A Comprehensive Risk Management Evaluation of the Entire Process of Executing Investments in Power Grid Projects

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Abstract. With the proposal of the national new energy development strategy and the reform of power system, accurate investment decision-making and investment efficiency improvement are quite important. For grid project investment needs to be considered from the whole process, constructing a risk management evaluation index system for the whole process of grid project investment implementation has become an important issue for grid enterprises. This paper proposes an evaluation model based on the combination of empowerment-TOPSIS, and the results of the case analysis show that the model can quantify the investment risk of grid projects from four dimensions: risk identification, risk early warning, risk response, and risk management mechanism improvement, so as to rank the investment risk evaluation level of the project.

Keywords: risk management, system of indicators, weight combination, TOPSIS

1 Introduction

With the proposal of China's national new energy development strategy, the investment of power grid enterprises has gradually increased, and the process of energy transition has been accelerated, which has compressed the profit margins of power grid enterprises. In the face of the complex environment of grid projects, involving many parts and the existence of multiple uncertainty risk factors, accurate investment decision-making and investment efficiency improvement are quite important.

Ref. [1] constructs the investment management system of power grid companies under the transmission and distribution tariff reform from the policy and its impact on the investment management of power companies. Ref. [2] analyzes the risk brought by

M. Zhang et al. (eds.), *Proceedings of the 2025 5th International Conference on Informatization Economic Development and Management (IEDM 2025)*, Advances in Economics, Business and Management Research 330,
https://doi.org/10.2991/978-94-6463-724-3_7

the new power to the investment management of power grid companies, evaluates the investment risk by using AHP-Fuzzy comprehensive evaluation model, and puts forward the coping strategy for the investment risk of power grid companies.

However, the intertwining of multiple factors, such as uncertainties in the external environment, technical risks, and deviations in the allocation and implementation of funds, may lead to the accumulation of risks and a decline in investment efficiency. Therefore, the implementation of scientific risk management and evaluation of grid investment from the perspective of the whole process can effectively identify and quantify the potential risks in key links.

Ref. [3] applied the WBS-RBS risk identification method to identify the risk factors of grid engineering cost, and assessed the risk in grid investment through quantitative analysis method. Ref. [4] fully combined the improved risk matrix with the Delphi method and hierarchical analysis method to establish a grid engineering investment risk indicator system consisting of eight main indicators. Ref. [5] used time series and holographic methods to assess the risk of different parts of the grid project in multiple dimensions and perspectives, and developed a holographic risk assessment index system. Ref. [6] adopts gray correlation analysis method to construct the investment risk correlation coefficient matrix of grid project to calculate the correlation degree and weight of investment risk index to realize investment risk assessment.

In this paper, an evaluation method based on Portfolio Empowerment-TOPSIS is proposed to further risk management of the whole process of power grid investment project execution.

2 Method

2.1 Risk Management Evaluation Indicator System

For the construction of the grid project investment risk management evaluation index system, the goal is centered around the grid investment project risk management. The construction of the indicator system is divided into risk identification ability indicators, risk warning ability indicators, risk response ability indicators and risk management mechanism improvement indicators according to the risk evaluation process.

The general objective of the risk management evaluation index system of power grid project investment is to evaluate the risk management ability of power grid project investment. From the perspective of the whole process of power grid project investment execution, the constructed risk management index system is divided into three levels. The objective layer reflects the risk management capability of power grid investment projects. The criterion layer includes four first-level indicators of risk identification, risk early warning, risk response and risk management mechanism improvement. The indicator layer includes a total of 26 secondary indicators. As shown in Table 1.

Table 1. Evaluation index system of risk management in the whole process of power grid project investment execution

target level	Level 1 indicators	Secondary indicators	
Grid Investment Project Risk Management capacity evaluation	Risk identification capabilitiesA	payback periodA1	quantitative
		internal rate of returnA2	quantitative
		Construction investment costsA3	quantitative
		Pollutant reduction effectA4	qualitative
		Distribution network voltage qualityA5	qualitative
		Public satisfactionA6	qualitative
		User market participationA7	qualitative
		Grid Enterprises Market PowerA8	qualitative
		Credit ratings of market participantsA9	qualitative
		Information Security Levels for the Electricity MarketA10	qualitative
	Risk early warning capacityB	Risk database establishmentB1	qualitative
		Risk quantification methodology selection and applicationB2	qualitative
		Estimated probability of risk occurrenceB3	qualitative
		Scope and severity of risk impact assessmentB4	qualitative
	Risk responsivenessC	Critical Risk Response ProgramC1	qualitative
		Effectiveness of risk response plan implementationC2	qualitative
		Secondary Risk Identification and ResponseC3	qualitative
		Financial, equipment and other resource inputsC4	qualitative
		Risk management technical reserve improvements C5	qualitative
	Well-established risk management mechanismsD	Talent Introduction and TrainingD1	qualitative
		Clear risk management objectivesD2	qualitative
		Viable risk management strategiesD3	qualitative
		Detailed risk management procedures and systemsD4	qualitative
		System of incentives and disincentives for risk managementD5	qualitative
		Qualitative competencies of managersD6	qualitative
		Risk management awareness among managers and employeesD7	qualitative

1）payback period：

The formula is expressed as：

$$PBP = min\left\{t: \sum_{i=1}^{t} \frac{CF_i}{(1+r)^i} \geq CI\right\} \tag{1}$$

Where, PBP represents the dynamic payback period;t is the required time period;$CF_i$is the cash flow in the i^{th} cycle;r is the discount rate; CI is still the total original investment.

2）internal rate of return：

The formula is as follows：

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} = 0 \tag{2}$$

Where, NPV stands for net present value; CF_t is the cash flow in the t^{th}period; IRR is the internal rate of return;; t is the time period; n is the total number of project periods.

3）Construction investment costs：

The specific calculation formula is as follows：

$$CIC = \sum_{j=1}^{k} \left(E_j + B_j + I_j\right) + \sum_{p=1}^{n} IC_p \tag{3}$$

Where ,CIC represents the construction investment cost; $E_j$is the acquisition cost of the j^{th}type of equipment;$B_j$is thej^{th}construction cost; $I_j$is the j^{th} installation cost; k is the total number of equipment, construction and installation cost items; $IC_p$is the p^{th} indirect cost; n is the total number of indirect cost items.

2.2 Evaluation Method Based on Portfolio Empowerment-TOPSIS

Based on the whole process risk management evaluation index system for grid project investment proposed in this paper, grid infrastructure, piecemeal purchase, power marketing, production and technical reform are set as project 1, project 2, project 3 and project 4, and the case evaluation is carried out by utilizing the combination of empowerment-TOPSIS method, and the evaluation process is as follows：

（1）Composite weighting calculation

AHP-entropy weight combination weighting method is a combination of subjective and objective weighting method, which can fully take into account the subjective judgment of the experts, but also ensure the objectivity of the evaluation, effectively avoiding the defects of a single evaluation. The calculation steps of AHP-entropy weight combination weighting method are as follows：

1）Data standardization. Various types of risk evaluation indicators may have positive, negative and interval types. In order to eliminate the influence of the differences in indicator types and the scale, it is first necessary to standardize the raw data with the following equation：

$$y_{ij}=\begin{cases}\dfrac{x_{ij}-min_i\{x_{ij}\}}{max_i\{x_{ij}\}-min_i\{x_{ij}\}}, & \text{Positive indicatorsj}\\ \dfrac{max_i\{x_{ij}\}-x_{ij}}{max_i\{x_{ij}\}-min_i\{x_{ij}\}}, & \text{Negative indicatorsj}\\ \begin{cases}1-\dfrac{a_j-x_{ij}}{M_j}, & x_{ij}<a_j\\ 1, \ a_j\le x_{ij}\le b_j, & \text{interval indicatorj}\\ 1-\dfrac{x_{ij}-b_j}{M_j}, & x_{ij}>b_j\end{cases}\end{cases} \tag{4}$$

Where $x_{ij}$and y_{ij}denote the original value and standardized index of the j^{th} index of the i^{th} evaluation object, respectively;$a_j$and $b_j$denote the lower and upper bounds of the best interval of the interval-type index j; the parameter $M_j=max\{a_j-minx_{ij},maxx_{ij}-b_j\}$。

2）Calculate the information entropyE_j for each indicator j：

$$E_j=-\frac{1}{ln^m}\sum_{i=1}^{m}p_{ij}ln^{(p_{ij})} \tag{5}$$

$$p_{ij}=\frac{y_{ij}}{\sum_{i=1}^{m}y_{ij}} \tag{6}$$

where parameter m is the number of objects to be evaluated.

3）Calculate entropy weights $w_j^1$for each indicator j：

$$w_j^1=\frac{1-E_j}{n-\sum_{j=1}^{n}E_j} \tag{7}$$

where parameter n is the number of evaluation indicators.

4）Calculate the AHP weight $w_j^2$for each indicator j as shown in Eq. (10),and then combine $w_j^1$and w_j^2as follows to obtain the corresponding composite weight w_j：

$$w_j=\delta\times w_j^1+(1-\delta)\times w_j^2 \tag{8}$$

Where $\delta\in[0,1]$ is the weight adjustment factor.

（2）TOPSIS Evaluation Modeling

The specific steps of TOPSIS are as follows：

1）The normalization matrix $Y=(y_{ij})_{m\times n}$is multiplied by the composite weight vector $W=(w_1,\cdots,w_n)^T$ to obtain the weighted normalization matrix C：

$$C=(c_{ij})_{m\times n}=\begin{bmatrix}w_1y_{11} & w_2y_{12} & \cdots & w_ny_{1n}\\ w_1y_{21} & w_2y_{22} & \cdots & w_ny_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ w_1y_{m1} & w_2y_{m2} & \cdots & w_ny_{mn}\end{bmatrix} \tag{9}$$

2)Calculate the positive ideal solution $C^+$and the negative ideal solution C^-:

$$C^+=(c_1^+,\cdots,c_n^+)=(max_i\{c_{i1}\},\cdots,max_i\{c_{in}\}) \tag{10}$$

$$C^-=(c_1^-,\cdots,c_n^-)=(max_i\{c_{i1}\},\cdots,min_i\{c_{in}\}) \tag{11}$$

3) Calculate the distance d_i^+,$d_i^-$from the positive and negative ideal solutions for each evaluation object i：

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(c_{ij} - c_j^+\right)^2} \tag{12}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(c_{ij} - c_j^-\right)^2} \tag{13}$$

4) Calculate the relative closeness B_i of each evaluation object i, where B_i takes values in the range of [0,1] , if the larger closeness B_i indicates that the i^{th} evaluation object is closer to the optimal level.

$$B_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{14}$$

3 Calculus Analysis

This study adopts the approximation of ideal point method based on entropy weighting method and AHP processing for comprehensive evaluation of power grid project 1, project 2, project 3 and project 4, and the raw data of quantitative indexes and qualitative indexes scored by experts are shown in Table 2. After obtaining the weights of the indicators through subjective and objective weighting method, the final weights can be obtained as shown in Table 3.

Table 2. Raw data table

	project 1	project 2	project 3	project 4
payback period	10	11	12	11.5
internal rate of return	8.09	8.07	8.076	8.083
Construction investment costs	113.45	118.56	122.97	120.73
Pollutant reduction effect	80	75	80	70
Distribution network voltage quality	85	80	80	75
Public satisfaction	70	75	70	80
User market participation	85	85	90	70
Grid Enterprises Market Power	70	75	75	70
Credit ratings of market participants	90	95	85	75
Information Security Levels for the Electricity Market	85	75	80	85
Risk database establishment	80	85	75	75
Risk quantification methodology selection and application	95	90	85	95
Estimated probability of risk occurrence	90	80	85	80
Scope and severity of risk impact	85	85	90	95

assessment				
Critical Risk Response Program	95	90	85	85
Effectiveness of risk response plan implementation	85	80	75	85
Secondary Risk Identification and Response	80	75	85	75
Financial, equipment and other resource inputs	85	75	80	80
Risk management technical reserve improvements	75	85	90	85
Talent Introduction and Training	90	85	95	85
Clear risk management objectives	75	80	75	80
Viable risk management strategies	80	80	75	85
Detailed risk management procedures and systems	75	75	80	80
System of incentives and disincentives for risk management	90	85	85	90
Qualitative competencies of managers	90	95	85	90
Risk management awareness among managers and employees	95	95	85	80

Table 3. Weighting table of risk management evaluation index system for the whole process of power grid project investment execution

Level 1 indicators	weights	Secondary indicators	entropy weighting	Hierarchical Analysis Weighting
Risk identification capabilitiesA	0.305	payback periodA1	0.024505	0.097
		internal rate of returnA2	0.017483	0.14
		Construction investment costsA3	0.027185	0.051
		Pollutant reduction effectA4	0.007492	0.0134
		Distribution network voltage qualityA5	0.010098	0.004
		Public satisfactionA6	0.079238	0.0031
		User market participationA7	0.001665	0.0047
		Grid Enterprises Market PowerA8	0.069527	0.003
		Credit ratings of market participantsA9	0.006474	0.006
		Information Security Levels for the Electricity MarketA10	0.007492	0.025
Risk early warning capacityB	0.249	Risk database establishmentB1	0.079238	0.023
		Risk quantification methodology selection and applicationB2	0.007492	0.064
		Estimated probability of risk occurrenceB3	0.079238	0.021

		Scope and severity of risk impact assessmentB4	0.079238	0.03
Risk responsivenessC	0.207	Critical Risk Response ProgramC1	0.079238	0.06
		Effectiveness of risk response plan implementationC2	0.007492	0.0021
		Secondary Risk Identification and ResponseC3	0.079238	0.042
		Financial, equipment and other resource inputsC4	0.010098	0.046
		Risk management technical reserve improvements C5	0.003364	0.0012
Well-established risk management mechanismsD	0.239	Talent Introduction and TrainingD1	0.079238	0.095
		Clear risk management objectivesD2	0.069527	0.002
		Viable risk management strategiesD3	0.010098	0.0021
		Detailed risk management procedures and systemsD4	0.069527	0.097
		System of incentives and disincentives for risk managementD5	0.069527	0.036
		Qualitative competencies of managersD6	0.010098	0.082
		Risk management awareness among managers and employeesD7	0.016182	0.042

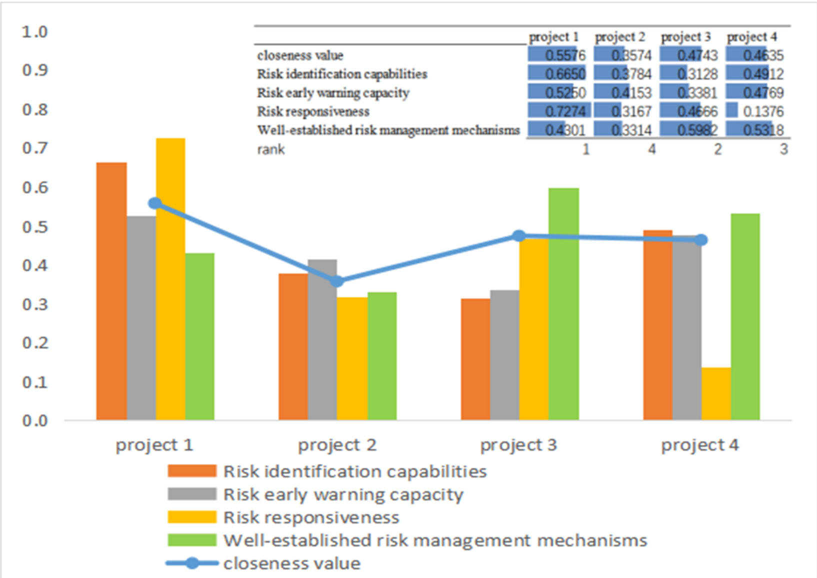

Fig. 1. Weights and closeness values for each item in the grid

Using the TOPSIS method for comprehensive evaluation of grid investment project risk management, based on the previous formula can be calculated for each project closeness value, as shown in Figure 1, to get the risk ranking of the project as 1-3-2-4.

In terms of overall evaluation results, project 1 has the best risk management evaluation results, project 3 and project 4 have similar risk management evaluation results, and project 2 is in the last place. In terms of the dimensions, Project 1 places more emphasis on risk identification and risk response. Project 2 emphasizes risk identification and risk warning. Project 3 emphasizes risk response and risk management mechanism improvement. Project 4 has a lower evaluation result for risk response, which may be related to the nature of the project.

4 Conclusion

The results of arithmetic analysis show that the whole process risk management evaluation model for grid project investment execution proposed in this paper is based on the four dimensions of risk identification, risk early warning, risk response and risk management mechanism improvement, able to quantify the risk of grid investment projects and rank the risk management capability of grid projects. The application of risk management evaluation methodology in grid infrastructure projects helps to improve project transparency and enable all project stakeholders to understand the potential risks and uncertainties of the project. Preventing or mitigating events that may cause damage to the project through the identification, assessment and control of potential project risks reduces the likelihood of project failure. At the same time, identifying key risk points in a project allows for more efficient allocation of resources and prioritization of those risks that have a high impact on the project. However, there are some shortcomings in this paper. Specifically, the evaluation model relies on expert experience and requires more sample data in the calculation process. Otherwise, it may lead to inaccurate calculation results. Therefore, there is still room for improvement and data processing can be further improved.

Acknowledgments

This work was financially supported by science and technology project of State Grid Corporation of China (SGHBJY00PSJS2400023(B1))

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