The Evaluation of Power Grid Projects’ Investment Based on the Reform of Transmission and Distribution Price

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Abstract. This paper designs the evaluation model of power grid investment benefit based on the characteristics of grid enterprises, so as to improve the investment efficiency of power grid projects under the reform of transmission and distribution price in China. Firstly, designed the evaluation index system of investment benefit. Then, the relevant importance of each index is determined by questionnaire survey method. Besides, the weight was calculated by AHP. Finally, the evaluation model of investment benefit is constructed.

1. Introduction

Comprehensive evaluation of power grid projects’ investment benefits is an important part of power grid construction, and its rationality will directly affect the efficiency of power grid and the sustainable development of power grid construction. With the rapid development of China's economy and the requirements of grid construction, the size of grid investment is increasing. In 2013, the grid investment of State Grid Corporation of China was 337.9 billion yuan, which increased to 385.5 billion yuan in 2014 and reached 452.1 billion yuan in 2015[1]. Due to the large scale of investment in power grid projects, the risks are relatively high. Moreover, the grid investment involves many factors such as economy, technology and society. Therefore, how to avoid invalid investment become a key issue for grid companies.

Based on the characteristics of power grid enterprises, this paper constructs the evaluation model and method of investment benefit of power grid enterprises. The rest of this article is structured as follows: Section 2 constructed the evaluation index system. Section 3 determined the weight of those index. Section 4 constructed the comprehensive benefit evaluation model. And then the conclusions are drawn in Section 5.

2. Design of Evaluation Index System for Power Grid Investment Benefit

2.1. Construction of evaluation index system

In this paper, the hierarchical structure model of investment benefit evaluation of power grid project is established by analytic hierarchy process (AHP). We divided the hierarchies into the decision hierarchy, the principle hierarchy, and the criteria index hierarchy [2]. The decision-making level is the first index of the investment benefit evaluation index system of power grid project, that is, the
comprehensive evaluation value \( (A) \). The decision-making level is the comprehensive evaluation value of the evaluation index system of the investment benefit of the power grid project, and the principle layer is the second-class index of the evaluation index system, which is mainly composed of engineering economic benefits \( (B_1) \), environmental benefits \( (B_2) \), the social benefits \( (B_3) \) and the technology and security benefits \( (B_4) \). The comprehensive benefit evaluation index system is listed in Table 1:

### Table 1. The comprehensive benefit evaluation index system.

| The decision hierarchy | The principle hierarchy | The criteria index hierarchy |
|------------------------|------------------------|-----------------------------|
| Comprehensive evaluation value \( (A) \) | Economic Benefit \( (B_1) \) | Economic net present value \( (C_1) \) |
|                        |                        | Internal rate of return \( (C_2) \) |
|                        |                        | Asset-liability ratio \( (C_3) \) |
|                        | Environmental Benefit \( (B_2) \) | Comprehensive energy consumption efficiency \( (C_4) \) |
|                        |                        | Carbon Dioxide Emission Reduction \( (C_5) \) |
|                        | Social Benefit \( (B_3) \) | Proportion of clean energy \( (C_6) \) |
|                        |                        | Employment effect \( (C_7) \) |
|                        |                        | Direct contribution rate of GDP \( (C_8) \) |
|                        |                        | Power slastic coefficient \( (C_9) \) |
|                        | Technical and Security Benefit \( (B_4) \) | Reliability rate of power supply \( (C_{10}) \) |
|                        |                        | N-1 criterion \( (C_{11}) \) |
|                        |                        | Average load rate of the transformer \( (C_{12}) \) |

### 2.2. Analysis of the Benefit Evaluation Index

#### 2.2.1. Economic Benefit.

(1) Economic Net Present Value: Economic net present value refers to the sum of the net benefit flow of each year in the project calculation period converted to the present value at the beginning of the project construction period with the social discount rate. The decision to proceed with a power engineering project is often preceded by some form of net present value analysis. The formula is as follows:

\[
NPV = \sum_{i=0}^{n} \frac{B_{Ti} - C_{Ti}}{(1 + r)^i}
\]

where \( B_{Ti} \) and \( C_{Ti} \) are the total benefits and total expenses occurring in the year \( i \), respectively; \( n \) is the calculation period of the project; and \( r \) is the social discount rate.

(2) Internal Rate of Return: Internal rate of return is a meaningful parameter for prospective owners of these power systems. It refers to the discount rate when the total present value of project capital inflows equals the total present value of capital flows and the net present value equals zero. The calculation method is calculated by:

\[
I = \frac{NPV_n \times (i_{n+1} - i_n)}{NPV_n + |NPV_{n+1}| + i_n}
\]

where is a low trial discount rate; \( i_{n+1} \) is a higher trial discount rate; \( NPV_n \) is the net present value corresponding to \( i_n \); \( NPV_{n+1} \) is the net present value corresponding to \( i_{n+1} \). Usually, when the gap between in and \( i_{n+1} \) is not more than 2%:

\[
| i_n - i_{n+1} | \leq 2%.
\]

(3) Asset-liability Ratio: Asset-liability ratio reflects the proportion of total assets in a project borrowed by debt. It has more explanatory power to study the adjustment behavior of asset-liability...
ratio of China’s power grid companies from a dynamic point of view [3]. The formula can be read as follows:

$$\text{DAr} = \frac{\text{Ti}}{\text{Ta}} \times 100\%$$

where total liabilities $\text{Ti}$ include long-term liabilities and short-term liabilities; the total assets $\text{Ta}$ is net after deducting accumulated depreciation.

2.2.2. **Environmental Benefit.**

(1) Comprehensive Energy Consumption Efficiency: The comprehensive energy consumption efficiency reflects the energy-saving effect of a project construction. The implementation of the transnational power grid interconnection project can directly or indirectly enhance the comprehensive energy consumption efficiency. If the comprehensive energy consumption efficiency of the project is lower than the average energy consumption level of the society, then the project has a better energy-saving effect.

$$E' = \frac{E}{O}$$

Where $E'$ is the energy consumption efficiency of the year; $E$ is the value of comprehensive energy consumption in the year of the project; $O$ is the net output of the company in the current year.

(2) Carbon Dioxide Emission Reduction: The power grid projects reduce CO2 emissions through clean energy transfer. Therefore, by calculating the total amount of CO2 expected to be transported during the project period and combining it with the average power supply emissions per kilowatt/hour of power plants in the receiving area, we can calculate the reduction of CO2 in such projects [4].

(3) Proportion of clean energy: Promoting “two substitutes” to form a clean energy-dominated energy pattern, the core of which is to continuously improve the efficiency and economy of clean energy development. This can be calculated by the ratio of clean energy generation to total transmission power in the transmission process.

2.2.3. **Social Benefit.**

(1) Employment effect: The construction and operation of the power grid project involve the design, construction, maintenance and other industries, which provide direct or indirect employment opportunities for the society.

$$\text{Ee} = \frac{\text{Ne}}{\text{Di}}$$

where $\text{Ee}$ is the employment effect, $\text{Ne}$ is the amount of new employment in this project, $\text{Di}$ is the direct investment.

(2) Direct contribution of GDP: Developing economy is a basic state policy of our country. The contribution to the economic growth of a region is one of the critical criteria to inspect the advantages and disadvantages of the project. Regional economic growth is the result of the combined effects of various factors, such as policy adjustment, technological progress and increased investment. However, the construction and the operation of power grid are the basic conditions to promote the economic growth of a region. The direct contribution rate of GDP can determine the influence of transnational power grid interconnection projects on the national economy.

$$S = \frac{C}{G} \times 100\%$$

where $S$ is the direct contribution rate of GDP; $C$ is the annual revenue of electricity sales; $G$ is the GDP of the corresponding year.

(3) Power elastic coefficient: The power elasticity coefficient reflects the macroscopic indicator of the relationship between the annual average growth rate of power consumption and the annual average growth rate of the national economy. The power elasticity coefficient can be expressed by the following formula:
B = \frac{A_y}{A_x}

where B is the power elasticity coefficient, \(A_y\) is the annual average growth rate of electricity consumption; \(A_x\) is annual average growth rate of the national economy. This is the ratio of the growth rate of electricity consumption to the growth rate of the national economy.

2.2.4. Technical and Security Benefit.

(1) Reliability Rate of Power Supply: After the interconnection of power grids, the reserve capacity of each power system can support each other, thereby improving the power supply system’s ability to sustain power supply and reducing power outage losses. Studying power supply reliability supports safety assessment, machine availability assessment, and can potentially improve power supply performance. The calculation method is as follow:

\[
RSI = \left(1 - \frac{t}{T}\right) \times 100\%
\]

where RSI refers to the power supply reliability rate, \(t\) represents the average power outage time of users, and \(T\) represents the annual number of hours.

(2) N-1 criterion: In the case of transmission interruption and variable renewable supply, network operators have to maintain a reliability margin to avoid interruption and blackouts of power grid projects. Transmission line is the basic equipment of a power grid, and its black out will cause subsequent cascading outages. The reliability margin is presently determined by the N-1reliability criterion.

(3) Average load rate of the transformer: The average load ratio of a transformer is defined as the ratio of the apparent power of the average output of the transformer to the rated capacity of the transformer over a certain period of time. Multiply the average load factor of the load curve by a multiple greater than 1, the higher the average load factor of the load curve. The transformer capacity should be selected according to the calculation load, for a single transformer that supplies power to a smooth load, the load rate is generally about 85%.

\[
\beta = \frac{S}{Se}
\]

where \(\beta\) is the load rate of the transformer \(S\) is the transformer load capacity (kVA); \(Se\) is the capacity of the transformer (kVA).

3. Construction of Evaluation Index system of Investment benefit of Power Grid Project

On the basis of designing the evaluation index system of investment benefit of power grid project, a questionnaire survey is conducted among experts, scholars, technicians and managers in power grid related fields, and the relative importance of each index is investigated and evaluated. After collecting the data of each evaluation index under the power grid reform, this paper uses AHP to analyze the data, collated the weight judgment matrix of the evaluation index.

3.1. The First-level Evaluation Index Weight

The first-order index weight judgment matrix A-B of evaluation as follow:

\[
A - B = \begin{pmatrix}
1 & 2 & 3 & 2 \\
1/2 & 1 & 2 & 2 \\
1/3 & 1/2 & 1 & 1/2 \\
1/2 & 1/2 & 2 & 1
\end{pmatrix}
\]

By calculating the weight values of each index, the results are as follows:

\[
W^{(1)} = (0.418, 0.271, 0.120, 0.191) \quad CR=0.0266 < 0.1
\]

The consistency test index of the weight judgment matrix is 0.0266, and less than 0.1, which indicates that the weight judgment matrix satisfies the consistency test, and the weight results is scientific and effective.
3.2. The Second-level Evaluation Index Weight
The second-level index weight judgment matrix B-C of evaluation as follow:

\[
B_1 - C = \begin{bmatrix}
1 & 1/2 & 1/2 \\
2 & 1 & 1/2 \\
2 & 1 & 1
\end{bmatrix}
\]

\[W_1^{(2)} = (0.196, 0.322, 0.493)\quad \text{CR}=0.0520 < 0.1\]

\[
B_2 - C = \begin{bmatrix}
1/2 & 1 & 2 \\
1/3 & 1/2 & 1
\end{bmatrix}
\]

\[W_2^{(2)} = (0.163, 0.540, 0.297)\quad \text{CR}=0.0342 < 0.1\]

\[
B_3 - C = \begin{bmatrix}
5 & 1 & 3 \\
3 & 1/3 & 1
\end{bmatrix}
\]

\[W_3^{(2)} = (0.105, 0.637, 0.258)\quad \text{CR}=0.039 < 0.1\]

\[
B_4 - C = \begin{bmatrix}
1/3 & 1 & 1/2 \\
1/2 & 2 & 1
\end{bmatrix}
\]

\[W_4^{(2)} = (0.163, 0.0297, 0.540)\quad \text{CR}=0.0143 < 0.1\]

The consistency test indexes of the above judgment matrices are less than 0.1, so the results are scientific and reliable.

4. The Comprehensive Benefit Evaluation Model
According to the weight calculation result, the investment benefit evaluation model of the power grid project is obtained as follows:

\[\text{Investment benefit (A)} = (0.418, 0.271, 0.120, 0.191)\quad (B_1, B_2, B_3, B_4)^T\]

Where

\[B_1 = W_1^{(2)} \cdot C_{1-3}^T = (0.196, 0.322, 0.493) \cdot (C_1, C_2, C_3)^T\]

\[B_2 = W_2^{(2)} \cdot C_{4-6}^T = (0.163, 0.540, 0.297) \cdot (C_4, C_5, C_6)^T\]

\[B_3 = W_3^{(2)} \cdot C_{7-9}^T = (0.105, 0.637, 0.258) \cdot (C_7, C_8, C_9)^T\]

\[B_4 = W_4^{(2)} \cdot C_{10-12}^T = (0.163, 0.0297, 0.540) \cdot (C_{10}, C_{11}, C_{12})^T\]

5. Conclusion
The paper designed the evaluation index system of the power grid projects’ investment benefits under the reform of transmission and distribution price. After collecting the relevant importance data of the evaluation index through the form of the questionnaire, the AHP is adopted to determine the weight of each index, and finally, the comprehensive benefit evaluation model is constructed. This paper can provide the scientific support and reference for improving the investment efficiency of the power grid companies.

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