Evaluation of Investment Project Prioritization of Power Grid Based on TOPSIS Model

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Abstract. With the new round of power system reform under the adjustment of the profit model of power grid enterprises, as an important source of effective asset growth, the efficiency of power grid investment has received more and more attention from enterprises. How to rationalize the power grid investment structure and timing, optimize the power grid investment structure, improve investment efficiency, so as to achieve optimal benefits, has become an important issue for enterprises to solve. In this paper, indicators are selected from five dimensions: project type, economic benefit, social benefit, network safety benefit, and project transfer rate, and a priority evaluation system for grid investment projects based on TOPSIS model is established. At the same time, it is applied to the priority evaluation of J's investment projects, based on the evaluation results to determine the timing of investment projects, and remove some projects that do not meet the expectations of investment planning, to provide a reference for the enterprise to achieve the effective expansion of fixed asset scale and the improvement of the overall revenue level of the enterprise.

Keywords: TOPSIS model; grid investment; priority evaluation.

1 Introduction

Power grid enterprises are related to the lifeblood of the national economy and national energy security[1] . In the new round of power system reform, the profit model of power grid enterprises has been significantly adjusted, which makes the investment demand and investment scale of power grid research attract much attention[2]. Power grid enterprises should reasonably plan the scale of investment and supervise the investment ceiling. It is also necessary to further optimize the investment structure and timing so as to meet the permitted revenue target and improve the comprehensive benefits of transmission and distribution prices. This will improve the science of power grid investment decision, make it reach the optimal benefit, and ensure the efficiency of power grid operation and its sustainable development[3].

At present, scholars have achieved certain results in evaluating the investment efficiency and priority of power grid projects. Zhang puts forward relevant suggestions to improve state-owned-enterprises' precise investment capability around the future investment regulation trend [4]. Yang proposes a composite model evaluation method for power grid infrastructure projects to optimize the research on the project precision investment system[5]. Wu uses information technology to build an investment plan management system to realize the unification of

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investment planning, submission and management [6]. Zeng uses triangular fuzzy numbers and matrix adjustment factors to effectively simulate experts' judgment information and fuzziness [7]. Patrick Balducci et al. proposed to use offline planning to realize the optimal distributed energy scheduling and maximize the economic benefits[8].Cai constructs a project evaluation index system to provide a strong decision basis for project preference[9]. By quantifying benefits in terms of dollars saved, Ahmet Onen is able to make more efficient use of coordinated control, delaying investments in large capital equipment and reducing customers' energy use[10].Chai designs a distribution network investment planning optimization model, and proposed that the core of investment project optimization is to rationalize the investment timing to maximize investment benefits[11]. Based on this, this study establishes a power grid investment project prioritization evaluation system based on TOPSIS model on the basis of the impact of transmission and distribution price reform on power grid investment, and further decomposes each index to form specific evaluation index measures to provide a basis for power grid construction project investment prioritization.

2 Grid investment project prioritization evaluation system construction

2.1 Basic principle of TOPSIS model and evaluation steps

The TOPSIS analysis method (ranking method that approximates the ideal value) is to analyze the characteristics of each indicator in the constructed index system and give an optimal solution and a worst solution. The best value of each indicator is selected as the optimal solution, and the worst value of each indicator is selected as the worst solution. The final comparison result is obtained by analyzing and comparing the gap between each evaluation object and the two, and then ranking all the objects to be evaluated. The calculation steps are as follows:

(1) Normalized decision matrix

Assuming that the number of programs is m and the number of indicators is n, r_{ij} denotes the object i to be evaluated for the evaluation indicator j of the original evaluation matrix $R=\{r_{ij}\}_{m\times n}$. The normalized values are denoted as r'_{ij}. The normalized decision matrix R' and the process is shown in equation (1).

$$r'_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \tag{1}$$

(2) Determine the indicator weighted evaluation matrix $\bar{V}$ and the calculation formula is shown in equation (2).

$$\bar{V} = \left(V_{ij}\right)_{n\times m} = W \times R = \begin{pmatrix} \omega_1\gamma_{11} & \omega_1\gamma_{12} & \cdots & \omega_1\gamma_{1m} \\ \omega_2\gamma_{21} & \omega_2\gamma_{22} & \cdots & \omega_2\gamma_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \omega_n\gamma_{n1} & \omega_n\gamma_{n2} & \cdots & \omega_n\gamma_{nm} \end{pmatrix} \tag{2}$$

where V_{ij} denotes the weighted evaluation result of alternative j on indicator i.

(3) Find the positive and negative ideal solutions according to TOPSIS V^+ and V^- that is

shown in equation (3).

$$V^{+} = \{v_1^{+}, v_2^{+}, \cdots, v_n^{+}\}, V^{-} = \{v_1^{-}, v_2^{-}, \cdots, v_n^{-}\} \tag{3}$$

where $v_i^{+} = \max_{1 \le j \le m} v_{ij}$ is the i-th element of the positive ideal solution V^{+}, and $v_i^{-} = \min_{1 \le j \le m} v_{ij}$ is the i-th element of the negative ideal solution V^{-} with i=1,2,...,n.

(4) Calculate the distance between the object of evaluation, i.e., an investment project, and the optimal solution and the worst solution. Let the distance from solution j to the positive ideal solution be S_i^{+} , and the distance to the negative ideal solution is S_i^{-}, see equation (4) for an example.

$$S_j^{+} = \sum_{i=1}^{n} w_i \left(v_{ij} - v_{ij}^{+}\right)^2, \quad S_j^{-} = \sum_{i=1}^{n} w_i \left(v_{ij} - v_{ij}^{-}\right)^2 \tag{4}$$

Where v_{ij} is the weighted evaluation value of an evaluation object j at the ith indicator, and v_{ij}^{+} is the optimal indicator value, and v_{ij}^{-} is the worst indicator value.

(5) Calculate the closeness of the evaluation object j to the optimal solution δ_j, the δ_j The closer to 1, the higher the investment value of the j-th project and the stronger the investment urgency. The calculation formula of δ_j is shown in equation (5).

$$\delta_j = \frac{S_j^{-}}{S_j^{+} + S_j^{-}} \tag{5}$$

2.2 Selection of evaluation indicators

For the positive and negative ideal characteristics of grid assets, this paper selects the TOPSIS method to calculate the priority of investment projects[12]. Combining the characteristics and key factors of grid enterprise operation, grid investment, the analysis found that grid investment firstly needs to meet the enterprise load growth and should have explicit economic benefits brought by the growth of load and power supply. Secondly, the grid investment in the grid capacity and development of hidden benefits, including the impact on the national economy and social development, while the timely transfer of investment projects in order to form effective corporate assets. Therefore, the priority evaluation of grid investment projects not only includes the economic benefits of the grid enterprise, but also should include the project category, social benefits, network security benefits and project transfer rate.

2.3 Determination of index weights

After selecting the indicators, it is necessary to determine the weights of each evaluation indicator W. Considering that the evaluation indicators contain both qualitative and quantitative indicators, hierarchical analysis is introduced to determine the indicator weights in order to ensure the practicality of the evaluation system.

(1) The First-level Evaluation Index Weight

The first-level indicator weighting judgment matrix A-B is shown in equation (6).

$$A-B=\begin{bmatrix}1 & 5/7 & 5/4 & 5/4 & 5/7\\ 7/5 & 1 & 7/4 & 7/4 & 1\\ 4/5 & 4/7 & 1 & 1 & 4/7\\ 4/5 & 4/7 & 1 & 1 & 4/7\\ 7/5 & 1 & 7/4 & 7/4 & 1\end{bmatrix} \tag{6}$$

$$W^{(1)} = (0.169,0.298,0.1117,0.117,0.297)^T \tag{7}$$

The consistency test index of $W^{(1)}$ is shown in equation (7) and less than 0.1, indicating that the weight judgment matrix satisfies the consistency test and the weight results are scientifically valid.

(2) The Second-level Evaluation Index Weight

The secondary indicator weight judgment matrix B-C is shown in equation (8), equation (10), equation (12), equation (14) and equation (16).

$$B_1 - C = \begin{pmatrix}1 & 1/2\\ 2 & 1\end{pmatrix} \tag{8}$$

$$W_1^{(2)} = (0.3333,0.6667)^T \tag{9}$$

The consistency test indexes of $W_1^{(2)}$ is shown in equation (9) and less than 0.1, so the results are scientific and reliable.

$$B_2 - C = \begin{pmatrix}1 & 2 & 3 & 2 & 3\\ 1/2 & 1 & 2 & 2 & 3\\ 1/3 & 1/2 & 1 & 1/2 & 2\\ 1/2 & 1/2 & 2 & 1 & 3\\ 1/3 & 1/3 & 1/2 & 1/3 & 1\end{pmatrix} \tag{10}$$

$$W_2^{(2)} = (0.3565,\ 0.2493,\ 0.1221,\ 0.1919,\ 0.0802)^T \tag{11}$$

The consistency test indexes of $W_2^{(2)}$ is 0.0291, shown in equation (11).

$$B_3 - C = \begin{pmatrix}1 & 1/5 & 1/3\\ 5 & 1 & 3\\ 3 & 1/3 & 1\end{pmatrix} \tag{12}$$

$$W_3^{(2)} = (0.105,0.637,0.258)^T \tag{13}$$

The consistency test indexes of $W_3^{(2)}$ is 0.0390, shown in equation (13).

$$B_4 - C = \begin{pmatrix}1 & 3 & 2\\ 1/3 & 1 & 1/2\\ 1/2 & 2 & 1\end{pmatrix} \tag{14}$$

$$W_4^{(2)} = (0.163,0.297,0.540)^T \tag{15}$$

The consistency test indexes of $W_4^{(2)}$ is 0.0143, shown in equation (15).

$$B_5 - C = \begin{pmatrix}1 & 4/3 & 4/3\\ 3/4 & 1 & 1\\ 3/4 & 1 & 1\end{pmatrix} \tag{16}$$

$$W_5^{(2)} = (0.4,0.3,0.3)^T \quad (17)$$

The consistency test indexes of $W_5^{(2)}$ is shown in equation (17) and less than 0.1. The consistency test indexes of the above judgment matrix are all less than 0.1, and the results are scientifically reliable. Finally, one decimal place is retained to determine the weights of each index as shown in Table 1.

Table 1. Grid investment project priority evaluation index weights

First Indicators	Indicator Weights $W^{(1)}$	Secondary indicators	Indicator Weights $W^{(2)}$	Combined weights W
Project Category (B_1)	0.2	Policy Support Strength (C_1)	0.3	0.06
		Project urgency (C_2)	0.7	0.14
Economic benefits (B_2)	0.3	Unit investment incremental power supply (C_3)	0.4	0.12
		Internal Rate of Return (C_4)	0.2	0.06
		Approved Size of Effective Assets (C_5)	0.1	0.03
		Return on Investment (C_6)	0.2	0.06
		Line Loss Ratio (C_7)	0.1	0.03
Social Benefit (B_3)	0.1	Employment Impact (C_8)	0.1	0.01
		Power elasticity factor (C_9)	0.6	0.06
		New energy transmission power (C_{10})	0.3	0.03
Grid Safety Benefit (B_4)	0.1	Power supply reliability (C_{11})	0.2	0.02
		Comprehensive voltage qualification rate (C_{12})	0.3	0.03
		Grid capacity-load ratio (C_{13})	0.5	0.05
Project Transfer Rate (B_5)	0.3	Project Construction Type (C_{14})	0.4	0.12
		Project construction cycle (C_{15})	0.3	0.09
		Project start time (C_{16})	0.3	0.09

3 Analysis of calculation cases

In order to further illustrate the application method of the asset efficiency evaluation system of the power grid enterprises constructed in this study, this study takes the 110kV and 220kV transmission line assets of Company J as an example for asset efficiency evaluation research.

3.1 J Company Investment Overview

As a large class I power supply enterprise, Company J has 139 substations of 35kV and above with a total capacity of 13.78 million kV, undertaking important power supply tasks and serving 1.5 million customers. The company has a wide variety of grid assets and a large scale, which is representative and the collected data is more complete, so Company J is selected for example analysis.

Take the "14th Five-Year Plan" project of 110kV power grid as an example, the total investment of the project is 80.305 million RMB. Among them, there are 14 projects to meet the power supply requirements of new loads, with a total investment of 475.93 million RMB.

3.2 Evaluation Results of The Priority of J's Asset Investment Projects

From the above data analysis, it can be seen that J Company 2021 110kV power grid "14th Five-Year Plan" project for example, the total project investment of 760.72 million yuan. Combined with the evaluation criteria, firstly, each project is numbered, and then the indicators of each different numbered project are scored to obtain the normalized decision matrix R'. The scores of each evaluation index for the five projects from project 1 to project 5 are shown below as an example, as shown in Table 2.

Table 2. Grid investment project prioritization scores for evaluation index

Project Number	Score of each evaluation index															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project 1	87	93	98	86	77	96	73	70	80	95	73	85	87	86	90	77
Project 2	93	95	71	90	85	89	93	89	93	78	76	81	89	94	80	82
Project 3	72	98	97	88	79	86	88	81	93	73	91	78	77	72	80	86
Project 4	82	87	96	83	89	79	77	74	86	93	73	96	95	77	80	72
Project 5	98	96	80	71	98	71	91	87	71	76	91	72	96	92	90	95

Combined with the TOPSIS model, the results of the above scores were brought into equation (18).

$$\bar{V} = (V_{ij})_{n\times m} = W \times R \tag{18}$$

That is grid investment project priority evaluation score= ∑(score of each secondary× combined weights of s). The results of prioritization of each investment project are calculated as shown in Table 3.

Table 3. Grid investment project priority scoring results

Project Number	Project Name	Priority evaluation results
Project 1	QX Zhangnan 110kV transmission and substation project	0.8871

Project Number	Project Name	Priority evaluation results
Project 2	TG Shangshan 110kV substation No.3 main substation expansion project	0.8800
Project 3	TG Xincun 110kV substation No.3 main substation expansion project	0.8782
Project 4	XY Shiyao Ping Traction Station 110kV External Power Supply Project	0.8736
Project 5	HW traction station 110kV external power supply project	0.8720
Project 6	SC traction station 110kV external power supply project (T connects to the new construction of Yang Zhang line)	0.8671
Project 7	SC traction station 110kV external power supply project (π connected to the new construction of the left upper line)	0.8653
Project 8	JX Donghulong 220kV substation 110kV Changsheng interval expansion project	0.8618
Project 9	JX Donghulong 220kV substation 110kV interval expansion project	0.8595
Project 10	TG Mingxian 220kV substation 110kV interval expansion project	0.8550
Project 11	XY220kV substation 110kV Poori interval expansion project	0.8512
Project 12	HS Yunshan 220kV substation 110kV Poori interval expansion project	0.8412
Project 13	JX Development Zone 220kV Substation 110kV Transmission Project	0.8400
Project 14	PY Nanzheng 110kV transmission and substation project	0.8336
Project 15	LS Yingwu 110kV Substation No.3 Main Transformer Expansion Project	0.8316
Project 16	TG Beiyang 110kV Substation No.3 Main Transformer Expansion Project	0.8307
Project 17	JX Wandubao 110kV transmission and substation project	0.8297
Project 18	YC North 220kV Substation 110kV Transmission Project	0.8274
Project 19	LS Wang Yu 220kV Substation 110kV Transmission Project	0.8274
Project 20	TG West 220kV substation 110kV transmission project	0.8170
Project 21	JX110kV Substation No.3 Main Transformer Expansion Project	0.8168
Project 22	110 kV mobile substation project	0.8108
Project 23	ZQ Stone Box 110kV Transmission and Transformation Project	0.8086
Project 24	ZQ Qinquan 110kV transmission and substation project	0.8066
Project 25	2025 New Energy 110kV Transmission Project	0.8060
Project 26	YC Longcheng 1 110kV transmission and substation project	0.7827
Project 27	TG New Generation 110kV Transmission and Transformation Project	0.7787
Project 28	YC Wanghao 110kV transmission and substation project	0.7749

Since this paper uses the percentage system for index evaluation scoring, it is known from $V^+ = \{v_1^+, v_2^+, \cdots, v_n^+\}$ and $V^- = \{v_1^-, v_2^-, \cdots, v_n^-\}$ that the maximum value of each evaluation index is 100, the minimum value of policy support and project start time index is 60, the minimum value of project urgency and project construction type index is 70, and the minimum value of the remaining indexes are all 0. Therefore, the higher the score of the grid investment project priority score result, the higher the priority. At the time of investment, priority is given to project 1, and then projects 2 to 25 are considered in that order. As projects 26, 27 and 28 are to meet the new load of the new city, the situation of the industry of the malleable steel load supporting project 27 declined, and the area where projects 26 and 28 are located is not developing as fast as expected, so these three projects are moved out of the plan.

3.3 Comparative analysis of optimization results

As the priority evaluation of power grid investment project is a multi-index complex decision-making problem including subjective and objective factors, the result will have a significant impact on the later development direction. Therefore, in order to verify the effectiveness of the proposed method, a comparative analysis is made with the fuzzy comprehensive evaluation method and the grey correlation method commonly used at home and abroad, as shown in Table 4.

Table 4. Comparison of optimization evaluation results of three schemes

Project Number	TOPSIS method	Fuzzy Integrated Evaluation	Gray correlation method
Project 1	0.8871	0.8917	0.9189
Project 2	0.8800	0.8898	0.8228
Project 3	0.8782	0.8893	0.8113
Project 4	0.8736	0.8823	0.8778
Project 5	0.8720	0.8735	0.8106
Project 6	0.8671	0.8722	0.8767
Project 7	0.8653	0.8687	0.8516
Project 8	0.8618	0.8668	0.8786
Project 9	0.8595	0.8589	0.8425
Project 10	0.8550	0.8545	0.8603
Project 11	0.8512	0.8494	0.8849
Project 12	0.8412	0.8372	0.8509
Project 13	0.8400	0.8304	0.8321
Project 14	0.8336	0.807	0.881
Project 15	0.8316	0.8064	0.8694
Project 16	0.8307	0.8055	0.8766
Project 17	0.8297	0.8048	0.8895
Project 18	0.8274	0.801	0.8866
Project 19	0.8274	0.7984	0.8661
Project 20	0.8170	0.7908	0.9163
Project 21	0.8168	0.768	0.8193
Project 22	0.8108	0.7575	0.8861
Project 23	0.8086	0.7467	0.9055
Project 24	0.8066	0.7393	0.9159
Project 25	0.8060	0.7279	0.8076
Project 26	0.7827	0.7247	0.8184
Project 27	0.7787	0.7189	0.908
Project 28	0.7749	0.7178	0.8103

According to the comparative analysis of the evaluation results of the above three methods, it can be seen that the priority ranking scheme of power grid investment projects obtained by any method is consistent, which proves the effectiveness of the method in this paper. Secondly, compared with TOPSIS method, both fuzzy comprehensive evaluation method and grey correlation method have corresponding defects. The fuzzy comprehensive evaluation method takes the comprehensive evaluation value as the unit of measurement, the higher the value, the better the scheme. But the index of fuzzy comprehensive evaluation method is subjective empowerment, lack of objectivity. And when the index set is large, it is easy to produce the phenomenon that the index weight does not match the fuzzy matrix, which increases the failure rate. The measurement unit of grey correlation method is grey correlation degree, the higher the value, the better the scheme. However, grey correlation method is mainly used by experts to score schemes through experience and professional knowledge, and the calculated results have little difference and strong subjectivity. Moreover, there are some fuzzy optimal value indexes in the result, which makes it difficult to judge its rationality.

However, the TOPSIS method used in this paper has a small difference in results and no strict restrictions on data distribution, sample size, number of indicators and other factors. It is suitable for both small sample data and large system with multiple evaluation units and indicators, and is relatively flexible. And the method avoids the subjectivity of the data to a certain extent, and can describe the comprehensive influence of multiple indicators without passing the test, ensuring the tightness of the evaluation value distribution and the ranking is more accurate. At the same time, TOPSIS method comprehensively considers the subjective preferences of experts and users, the interests and needs of users, and the evaluation results are more reasonable and accurate.

4 Conclusion

In this paper, an evaluation study on the investment priority of enterprise projects was conducted in conjunction with the operational and investment characteristics of power grid enterprises, and the results found that:

(1) The project category, economic benefit, social benefit, grid safety benefit and project transfer rate of the grid enterprise all have an impact on the investment project priority evaluation, and the important order of evaluation indexes is economic benefit = project transfer rate > project category > social benefit = grid safety benefit.

(2) Comparing the priority evaluation scores of power grid investment projects with each other, when investing, priority should be given to project 1, i.e. QX Zhangnan 110kV transmission and substation project, and then project 2 to project 25 should be considered in turn. As project 26, project 27 and project 28 are to meet the new load requirements of the new city, their supporting industry situation has declined or the development rate of their area is not up to the standard, so these three projects will be removed from the planning.

(3) The establishment of a qualitative and quantitative power grid investment project priority evaluation model based on TOPSIS model can conduct quantitative evaluation of investment priorities. It can also provide decision support for the company to reasonably arrange the timing of investment projects and realize the effective expansion of the scale of fixed assets of enterprises and the improvement of the overall income level of enterprises. Moreover, the accuracy and effectiveness of the proposed method are verified by comparing it with fuzzy comprehensive evaluation and grey correlation method.

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