Performance evaluation of main transformer equipment suppliers for 500kV main transformer equipment

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Abstract. Scientific evaluation of the main transformer equipment suppliers is the premise to ensure the cost control and safe operation of the power grid. Based on the analysis of various factors affecting the main transformer equipment supplier, the evaluation index of the main transformer equipment supplier is constructed. Considering the fuzziness of the evaluation index, the index weight is determined by AHP, and the evaluation model of main transformer equipment supplier based on fuzzy comprehensive evaluation is established. The example calculation shows that the fuzzy comprehensive evaluation method can fully reveal the evaluation index information and reflect the actual situation of main transformer equipment suppliers scientifically and reasonably.

Keywords: main transformer equipment; main transformer equipment supplier; performance evaluation; fuzzy comprehensive evaluation method.

1. Introduction

The normal operation of power system and the economic cost of power grid operation cannot be separated from the support of main transformer equipment. The safety and reliability of main transformer equipment operation is the operation cornerstone to ensure the safe transmission and distribution of power grid, Therefore, the comprehensive evaluation and selection of main transformer equipment suppliers is a very important link in the process of power grid company's main transformer equipment procurement and management. It is not only related to the protection of the economic profit, maintenance cost and safe operation of the power grid company, but also related to the scientific management of the main transformer equipment, so as to reduce the power system management cost and the purpose of safe operation.

In recent years, there are more and more methods to evaluate main transformer equipment suppliers, including subjective judgment, bidding method, Delphi method, entropy weight and analytic hierarchy process, grey correlation and neural network. There are more and more factors affecting suppliers, such as sun Chaoyuan and Peng Qiyuan, who evaluate equipment suppliers from four aspects of price, quality, delivery lead time and service level [1]. Dou Peng et al. Put forward the defect, fault evaluation calculation method and nonlinear life evaluation method to eliminate the influence of factors such as
operation period and operation year, and build the product quality evaluation model of transformer manufacturers based on this method [2]. Chen Meng constructs an evaluation index system based on the supplier's enterprise environment, internal situation, service ability, delivery ability and response ability to evaluate the comprehensive strength of equipment suppliers [3]. Li Yiwen designs a supplier performance evaluation and risk early warning scheme covering the whole life cycle of assets from the perspectives of integrity, quality and service [4]. Wu Wenbo conducts a comprehensive evaluation of power equipment by modeling and quantifying the five dimensions of qualification performance, performance, economic life, equipment quality and comprehensive credit [5]. Kiritsis uses ontology based technology to manage the life cycle of equipment assets [6]. Raghavan et al. Proposed that the asset life cycle model combined with reliability can achieve the level of equipment quality and solve the problem of low efficiency [7]. Kilby and remenyte proposed to use the life cycle cost to analyze and evaluate the asset management strategy of overhead line equipment [8]. Bagdadee et al. Proposed using wireless sensor network model to improve the quality of power grid equipment [9]. Gandomand et al. Used flexible AC transmission system to improve equipment quality [10].

The purpose of selecting the main transformer equipment supplier evaluation system is to enable the enterprise to evaluate the main transformer equipment supplier through scientific and reasonable methods, and the managers can provide reliable basis for enterprise decision-making. This will enable companies to build strategic partnerships in a supply chain environment. In this paper, combined with the actual situation of the main transformer equipment supplier, the evaluation index system of the main transformer equipment supplier selection is established, and the fuzzy comprehensive evaluation theory is introduced to evaluate the main transformer equipment supplier.

2. Main transformer equipment supplier evaluation index system

At present, there are many evaluation systems for main transformer equipment suppliers. However, many enterprises do not decompose these factors in detail, so as to establish a set of operational evaluation index system. Therefore, with the support of information technology, it is necessary to establish the main transformer equipment supplier evaluation system and index system based on the main transformer equipment supplier. The purpose of selecting the main transformer equipment supplier evaluation system is to enable the enterprise to evaluate the main transformer equipment supplier through scientific and reasonable methods, and the managers can provide reliable basis for enterprise decision-making. This will enable companies to build strategic partnerships in a supply chain environment. Through the analysis of main transformer equipment suppliers, the product procurement process is analyzed and investigated, and the evaluation index of main transformer equipment supplier selection is initially constructed, as shown in Table 1.

Table 1. Main transformer equipment supplier evaluation index

| Target layer | Primary indicator B | Secondary indicator C       |
|--------------|---------------------|-----------------------------|
| transformer equipment suppliers | quality | manufacturing environment |
| Social credit | Manufacturing | Equipment quality |
| Qualification and capability | Dishonesty | Trustworthy behavior |
| Performance of performance | Financial situation |
| Operational performance | Service | Company size |
| service level | Supply capacity | Installation services |

3. Fuzzy analytic hierarchy process evaluation model

Fuzzy comprehensive evaluation method is a comprehensive evaluation method with fuzzy mathematics as the core. This evaluation method is based on the theory of membership degree in fuzzy mathematics,
which transforms the qualitative evaluation into quantitative evaluation, and is suitable for comprehensive and effective evaluation of the evaluated objects affected by multiple factors. It is not limited to the language and logic of precise mathematics, and the results are clear and systematic. Its mathematical model can be divided into single level evaluation model and multi-level evaluation model.

(1) The index set and comment set of the evaluation object are determined. The index set is a common set composed of all the indexes that affect the object to be evaluated.

\[ \mathcal{U} = \{ u_1, u_2, \ldots, u_p \} \]  
\[ \mathcal{V} = \{ v_1, v_2, \ldots, v_q \} \]

(2) Construction of standardized evaluation matrix

A new matrix R1 is obtained by normalizing the matrix R.

\[ r_{ij} = \frac{r_{ij} - r_{\text{min}}}{r_{\text{max}} - r_{\text{min}}} \]

Where \( r_{\text{min}} \) and \( r_{\text{max}} \) are the minimum and maximum values of different objects under the same evaluation index.

(3) Determining weight value by analytic hierarchy process

1) Determine the evaluation object, construct the judgment matrix of the evaluation index
2) Check the consistency of judgment matrix

\[ CR = \frac{CI}{RI} \]

CR is the random consistency ratio of the judgment matrix. When CR < 0.1, the judgment matrix meets the consistency requirements, otherwise, the judgment matrix needs to be modified until CR < 0.1 is met. RI is the random consistency index, and the specific values are shown in Table 2.

| Order | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI    | 0   | 0   | 0.52| 0.89| 1.12| 1.26| 1.36| 1.41| 1.46|

(3) According to the judgment matrix, the eigenvector corresponding to the maximum eigenvalue is calculated, that is, the weight coefficient of each index.

(4) Establishing fuzzy relation matrix

After the hierarchical fuzzy subset is constructed, it is necessary to quantify the evaluated things from each evaluation factor one by one, in which the evaluation factor is expressed as; according to the membership degree (R | UI) of single factor to the hierarchical fuzzy subset, the fuzzy relation matrix is determined as follows:

\[ R = \begin{bmatrix} R \mid u_1 & R \mid u_2 & \ldots & R \mid u_p \\ r_{11} & r_{12} & \ldots & r_{1p} \\ r_{21} & r_{22} & \ldots & r_{2p} \\ \ldots & \ldots & \ldots & \ldots \\ r_{p1} & r_{p2} & \ldots & r_{pp} \end{bmatrix} \]

Among them, the element \( R_{ij} \) represents the fuzzy membership degree of a certain factor \( UI \) of the evaluated thing to the VJ level.

The formula is as follows:
\[ A \cdot R = \begin{bmatrix} r_{x1} & r_{x2} & \cdots & r_{xm} \\ r_{y1} & r_{y2} & \cdots & r_{yn} \end{bmatrix} = \begin{bmatrix} a_1 \cdot b_1 & a_2 \cdot b_2 & \cdots & a_m \cdot b_m \end{bmatrix} = B \tag{6} \]

Where \( B_i \) is the membership degree of the evaluated object to the fuzzy subset of \( \Phi \) grade.

(5) The fuzzy comprehensive evaluation result analysis normalizes the vector \( B \) and multiplies the processing result \( B \) with the fuzzy evaluation vector \( V \) to obtain the comprehensive evaluation result score

\[ G = \overline{B} \circ V^T \tag{7} \]

4. Example analysis

Taking 500kV main transformer as the research object, this paper evaluates the main transformer equipment suppliers (A, B, C, D) of six provincial power companies in a regional power grid area, so as to determine the main transformer equipment supplier level, and make guidance for the performance rating and selection of main transformer equipment suppliers in the future. The data is from t provincial power company. Four main transformer equipment suppliers will provide 106 main transformers for t provincial power company in 2019.

Through the method of fuzzy comprehensive evaluation, t provincial electric power company began to consider all the problems conveniently. Due to the variety of evaluation factors of suppliers, t provincial power company analyzed and applied the screening method to analyze each factor, and obtained six important evaluation indexes, namely, quality, social credit, qualification ability, operation performance, performance performance and service level.

(1) By asking customers and past experience, the factor set \( U = \{ \text{quality, social credit, qualification, operation performance, performance, and service level} \} \) is determined.

(2) There are many factors for supplier evaluation in this paper. We set the evaluation set as \( V = \{ \text{very good, relatively good, good, general, poor} \} \). In order to reduce the rank.

The hierarchical structure of main transformer equipment suppliers is established, as shown in Figure 1 below,

**Figure 1.** Hierarchy chart
According to the chart of AHP model established in Figure 1 and the comparison of main transformer equipment supplier index, the weight is calculated and tested. R1, R2, R3, R4, R5 and R6 represent the scores from 1 to 6. The specific results are shown in Table 3.

| Table 3 Judgment matrix A-B |
|-----------------------------|
| Select evaluation index     | B1 | B2 | B3 | B4 | B5 | B6 |
| Quality B1                  | 1  | 2  | 4  | 3  | 2  | 5  |
| Social credit B2            | 1/2| 1  | 3  | 2  | 4  | 7  |
| Qualification and capability B3 | 1/4 | 1/3 | 1  | 2  | 3  | 1  |
| Performance of performanceB4 | 1/2 | 1/2 | 1/2 | 2  | 1  | 1/5|
| Operational performance B5  | 1/2 | 1/4 | 1/3 | 1  | 1/3 | 2  |
| Service level B6            | 1/5 | 1/7 | 1  | 5  | 1/2 | 1  |

Calculate the single rank of each level and check the consistency index

$$W_i = \phi \prod_{j=1}^{n} a_{ij} = \sqrt[6]{1*2*3*4*5} = 2.492$$ (8)

Similarly, there are $$2.092, 0.890, 0.607, 0.550, 0.645$$. Normalizing the vector $$w = (W_1 W_2 W_3 W_4 W_5 W_6)^T$$, we get $$W_1 = 0.34, W_2 = 0.29, W_3 = 0.12, W_4 = 0.08, W_5 = 0.08, W_6 = 0.09$$, then the eigenvector $$w = (0.340.290.120.080.09)^T$$

There are some differences between practice and theory. In order to ensure the reliability of the conclusions, it is necessary to test their consistency.

$$\lambda_{\text{max}} = \sum_{n_i} A_i \psi_i = 1 \left( \frac{2.250}{0.34} + \frac{2.092}{0.29} + \frac{0.890}{0.12} + \frac{0.607}{0.08} + \frac{0.645}{0.09} + \frac{0.589}{0.08} \right) = 6.311$$ (10)

$$CI = \frac{\lambda_{\text{max}} - n}{n-1} = \frac{6.311-6}{5} = 0.0622$$ (11)

If RI = 1.24, then

$$CR = \frac{CI}{RI} = \frac{0.0622}{1.24} = 0.05 < 0.1$$ (12)

When CR < 0.1, there is consistency, otherwise there is no, because the data results in this paper conform to the consistency index. For the above data, using AHP method to conform to the consistency index, we can equate the weight of each factor with the value of judging the relativity of each factor of the matrix eigenvector. The weight of quality is 0.34; the weight of social credit is 0.29; the weight of qualification ability is 0.12; the weight of performance performance is 0.08, the weight of operation performance is 0.08, the weight of service level is 0.09. In addition, a set of weight sets a = (0.34, 0.29, 0.12, 0.08, 0.08, 0.09) are obtained by customer evaluation method.

After normalization, the maximum value of enterprise a is 0.25, which belongs to the very good level in the evaluation concentration, the maximum value of enterprise B is 0.23, which belongs to good and
bad in the evaluation set, the maximum value of enterprise C is 0.28, which belongs to the relatively good level in the evaluation concentration, and the maximum value of enterprise D is 0.28, which belongs to the very good grade in the evaluation set. Comparing the second maximum value between A and D, the main transformer equipment supplier of A should be selected.

5. Summary
Based on the provincial power grid main transformer equipment quality, this paper puts forward the performance of main transformer equipment suppliers. Due to the gradual strengthening of power grid safety awareness, in order to ensure safe operation, first of all, the equipment quality should be strictly controlled in the material department. The index weight is determined by analytic hierarchy process (AHP), and the evaluation model of main transformer equipment supplier based on fuzzy comprehensive evaluation is established. The example calculation shows that the fuzzy comprehensive evaluation method can fully reveal the evaluation index information, scientifically and reasonably reflect the actual situation of the main transformer equipment suppliers, and provide decision support for the future procurement of main transformer equipment in the provincial power grid.

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