A New Comprehensive Evaluation Method for Construction Results of the Power System Communication Networks

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ABSTRACT: Power system communication networks are responsible for data transmitting among different entities in power systems. This paper aims to propose a method for the comprehensive evaluation for construction results of the power system communication networks. Firstly, factors in a multi-criteria decision making approach can be arranged in a hierarchic structure based on the Analytic Hierarchy Process (AHP),then the Fuzzy Decision Theory (FDT) is used to combine the factors into one. The method proposed in this paper can be used to provide necessary basis for decision making with certain credibility. In the end, this paper provide a case for validating the method based on statistical data from State Grid Corporation of China.
KEYWORD: Power System Communication Networks; Comprehensive evaluation; Analytic Hierarchy Process; Fuzzy Decision Theory

1 GENERAL INSTRUCTION

The communication channel, which is used to provide information transmitting in remote monitoring, control and protection, plays an important role in the development of smart grid. Moreover, office automation and management information of the power enterprises are depending more and more on the broad-band and high speed communication network [1]. We can see that, electric power communication network carries the major business, and provides important guarantee to the security and stability of the grid operation and enterprise management.

As the world largest electric power communication network has been built in China, more sophisticatedly professional management is needed. For example, reasonable and scientific evaluation for construction results of the power system communication network can quantify the planning, construction and management of the power system communication network, and provide necessary basis for decision making with certain credibility [2].

Our motivation of the present work lies in building the comprehensive evaluation for construction results of the power system communication networks with the top-down analysis, which has not been studied yet. Based on the Analytic Hierarchy Process (AHP) [3] and Fuzzy Decision Theory (FDT) [4-5], the structure of this paper will be as follows. In section 2, we will construct the evaluation index vectors; Judgment matrix and its eigenvectors will be presented in section 3; Section 4 will offer the comprehensive evaluation and some cases. Section 5 will be our conclusions.

2 EVALUATION INDEX VECTORS

The structure diagram for the power system communication networks is established as seen in Figure 1.

With the aid of Figure 1, we can present the index vectors:

The top level,

$$W_A = (w_{B1}, w_{B2}, w_{B3});$$

The below level,

$$W_{B1} = (w_{B1C1}, w_{B1C2}, w_{B1C3}, w_{B1C4});$$

$$W_{B2} = (w_{B2C5}, w_{B2C6}, w_{B2C7});$$

$$W_{B3} = (w_{B3C8}, w_{B3C9});$$

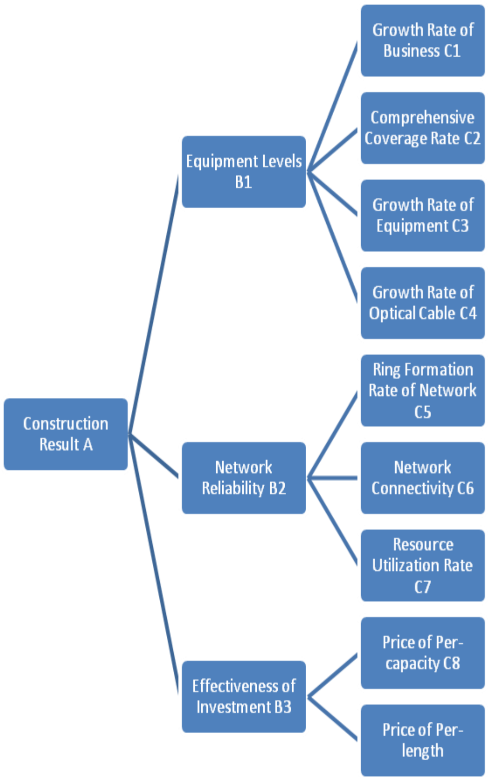

Figure 1 The structure diagram for the power system communication networks.

3 JUDGMENT MATRIX AND ITS EIGENVCTORS

3.1 *1-9 scales method*

To quantity the decision analysis, we compare the importance of a factor y_i in the certain level with that of another y_j (i, j=1,⋯r), and illustrate that by the natural numbers 1-9 as follows:

L_{ij} =1, denote that y_i and y_j are equally important;

L_{ij} =3, denote that y_i is weakly more important than y_j;

L_{ij} =5, denote that y_i is obvious more important than y_j;

L_{ij} =7, denote that y_i is much more important than y_j;

L_{ij} =9, denote that y_i is extremely more important than y_j;

L_{ij} =2, 4, 6, 8, denote that the importance falls in between the above two degrees. Otherwise, $L_{ji} = 1/L_{ij}$.

3.2 *Judgment matrix*

According to the 1-9 scales method presented in Section 3.1, for a factor x in the certain level, which contains the factors y_k (k=1,2,…r) in the next level, we can construct the judgment matrix as

$$\begin{pmatrix} L_{11} & L_{12} & \cdots & L_{1r} \\ L_{21} & L_{22} & \cdots & L_{2r} \\ \vdots & \vdots & \vdots & \vdots \\ L_{r1} & L_{r2} & \cdots & L_{rr} \end{pmatrix}$$

Then the judgment matrix for the power system communication networks can be given as follows:

Tab.1 A-B Matrix

A	B1	B2	B3
B1	1	1/2	1/3
B2	2	1	1
B3	3	1	1

Tab.2 B1-C Matrix

B1	C1	C2	C3	C4
C1	1	1/3	1/2	1/4
C2	3	1	2	1
C3	2	1/2	1	2
C4	4	1	1/2	1

Tab.3 B2-C Matrix

B2	C5	C6	C7
C5	1	1/4	1/3
C6	4	1	2
C7	3	1/2	1

Tab.4 B3-C Matrix

B3	C8	C9
C8	1	2
C9	1/2	1

3.3 *Eigenvectors*

In this section, we will derive the eigenvectors of the judgment matrix for the power system communication networks as

W_A=(w_{B1}, w_{B2}, w_{B3})

=(0.1570, 0.3494, 0.5936);

W_{B1}=(w_{B1C1}, w_{B1C2}, w_{B1C3}, w_{B1C4})

=(0.1028, 0.3560, 0.2706, 0.2760);

W_{B2}=(w_{B2C5}, w_{B2C6}, w_{B2C7})

=(0.1320, 0.5584, 0.3196);

W_{B3}=(w_{B3C8}, w_{B3C9})=(0.2000, 0.1000);

4 COMPREHENSIVE EVALUATION

4.1 *Comprehensive index vector*

The evaluation index vector for the construction results of the power system communication networks P can be obtained through some calculations as

$w_1 = w_{B1} \times w_{B1C1}$ =0.1570×0.1028=0.0161,

$w_2 = w_{B1} \times w_{B1C2}$ =0.1570×0.3560=0.0559,

$w_3 = w_{B1} \times w_{B1C3}$ =0.1570×0.2706=0.0425,

$w_4 = w_{B1} \times w_{B1C4}$ =0.1570×0.2760=0.0433,

$w_5 = w_{B2} \times w_{B2C5}$ =0.3494×0.1320=0.0461,

$w_6 = w_{B2} \times w_{B2C6}$ =0.3494×0.5584=0.1951,

$w_7 = w_{B2} \times w_{B2C7}$ =0.3494×0.3196=0.1117,

$w_8 = w_{B3} \times w_{B3C8}$ =0.5936×0.2000=0.1187,

$w_9 = w_{B3} \times w_{B3C9}$ =0.5936×0.1000=0.0594,

and that

P=($w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9$)

=(0.0161,0.0559,0.0425,0.0433,0.0461,0.1951,0.1117,0.1187,0.0594).

4.2 *Established case*

Firstly, rating system of the vector element is designed according to the Fuzzy Decision Theory, as follows:

Tab.5 Rating system of vector element.

Si	100	90	80	70	60	50	40	30	20	10
N	n1	n2	n3	n4	n5	n6	n7	n8	n9	n10

where $\sum_{i=1}^{10} n_i = N$.

Then the final score can be obtained by

Score= $\sum_{i=1}^{10} n_i Si / N$.

For example, to the Cj=[0.08,0.09] and N=30,

Tab.6 Case of the rating system.

Si	100	90	80	70	60	50	40	30	20	10
N	3	6	6	7	5	2	1	0	0	0

Then the score for Cj is 75.

Based on above designed formula, each element of index vector can be graded with the centesimal as

Tab.7 Scores of the element of index vector Cj.

Cj	score
[0.1,1]	100
[0.09,0.1]	80
[0.08,0.09]	75
[0.07,0.08]	70
[0.06,0.07]	65
[0.05,0.06]	60
[0.04,0.05]	55
[0.03,0.04]	50
[0,0.03]	30

Then we will take K1, K2, K3 and K4 provinces as examples,

Tab.8 Case of the comprehensive evaluation for construction results of the power system communication networks.

	K1	K2	K3	K4
C1	0.06	0.05	0.07	0.06
C2	0.05	0.07	0.05	0.06
C3	0.1	0.08	0.06	0.05
C4	0.04	0.04	0.05	0.07
C5	0.07	0.06	0.07	0.05
C6	0.02	0.02	0.03	0.05
C7	0.06	0.05	0.06	0.06
C8	0.07	0.05	0.05	0.07
C9	0.08	0.05	0.06	0.05

4.3 *Synthesize*

On the basis of Sections 4.1 and 4.2, the 9 factors in the comprehensive index vector can be synthesized into one as

$$W_{K1} = P(65,60,100,50,70,30,65,70,70)^T$$

=39.623;

$$W_{K2} = P(60,65,75,50,65,30,60,60,60)^T$$

=36.190;

$$W_{K3} = P(70,60,65,60,70,50,65,60,65)^T$$

=41.067

$$W_{K4} = P(65,65,60,70,60,60,65,70,60)^T$$

=44.164.

From the above calculations, we can see that construction results of the power system communication networks in the areas K1, K2, K3 and K4: $W_{K4} \geq W_{K3} \geq W_{K1} \geq W_{K2}$.

5 CONCLUSIONS

With the Analytic Hierarchy Process (AHP) and Fuzzy Decision Theory (FDT), we have investigated the comprehensive evaluation for construction results of the power system communication networks, which can be used to provide necessary basis for decision making with certain credibility. The area K1, K2, K3 and K4 have been taken as examples, through which we have found that construction results of the power system communication networks of K1, K2, K3 and K4: $W_{K4} \geq W_{K3} \geq W_{K1} \geq W_{K2}$. This work may be useful in studying the construction results of the power system communication networks.

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