Application of Cloud Platform Technology in the Test Process of Power Transformer

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Abstract. The power transformer is the hub equipment in the power system, and its health status directly affects the safety and reliability of the power system operation. According to the operation principle and structural characteristics of the transformer, the idea of information fusion is introduced into the experiment of the transformer, and a cloud-based platform is established. The technical experimental mode is to use surface fitting algorithm and evidence reasoning technology to diagnose faults of transformers from different sides and make full use of various characteristic information to effectively improve the diagnosis rate.

Keywords: Power Transformer, Experiment, Information Fusion, Evidence Reasoning

1. Introduction

Power transformers are not only among the most important and expensive equipment in the power system, but also one of the equipment that causes the most accidents in the power system \cite{1-2}. Nowadays, the power operation department generally adopts the method of analyzing the gas composition, content and gas production rate dissolved in the oil of the transformer in operation, and strives to detect the latent fault inside the transformer as soon as possible, and judge whether it will endanger the safe operation. All countries are based on the IEC's three-ratio method, but the correct rate of judging failures is only 80\%, and there is a single sensor measurement error and the cross-effect of some sensors during simultaneous measurement \cite{3-4}, while the three-ratio method is The recommended fault ratio range codes are not many, and in actual work, the ratio range is often not found and cannot be judged. Therefore, it is very limited to conduct experiments based on the information provided by the gas in the oil \cite{5-6}. This paper uses cloud platform technology to combine the conclusions of the oil chromatography analysis method with the judgment of the partial discharge method for DS evidence reasoning. The partial discharge method uses a typical discharge model to perform pattern recognition on the discharge map, because the status information of the equipment can be reflected in In terms of the structure of the waveform, the waveform feature extraction and description are realized through the segmentation of the waveform, including the recognition and description of the waveform segment. The segment of the waveform corresponds to the operation of the transformer, and different waveform structure primitives should be defined in different waveform segments to effectively describe the structural characteristics of each waveform segment. Therefore, the fusion information, maintenance records and expert experience are used as the basis for
decision-making in order to improve the validity and credibility of the experiment.

2. Hierarchical classification of transformer faults
The internal faults of the transformer are divided into sudden faults composed of electrical circuit defects and slow-developing latent faults composed of partial overheating of cores, switches, and parallel wire insulation damage according to the formation and development process. The classification from the structural level is shown in Figure 1.

![Figure 1. Transformer failure](image)

3. Experimental technology of transformer information fusion

3.1. Application of evidence theory in information fusion
Information fusion is to make full use of multi-sensor information resources of different time and space, and use computer technology to automatically analyze the multi-sensor observation information obtained in time sequence under certain criteria (this article is based on DS evidence theory), optimize synthesis, and obtain the measured object Consistent interpretation and description to complete the required decision. Since evidence theory uses an "identification framework", it is a finite set of mutually independent possible outcomes or hypotheses about a proposition, and it is the set of all subsets. According to the classification of the fault, the identification framework of this article can be obtained as \{A, B, C, D\} representing windings, magnetic circuits, structures and accessories, and cooling oil. Each Hi (i is 1~10) successively represents ten types of faults in the above fault classification. The D-S evidence theory performs operations on this identification framework and provides the logic for calculating the elements of the scene set, and then uses these calculation results to complete the calculation of high and low uncertainties. Therefore, important situations such as "uncertainty" and "ignorance" can be expressed well, and the processing of uncertain data has good results.

3.2. Transformer experimental model based on information fusion
The transformer experiment is a multi-source information fusion process. The information of the experiment (measured from sensors, some knowledge and some intermediate results) may be the same, similar or different, which are called redundant information, cross information, and complementary information. On the other hand, the information of the sensors in the experiment is the most primitive information, which can be used to extract some characteristic information about system faults, called fault characterization, and then perform a more detailed diagnosis based on the fault characterization and system knowledge to determine whether the system is faulty And the nature of the source of the fault. Therefore, according to the characteristics and requirements of the transformer experiment, the level of information fusion can be divided into a data layer, a characteristic layer and a decision layer, as shown in Figure 2.

(1) Data layer fusion. Transformers in normal operation have very little gas content in the oil, especially the flammable gas is lower, below 0.1%, while the transformer with a mild fault is between
0.1% and 0.5%, and the total amount of flammable gas in the faulty transformer is 0.5 % the above. Therefore, it is feasible to determine the operating status of the transformer by accurately measuring the flammable gas content. However, the measured gas is a mixed gas, and some sensors have cross-reactions. According to practice, it is found that the pressure characteristic sensor reacts to C₂H₄ more than gas. The characteristic sensor of CH₄ reacts to C₂H₆ more than gas, and the temperature of the environment is also related to the micro-water signal, which requires the fusion of data to correct errors. Therefore, this paper adopts a curved surface fitting algorithm. The basic idea is to establish the corresponding relationship between the measured target parameter and the sensor output from the two-dimensional regression equation, and then calculate the mean square from the experimental calibration/calibration data according to the principle of least squares. The coefficient in the regression equation under the condition of minimum error. In this way, when the output value of the sensor is measured, the corresponding input target parameters can be calculated from the two-dimensional regression equation with known coefficients, and then the fault condition can be judged according to the ratio of the three items in the feature extraction.

![Diagram](image)

**Figure 2.** Transformer information fusion framework

(2) Feature layer fusion. The fusion of feature layers is based on D-S evidence theory. Use characteristic data as corresponding evidence. On the one hand, the main basis of the evidence is the knowledge and real-time data of thousands of experts, and on the other hand, it is the regulations and standards promulgated by the state. At the same time, the evidence cannot be too specific or too special. It will lead to the problem of combination "explosion" due to too fine division, making the experiment impossible. Therefore, feature extraction should be performed on the data obtained after data fusion, and combined with other relevant information for feature fusion. The input information from this layer has more specific features such as the partial discharge pattern, the leakage current of the iron core, and the main transformer casing. Parameters, etc., can make the conclusions of the experiment clearer and the fault location more accurate, which is more guiding significance for troubleshooting and transformer maintenance.

(3) Fusion of decision-making levels. The decision-making level fusion is the final result of the three-level fusion, which is directly aimed at the specific decision-making target, namely the type and location of the fault, while taking corresponding fault isolation measures.

4. Experiment and result analysis

A SSPZ-45000/110 transformer in a certain factory was analyzed by the oil chromatographic data of 2002.1.11 as shown in Table 1. At the same time, the absolute gas production rate (ml/h) = 24,758 was calculated. The calculated gas production rate qualification rate=0, and the chromatographic analysis qualification rate=0. It shows that the gas content and growth rate are seriously exceeding the standard. The mass fraction of water in the insulating oil is the limit value of 70/10000>3/10000 (ambient temperature is 10°C).

| Ingredient | H₂ | CH₄ | C₂H₆ | C₂H₄ | C₂H₂ | Total hydrocarbons | CO | CO₂ |
|------------|----|-----|------|------|------|-------------------|----|------|
| Date       |    |     |      |      |      |                   |    |      |

Table 1. Oil chromatographic analysis data (unit: ppm)
4.1. Specific steps of data fusion
Experimental calibration. Taking the characteristic sensor of H₂ and the characteristic sensor of C₂H₄ as an example, the two sensors are statically calibrated under different gas mixtures, and n points, namely \( P_i : P_1 \cdots P_n \) and \( Q_i : Q_1 \cdots Q_n \), are calibrated within the range.

Determine the two-dimensional fitted regression equation. Suppose the output voltage of the ratio sensor and the C2H4 sensor are \( U_1 \) and \( U_2 \), and the H₂ content is determined by the two-dimensional coordinates \( (U_{i1}, \ U_{i2}) \) on a curved surface, which can be described by the following two-dimensional regression equation

\[
M = a_0 + a_U U_1 + a_2 U_2 + a_u U_1^2 + a_{u2} U_2^2 + a_{uu} U_1 U_2 + o
\]

(1)

In the formula, \( a_0 \)~\( a_5 \) are constants, and \( o \) is a high-order infinitesimal.

The coefficients of the equation are obtained. Using the principle of least squares method, the obtained coefficients all meet the minimum mean square error condition, that is, there is an error \( \Delta K \) between \( P(U_{i1}, U_{i2}) \) calculated by the quadric surface fitting equation and the calibration value \( P_K \), and the variance is:

\[
\Delta K^2 = \left[ P_K - P(U_{i1}, U_{i2}) \right]^2, K = 1, 2 \cdots n \times n
\]

(2)

The mean square error \( R_s \) should be the smallest.

The mean square error \( R_s \) is a function of constant coefficients \( a_0 \)~\( a_5 \). According to the extreme value conditions of the multivariate function, the following partial derivatives are respectively set to 0.

I.e. \( \frac{\partial R_s}{\partial a_i} = 0, i = 0, 1 \cdots 5 \)

According to the experimentally calibrated input values \( P_K \) and \( U_K \), the corresponding output values \( U_{i1K} \) and \( U_{i2K} \) of the two sensors, so that the constants \( a_0 \)~\( a_5 \) of the two-dimensional regression equation can be calculated.

Table 2. Oil chromatographic analysis data after fusion (unit: ppm)

| Date       | H₂ | CH₄ | C₂H₆ | C₂H₄ | C₂H₂ | Total hydrocarbons | CO | CO₂ |
|------------|----|-----|------|------|------|-------------------|----|-----|
| 2001.7.9   | 87 | 53  | 5.6  | 47   | 3.1  | 109               | 82 | 738 |
| 2002.1.11  | 195| 162 | 17   | 62   | 7.4  | 248               | 103| 751 |

According to the three-ratio judgment method, the transformer fault belongs to type 1,000, 1, 2, and the table is a high-energy discharge fault. After feature extraction, it is preliminarily judged that an internal fault has occurred, which may be: ① The body insulation is damaged, such as moisture. ② There is a problem with the iron core. ③ Winding problems, such as short-circuit between phases, broken windings and lead wires.

4.2. Oil chromatographic analysis and partial discharge method
See Table 3 for the basic probability of failure and its fusion information experiment results.

Table 3. Basic probability table

| Malfunction | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 |
|-------------|----|----|----|----|----|----|----|----|----|-----|
| Method 1    | 0.025 | 0.071 | 0.086 | 0.214 | 0.017 | 0.022 | 0.035 | 0.017 | 0.368 | 0.003 |
| Method 2    | 0.062 | 0.071 | 0.050 | 0.156 | 0.079 | 0.025 | 0.022 | 0.038 | 0.169 | 0.110 |
| Method 3    | 0.042 | 0.038 | 0.021 | 0.215 | 0.035 | 0.020 | 0.105 | 0.016 | 0.388 | 0.036 |
At the same time, the definition of evidence theory calculates the uncertainty analysis of various methods as 0.125, 0.218 and 0.063. It can be seen that the uncertainty of oil chromatography and partial discharge method is higher, and the uncertainty (0.063) after fusion is reduced by one. Therefore, it can be concluded that the cooling oil of the transformer is oxidized by moisture (0.388). Combined with other information as follows: core leakage current is 0.45A, three-phase voltage balance current is normal, etc. Analyzing the above judgments, it can be concluded that the nature of the fault is that the insulation damage causes damp, and then the account and historical data are automatically transferred for longitudinal analysis. According to the insulation resistance and dielectric loss test data obtained during the 2001.12.7 inspection, see Table 4.

| Experiment date | Temperature | Insulation resistance | Absorption ratio | Polarization index | Medium loss |
|-----------------|-------------|-----------------------|------------------|-------------------|-------------|
|                 |             | High voltage coil     | Low voltage coil | High voltage coil | Low voltage coil | High voltage coil | Low voltage coil |
| 2001.4.5        | 16          | 887                   | 650              | 1.29              | 1.31         | 1.44              | 1.53         | 0.47          | 0.21 |
| 2001.12.7       | 14          | 638                   | 330              | 1.28              | 1.37         | 1.32              | 1.49         | 0.69          | 0.51 |

It can be seen from Table 4 that the dielectric loss is greater than 0.5%, and the qualification degree is calculated as 0.71. Qualification <0.8 indicates that there is a problem with the insulation. Based on the above situation, the experimental result is obtained: the transformer should be closely monitored and shut down for maintenance as soon as possible. The actual maintenance situation is that the transformer has not been replaced in time due to long-term operation and the seal is aging, causing the transformer to enter water and damp, and cause discharge, which proves that the judgment is accurate.

5. Conclusion
This paper uses the sub-index evaluation results of the evaluation object to calculate the target index evaluation results, applies the method to the transformer state experiment, uses the analytic hierarchy process to obtain the weight information of each index, and uses the universality of cloud platform technology to propose a new The experimental method of transformer state based on cloud platform technology. The application of cloud platform technology can better overcome the misdiagnosis and missed diagnosis of transformer faults, solve the uncertain reasoning process in the transformer experiment, and make the reasoning process logical, which is of great significance for improving the intelligent level of the transformer experiment.

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