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Research on the Evaluation Model of Investment Benefits of Major Power Transmission and Transformation Projects Based on BWM and TOPSIS Methods

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Abstract. Transmission and transformation project is the foundation of power grid construction, the development of large-scale transmission projects can not only realize the optimal allocation of resources, but also improve the overall efficiency of power transmission. This paper takes the investment benefit of major power transmission and transformation project as the research object, and explores its complete evaluation system in depth. According to the characteristics of various types of projects, an evaluation indicator system has been built to meet all kinds of major power transmission and transformation projects. Considering the differences in the focus of evaluation indicators of different projects, the paper puts forward an indicator evaluation idea based on BWM method (Best-Worst Method) and TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution Method), so as to establish an investment benefit evaluation model applicable to various power transmission and transformation projects. Finally, the paper verifies the above investment benefit evaluation model through the actual engineering project, and the evaluation process and results show the practicality and superiority of the model.

1 Introduction

With the continuous development of China's transmission and transformation technology, various major power transmission and transformation projects are gradually built and improved and put into operation in recent years. In order to make subsequent projects achieve higher comprehensive benefits, it is necessary to analyze advantages and disadvantages of existing power grid projects in depth, and how to evaluate the comprehensive benefit of power transmission and transformation projects objectively and accurately has become a key problem in the process. Based on the above situation, domestic and international scholars have carried out a lot of research work on the evaluation of the investment benefits of power grid projects, including the exploration of the comprehensive evaluation method of investment benefits of power grid projects, the establishment of the evaluation indicator system and the evaluation modeling.

Extensively used evaluation methods at present mainly include analytical process of hierarchy (APH) method[1], fuzzy comprehensive evaluation method[2-4], TOPSIS method[5], graph model method[6], and entropy weight method. The literature[7] has built the evaluation system by using the APH method. However, the implementation of this method depends on preference of experts which has a strong subjective consciousness. The literature[8] determines the subjective weight and objective weight in the indicators by the set-value iteration method and the entropy weight method respectively, and combines the two to determine the final weight to reduce the subjectivity in the evaluation process. The literature[9] integrates fuzzy evaluation method, APH method, correlation method and other evaluation methods, and establishes an evaluation model applicable to rural power grid construction and renovation projects. The literature[10] combines the investment and construction of rural power grid projects in 27 provinces, and establishes a comprehensive evaluation indicator system for the renovation and upgrading of rural power grids, with the largest weight of power grid performance indicator in the evaluation process. The literature[11] makes a comprehensive evaluation of three types of investment benefits of power engineering projects using time, value and efficiency in terms of investment recovery cycle, power grid value and power grid efficiency during the life cycle of power grid projects.

From the overall situation of domestic and international research, the power grid projects under evaluation mainly focus on a single power grid project and rural power grid, and there is a lack of a unified, systematic evaluation system for a number of major power transmission and transformation projects. In the light of the above, the paper establishes a system of evaluation indicator of investment benefit of major power transmission and transformation projects, and puts forward a method of evaluating the investment benefit of major power transmission and transformation projects based on BWM method (the Best-Worst Method) and TOPSIS method (Technique for Order Preference by

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Similarity to Ideal Solution method), and verifies the feasibility and practicality of the evaluation model through empirical analysis.

2 Investment Benefit Evaluation Modeling for Major Power Transmission and Transformation Projects

Figure 1 shows the basic process of investment benefit evaluation modeling for major projects, which includes the following three stages.

Stage 1: determine the evaluation indicator system. Based on the collection and collation of relevant information, the evaluation indicator system is built for the characteristics of major power transmission and transformation projects.

Stage 2: determine the weight of the evaluation indicator system. After determining the evaluation indicator system, calculate the weight of each indicator.

Stage 3: based on the indicator weight, choose the appropriate method for comprehensive evaluation, build a multi-dimensional comprehensive evaluation model of the operational effect of major power transmission and transformation projects, and analyze the actual operation effect of major power transmission and transformation projects.

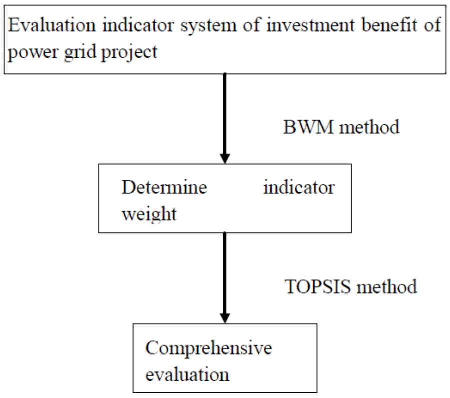

Fig1. Evaluation model of investment benefit of power grid project

3 Building of the Evaluation Indicator System of Investment Benefit of Major Power Transmission and Transformation Projects

The actual function positioning of a power grid project in the whole power grid has to be taken into account in evaluating the effectiveness of investment in the power grid project, and the differences between various functions should be considered in the evaluation of power grid projects. Major transmission and transformation projects can be generally divided into three types: power delivery projects, grid frame strengthening projects and load power supply projects. According to the power industry standard DL/T 5523-2017 "Typical grid engineering project post-evaluation guideline", the transmission project is mainly to evaluate its power delivery target in the evaluation of project objectives; grid connection projects can evaluate the goals of optimizing the allocation of resources and strengthening the grid frame structure through mutual transmission of maximum power, annual exchange of electricity and trend distribution; and typical power grid projects in the region (province) can evaluate the goal of increasing regional power supply capacity and strengthening the grid frame structure through equipment load rate.

The role played by the above three types of power grid projects is fully considered in the paper in the design of the investment effectiveness evaluation indicator of power grid projects, and the indicator system for the evaluation of investment effectiveness of power grid projects is put forward from the six dimensions of transmission efficiency, operation efficiency, incremental benefit, scale merit, environmental benefit and social benefit, which is composed of 6 first-level indicators, 16 second-level indicators and 22 third-level indicators, as shown in Table 1.

Table 1 Evaluation indicators of investment effectiveness in power grid projects

First level	Second level	Third level	Unit	Indicator attribute
Transmission efficiency	Transmission capacity	Annual transmission capacity	100 million kWh	Extremely large
	Transmission loss	Annual transmission loss rate	%	Extremely small
	Utilization efficiency	Annual equivalent utilization hours	hour	Extremely large
	Transmission of electricity	Annual maximum power	10000kW	Extremely large
		Ratio of scheduling limits	%	Extremely large
		Ratio of annual maximum power in scheduling control power	%	Extremely large

		Annual maximum power duration	hour	Extremely large
Operating efficiency	Planned outage	Planned outage time/hour	time/hour	Section type
	Breakdown outage	Breakdown outage time/hour	time/hour	Extremely small
Incremental benefit	Electric quantity increment	Increase value of electric quantity transmitted by section	100 million kWh	Extremely large
		Annual power transmission per unit investment	kWh/RMB	Extremely large
	Power increment	Extreme increase value of power transmitted by section	10000kW	Extremely large
		Annual maximum power per unit investment	kW/ RMB10000	Extremely large
Scale merit	Scale of electric quantity	Annual transmission capacity ratio of province-wide grid electricity consumption	%	Extremely large
	Scale of power	Ratio of annual maximum power in province-wide grid maximum load	%	Extremely large
		Ratio of annual maximum power in province grid-connected installed capacity	%	Extremely large
Environmental benefit	Clean energy	Clean energy transmission ratio	%	Extremely large
	Fire coal saved	Fire coal saved	10000tce	Extremely large
	Reduction of equivalent emissions of CO2	Reduction of equivalent emissions of CO2	ton	Extremely large
Social benefit	Drive investment	Drive investment scale	RMB100 million	Extremely large
	Drive employment	Quantity of employment increased	person	Extremely large
	Increase tax revenue	Increase tax revenue	RMB100 million	Extremely large

4 Evaluation Method of Investment Benefits of Major Power Transmission and Transformation Projects Based on BWM and TOPSIS Methods

4.1 Selection of indicator endow weight method

The Best-Worst Method (BWM) is used for indicator endower weight in the paper, and the BWM method was first proposed by J Rezaei to solve the problem of multi-indicator decision evaluation. The traditional AHP method, by comparing the importance between the indicators to confirm the weight relationship of each indicator, needs to make $n(n-1)/2$ comparisons, the process of determining the weight is more complex and consumes more time, while the BWM method only needs to determine the best indicator and the worst indicator before comparing the importance, needs to be compared $(2n-3)$, can reduce a lot of workload and save much time without affecting the evaluation results. The steps of the BWM method are as follows:

(1) Establish a system of evaluation indicators for the effectiveness of investment in power grid projects, $\{c_1,c_2,\ldots,c_n\}$, to determine the best indicator (the most important indicator) c_B and the worst indicator c_W (the lowest important indicator).

(2) Compare the best indicator with other indicators, using 1-9 to measure the importance of the best indicator c_B compared to other indicators c_j, 1 indicates that the two are equally important, 9 indicates that the best indicator c_B is of prime importance in comparison with the indicator c_j, and thus the best comparison vector is obtained:

$$A_B = \left(a_{B1}, a_{B2}, \ldots, a_{Bn}\right) \tag{1}$$

Where, a_{Bj} indicates how important the best indicator is compared to other indicators.

(3) Compare the worst indicator with other indicators, 1-9 is used to measure the importance of other indicators c_j compared to the worst indicator c_W, 1 indicates that the two are equally important, and 9 indicates that the indicator c_j is of prime importance in comparison with the worst indicator c_W, so that the worst comparison vector is obtained:

$$A_W = \left(a_{1W}, a_{2W}, \ldots, a_{nw}\right) \tag{2}$$

Where, a_{jW} indicates how important other indicators are compared to the worst indicator.

(4) Determine the best weight for each indicator:

$$minmax_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jW} \right| \right\} \tag{3}$$

$$s.t. \begin{cases} \sum_j w_j = 1 \\ w_j \geq 0, j = 1, 2 \ldots n \end{cases} \tag{4}$$

(5) Translate the equation (4) into a nonlinear constraint optimal problem:

$$s.t. \begin{cases} min\xi \\ \left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \xi \\ \left| \frac{w_j}{w_W} - a_{jW} \right| \leq \xi \\ \sum_j w_j = 1 \\ w_j \geq 0, j = 1, 2 \ldots n \end{cases} \tag{5}$$

It is worth noting that different types of large-scale power transmission and transformation projects play a different role in the power grid, so there are differences in the weight setting of indicators for evaluation of different types of projects. For power delivery projects, the evaluation will focus on the effect of power transmission, so the power indicator is assigned a higher value in the evaluation indicator weight, and the same reason is given to the grid frame strengthening type indicator, focusing on evaluating the improvement of the project transmission capacity by the system section where the project is located, so the power efficiency indicator is assigned a higher value in the evaluation indicators. In summary, it is possible to achieve a unified evaluation of different types of large-scale power transmission and transformation projects by the method.

4.2 Selection of comprehensive evaluation methods

TOPSIS method is one of the more applied methods in comprehensive evaluation methods, which is simple, consumes less time and can compare advantages and disadvantages of many projects to be evaluated. Generally speaking, the TOPSIS method is used to determine the indicator score, first determines the best value and the worst value of the evaluation indicator, and then calculates the relative closeness of each unit indicator to the worst value, evaluates the advantages and disadvantages of the indicator, and the concrete steps of the evaluation method are as follows:

(1) Assume $(x_1^+, x_2^+, ..., x_m^+)$ as positive ideal system, $(x_1^-, x_2^-, ..., x_m^-)$ as negative ideal system, and then Euclidean distance between the evaluated target and positive ideal point y_i^+ is:

$$y_i^+ = \sum_{j=1}^{m} w_j (x_{ij} - x_j^+)^2 \tag{6}$$

(2) Euclidean distance between the evaluated target and negative ideal point y_i^- is:

$$y_i^- = \sum_{j=1}^{m} w_j (x_{ij} - x_j^-)^2 \tag{7}$$

Negative ideal point is generally the virtual worst scenario, each of its attribute values is the worst value of the attribute in the decision matrix, the scenario close to the positive ideal point and away from the negative ideal point is the best scenario, in case of the same distance from the positive ideal solution, the farthest from the negative ideal point is the best scenario.

(3) Calculate queue indicator value C_i, the queue indicator value underlines the distance with the negative ideal point, the greater queue indicator value, the better scenario.

$$C_i = \frac{y_i^-}{y_i^+ + y_i^-} \tag{8}$$

5 An Evaluation Example of Major Power Transmission and Transmission Projects

In order to verify the practicality of the above evaluation model, this chapter selects 1 transmission and transformation project from power supply delivery projects and grid frame strengthening projects each according to the classification of major power transmission and transformation projects. Project A is selected from power supply delivery projects, Project B is selected from grid frame strengthening projects, the indicator evaluation method of Chapter 3 is adopted to score the indicators of the two projects, and the scoring results obtained are shown in Table 2.

Table 2 Score result table for each indicator in case project

Indictor	Project A score	Project B score
Annual transmission capacity	84.37	78.95
Annual transmission loss rate	93.24	71.39
Annual equivalent utilization hours	77.08	85.16
Annual maximum power	89.91	92.84
Ratio of scheduling limits	89.73	88.93
Ratio of annual maximum power in scheduling control power	86.24	72.70
Annual maximum power duration	78.68	72.43
Planned outage time/hour	86.94	93.32
Breakdown outage time/hour	81.00	97.15
Increase value of electric quantity transmitted by section	77.68	86.01
Annual power transmission per unit investment	79.25	73.27
Extreme increase value of power transmitted by section	92.90	94.77
Annual maximum power per unit investment	76.43	80.14
Annual transmission capacity ratio of province-wide grid electricity consumption	79.85	78.82
Ratio of annual maximum power in province-wide grid maximum load	76.08	92.39
Ratio of annual maximum power in province grid-connected installed capacity	83.83	70.31
Clean energy transmission ratio	75.27	71.45
Fire coal saved	92.94	90.04
Reduction of equivalent emissions of CO2	78.93	88.10
Drive investment scale	76.87	85.78
Quantity of employment increased	81.15	91.89
Increase tax revenue	84.12	91.22

From the above scoring results, it can be seen that Project A has excellent performance in the actual output indicators with reasonable operating and maintenance costs, and the project reached a better technical indicator while considering the economy. However, there is still room for improvement in terms of operational efficiency, i.e. indicators of the number of planned and non-planned outages.

Project B has a good performance in transmission efficiency and has played its own great value in scale efficiency. However, in terms of incremental benefits, that is, the section transmission power limit boost value and the maximum power per unit investment year indicators, the project has some deficiencies. In addition, the project is less economical in scores of operation and maintenance expenses and depreciation costs.

Through analysis for the score results of the above two projects, the technical and economic indicator score of Project A is fairly balanced, while the technical character of Project B has advantages with fairly poor economy, though.

6 Conclusion

The indicator system for the evaluation of investment effectiveness of large-scale transmission and transformation projects is built in the paper from the six dimensions of transmission efficiency, operation efficiency, incremental benefit, scale merit, environmental benefit and social benefit, an evaluation model of investment benefit of major transmission and transformation projects based on BWM method and TOPSIS method is established, and each one transmission and transformation project is selected from power supply delivery projects and grid frame strengthening projects for case study. The results show that when the model is applied to evaluate the project, the results of the evaluation are more comprehensive and intuitive, which provides a new way of thinking for the evaluation of the investment effectiveness of other major transmission projects.

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