Interactive Visualization of Transformer Diagnosis Based on Multiple Views

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Abstract. Transformer is one of the most expensive and critical equipment in power industry. The research on condition monitoring and fault diagnosis of transformer is significant for the stability of power system. However, transformer diagnosis involves many factors, so it is very difficult to evaluate transformer operation state effectively and accurately by single diagnosis method. In this paper, we present a novel interactive visualization model of transformer diagnosis based on multiple views. This model imitates multi-angle analysis by combining multi-source information including operation information, experiment information and environmental information through multi-view collaborative visualization. Data are displayed in different dimensional and a variety of interaction technology are used so that analysts can access the original data from multiple perspectives. With the help of visual perception of human eyes and intelligent cognitive ability of human brain, users can find useful information from large-scale, high-dimensional, or even incomplete data to make effective decisions.

1. Introduction

Power transformer is one of the most important and expensive equipment in the power industry and the reliable operation of transformer is directly related to the safety of power supply. The research on condition monitoring and fault diagnosis of transformer can help maintenance personnel find insulation failures in power transformers at an early date. It is great significant to ensure the safe, reliable and stable of the whole power system.

Power transformer itself is a very complex system which has a lot of factors to characterize its state. The factors are uncertain and fuzzy, so it is very difficult to evaluate transformer operation state effectively and accurately [1]. With the improvement of power information platform, a large number of power grid operation information, status information and environmental information data are constantly acquired and accumulated. Based on the existing theory about condition assessment of transmission and combined with the precise information provided by massive data, it can provide more precise information support for the equipment condition assessment. Visual analysis is an important data analysis method. A picture wins a thousand words. When data is presented to the analyst in visual graphical form, the analyst is often able to see the hidden information behind the data[2].

We make full use of the state information and environmental information for comprehensive analysis and judgement. By introducing the information fusion and visualization technology, a multi-
dimensional visualization model is proposed for transformer fault diagnosis. This model displays operation information, experiment information and environmental information of transformers through multi-view collaborative visualization and filter technology. With the help of visual perception of human eyes and intelligent cognitive ability of human brain, the integrated operation of equipment can be expressed quickly and effectively. Users can find useful information from large-scale, high-dimensional, or even incomplete data to make effective decisions.

2. Related Work
Dissolved gas analysis (DGA) is an effective way for internal fault diagnosis of power transformer. It detects the content and production rate of characteristic gases such as hydrogen (H₂), methane (CH₄), ethane (C₂H₆), ethylene (C₂H₄), acetylene (C₂H₂), carbon monoxide (CO) and carbon dioxide (CO₂) dissolved in transformer oil to judge the fault of the transformer. There are many fault diagnosis methods based on DGA technology. The characteristic gas method judges the equipment failure by establishing the relationship between the unsaturation of hydrocarbon gas at the fault point and the energy density of the fault source. This method is convenient and has strong direction for fault properties. However, there is no clear concept of amount in this method. Based on the above viewpoints, scholars proposed a method by constructing a triangle map based on the relative contents of the three components - CH₄, C₂H₄, and C₂H₂. By viewing the distribution position of the measured data in the graph, it is possible to judge the fault of the device according to the fault-position comparison table [3].

However, whether the characteristic gas method or the three-ratio method is too absolute and cannot locate the fault. Besides, Traditional DGA has a long analytical period and couldn’t continuous monitoring equipment. The commission and operation of online dissolved gas analysis (DGA) monitoring make up for the weaknesses. [4] However, due to the limitation of sensor technology, online monitoring device is not satisfactory on its reliability and sensitivity [5].

Since single diagnosis method cannot realize the effective diagnosis of transformer state, we combine multi-dimensional information including on-line monitoring data, gas analysis, load and environmental information to construct multidimensional visualization model. We display each group of data in a visual way, so as to realize the multi-dimensional diagnosis of the equipment diagnosis.

3. Visualization
The transformer visual diagnosis based on multi-source data fusion involves many state variables such as environment information, energy information, experiment information and so on. It is necessary to provide multi-angle and multi-level data query and analysis, so that analysts, managers or executives can access information quickly, consistently and interactively from multi-dimension and get a deeper understanding of data.

Multidimensional data model is a fact-based database established for of users to query and analyze data from multiple perspectives and levels. Dimension is the perspective of people observing the world. It defines many important attributes of an entity as multiple dimensions and users can compare data on different dimensions. We visually analyse the quantity of state such as DGA data, moisture content in oil, core grounding current and so on from three dimensions constructed by time, load and temperature.
3.1. Time dimension
With the improvement and perfection of online monitoring system and production management system, the data used for transformer diagnosis shows the characteristics of consecutive arrived, the characteristics of potential infinite and constantly changing. These data can be considered as order of time sequence composed of variety multi-source state information. We use time dimension as the most important dimension and the state parameters are displayed according to the distribution of time dimension. We also aggregate time into two different levels -quarter and week, so that users can analyze data from different scales. We use pie chart and histogram to represent quarterly aggregated data, where the size of the loop (column) represents the number of data, as shown in Figure 1.

3.2. Load dimension
Load condition also has an impact on the state of equipment. The failure rate and experiment state of the same equipment under high-load are different from those under low-load. So we take the equipment load rate as an analysis dimension, we calculate the transformer load rate through the energy information of the transformer, and then divide the equipment load into two parts with a threshold of 50%. The load distribution is represented by pie chart and the size of the cake represents the number of test data, as shown in Figure 2.

3.3. Temperature dimension
Large-scale transformer is usually installed outdoors. The temperature difference will also have an impact on the state of the equipment, so we will also take the ambient temperature as an analysis dimension. We take the temperature as the x-axis and the frequency of experiment data as the y-axis to construct the temperature frequency histogram to count the experiment times at different temperatures, as shown in Figure 3.

3.4. Experiment data
By combining offline analysis with on-line monitoring variables, we can diagnose and analyze the transformer state comprehensively. Dissolved Gas Analysis is an effective method for internal fault diagnosis of power transformer, and three-ratio method is considered to be the most intuitive display of DGA. Therefore, we use the David triangle method based on the relative content of CH₄, C₂H₆ and C₂H₄ to display off-line DGA data. As shown in Figure 4, by looking up the distribution of the measured data in the diagram, the fault type of the equipment can be determined according to the fault-location table.

The commission and operation of online monitoring realize the real-time monitoring of the equipment operation. Core grounding current, as a monitoring item in on-line monitoring, can continuously monitor the equipment at high frequencies. Therefore, we draw a bar chart with time as the X-axis and current value as the y-axis to show the the relationship between time and current. As shown in Figure 5, the moisture in oil will reduce breakdown voltage and increase the dielectric loss, even caused the deterioration of oil quality and bring serious faults. We construct a histogram of moisture content the same as current as shown in Figure 6.

Although on-line DGA device need to be improved on reliability and accuracy, it can monitoring of changes in gas content continuously. Therefore, we construct a stacked area chart of on-line DGA data...
using time as X-axis and content of CH₄, C₂H₆, C₂H₂ as Y-axis to show the change of gas. At the same time, we use the same time axis to construct an area chart with the total hydrocarbon content as the Y axis to show the change of total hydrocarbon at the corresponding time as shown in Figure 7.

Figure 7. Online DGA

4. Interaction
Single analysis technology only analyzes or displays the data from a certain angle, ignoring other information, which affects the comprehensive analysis of multi-dimensional data. Multi-view cooperative visual analysis uses a variety of technologies to visualize a data object at the same time, and achieves nested multi-view parallel cooperative analysis through a variety of interaction to technology. It enables analysts, managers or executives to quickly, consistently, and interactively access the original data from multiple perspectives, and the information could be truly understood by users.

Figure 8. Multi-dimensional visualization model based on information fusion
Our model uses Crossfilter.js to realize the interactive display of multi-dimensional data. The overall interface of the model is shown in Figure 8. The multi-dimensional visualization model based on information fusion includes time charts, load charts, temperature charts, DGA charts, electrical charts and so on. Each basic chart represents a dimension or a kind of factors. When a chart is selected and filtered, the other charts will interact accordingly.

For the quarter, week and load charts, since the number of elements in charts is few and the dispersion of data is high, we use click-on elements to filter the corresponding selection. As shown in Figure 9, after clicking on the 1st quarter and Friday, the rest of the chart changed with the filtering conditions. For the rest charts, users usually only use a certain range of data for interactive analysis, so we use the brush technology to select the continuous area for filter. As shown in Figure 10, after click the first quarter and high load, a certain range of temperature is selected by the brush, all of the chart data are displayed with the selected conditions.

Figure 9. Filter by time dimension

5. Conclusion
The complexity and fuzziness of transformer state characteristics bring great difficulties to evaluate the running state of transformer. In this paper, a multi-dimensional visualization method is proposed based on information fusion for transformer fault diagnosis. The energy information, experiment information and environment information are displayed comprehensively by multi-view collaboration technology and filtering technology. This model can help users to analyze data effectively and improve the ability to make decision. It has important significance for the development of intelligent substation construction.
Figure 10. Filter by time dimension, load dimension and temperature dimension

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