Information Fusion in the Application of Distribution Network Automation Management Evaluation

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Abstract: In the evaluation of distribution network management level, analytic hierarchy process is generally adopted. By setting assessment criteria and scoring weights, this method can fully and accurately reflect the level of construction automation, development trends and weak links. It provides guidance for distribution automation construction and operation and maintenance. However, when applying this method to evaluate the distribution network, it is necessary to score the various influencing factors through experts. Because the expert scoring is subjective, the evaluation results are not the same according to the different experts. In order to objectively evaluate the automation management level of distribution network, a method based on information fusion is proposed in this paper. According to the selected automation management evaluation indicators, an analysis model is established to obtain the distribution network evaluation results. Through the D-S evidence theory, the evaluation results of different experts are combined. And the subjective factors are combined to obtain a relatively objective evaluation result of the automation management level of the distribution network. Taking a certain urban area as an example, this paper evaluates the management level of distribution network by applying the proposed method. According results, it provides reference for grid economic evaluation, power grid planning and transformation work.

1. Introduction
As a terminal link directly facing the user, the power distribution system directly relates to the user's power quality and power reliability. Compared with the transmission grid, the distribution station has many types, widely distributed, and a large number. The geographical environment is complex and variable. It is susceptible to interference and destruction by external activities. The operation and maintenance work are large. The urban and rural economic development is currently in a period of rapid development, the distribution network is expanding rapidly. And the number of new sites and equipment are also rising rapidly. It is the main direction of development and construction of distribution networks\(^{[1-2]}\).

In some industrialized countries, urban distribution networks have been formed and the structure is relatively complete, which has created a good foundation for distribution automation. However, many countries do not implement feeder automation on a large scale, but only implement feeder automation in some load-intensive and sensitive areas\(^{[3-4]}\). It is particularly worth mentioning that they attach great importance to the management of power distribution basic data, attach importance to power distribution repair management and improve the efficiency of power distribution management through advanced tools and means. It ultimately reflects the quality service to customers.

The management level of distribution network has been improved. One of the important technical means is to construct and apply distribution automation. The distribution automation construction has gone through three stages of “local” distribution automation, distribution monitoring automation and integrated distribution automation. With the importance of distribution network application, the level of
distribution network management needs to be improved accordingly. For the research of distribution network management, scholars have carried out relevant research from their respective perspectives. Among them, more studies have adopted the analytic hierarchy process to comprehensively evaluate the operation and management of distribution networks. For the comprehensive evaluation problem, the weight directly affects the scientific rationality of the comprehensive evaluation results. Researchers have put forward many effective methods on the issue of comprehensive evaluation. Some documents only use subjective or objective methods to determine weights. Subjective or objective single factors have a greater impact on the weighting results. Literature [5] relies on expert experience to determine weights. Its objectivity is relatively poor. Literature [6] relies on data samples. There will be loss of information and its weighting results have a certain gap with the actual situation. In order to avoid the bias of weight caused by single aspect weighting, a comprehensive evaluation method of information fusion combined with expert scoring is proposed, taking into account the subjectivity and objectivity of evaluation. According to the evaluation results, the automation management level of the distribution network can be improved through the construction of the distribution automation main station.

2. Distribution network automation evaluation

The automatic management refers to the management of the distribution network automation system, mainly including the management of the distribution automation master station data, the establishment of the distribution network automation master station to solve the data quality problems of distribution automation and realize the automation of the distribution network management. After researching a distribution network in a certain urban area, it is finally determined to establish an evaluation index system for the automation management of distribution networks from the aspects of data extraction efficiency, data quality, and automation ratio.

After the evaluation indicators are determined, the analytic hierarchy process is usually used to evaluate the automation management level of the distribution network. Analytic Hierarchy Process (AHP) is a combination of quantitative and qualitative decision-making methods [7]. The main steps of the method are as follows:

(1) Structural judgment matrix

By establishing an analysis model, each element is compared in pairs. And the judgment matrix is constructed. The analytic hierarchy process is mainly represented by scaled values. And the scale value is obtained mainly by the value of reasonable judgment given by the relative importance of each factor. Finally the required judgment matrix is formed. The judgment matrix mainly uses the pairwise comparison method to construct the judgment matrix. The severity of the pairwise comparison method is indicated by the scale in Table 1.

| Scaling | Meaning                                      |
|---------|----------------------------------------------|
| 1       | Expressing the same importance compared to two factors |
| 3       | Compared with the two factors, the former is slightly more important than the latter |
| 5       | Compared with the two factors, the former is obviously more important than the latter |
| 7       | Compared with the two factors, the former is more important than the latter |
| 9       | Compared with the two factors, the former is more extremely important than the latter. |
| 2, 4, 6, 8 | Indicates the intermediate value of the above adjacent judgment |

Table 1. Judgment matrix construction basis

If the ratio of the factor i to the importance of the factor j is $a_{ij}$, then the ratio of factor j to factor i is $a_{ji} = \frac{1}{a_{ij}}$. 

2
Calculation weight vector

The maximum eigenvalue and its corresponding eigenvector are calculated for each judgment matrix. Then the consistency test is performed by using the consistency index, the random consistency index and the consistency ratio. If the test passes, the feature vector (normalized) is the weight vector. If not, the reconstruction matrix should be considered. The approximation of the eigenvector is usually obtained by the summation method or the root method.

Calculated index

According to the fuzzy matrix, each individual factor in the evaluation factor plays a different role in the "evaluation target", that is, the single factor occupies different weight ratios in the comprehensive evaluation. \( A \) is obtained by analysis, which is weight or weight distribution set, \( A = (a_1, a_2, \ldots, a_m) \), \( a_i \geq 0 \), \( \sum a_i = 1 \). It reflects a trade-off between factors. Then the fuzzy synthesis is performed. And the fuzzy weight vector is used to obtain the degree of membership of the evaluated items.

Using the current distribution network automation management evaluation method, the automation management level can be quantitatively evaluated. However, since the weight vector matrix needs to be calculated by expert scoring. The result depends on the subjective knowledge of the expert. When you invite different experts to score the same indicators, you will get different ratings. Based on different scoring results, the calculated evaluation results are also different. At this time, it is necessary to use a fusion evaluation method to combine different evaluation methods, so as to obtain relatively objective evaluation results.

3. Information fusion evaluation method

Evidence theory is a method of uncertainty reasoning. It was originally proposed by Dempster in 1967. He used multi-valued mapping to derive the upper and lower bounds of probability. Later, it was extended by Shafer in 1976 and formed evidence reasoning. Therefore, it is also called D-S theory[8]. As a kind of uncertainty reasoning method, D-S evidence theory has developed greatly in recent years and is receiving more and more attention. D-S evidence theory not only better grasps the unknown and uncertainty of the problem than the traditional probability theory, but also provides a useful synthetic method of relevant evidence, which can fuse the evidence provided by multiple evidence sources. The basic content of the D-S theory is described below.

3.1 Basic concept of D-S evidence theory

In the D-S reasoning method, the most basic entity is the authentication framework (usually written as \( \Theta \)), which consists of all incompatible propositional possible values (called Singletons) in a domain. This set \( \Theta \) can be defined by formulation (1):

\[
\Theta = \{H_i\} \tag{1}
\]

The basic probability assignment function represents an exact trust to the identified object \( H \) given by an information source \( S_j \), for all \( j \), \( j \in [1, Q] \). \( Q \) indicates the number of information sources. For the information source \( S_j \), the corresponding basic probability assignment function can be obtained:

\[
m_j : 2^\Theta \rightarrow [0, 1] \tag{2}
\]

It can be shown that this function has the following properties:

\[
m_j (\Phi) = 0 \tag{3}
\]

\[
\sum_{H \in \Theta} m_j (H) = 1 \tag{4}
\]

The D-S evidence theory provides a very useful synthesis formula that allows us to synthesize
evidence from multiple sources of evidence. The formula is as follows:

\[ m(H) = \frac{1}{1-k} \sum_{H \cap H_i \neq \emptyset} m_1(H_i) \cdot m_2(H_i) \cdot m_3(H_i) \cdots \quad \forall H \in 2^\Theta \]  

(5)

Where \( k = \sum_{H \cap H_i \neq \emptyset} m_1(H_i) \cdot m_2(H_i) \cdot m_3(H_i) \cdots \), its size reflects the extent of evidence conflicts. The coefficient \( 1/(1-k) \) is called the normalization factor. It is used to avoid assigning a non-zero probability to the empty set during synthesis.

According to formula (5), the result of the fusion can be obtained.

3.2 Evaluation method of D-S evidence theory

Aiming at the problems existing in the evaluation of automation management level of distribution network, this paper proposes an evaluation method based on D-S evidence theory. The identification framework \( \Theta \) in this paper includes five complete propositions \( H_1, H_2, H_3, \ldots, H_5 \), which correspond to the five states of the distribution network automation management level evaluation \{excellent, good, accepted, not bad, bad\}. For the sake of simplicity, only two different experts are considered to score the corresponding indicators and record them as evidence \( E_1, E_2 \). Its basic probability distribution function is \( m_1, m_2 \). Satisfied \( m(\emptyset) = 0 \) and \( \sum_{j=1}^{5} m_k(\{H_i\}) = 1 \) (where \( k = 1, 2 \), indicates the expert group number that determines the level of automation management, \( i = 1, 2, 3, 4, 5 \) indicates that the state of the automation management level of the distribution network is excellent, good, qualified, basically qualified, Not qualified).

Thus, an automated management level evaluation framework based on information fusion can be obtained, as shown in Figure 1.
4. Distribution network automation integration evaluation

4.1 Evaluation based on expert scoring

In order to analyze the influencing factors in the automation construction of a distribution network in a certain city, we invited two different groups of the ten experts to score the influencing factors and determine the height of the different comment indicators in each comment indicator. The comment set is {excellent, good, acceptable, not bad, bad} five levels. Each expert puts forward his own opinions and suggestions according to the contribution of the automation management level to the current distribution management of a certain urban area. He scores the effect of each management mode. The statistics of the scores are shown in Table 2 and Table 3, respectively.

Table 2. Automated management level expert score sheet 1

| A1 | Excellent | Good | Acceptable | Not bad | Bad |
|----|-----------|------|------------|---------|-----|
| data extraction efficiency | 1 | 3 | 4 | 2 | 0 |
| data quality | 3 | 2 | 4 | 1 | 0 |
| automation ratio | 1 | 2 | 4 | 2 | 1 |

Table 3. Automated management level expert score sheet 2

| A2 | Excellent | Good | Acceptable | Not bad | Bad |
|----|-----------|------|------------|---------|-----|
| data extraction efficiency | 1 | 4 | 3 | 2 | 0 |
| data quality | 3 | 3 | 3 | 1 | 0 |
| automation ratio | 2 | 2 | 3 | 2 | 1 |

Through the comparison of indicators, the automatic management weight judgment matrix is established, as shown in Table 4.

Table 4. Automated management weight judgment matrix

| A | data extraction efficiency | data quality | automation ratio |
|---|---------------------------|--------------|-----------------|
| data extraction efficiency | 1 | 1 | 2 |
| data quality | 1 | 1 | 3 |
| automation ratio | 1/2 | 1/3 | 1 |

According to the expert opinion, for the data extraction efficiency, data quality and automation scale indicators under the automated management mode, each expert puts forward his own point of view. And the fuzzy evaluation matrix of the automated management model benefit is obtained through the normalization of the statistical results. Furthermore, according to the weights of each index under the automation management and the fuzzy evaluation matrix of the automation management model, the evaluation of the automation management benefit under different expert scores is calculated, as shown in Table 5.

Table 5. Evaluation results of distribution network automation management level obtained by different expert scores

| Automated management A1 | Bad | Not bad | Acceptable | Good | Excellent |
|-------------------------|-----|---------|------------|------|-----------|
| Automatic management A1 | 0.0960 | 0.1880 | 0.2520 | 0.1440 | 0.3180 |
| Automated management A2 | 0.0169 | 0.1555 | 0.3996 | 0.2385 | 0.1885 |

It can be seen from Table 5 that when different experts score, there is a big difference in the evaluation of the automation management level of the distribution network. When using scores by the first group of experts, 31.8% of the experts believe that the management level is excellent. When the second group of experts scored, only 18.9% of the experts believed that the management level was excellent. The evaluation of the management level is not objective enough. There are subjective influence from people.
4.2 Comprehensive evaluation based on information fusion
In view of the strong subjectivity of the evaluations in section 3.1, the fusion evaluation method proposed in section 2.2 is used to fuse the evaluation results of the two groups of different experts. Among them, the basic probability distribution function of the evaluation results of different expert groups is shown in Table 6.

|       | $H_1$ | $H_2$ | $H_3$ | $H_4$ | $H_5$ |
|-------|-------|-------|-------|-------|-------|
| $m_1$ | 0.3180| 0.1440| 0.2520| 0.1880| 0.0960|
| $m_2$ | 0.1885| 0.2385| 0.3996| 0.1555| 0.0169|

According to the formula (5), the fusion result can be obtained as shown in Table 7.

|       | $H_1$ | $H_2$ | $H_3$ | $H_4$ | $H_5$ |
|-------|-------|-------|-------|-------|-------|
| $m$   | 0.2650| 0.1528| 0.4446| 0.1299| 0.0077|

It can be seen from Table 7 that the evaluation results after the integration of the two groups of experts, is more objective in the urban area. Among them, 26.5% and 15.3% of the experts believe that the improvement of the automation management level in the urban distribution network management mode is very obvious and obvious. 44.5% of the experts believe that the improvement of the automation management level is accepted. 14% of the experts believe that the level of automation management basically not improved.

5. Conclusion
A method is proposed in this paper for evaluating the level of automation management of distribution network based on information fusion. The method can integrate the evaluation results obtained by different expert group, which gives a relatively objective comprehensive evaluation for the subjectivity of expert scores. The comprehensive evaluation is closer to the actual situation and can more accurately reflect the automation management level of the distribution network. This method is of great significance for strengthening the professionalization and lean management of distribution networks. In the continue work, the improvement of the fusion method can be introduced and the uncertainty of the evaluation can be introduced to further increase the objectivity of the evaluation of the automation management level of the distribution network.

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