Selection of Cost Allocation Methods for Power Grid Enterprises Based on Entropy Weight Method

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Abstract. With the liberalization of the electricity trading market, market participants pay more attention to the fair and reasonable distribution of relevant costs. However, the traditional transmission and distribution cost allocation methods based on fixed costs have serious cross-subsidies. In this context, a variety of methods for amortizing transmission and distribution costs from different angles have emerged, but these methods generally have some shortcomings, such as excessive calculations. To select the optimal cost allocation method objectively and rationally, this paper uses the entropy weight method to evaluate different cost allocation methods based on four indicators: comprehensibility, application difficulty, load change reflection ability, and transmission stability. Studies have shown that the hybrid transmission and distribution cost allocation method combining the stamp method and the peak liability method is more reasonable and effective.

Keywords: Cost Allocation, Entropy Method, Power Grid Enterprise

1. Introduction
Under the new electricity reform model, reforming the electricity price formation mechanism and promoting the marketization process has become the core of the new round of reforms. Under a certain level of electricity and power load, the level of permitted income determines the level of transmission and distribution prices during the control period [1]. At present, my country adopts the allowable income restriction to supervise the income of power grid companies through the transmission and distribution business within a certain period, that is, to approve provincial-level power grid transmission and distribution permitted income through the method of "permitted cost + reasonable income + tax". Combined with domestic and foreign research on the control methods of power grid companies, considering the current resource endowments and economic environments across the country, this model can be used to relatively independently supervise the power transmission and distribution costs of power grid companies and facilitate reasonable transmission and distribution Electricity cost-sharing. Traditional transmission and distribution cost allocation is based on the proportion of fixed costs. However, the cost of substation projects and transmission line projects under various types, voltage levels, various scales, and different operating conditions varies greatly during the construction period. Periodic maintenance and overhaul costs are also not proportional to fixed assets, so the traditional cost-sharing method based on fixed-cost cross-subsidies is serious, which has caused certain obstacles to the fair allocation of costs. Reasonable allocation of transmission and distribution costs will help to
achieve accurate measurement of effective grid assets and permitted costs after the power reform, and provide support for the investment transformation of grid companies under the new profit model. Moreover, marketization requires open access to the transmission and distribution network, making the fair allocation of transmission and distribution costs and their methods a key theoretical issue to be solved urgently. Besides, the complexity of the power system makes it impossible to accurately determine the actual path of electric energy transmission in the grid, so it is difficult to determine which equipment each power user uses and the degree of use, resulting in a variety of transmission and distribution cost allocation methods, and the lack of uniform standards. The entropy weight method can measure index dispersion degree through information entropy, avoid subjective influence, and obtain more objective index weight. In this paper, the entropy weight method is used to select comprehensibility, application difficulty, load change reflection ability, and transmission stability. As an evaluation index, the existing transmission and distribution cost allocation methods are analyzed to select more advantageous cost allocation methods.

2. Method Introduction

Based on the principle of " who benefits, who bears", under the background of the policy of reasonably dividing the business cost between transmission and distribution and other business cost operated by power grid enterprises, a variety of transmission and distribution cost allocation methods have emerged. This chapter introduces the cost apportionment method, including the stamp method and peak liability method. Secondly, the entropy weight method for evaluation is introduced.

2.1. Stamp Method

The stamp method is also known as the comprehensive cost method [2,3,4]. It was first applied in the field of post and telecommunications billing. The cost of transmission and distribution was equally apportioned according to the electricity or power transmitted by the entire power grid. After calculating the total cost, the total cost is calculated according to the proportion of the transmission power of a single user to all users. The stamp method is easy to understand and operate, but it does not consider the location of the power grid and ignores the influence of the power distribution distance, which makes the power grid cross The subsidies are severe and the guidance for economic development is poor.

2.2. Peak Liability Method

The peak liability method is based on economic theory and can be used to study commodities with special attributes [5,6]. It provides a new idea for the allocation of non-storable and periodic electric energy resources. It is based on the maximum value of all users in the area. The use of electricity (or the maximum load of a power generation company) to share costs will help guide rational investment in the power grid, strengthen internal management, reduce costs and increase efficiency, and also provide some reference for other related businesses.

2.3. Entropy Method

Entropy is a physical concept of thermodynamics [7]. It is a measure of the degree of disorder or disorder of the system [8]. The larger the entropy, the more chaotic the system (that is, the less information it carries). The smaller the entropy, the more orderly the system (that is, the more information it carries). Information entropy draws on the concept of entropy in thermodynamics and is used to describe the average amount of event information [9,10]. Therefore, in mathematics, information entropy is the expectation of the amount of information contained in the event (mean or mean, or expectation, is the probability of each possible outcome in the experiment is multiplied by the sum of its outcomes). According to the definition of information entropy, for a certain index, the entropy value can be used to judge the degree of dispersion of an index. The smaller the entropy value, the greater the degree of dispersion of the index, and the greater the influence of the index on the comprehensive evaluation. If the values of a certain index are all equal, the index will not play a role in a comprehensive evaluation.
The calculation steps of the entropy method are as follows:

1) Construction of indicator matrix

There are $m$ evaluation objects, and each object has $n$ evaluation indexes, and the initial evaluation index matrix $A = (a_{ij})_{m \times n}$ can be obtained. This article takes the stamp method, the peak load method, and the stamp method and the peak load comprehensive method as the evaluation objects, which are expressed as $H_1, H_2, H_3$; besides, The understandability, application difficulty, load change responsibility, and transmission stability of the method were selected as evaluation indexes, Expressed as $X_1, X_2, X_3, X_4$, namely $A = (a_{ij})_{3 \times 4}$.

2) Data normalization

For different indicators, there are large or small differences in their units and dimensions. Such differences may lead to deviations in a comprehensive evaluation. In this regard, it is very important to eliminate differences, evaluate various indicators uniformly, and perform dimensionless processing. There are two main methods for dimensionless.

(1) Critical value method

$$a'_{ij} = \frac{a_{ij} - \min(a_j)}{\max(a_j) - \min(a_j)}$$

(1)

or

$$a'_{ij} = \frac{\max(a_j) - a_{ij}}{\max(a_j) - \min(a_j)}$$

(2)

If the index is positive, the first formula can be used, if the index is negative, then the second formula can be used, where $\max(a_j)$ is the maximum value of the jth index, $\min(a_j)$ is the minimum value of the jth index.

(2) Cosine metric

$$a'_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

(3)

The matrix is weighted and normalized, and each column vector is divided by the norm of the current column vector. In this paper, the cosine metric is used for the dimensionless processing of the data.

3) Calculate the entropy and weight of each indicator

First, calculate the weight of the j-th index of the i-th object

$$b_{ij} = \frac{a'_{ij}}{\sum_{i=1}^{m} a'_{ij}}$$

(4)

Second, calculate the information entropy of each indicator

$$e_j = -K \sum_{i=1}^{m} b_{ij} \ln b_{ij}$$

(5)

among them, $K = \frac{1}{\ln m}$

Third, calculate the weight of the j-th index

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)}$$

(6)

4) Weighted calculation of the final score
3. Method Comparison Analysis

This chapter will compare the three methods of stamp method, peak liability method, and the mixed method of stamp method and peak liability method. The research process is shown in the figure below.

![Figure 1. Technical roadmap](image)

### 3.1. Selection of Evaluation Index

According to the " A Survey of Transmission Cost Allocation Issues, Methods and Practices " published by PJM in the United States [7], the elements of evaluating transmission and distribution cost allocation methods include comprehensibility, ease of management, and ability to reflect system changes over time. The stability of the transmission rate caused by cost-sharing, etc. For stakeholders, an easy-to-understand cost allocation method will help monitor responsibility allocation and measure the impact of decision-making; easy-to-apply cost allocation methods mean fewer data requirements and allocation steps and make cost allocation methods easier to understand. And manage; changes in capacity input and output and fuel costs in the regional system will cause changes in power generation capacity and dispatch mode. The ability to evaluate the cost allocation method to reflect load changes can ensure that the method still allocates costs according to expectations; transmission rate or expenditure Stability helps to more accurately predict future business conditions and needs from the perspective of transmission customers. In summary, this article selects comprehensibility, application difficulty, load change reflection ability, and transmission stability as evaluation indicators.

### 3.2. Weight Calculation

After the preliminary investigation, the index data required for calculation was obtained from the literature and related enterprises, and after sorting, the dimensionless $X_1$–$X_4$ were obtained. The results are shown in Table 1. Schemes $H_1$–$H_3$ respectively represent the three cost-sharing methods of stamp method, peak liability method, and stamp method-peak liability method.

| method | $X_1$  | $X_2$  | $X_3$  | $X_4$  |
|--------|--------|--------|--------|--------|
| $H_1$  | 0.6462 | 0.6965 | 0.4016 | 0.4851 |
| $H_2$  | 0.5744 | 0.5970 | 0.5623 | 0.4851 |
| $H_3$  | 0.5026 | 0.3980 | 0.7229 | 0.7276 |

The dimensionless indicators are processed, and the corresponding individual indicator weights under each method are calculated, and the information entropy of each indicator is calculated.
accordingly. The weight of each indicator is obtained according to the information entropy, as shown in Table 2.

| Index | X₁ | X₂ | X₃ | X₄ |
|-------|----|----|----|----|
| information entropy | 0.9952 | 0.9770 | 0.9749 | 0.9821 |
| weight | 0.0672 | 0.3248 | 0.3553 | 0.2526 |

Table 2. Index information entropy and weight

After obtaining the weight of each indicator according to the entropy method, the final score results of the three methods are calculated as shown in Table 3.

| method | Comprehensive results |
|--------|-----------------------|
| H₁     | 5.1608                |
| H₂     | 5.4793                |
| H₃     | 5.7256                |

Table 3. Comprehensive score of each method

It can be seen from the results that the combined method of stamp method and peak liability method has the highest comprehensive score, which can better allocate costs.

4. Conclusion

Cost-sharing has been paid more and more attention in practice. This article uses the entropy method to score and compare the three methods of stamp method, peak liability method, and the mixed method of stamp method and peak liability method.

Among the three cost-sharing methods of stamp method, peak liability method, and the hybrid method of stamp method and peak liability method, the four indicators of comprehensibility, application difficulty, load change reflection ability, and transmission stability are comprehensively considered. Among them, the optimal cost allocation method is a mixture of the stamp method and peak liability method.

Although the stamp method ignores the influence of distribution distance on the distribution of transmission and distribution costs and is not conducive to the fair and reasonable distribution of transmission and distribution costs, in some small systems or networks with relatively strong grids and relatively uniform distribution, that is, the load is dense and distributed. In a uniform local power grid, it has better applicability. For some areas with lower living standards, appropriate cross-subsidies can help relieve local economic pressures and give play to the social benefits of power; The quantified contribution is reflected in the allocation of transmission and distribution costs, which can reflect the actual utilization of transmission and distribution resources by different voltage levels, and also help to realize the fair allocation of transmission and distribution costs by users. Combining the stamp law with the peak liability law, based on promoting a more fair and reasonable allocation of transmission and distribution costs, and further combining with national public policy goals, reflecting the nature of the social welfare of power grid companies.

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