

On-line Monitoring of Electrical Equipment and Fault Diagnosis Analysis

Zhao Jian-wei

Department of Computer and Information Engineering, Baoding Vocational and Technical College,
Baoding, China

50968998@qq.com

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Abstract. In order to improve the reliability of power system, on-line monitoring and fault diagnosis for electrical equipment is very necessary. In this paper, we research on-line monitoring and fault diagnosis of transformer, building the gas online monitoring system in transformer oil, and improved transformer fault diagnosis -characteristic gas method through the BP neural network. Through gas on-line monitoring of transformer oil, and the example verification, improved diagnosis method is effective for transformer fault diagnosis.

Introduction

With the development of society and economy, the position of the power system has become more important in national economy, therefore the higher safety and reliability on power system are required. At the same time, the reform of the power system also prompted to achieve the ultimate goal that is each power operator hopes using the lowest cost to meet the quality requirements. Taking the scientific means of monitoring and fault diagnosis for electrical equipment for maintenance is the important measures. So that they can find any hidden danger early, then to improve the reliability of equipment, and reduce the cost of operation and maintenance.

Beginning the 60s, every developed country attaches great importance to research the technology about electrical equipment condition monitoring and fault diagnosis. In April 1967, the mechanical failure prevention group was formed by the U.S. navy lab with NASA's guide. In 1976, American Westinghouse development power plant equipment diagnosis system based on the computer. In the 80s, the company shows diagnosis system of generator in the power sector based on a microprocessor. European equipment diagnosis technology research and development of some industrial countries have made progress, and each has its own expertise and characteristics. Equipment diagnosis technology research and development in our country started from the late 70 s, starting in the 80 s, domestic colleges and universities, scientific research and so on to carry out the development of electric power equipment diagnosis technology, developed and made a number of results. In addition, artificial intelligent diagnosis technology is gradually applied in the fault diagnosis of power equipment [1].

Application practice at home and abroad shows that the condition monitoring and fault diagnosis system can reply the real-time control of electrical equipment running status and the characteristics of electrical parameters. So, the occurrence of sudden failure will be reduced, and equipment reliability and operational efficiency will be improved. In the ending, we prolong the service life of equipment, and increase the economic benefit of power system through reduce equipment forced down rate and maintenance cost and life cycle cost. Due to transformer is the most important equipment in power transmission and transformation system, its running reliability directly affects the safety of the power system, the operation cost and economic benefit. Therefore, in this paper, the transformer on-line monitoring and fault diagnosis is studied.

Transformer fault diagnosis

The principle of transformer fault diagnosis. Due to many types of transformer fault, complex reasons and fault types which may also convert, sometimes it needs various tests and comprehensive

analysis to accurately determine fault type, degree, position and reason. Although the evaluation of transformer needs all sorts of results, but the DGA (dissolved gas analysis) find equipment failure situation in a timely and effective manner when it is charged, so it has become one of the effective methods of improving the operation reliability of oil filled equipment and putting an end to burning accident.

The principle of transformer fault diagnosis is as follows: when the normal operation of transformer, because of the influence of electricity and heat its insulation oil and organic insulating material will be aging gradually and decompose a small amount of low molecular hydrocarbons and carbon monoxide, carbon dioxide and other gases. As local overheating, internal partial discharge and arc discharge failure, the gas generation rate will accelerate and the number will increase. The gas from the oil will form bubble and constantly dissolve in oil in the process of oil convection and diffusion. When transformer serious accident occurs, gas production rate is greater than the amount of dissolved. Then there is a part of the gas into the gas relay, when accumulated to a certain amount, the gas relay will take action. By relay internal gas analysis and simulation experiment, we will find that gas composition and gas volume of different fault properties and different severity are also different. The main gases which can be used to judge transformer latent fault have hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon monoxide (CO) and carbon dioxide (CO_2). The meaning of each gas to judge fault is not the same, but contact with each other. Total hydrocarbon refers to methane, ethane, ethylene and acetylene.

The method of transformer fault diagnosis (characteristic gas method). When the normal operation of transformer, the insulating oil in the process of aging will mainly produce CO and CO_2 . When there is partial discharge in oil paper insulation, oil cracking will mainly produce H_2 and CH_4 . When the fault temperature is not much higher than the normal operating temperature, the CH_4 is mainly produced. When the fault temperature rises, C_2H_4 and C_2H_6 gradually become the main characteristics. When the temperature is higher than 1000 degrees Celsius, the oil cracking contains more C_2H_2 . If it is affected with damp or bubbles in the oil, it will contain more H_2 . If the fault involves solid insulation materials, it can produce more CO and CO_2 ^[2]. The gas composition of different fault types is shown in the Table 1.

Table 1 The gas composition of different fault types

Serial number	Fault type	The main gas composition	The secondary gas composition
1	Overheated oil	CH_4 C_2H_4	H_2 C_2H_6
2	Overheated oil and paper	CH_4 C_2H_4 CO CO_2	H_2 C_2H_6
3	Partial discharge in oil paper insulation	H_2 CH_4 C_2H_4 CO	C_2H_6 CO_2
4	Spark discharge in transformer oil	H_2 C_2H_2	
5	Arc in the oil	H_2 C_2H_2	CH_4 C_2H_4 C_2H_6
6	Arc in the oil and paper	H_2 C_2H_2 CO CO_2	CH_4 C_2H_4 C_2H_6
7	Be affected with damp or oil bubble	H_2	

The above chart is qualitative description and it can not quantify the gas. The table below can be used to determine fault properties.

Table 2 Fault property and the characteristics of characteristic gas

Serial number	Fault property	Main ingredients	The characteristics of characteristic gas
1	Overheating fault in general	CH ₄ C ₂ H ₄	High total hydrocarbon, C ₂ H ₂ <5 ppm
2	Serious overheating fault	CH ₄ C ₂ H ₄	High total hydrocarbon, C ₂ H ₂ >5 ppm, but it did not constitute major component of total hydrocarbon, H ₂ is higher. Total hydrocarbon is not high, H ₂ >100
3	Partial discharge	H ₂ CH ₄	ppm, CH ₄ constitutes the main components of the total hydrocarbon.
4	Spark discharge	H ₂	Total hydrocarbon is not high, C ₂ H ₂ >10 ppm, H ₂ is higher.
5	Arc discharge	H ₂ C ₂ H ₂	High total hydrocarbon, C ₂ H ₂ is high and constitutes major component of total hydrocarbon, H ₂ is high.

The quantitative conditions of various kinds of gas are shown above when five kinds of fault occur. However, these quantitative expressions are not very accurate. In order to be able to more effectively and accurately diagnose the transformer fault, this paper uses BP neural network to identify fault, in order to improve the accuracy of fault diagnosis.

Transformer Fault Diagnosis Based on BP Neural Network

Back Propagation Neural Network. BP (Back Propagation) neural network is a kind of learning algorithm with error Back Propagation. It is the multilayer feed forward network that composed of input layer, one or more of the hidden layers and output layer of. Assuming that has the number of processing units on each floor is N, the number of mode training set contains sample is M in the BP network.

In the first, a learning sample p (p = 1, 2,..., M), node j remember to input combined net_{pj} , for

$$\text{output } O_{pj}, \text{ then } net_{pj} = \sum_{i=1}^N W_{ji} O_{pi} \quad O_{pj} = f(net_{pj})$$

If we set arbitrary number as the initial weights, , its network error between the output and the desired output (d_{pj}) to each input sample p as follows:

$$E = \sum_p E_p = \left[\sum_j (d_{pj} - O_{pj})^2 \right] / 2$$

BP network with hidden and the output layer unit of the error of calculation is different. BP network has a weight correction formula is:

$$W_{ji} = W_{ji}(t) + \eta \delta_{pj} O_{pi}$$

δ_{pj} for input and output nodes is different, the output node is $\delta_{pj} = f'(net_{pj})(d_{pj} - O_{pj})$, for input nodes is $\delta_{pj} = f'(net_{pj}) \sum_k \delta_{pk} W_{kj}$. The η is the learning rate. Usually, a weight correction formula still need to adding

inertial parameters of α , which are:

$$W_{ji} = W_{ji}(t) + \eta \delta_{pj} O_{pj} + \alpha (W_{ji}(t) - W_{ji}(t-1))$$

The learning process of BP algorithm is composed of forward and reverse transmission. In forward propagation, the input information from the input layer through the hidden layer can handle step by step, and then to output layer. If we want not get the desired output, the output layer will return into the back propagation and the error signal will be back. By modifying the weights of each neuron, we hope the error signal is minimal. Through ongoing positive and reverse transmission, eventually we make the network output values and expectations converge. The trained BP network can work for transformer fault diagnosis [3-5].

The Process Based on BP Neural Network. We can judge the latent fault about transformer by some kinds of gases, the main ones: hydrogen (H₂), methane (CH₄), ethane (C₂H₆), ethylene (C₂H₄), acetylene (C₂H₂), carbon monoxide (CO), carbon dioxide (CO₂). We use the content of 7 kinds of gas as the input end of the BP neural network. The fault of transformer is classified 7 kinds in the paper, they are: oil overheating, oil and paper overheating, partial discharge in oil paper insulation, spark discharge in oil, oil in the arc, oil and arc in the paper, and affected with damp or any air bubbles in oil. According to the seven kinds of fault types, the paper will be set up the expectations of the BP neural network output. Settings as shown in table 3. Input layer node number is 7, number of hidden layer nodes is 12, and the number of BP neural network nodes in the output layer is 4. Firstly, we need get enough samples for training, after that, the completion of other data for diagnosis.

Table 3 The Expectations of the BP Neural Network Output Settings

Serial Number	Fault Type	Expected Output
1	oil overheating	(0.9,0.1,0.1,0.1)
2	oil and paper overheating	(0.1,0.9,0.1,0.1)
3	partial discharge in oil paper insulation	(0.1,0.1,0.9,0.1)
4	spark discharge in oil	(0.1,0.1,0.1,0.9)
5	oil in the arc	(0.9,0.9,0.1,0.1)
6	oil and arc in the paper	(0.1,0.9,0.9,0.1)
7	affected with damp or any air bubbles in oil	(0.1,0.1,0.9,0.9)

Numerical Example

The Training Process. To collect 200 samples as training samples of BP neural network. The times of neural network training iterations are 1000, in the process, the error is 0.0001, and the learning speed is 0.1. After learning, network fully identifies the learning samples, and gives neural network training.

The Diagnostic Process. In this part, we do the online monitoring of transformer. The result shows that there are 7 kinds of gases. The content of the seven kinds of gas look as the training of the neural network input, to diagnosis. And then we get the final result is: (0.0952, 0.0930, 0.0920, 0.9066), that the type of the transformer failure to spark discharge in transformer oil.

Summary

The means of scientific monitoring and fault diagnosis which is adopted for electrical equipment maintenance can effectively improve the reliability of electrical equipment and reduce the cost of operation and maintenance. Transformer is the most important equipment in power transmission and transformation system and its operation reliability directly affects the safety of the power system, the operation cost and economic benefit, therefore in this paper the online monitoring and fault diagnosis

of transformer are studied. This paper establishes gas online monitoring system from transformer oil and uses BP neural network to improve transformer fault diagnosis method (characteristic gas method). By gas online monitoring of transformer oil, and then the numerical example verifies the effectiveness of the improved diagnostic method.

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