Research on Evaluation of Power Grid Investment Capability Based on TOPSIS Method

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Abstract. With the rapid development of China's national economy and the continuous improvement of people's living standards, the demand for electricity is increasing day by day; the investment scale of the power grid is also increasing. In order to evaluate the investment capacity of power grid scientifically , this paper constructs the evaluation index system of grid investment ability from five aspects: grid operating efficiency, grid operation efficiency, grid safety, coordination of power grid development and social environmental benefits, and constructs the TOPSIS comprehensive evaluation model on the basis of the weighted the order relation method. Finally, this paper uses examples to make an empirical analysis on the comprehensive evaluation of the investment capacity of the grid, and explores the reasons for the poor investment capacity of the power grid in individual year and puts forward relevant suggestions.

Introduction

The current domestic analysis of comprehensive evaluation on the investment ability of power grid and technology economy mainly concentrated on a single power project , and lack of macro control of the overall investment capacity of the grid. And it analyzes the economic benefit and market prospect of the power grid ,which is confined to condition of plant-grid separation in electricity market. Thus it ignores the impact of grid operation efficiency, power grid security, power grid development coordination, social and environmental benefits and other factors on the investment capacity of power grid.

Therefore, the existing evaluation index system can not reflect the power grid investment ability, and there are some problems such as repeated index and strong correlation. It is difficult for electric power companies to find the key points in the comprehensive evaluation of investment capability, so as to find out the problems in the operation management of power grid [1-2].

Construction of Evaluation Index System

Construction of Evaluation Index System. The evaluation of the investment ability of the power grid, that is, under the premise of meeting the national economic benefits, makes a comprehensive evaluation of the investment benefit of the grid, and the investment benefits include dominant benefits and recessive benefits. To establish the evaluation index system of power grid investment capacity, not only to meet the evaluation of the dominant benefits, including factors such as electricity sales, sales revenue, profit rate, but also to meet the assessment of recessive benefits, including power grid security, development, operation as well as environmental impact and other factors.

The investment capability evaluation of power grid belongs to the category of multi-attribute utility theory, which needs to compare and evaluate the comprehensive value formed by the factors such as economy, technology, management, development and environment. Therefore, this paper will build grid investment capability evaluation index system from five aspects of power grid operation benefit, power grid operation efficiency, power grid security, power grid development coordination and social environmental benefits.

Construction of Comprehensive Evaluation Model

Index Weighting Based on Order Relation Method. The order relation method is a subjective weighting method which is simple to compute and has good ordering and application. Firstly, the evaluation index should be qualitatively sorted according to expert experience, and then the importance of adjacent indexes is compared, and finally using the mathematical method to determine the weight by quantitative calculation [3-4].

The calculation procedure of order relation method is as follows:

Definite order relation

For an evaluation criterion, if the importance of the evaluation index x_i is greater than x_j, it is denoted as $x_i > x_j$.

For the evaluation index set $\{x_1, x_2, \cdots, x_n\}$, the specific steps of establishing order relations are as follows:

First of all, in the index set $\{x_1, x_2, \cdots, x_n\}$, the most important indicator is selected, which is denoted as x_1^*.

Then, in the remaining n-1 indicators, the most important indicator is selected, which is denoted as x_2^*.

Next, repeat the steps above and mark them to x_n^*.

Finally, the unique order relation $x_1 > x_2 > \cdots > x_n$ is determined.

Give the comparative judgment of the relative importance between x_{k-1} and x_k

The w_{k-1} / w_k is assigned as r_k to judge the ratio of the importance of the index x_{k-1} to the x_k, that is $w_{k-1} / w_k = r_k (k = n, n-1, \cdots, 2)$ .The assignment reference of r_k is shown in Table 1:

Table 1 The assignment reference table of r_k

r_k	Illustration
1.0	The index x_{k-1} is as important as the index x_k
1.2	Index x_{k-1} is a little more important than index x_k
1.4	Index x_{k-1} is evidently important than index x_k
1.6	Index x_{k-1} is intensely important than index x_k
1.8	Index x_{k-1} is extremely important than index x_k

Calculation of weight coefficient w_k

Suppose that the rational assignment of r_k satisfies the relation $r_{k-1} > 1/r_k$, $k = n, n-1, \cdots, 2$,then there is:

$$w_n = \left(1 + \sum_{k=2}^{n} \prod_{i=k}^{n} r_i\right)^{-1} \tag{1}$$

$$w_{k-1} = r_k w_k, \ k = n, n-1, \cdots, 2 \tag{2}$$

Finally, according to the above steps, the subjective weight of the evaluation index is determined to be $w' = (w_1', w_2', \cdots, w_n')$.

Construction of Evaluation Model Based on TOPSIS Method. The TOPSIS method, that is, the ranking method of approaching ideal solution, determines the ranking of the evaluated object by calculating the relative distance between the index vector of the evaluated object to the positive ideal solution and the negative ideal solution. If the index vector of the evaluated object close to the positive ideal solution and at the same time far away from the negative ideal solution, then the evaluation results were excellent; on the other hand, the evaluation of the effect of poor.

The application of TOPSIS method is not limited by the number of indicators, sample size, data distribution and other factors. It can be applied to multi-index and multi-dimensional comprehensive evaluation system, and the evaluation results can be horizontally compared and analyzed longitudinally. TOPSIS method is not only simple and flexible in the calculation process, but also its evaluation results are objective, comprehensive and accurate. It is widely used in the field of investment benefit evaluation, economic benefit evaluation, performance evaluation, risk assessment and so on [5-7].

The specific calculation process of power grid investment capability evaluation by using TOPSIS method is as follows:

Constructing weighted standardized decision matrices

The weighted decision matrix is obtained by using weighted combination to weight the decision matrix which is normalized by the Z-Score method:

$$x_{ij} = w_j \times z_{ij} \tag{3}$$

Where: x_{ij} is a weighted standardized decision matrix , w_j is a combination weight, z_{ij} is a standardized decision matrix.

Determine positive ideal solution and negative ideal solution

On the premise that the inverse index completes the forward processing, the ideal solution is determined to be

$$x_j^* = \max_i x_{ij} \tag{4}$$

The negative ideal solution is determined to be

$$x_j^0 = \min_i x_{ij} \tag{5}$$

Calculate the distance between solutions to positive ideal solution and negative ideal solution

The distance from the i-th scheme to the ideal solution:

$$d_i^* = \sqrt{\sum_{j=1}^{n} (x_{ij} - x_j^*)^2} \tag{6}$$

The distance from the i-th scheme to the negative ideal solution:

$$d_i^0 = \sqrt{\sum_{j=1}^{n} (x_{ij} - x_j^0)^2} \tag{7}$$

Calculate the queuing indication value of each scheme

Now using the queuing indicator value to conduct the comprehensive evaluation of the system. The calculation method of the queuing indicator value C_i is shown in Formula 3-21:

$$C_i = \frac{d_i^0}{d_i^* + d_i^0} \tag{8}$$

Among them, the greater the queuing indicator C_i, the stronger the grid investment capacity; otherwise, the weaker the grid investment capacity.

Empirical Analysis

This paper selects S-grid data for 2012-2016 years, and carries on the comprehensive evaluation to its annual investment capacity.

Determination of Weight of Evaluation Index. For the evaluation of the investment capacity of the grid, according to the expert's experience, the relative importance between the first level index layer and the two level index layer is determined. And the weight of each evaluation index is determined, as shown in Table 2:

Table 2 Weight of evaluation index

Two - level index	Weight
Unit electricity assets sale,[KWh / yuan]	0.052672
Power grid infrastructure investment accounts for the proportion of grid investment	0.052672
Unit sale revenue of power grid assets	0.043893
Growth rate of main business income	0.036578
Interest-bearing debt ratio	0.036578
Power supply load of unit grid assets,[KW/million yuan]	0.026127
Average load rate of transformer	0.072485
Average load rate of line	0.072485
Comprehensive line loss rate	0.060404
Average length of single circuit line,[Km]	0.043146
Comprehensive voltage qualification rate	0.060404
N-2 passing rate of double circuit lines on the same tower	0.060404
Availability factor of transformer equipment	0.043146
Availability factor of overhead line equipment	0.043146
Annual growth rate of electricity sales	0.051347
Annual growth rate of public substation capacity	0.042789
Annual growth rate of public line length	0.042789
Annual growth rate of electricity consumption in the whole society	0.035658
Renewable energy generating capacity,[million kwh]	0.034944
Save standard coal,[million tons]	0.034944
Sulfur dioxide emission reduction,[million tons]	0.029120
Carbon dioxide emission reduction,[million tons]	0.024267

Comprehensive Evaluation. Combined with the TOPSIS evaluation model introduced in the previous paper, the evaluation results of investment capacity of S-Grid in recent five years are shown in Table 3 and Fig. 1

Table 3 2012-2016 State Grid Hunan Electric Power Company investment ability queuing indicated value

Years	Distance from positive ideal point	Distance from negative ideal point	queuing indicated value
2012	0.3685	0.3520	0.4886
2013	0.3434	0.2812	0.4502
2014	0.3494	0.3446	0.4965
2015	0.2686	0.3292	0.5507
2016	0.2126	0.4185	0.6631

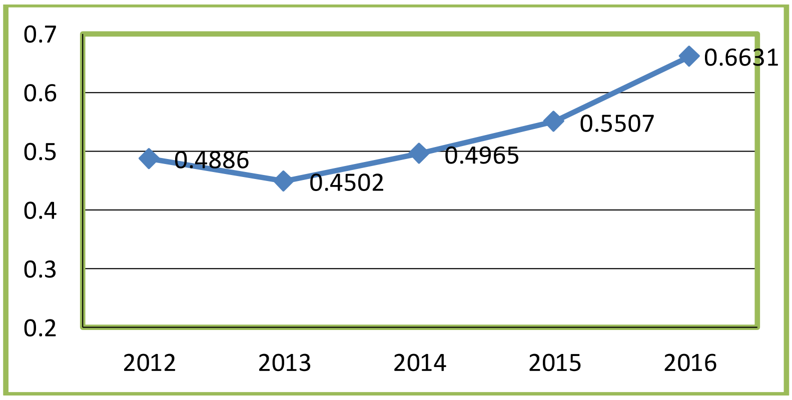

Figure 1. 2012-2016 years S-grid investment capacity queuing indicated value

Conclusions

According to the TOPSIS model calculation results, the ranking results of the annual investment ability of S province Power Company in 2012-2016 years are as follows: 2016> 2015> 2014> 2012> 2013. As can be seen from Table 6 and Fig.1, the queuing indicated index of the grid investment capacity was 0.4886 in 2012, the queuing indicated index in 2013 dropped to 0.4502, which is the lowest point in nearly five years. In 2014, it rose again to 0.4965, and maintained an upward trend in the next few years. The queuing indicated index of the grid investment capacity in 2016 rose to 0.6631. On the whole, the investment capacity of State Grid Hunan Electric Power Company in the past 2012-2016 years shows an increasing trend.

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