation method uses fuzzy set theory. Through single factor evaluation of the evaluation object, and then considering the weight of each factor, a comprehensive evaluation result is given. The basic steps are as follows:

1. Establish a set of factors and select various factors to describe the attributes of the evaluation object;
2. Establish an evaluation set to combine various possible evaluation results for the evaluation object;
3. Single-factor fuzzy evaluation. Experts evaluate individual factors and fill in the evaluation form;
4. Establish a weight set, which can be regarded as a fuzzy set on the factor set. The weight of each index has been determined in section 3.1.
5. Fuzzy comprehensive evaluation. Combining weight set and single-factor fuzzy evaluation, fuzzy transform is used for fuzzy comprehensive evaluation.

4. Case analysis

4.1. Basic data

Assume that the retail package contracts signed by a retail company and users are shown in Table 3. Code 1 to 9 corresponds to 9 package types respectively. The catalog price is set to 0.6 yuan/kWh. The deviation power within the allowable negative deviation (5%) is not assessed, for the part of the electricity outside the allowable negative deviation range, deviation proportion \(\alpha\) of electricity charges borne by the retail company is set to 10%.

| Code | Signed user | Final transaction electricity volume(MWh) | Final transaction price (yuan/kWh) | Contract content | Negative deviation bill(yuan) |
|------|-------------|------------------------------------------|----------------------------------|----------------|---------------------------|
| 1    | User 1      | 100                                      | 0.557                            | \(P_{1i}^d = 0.56\) (yuan/kWh) | 300           |
| 2    | User 2      | 145                                      | 0.562                            | \(P_{2i}^d = 0.57\) (yuan/kWh), \(\omega =40\%\) | 500           |
| 3    | User 3      | 100                                      | 0.582                            | \(P_{3i}^d = 0.56\) (yuan/kWh), \(\lambda =30\%\) | 325           |
| 4    | User 4      | 235                                      | 0.553                            | \(P_{4i}^d = 0.56\) (yuan/kWh) | 435           |
|      |             |                                          |                                  | \(P_{4i}^s = 0.001\) (yuan/kWh)     |              |
| 5    | User 5      | 150                                      | 0.552                            | \(P_{5i}^d = 0.56\) (yuan/kWh), \(F_{5i} = 150\) (yuan/time-month) | 655           |
| 6    | User 6      | 60                                       | 0.58                             | free            | 400           |
| 7    | User 7      | 135                                      | 0.563                            | \(P_{7i}^c = 0.001\) (yuan/kWh)        | 215           |
| 8    | User 8      | 355                                      | 0.57                             | \(F_{8i} = 150\) (yuan/time-month)      | 250           |

Table 3. Basic data
The operating conditions calculation results and the fuzzy comprehensive evaluation results are shown in the following table. The evaluation scale is (60, 70, 80, 90, 100).

Table 4. Calculation and evaluation results of each package

| Code | Net Income (yuan) | $DE_p$ (yuan/MWh) | $NI_p$ (yuan/kWh) | $PM$ | Score | Rating |
|------|------------------|------------------|------------------|------|-------|--------|
| 1    | 270              | 0.300            | 0.00270          | 0.48%| 91.3354| Great  |
| 2    | 414              | 0.345            | 0.00286          | 0.51%| 96.7315| Great  |
| 3    | 507.5            | 0.325            | 0.00508          | 0.87%| 96.7315| Great  |
| 4    | 191.5            | 0.185            | 0.00081          | 0.15%| 80.2989| Good   |
| 5    | 84.5             | 0.437            | 0.00056          | 0.10%| 68.3658| Bad    |
| 6    | -40              | 0.667            | -0.00067         | -0.11%| 60     | Terrible|
| 7    | 113.5            | 0.159            | 0.00084          | 0.15%| 80.2989| Good   |
| 8    | 125              | 0.070            | 0.00035          | 0.06%| 71.9331| Ordinary|
| 9    | 100              | 0.259            | 0.00074          | 0.13%| 73.2685| Ordinary|

The comprehensive evaluation result of the electricity sales company is 79.8848 points, which is close to the average level. It shows that the overall operating conditions of the company are insufficient compared to the market average. Among them, package 6 has the worst evaluation result, the evaluation scores of package 5, 8 and 9 are all lower than 75.

Regardless of the package 6 (free type), Package 5 has a terrible deviation expenditure $DE_p$ at 0.437 yuan/MWh, bad $NI_p$ and $PM$ at 0.00056 yuan/kWh and 0.10% respectively. Thus, the package can increase the agency service price $F_{s,j}$. And when signing a new contract with user 5, the company can reduce the proportion $\alpha$ of deviation costs. The profits of packages 8 and 9 are lower than other packages, so the packages’ price should be increased appropriately.

According to the case, the result of the fuzzy evaluation corresponds to the actual transaction result of each package. The scores of the evaluation can be used to distinguish the operating situation of the retail company and each retail package, which can intuitively reflect the advantages and disadvantages of the package, so as to provide direction guidance for the package improvement.

5. Conclusion

With the improvement of electricity retail market rules and mechanisms, the scale of the electricity retail market continues to grow. In order to stand out from the increasingly fierce competition, electricity sales companies need to ensure the benefits of retail packages through business measurement, analysis and evaluation.

This article first studies the allocation of retail prices and volumes. Next, based on the 9 types of retail packages in the Yunnan power retail market, the methods for calculating the incomes of different packages are given. Then, based on the evaluation indicators $DE_p$, $NI_p$ and $PM$, a two-tier evaluation index system is established, and the weight of each index is determined according to AHP. Finally, the FCE method is used to evaluate and analyze the operation of the electricity sales company and its packages in the designed case, demonstrating the feasibility and effectiveness of the method.
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