Comprehensive evaluation index system of total supply capability in distribution network

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Abstract. Aiming at the lack of a comprehensive evaluation of the distribution network, based on the existing distribution network evaluation index system, combined with the basic principles of constructing the evaluation index, put forward a new evaluation index system of distribution network capacity. This paper is mainly based on the total supply capability of the distribution network, combining single index and various factors, into a multi-evaluation index of the distribution network, thus forming a reasonable index system, and various indicators of rational quantification make the evaluation results more intuitive. In order to have a comprehensive judgment of distribution network, this paper uses weights to analyse the importance of each index, verify the rationality of the index system through the example, it is proved that the rationality of the index system, so as to guide the direction of distribution network planning.

1. Introduction
As the most basic component of the power system, the distribution network has important significance to the modern power industry. It is the basic guarantee for the normal operation of the whole system, and also the forefront of connection with the user. The safe, economic and reliable operation of distribution network directly affects the improvement of people's daily living standard, and plays a decisive role in the development of a city or a regional economy. In order to evaluate the status of the distribution network and measure the benefit and influence of distribution network to society, an effective evaluation system is needed. It is expected that the distribution network can be evaluated in many angles and in all respects.

At present, there are some evaluation index systems of the distribution network, most of the basic requirements of distribution network security, reliability and economy etc. to do the evaluation, and then add some power distribution network evaluation index and evaluation [1]. In the document, the index of power quality is added to improve the index system of the distribution network. The index of quality is introduced in the document, and its essence is also to evaluate the power quality. This method can reasonably evaluate the distribution network, but it ignores the total supply capability of the distribution network, which is a direct evaluation of the distribution capacity index and does not take into account...
the fact that the distribution network contains multiple voltage levels. Therefore, this paper will focus on the distribution network maximum power supply capacity and multi-voltage level, to complement the existing evaluation index system of the distribution network.

This paper will focus on the distribution network evaluation system in-depth research, and strive to build a complete index system to the comprehensive evaluation of the distribution network, so as to facilitate the implementation effect analysis of distribution network planning measures, provide a theoretical basis for the distribution network construction and reconstruction project[2].

2. The construction principle of evaluation index for distribution network
As the terminal of the power grid, the distribution network is directly connected with the users. There are many influencing factors and the regional differences are great. In the establishment of evaluation index system of the distribution network, for the index selection, on the one hand as far as possible to reflect the actual situation of the power grid, on the other hand, we should also take into account the degree of difficulty of data acquisition and computation. Therefore, the establishment of the evaluation index system needs to meet the following principles: consistency with the purpose of evaluation, direct testability, comparability, mutual independence and completeness of the whole [3].

In addition to the above principles, the establishment of the evaluation index of distribution network has its own characteristics:
1) For the complex structure of the distribution network, more attention should be paid to the overall evaluation of the distribution network, and the index settings are more concise.
2) The evaluation index system of distribution network should be adapted to the load characteristics.
3) For the evaluation of distribution network, besides the absolute quantity of index value, the relative change of index value should be paid more attention to.
4) The ability to adapt to the development of the load is needed for the results of the evaluation.

3. Distribution network evaluation index system

3.1. Index system
In order to make a comprehensive and scientific assessment of the distribution network, the power supply capability of the distribution network can be further explored. The comprehensive evaluation system of power distribution network in this paper includes 5 aspects, such as power supply capability, economy, coordination, uniformity, scalability, and adaptability [4-5]. As shown in Fig. 1.
3.2. Evaluating Indicator

1) Power Supply Margin

The power supply capability of distribution network is an important index to evaluate the distribution network, it is the meaning of the evaluation of distribution network capacity to meet the current load, the evaluation index of the distribution network of the basic, here the deformation for power supply capacity margin, refers to the premise of an N-1 security, a power supply area in the distribution network can increase power supply capacity based on the existing load, It can directly reflect the power supply that the distribution network can increase, and reflect the state of the distribution network operation from the side[6].

This paper defines it as a percentage of the power supply capacity that can be increased on the basis of the existing load in a certain power supply area under the condition of guaranteeing the N-1 safety. Formula is:

$$\frac{TSC - \sum_{i=1}^{n} P_{Li}}{TSC} \times 100\%$$

Where S represents the power supply margin; TSC represents the total supply capability of distribution network; PL represents the load.

2) Total Supply Capacity Cost Performance, TCP

Due to the economic, technological, social and ecological environment and many other influences, there are many constraints in the construction of power grid, and these constraints are finally expressed in the form of funds. Therefore, this paper puts forward the total supply capacity cost performance, refers to the total supply capability distribution network to enhance the value and the ratio of distribution network transformation and new economic expenditure, can directly reflect the improvement of the economy, in order to evaluate the improvement measures of single economic aspects. Formula is:

$$TCP = \frac{TSC}{m}$$

Where TCP represents the total supply capacity cost performance; m represents the total cost of equipment investment in the distribution network.

3) Interlinear Supply Capability Matching Degree, ISMD

The distribution system covers a wide range of voltage and low voltage distribution network, the total supply capability is affected by the high voltage distribution network, so this paper layer Interlinear Supply Capability Matching Degree. It refers to the ratio of two different total supply capability of distribution network considering and without considering the influence of higher distribution network. In this paper, based on each substation, a new index is defined as Interlinear Supply Capability Matching Degree. Formula is:

$$ISMD = \frac{TSC_{dn+up}}{TSC_{dn}}$$

Where TSCdn represents the TSC of the distribution network without any other constraints; TSCdn+up represents the TSC of the lower distribution network when there is a limit to the overhead distribution network.

4) Load Margin Balance

When the distribution network achieves the total supply capability, there will be some differences in the load between the feeders and the main transformer in the network, which will lead to the existence of the vulnerable link of the power grid. The configuration of main transformer capacity and distribution...
of grid structure will cause the line load rate is not balanced, some lines bear larger transmission capacity, overload operation, and even full load operation, while the other line is in light load conditions, cannot give full play to its value. This paper takes substation as the object of study and studies the load margin balance in the substation. This paper connected Feeder Load Margin Balance, FLMB; Transformer Load Margin Balance, TLMB; Load Margin Balance in balance Substation, LMBI; and Load Margin Balance between Substations, LMBB. Through the above four indicators, a comprehensive index is Comprehensive Load Margin Balance, CLMB [7]. Formula is:

\[
FLMB = \sqrt{\left( \sum_{i=1}^{x} (F_i - \bar{\alpha})^2 \right) / (x-1)}
\]

(4)

\[
TLMB = \sqrt{\left( \sum_{i=1}^{y} (P_i - \bar{\alpha})^2 \right) / (y-1)}
\]

(5)

\[
LMBI = \omega_1 \cdot FLMB + \omega_2 \cdot TLMB
\]

(6)

\[
LMBB = \sqrt{\left( \sum_{i=1}^{z} (L_i - \bar{\alpha})^2 \right) / (z-1)}
\]

(7)

\[
CLMB = \omega_1 \cdot \left( \sum_{i=1}^{n} LMBI_i / n \right) + \omega_2 \cdot LMBB
\]

(8)

Where \( F_i \) represents the load margin of the feeder \( i \); \( \bar{\alpha} \) represents the average value of the load margin for all feeders; \( x \) represents the number of feeders connected to the substation; \( P_i \) represents the load margin of the transformer \( i \); \( \bar{\alpha} \) represents the average value of the load margin for all transformers; \( y \) represents the number of transformers in the substation; \( L_i \) represents the load margin of the substation \( i \); \( \bar{\alpha} \) represents the average value of the load margin for all Substations; \( z \) represents the number of substations in the distribution network; \( \omega_1 \) and \( \omega_2 \) represent weights, \( \omega_1 + \omega_2 = 1 \);

5) Total Supply Capacity Scalability, TS

The development of the social economy is bound to lead to the continuous growth of load, and the goal of distribution network planning is to meet the short-term and even long-term load growth of distribution network and to ensure the quality of power distribution network. At present, the domestic power companies generally formulate 5 or 10 years distribution network planning, to determine the planning level, the annual power grid to implement the power transmission project, reconstruction and expansion projects. Therefore, this paper defines the total supply capacity scalability, which is intended to reflect the current distribution network in the existing grid based on the expansion of its topology can enhance the maximum power supply capacity.

When the grid structure of the distribution network is determined, the total supply capability is determined. To maximize the total supply capability, two methods can be added by adding the main transformer and adding a feeder. Relatively, the method of adding feeders is more convenient and more economical. On the premise that the number of transformers is constant, feeders are added to optimize the structure of the grid, and the total supply capability is raised as much as possible. However, due to the limited capacity of the transformer, the total supply capability provided by the extended feeder line will be limited. Formula is:
max

i
n

ii
n
i
i

P
P
TSC

TS = \omega_1 (\sum_{i=1}^{n} P_i - \max P_i - TSC) + \frac{\sum_{i=1}^{n} P_i - \max P_i - TSC}{n} \quad (9)

Where \sum_{i=1}^{n} P_i - \max P_i represents the total supply capability of a distribution network under the premise that the number of primary changes remains unchanged; \( P_i \) represents the capacity of the main transformer I; \( \max P_i \) represents the capacity value of the capacity maximum principal variable; \( n \) represents the annual investment cost of the expansion. Type (9) fully considers the amount of maximum power supply capacity and the investment economy required by the expansion of the existing grid in the distribution network, and makes a reasonable weighting of both of them, and comprehensively evaluate the scalability of the distribution network.

6) Medium Voltage Structure Adaptability, MVSA

The distribution network equipment is huge and the structure is complex. In the early years, the distribution network has been neglected in the whole power system, and the distribution network has been exposed to more and more problems because of the lack of attention and the unreasonable planning of the distribution network according to the user side. Therefore, this paper proposes the medium voltage Structure adaptability to evaluate the degree of matching between the distribution network and the user side. Adaptive evaluation is an important part of analyzing and judging the quality of power grid construction. It is also a feedback for the follow-up construction quality and operation status of the power grid planning system. The distribution network is divided into different functional partitions according to the different functions of the supplied area. This index will directly draw the matching degree between the distribution network and each functional area. Formula is:

\[
MVSA = \left[ \frac{\sum_{i=1}^{n} \alpha(i) f(i)}{\sum_{i=1}^{n} f(i)} \right]
\]

(10)

Where \( \alpha(i) \) represents the adaptive score of structural \( i \) relative to a function partition. \( f(i) \) Represents the number of structural \( i \) in an existing distribution network. The larger the MVSA, the more adaptive the current distribution network is to the target power supply function area.

4. Evaluation Methods and Case hypothesis

In the use of multiple evaluation index system to evaluate a model, determine each index in the whole system of the proportion, will help to grasp the main contradiction, research on key factors, is conducive to more scientifically and comprehensively carry out the evaluation. This paper uses AHP to evaluate the whole index system, and finally, establishes the evaluation weight of each index. This paper uses AHP to evaluate the whole index system, and finally, establishes the evaluation weight of each index. AHP refers to the establishment of a complex multi-target system, target decomposition for multiple targets, and then divided into several levels of multi-index, quantitative index to calculate the hierarchy, which is a multi-objective optimization method.

4.1. Establish hierarchical structure

For the multi-index system, the evaluation content is specific, highly summarized evaluation content using key indicators, and the indicators through balancing, scientific analysis for specific indicators decomposition. The hierarchical structure established in this paper includes three levels: target layer, criterion layer, and index layer. The target layer is the evaluation target; the principle includes factors of establishing the index system of reference: power supply capacity, economy, coordination, balance, scalability, adaptability; each index layer is composed of index system. [8-9] as shown fig.2.
4.2. Set up a comparison judgment matrix
An important characteristic of AHP is to express the relative importance degree of the two schemes in the form of the ratio of two importance degree. 9 importance levels and their assignments are listed in the table. The matrix formed by the comparison result is called the judgment matrix.

| Comparison between two factors                        | Quantization value |
|--------------------------------------------------------|--------------------|
| Equally important                                     | 1                  |
| Slightly important                                    | 3                  |
| More important                                         | 5                  |
| Very important                                         | 7                  |
| Great important                                        | 9                  |
| Intermediate values of adjacent judgments              | 2 4 6 8            |

This paper assumes that 6 experienced scholars are selected to set the weights of each index. First, all scholars are divided into 3 groups, each of which determines the weights of different indicators. Secondly, each group according to the principle of index contrast, in accordance with the 1-9 scale method of comparative valuation. Finally, the weighted average of the scoring results is obtained, and two judgment matrices are obtained. Give the result as follows.

| Table 2. The judgment matrix of target layer and criterion layer |
|---------------------------------------------------------------|
| Z    | A1 | A2 | A3 | A4 | A5 | A6 |
|------|----|----|----|----|----|----|
| A1   | 1  | 2  | 3  | 3  | 4  | 5  |
| A2   | 1/2| 1  | 2  | 2  | 3  | 4  |
| A3   | 1/3| 1/2| 1  | 1  | 2  | 3  |
| A4   | 1/3| 1/2| 1  | 1  | 2  | 3  |
| A5   | 1/4| 1/3| 1/2| 1/2| 1  | 2  |
| A6   | 1/5| 1/4| 1/3| 1/3| 1/2| 1  |
Table 3. Judgment matrix of criterion layer and index level

|     | A2 | B2 | B5 |
|-----|----|----|----|
| B2  | 1  |    | 3  |
| B5  | 1/3|    | 1  |

4.3. Consistency test

Set the matrix $A$, and if $A$ is completely consistent, then $\hat{\lambda}_{\max} = A$. The formula for calculating the degree of consistency of matrices is:

$$CR = \frac{CI}{RI}$$  \hspace{1cm} (11)

$RI$ represents the random consistency index; $CI = \frac{\hat{\lambda}_{\max} - n}{n - 1}$. When $CR < 0.1$, that consistency matrix $A$ can be accepted, if $CR$ is greater than 0.1, that consistency matrix $A$ can be not accepted.

According to the above theory, the consistency matrix of the judgment matrix is checked. The second matrices are two rows and two columns, and there is no consistency problem. Only the first matrix is tested. The results are as follows:

$\hat{\lambda}_{\max} = 6.0732$

$$CI = \frac{6.0732 - 6}{6 - 1} = 0.01464$$

$$CR = \frac{CI}{RI} = \frac{0.01464}{1.24} \approx 0.012 < 0.1$$

Judging from the above results, the judgment matrix has a satisfactory consistency.

4.4. Compute weight vectors

In order to extract useful information from the judgment matrix, it is necessary to compute the weight vector of the judgment matrix. The existence of unique nonzero eigenvalues, whose corresponding eigenvectors are normalized, is called a weight vector. For all the column vectors of the matrix, the geometric mean of each component is computed, and then the normalized vector is the weight vector. Therefore, for the judgment matrix, the eigenvector corresponding to the maximum eigenvalue can be found and then normalized to the weight.

In this paper. The normalized eigenvalues of the maximum eigenvalue of matrix 1 are [0.3657, 0.2311, 0.1357, 0.1357, 0.0803, and 0.0516]. The normalized eigenvalue of the maximum eigenvalue of matrix 2 is [0.75, 0.25]. After calculation, the weight vectors of the target layer relative to the target layer are [0.3657, 0.1732, 0.1357, 0.1357, 0.1381, and 0.0516].

The evaluation weights of each index are: 36.57%, 17.32%, 13.57%, 13.57%, 13.81%, and 5.16%. For this case, use the evaluation index system to evaluate the model, Power supply margin accounted for 36.57%, Total Supply Capacity Cost Performance accounted for 17.32%, Interlinear Supply Capability Matching Degree accounted for 13.57%, Load Margin Balance accounted for 13.57%, total supply scalability accounted for 13.81%, medium voltage Structure fitness accounted for 5.16%.

5. Conclusion

The traditional methods of distribution network evaluation mainly focus on the evaluation of the distribution network operation status. On this basis, this paper puts forward a new index system. Compared with the traditional distribution network evaluation index system, this paper aims to evaluate
the ability of distribution network, combined with the new index of total supply capability of distribution network, the distribution network power supply capacity, economy, coordination, balance, scalability and to make a comprehensive assessment of the distribution network and other aspects, highlighting the promotion of maximum power supply the ability of distribution network target.

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