Research on Comprehensive Evaluation Method of Distribution Network Based on Entropy Weight Analytic Hierarchy Process

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Abstract

The comprehensive evaluation and analysis of distribution network and investment decision- making are com-plex and wide-ranging, therefore, the effective evaluation of power distribution system can help to summarize experience and provide scientific reference for investment decision making in the next stage. A comprehensive evaluation method of entropy weight-analytic hierarchy process has been proposed in this paper, combined with the advantages of entropy weight and analytic hierarchy process, establishing an evaluation index system of power distribution network investment decision, with comprehensive score as the goal layer, economic benefit, power supply reliability and coordination adaptability as the rule layer and the specific evaluation index as the index layer. Taking the 142 power supply stations as the research object, based on the comprehensive evaluation method of the method of entropy weight hierarchy analysis, the comprehensive scores of each power supply station in the past three years were calculated, and the composite scores were clustered.Suggestions on the investment efficiency of the distribution network will be put forward through the analysis of each power supply. The method proposed in this paper is effective for the evaluation and subsequent development of the distribution network by proving.

Keywords

Power distribution network; Comprehensive evaluation method; Composite scores; Investment decision-making; Entropy weight-analytic hierarchy process

1. Introduction

The development of large-scale distribution network construction, with many uncertainties and wide coverage, is a complicated and arduous system project. It is necessary to systematically explore the problems in the investment process of distribution network construction, propose corresponding construction investment proposals, and accelerate the upgrading of distribution systems. Power grid related indicators. In recent years, the scale of demand for construction and renovation of distribution networks with 10kV and below has increased year by year, while the approval investment for distribution network projects has been less, and each investment has to be fully utilized to maximize its benefits[1]. The comprehensive evaluation and investment decision-making of investment benefits for complex distribution systems are faced with many difficulties and involve many factors. Simply relying on the statistical results of unilateral indicators such as equipment size and load ratio, relying on qualitative analysis of expert experience to evaluate the distribution system, can no longer meet the needs of future scientific management of distribution systems. For an actual large-scale distribution system, it is a very challenging task to obtain technical evaluation results as a whole and to obtain detailed quantitative indicators at key points[2].

At present, many scholars have studied the evaluation methods of power grids. The literature[1] uses the analytic hierarchy process to establish the investment decision-making evaluation index system for distribution network construction projects and determine the optimal investment program; literature[3]from the overall investment benefits of power distribution, In terms of individual project investment efficiency, investment decision-making and other aspects, a 35 kV distribution network investment benefit evaluation model has been established in all directions; literature[4] has used data envelopment analysis method to establish a comprehensive evaluation model of rural power grid investment efficiency. Comprehensive Evaluation of Investment Benefits ; literature[5] has established a set of evaluation systems for county power grids using principal component analysis and system cluster analysis to achieve assessments of safety, economy, reliability, adaptability, and quality of county power grids. Then through the system cluster analysis method to develop the corresponding development path and the next stage of investment decisions; literature[6] introduced improved gray correlation analysis method to calculate the weight of the index system, which is used to evaluate the project's comprehensive investment effect. The literature[7] selects input-output benefit indicators based on key factors and proposes a comprehensive evaluation system for the input-output benefits of distribution network construction projects.

2. Building of Comprehensive Evaluation Model Based on Entropy Weight Analytic Hierarchy Process

In this paper, a comprehensive evaluation method based on entropy weight analytic hierarchy process method is proposed. The specific steps are as follows:

(1) For the distribution network object to be evaluated, collecting basic data for each indicator, and calculating the value of each indicator.

(2) Classifying the indicators according to their nature, constructing a hierarchical structure index system, and constructing a judgment matrix using the analytic hierarchy process,which can be seen from Table 1, further calculating the subjective weight values of each index and performing consistency check.

Table 1 Indicator Level Based on AHP

First-level Indicators	Second-level Indicators
Economic benefits A1	Comprehensive line loss rate B1
	Unit power distribution capacity B2
	New power supply in unit investment B3
	Unit investment loss reduction B4
Power supply reliability A2	Power supply reliability B5
	Average number of user outages B6
	User average power outage time B7
	Line N-1 pass rate B8
	Comprehensive voltage qualification rate B9
Coordinating adaptability A3	Contact rate B10
	Conductor cross section B11
	Capacity ratio B12
	Average capacity per household B13
	Cable rate B14

From Table 1, it can be seen that the target layer contains three elements: economic efficiency, power supply reliability, and coordination adaptability. The judgment matrix is constructed according to the 1-9 scale method.

$$G=\begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ 0.5 & 0.5 & 1 \end{bmatrix}$$

By solving the above judgment matrix G, the maximum eigenvalue of the matrix can be obtained, $\lambda_{\max}=3$, and the judgment matrix is verified to meet the consistency requirement. After the eigenvector corresponding to the maximum eigenvalue of the judgment matrix is normalized, it is the weight value of the corresponding index. The weights of A1-A3 are 0.4000, 0.4000, and 0.2000 respectively.

Similarly, the weights of B1-B14 are 0.4000, 0.2000, 0.2000, 0.2000, 0.1667、0.1667、0.3333、0.1667, 0.1667, 0.2000、0.2000、0.2000、0.2000 and 0.2000 respectively. Based on the above analysis, the total sorting weights of the analytic hierarchy process can be further found and all meet the consistency requirements.

(3) Using the entropy weight method to calculate the objective weight value.

(4) For the subjective weights in step (2) and objective weights in step (3), use the "addition" integration method to obtain the weight values of each index combination.

The calculation of weight with different methods from (2) to (4) can be seen in Table 2.

Table 2 Index weight with different methods

Index	AHP	Entropy	Entropy-ahp
B1	0.1600	0.0109	0.1103
B2	0.0800	0.0465	0.0688
B3	0.0800	0.0883	0.0828
B4	0.0800	0.1004	0.0868
B5	0.0667	0.0057	0.0463
B6	0.0667	0.1060	0.0797
B7	0.1333	0.0069	0.0912
B8	0.0667	0.0714	0.0682
B9	0.0667	0.0695	0.0676
B10	0.4000	0.0797	0.0532
B11	0.4000	0.1052	0.0617
B12	0.4000	0.0710	0.0503
B13	0.4000	0.1280	0.0693
B14	0.4000	0.1105	0.0635

(5) Calculate the score of each indicator based on the weights obtained in step (4) and the normalized values of each indicator.

(6) Add the scores of each index obtained in step (5) to get the comprehensive score of each evaluation object.

3. Comprehensive Cluster Analysis of Power Supply Stations

Combine the index normalization process and index combination weight values to obtain the comprehensive scores of each power supply station, and classify scores using clustering method. The number of power supply stations at each level for the period 2014-2016 is shown in Table 3.

Table 3 The number of grades of 142 power supply station from 2014 to 2016

	2014	2015	2016
A	1	10	22
B	53	63	64
C	84	69	56
D	4	—	—

From Table 3, we can see that from 2014 to 2016, the number of power supply stations with a comprehensive score rating "A" has risen significantly, and the number of "A" power supply accounts for 0.7% of the total in 2014. After two years of development, it accounted for 15.5%; within three years, the number of "B" grade power supply stations rose steadily, reaching a maximum of 64 in 2016, accounting for 45.1% of the total; the number of "C" grade power supply stations dropped significantly,from 84 in 2014 to 56 in 2016; the number of "D" grade power supply stations was 0 in 2015 and 2016, which was significantly improved compared to 2014. From the above table, it can be seen that the overall development of 142 power supply stations is on the rise, that is, the overall investment efficiency has played an active role in the past three years.

4. Conclusion

(1) This paper proposes a method of comprehensive evaluation of distribution network based on the method of entropy weight hierarchy analysis. This method combines the objective analysis of the entropy method and the subjective analysis of the analytic hierarchy process to meet the actual needs of the comprehensive evaluation of the distribution network power supply.

(2) Through the analysis of the comprehensive scores of 142 power supply stations, it has been found that the development status of the power supply stations in the city has been greatly improved and improved in the past three years, and further investment suggestions have been put forward for the current development status.

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