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Research on Evaluation System for Comprehensive Operation Capability of Distribution Network Based on Line

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Abstract: The existing distribution network evaluation system is based on the analysis of cities, the conclusions reached can only be used as a holistic evaluation instead of providing a specific direction for the next step of remediation. Therefore, a comprehensive evaluation system for medium-voltage distribution networks with more subtle levels based on lines is proposed. Firstly, find out the factors affecting the operation of the distribution network line through the logic tree, establish a comprehensive evaluation system through analytic hierarchy process. Secondly, determine the weight of the indicator and the scoring standard of the indicator value by the Delphi method. Finally, use the curve fitting to obtain the evaluation criterion function of the index, thereby a comprehensive evaluation system for medium voltage distribution network is formed. The evaluation system can reflect the development level of the distribution network between regions and provide direction for the rectification and management of the distribution network.

Keywords: Line; distribution network; evaluation; curve fitting.

1. INTRODUCTION

The medium voltage distribution network is an important part of the entire power grid. It includes the characteristics of large structure, large operational data and wide coverage. In recent years, with the rapid development of urban construction, higher requirements have been put forward for the planning and transformation of the distribution network, and the determination of the construction plan of the distribution network needs to be based on the evaluation and analysis of the distribution network [1]. Therefore, it is necessary to establish a comprehensive and scientific evaluation system for the distribution networks [2].

The traditional distribution network evaluation mainly evaluates the single aspect of the distribution network such as reliability, economy and power quality, but it cannot reflect the status of the distribution network as a whole, and the guiding significance for the construction of the distribution network is not strong. This paper conducts a comprehensive study on the evaluation indicators and uses the line as the basic research unit to construct an indicator evaluation system from multiple dimensions [3-4]. Finally, establish a comprehensive evaluation system model of distribution network based on line analysis and the operational requirements of the first-class distribution network.

2. EVALUATION THEORY BASIS

2.1 Analytic hierarchy process (AHP)

The core of AHP is to decompose a complex multi-objective decision problem into multiple goals or criteria and then decompose it into several levels of multiple indicators. AHP is a key technology for evaluating complex problems and constructing evaluation systems [5].

2.2 Delphi method

Delphi Method is a method which fully integrates expert knowledge, experience and information, it also known as expert scoring. Delphi Method is characterized by the evaluation of indicators, weights and scores through experts' experience and opinions, then better results would be obtained through continuous feedback modification.

3. DISTRIBUTION NETWORK COMPREHENSIVE EVALUATION SYSTEM

The evaluation object in this paper is the distribution network line. The operation of the line is to continuously meet the needs of stakeholders, maximize the benefits and achieve the goal of mutual benefit. At a macro level, stakeholder demand for distribution networks reflects a grid operation outcome, so the indicators which could reflect this type of problem can be attributed to indicators of resulting class. In order to meeting the needs of grid stakeholders, it is necessary to ensure the quality of the line. These indicators which reflect the structure of the line and the operating state are called the characteristic indicators. The operation of the line is inseparable from the development and application of advanced technology. It can be said that technology determines the future development of line operations, and the indicators that evaluate these technologies are called technical indicators.

3.1 Screening of indicators

Through the above analysis, it can be found that the technical indicators will affect the characteristic indicators, while the characteristic indicators will also affect the performance indicators and the indicators are coupled to each other. The characteristic indicators are able to affect the operation of the line directly. The content is complex and can be analyzed from three aspects: equipment level, power grid structure, intelligence level. The indicators of resulting class reflect the final result of the line operation. According to the requirements of the stakeholders for the distribution network, the indicators of resulting class can be summarized into four aspects: power supply capacity, power supply quality, operational efficiency and comprehensive benefits. Technical indicators are related to various areas of line operation which are very complicated and inseparable. Also they cannot affect the results directly. Therefore, technical indicators are not discussed in this paper.

The specific effects of the above seven aspects on line operations can be analyzed through a logical tree. For example, the impact of the grid structure on the line operation is mainly reflected in the power supply radius of the line and the contact rate of the line. The related factors are listed through the logic tree which are the specific indicators that affect the line operation.

The main factors of the characteristic indicators are shown in Fig. 1.

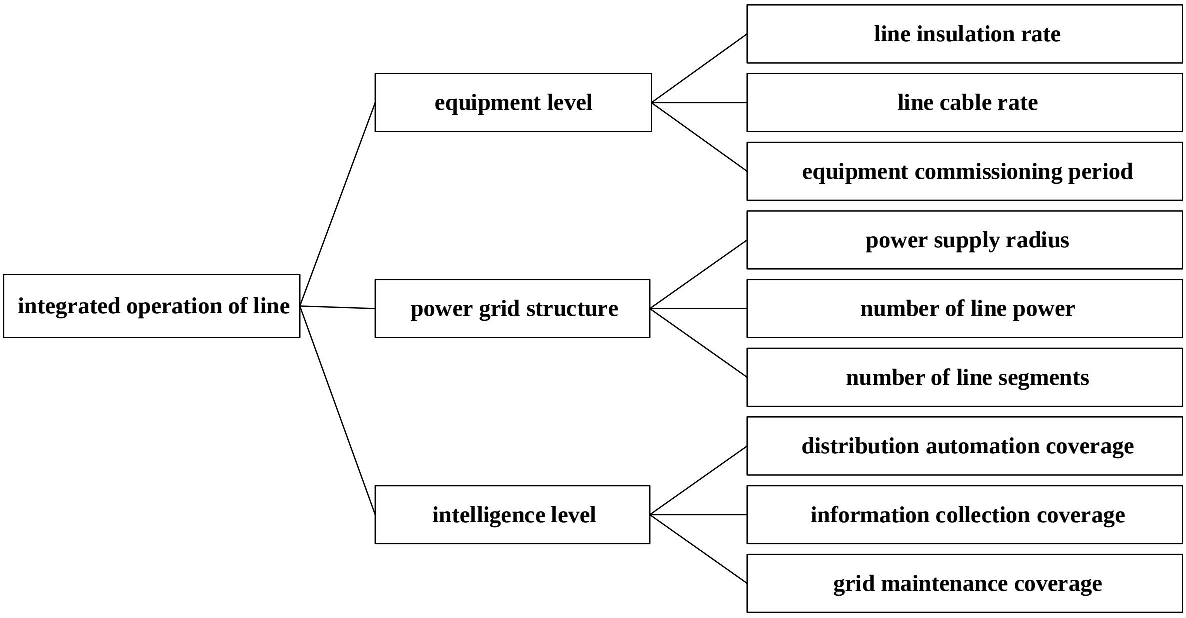

Fig 1. Phase analysis of arrangement

The factors that can affect the comprehensive operation of the line are mainly the failure rate and maintenance time of the equipment. The insulation rate of the line will affect the number of failures caused by external forces. The cable rate of the line improves the reliability of the power supply and the maintenance of the line. The commissioning period of the equipment in operation have an impact on the reliability of the line operation.

The impact of the grid structure on the line operation is it could minimize the power outage range and power outage time caused by the fault according to the grid rack. It is mainly reflected in the following aspects. Firstly, the load can be transferred out as soon as possible in the event of a failure. The main consideration is the backup and communication of the network. The indicator for the standby area is the average number of lines of power. The contact area includes the line contact rate and the inter-station contact rate. Secondly, it is necessary to minimize the scope of the impact of the fault and the main indicator involved is the average number of segments. The third is the convenience of operation when the network structure is adjusted. The indicator involved is the 10kV standby interval ratio of the substation.

The level of intelligence of the power grid has a greater impact on line operations. The implementation and coverage of distribution automation can effectively improve power quality and power supply reliability. The state maintenance of the power grid has the characteristics of high efficiency, strong predictability and good safety, which is an inevitable trend of line operation.

The main factors of the indicators of resulting class are shown in Fig. 2.

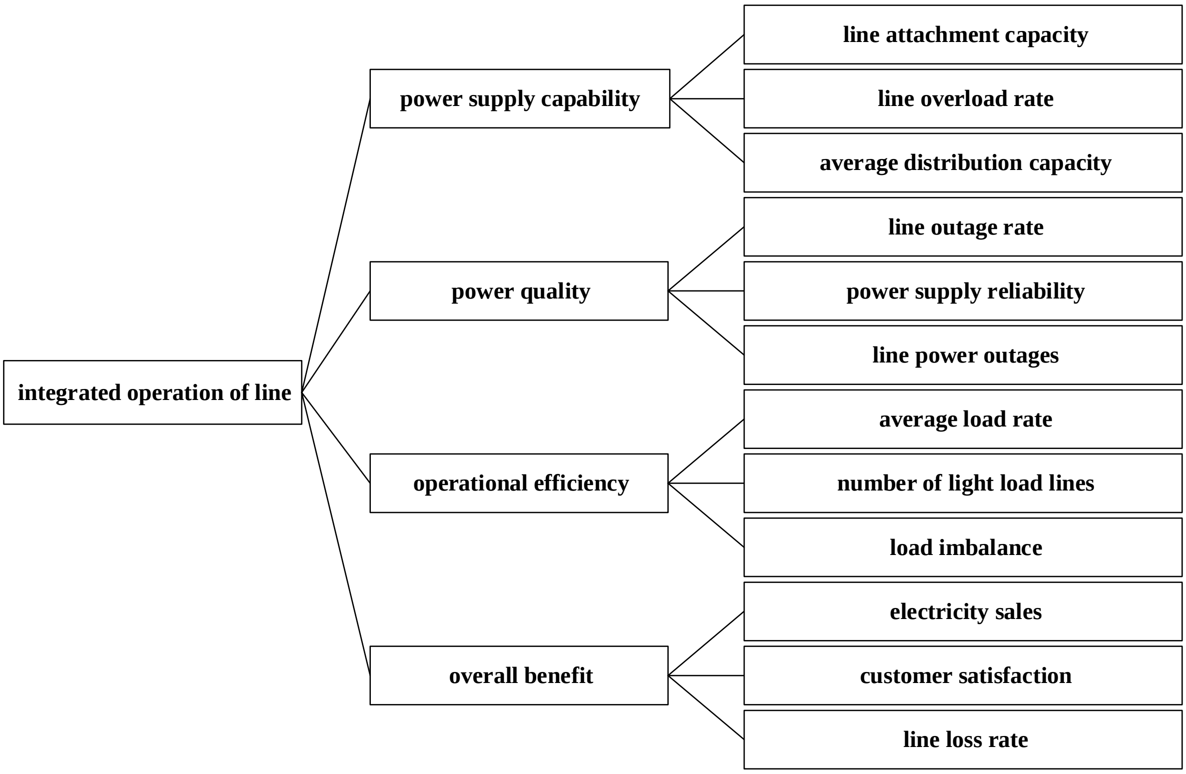

Fig 2. Analysis of indicators of resulting class

The same method could be used to analyze the factors which affect line operation from four aspects: power supply capability, power supply quality, operational efficiency and comprehensive benefits. After finishing these tasks the screening of the indicator of resulting class used for comprehensive evaluation of the distribution network would be completed.

3.2 Establishment of indicator system

The comprehensive evaluation system of the distribution network based on the line is shown in the figure. In Fig. 3, the seven indicators of equipment level, power grid structure, power supply capacity, power supply quality, operational efficiency, intelligence level and comprehensive benefits constitute the first level of indicators which related to the assessment target directly. Under each level of indicators, there are more detailed secondary indicators that constitute the next level of sub-attributes.

A reasonable indicator system is good for improving evaluation efficiency and evaluation results. The index system proposed in this paper is a three-layer structure with high degree of polymerization and simple structure. It can fully characterize the operation process of the distribution line with good integrity and adaptability. The underlying indicators have clear meanings and the basic data needed for calculation is obtained through statistics after collection. The data source is convenient to get and the calculation method is simple.

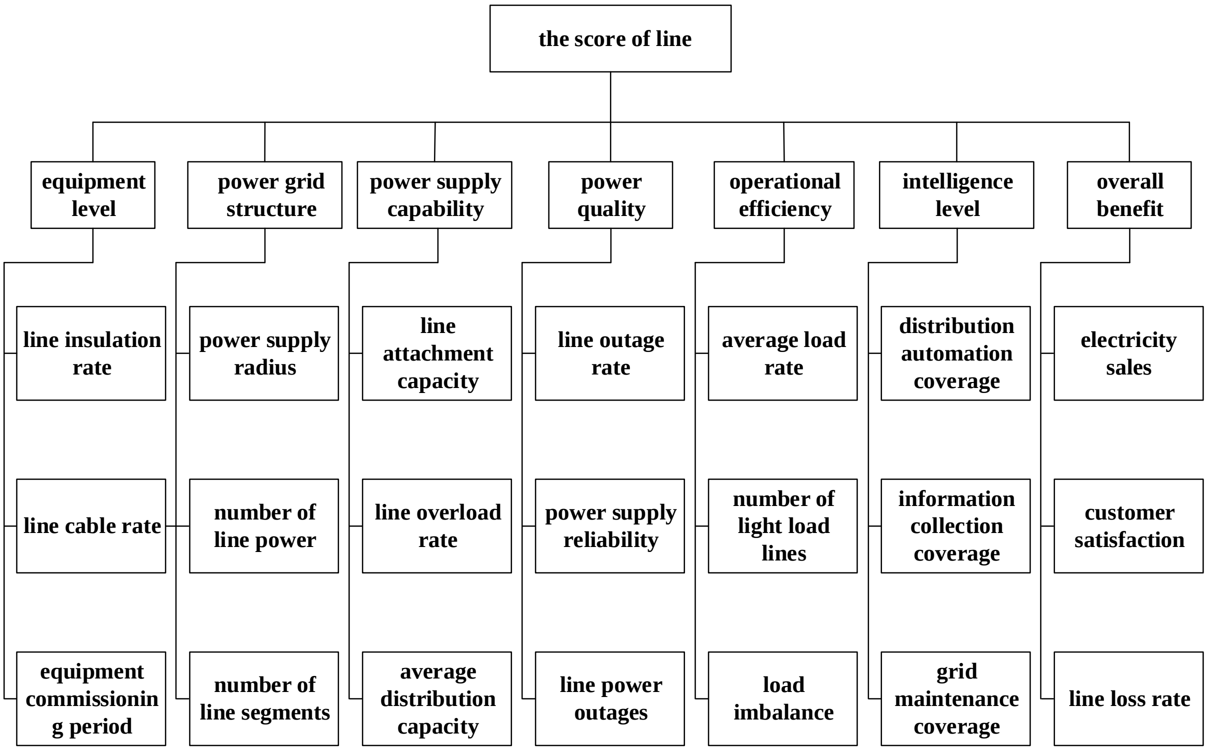

Fig 3. Distribution network evaluation system

4. INDICATOR WEIGHTS AND SCORING RULES

4.1 Indicator weights

Index weight is an important part of the comprehensive evaluation system. The rationality of the weight setting will affect the final evaluation result directly. In this paper, the weight between the indicators would be determined reasonably according to the ring ratio scoring method and the Delphi method.

Table 1. Determination of index weight

indicator	Tentative coefficient	corrective coefficient	Weights
A1	X1	Y1	U1
A2	X2	Y2	U2
…	…	…	…
An	Xn	Yn	Un

The table of design process is illustrated above, and the evaluation indicators will be inserted in the first column in any order. According to the experience of experts, the multiply results of two adjacent will be put in the tentative coefficient. Xi represents the ratio of i indicator divided by the i+1 indicator. Then the tentative coefficient should be modified and the corrective coefficient of the last indicator is assigned the value 1. In that way, Yn-1=YnXn-1, Yn-2=Yn-1Xn-2. All correction factors can be calculated. Finally, the correction coefficient of the third column is normalized and the result is recorded in the fourth column which is the weight of each indicator. According to the method above, the weight of each indicator is finally determined which combined with the opinions of many experts.

4.2 Indicator evaluation criteria

In this paper, fuzzy curve fitting and expert scoring method are used to set the evaluation criteria of indicators. Firstly, set the full score of the indicator to be the first-class level of the first-class distribution network, and then set the index value corresponding to the remaining scores of each indicator according to the Delphi method. Partial evaluation criteria are shown in Table 2.

Table 2. Relationship between indicators and scores

indicator	0	20	40	60	80	100
line overload rate	80	40	25	10	5	0
line insulation rate	20	40	60	75	90	100
line power outages	20	10	7	4	2	0
line loss rate	25	16	10	5	2	0

The evaluation criteria obtained above are discrete and cannot fully reflect the changes in the scores of the indicators. Therefore, the evaluation criterion is processed by curve fitting method and the evaluation function of the index is obtained.

According to the above method, the scores of all the secondary indicators would be calculated upwards layer by layer in order to obtain the overall score of each line. The specific calculation formula is presented below:

$$S^k = \sum_{j=1}^{n} S_j^{(k+1)} W_j^{(k+1)}$$

Sk represents the score of a certain indicator Ak in the k layer of the structure, n represents the number of sub-indicators of Ak, Sj represents the score of the sub-indicator of Ak, Wj represents the weight of the sub-indicator of Ak.

In summary, the comprehensive evaluation process of the distribution network based on the line is as follows: Firstly, the evaluation area is determined; the collected basic data is processed through the evaluation criteria of the indicator to obtain the basic indicator score; the score and total score of each level of the evaluation object should be calculated based on the index weight.

5. THE DESIGN OF SYSTEM FRAME

The overall architecture design of the comprehensive evaluation system for distribution network operation capability based on the line is shown in Fig.4, including external data, data layer, result layer and service layer. External data mainly includes distribution network equipment ledgers, electricity consumption information, dispatch automation, etc. The original basic data of the distribution network was built by accessing external data, then combining the opinions of experts to develop scoring rules and calculate data. In the service layer, the trend analysis of the distribution network is carried out according to the data uploaded by the result layer, the weak links of the distribution network are mined to better serve the rectification and planning of the distribution network.

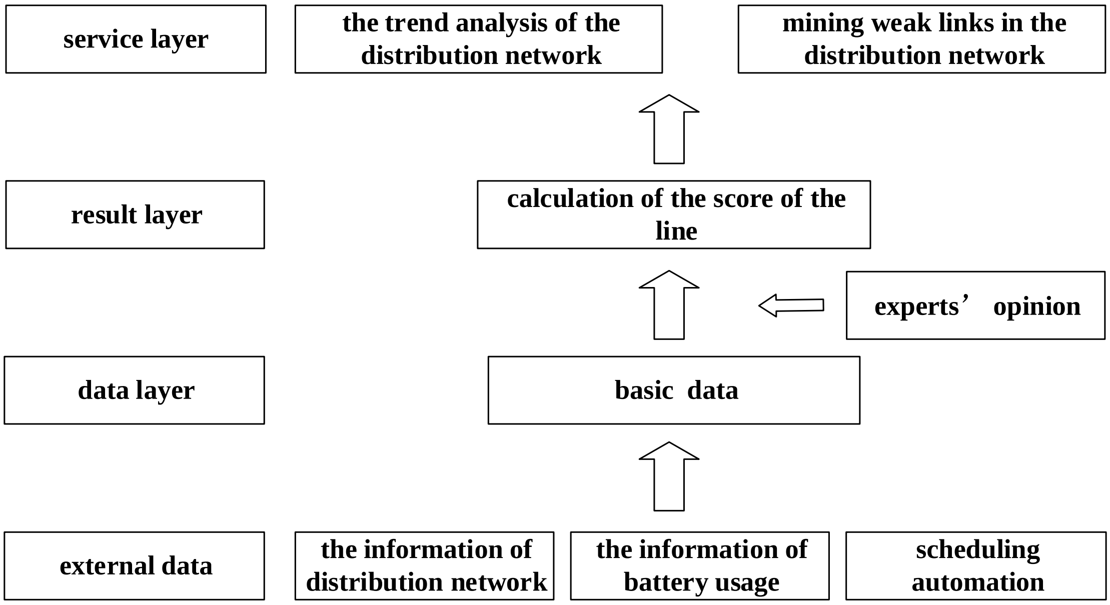

Fig 4. The construction of evaluation system

6. CONCLUSION

In this paper, a comprehensive evaluation system for distribution network is proposed from the multiple dimensions of operation effect and distribution network characteristics. The evaluation system not only can fully represent all aspects of the traditional distribution network, but also can find problems from the line level. Based on the work of this paper, the gap between the distribution networks in the whole and the weak links of the distribution network could be grasped. Beside, opinions on distribution network planning and rectification could be provided.

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