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OPTIMAL SELECTION ON POWER GRID TRANSMISSION AND TRANSFORMATION PROJECTS BY A HYBRID MCDM METHOD

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ABSTRACT

Selecting the optimal power grid transmission and transformation project (TTP) is quite important, which can ease financial pressure and promote sustainable development of power grid enterprise. In this paper, the optimal TTP is selected by employing a hybrid MCDM technique. After the evaluation index system was built, the index weights were determined by entropy weighting method. Then, the performance scores of three TTPs were valued by employing grey clustering decision-making model (GCDM). The empirical analysis result shows TTP#3 should be selected as the optimal one due to its highest integrated clustering coefficient. This hybrid MCDM method is effective and practical, which can be employed in the optimal TTP selection issue.

KEYWORDS: transmission and transformation projects; optimal selection; entropy weighting method; GCDM

INTRODUCTION

The electric power industry is an important and essential energy industry in the national economic development. The development of electric power industry plays a vital role in the economic and social development of a country [1]. The electric power projects need large investment, the construction of which will bring big impact on the enterprise and local development. In recent years, with the continuous reform of electric power industry and rapid development of national economy in China, the power grid enterprises need large capital to support the power grid construction to meet the need of economic development [2]. However, as a limited financial resources-oriented enterprise, the power gird enterprise needs other supports from external environment to help perform the construction of grid projects. Therefore, in this context, the rational selection on power grid projects becomes quite important, which can relieve the financial pressure, improve the profitability, and promote the sustainable development of power grid enterprises [3].

To perform scientific and reasonable selection on power grid transmission and transformation project (TTP), this paper employs a hybrid multiple criteria decision making (MCDM) method to tackle this practical issue. First, the evaluation index system was built. Then, the weights of index were determined by entropy weighting method. Finally, the TTPs were comprehensively evaluated and the optimal TTP was selected by grey clustering decision-making model (GCDM). This research can provide certain references for grid power project managers.

BUILDING EVALUATION INDEX SYSTEM

Building a scientific and effective evaluation index system for TTP selection is a very important work. A scientific and reasonable index system should follow the following principles: comprehensiveness, significance, simplicity, and maneuverability [4-5]. Based on the aforementioned principles, the evaluation index system for optimal TTP selection was built, as shown in Figure 1. From Figure 1, it can be seen that the evaluation index system for optimal TTP selection includes six indicators, namely internal rate of return (C1), payback period of investment (C2), net present value (C3), technical reliability (C4), social risk (C5), and environmental protection benefit (C6). Those six indicators represent the economic, technical, social and environmental aspects which are considered as the important selection criteria of TTPs.

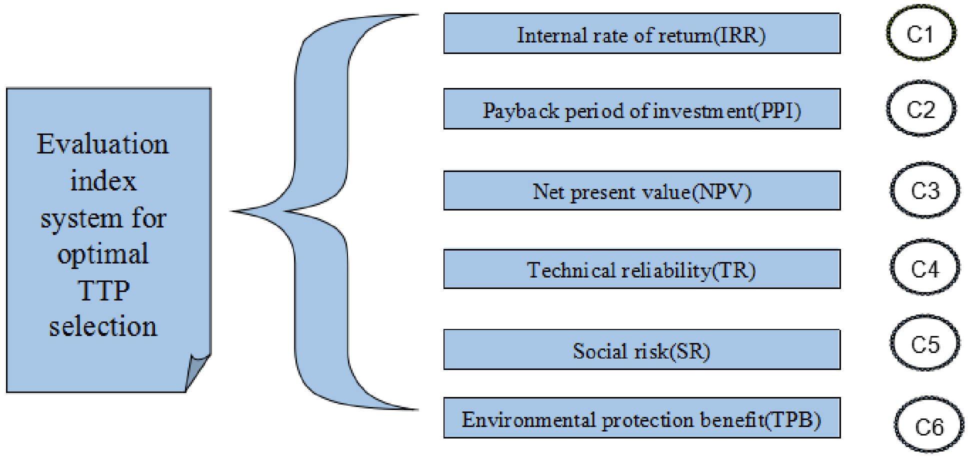

Figure 1. Evaluation index system for optimal TTP selection

ENTROPY WEIGHTING AND GCDM METHODS

In this section, the basic theories of entropy weight method and grey clustering decision-making model (GCDM) method will be introduced.

Entropy weighting method

Entropy weighting method is an objective method for index weight determination, and it can effectively reflect the information essence and measure the useful information of the provided data [6].

The procedure of index weight determination for optimal TTP selection is as follows.

Step 1: Suppose h_{ij} be the index value of alternative A_i in terms of index C_j. Let *m* and *p* represent the numbers of alternatives and index, respectively. Define

$$H = \left[h_{ij}\right]_{m\times p}, \quad i=1,2,\cdots,m, \quad j=1,2,\cdots,p \tag{1}$$

$$H_j = \sum_{i=1}^{m} h_{ij}, \quad j=1,2,\cdots,p \tag{2}$$

Step 2: Calculate the entropy value of index C_j.

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m}\frac{h_{ij}}{H_j}\ln\frac{h_{ij}}{H_j} \tag{3}$$

where . $e_j \geq 0$

Step 3: Calculate the weight of index C_j.

$$\eta_j = \frac{1-e_j}{p-\sum_{j=1}^{p} e_j} \tag{4}$$

where $0 \leq \eta_j \leq 1$, $\sum_{j=1}^{p}\eta_j = 1$.

Grey clustering decision-making model (GCDM)

Grey clustering decision-making model is commonly used in the classification decision of things in the real world [7], and the basic steps are as follows:

Step 1: Divide the evaluation grey class

According to the characteristics of studied issue, the number of evaluation grey class needs to be firstly determined, namely *s*. Then, the center point of each grey class needs to be set, namely $\lambda_1, \lambda_2, \cdots \lambda_s$. Divide the range of all the evaluation index into *s* grey class, and suppose $\lambda_1, \lambda_2, \cdots \lambda_s$ as the representative of each grey class.

Step 2: Expand the grey domain of evaluation index

Expand the grey class domain in different directions, and add the grey class of '0' and 's+1' whose center points are λ_0 and λ_{s+1}. Then, we can obtain a new center point domain, namely $\lambda_0, \lambda_1, \lambda_2, \cdots \lambda_s, \lambda_{s+1}$.

Step 3: Calculate the whitening clustering coefficient of evaluation index

Connect the center points $(\lambda_k, 1), (\lambda_{k-1}, 1)$, and $(\lambda_{k+1}, 1)$, and then the triangle whitening function of center point $f_j^k(\bullet)(k = 1, 2, \cdots, s;\ j = 1, 2, \cdots, m)$ can be obtained, which *j* represents the evaluation index and *k* represents the grey class. The triangle whitening function of center point is as shown in Figure 2.

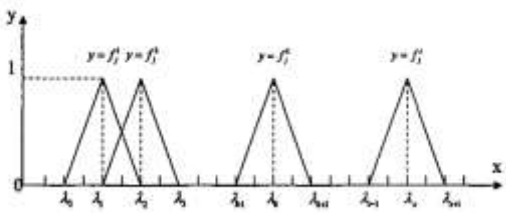

Figure 2. The triangle whitening function of center point

According to the evaluation value of index *j*, we can calculate its membership which belongs to the *k* grey class (*k*=1, 2, ⋯, *s*) according to Equation (5).

$$f_j^k(x) = \begin{cases} 0, x \notin [\lambda_{k-1}, \lambda_{k+1}] \\ \dfrac{x - \lambda_{k-1}}{\lambda_k - \lambda_{k-1}}, x \in (\lambda_{k-1}, \lambda_k] \\ \dfrac{\lambda_{k+1} - x}{\lambda_{k+1} - \lambda_k}, x \in (\lambda_k, \lambda_{k+1}) \end{cases} \quad (5)$$

Step 4: Calculate the integrated clustering coefficient

The integrated clustering coefficient σ_j^k can be calculated according to Equation (6).

$$\sigma_j^k = \sum_{j=1}^{m} f_j^k(x_{ij}) \bullet \eta_j \quad (6)$$

where $f_j^k(x_{ij})$ represents the whitening function, η_j represents the weight of index *j*.

Then, according to $\max_{1 \le k \le s}\{\sigma_i^k\} = \sigma_i^{k^*}$, we can judge the studied object belongs to the k^* grey class.

EMPIRICAL ANALYSIS

There are three TTPs need to be judged. The index performance details of three alternatives are listed in Table 1. The optimal TTP will be selected by employing Entropy weighting and GCDM methods. The selection procedure is shown as follows.

Table 1. Index performances of three TTPs

	IRR(%)	PT(year)	NPV(million yuan)	TR	SR	TPB
TTP#1	8.51	10.91	1563.45	8.9	8	9.2
TTP#2	8.39	10.99	2023.54	9.2	7	9

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TTP#3	8.23	11.11	1974.67	9.6	8.2	9.5

According to the performances of six indicators related to three alternatives, the index weight of those six indicators can be determined by employing entropy weighting method, and the result is listed in Table 2.

Table 2. Index weight

	C1	C2	C3	C4	C5	C6
Weight	0.01	0.003	0.666	0.05	0.245	0.026

Step 1: Divide the evaluation grey class

According to the evaluation index characteristics, the evaluation index is divided into four grey classes, namely 'Excellent', 'Good', 'Medium' and 'Poor'. Determine the center points of all grey class as $\lambda_1 = 0.9, \lambda_2 = 0.8, \lambda_3 = 0.7, \lambda_4 = 0.5$.

Step 2: Expand the grey domain of evaluation index

Expand the grey class domain in different directions, and add the grey classes of 'Best' and 'Worst' whose center points are $\lambda_0 = 1$ and $\lambda_5 = 0.3$. Then, we can obtain a new center points domain,namely $\lambda_0 = 1, \lambda_1 = 0.9, \lambda_2 = 0.8, \lambda_3 = 0.7, \lambda_4 = 0.5, \lambda_5 = 0.3$.

Step 3: Calculate the whitening clustering coefficient of evaluation index

Connect the center points $(\lambda_k, 1)$, $(\lambda_{k-1}, 1)$ and $(\lambda_{k+1}, 1)$, and we can get the triangle whitening function of center point $f_j^k(\bullet)(k = 1,2,3,4; j = 1,2,\cdots,6)$, which are given in Equations (7)-(10), respectively.

$$f_j^1(x) = \begin{cases} 0, x \notin [0.8,1], \\ \dfrac{x-0.8}{0.1}, x \in (0.8,0.9] \\ \dfrac{1-x}{0.1}, x \in (0.9,1), \end{cases} \tag{7}$$

$$f_j^2(x) = \begin{cases} 0, x \notin [0.7,0.9] \\ \dfrac{x-0.7}{0.1}, x \in (0.7,0.8] \\ \dfrac{0.9-x}{0.1}, x \in (0.8,0.9) \end{cases} \tag{8}$$

$$f_j^3(x) = \begin{cases} 0, x \notin [0.5,0.8] \\ \dfrac{x-0.5}{0.2}, x \in (0.5,0.7] \\ \dfrac{0.8-x}{0.1}, x \in (0.7,0.8) \end{cases} \tag{9}$$

$$f_j^4(x) = \begin{cases} 0, x \notin [0.3,0.7] \\ \dfrac{x-0.3}{0.2}, x \in (0.3,0.5] \\ \dfrac{0.7-x}{0.2}, x \in (0.5,0.7) \end{cases} \tag{10}$$

The index value needs to be firstly standardized. Then, put the standardized evaluation index values into Equations (7)-(10), and the whitening function value of all the evaluation indicators related to k grey class can be calculated. The results are listed in Table 3.

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Table 3. Whitening function value of six indicators related to three TTPs

Index	C1	C2	C3	C4	C5	C6
Grey class	TTP#1					
Excellent	0.00	0.00	0.00	0.73	0.75	0.32
Good	0.00	0.00	0.73	0.00	0.25	0.00
Medium	0.00	0.00	0.27	0.00	0.00	0.00
Poor	0.00	0.00	0.00	0.00	0.00	0.00
Grey class	TTP#2					
Excellent	0.14	0.07	0.00	0.42	0.00	0.53
Good	0.00	0.00	0.00	0.00	0.00	0.00
Medium	0.00	0.00	0.00	0.00	0.00	0.00
Poor	0.00	0.00	0.00	0.00	0.00	0.00
Grey class	TTP#3					
Excellent	0.33	0.18	0.24	0.00	0.54	0.00
Good	0.00	0.00	0.00	0.00	0.46	0.00
Medium	0.00	0.00	0.00	0.00	0.00	0.00
Poor	0.00	0.00	0.00	0.00	0.00	0.00

Step 4: Calculate the integrated clustering coefficient

According to Equation (6) and the obtained index weight, the integrated clustering coefficient of each index related to each alternative can be calculated, and the results are listed in Table 4.

Table 4. Integrated clustering coefficient of six indicators related to three TTPs

Grey class	TTP#1	TTP#2	TTP#3
Excellent	0.23	0.04	0.30
Good	0.55	0.00	0.11
Medium	0.18	0.00	0.00

Poor	0.00	0.00	0.00

According to $\max_{1\le k\le s}\{\sigma_i^k\}=\sigma_i^{k^*}$, it can be judged that the TTP#1 belongs to 'Good' grey class, TTP#2 and TTP#3 belong to 'Excellent' grey class. Therefore, the TTP#2 and TTP#3 show better performances than TTP#1. Meanwhile, according to the integrated clustering coefficient, TTP #3 obtains higher value than TTP#2. So, it can make the conclusion that TTP#3 is the optimal.

CONCLUSION

The construction of transmission and transformation project requires large-scale investment of fund from power grid enterprise. Therefore, selecting the optimal TTP can not only relieve the financial pressure, but also improve the profitability and promote the sustainable development of power grid enterprises. In this paper, the optimal TTP was evaluated and selected by a hybrid MCDM method, namely the entropy weighting method and GCDM. After building the evaluation index system, the index weight was determined by entropy weighting method. According to the empirical calculation, TTP#3 obtains the best performance score and should be selected as the optimal. This hybrid MCDM method is effective and practical, which can be employed for optimal TTP selection.

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