

A new method for the diagnosis of power backbone communication network based on extension rating

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Abstract. Electric power communication network is an important part of power system, which plays a vital role in the operation of power network. This paper established an index system of electric power communication network and proposed a diagnostic method of electric power communication network system based on extension rating. This evaluation method can not only evaluate the impact factors of the electric power communication network, but also can diagnose and rate the whole electric power communication network.

Introduction

The power system communication network is one of the important parts of the power system. It is the basis of the power system dispatching automation. The safe operation of power system communication network is important to the safety operation of power network. Electric power communication network gradually formed by cross regional, city regions, provinces (including counties), a total of four level communication network. At present, there are few studies on the overall diagnosis of power backbone communication network.

Paper [1] analyzes the important factors that influence the development of power grid from the two levels of technology and operation, and construct a regional power network development level diagnosis system. Paper [2] presents a kind of fuzzy consistent evaluation method according to the requirement of DER network monitoring communication. Analytic hierarchy process method [3] can select the best program from many alternatives but it can't evaluate a single program. Paper [4] builds the evaluation model of the functional effect of the substation construction project based on the multilevel extension evaluation method, and evaluates the effect of the project function. The method in paper [4] can evaluated the object according to the composite operation of all the indexes and their weights, but it can't reflect the overall quality of all the indexes from the whole point of view. Paper [5] builds a risk evaluation index system of photovoltaic power generation project, and uses the TOPSIS model based on grey relational degree to evaluate the risk of the program.

In this paper, a new method for the diagnosis of electric power communication network based on extension rating is presented. This method uses the interval weight to reduce the subjectivity of the index weight and applies the extension theory to the evaluation of the power communication network. It can not only make a comprehensive diagnosis and evaluation of the electric power communication network from the whole angle, but also can evaluate the key factors that effect the electric power communication network. The feasibility and rationality of the method are verified by the empirical analysis.

Diagnostic Index Model of Electric Power Communication Network

The Diagnostic Requirements of Power Communication Network. With the development of

power network, power communication network is growing rapidly. According to state grid development planning, prefectures and counties network will integrate the four-level power communication network, municipal communication network will converge to the access network business. The construction method of relying on the experience can't meet the current development trend. Moreover, with the upgrading of the communication equipment, the mixed use of obsolete equipment and new equipment would cause failures of equipment. So the security, reliability and adaptability of the new power communication network should be reconsidered. And the analysis of the power communication network is the key to solve these problems.

Diagnostic Index Model. Through the research on the characteristics of the power communication network, this paper establishes the index system of the power communication network, including three first-level indexes: safety reliability, equipment status and service support. The safety reliability indexes include seven second-level indexes: number of business interruption A_1 , number of optical transmission equipment A_2 , failure rate of communication power A_3 , failure time of optical transmission equipment A_4 , failure time of communication power A_5 , failure rate of cable A_6 , number of cable failure A_7 . The equipment status indexes include five second-level indexes: the ratio of 48 core-optic cable B_1 , the ratio of optical transmission equipment that is used more than 10 years B_2 , the length ratio of optical cable that is used more than 10 years B_3 , total length of OPGW optical link B_4 , total length of ADSS optical link B_5 . The service support indexes include five second-level indexes: number of power production communication service C_1 , number of power information communication service C_2 , the net flow of main export business C_3 , the net flow of spare export business C_4 , municipal 10kV site communication coverage C_5 .

Evaluation Model of Multilevel Extension Diagnosis Method

Overview of Multilevel Extension Method. The extension method can obtain the membership degree of the upper level index by the complex operation of the index weight and the actual index value. And the method gave the evaluation result according to the maximum membership principle. Multilevel extension method can obtain the evaluation results by the complex combination of the upper level indexes' weights and upper level indexes' evaluation results. Its logical block diagram is shown in Fig.1.

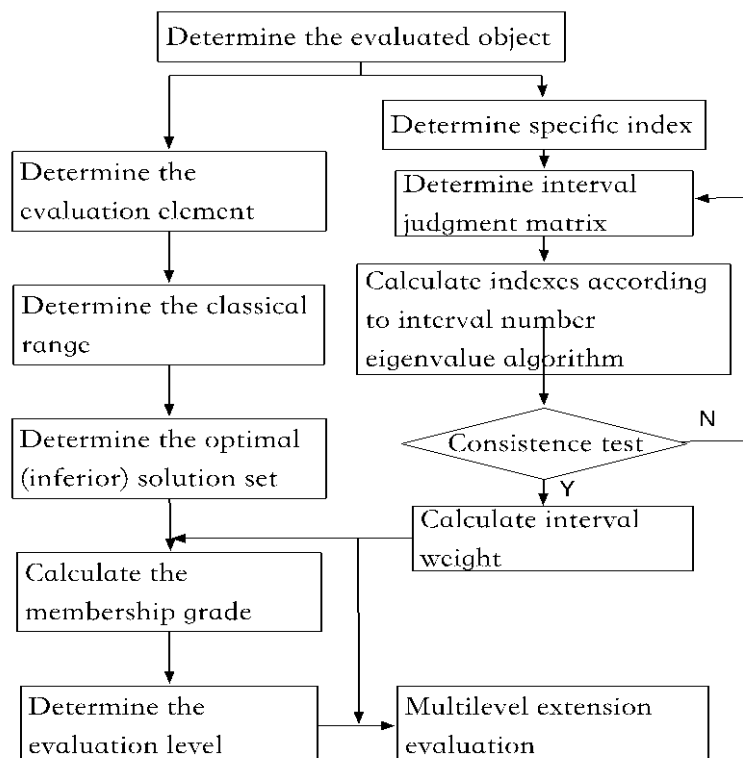


Figure 1 logical block diagram of extension

Determine the Index Weight. According to the 1~9 scale method in Tab.1, we mark the relative importance of each two indexes. In order to eliminate the uncertainty of subjective judgment, the comparison results are expressed in the interval number. The final result of the interval number judgment matrix is shown in Eq.1.

Tab.2 1 ~ 9 scale rules

Level	Degree	Meaning
1	The same	Index a and B are equally important
3	A bit	Index a is slightly more important than the index b
5	Obviously	Index a is obviously more important than the index b
7	Strongly;	Index a is strongly more important than the index b
9	Extremely	Index a is extremely more important than the index b

$$A = \begin{bmatrix} [1,1] & [a_{12}^-, a_{12}^+] & \dots & [a_{1n}^-, a_{1n}^+] \\ [a_{21}^-, a_{21}^+] & [1,1] & \dots & [a_{2n}^-, a_{2n}^+] \\ \dots & \dots & \dots & \dots \\ [a_{n1}^-, a_{n1}^+] & [a_{n2}^-, a_{n2}^+] & \dots & [1,1] \end{bmatrix} \quad (1)$$

In Eq.(1), a_{ij}^+ and a_{ij}^- represent the upper and lower bounds for the relative importance of index i and the index j . According to the arithmetic method based on interval number, there is $A = [A^-, A^+]$. A^+ and A^- are the upper and lower bounds matrix.

According to the interval number eigenvalue method, the largest eigenvalue of A^+ and A^- can be calculated, that are λ_{\max}^+ and λ_{\max}^- . Normalized feature vector with positive components w^+ and w^- can also be calculated. Then the positive component coefficient m and the negative component coefficient k of the matrix A are calculated by using the Eq.(2) and Eq.(3).

$$m = \sqrt{\sum_{j=1}^n (1 / \sum_{i=1}^n a_{ij}^-)} \quad (2)$$

$$k = \sqrt{\sum_{j=1}^n (1 / \sum_{i=1}^n a_{ij}^+)} \quad (3)$$

According to the [6], the consistency test index CR^+ and CR^- can be calculated. When the value of $\frac{1}{2}(CR^+ - CR^-)$ is less than 0.1, the matrix A pass conformance test. Assuming the second-level index interval weight vector is $W = [kw^-, mw^+]$, the first-level index interval weight vector is $\mu = [\mu_1, \mu_2, \dots, \mu_k]$. (μ_k is interval number)

Extension Rating Model.

(1) Determine the evaluation matter

Assume the evaluation object contains m indexes, that are C_1, C_2, \dots, C_m . The element model is shown in Eq.(4).

$$M = (U, C_k, v_k) = \begin{bmatrix} U & C_1 & v_1 \\ & C_2 & v_2 \\ & \dots & \dots \\ & C_m & v_m \end{bmatrix} \quad (4)$$

In Eq.(4), M represents the element model. U represents the evaluation classes for the evaluation of the object. v_k ($k=1,2,\dots,m$) represent the practical value of each index.

(2) Determine the classical range

Divide the evaluation results into n levels. The classical range model is shown in Eq.(5).

$$M_j = (U_j, C_k, v_{jk}) = \begin{bmatrix} U_j & C_1 & <a_{j1}, b_{j1}> \\ & C_2 & <a_{j2}, b_{j2}> \\ & \dots & \dots \\ & C_m & <a_{jm}, b_{jm}> \end{bmatrix} \quad (5)$$

In Eq.(4), M_j represents the element model of level j. U_j represents the evaluation result of level j. $<a_{jk}, b_{jk}>$ represent the value range of C_k in level j.

(3) Determine the optimal and inferior solution set

First, put the maximum value of the positive index and the minimum value of the negative index of each level as the optimal solution set V^+ . Similarly, put the minimum value of the positive index and the maximum value of the negative index of each level as the inferior solution set V^- .

$$V^+ = \begin{bmatrix} v_{11}^+ & \dots & v_{1m}^+ \\ \dots & \dots & \dots \\ v_{n1}^+ & \dots & v_{mn}^+ \end{bmatrix} \quad (6)$$

$$V^- = \begin{bmatrix} v_{11}^- & \dots & v_{1m}^- \\ \dots & \dots & \dots \\ v_{n1}^- & \dots & v_{mn}^- \end{bmatrix} \quad (7)$$

In Eq.(6) and Eq.(7), v_{ij}^+ represents the optimal value of index j in level i. v_{ij}^- represents the inferior value of index j in level i.

(4) Determine the correlation degree between second-level index and the each level

First, calculate the proximity degree between the practical index value set and the optimal (inferior) set in each level.

$$(D_j^+)_- = \sqrt{\sum_{i=1}^m (w_i)_- [(v_i - v_{ij}^+) / (v_{ij}^+ - v_{ij}^-)]^2} \quad (8)$$

$$(D_j^+)_+ = \sqrt{\sum_{i=1}^m (w_i)_+ [(v_i - v_{ij}^+) / (v_{ij}^+ - v_{ij}^-)]^2} \quad (9)$$

$$(D_j^-)_- = \sqrt{\sum_{i=1}^m (w_i)_- [(v_i - v_{ij}^-) / (v_{ij}^+ - v_{ij}^-)]^2} \quad (10)$$

$$(D_j^-)_+ = \sqrt{\sum_{i=1}^m (w_i)_+ [(v_i - v_{ij}^-) / (v_{ij}^+ - v_{ij}^-)]^2} \quad (11)$$

In Eq.(8)~(11), $D_j^+ = [(D_j^+)_-, (D_j^+)_+]$ represents the proximity degree interval between the practical index value set and the optimal set in level j. $D_j^- = [(D_j^-)_-, (D_j^-)_+]$ represents the proximity degree interval between the practical index value set and the inferior set in level j.

Then, calculate the correlation degree between the practical index value set and the optimal (inferior) set in each level according to Eq.(12) and Eq.(13).

$$\rho(v, D_j^+) = \frac{(D_j^+)_-}{(D_j^+)_- + (D_j^-)_-} + \frac{(D_j^+)_+}{(D_j^+)_+ + (D_j^-)_+} \quad (12)$$

$$\rho(v, D_j^-) = \frac{(D_j^-)_-}{(D_j^+)_- + (D_j^-)_-} + \frac{(D_j^-)_+}{(D_j^+)_+ + (D_j^-)_+} \quad (13)$$

In Eq.(12) and Eq.(13), $\rho(v, D_j^+)$ represents the correlation degree between the practical index value set and the optimal set in level j. $\rho(v, D_j^-)$ represents the correlation degree between the practical index value set and the inferior set in level j.

(5) Determine the membership degree between second-level index and each level
Calculate the membership degree according to Eq.(14).

$$K_j(U) = \frac{\rho(v, D_j^+)}{\rho(v, D_j^+) + \rho(v, D_j^-)} = \frac{\rho(v, D_j^+)}{2\rho(v, D_j^+) - 1} \quad (14)$$

$$K_{j_0}(U) = \max_{1 \leq j_0 \leq n} K_j(U) \quad (15)$$

According to the principle of maximum membership degree, the evaluation result is j_0 .

(6) Multilevel extension rating

Using the index model and algorithm model above, we can evaluate the first-level index through the combination between the evaluation result of second-level index and the weight of first-level index. Assume the evaluation result of second-level index k is j_k ($1 \leq j_k \leq n$), we can calculate the evaluation result of the first-level index using Eq.(16).

$$j^* = \sum_{k=1}^t j_k \mu_k \quad (16)$$

In Eq.(16), j^* is the evaluation result of the first-level index. t represents the number of the first-level index. μ_k represents the weight of the first-level index.

Case Analysis

In this paper, we pick a typical area as an example to verify the feasibility of this algorithm. The evaluation result is divided into 5 grades, which are excellent, good, medium, qualified, and poor. According to the index system and the relevant data, we can get the actual data and the classical range of each index.

We ask ten experts to mark the relative importance of each index, and we can calculate the interval weight of each index according to the weight algorithm above. According to Eq.(6)~(15), we can calculate the membership degree of the first-level degree. The results are as shown in Tab.3.

Tab.3 Interval weight and evaluation results

First-level index	Interval weight	Grade	Maximum membership degree	Second-level index	Interval weight
Safety and reliability A	[0.5427,0.5904]	j=2	2.4599	A_1	[0.1987,0.2268]
				A_2	[0.1073,0.1429]
				A_3	[0.0361,0.0436]
				A_4	[0.1374,0.1663]
				A_5	[0.0293,0.0323]
				A_6	[0.3581,0.3761]
				A_7	[0.0512,0.0618]
Equipment status B	[0.2096,0.2608]	j=2	1.7216	B_1	[0.0365,0.0375]
				B_2	[0.0849,0.1013]
				B_3	[0.0598,0.0725]
				B_4	[0.4038,0.4527]
				B_5	[0.3191,0.3605]
Service support C	[0.1507,0.1804]	j=2	1.4323	C_1	[0.0339,0.0349]
				C_2	[0.0562,0.0801]
				C_3	[0.2328,0.2652]
				C_4	[0.1411,0.1700]
				C_5	[0.4474,0.4708]

The results in Tab.3 show that the level of safety and reliability and the service support index is medium, and the level of equipment status is good. According to the weight of the first-level index and Eq.(16), the final evaluation result of power communication network in this typical area can be calculated, that is $j^* = [1.8060, 2.0632]$. It can be seen that the final evaluation result is between excellent and medium, and it has a strong tendency to good.

From the analysis of the example, it can be seen that the new method for the diagnosis of power backbone communication network based on extension rating can evaluate the power communication network from the whole angle. Moreover, the method can also evaluate the safety and reliability, the equipment status and the service support, so as to provide theory principle to the construction of the power communication network.

Conclusion

This paper studied the power communication network and built an index system of the power communication network. In addition, this paper used the interval weight to reduce the subjectivity of the weight and proposed a new method for the diagnosis of power backbone communication network based on extension rating. It can be seen that this method can evaluate the power communication network and has a great significance to the construction of the power communication network.

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