Research on Post Evaluation Method for Power Grid Technology Projects Based on AHP-CRITIC-TOPSIS

Jianjun Wang*, Qidi Zhao, Cunbing Li and Jiayin Pan
School of Economics and Management, North China Electric Power University, Beijing, China

Keywords: Power Grid Technology Project, Post-Evaluation, AHP, CRITIC, TOPSIS.

Abstract: The power system serves as a crucial foundational measure for facilitating national economic development and ensuring convenient energy access for the people. In order to promote China to achieve carbon peak and carbon neutral vision, China is actively promoting the development of a new low-carbon power system. To meet the urgent demand for precise investments in the power grid within the context of carbon peak and carbon neutrality, there has been a significant increase in the number of power grid technology projects. The scientifically objective post-evaluation methods for power grid technology projects are of utmost importance in effectively guiding the innovative development of these projects. This paper focuses on the post-evaluation of power grid technology projects, aiming to provide valuable research support in this field. Based on the relevant concepts and objectives of post-evaluation for power grid technology projects, eight indicators are selected from the four aspects of organizational management, technical level, achievement application and influence to construct an indicator system for the post-evaluation of power grid technology projects. According to the value of indicators, an evaluation model of post evaluation of power grid technology projects is constructed by using AHP and CRITIC subjective and objective weight method. Additionally, we validate the effectiveness of this approach using a case study of typical technologies in the new power grid. The research of this paper can provide quantitative reference for promoting the innovation and development of power grid technology projects.

1 INTRODUCTION

In the face of the global challenge posed by climate change, the international community has reached a broad consensus and taken concerted action. Currently, close to two-thirds of nations have explicitly set carbon peaking and carbon neutrality goals, signifying the emergence of a global trend towards low-carbon transformation. In order to advance sustainable development, China has set forth the objectives of achieving carbon peaking by 2030 and carbon neutrality by 2060. As an industry with high carbon emissions, the electric power system is in urgent need of accurate investment in power grid under the background of carbon peaking and carbon neutrality. At present, the number of power grid technology projects has increased significantly, so a scientific and technological post-evaluation method for assessing the scale and speed of power grid development is essential, structure and safety, efficiency and benefit under the new power system characterized by the integration of low-carbon green development, operational efficiency and economic benefit.

The power grid innovation technology has a significant and far-reaching impact on the power grid enterprises, and will even influence the development of energy and economy. So, it is significant to develop the study on the impact assessment of power network innovation technology to guide power network's development and establish the innovation mechanism. Many developed countries and top scientific and technological enterprises have carried out relevant research.

The development of smart power grids is leading to the transformation of the power system into a new intelligent system. Therefore, many scientific and technological projects are mainly evaluated and studied based on intelligence. For example, IBM has identified five stages for the construction of a smart power grid, which are used to assess the maturity of innovative technologies in developing a smart power grid. These stages focus on improving the reliability, efficiency, acceptance of new energy, and interaction ability of the smart power grid. The constructed

Wang, J., Zhao, Q., Li, C. and Pan, J.
Research on Post Evaluation Method for Power Grid Technology Projects Based on AHP-CRITIC-TOPSIS.
DOI: 10.5220/0012280500003807

In *Proceedings of the 2nd International Seminar on Artificial Intelligence, Networking and Information Technology (ANIT 2023)*, pages 262-270
ISBN: 978-989-758-677-4

evaluation system selects 8 items and about 200 indicators to find differences through comparison and direct the development of power grid development. The U.S. Department of Energy evaluates the impact of innovative technologies on smart grids from six perspectives: user involvement, new products' introduction, power grid operation efficiency, quality of power service, energy storage devices, and power grid disaster prevention capability. On the basis of this evaluation indicator system, the American Institute of Electrical Science and Technology further expanded the evaluation index system of a specific grid construction project, and refined the index system of the Department of Energy, to evaluate the impact of innovative technology on the benefits and development of construction projects. For the purpose of building smart grids, namely, to realize low-carbon economic development by increasing the connectivity of renewable energy sources such as wind power and promoting the use of technologies for distributed power generation and demand-side management, Europe has established an impact evaluation system of innovative technologies on smart grids and made use of KPI theory. A total of 21 KPI indicators were extracted from the perspectives of sustainable development, power transmission, power grid access standards, safe and high-quality power supply, power grid operation efficiency quality, networking ability, coordinated planning and development, cost efficiency, innovation ability, etc., to evaluate the impact of smart grid technology, equipment, interaction, and revenue ability (Amin D, 2021). Researchers in Brazil considered 13 technical and economic criteria to investigate a multi-criteria approach and developing an expert system-based computational model to assess the effectiveness of distribution network operators in Brazil (Ghizoni C R T, 2022). Based on the TSFPMSM operator, a MAGDM algorithm was developed for the evaluation of Pakistan's smart grid network. Based on the observation of the response to changes in sensitive parameters, the proposed numerical examples are subjected to sensitivity analysis, and a comprehensive comparative study is conducted (Areeba N, 2022).

In addition, there are many related studies in the field of power system evaluation. Xiufan M established a comprehensive set of evaluation indicators across five dimensions: reliable operation, economic performance, efficient interaction, technological intelligence, and green emissions reduction. A comprehensive evaluation model for a 5G+ smart distribution network was proposed based on cloud modeling, which incorporates the principle of minimizing variance and accounts for the uncertainty of information pertaining to distribution network nodes and equipment statuses0. Long C W introduced a new analytical model and relationship assessment method that takes into account grid evolution, integrating both rapid dynamics and slow evolution. This model encompasses load increases, upgrades, and construction of equipment such as power plants, transformers, and transmission lines, simulating the development of the power grid by modeling 0. However, with the release of the "carbon peaking and carbon neutrality" action plan and the continued drive for energy transformation, accelerating the establishment of a clean, low-carbon, secure, and efficient energy system while continually advancing carbon reduction has become the next crucial focus. To achieve this goal, the power grid needs to undertake a significant number of technology projects and research as support. A multitude of technology projects not only facilitates the rapid advancement of low-carbon power generation technologies but also develop new energy projects according to local conditions based on the advantages of each province. In the face of this vast array of technology projects, Faced with a far larger number of technology projects, it is essential for the power grid to conduct systematic screening and evaluation. Therefore, establishing a post-evaluation system for technology projects is necessary to identify the most valuable initiatives to pursue, ensuring that the research outcomes from these technology projects can assist the power grid in addressing technical challenges and achieving resource allocation and optimization during the transition. This will support the power grid in completing energy transformation and promoting the low-carbon transformation of the power system. It can provide information support and reference for project investment decision and process management.

2 CONSTRUCTION OF POST-EVALUATION CONCEPT AND EVALUATION INDEX SYSTEM FOR SCIENCE AND TECHNOLOGY PROJECTS

2.1 The Concept of Post-Project Evaluation

Post-evaluation of science and technology projects refers to the activities of comprehensively analyzing and evaluating the implementation process, benefits and internal and external influences of the projects by using scientific and systematic evaluation methods after the projects are completed or put into operation. Through the analysis of the actual completion and operation of the project, it can compare whether the project has reached the predetermined target when the project was set up in terms of output, benefit and other indicators, and make a scientific evaluation by comparing the completed target and the predetermined target; Analyze the decision-making process and implementation process of the project, find the existing problems, summarize the experience and lessons, and provide feedback. According to the definition of post-evaluation, it can be interpreted from the following three aspects: From a purpose standpoint, post-evaluation of technology projects serves as the primary approach by which project management departments manage and assess technology projects, and is also an important means of science and technology project management. Its main task is to evaluate the benefits of science and technology projects in an all-round way, and to feed back the evaluation results to the science and technology management department, so as to provide a basis for the modification of science and technology project management mode and policy. Secondly, from the perspective of stages, the whole process management of science and technology projects is composed of post-evaluation, project selection demonstration, project evaluation, mid-term inspection, acceptance appraisal and other stages. Although post-evaluation constitutes the final phase of a technology project, its significance is paramount within the entire lifecycle management of such projects0. Only after evaluation can science and technology projects accurately reflect the long-term impact of results. Finally, from the perspective of object, post-project evaluation of science and technology can evaluate a single project or multiple projects under a certain type of special plan.

2.2 Power Grid Science and Technology Project Post-Evaluation Content

According to the characteristics of the project, the content of post-evaluation of power grid science and technology projects is evaluated from the aspects of the completion of the project objectives, the project implementation and management, the comprehensive benefit of the project results, the comprehensive influence of the project, the technical level and application of the project results.

(1) Achievement of project objectives

By comparing some economic and technical indicators actually produced by the project with the goals determined during the project decision-making, the project can be checked whether it has reached the expected goals or the degree to which it has reached the goals, and the deviation can be analyzed to judge the success of the project. Additionally, it is necessary to analyze and assess the effectiveness, reasonability, and feasibility of the initial project decision objectives.

(2) Project implementation and management status

By analyzing whether the project decision is scientific and feasible, whether the resource investment can be further optimized, whether the project scheduling is reasonable and other aspects, the fine degree of management in the process of project implementation is evaluated, and the deficiencies in management organization are found and solutions are proposed.

(3) Comprehensive benefits of project results

From the perspective of economic benefit, according to the actual input and income data of each year during the post-evaluation, the economic benefit is evaluated; from the perspective of social benefits, whether to support the implementation and theory of major national policies, whether to lead or open up new technical fields, to help the company's high-quality development; and consider the comparison with the pre-project assessment, identify the reasons for the significant changes, and summarize the experience and lessons.

(4) Comprehensive project influence

After the project is completed and put into operation, an assessment should be conducted to evaluate its actual impact on the local economy, society, and environment. Based on this assessment, the project's decision objectives should be determined, including evaluations of its economic impact, social impact, and environmental impact.

(5) Technical level and application of project achievements

Judge whether the technical level of the project results is advanced enough, whether they can be applied according to the current characteristics and have enough applicability; Whether the technology of the project results is mature enough, whether it reaches the expected goal, and whether the application method is clear.

Construction of post-evaluation index system for power grid science and technology projects

The post-evaluation of power grid science and technology projects generally needs to achieve four objectives: 1) Better understanding of the influence of competition policy decisions; 2) Improve the transparency and accountability of competition policy decisions; 3) Promoting competition and competition policy; 4) Improve future decision-making practices. Therefore, we understand the objective of post-project evaluation as follows: through a comparative analysis between the project's anticipated objectives and actual outcomes, comprehensively summarizing the project implementation process, drawing lessons from it, with the aim of improving project decision-making, design, execution, and management, and ultimately achieving the project's anticipated objectives.

Table 1. Evaluation index model of basic prospective scientific research projects.

Serial number	First-order index	Secondary index
1	Organization management A_1	Project completion schedule B_1
2		Project acceptance status B_2
3	Technical level A_2	Technological maturity B_3
4		Project approval accuracy B_4
5	Application of results A_3	Intellectual property rights B_5
6		Technical support B_6
7	Influence A_4	Project extension B_7
8		Personnel training situation B_8

From the above definition and the objective of post-evaluation, the post-evaluation indicators of power grid science and technology projects are selected from four dimensions: organizational management, technical level, achievement application and influence, and a number of supporting indicators are set under each dimension (a total of 8 supporting indicators) to improve the degree of refinement and comprehensiveness of post-evaluation. The evaluation index model of basic prospective scientific research projects is shown in Table 1.

3 CONSTRUCTION OF GRID SCIENCE AND TECHNOLOGY PROJECT POST EVALUATION MODEL BASED ON AHP AND CRITIC

3.1 Index Weight Calculation Method

The post evaluation index system of different types of scientific research projects established in this paper not only includes the subjective evaluation method based on AHP, but also includes the objective evaluation method based on CRITIC method. The evaluation index system for various types of scientific research projects is a complex and dynamic system containing fuzziness and accuracy at the same time, with a variety of factors, certainty and uncertainty. If only one evaluation index is considered, it is difficult to obtain comprehensive evaluation results. It is a necessary feature of weight determination method to reflect the fuzziness and correlation among evaluation indexes. Therefore, in the comprehensive evaluation, it is more appropriate to adopt the subjective and objective weight combination calculation method combining AHP method and CRITIC method. This method quantifies the weight of various evaluation indicators, making the comprehensive evaluation results have obvious rationality.

(1) Subjective evaluation method based on AHP

The specific operation steps of AHP are shown as follows0:

1) Establish the hierarchical structure model

AHP can simplify complex problems by layering, and divide factors into different levels according to the interrelation and dominance of various factors.

2) Construct a comparative judgment matrix

Judgment matrix is a matrix constructed by decision makers in judging the mutual importance of elements of each layer in the index system according to certain methods. Judgment matrix B is as follows:

$$B = \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{pmatrix} \tag{1}$$

b_{ij} indicates the importance of elements p_i and p_j relative to the criterion C_k of the upper layer. In this study, the value of b_{ij} comes from researchers with senior research experience in related fields. Therefore, the preliminary judgment matrix B is consistent, that is, it meets the following conditions:

$$b_{ij}+b_{ij}=1, b_{ji}=\frac{1}{b_{ij}}, b_{ij}=\frac{b_{ik}}{b_{jk}}(i,j,k=1,2,\cdots, n) \quad (2)$$

The evaluation indicator system established in this paper includes many qualitative indicators, and the evaluation of the importance of different indicators comes from the subjective judgment of researchers in this field. In order to make the qualitative data easier to be quantified, this paper adopts the 9-level scale method to determine the importance of each indicator X_{ij}, as shown in Table 2.

Table 2. Evaluation criteria of the grade scale method.

Assignment of b_{ij}	How important x_i is compared to x_j
1	x_i is of equal importance to x_j
3	x_i is slightly more important than x_j
5	x_i is more important than x_j
7	x_i is very important than x_j
9	x_i is extremely important over x_j
2，4，6，8	The corresponding transition scale between the preceding and the following two stages
Reciprocal	Scale of importance of x_i over x_j

3) Calculate the weight of each layer

①Multiply each row of elements of the judgment matrix:

$$m_i=\Pi_{j=1}^{n}b_{ij},(i=1,2,\cdots,n) \quad (3)$$

②Calculate the NTH root of m_i to get the feature vector w_i:

$$w_i=\sqrt[n]{m_i},(i=1,2,\cdots,n) \quad (4)$$

③The vector $W=(w_1,w_2,\ldots,w_n)$ is normalized:

$$W_i=w_i/\sum_{i=1}^{n}w_i(i=1,2,\cdots,n) \quad (5)$$

$W=(w_1,w_2,\ldots,w_n)^T$ is the approximate solution to the eigenvector.

4) Consistency check

①Calculate the maximum characteristic root $\lambda_{\max}$:

$$\lambda_{\max}=\frac{1}{n}\sum_{i=1}^{n}\frac{BW}{w_i} \quad (6)$$

Where, B is the judgment matrix and W is the weight vector.

②Calculate the matrix consistency index CI:

$$CI=\frac{\lambda_{max}-n}{n-1} \quad (7)$$

③Calculate the consistency ratio CR:

$$CR=\frac{CI}{RI} \quad (8)$$

Where, RI is the average randomness index, whose value is selected from the table given by Thomas (1986) (TABLE 3). The judgment criteria are as follows: when CR is less than or equal to 0.1, the matrix has consistency, indicating that the consistency test is passed, and then the next operation can be carried out, that is, to sort the weight. When the value is greater than 0.1, it means that the judgment matrix does not have good consistency and cannot pass the consistency test. At this point, the matrix needs to be modified and the weight value of the judgment matrix reevaluated until the consistency criteria is passed.

Table 3. Values of RI indicators.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.57	0.87	1.12	1.26	1.36	1.41	1.46	1.49

5) Calculate the final weight set

The premise of this step is that the judgment matrix has passed the consistency criteria. At this time, the weight of each evaluation index in the middle layer for different types of scientific research projects can be calculated. The formula is:

$$W=W_i\times W_{ij} \quad (9)$$

Where, $i=1,2,3,4$ and $j=1,2,3,4,5$.

(2) An objective evaluation method based on CRITIC method

Under normal circumstances, objective weighting method is based on sample data. Coefficient of variation, standard difference and other values are used to represent the information content of each index, and index weights are allocated according to this standard. However, the CRITIC objective weight method not only takes into account the amount of information carried by each indicator, but also takes into account the problem of information duplication caused by the correlation between indicators. The specific calculation steps are as follows:

Under normal circumstances, objective weighting method is based on sample data. Coefficient of variation, standard difference and other values are used to represent the information content of each index, and index weights are allocated according to this standard. However, the CRITIC objective weight method not only takes into account the amount of information carried by each indicator, but also takes into account the problem of information duplication caused by the correlation between indicators. The following are the specific steps for performing the calculation:

1) Dimensionless processing is carried out for each index

The process of dimensionless processing of sub-indexes can neutralize the influence of varying dimensions on the assessment outcomes. Under normal circumstances, forward or reverse treatment is selected for the CRITIC method, and standardization processing is not recommended, because standardized treatment will cause all the standard deviations to become 1. In this way, all indicators will have completely consistent standard deviations, and the volatility indicator is meaningless.

Forward or reverse processing:

When the value of the used index is larger, the better (positive index):

$$\chi_{ij} = \frac{\chi_j - \chi_{\min}}{\chi_{\max} - \chi_{\min}} \tag{10}$$

When the value of the index used is as small as possible (inverse index):

$$\chi_{ij} = \frac{\chi_{\max} - \chi_j}{\chi_{\max} - \chi_{\min}} \tag{11}$$

2) Index variability was calculated

The jth index is expressed as δ_j in the form of standard deviation, and the calculation formula is as follows:

$$\delta_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\chi_i - \mu\right)^2} \tag{12}$$

Where, χ_i is the ith value of index j, μ is the arithmetic mean of x_i, n is the total number of x_i. The standard deviation is employed to quantify the internal dispersion of numerical values among various indicators, thus reflecting the disparities in values within each indicator. A larger standard deviation indicates greater numerical variations among the indicators, signifying a wealthier information content within these indicators and a higher evaluative significance. Consequently, indicators with larger standard deviations should be assigned a greater weight in the evaluation process.

3) Calculate the index conflict

Expressed by correlation coefficient, the quantization formula of the conflict between the jth index and other indicators is:

$$R_j = \sum_{i=1}^{n}(1 - r_{ij}) \tag{13}$$

Where, r_{ij} evaluates the correlation coefficient between index i and j. Correlation coefficients are used to measure the degree of interrelation between indicators. The stronger the correlation, the less conflict exists between this indicator and others, and the more redundant information is present. This redundancy leads to repetition in the evaluation process, consequently weakening the evaluation strength of the indicator. Therefore, when balancing the importance of evaluation indicators, it is necessary to appropriately reduce the weights of indicators that exhibit high levels of correlation.

4) Computational comprehensive information

The objective weight of each index is comprehensively measured by its variability and conflict. Let C_j represent the comprehensive information contained in the jth evaluation index, then C_j can be expressed as:

$$C_j = \delta_j * \sum_{i=1}^{n}(1 - r_{ij}) = \delta_j * R_j \tag{14}$$

The larger C_j is the greater the role of the j^{th} evaluation index is, and the more weight should be assigned to it.

5) Calculated objective weight

Therefore, the calculation formula of the jth index is:

$$W_{CRITIC_j} = \frac{C_j}{\sum_{i=1}^{n} C_j} \tag{15}$$

(3) A combination calculation method of subjective and objective weight based on AHP-CRITIC method

The subjective weighting method of AHP mainly relies on the subjective judgment of evaluators and lacks reliability and stability. The objective weight method of CRITIC just judges the importance of indicator from sample data, without taking into account information other than data, and the sample data itself has certain limitations. Each of these two methods has its own advantages and disadvantages. Therefore, in this paper, they are combined. First, AHP method and CRITIC method are used to calculate indicator weight respectively, and then weight data are combined to calculate combined weight, so as to carry out performance evaluation on this basis. The specific combination weight calculation formula is as follows:

$$W_j = \frac{W_{AHP_j} * W_{CRITIC_j}}{\sum_{j=1}^{n} W_{AHP_j} * W_{CRITIC_j}} \tag{17}$$

3.2 TOPSIS Evaluation Methods

TOPSIS method is a classic data-driven evaluation method. It was put forward by C. L. Hwang and K. Yoon in 1981, ranking the proximity between evaluation objects and idealized targets to determine their relative merits and demerits.

In this paper, a multi-objective comprehensive evaluation method combining CRITIC method, AHP combined weight method and TOPSIS method is adopted to analyze power grid science and technology projects.

The specific calculation process of TOPSIS method is shown as follows:

(1) The original matrix is turned forward. The so-called positive transformation means that all types of indicators are converted into extremely large indicators. The conversion process of different types of indicators is also different. The specific conversion process is as follows:

1) Very small indicators—> very large indicators

$$x' = max - x \tag{17}$$

Where, x' is the transformed index value, x is the extremely small index value, and max is the maximum value of this extremely small index in all evaluation objects.

2) Intermediate indicators—> very large indicators

$$M = \max\{|x_i - x_{best}|\} \tag{18}$$

$$x_i' = 1 - \frac{|x_i - x_{best}|}{M} \tag{19}$$

Where, x_i' is the index value after transformation, x_i is the intermediate index, and x_{best} is the best value in the index value.

3) Interval type indicator—> extremely large indicator

$$M = \max\{a - \min\{x_i\}, \max\{x_i\} - b\} \tag{20}$$

$$x_i' = \begin{cases} 1 - \frac{a - x_i}{M}, x_i < a \\ 1, a \le x_i \le b \\ 1 - \frac{x_i - b}{M}, x_i > b \end{cases} \tag{21}$$

Where, x_i' is the index value after transformation, x_i is the interval type index value, and $[a,b]$ is the interval of the index.

(2) The forward matrix is normalized to eliminate the influence of different index dimensions.

Assuming that there are n objects to be evaluated and m evaluation indicators after normalization, the forward matrix formed is shown in Equation (22) below.

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \tag{22}$$

Where, x_{ij} represents the index value of the ith index of the jth evaluation object.

The normalized matrix is denoted as Z, then the calculation formula of element z_{ij} in matrix Z is shown in Equation (23) below.

$$z_{ij} = x_{ij} \Big/ \sqrt{\sum_{j=1}^{m} x_{ij}^2} \tag{23}$$

(3) Calculate the final score.

Assuming that there are n objects to be evaluated and m evaluation indicators, the final standardized matrix is obtained, as shown in Equation (24) below.

$$Z = \begin{pmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{pmatrix} \tag{24}$$

Define maximum Z^+:

$$\begin{aligned} Z^+ &= (Z_1^+, Z_2^+, \cdots, Z_n^+) \\ &= (\max\{z_{11}, z_{21}, \cdots z_{m1}\}, \max\{z_{12}, z_{22}, \cdots z_{m2}\}, \cdots, \max\{z_{1n}, z_{2n}, \cdots z_{mn}\}) \end{aligned} \tag{25}$$

Define minimum Z^-:

$$\begin{aligned} Z^- &= (Z_1^-, Z_2^-, \cdots, Z_n^-) \\ &= (\min\{z_{11}, z_{21}, \cdots z_{m1}\}, \min\{z_{12}, z_{22}, \cdots z_{m2}\}, \cdots, \min\{z_{1n}, z_{2n}, \cdots z_{mn}\}) \end{aligned} \tag{26}$$

Define the distance D_j^+ between the $jth, j = 1, 2, \ldots, n$ evaluation object and the maximum value.

$$D_j^+ = \sqrt{\sum_{i=1}^{m} w_i (z_i^+ - z_{ij})^2} \tag{27}$$

Define the distance D_j^- between the $jth, j=1,2,\ldots,n$ evaluation object and the minimum value

$$D_j^- = \sqrt{\sum_{i=1}^{m} w_i (z_i^- - z_{ij})^2} \quad (28)$$

In the final calculation, the score S_j of the $jth, j=1,2,\ldots,n$ rating object without normalization can be written:

$$S_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad (29)$$

Obviously, and the higher the score is $0 \le S_i \le 1$, the larger D_j^- is, that is, the closer it is to the maximum value.

(4) The scoring criteria are normalized

$$\widetilde{S_j} = S_j \Big/ \sum_{j=1}^{n} S_j \quad (30)$$

Where, $\widetilde{S_j}$ is the score of the jth evaluation object after normalization, Obviously, $\sum_{j=1}^{n} \widetilde{S_j} = 1$.

4 CASE ANALYSIS

(1) Determine subjective weight based on AHP

Taking the calculation of the first-level indicator layer as an example, the judgment matrix of the first-level indicator layer is determined through expert review and scoring, as shown in TABLE 4 below.

Table 4. First-level indicator judgment matrix.

M	A_1	A_2	A_3	A_4
A_1	1	1/3	1/5	1
A_2	3	1	1/3	3
A_3	5	3	1	5
A_4	1	1/3	1/5	1

Through the calculation and analysis of the above matrix, the weight of the final index layer is determined as: 0.0976, 0.2516, 0.5549, 0.0967, $CR = 0.0056 < 0.1$, the matrix passes the consistency test.

Similarly, the index weight of the second-level indicator layer relative to the first-level indicator layer is further determined, and the final weight of each indicator is obtained as shown in TABLE 5 below.

Table 5. Indicator weights based on AHP.

Indicator	Weight	Indicator	Weight
B_1	0.0242	B_5	0.1387
B_2	0.0725	B_6	0.4162
B_3	0.1258	B_7	0.0725
B_4	0.1258	B_8	0.0242

(2) Determine objective weight based on CRITIC

Based on the actual data of each science and technology project and the basic theory of CRITIC, the results of the weight of each index are calculated, and the objective weight results are shown in TABLE 6 below.

Table 6. Indicator weight based on CRITIC.

Indicator	Weight	Indicator	Weight
B_1	0.1081	B_5	0.1301
B_2	0.1992	B_6	0.0819
B_3	0.1138	B_7	0.1295
B_4	0.1382	B_8	0.0992

(3) Combinatorial weighting

Based on the above equation (16), the subjective and objective combination weights are calculated, and the final weights of each index are obtained as shown in TABLE 7 below.

Table 7. Indicator combination weighting.

Indicator	Weight	Indicator	Weight
B_1	0.0232	B_5	0.1602
B_2	0.1282	B_6	0.3024
B_3	0.1271	B_7	0.0834
B_4	0.1543	B_8	0.0213

(4) Comprehensive evaluation based on TOPSIS

Based on the theory of TOPSIS method, the distance between the object to be evaluated and the positive ideal point and the negative ideal point is calculated, and the final evaluation results are given, as shown in TABLE 8 below.

Table 8. Scores of the objects to be evaluated.

Project	D_j^+	D_j^-	S_j	$\widetilde{S_j}$
Big data scheduling technology	0.0501	0.0335	0.4009	0.1288
Virtual power plant technology	0.0325	0.0496	0.6043	0.1941
DC networking technology	0.0349	0.0454	0.5651	0.1815
DC microgrid technology	0.0357	0.0410	0.5347	0.1718
AC-DC hybrid distribution network technology	0.0342	0.0364	0.5156	0.1656
Digital compound networking technology	0.0473	0.0459	0.4922	0.1581

As can be seen from the above table, among the six technologies of big data scheduling technology, virtual power plant technology, DC networking technology, DC microgrid technology, AC-DC hybrid distribution network technology, and digital compound networking technology, the order of evaluation is virtual power plant technology, DC networking technology, DC microgrid technology, AC-DC hybrid distribution network technology, digital compound networking technology and big data scheduling technology.

5 CONCLUSION

This paper investigates the indicator system and evaluation model for post-evaluation of technology projects within power grid companies. Firstly, based on the relevant concepts of post-evaluation for technology projects, the post- evaluation objectives for power grid technology projects were clarified, and an indicator system for post-evaluation of technology projects was constructed. Then, by considering the characteristics of these indicators, a technology project post-evaluation model based on AHP-CRITIC-TOPSIS was developed, and typical power grid technical projects were evaluated by collecting data. Feasibility of this method was validated through a case analysis.

ACKNOWLEDGMENT

This study is supported by the project of State Grid Economic and Technological Research Institute Co., LTD. “Technology maturity evaluation and post-project evaluation of key technologies and application research” (SGSH0000SCJS2200105). The authors are grateful to the participants who help to improve the paper with many pertinent comments and suggestions.

REFERENCES

Grid modernization multi-year program plan(R). U. S. Department of Energy, 2015.

Amin D, L C T. A complex network approach for analyzing early evolution of smart grid innovations in Europe (J). *Applied Energy*, 2021, 298: 117143.

Ghizoni C R T, Roesler L A R, Paulo J P. An Intelligent System for Operators Performance Multicriteria Evaluation of Distribution Networks (J). *Applied Artificial Intelligence*, 2022, 36(1): 1-24.

Areeba N, Kifayat U, Maria A, et al. Assessment of Smart Grid Systems for Electricity Using Power Maclaurin Symmetric Mean Operators Based on T-Spherical Fuzzy Information (J). *Energies*, 2022, 15(21): 1-25.

Xiufan M, Ying W, Zihao L, et al. Comprehensive evaluation of 5G+ smart distribution network based on combined weighting method-cloud model(J). *Global Energy Interconnection*, 2022, 5(6): 675-691.

Long C W, Han F, Zhang M X, et al. The Relationship among the Security, Efficiency and Adequacy of Electrical Power Grid Based on the Novel Evaluation Method (J). *Advanced Materials Research,* 2014, 3247: 960-961.

Hu Z, Hu L, Cheng H, et al. Application of Pollution Index Method Based on Dynamic Combination Weight to Water Quality Evaluation(J). *IOP Conference Series: Earth and Environmental Science*, 2018, 153(6): 1-3.

ZiWei L, QiongYao X, Lu D, et al. Research on comprehensive evaluation method of distribution network based on AHP-entropy weighting method (J). *Frontiers in Energy Research*, 2022, 10: 1-9.