Status Detection Evaluation Method of Distribution Network Fault Indicator Based on Artificial Intelligence

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Abstract. In order to solve the problem of status detection evaluation of field operation fault indicator, a status detection evaluation method of distribution network fault indicator based on artificial intelligence is proposed. Firstly, the fault indicator status detection evaluation model is established, and the result information of fault indicator detection using portable detector is described by fault indicator status detection information matrix. Secondly, based on the principle of "3 selection 2", the fault indicator status detection comprehensive result table is established. Then, the same factory fault indicator status detection evaluation matrix and the fault indicator single state detection comprehensive evaluation matrix are established to evaluate the 10 functional detection results of a single fault indicator of a manufacturer. Secondly, the fault indicator sub-detection comprehensive evaluation matrix is established to describe the evaluation results of all fault indicators in the same plant on different sub-function detection. Finally, the comprehensive evaluation results of all fault indicator detection in the same plant are evaluated by means of the average method. The example analysis shows that the method described in this paper can evaluate the status detection results of fault indicators from three aspects: individual, sub-item and comprehensive, which has good practical significance.

1. Introduction

As an important part of intelligent maintenance, equipment status assessment can evaluate and analyze the real-time and historical operation status of equipment, predict and analyze the future operation situation of equipment, screen the weak parts of equipment, and eliminate the hidden faults of equipment in the budding state. It is one of the important means to improve the reliability of power supply in power grid [1-3].

As an important terminal equipment for feeder automation, the fault indicator is widely used in the current distribution network because of its small size, low price, live installation, and good adaptability to short circuit and ground fault. It is of great practical significance to accurately evaluate the equipment detection status of the fault indicator in order to better guide the maintenance.

The current equipment status evaluation is mostly concentrated in the primary equipment field of the transmission network and distribution network. The status detection evaluation of secondary protection equipment and terminal equipment is less common in the newspaper. The reference [4]...
proposed a transformer operating state assessment method based on multi-information fusion. The reference [5] proposed an operation status assessment method of high voltage circuit breakers based on credibility theory. The reference [6] proposed a practical method for comprehensive state assessment of distribution networks based on improved radar charts. The reference [7] proposed a distribution transformer state assessment method based on real-time operational data mining. Based on the widely distributed electrical quantity acquisition terminals in medium voltage distribution network, the above methods evaluated the operation status of distribution network equipment and network from many aspects, such as equipment layer and network layer. However, the detection state of the secondary terminal such as the fault indicator has not been evaluated.

This paper introduces a portable fault indicator detector based on the Internet of Things, and establishes a fault indicator status detection evaluation model. According to this model, a distribution network fault indicator status detection evaluation method based on artificial intelligence is proposed.

2. Distribution network fault indicator status detection evaluation model

2.1. Portable fault indicator detector based on Internet of Things

The portable fault indicator detector downloads the relevant information of the fault indicator from the production management system by scanning the two-dimensional code of the fault indicator to be detected, including manufacturer information, commissioning time, maintenance time and other related parameters. Secondly, the fault indicator to be detected is grouped according to the online operation, and one set of three probes is respectively placed in the area to be inspected of the portable fault indicator detector. Then, according to the detection procedure, corresponding operations are performed on the human-machine interface, and the function of detecting the fault indicator is detected. Finally, the test results are displayed in the human-machine interface, and the result information is uploaded to the production management system through the Internet of Things communication network.

In order to ensure information security, the portable fault indicator detector and the production management system exchange information through the secure access zone. The communication method can use optical fiber, carrier wave, wireless public network, wireless private network, NB-IoT and other communication means. In areas with weak signal intensity, concentrator can be used to collect and amplify signals by WIFI, Zigbee, Bluetooth, infrared and other means, and then to interact with data by means of Internet of Things communication.

2.2. Fault indicator status detection evaluation model

The Fault Indicator Status Detection Information Matrix (FSDI) is established to record the result information of a fault indicator 3 times using portable fault indicator detector. Specifically described as:

\[
FSDI = \begin{bmatrix}
D_{I1} & D_{I2} & \cdots & D_{Ij} & \cdots & D_{In}
\end{bmatrix}
\]

(1)

Wherein, the first to third action is the detection result information of the first to third times of a fault indicator. \( j=1,2,3,\cdots,n \), \( n=10 \). \( D_{I1} \) is the result information value of the first short-circuit fault alarm detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. \( D_{I2} \) is the result information value of instantaneous fault detection for the first reclosure of fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. \( D_{I3} \) is the result information value of permanent fault detection for the first reclosure of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. \( D_{I4} \) is the result information value of the first load fluctuation anti-false alarm detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. \( D_{I5} \) is the result information value of the first transformer no-load closing inrush current anti-false alarm...
Detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. $DI_{16}$ is the result information value of the first line closing load inrush current anti-false alarm detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. $DI_{17}$ is the result information value of the first large load switching anti-false alarm detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. $DI_{18}$ is the result information value of the non-fault phase reclosing inrush current anti-false alarm detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. $DI_{19}$ is the result information value of the first telemetry accuracy detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0. $DI_{1a}$ is the result information value of the first charging and unloading detection of the fault indicator. If the detection result is correct, it is 1; otherwise, it is 0.

When the fault indicator is inspected on the spot, because of the operating environment, the operator and the inspecting machine, it can not ensure that the results of the portable detector can correctly reflect the status of the fault indicator. Assume that the probability of accurate detection by the detector at the first detection is $P(1)$, and the probability of accurate detection by the detector at the second detection is $P(2)$. If the same information of two detections is selected as the final result, consider The exact probability $P(U)$ in both cases will become $P(1)P(2)$, and it is clear that $P(U)$ will be less than $P(1)$ or $P(2)$.

In order to ensure the accuracy of the on-site inspection, the final result of the fault indicator detection can be determined according to the "3 selection 2" principle using the results of 3 detections. The principle of "3 selection 2" refers to the use of two identical detection results to represent the final detection results in three detections. Assume that the probability of accurate detection by a single detector is 95%, 1 means the detection result is correct, 0 means the detection result is wrong, then 8 cases are shown in Table 1.

| Case | 1 | 2 | 3 | $P_i$  | Case | 1 | 2 | 3 | $P_i$  |
|------|---|---|---|-------|------|---|---|---|-------|
| 1    | 0 | 0 | 0 | 0.000125 | 5    | 1 | 0 | 0 | 0.002375 |
| 2    | 0 | 0 | 1 | 0.002375 | 6    | 1 | 0 | 1 | 0.045125 |
| 3    | 0 | 1 | 0 | 0.002375 | 7    | 1 | 1 | 0 | 0.045125 |
| 4    | 0 | 1 | 1 | 0.045125 | 8    | 1 | 1 | 1 | 0.857375 |

It can be seen from Table 1 that according to the "3 selection 2" principle, the detection results in the first, second, third, and fifth cases are erroneous, and the error probability is the probability sum in four cases, that is, 0.00725. Conversely, the probability of a correct test result is 0.99275. From the above analysis, the final detection result determined according to the "3 selection 2" principle is higher than the accuracy of the single detection result and the two detection results.

The Fault Indicator Status Detection Comprehensive Result Table (FDCR) is established to record the final results of a fault indicator status detection using a portable fault indicator detector. Specifically described as:

$$FDCR = \left[ DR_1, DR_2, \ldots, DR_j, \ldots, DR_n \right]$$

$DR_j = \begin{cases} 
1 & (DI_{1j} + DI_{2j} + DI_{3j}) \geq 2 \\
0 & (DI_{1j} + DI_{2j} + DI_{3j}) < 2 
\end{cases}$

Wherein, $j = 1, 2, 3, \ldots, n, n = 10$. $DR_i$ is the final result of the fault indicator item $i$ detection.

3. Status detection evaluation method of fault indicator based on artificial intelligence

The quality of the fault indicator is closely related to its production material, manufacturing process, R&D level, operating environment, etc. Therefore, the same manufacturer's fault indicator often has the same product problem. The evaluation of the fault indicator status detection is greatly influenced by the subjective consciousness of the person. Based on the idea of artificial intelligence, the weighted comprehensive method can be used to comprehensively evaluate the status detection result of the fault
The comprehensive evaluation can be carried out from 3 directions and 10 functions. The so-called 3 directions refer to the evaluation of the detection results of the fault indicator from 3 aspects: single device, same manufacturer, and same feeder. The so-called 10 kinds of functions refer to the short-circuit fault alarm detection, the reclosing transient fault detection, the reclosing permanent fault detection, the load fluctuation anti-false alarm detection, the transformer no-load switching inrush current anti-false alarm detection, the line switching inrush current anti-false alarm detection, the heavy load switching anti-false alarm detection, the non-fault coincidence anti-false alarm detection, the thrust current anti-false alarm detection, the telemetry accuracy detection, and the live loading and unloading detection.

The Same Factory Fault Indicator Status Detection Evaluation Matrix (SFDE) is established to describe the status detection evaluation results of the same manufacturer's fault indicators using portable detectors. The specific description is:

$$SFDE = \begin{bmatrix} DE_{11} & DE_{12} & \ldots & DE_{1j} & \ldots & DE_{1n} \\ DE_{21} & DE_{22} & \ldots & DE_{2j} & \ldots & DE_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ DE_{i1} & DE_{i2} & \ldots & DE_{ij} & \ldots & DE_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ DE_{m1} & DE_{m2} & \ldots & DE_{mj} & \ldots & DE_{mn} \end{bmatrix}$$

Wherein, $DR_{ij}$ is the comprehensive result of the $j$-th functional status detection of the $i$-th fault indicator; $i=1, 2, \ldots, m$, $m$ is the number of fault indicators of the same manufacturer that have been detected; $DE_{ij}$ is the $j$-th item of function status detection evaluation of the $i$-th fault indicator.

The Fault Indicator Single State Detection Comprehensive Evaluation Matrix (FSCE) is established to describe the comprehensive evaluation results of single fault indicator in the same plant. Specifically described as:

$$FSCE = \begin{bmatrix} SE_1 \\ SE_2 \\ \vdots \\ SE_i \\ \vdots \\ SE_m \end{bmatrix}$$

$$SE_i = \frac{100 \sum_{j=1}^{n} \alpha_j DE_{ij}}{\sum_{j=1}^{n} \alpha_j}$$

$$0 \leq \alpha_j \leq 1$$

In the formula, $SE_i$ is the comprehensive evaluation result of the state detection of the fault indicator $i$, and $\alpha_j$ is the influence factor of the single function evaluation of the fault indicator, which can be determined according to the importance degree of the detection item, and the default values of each factor are 1,0.8,0.8,0.8,0,6,0.8,0,8,0,8,0,4,0.6. The value of $SE_i$ is between 0 and 100. The closer to 100, the better the detection result of the fault indicator. The closer to 0, the worse the detection result of the fault indicator is. If it is less than a certain threshold, it needs to be replaced as soon as possible.

The Fault Indicator Sub-detection Comprehensive Evaluation Matrix (FSDE) is established to describe the comprehensive evaluation results of all fault indicators in the same plant on different sub-function detection. Specifically described as:

$$FSDE = \left[ SD_1, SD_2, \ldots, SD_j, \ldots SD_n \right]$$

$$SD_j = \frac{100 \sum_{i=1}^{m} DE_{ij}}{m}$$

Wherein, $SD_j$ is the comprehensive evaluation result of the $j$-th function detection of all the fault indicators of the same factory, and its range of values is 0-100. The closer to 100, the better the
function of item $j$ of the fault indicator produced by the factory is; the closer to 0, the worse the function of item $j$ of the fault indicator produced by the factory is, and the equipment must be replaced when the value is less than a certain threshold.

The same factory fault indicator detection comprehensive evaluation value (SDCE) is used to describe the comprehensive evaluation results of all fault indicator detections in the same plant. The specific description is:

$$SDCE = \frac{1}{m} \sum_{i=1}^{m} SE_i$$  \hspace{1cm} (7)$$

Wherein, the value range of SDCE is 0-100. The closer to 100, the higher the overall quality level of the fault indicator produced by the factory is. The closer to 0, the lower the overall quality level of the fault indicator produced by the plant is. When it is less than a certain threshold, the bidding qualification of the factory will be cancelled.

The status detection evaluation of the fault indicator of the same feeder is completely similar to the evaluation of the same manufacturer, and will not be described again.

4. Case analysis

A portable fault indicator detector based on the Internet of Things is used to detect a local fault indicator. Table 2 shows the final detection results of eight fault indicators in factory S. The influence factors ($\alpha_1$-$\alpha_{10}$) are 1,0.8,0.8,0.8,0.6,0.8,0.8,0.8,0.8,0.4,0.6. Then the status detection evaluation analysis of the S factory fault indicator is as follows:

| Name | Function 1 | Function 2 | Function 3 | Function 4 | Function 5 | Function 6 | Function 7 | Function 8 |
|------|------------|------------|------------|------------|------------|------------|------------|------------|
|      | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 1    | normal     | abnormal   | normal     | normal     | normal     | normal     | normal     | normal     |
| 2    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 3    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 4    | normal     | abnormal   | normal     | normal     | normal     | normal     | normal     | normal     |
| 5    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 6    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 7    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |
| 8    | normal     | normal     | normal     | normal     | normal     | normal     | normal     | normal     |

According to the method described in Section 2, the matrix SFDE is generated from Table 2, and the matrix FSCE is generated from the single function evaluation influence factor value of the fault indicator. The comprehensive evaluation value of the single state detection of the fault indicator 1-8 is shown in Table 3.

| Name | $SE_1$ | $SE_2$ | $SE_3$ | $SE_4$ | $SE_5$ | $SE_6$ | $SE_7$ | $SE_8$ |
|------|--------|--------|--------|--------|--------|--------|--------|--------|
| Value| 81.081 | 67.568 | 100    | 81.081 | 89.189 | 75.676 | 91.892 | 100    |

From Table 2, it can be seen that the status detection evaluation values of fault indicators 3 and 8 are 100, indicating that the functions of these two fault indicators are completely normal. The evaluation values of the fault indicators 1, 4, 5, and 7 are above 80 points, indicating that some functions are abnormal, but they do not affect the overall operation, and may also be operated for a period of time. The evaluation values of the fault indicators 2 and 6 are below 80 points, indicating that the multiple functions of the fault indicator are not functioning properly, which seriously affects the on-site monitoring and needs to be replaced in time.

The matrix FSDE can be generated by the matrix SFDE, and the comprehensive evaluation results of the function indicators of the fault indicator are shown in Table 4.
Table 4. Fault indicator sub-detection comprehensive evaluation result

| Name | SD₁ | SD₂ | SD₃ | SD₄ | SD₅ | SD₆ | SD₇ | SD₈ | SD₁₀ |
|------|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Value| 87.5| 87.5| 87.5| 75  | 37.5| 87.5| 100 | 100 | 87.5 |

From Table 4, it can be seen that the evaluation value of 7, 8 and 10 functions of the fault indicator in factory S is 100 points, and its performance is very good; the evaluation value of 1, 2, 3, 6 and 9 functions is above 80 points, and some functions are not working normally, but it does not affect the overall use. The 4th and 5th functions are poorly evaluated, especially the 4th load fluctuation anti-false alarm function, which should be paid special attention to in future bidding. The comprehensive evaluation value SDCE of fault indicator detection in the same plant is 85.811 points. Overall, the state detection results of fault indicator in factory S are better.

5. Conclusion

Firstly, the fault indicator status detection evaluation model is established, and the result information of fault indicator detection using portable detector is described by fault indicator status detection information matrix. Secondly, based on the principle of "3 selection 2", the fault indicator status detection comprehensive result table is established. Then, the same factory fault indicator status detection evaluation matrix and the fault indicator single state detection comprehensive evaluation matrix are established to evaluate the 10 functional detection results of a single fault indicator of a manufacturer. Secondly, the fault indicator sub-detection comprehensive evaluation matrix is established to describe the evaluation results of all fault indicators in the same plant on different sub-function detection. Finally, the comprehensive evaluation results of all fault indicator detection in the same plant are evaluated by means of the average method. The example analysis shows that the method described in this paper can evaluate the status detection results of fault indicators from three aspects: individual, sub-item and comprehensive, which has good practical significance.

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