Design of State Evaluation Platform for Distribution Automation Terminal unit Based on AHP

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Abstract. The requirement of modern power grid for distribution automation is becoming more and more stringent and standardized. Aiming at the situation that the large number of distribution automation terminal units brings to for a lot of inconvenience of maintenance work, this paper establishes a state evaluation system of distribution automation terminal unit based on AHP, and designs a software platform for the system. The software platform occupies little memory, and has friendly interface and is simple. It only needs to input the state of the terminal unit to get the evaluation level of the terminal unit. The software platform can also modify the weight score of each index according to the evaluation results, to constantly revise the judgment matrix and evaluate the terminal more accurately. It provides a reference for terminal state control of distribution automation.

1. Introduction

The safe and stable operation of distribution network directly relates to the power reliability of power users. The construction of distribution automation is the key measure to improve the safe and stable operation of distribution network [1, 2]. Because of the large number and wide distribution of distribution automation terminal units, the different batches of construction and installation, the numerous manufacturers of related equipment and the uneven quality of equipment, the operation and maintenance of distribution automation terminal equipment is very complex.

At present, the maintenance methods for distribution automation terminal units are mainly divided into two kinds, fault maintenance and regular maintenance [3]. As a traditional way of power equipment maintenance, fault maintenance often adopts replacement repair strategy, which has high overhaul cost, and it is difficult to locate and analyze the fault causes of the equipment. Regular maintenance involves a large number of distribution automation terminals, huge workload, difficult to match the relevant maintenance personnel, and easy to build. The problem of overhaul makes the limited overhaul resources further wasted.

Distribution automation terminal units exist the following problems in operation-maintenance and management at present. Such as, the traditional fault repair and regular maintenance methods are still used for distribution automation terminal; the quality of intelligent equipment in distribution network does not meet the requirements of technical specifications occur from time to time; the detection of distribution automation terminal equipment by employees; Operations and maintenance knowledge is not in place.

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Therefore, it is necessary to control the status of distribution automation terminals and bring them into the completely state evaluation system. By adopting the pre-condition evaluation method, the maintenance plan can formulate reasonably. On the one hand, the limited maintenance resources can use reasonably; on the other hand, the economic and stable operation of distribution network can improve [4, 5].

This paper develops a hierarchical evaluation system for the state of distribution automation terminal units, and determines the weights of each evaluation index by using the Analytic Hierarchy Process (AHP). According to the weights, the scoring rules of each index are given, which provides decision-making basis for the condition-based maintenance of distribution automation terminal equipment.

2. AHP theory

2.1. Establish Hierarchical Structure
Firstly, clarify the purpose of analytic hierarchy process, and decompose it into hierarchical structure. Prefer to decompose and study the influencing factors of the project, it is necessary to clarify the indicators and their relationships that have an impact on the project. The hierarchical structure is generally composed of three parts. The target layer refers to the purpose of the problem, i.e. the predetermined goal; the criterion layer refers to the relevant factors and criteria affecting the achievement of the goal; and the scheme layer refers to the scheme and result chosen by the preset problem. In practice, there may be many criteria affecting the achievement of goals. At this time, it is necessary to analyze the relationship among the criteria factors in detail, and to distinguish the main criteria from the sub-criteria which belong to the main criteria [5-8].

2.2. Construct judgment matrix and calculate assignment
The judgment matrix is established according to the hierarchical structure. Compare each factor in pairs, and judge the importance of each factor according to its importance scale value. In the AHP, the expression of importance degree is clear and clear. Usually, the form of 1-9 assignment is used to show the difference of importance degree [8]. In the process of calculation or evaluation, the importance of elements can be identified quickly without any redundant analysis and thinking [5, 6].

| scale | definition |
|-------|------------|
| 1     | factor $i$ is as important as factor $j$ |
| 3     | factor $i$ is often important compared with factor $j$ |
| 5     | factor $i$ is fairly important compared with factor $j$ |
| 7     | factor $i$ is very important compared with factor $j$ |
| 9     | factor $i$ is absolutely important compared with factor $j$ |
| 2, 4, 6, 8 | scale values corresponding to the intermediate state between the above two judgments |
| reciprocal | $a_{ij}=1/a_{ji}$ |

2.3. Calculate the weight vector and test it
Judgment matrix is usually constructed according to expert opinions. In order to convert the importance or score into fraction or decimal form, the hierarchy should be sorted in a single order, that is, to calculate the weight vector. It should be noted that in the sorting process, the consistency test of the judgment matrix should be carried out. The purpose of verification is to verify the logic between elements and to determine whether they conform to the consistency criteria. Only on the premise of meeting the requirements of consistency can the next calculation be carried out, otherwise it will be revised.

The steps of consistency checking are as follows [5, 6].
Step 1: calculate Consistency Index ($CI$)

$$CI = \frac{\lambda_{\text{max}} - n}{n - 1}$$  \hspace{1cm} (1)

Where $\lambda_{\text{max}}$ is the largest eigenvalue of the judgment matrix.

Step 2: Determine the Mean Random Consistency Index ($RI$)

According to the different order of the judgment matrix, the value of $RI$ can be obtained by looking up the table. The following table gives the average random consistency index of 1-9 order judgment matrix calculated 1000 times.

| Order n | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI      | 0   | 0   | 0.58| 0.90| 1.12| 1.26| 1.36| 1.41| 1.46|

Step 3: Calculate the consistency ratio $CR$ and judge it

$$CR = \frac{CI}{RI}$$  \hspace{1cm} (2)

When $CR < 0.1$, the consistency of the judgment matrix is acceptable; when $CR > 0.1$, the judgment matrix should be reconstructed, and the judgment matrix should be corrected properly until the consistency test is passed.

In order to obtain relevant weights and results, the calculation process of the analytic hierarchy process can be summarized and sorted, if necessary. Through the analysis of the results, the weight of each factor can be obtained, and the accuracy of the results can be determined by combining with the actual project requirements.

3. State Assessment Platform for Distribution Automation Terminal Based on AHP

Based on AHP, this paper establishes an evaluation system of distribution automation terminal unit, and builds a software platform of distribution automation terminal unit condition evaluation. The platform mainly includes eight parts, namely, first-level index, second-level index, system charts, first-level index analysis, second-level index analysis, index ratio chart, scoring rules, grade analysis.

Fig. 1 is first-level index module. Here, the user can enter the name of the first level index in the blue text box. The number of index is also determined by user input. Fig. 2 is the secondary index. The secondary index is the lower level of the primary index, and the corresponding secondary index can be input under each first index.

After inputting the first and second level indexes, a complete evaluation system of distribution automation terminal unit can be displayed, as shown in Fig.3. The graph clearly expresses the relationship among the indexes. According to the instructions in Fig.4, input the judgment matrix of the first level index. The judgment matrix is scored by experts. Click on the analysis results button, and on the right side of Fig.4, the results of calculating the weights of each element of the first-level index will be displayed.
Similar to the first-level index, the judgment matrix of each second-level index can be input according to the prompt, as shown in Fig. 5, and the weight calculation value and pie chart of each index can be obtained. After inputting all the judgment matrices of the first index and the second index, the weight proportion maps of all the second index can be obtained by calculating, as shown in Fig.6. If the input comparison matrix does not pass the consistency check, the dialog box shown in Fig. 7 will pop up. The dialog box is used to prompt the user to reconstruct the judgement matrix.

Users can define the scoring rules of terminal equipment according to the specific situation, and input them in Fig. 8. Usually the scoring rule is a range value. After defining the scoring rules, the user can input the indexes of the terminal device and click on the calculation to get the status level of the terminal device. As shown in Fig.9.
Fig. 8 scoring rules

Fig. 9 status level

What are shown above is the design ideas of the software platform. The whole software platform is simple, practical, flexible and operable, which provides a reference for the state evaluation of distribution automation terminal units.

4. Conclusion

Based on the analytic hierarchy process (AHP), this paper establishes the evaluation system of distribution automation terminal, and builds a software platform of distribution automation terminal unit condition evaluation. The platform occupies less memory, and has friendly and simple interface. The input of the software platform is very flexible. It can input the number of indicators, the scale of each indicator, and the scoring rules of each indicator. Finally, the state of the terminal device can be obtained by only inputting the relevant indicators of the terminal unit. The software platform is relatively objective, practical and operable, and provides a reference for the evaluation of distribution automation terminal unit status.

References

[1] ZHAO Jianghe, CHEN Xin, LIN Tao, et al. Distribution automation construction in smart grid[J]. Automation of Electric Power Systems, 2012, 36 (18) : 33-36.

[2] WANG Yimin. Research framework of technical standard system of strong and smart grid [J]. Automation of Electric Power Systems, 2010, 34 (22) : 1-6.

[3] LI Ming, HAN Xueshan, YANG Ming, et al. Basic concept and theoretical study of condition-based maintenance for power transmission system [J]. Proceedings of the CSEE, 2011, 31 (34) : 43-52.

[4] ZHANG Bo, ZHAO Jianghe, LIN Tao, et al. Research and establishment of standard system for distribution automation system [J]. Distribution & Utilization, 2014, 31 (5) : 25-28.

[5] ZHU Jiran, LENG Hua, WANG Yijian, et al. Research on State Evaluation for Distribution Automation Terminals [J]. Distribution & Utilization, 2017, 6: 59-63.

[6] CAI Jingxu, YANG Chunyu. Study on Distribution Automation Terminal State Evaluation Method Based on Analytic Hierarchy Process [J]. GUANGXI ELECTRIC POWER, 2018, 41(3):6-9.

[7] DENG Xuyang, ZHANG Chi, CAO Jiandong, et al. Evaluation of relay protection system in the power plant based on AHP LJJ. Advances of Power System& Hydroelectric Engineering, 2013, 29 (12) : 66-69.

[8] LI Ming, HAN Xueshan, WANG Yong, et al. Decision making model and solution of condition-based maintenance for substation [J]. Proceedings of the Chinese Society for Electrical Engineering, 2012, 32 (25) : 196-202.