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Supplier performance evaluation for 500 kV main transformer

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Abstract. As an important state-owned energy backbone enterprise related to national energy security and the lifeline of national economy, power grid enterprises are responsible for ensuring the quality and safety of equipment and promoting the development of equipment quality. Therefore, continuously improving the quality evaluation of main transformer equipment is very important to improve the quality of power grid main transformer equipment. This paper first constructs the main transformer equipment quality evaluation index system from equipment procurement, equipment installation, equipment use and equipment decommissioning and scrapping; on this basis, the scoring method of each evaluation index is given, and the final main transformer equipment quality evaluation score is calculated by combining subjective and objective weight determination method; Finally, according to the evaluation of 500kV main transformer equipment of provincial power grid company price score, to evaluate the performance of equipment quality provided by suppliers.

Keywords: provincial power grid enterprise; main transformer equipment quality; supplier; performance evaluation.

1. Introduction

With the people's increasing demand for high-quality products, China's comprehensive implementation of the quality strategy. As the largest state-owned energy backbone enterprise in the world, power grid enterprises have been committed to continuously improving the overall and systematic work of quality management. Power grid main transformer equipment is an important material basis for power construction and safe and stable operation of the system, and an important guarantee for the smooth development of engineering construction and safe and reliable operation of power grid. Therefore, in the procurement process of main transformer equipment, the quality of main transformer equipment should be continuously regarded as the key assessment object of supplier performance evaluation, so as to ensure the quality of main transformer equipment, which is very important to improve the overall equipment quality management level of power grid enterprises and implement the "rejuvenating power grid with quality".



At present, domestic and foreign scholars have carried out relevant research on the evaluation of power grid main transformer equipment suppliers. Sun Chaoyuan and Peng Qiyuan used multidimensional grey comprehensive evaluation method to 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, so as to provide quantitative reference for power grid companies to select the best suppliers efficiently. According to the equipment life cycle management and equipment quality problems, Jin Yongchuan constructed the power equipment quality event life cycle link matrix [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]. Kilsby and remenyte proposed to use 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 [10]. Used flexible AC transmission system to improve equipment quality [11].

2. Main transformer equipment quality evaluation index system

2.1. Determination of evaluation index weight

Due to the different importance of different indicators, it is necessary to give reasonable weight to each evaluation index to improve the rationality of the evaluation results. In order to avoid the subjective or objective weight of each index, this paper chooses the optimal combination weight method based on the combination of subjective and objective weights to calculate the weight of each index. The subjective weighting method and the objective weighting method select AHP and entropy method respectively, and finally calculate the weight of each index through the optimal combination weight method.

(1) Analytic hierarchy process

Table 1. Main transformer equipment quality evaluation index based on life cycle

Target layer	Primary indicators	Secondary indicators	Third level index	Standard score	Calculation method or scoring rules
Quality evaluation index of power grid main transformer equipment	Equipment procurement stage	Equipment manufacturing supervision	Key points of quality management witness in equipment manufacturing process	10score	In case of incomplete or wrong key points in the manufacturing supervision task such as manufacturing process and process, 2 points will be deducted for each case, and the maximum 10 points will be deducted.
		Factory test	Equipment factory test pass ability	10score	No point will be deducted if the factory test passes once; 5 points will be deducted if the delivery test fails to pass the factory test once and the retest after simple repair does not affect the delivery date; 10 points will be deducted if the factory test fails to pass once and needs to be repaired for a long time or fails to pass multiple retests.

Equipment installation stage	Installation process	Equipment installation process	10score	2 points will be deducted for each piece of equipment in case of oil leakage (gas) leakage; 2 points will be deducted for each non-conforming part due to lack of equipment installation and nonstandard bolt installation; 2 points will be deducted for each place without gasket installation and obvious gap between equipment base and foundation, with 10 points at most.
	Equipment quality event	Number of failures or unplanned outages caused by equipment quality problems	10score	No point will be deducted for failure or non-stop, or failure or non-stop caused by quality problem; 5 points will be deducted for fault or non-stop once caused by equipment quality; 10 points will be deducted for failure or non-stop for two or more times caused by equipment quality.
		Annual familial defects of equipment	10score	In case of occurrence, the score of this item is zero
Equipment use stage	Equipment operation economy	Equipment transportation and inspection cost	10score	If the transportation inspection cost is located in $[0, C]$, no point will be deducted; if the transportation inspection cost is located in (C, d) , 5 points will be deducted; if the transportation inspection cost is located in $[D, +\infty]$, 10 points will be deducted.
		Unplanned outage loss	10score	If the unplanned outage loss is located in $[0, a]$, no point will be deducted; if the unplanned outage loss is located in (a, b) , 5 points will be deducted; if the unplanned outage loss is located in $[b, +\infty]$, 10 points will be deducted.
	Equipment defects	Equipment defect level	10score	No points will be deducted for defects not caused by equipment quality; 5 points will be deducted for general defects caused by equipment quality problems; 10 points will be deducted for serious defects caused by equipment quality problems.
Equipment decommissioning / scrapping stage	Reasons for decommissioning / scrapping	Technical economy of equipment decommissioning / scrapping	10score	10 points will be deducted if the equipment is decommissioned due to its own quality problems and can not be reused; 5 points will be deducted if the equipment is decommissioned due to its own quality problems and can be reused; no points will be deducted for other reasons of decommissioning.

Determine the evaluation object, construct the judgment matrix of the evaluation index, and establish the judgment matrix according to the 1-9 scale principle.

Table 2. 1-9 scaling method

Scale	meaning
1	It shows that the two factors are equally important
3	It shows that the former is slightly more important than the latter
5	It shows that the former is more important than the latter
7	It shows that the former is more important than the latter
9	It shows that the former is more important than the latter

(2) Check the consistency of judgment matrix

$$CR = \frac{CI}{RI} \quad (1)$$

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 3.

Table 3. RI value table

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.

2.2. Entropy method

Entropy method is to calculate the information entropy of the original data to reflect the impact of different indicators on the system. The greater the numerical difference of the same index, the greater the information entropy and the greater the weight, otherwise, the smaller the weight. The specific steps of entropy method are as follows:

1) Is the entropy value of the jth evaluation index, then

$$\varepsilon_j = -\frac{1}{\ln n} \sum_{i=1}^n f_{ij} \ln(f_{ij}) \quad (2)$$

Where ε_j is the proportion of J index in all time of the j evaluation index at the n time.

2) Suppose that the entropy weight of the j-th evaluation index is as follows:

$$w_j = \frac{1 - \varepsilon_j}{n - \sum_{j=1}^n \varepsilon_j} \quad (j = 1, 2, \dots, n) \quad (3)$$

2.3. Combination weight

In order to make the evaluation results more realistic, not only the subjective experience but also the objective situation of the equipment itself should be considered in the weighting process of each index. Therefore, the combination weighting method of subjective and objective weights is selected in this paper, and its expression is as follows:

$$w = \alpha\mu + (1 - \alpha)\nu \quad (4)$$

Among them, is the weight calculated by the i-th weighting method, and is the weight calculated by the j-weighting method. And are the weight coefficients of the i-th weighting method and the j-weighting method respectively. Finally, the combined weight vector of each index can be determined according to the value.

2.4. Final score value of main transformer equipment

(1) The revised score based on Wilson confidence interval

Generally speaking, if the number of samples is small, the equipment quality will be low. In the quality evaluation of main transformer equipment, the evaluation results are beneficial to the suppliers with less supply, which is unfair to some extent. Therefore, we need to consider the influence of the number of samples. According to the initial score value of main transformer equipment quality and the

number of equipment, the lower limit of Wilson confidence interval of the initial score of main transformer equipment is calculated, and the lower limit value is taken as the revised score value of main transformer equipment quality rating. The modified score value is calculated as follows.

$$P_{down} = \frac{P + \frac{z^2}{2n} - z\sqrt{\frac{P(1-P)}{n} + \frac{z^2}{4n^2}}}{1 + \frac{z^2}{n}} \quad (5)$$

Among them:

P—initial quality score of main transformer equipment;

N—the number of samples;

Z—represents the Z statistical constant with the corresponding confidence level of $1 - \alpha$ (the confidence level is usually taken as 95%, and the Z statistical constant is 1.96);

P_{down} —lower limit of Wilson confidence interval of initial score of main transformer equipment quality.

(2) Initial rating principle

According to Wilson's confidence interval correction score value, it is divided into different grades from high to low: if it is divided into 5 levels, it is a, B, C, D, e, accounting for 10%, 20%, 40%, 20%, 10%; if it is divided into 4 levels, it is a, B, C, D, accounting for 30%, 40%, 20%, 10%; if it is divided into 3 levels, it is a, B, C, accounting for 30%, 40%, 30%; if it is divided into 2, it is a Grade B, accounting for 50% and 50% respectively.

(3) Calculation of main transformer equipment quality score system

According to the correction results of equipment quality rating and the corresponding correction score value, linear function mapping interpolation is carried out to calculate the equipment quality rating hundred point system score. The mapping interval of level a is 93-100, that of level B is 85-92, that of level C is 77-84, that of level D is 69-76, and that of level E is 60-68. The latest interpolation calculation of linear function mapping is shown in formula (6).

$$R_i = U_{min} + \frac{(P_{downi} - P_{downmin})(U_{max} - U_{min})}{P_{downmax} - P_{downmin}} \quad (6)$$

Among them:

P_{downi} —equipment quality correction score;

$P_{downmax}$ —the maximum value of equipment quality correction score;

$P_{downmin}$ —the minimum value of equipment quality correction score;

U_{max} —the maximum value of the score range of the hundred mark system;

U_{min} —the minimum value of the score range of the hundred mark system;

R_i —is the score of equipment quality rating system.

2.5. Example analysis

Taking 500kV main transformer as the research object, this paper evaluates the equipment quality of main transformer equipment suppliers (A, B, C, D, F, G main transformer equipment suppliers) of six provincial power companies in a regional power grid area, so as to determine the supplier level and make guidance for the performance rating and selection of suppliers in the future. Among them, the data is from t provincial power company. Six suppliers will provide 106 main transformers for t provincial power company in 2019. Firstly, the importance of indicators at all levels of the index system is compared, and the judgment matrix is constructed according to the attention degree of each index in the region. Then, the maximum eigenvalue and corresponding eigenvector of the judgment matrix are solved by the square root method. The established judgment matrix is as follows:

Therefore, the comprehensive score of 106 main transformer equipment is calculated, and Wilson confidence interval score is corrected, and then combined with the quintile method to determine the

supplier level and mine the characteristics of suppliers. The application results show that the evaluation results are more scientific and the proposed method is reasonable and effective. As a result, the supplier's equipment classification results are shown in Table 4:

Table 4. Supplier equipment classification

Spplie	Grade A	Grade B	Grade C	Grade D	Grade E	total
Chongqing supplier	3	11	22	8	7	51
Japanese suppliers	2	4	4	2	1	13
Jinan supplier	2	2	4	4	0	12
Shenyang supplier	2	1	3	1	2	9
Changzhou supplier	1	2	6	2	1	12
Baoding supplier	0	2	4	3	0	9
total	10	22	43	20	11	106

The five grades were assigned 5-1 points respectively, and the total scores of 6 suppliers were calculated, which were 148, 43, 38, 27, 36, 26. The average scores were 2.90, 3.31, 3.17, 3.0, 3.0, 2.89. Therefore, it can be determined that the grade of six suppliers is about C, but the main transformer equipment of Japanese suppliers is better, and Baoding is the worst. It is suggested that different cooperation strategies should be adopted for suppliers with different sub positions and different safety types. Suppliers in a and B levels can give priority to continue cooperation; suppliers in sub C can continue to cooperate. It is suggested that differentiated quality sampling and operation inspection strategies should be formulated for such suppliers to do well in equipment quality inspection and strictly prevent quality control; for D and e grade suppliers, cooperation should be given priority. The supplier of low-quality equipment needs to re evaluate its qualification, strictly control the equipment quality, or consider replacing the supplier.

3. Summary

In this paper, based on the provincial power grid main transformer equipment quality, supplier performance is proposed. Due to the gradual strengthening of power grid safety awareness, in order to ensure safe operation, the equipment quality should be strictly controlled in the material department. According to Wilson confidence interval, the final score of main transformer equipment is modified to divide the equipment grade, and the supplier is judged according to the equipment quality provided by the supplier, so as to determine the average grade of the equipment provided by the supplier, so as to provide decision support for the procurement of main transformer equipment in t provincial power grid in the future.

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