Benefit evaluation of power grid project based on matter-element extension model

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Abstract. Under the background of power market reform, power grid enterprises should continue to expand new business and new mode. Based on the background of power reform, this paper constructs the power grid evaluation index system considering the economic, technical and social aspects, and uses the variable weight theory to determine the weight of each index. The matter-element extension comprehensive evaluation model based on the ideal interval method is used to evaluate the benefits of power grid projects. It lays a theoretical foundation for the formulation of marketing strategy and the promotion of economic benefits of power grid company.

1. Introduction

Many countries have carried out power market reform according to their national conditions. For example, the United States is currently adjusting and improving the power market system in response to the problems of insufficient investment in the power market and large-scale development of renewable energy [1]. Japan's new round of power market reform is to fully liberalize the competition on the sales side and realize the legal separation of power generation and distribution business [2]. Under the global low carbon background, China's green cycle strategy and energy transformation strategy continue to advance [3-4]. At the same time, in order to deepen the reform of electric power market and promote the optimal allocation of electric power resources, China began to enter the implementation stage of electric power system reform since 2002. China's power grid enterprises are gradually separating the main business of the power grid from the auxiliary industries such as power equipment manufacturing, power transmission and transformation construction teams and exploration and design. After the release of document No. 9 of the CPC Central Committee, the reform of the electric power system was accelerated, and the incremental distribution market and the power selling side were liberalized. This enables power grid enterprises to have first-mover advantages in power operation system adjustment, power grid construction transformation and corresponding value chain remodeling, etc., and can win more opportunities in a more open market. Based on this background, this paper constructs the benefit evaluation method of variable weight matter-element extension model based on the ideal interval method, and puts forward the project comprehensive decision-making method to improve the comprehensive benefit.
2. The influence of electricity reform on the benefit of power grid project

Power grid enterprises have suffered a great impact in this round of electricity reform. Although power grid enterprises still participate in the market competition of the power distribution side and are in a strong position in the field of power transmission, in a sense, the "three release and one independence" of article 9 has stripped power grid companies of their pricing, quantitative and trading rights. The loss of these rights makes power grid enterprises transform from power traders to logistics providers, and the profit model has fundamentally changed.

Power grid enterprises should constantly explore new business models and create profit growth points. The company is mainly engaged in the electricity purchase and sale business, providing electricity sale, trading strategy consulting, electricity purchase agent trading and other related businesses. At the same time, in order to attract customers, it will also provide energy management and other energy use services, which will impact the energy service industry of three industries under the power grid enterprises [5]. In view of the increasingly competitive electricity sales market, power grid enterprises should turn from "passive" to "active" to maintain their existing market share, extend the service chain, and create new profit growth points. Power grid enterprises can carry out different value-added services according to their own characteristics and advantages to maximize meet the energy needs of different types of users.

Table 1. Comprehensive evaluation index system for substation projects.

| First grade indexes | Second grade indexes | Third grade indexes |
|---------------------|----------------------|---------------------|
| Economic index      | Project profitability| Financial net present value |
|                     |                      | Financial internal rate of return |
|                     |                      | Payback period |
|                     |                      | Profit and tax investment ratio |
|                     | Project liquidity    | Asset-liability ratio |
|                     |                      | Debt-service provision ratio |
|                     |                      | Interest coverage ratio |
| Technical index     | Rationality of power system | Reliability of relay protection |
|                     |                      | Reliability of dispatching automation |
|                     |                      | Reliability of communication |
|                     | Rationality of electricity | Intelligent level of equipment |
|                     |                      | Rationality of overvoltage protection |
|                     |                      | Rationality of electrical equipment layout |
|                     |                      | Rationality of secondary connection |
|                     |                      | Rationality of element protection |
|                     | Rationality of operational | Rationality of power supply |
|                     |                      | Failure rate of primary device |
|                     |                      | Pass rate of comprehensive voltage |
|                     | Rationality of other specialized target | Rationality of civil part |
|                     |                      | Rationality of hydraulic part |
|                     |                      | Rationality of fire protection |
|                     |                      | Rationality of safety and hygiene of labour |
| Social index        | Socio-economic impact | The extent of local economic develop promotion |
|                     |                      | Local employment promotion rate |
|                     | Environmental impact | Influence of sewage |
|                     |                      | Influence of noise |
|                     |                      | Influence of electromagnetic radiation |
3. The benefit evaluation method considering new situation after electricity reform

3.1. Construction of benefit evaluation system

The accuracy of the result of comprehensive benefit evaluation and the rationality of the evaluation index system are very important. Therefore, a perfect index system must be established according to relevant theories and the actual situation of the project. In this section, the comprehensive benefit evaluation index system of the project will be constructed, and the indexes will be screened considering the index variability and electrical reform requirements, so as to lay a foundation for the comprehensive evaluation of the project in the following part[6-7]. The project comprehensive evaluation index system will be constructed from the perspectives of economy, technology and sociality.

The project evaluation index is divided into economic index, technical index and social index, and the three-level evaluation index system of project benefit is designed[8]. Taking substation project as an example, this paper constructs a three-level index evaluation system, as shown in Table 1.

3.2. Construction of extension model of variable weight element based on ideal interval method

This paper adopts the extension method of variable weight element based on the ideal interval method to establish a comprehensive evaluation model of the project[9]. Matter-element extension theory consists of two parts, matter-element theory and extension theory. Matter element is the reflection of the quality and quantity of things, which can clearly show the relationship between quality and quantity and its change process. The core of extension theory lies in creativity, including the laws that creativity generally needs to follow and the methods of creativity.

3.2.1. The determination of classical domain and node domain. Firstly, let $R$ be the matter element, $C_i$ be the feature $P$, $v_j$ be the feature value, and the matter element matrix be denoted as:

$$
R = (P, C, V) = \begin{bmatrix}
    p & c_1 & v_1 \\
    c_2 & v_2 \\
    \vdots & \vdots \\
    c_n & v_n 
\end{bmatrix}
$$

(1) Determining the matter-element matrix in the classical domain

The matter-element matrix composed of $P_i$, feature $C_j$, and the standard range of features is the matter-element matrix in the classical domain, denoted as $R_i$.

$$
R_i = (P_i, C_j, V_i) = \begin{bmatrix}
    p_i & c_{i1} & v_{i1} \\
    c_{i2} & v_{i2} \\
    \vdots & \vdots \\
    c_{in} & v_{in} 
\end{bmatrix} = \begin{bmatrix}
    p_i & c_{i1} & \{a_{i1}, b_{i1}\} \\
    c_{i2} & \{a_{i2}, b_{i2}\} \\
    \vdots & \vdots \\
    c_{in} & \{a_{in}, b_{in}\} 
\end{bmatrix} 
$$

(2) Determining the matter-element matrix in the node domain

The matter-element matrix composed of thing $P_i$, feature $C_j$ and their extended range of features is the matter-element matrix in the node domain, denoted as $R_p$.
Where, $p$ is the total evaluation grade, section area $\nu_{pj} = [a_{pj}, b_{pj}]$ is the range of the measure value of index $C_j$ for $p$, where $a_{pj} = \min a_j$, $b_{pj} = \min b_j$, $j = 1, 2, \cdots, n$.

(3) Determining the matter-element matrix to be measured

For something $P_0$ to be evaluated, the value of the $j$ evaluation index $C_j$ is $\nu_j$, and the matrix to be measured is denoted as $R_0$:

$$ R_0 = (P_0, C_j, V_j) = \left[ \begin{array}{ccc} P_0 & c_1 & \nu_1 \\ c_1 & \nu_2 \\ \vdots & \vdots \\ c_n & \nu_n \end{array} \right] $$(4)

Where, $P_0$ represents the comprehensive evaluation of the project; $\nu_j$ is the actual index value of index $C_j$ for $P_0$.

(4) Normalization of indicators

The classical domain and the object element to be measured are normalized by formula (5) to solve the problem that the value of correlation function cannot be calculated.

$$ x_j = \begin{cases} 1, x_j \geq b_p \\ \frac{x_j - a_p}{b_p - a_p}, a_p \leq x_j \leq b_p, j = 1, 2, \cdots, n \\ 0, x_j \leq a_p \end{cases} $$(5)

3.2.2. Variable weight theory determines weights. In this paper, the variable weight theory is used to determine the variable weight, so as to distinguish the difference between the indicators, so as to ensure the accuracy of the final results.

(1) Determination of normal weight - analytic hierarchy process

If $W = (w_1, w_2, \cdots, w_n) \in (0,1]^n$ satisfies $\sum_{j=1}^{n} w_j = 1$, Which called constant weight variable. AHP is adopted in this paper to determine the normal weight.

The basic steps of AHP are as follows:

1) use Saaty and 1-9 scale method to compare pairwise indicators of the same layer, establish judgment matrix, and carry out normalization processing.

2) calculate the maximum eigenvalue of the judgment matrix $\lambda_{\text{max}}$.

$$ \lambda_{\text{max}} = \sum_{j=1}^{n} \frac{(AW)_{jj}}{W_j} $$(6)

(2) Consistency check

$$ CI = \frac{\lambda_{\text{max}} - n}{n - 1}, CR = \frac{CI}{RI} $$}(7)
The random consistency index table was used to find the $RI$ value. When $\frac{CR}{RI} < 0$, the consistency requirement is satisfied, otherwise, the judgment matrix is re-constructed.

(2) Determination of variable weight

If the mapping $W : [0,1] \rightarrow (0,1]^n$ satisfies the following conditions, it is called variable weight vector $W(X) = (\omega_1(X), \omega_2(X), \cdots, \omega_n(X))$:

Normalization: $\sum_{j=1}^{n} \omega_j(X) = 1$.

Continuity: $\omega_j(X)$ is continuous with respect to $x_j$.

Punishment and motivation: $\exists \alpha_j, \beta_j \in (0,1], \alpha_j \leq \beta_j$, $\omega_j(X)$ decreases when $x_j \in (0, \alpha_j)$ and increases when $x_j \in (\beta_j, 1]$.

(3) State vector

If $S : [0,1] \rightarrow (0, \infty)^n, S(X) = (S_1(X), S_2(X), \cdots, S_n(X))$ is state variable weight vector, $\exists \alpha_j, \beta_j \in (0,1], \alpha_j \leq \beta_j, S_j$ decreases when $S_j \in (0, \alpha_j)$ and increases when $S_j \in (\beta_j, 1]$. 

$$W(X) = \frac{WS(X)}{\sum_{j=1}^{n} \omega_j S_j(X)} = \left( \frac{\omega_1 S_1(X)}{\sum_{j=1}^{n} \omega_j S_j(X)}, \frac{\omega_2 S_2(X)}{\sum_{j=1}^{n} \omega_j S_j(X)}, \cdots, \frac{\omega_n S_n(X)}{\sum_{j=1}^{n} \omega_j S_j(X)} \right) (8)$$

(4) Balanced function

If $\frac{\partial B}{\partial x_j} = S_j(X), B(x_1, x_2, \cdots, x_n)$ is balanced function and put it into (8).

$$\omega_j = \frac{\omega_j \frac{\partial B}{\partial x_j}}{\sum_{j=1}^{n} \omega_j \frac{\partial B}{\partial x_j}} (9)$$

3.2.3. Calculation of posting progress based on ideal interval methods. In this paper, the ideal interval method of multi-objective decision-making is applied to determine the comprehensive evaluation standard of the project. On this basis, the actual value of each index is compared with the ideal interval[10], the distance difference is calculated, and the reciprocal of the distance difference is obtained. Then normalize the reciprocal of these distance differences to get the degree of closeness and take its maximum value. The grade corresponding to the maximum degree of closeness was taken as the comprehensive evaluation result of the sample.

After standardized treatment, the index $j$ of the object to be evaluated is written as $v_j \ (j = 1, 2, \cdots, n)$, and the ideal interval number is $[a_{ij}, b_{ij}] \ (i = 1, 2, \cdots, m, j = 1, 2, \cdots, n)$. After standardized treatment, the ideal interval number is $[a_{ij}', b_{ij}']$. Distance $D_i$ is:

$$D_i = \sum_{j=1}^{n} w_j d(i, j) (10)$$

The reciprocal distance is used to represent the closeness degree to describe the evaluation results of each index, and the grade corresponding to the maximum of the normalized Posting progress is taken as the comprehensive evaluation result of the evaluation object.

$$R_i = \frac{1}{D_i} / \left( \sum_{i=1}^{n} \frac{1}{D_i} \right), i = 1, 2, \cdots, m (11)$$

The element to be evaluated belongs to the grade $i^*$ from $R_i = \max \{R_j\}$.
4. The project synthesis decision method that promotes comprehensive benefit

Under the new situation of electricity reform, adopting certain decision-making methods can help improve the comprehensive benefits of power grid projects. Based on the influence of the above mentioned electricity reform on projects, this section puts forward decision-making suggestions from three aspects of economy, technicality and sociality[11].

(1) Economy

Power grid enterprises have the natural advantages of user resources and power grid platform, and also have obvious disadvantages in gas, water, cooling, equipment manufacturing and other specialized segments. To build energy Internet, the key is still to find out their own positioning in the network ecology. As a platform to explore and extend customer needs as much as possible, and to provide customers with more alternative energy use solutions. With more choices for users, the scope of energy interconnection will be broader. Grid enterprises can provide customers with power supply services and energy value-added services. Power grid enterprises can create profit points from two aspects of strengthening core business strength and expanding value-added business and improve enterprise benefits.

(2) Technicality

Make use of energy Internet, widely use cloud computing, big data technology. The upstream of electricity sales business carries the supply side of power generation, transmission and distribution, and distribution, while the downstream carries multi-dimensional customers such as industry and commerce, residents, parks, etc. In the future, enterprises will be the managers and users of power big data resources. Based on these massive data, the cloud platform can be used to fully understand the diverse forms of energy demands of users, customize innovative comprehensive energy solutions for users, and achieve energy saving, emission reduction and power cost reduction for different users.

(3) Sociality

Strengthening the analysis of the construction scheme of the technical support system for power grid energy-saving power generation scheduling can guarantee the stable operation of the system, enhance the efficiency of power grid energy-saving power generation scheduling, reduce the energy consumption in the process of power grid scheduling, so as to realize the maximization of social benefits of power grid. Realize the goal of this development, need from multiple aspects, according to industry specifications and energy-saving power grid scheduling support system construction requirements, specific construction key points of construction scheme, the use of advanced the concept of reliable technology measures enriched the contents of the system construction scheme and minimize the energy consumption in the process of power grid dispatching.

5. Conclusions

Based on the background of the new round of power reform in China, this paper analyzes the impact of the new round of power reform on the company's project benefits. Power grid enterprises have suffered a great impact in this round of power reform, which has a certain impact on power grid efficiency from three aspects of economy, technology and sociality. Under the background of power reform, the company should strengthen the development of core business, constantly expand new business, and create profit growth points. Secondly, considering the economy, technology and sociality of power grid projects, this chapter establishes the project comprehensive evaluation model based on the extension method of variable weight matter element based on the ideal interval method. Finally, based on the above background and model, the paper puts forward the concrete comprehensive decision-making method of improving the company's project. Under the background of the new power reform, power grid companies should find their own positioning in the network ecology, expand personalized user services, and comprehensively utilize the new generation of information technology to maximize the social benefits of power grid.
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