

Effect of Rural Power Grid Construction Evaluation Based on Entropy Method

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Abstract—Rural power grid is an important part of the power grid as it providing basic public services essential to people's livelihood. Construction of the rural power grid upgrades is benefit for the local economy. In this paper, a model for the rural power grid construction evaluation has been established based on the entropy method. The related index system is composed of 4 first-grade indexes and 13 second-grades indexes. This index system can be further divided into 8 incremental index and 5 decremental index of the 13 second-grades indexes. The weight of each index will be measured using entropy method. Comprehensive evaluation results for the rural power construction in specific area can be obtained. An example of the rural power grid evaluation was given to verify both the validity and practicability of this method. The establishment of this model provides a scientific basis for later rural power grid construction project.

Keywords—entropy method; rural power grid; construction effect; index system

I. INTRODUCTION

Rural power grid plays an important role in the whole power grid system [1]. It provides important infrastructure to serve the economic and social development at the county-level. Rural power grid upgrading projects are popular projects of the government as they can benefit farmers. The main purpose of these kind of project is to reduce the burden of electricity consumption of farmers so that their standard of living can be improved. The local economy and power market can also be energized by improving the situation of rural power grid.

In recent years, the progress of rural power grid upgrading project has been accelerated by many provincial grid corporations [2]. Significant economic and social benefits have been achieved. According to relevant regulations, it is necessary to summarize the reconstruction effect of this project at the end of each rural power grid upgrading project. Therefore, the research of rural power grid construction effect evaluation has the characteristics of timeliness and practicality, which is of theoretical significance to the rural power grid upgrading projects in the next stage.

Pervious researches on rural power grid upgrading projects mainly focus on the research of cost [3], finance [4] or related material and equipment [5]. Suggestions were given based on the qualitative discussions. Although effective suggestions for rural power grid upgrading project have been presented,

however, most of the evaluation methods were only applicable to the project before implementation rather than evaluate the construction effect after the completion of the project. In addition, most of these studies are based on a single aspect of study which is difficult to give convincing suggestions.

This paper focuses on the evaluation of the construction effect of rural power grid upgrading project. Comprehensive evaluation method which consisted by the evaluation index system and objective weighting method will be introduced

d. In order to present the construction effect of rural power grid upgrading project comprehensively and objectively, four first-grade indexes, namely operation level, network frame structure, power supply quality and power supply capacity were proposed. These four primary indexes were refined and the secondary index including 8 incremental indexes and 5 decremental indexes were obtained. Entropy weight method was adopted to determine the weights of first-grade and second-grade indexes. The weighted superposition of the weights and quantitative values of each index was carried out to obtain the comprehensive evaluation results of the rural power grid construction effect in each specific region. Finally, an example is given to verify the effectiveness of this model.

II. EVALUATION SYSTEM ESTABLISHMENT

The evaluation index is the basis for the evaluation of the construction effect. The selection of evaluation index depends on the evaluation purpose and requirements [6]. In addition, the selection of evaluation indexes should be compatible with the actual situation of each city to meet the requirements of generality and accessibility.

According to the selection principle, the index evaluation system of the construction effect of agricultural network is constructed into two levels. At each level, the evaluation system was established under the consideration of characteristics of rural power grid, literature review, case analysis, expert investigation and other methods. In the first level, the evaluation system consists of 4 first-grade indexes ($C_1 \sim C_4$) as the operation level, network structure, power supply quality and power supply capacity. The increase and decrease of all kinds of data before and after the implementation of the project can be calculated directly to reflect the construction results of the rural power grid upgrading project. Further refine the first-grade indexes leads to the second-grade indexes system ($D_1 \sim D_{13}$) which contains 8

incremental indexes and 5 decremental indexes. These characteristic indicators are all statistic results that indicate the project construction effect. This two-level evaluation index system and corresponding units are shown in Table I.

TABLE I. EVALUATION INDEXES WITH UNITS

| First-Grade Indexes | Second-Grade Indexes | Units |
|--|--|-------|
| Rural power gird structure C ₁ | Growth of the power gird maximum loads D ₁ | MW |
| | Growth of the electricity sale D ₂ | kWh |
| Rural power gird structure C ₂ | Growth of the interconnection rates for 10kV grid D ₃ | % |
| | Growth of "N-1" passing rate for 10kV grid D ₄ | % |
| Rural power supply quality C ₃ | Investment regarding to the low voltage issue D ₅ | yuan |
| | Growth of the reliability D ₆ | % |
| | Growth of the qualified voltage rate D ₇ | % |
| | Reduction of the average duration of customer interruptions D ₈ | hour |
| Rural power supply capacity C ₄ | Growth of the distribution and substation capacity for each household D ₉ | kVA |
| | Reduction of the number of overload line for 10kV grid D ₁₀ | / |
| | Reduction of the number of overload transformer D ₁₁ | / |
| | Reduction of the composite loss rate D ₁₂ | % |
| | Reduction of the length of small cross-section line D ₁₃ | km |

III. WEIGHT OF INDEX

A. Data Standardization

Second-grade indexes can be calculated using the index system. The index raw data matrix is shown below where n represents the number of cities, p represents the second-grade indexes and d represents the primary data [7].

$$D_{n \times p} = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1p} \\ d_{21} & d_{22} & \cdots & d_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{np} \end{bmatrix}$$

The units and order of magnitude for different indexes varies a lot, therefore, standard deviation method was adopted to standardize the primary data. The calculated indexes realize in an interval between 0 to 1. Transformation function is shown below, i represents the number of city and j represents the number of indexes.

$$d_{ij}^* = \frac{d_{ij} - \min d_j}{\max d_j - \min d_j} \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, p)$$

Where d_{ij}^* is the initial value of evaluation index $mind_j$ is the minimum initial value for indexes j and $maxd_j$ is the maximum initial value for indexes j .

B. Entropy Method

Entropy weight method is an objective weighting method which determines the index weight through quantitative analysis of the actual data to ensure the absolute objectivity of the weight [8]. This method calculates the entropy value of each index according to the entropy value function and then normalizes the entropy value to the index weight. Generally speaking, if the information entropy of an index is lower, the index is worth more variation which means more information can be provided. Indexes with more weight usually plays a greater role in the comprehensive evaluation process.

Assuming n represents the city and m represents the number of indexes, the entropy weight calculation process is shown below.

- (1) Calculation of the proportion

$$p_{ij} = \frac{D_{ij}}{\sum_{i=1}^n D_{ij}} \quad i = 1, 2, \dots, n; j = 1, 2, \dots, m \quad (1)$$

Where, P_{ij} is the weight of index j associated with city i , D_{ij} is the standardized data value of index j associated with city i .

- (2) Calculation of the Entropy e_j of index j

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (2)$$

- (3) Calculation of the information utility value f_j

$$f_j = 1 - e_j \quad (3)$$

- (4) Calculation of the weight w_j

$$w_j = \frac{f_j}{\sum_{j=1}^m f_j} \quad (4)$$

- (5) Calculation of the upper-level index weight

According to the additivity of entropy value, the information utility value of the lower structure can be used to determine the information utility value of upper structure. Sum the information utility value of each type of index at lower structure to obtain the information utility value of the upper structure D_k ($k=1, 2, \dots, K$), and then the upper index weight can be obtained consequently.

$$W_k = \frac{D_k}{\sum_{k=1}^K D_k} \quad (5)$$

By substituting the standardized data into the above steps, the weights of the first-grade and second-grade indexes can be obtained. The weights and quantitative values of each index can be calculated consequently. Finally, the comprehensive score values of each city can be obtained by weighted stacking process.

IV. CASE STUDY

Taking a province as an example, the comprehensive score of rural power grid upgrading construction effect of each city was calculated by taking each prefecture-level city as the basic unit. There are 18 cities in this province, and each city has 13 secondary evaluation indexes. The standardized data of each index are shown in Figure I. Depth of color and size of ellipse indicate the index value.

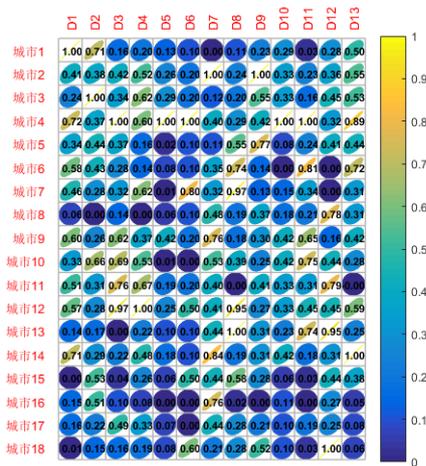


FIGURE I. EVALUATION INDEX VALUE FOR EACH CITY

Entropy weight method was then used to calculate the weights of the first and second grade indexes, results are shown in Table II.

TABLE II. THE SCALE MEANING OF JUDGMENT MATRIX

| First-grade indexes | Weight | Second-grade indexes | Weight |
|---------------------|--------|----------------------|--------|
| C ₁ | 0.1162 | D ₁ | 0.0713 |
| | | D ₂ | 0.0449 |
| C ₂ | 0.1317 | D ₃ | 0.0743 |
| | | D ₄ | 0.0574 |
| C ₃ | 0.4076 | D ₅ | 0.1481 |
| | | D ₆ | 0.1312 |
| | | D ₇ | 0.0472 |
| | | D ₈ | 0.0811 |
| | | D ₉ | 0.0501 |
| C ₄ | 0.3446 | D ₁₀ | 0.0745 |
| | | D ₁₁ | 0.0942 |
| | | D ₁₂ | 0.0614 |
| | | D ₁₃ | 0.0644 |

Among the first-grade indexes, the index weight of power supply quality C₃ of rural power grid is the largest, while that of operation level C₁ of rural power grid is the smallest. In the secondary index, the index weights of project investment associated with low voltage issue D₅, growth of power supply reliability rate D₆ and reduction of the number of overload distribution transformer D₁₁ are large. The index weights of power sales growth D₂, comprehensive voltage qualification rate growth D₇ and household distribution transformer capacity growth D₉ are small.

Weighted superposition of the weights and quantitative values of each index provides the comprehensive score of rural power grid upgrading construction effect in 18 cities. Results were shown in Figure II.

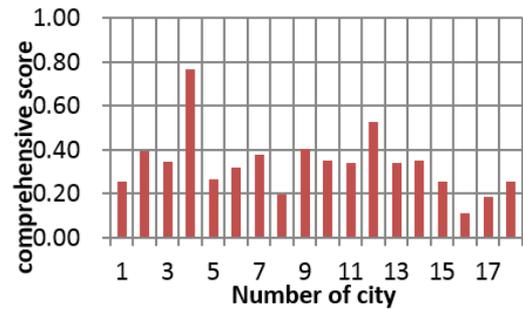


FIGURE II. COMPREHENSIVE SCORE

The top three cities with high scores were city 4, city 12 and city 9, while the bottom three cities with low scores were city 16, city 17 and city 8. It can be seen that the construction effect of rural power grid upgrading projects in city 4, city 12 and city 9 is relatively more obvious. The reason for the low scores of city 16, city 17 and city 8 may due to a better initial situation of the rural power grid construction, otherwise, the transformation project scheme needs to be improved in these areas.

Take city 4, city 12 and city 9 as the research objects, a detailed comparison of the scores was made between first-grade and second-grade indexes, results are shown in Figure III and Figure IV.

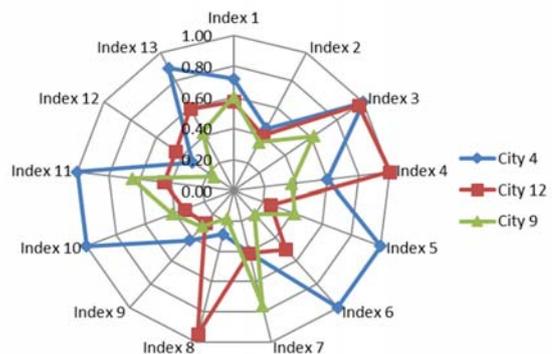


FIGURE III. SECOND-GRADE INDEXES SCORES

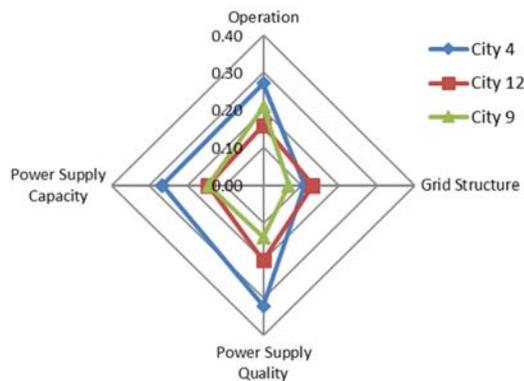


FIGURE IV. FIRST-GRADE INDEXES SCORES

As can be seen from the figure above, the construction effect of rural power grid in cities 4, 12 and 9 is highly rated. The second-grade indexes 5, 6, 10, 11 and 13 of city 4 have high scores which indicates that the operation level, power supply quality and power supply capacity are good. The second-grade indexes 3, 4 and 8 of city 12 have high scores which indicates the operation level, network structure and power supply quality are relatively good. The second-grade indexes 1, 3, 7 and 11 of city 9 have high scores indicates the operation level and power supply capacity are relatively good.

V. CONCLUSION

Rural power grid is the foundation of rural development. It is of great theoretical value and practical significance to evaluate the construction effect of rural power grid upgrading projects. This paper focuses on the evaluation of the construction effect of rural power network upgrading project. The comprehensive evaluation method combining with the evaluation index system and objective weighting method was introduced. Through the study, the following conclusions are drawn:

1. The evaluation index system established in this paper includes 4 first-grade indicators and 13 second-grade indicators, which can comprehensively and objectively reflect the construction effect of rural power grid upgrading projects.
2. There are many evaluation indexes for the construction effect of rural power grid upgrading projects, therefore, the data are complex. In this paper, entropy method is used to conduct quantitative analysis on the indexes and objectively determine the weight. Relatively good effect can be obtained.
3. The evaluation system introduced in this paper can objectively analyze the project construction effect at a certain stage. Results can be used to provide further guidance for later rural power grid upgrading construction project.

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