Comprehensive Evaluation of Investment Benefits of Power Grid Enterprises Based on AHP-TOPSIS Method

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Abstract—With the deepening of the new round of electric power reform, the dual changes of the supervision mode and profit mode of power grid enterprises will bring tremendous pressure on the operation of power grid enterprises. In order to improve the precision investment level of power grid enterprises and evaluate its investment ability, this paper firstly establishes the evaluation indicator system of investment benefit of power grid enterprises from four aspects: operation benefit, social benefit, safety production and technological innovation. Secondly, the AHP-TOPSIS comprehensive evaluation model is established. Finally, an example is given to verify the feasibility and reliability of the model, which can provide a reference for the operation management and steady development of the company.

Keywords—Investment benefits of power grid enterprises, Evaluation indicator system, AHP-TOPSIS, Comprehensive evaluation

I. INTRODUCTION

In recent years, with the rapid development of China's national economy, electricity as an important basis for development, its demand is also growing, and the investment scale of power grid enterprises is expanding. At the same time, with the continuous deepening of China's power system reform, the new power reform plan clarifies that the dual changes in the regulatory mode and profit model of power grid enterprises - which will make power grid enterprises face enormous pressure in operation. Therefore, how to evaluate the investment benefit of power grid enterprises, how to help them use investment funds and arrange investment projects scientifically and rationally, and how to effectively prevent and evade operational risks are urgent issues to be discussed and solved.

C. Han put forward the economic benefit evaluation method and constructed the function mechanism of project economic evaluation results in investment decision-making of power grid enterprises [1]. Y. He uses the analytic hierarchy process and fuzzy comprehensive evaluation method to evaluate the economic benefits of the project investment [2]. J.C. Wang constructed the investment benefit evaluation indicator of power grid enterprises only from the technical point of view [3]. X. An thinks that the overall analysis should be made from the aspects of finance, personnel, economy, technology and management, but no specific evaluation method has been put forward [4]. W. Jie only comprehensively evaluates grid investment and investment quotas of 35kV and below, but the established model does not apply to projects above 35kV [5]. Z.F. Yu takes the impact of power grid investment on business operation efficiency as a research perspective, and proposes measures to improve investment efficiency from the technical and economic level [6].

It can be seen from the above research results that the setting of the indicator system is relatively one-sided. At the same time, the status and nature of the public utilities and state-owned enterprises owned by the power grid enterprises require that the safety of the power grid and the social benefits of the enterprises should be taken into account when evaluating the investment benefits of the power grid enterprises. Therefore, it is necessary to establish a systematic and comprehensive evaluation indicator system for investment benefit of power grid enterprises, and make a comprehensive evaluation on it, objectively analyze and study the fine degree of investment benefit of power grid enterprises, and provide the direction for improving the operation management and steady development of the company.

In summary, based on the investment perspective of power grid enterprises, this paper considers the social benefits of investment of power grid enterprises, combines qualitative and quantitative indicators to construct the evaluation indicator system of investment benefits of power grid enterprises. Analytic Hierarchy Process (AHP) and TOPSIS are combined to put forward a systematic and scientific evaluation method for investment benefit of power grid enterprises.
II. CONSTRUCTION OF EVALUATION INDICATOR SYSTEM FOR INVESTMENT BENEFITS OF POWER GRID ENTERPRISES

This paper establishes 18 secondary indicators from four aspects of operation benefit, social benefit, safety production and technological innovation to construct the evaluation indicator system of investment benefit of power grid enterprises. The specific indicator system is shown in the Table I.

<table>
<thead>
<tr>
<th>Target layer</th>
<th>Single-Level Indicators</th>
<th>Two-Level Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment benefits of power grid</td>
<td>Return on total assets (%)</td>
<td>Rate of return on common stockholders’ equity (%)</td>
</tr>
<tr>
<td>benefits of power grid enterprises</td>
<td>Main business revenue growth rate (%)</td>
<td>Debt asset ratio (%)</td>
</tr>
<tr>
<td></td>
<td>Current ratio (%)</td>
<td></td>
</tr>
<tr>
<td>Safety production</td>
<td>Annual saving of standard coal (ten thousand tons)</td>
<td>Carbon dioxide emission reduction (ten thousand tons)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sulfur dioxide emission reduction (ten thousand tons)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Renewable energy generation (Ten thousand kWh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Government satisfaction (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer satisfaction (%)</td>
</tr>
<tr>
<td>Technological innovation</td>
<td>Power supply reliability (%)</td>
<td>Comprehensive voltage qualification rate (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Emergency response capability (%)</td>
</tr>
<tr>
<td></td>
<td>Technology input-output ratio (%)</td>
<td>Innovation input-output ratio (%)</td>
</tr>
<tr>
<td></td>
<td>Technology demand satisfaction (%)</td>
<td>Number of new patents</td>
</tr>
</tbody>
</table>

III. CONSTRUCTION OF AHP-TOPSIS EVALUATION MODEL

Based on the establishment of the grid enterprise investment benefit evaluation indicator system, this paper uses the analytic hierarchy process (AHP) to distribute the weight of each indicator decision-making for evaluating the investment benefit of power grid enterprises.

According to the scale thinking method of 1-9 [7], the judgment matrix is constructed by comparing two evaluation indicators, and the maximum eigenvalue of the judgment matrix is calculated according to the following equation.

$$w_j = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}, \quad i, j = 1, 2, ..., n$$

$$w'_i = \sqrt{\prod_{j=1}^{n} w_j} / \sum_{j=1}^{n} \sqrt{\prod_{j=1}^{n} w_j}$$

$$\lambda_{max} = \frac{1}{n} \sum_{j=1}^{n} a_{ij} w_j$$

$CR = \frac{\lambda - n}{(n-1) \cdot RI} < 0.01$

When the consistency indicator $CR$, the judgment matrix is considered to pass the consistency test, that is, the indicator weight can be determined according to the judgment matrix.

The main principle of TOPSIS is to rank the evaluation objects by the relative distance between the evaluation objects and the positive ideal solution and the negative ideal solution [8].

1) Initial evaluation matrix and its standardization

Assuming that there are $m$ groups of samples, then the sample group is $A = \{A_1, A_2, ..., A_m\}$. The indicator number of each scheme is $n$, then the corresponding indicator group is $X = \{X_1, X_2, ..., X_n\}$. Therefore, the evaluation indicator $X_{ij} (i \in [1, m], j \in [1, n])$ is obtained, and the initial evaluation matrix is as follows:
In order to reduce the errors caused by the different dimension level of each evaluation indicator, this paper uses Z-Score method to nondimensionalize the indicators [9]. The equation is as follows:

\[ x_{ij}^* = \frac{x_{ij} - \bar{x}_j}{s_j}, \quad i = 1, 2, ..., m \quad j = 1, 2, ..., n \]  

(5)

(2) Construct the weighted normalization matrix

According to the combination weight determined by AHP method, the weighted normalized matrix can be obtained by weighting the initial evaluation matrix normalized by Z-Score method.

\[ R = (r_{ij})_{mn} = \begin{bmatrix} w_1x_{i1}^* & w_2x_{i2}^* & \cdots & w_nx_{in}^* \\ w_1x_{i1}^* & w_2x_{i2}^* & \cdots & w_nx_{in}^* \\ \vdots & \vdots & \ddots & \vdots \\ w_1x_{im}^* & w_2x_{im}^* & \cdots & w_nx_{in}^* \end{bmatrix} \]  

(6)

(3) Determine positive and negative ideal solutions

Under the premise of positive processing of the inverse indicator, positive and negative ideal solutions are obtained respectively as follows:

\[ r_j^+ = \max_i r_{ij} \quad r_j^- = \min_i r_{ij} \]  

(7)

(4) Calculate evaluation distance

The evaluation distance between the sample of group \( i \) and the positive ideal solution is:

\[ d_j^+ = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^+)^2} \]  

(8)

The evaluation distance between the sample of group \( i \) and the negative ideal solution is:

\[ d_j^- = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^-)^2} \]  

(9)

(5) Calculate the proximity of each sample

\[ C_i = \frac{d_j^-}{d_j^+ + d_j^-}, \quad \left( C_i \in [0,1] \right) \]  

(10)

When \( C_i \) approaches 1, the evaluation object reaches a positive ideal solution. The greater the proximity, the better the investment benefit of power grid enterprises [10].

IV. EXAMPLE ANALYSIS

Based on the above-mentioned indicator system, this paper selects the relevant indicator data of S Power Grid Company
from 2014 to 2017, and uses the above AHP-TOPSIS model to comprehensively evaluate the investment benefit of power grid enterprises.

**A. Determine the Weights of Evaluation Indicators.**

The weight of each second-class indicator is determined as shown in the table.

<table>
<thead>
<tr>
<th>Two-level indicators</th>
<th>Weights of Indicators</th>
<th>Two-level indicators</th>
<th>Weights of Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return on Total Assets (%)</td>
<td>0.0226</td>
<td>Government satisfaction (%)</td>
<td>0.0596</td>
</tr>
<tr>
<td>Rate of Return on Common Stockholders’ Equity (%)</td>
<td>0.0350</td>
<td>Customer satisfaction (%)</td>
<td>0.2021</td>
</tr>
<tr>
<td>Main business revenue growth rate (%)</td>
<td>0.0090</td>
<td>Power supply reliability (%)</td>
<td>0.0506</td>
</tr>
<tr>
<td>Debt Asset ratio (%)</td>
<td>0.0061</td>
<td>Comprehensive voltage qualification rate (%)</td>
<td>0.0320</td>
</tr>
<tr>
<td>Current ratio (%)</td>
<td>0.0061</td>
<td>Emergency response capability (%)</td>
<td>0.1183</td>
</tr>
<tr>
<td>Annual saving of standard coal (ten thousand tons)</td>
<td>0.0315</td>
<td>Technology input-output ratio (%)</td>
<td>0.0325</td>
</tr>
<tr>
<td>Carbon dioxide emission reduction (ten thousand tons)</td>
<td>0.0848</td>
<td>Innovation input-output ratio (%)</td>
<td>0.0325</td>
</tr>
<tr>
<td>Sulfur dioxide emission reduction (ten thousand tons)</td>
<td>0.0848</td>
<td>Technology demand satisfaction (%)</td>
<td>0.1208</td>
</tr>
<tr>
<td>Renewable energy generation (Ten thousand kWh)</td>
<td>0.0566</td>
<td>Number of new patents</td>
<td>0.0150</td>
</tr>
</tbody>
</table>

**B. Comprehensive Evaluation.**

According to the Z-Score method, the two-level evaluation indicators of investment benefits of power grid enterprises are nondimensionalize by using Eq.5. According to the established AHP-TOPSIS model, the proximity of investment benefits of S Power Grid Company from 2014 to 2017 is calculated. In order to simplify the calculation, the data is processed by MATLAB software [11], and the concrete data is shown in the following table:

<table>
<thead>
<tr>
<th>Year</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity $C_i$</td>
<td>0.1667</td>
<td>0.3988</td>
<td>0.7032</td>
<td>0.7616</td>
</tr>
</tbody>
</table>

According to the calculation results of TOPSIS, the ranking results of the investment benefits of S grid enterprises from 2014 to 2017 are: 2017 > 2016 > 2015 > 2014. As can be seen from Table 3 and Figure 1, the proximity of investment benefits of S Grid Company in 2014 was 0.1667, which is the lowest point in four years. Then it gradually climbed to 0.3988 in 2015 and 0.7032 in 2016. Finally, the proximity of investment benefits of S Grid Company in 2017 was 0.7616, which is the highest point in four years. From the general trend, the investment benefits of S Power Grid Company increased gradually in 2014-2017.

**V. CONCLUSION**

In order to evaluate the investment benefit of power grid enterprises scientifically, comprehensively and objectively, this paper establishes the evaluation indicator system of investment benefits of power grid enterprises, and puts forward the AHP-TOPSIS model to evaluate the indicator system comprehensively. And then an example is given to verify the model. The results show that the model is in good agreement with the actual situation. The evaluation of investment benefits of power grid enterprises has high accuracy, which can reflect the investment benefit more reliably and can provide help for enterprise investment planning.

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