Comprehensive evaluation of transmission network planning scheme for large scale new energy integration

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Abstract. The demand of large-scale new energy grid connection and transmission promotes the development of transmission network. In order to improve the accuracy of power grid planning scheme evaluation and select a better power grid planning scheme, a power grid planning scheme evaluation and optimization method based on analytic hierarchy process (AHP) is proposed. Firstly, the analytic hierarchy process (AHP) is used to establish the evaluation index system of power grid planning scheme, and the weight of each index is determined. Then, the evaluation index is taken as the input of entropy weight TOPSIS, and the relative paste progress Ci⁺ of each scheme and positive ideal, and select the scheme with the largest paste progress as the most appropriate scheme. The results of case analysis show that the method can reasonably determine the weight of evaluation index, accurately evaluate the power grid planning scheme, and provide a scientific basis for the selection of power grid planning scheme.

1. Introduction

With the rapid development of China’s new energy in recent years, the installed capacity of new energy has gradually increased, and the installed capacity of non water renewable energy has exceeded 30% in some parts of China. The output of wind power, photovoltaic and other new energy generation has obvious characteristics of randomness and intermittence. Its uncertainty makes great changes in the form and structure of the power system, which has a far-reaching impact on the planning of the power system [1]. The evaluation and optimization of power grid planning scheme belongs to the problem of power grid planning decision-making. The problem of power grid planning decision-making is to comprehensively consider the rationality, economy and development of various planning schemes on the basis of power grid planning, and select the optimal planning scheme through the comprehensive evaluation results [1-3]. There are many uncertain factors in the evaluation of power grid planning scheme, which affect the evaluation of power grid planning scheme Optimization faces great challenges [4-5].

Cheng Yaohua[6] studied the comprehensive evaluation of the transmission network planning scheme of renewable energy integration. According to the characteristics of high proportion of renewable energy integration, the transmission network planning scheme was comprehensively evaluated from the aspects of renewable energy consumption pressure and strong uncertainty of renewable energy. Literatures [7-8] proposed the improved TOPSIS method in this method, absolute ideal point and projection method are introduced to improve TOPSIS method, which can effectively improve the decision-making and effectiveness of power grid planning. However, these methods do not
consider the differences between the indicators, resulting in the low accuracy of power grid planning scheme evaluation. In order to improve the accuracy of power grid planning scheme evaluation and select a better power grid planning scheme, a power grid planning scheme evaluation and optimization method based on analytic hierarchy process and entropy weight TOPSIS is proposed, and compared with other methods, the superiority of this method is verified.

2. Evaluation and optimization method of power grid planning scheme based on AHP and TOPSIS

2.1. Construction of power grid evaluation index system based on AHP
In the process of power grid planning scheme evaluation, it is necessary to clarify the decision-making objectives of power grid planning, analyse the relevant factors according to the required objectives, and establish a clear hierarchical structure by classifying the factors affecting the evaluation objectives, so as to facilitate the evaluation and optimization of the final power grid planning scheme.

The optimal setting of comprehensive superiority score is the decision objective, and the evaluation index system of power grid planning is established, as shown in Figure 1.

2.2. Index weight of power grid planning scheme evaluation
The contribution of different indicators to the evaluation results of power grid planning schemes is different. Therefore, this paper introduces the analytic hierarchy process to obtain the comprehensive weight of different power grid planning schemes relative to the overall goal, and uses the relative importance to evaluate the comprehensive weight, and takes the relative comprehensive superiority evaluation of different schemes as the comprehensive weight acquisition method of different power grid planning schemes.

The original data in the index is transformed into the planning norm format by using the fixed scale system. The planning norm format is convenient for direct comparison of different indexes. The above process is scalarization. Suppose there are two indexes expressed by $i$ and $j$ respectively, the comparison result between index $i$ and index $j$ is expressed by $d_{ij}$, and the comparison result between index $j$ and index $i$ is expressed by $d_{ji}$, as shown in Equation (1).

![Figure 1. Sub structure of evaluation index system for power grid planning scheme.](image)
The relative weights of evaluation indexes at different levels are obtained by eigenvector method. The maximum eigenvalue $\lambda_{\text{max}}$ and eigenvector $W$ of the judgment matrix are solved to obtain the weight vectors $(w_1, w_2, \ldots, w_n)$. After normalizing the feature vector $W$, the relative weight of each evaluation index in different layers relative to the upper index is obtained as:

$$w'_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$  \hspace{1cm} (2)

$W' = \begin{bmatrix} w'_1 & w'_2 & \cdots & w'_n \end{bmatrix}$ represents the relative weight value of the evaluation index of a certain layer relative to the index layer.

The consistency of the judgment matrix is tested by the maximum eigenvalue using the compatibility index, as shown in Equation (3).

$$\text{CI} = \left( \lambda_{\text{max}} - n \right) (n - 1)^{-1}$$  \hspace{1cm} (3)

CI is the consistency index; $n$ is the order of judgment matrix. When CI $< 0.1$ and CI $\geq 0.1$, the consistency of judgment matrix was considered acceptable and unacceptable respectively. When the judgment matrix cannot be accepted, it is necessary to modify the judgment matrix [12], recalculate the weight of the modified matrix, and check the consistency of the judgment matrix again until the consistency test is passed.

### 2.3. The evaluation model of power grid planning scheme is established based on entropy weight TOPSIS

In this section, entropy weight TOPSIS is used to make comprehensive decision on multi-scheme and multi-attribute. Suppose that for $m$ schemes, $n$ objective function values of each scheme are determined, $n$ objectives are standardized, the evaluation set is established, and weighted normalized decision matrix $F(m, n)$ is obtained, in which each element is $F_{ij}$, which represents the weighted normalized evaluation values of $j$th objective function of the scheme $i$. Then determine the positive ideal scheme $A^+$ and the negative ideal scheme $A^-$. Calculate the distance from each evaluation scheme to positive ideal scheme and negative ideal scheme $D^+\text{, } D^-$, as shown in the equation

$$D^+_i = \sqrt{\sum_{j=1}^{n} (F_{ij} - A^+)^2} \hspace{1cm} i = 1, 2, \ldots, m;$$  \hspace{1cm} (4)

$$D^-_i = \sqrt{\sum_{j=1}^{n} (F_{ij} - A^-)^2} \hspace{1cm} i = 1, 2, \ldots, m;$$  \hspace{1cm} (5)

Calculate the relative paste progress $C^+_i$ of each scheme and positive ideal, and select the scheme with the largest paste progress as the most appropriate scheme.

$$C^+_i = \frac{D^+_i}{D^+_i + D^-_i} \hspace{1cm} i = 1, 2, \ldots, m$$  \hspace{1cm} (6)

### 3. Examples

Taking three planning schemes of 500kV network in a certain power system in the next five years as an example, three power grid planning schemes are adopted as the test objects. The number of nodes and
branches in the power grid area is 68 and 81 respectively, including 41 generator nodes. There are two types of bracket type in the power grid. The evaluation results are shown in the Table 1.

From Table 1, it can be seen that scheme 1 has the lowest cost but the worst security and stability; both scheme 2 and scheme 3 meet the needs of power grid security and stability, but the reliability of scheme 2 is poor, so scheme 3 is the best among the three power grid planning schemes. Scheme 3 is selected as the best scheme for the power grid planning, which is the same as the actual situation. The experimental results show that the proposed method can effectively and reasonably evaluate and optimize the power grid planning scheme.

Table 1. Evaluation results of each scheme indexes.

| INDEX                              | SCHEME | 1   | 2   | 3   |
|------------------------------------|--------|-----|-----|-----|
| Reliability                        | Equipment operation | 8.9 | 6.5 | 7.3 |
|                                    | Power supply capacity | 8.8 | 7.3 | 7.9 |
|                                    | Power supply quality  | 6.4 | 8.6 | 6.4 |
|                                    | Power supply stability| 6.8 | 7.8 | 8.5 |
| Coordination                       | Expansibility        | 3.9 | 5.9 | 8.8 |
|                                    | Coordinate regional economic development | 5.1 | 6.7 | 8.7 |
| Economy                            | Investment cost      | 4.9 | 7.5 | 7.7 |
|                                    | Operation cost       | 1.5 | 1.4 | 1.2 |
| Society                            | Coordination with cities | 5.8 | 6.9 | 9.8 |
|                                    | Environmental impact | 8.1 | 5.9 | 9.7 |
|                                    | Land occupation      | 5.8 | 8.3 | 9.9 |

4 Conclusions

In order to obtain a better power grid planning scheme, a power grid planning scheme evaluation model based on the combination of analytic hierarchy process (AHP) and entropy weight TOPSIS is proposed. The AHP is used to comprehensively consider the technicality and economy of power grid planning scheme. A complete hierarchical structure of power grid planning scheme evaluation is established and the evaluation index is established to evaluate the transmission network planning in many aspects and multi-dimensions. The entropy weight TOPSIS can make full use of the information of the original data, objectively carry out the weight amplitude, and the results can objectively reflect the gap between the evaluation schemes. It can effectively improve the evaluation efficiency and accuracy, and realize the accurate evaluation and optimization of power grid planning scheme.

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