ANN based On-Line Monitoring System Of Incipient Fault Detection in Power Transformer

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Abstract- **Technology of on-line monitoring of dissolved gas in transformer oil is the focus of attention nowadays. As the technologies of computer, macromolecule materials and optical spectrum analysis develop rapidly, the on-line monitoring devices are more and more perfect and are used more popular in electric power production. In this paper, the on-line monitoring device of dissolved gas in transformer oil typed HYDRAN is set as an example and the working principle and the properties of this kind of systems are introduced. Some common problems in using on-line monitoring devices are brought up and the settlement methods are described. This paper gives consultation to the maintaining of the on-line monitoring devices.**

Artificial Neural Network (ANN) technique to recognize the incipient faults of power transformers. The technique presented in this discussion conventional dissolved gas analysis (DGA) accuracy of diagnosis improves. The ANN is trained by using Adaptive Back-propagation learning algorithm that converges much faster than the conventional Back-propagation algorithm. The developed ANN system for the power transformer fault diagnosis has superior performance in fault diagnosis has superior performance in fault diagnosis as compared to the conventional methods.

Keywords: Dissolve gases, incipient fault, Hydran, Artificial Neural Network

I INTRODUCTION

In common condition, the transformer oil and insulation will age and break up under the effect of the heat and electricity. some small molecule hydrocarbon is produced. And gases as carbon dioxide, carbon monoxide are released. Most of these gases dissolved in oil and increase as time pass. If there is some fault in the transformer, the gases dissolved in oil increase much faster than normal speed. As a result, by analyze the dissolved gases; the latency fault can be diagnosed in time. The DGA (Dissolved Gas Analysis) can be taken online. And the result is repeatable. So the DGA is considered as one of the best method in diagnosing latency fault.

Generally speaking, the traditional monitoring method is to take out oil-samples or iron-core from transformers. As a result, it leads to the cost high, the reliability of power supply poor. The worst of all, the method can't forecast the state of transformers in time. [1, 2].

II PRINCIPLE OF THE SYSTEM

Latent hazards in power transformer, if not detected in time, will lead to serious incidents. To strengthen transformer oil dissolved gas-monitoring and early detection that exists within the transformer latent potential safety problems.

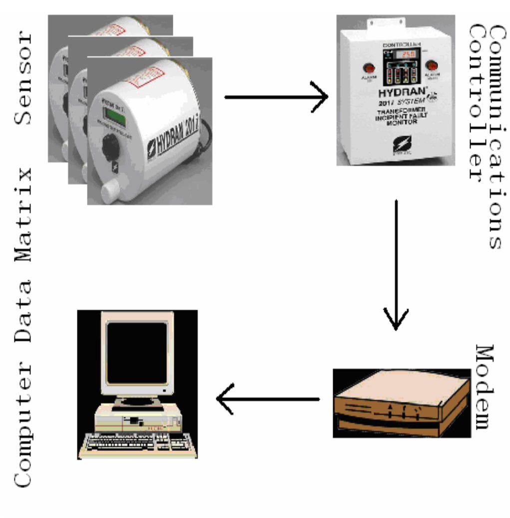


Fig.1 Architecture of HYDRAN System.

The system consists of sensors (201Ti), the communications controller (201Ci-C), computer data matrix.

The sensor data collection terminals installed on each transformer valve using its internal polymer membrane permeability choose H_2, CO, C_2H_2, C_2H_4,CH_4,C_2H_6 from transformer oil dissolved gas. Then these gases are sent to the electrochemical reaction detectors, react with oxygen to produce a signal which is proportional to the reaction rate. After amplification processed, the signal is stored in the memory of CPU board, and provided to sensor panel to display. In the mean time, this signal is transmitted to communications controller through dedicated telecommunication cables[4]. Communications controller will be responsible to gather together the signals from different sensors, and then send them to the computer data matrix through RS-485, RS-232 or dial-up modem.

The computer data matrix works out the concentration of transformer oil dissolved gas and rate of change by using data acquisition software HYDRAN-HOST, and these data are stored in the hard drive of the data matrix computer.

The technology features include:

1. Online Monitoring
2. Sharing data on networks
3. Professional software to manage data Scientifically.
4. Periodic self-test function
5. anti- interference capability.

III ANALYSIS OF MONITORING SYSTEM

To ensure reliable operation of the system, we must first ensure that the faults of the system itself are excluded in time. This chapter introduces the faults that may be appear during the operation of the monitoring system and the corresponding measures.

A Fault caused by sensor electromagnetic interference

During the opteration of the system, the sensor internal components are likely to be interferenced by strong external electromagnetic. Then the alarm system will show "CABLE SHORT" on its screen which means the sensor cable short-circuit. To prevent the occurrence of the fault, the grounding line should be installed onto the sensor shell. Then the sensor data processing unit I/O coupler shell will be grounded reliably.

Online monitoring system of main transformer alarm "CABLE SHORT". After examination the I/O coupler is found failure. Technical staff of manufacturers believes that the fault is caused by sensor electromagnetic interference according to operating experience of detection. Sensor itself has periodic self-test function, the cycle of 15 days, self-test to judge whether the internal components of the normal work. After a period of observation, the main transformer on-line monitoring system sensor cable short- circuit testing alarm automatically disappear. After the shell of sensor and data processing units I/O coupler shell reliable grounding, in such false alarm has not emerged.

B The voltage sampling circuit of sensor battery

There is a voltage sampling circuit for the sensor battery's voltage inspection in the sensor body. If the battery voltage is too low to guarantee the common operation of system, the circuit will be conscious of the low voltage and send the signal to the alarm system. Then the alarm sounds to remind of the change of battery. But there could be some mistaken alarm because of the fault of sampling circuit. It means that when the alarm sounds, the actual voltage of battery should be the criterion to judge the fault of sampling circuit.

Online monitoring system of main transformer alarms"Battery L" , which means voltage of transistor battery is too low. Actually the battery is new and the voltage is 3.09 V quite close to the rating vlotage 3.10 V. After examination the voltage sampling circuit of sensor battery is found failure. When the circuit board is changed, the alarm disappears.

IV ALARM OF GAS THICKNESS PROCESSING AND ANALYSIS

To deal with the alarm of thickness of gas correctly, the detection data should be analyzed to be sure to the state of the transformer. To confirm the detection data is right, the manual sampling should be taken and the result should be contrasted with data of online monitoring system. If the error is lower than 20%, the online system is reliable. Besides, in common condition, the transformer oil and insulation will age and break up under the effect of the heat and electricity. During this course, some small molecule hydrocarbon is produced and gases as carbon dioxide, carbon monoxide are released. Most of these gases dissolved in oil and increase as time pass. If the correct measures are not taken, even the transformer is under common condition, the online system will alarms when the operating time is long enough.

The online system of main transformer alarmed then computer data matrix showed Class 1 alarm. To make sure the online system data was correct, the manual sampling was taken and convert the data. formula:

The HYDRAN reading is 213 ppm just a little higher than the converted HYDRAN reading 211.5838. It means the online system detection data is right.

Table. 1 Hydran reading

CH4	C2H4	C2H6	C2H2	H2	CO	Con. Read.	Hydran	% Error
8.18	11.82	2.69	0.1	5.06	663	124.644	119	4.52
8.29	11.83	2.8	0.17	5.59	676	127.5198	149	16.84
7.77	10.93	2.69	0.1	5.53	739	138.7766	160	15.29
11.4	17.71	4.74	0.12	9.44	1121	211.5838	213	0.669
10.4	14.86	4.03	0.13	8.53	1032	194.7038	228	17.1
18.9	37.97	6.41	0.24	7.51	961	181.2992	187	3.14

But it did not mean there was some fault in the transformer. When the changing rate of HYDRAN reading is lower than 15ppm/24hr or 25ppm/30d, the condition of transformer is movement of thickness of kinds of gases:

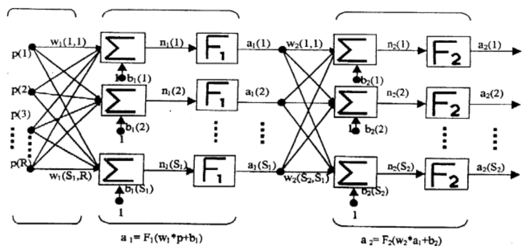
According to these figures, the thickness of gas increased slowly. By analyzing these data, it is believed that the rate of gas thickness increasing is quite limited. The possibility of latency superheat and discharge can be excluded.

Accordingly, it is known that small molecule hydrocarbon, which is produced during the aging of transformer oil and insulation by the effect of the heat and electricity, made the gas thickness inner the transformer increased. And that increasing is the reason of the alarm.
To get rid of this kind of wrong alarm, the percolation should be taken periodically to decrease the thickness of dissolved gas in transformer oil.

V ARTIFICIAL NEURAL NETWORK

The basic idea of neural network based fault diagnosis is nonlinear mapping. It is assumed that the relationships between the input vector ***X*** and the output vector ***Y*** are predefined by the physical nature of the problem, and these relationships can be represented by a limited number of input output pairs (data samples). The application of neural network in fault diagnosis has two phases. Phase 1 is the training process, during which the data samples are provided to the network, the memorial coefficients of the network are iteratively adjusted to "memorize" the input-output relationships. Phase 2 is a testing process, during which the input vector ***x*** is fed into the network, and the memorized coefficients of the network are recalled to "discover" the possible output.

TRAINING OF ANN



There was no theoretically sound algorithm for training multi-layer ANN, and therefore, the applications of ANN were severely limited. Vital role of theThe invention of Back propagation algorithm in the resurgence of interest in ANN. Back-propagation is a systematic method for training multi-layer ANN. It has a strong mathematical foundation.
A two-layer feed forward network. It consists of number of neurons connected by links divided into two layers. A set of inputs is applied from outside or from previous layer. Each of these is multiplied by a corresponding weight w. The sum of the weighted inputs and the bias b. forms the input n. to the transfer/activation function.. Neurons may use any differentiable, monotonic increasing transfer functions to generate their outputs. Back-propagation networks often use the log-sigmoid and tan-sigmoid transfer functions.
For each neuron in the first layer, the neuron output is given by:

$a_1= F_1(w_1*p +b_1)$ (1)

Output of second layer is :

$a_2= F_2(w_2*a_1 +b_2)$

$a_2 = F_2[w_2*F_1(w_1*p+b_1)+b_2]$ (2)

The network is trained to learn the relationships between the inputs and target outputs. For training, a number of pairs of input patterns p and target patterns t are presented to the ANN and then the ANN is asked to adjust weights in all connecting links and also the biases in the nodes such that the desired output patterns are produced at output nodes. In general, the network output a2 will not be same as the target or desired values, i.e. t For each pattern, the Sum Square of the Error is:

$SSE = ½ \sum(\tau - \alpha 2) 2$ (3)
Due to back-propagation (BP) algorithm it can adjust the connection weights w and biases b to minimize error between desired output and actual network output[7].

To achieve this goal is the common approach obtain by generalized delta rule (GDR).
In the current study, the ANN is trained using the Adaptive back-propagation learning algorithm as described above. This algorithm consists of repeatedly passing the training sets through the neural network until its weights and biases minimize the output error the entire set of inputs. The learning rate (h) is updated during training process. First, the initial network output and error are calculated. At each epoch, new weights and biases are calculated using the current learning rate. New output and error are then calculated. If the new exceeds the old error by more than a predetermined ratio ,the new weights, biases, output and error are discarded. In addition, the h is decreases (by multiplying it by 0.74), otherwise the new weights etc are kept. If the error is less than the old error, the h is increased (by multiplying it by 1.05).

VI. DIAGNOSIS RESULT

60 neurons in the hidden layer is designed with two layer feed forward ANN and trained by using 30 training patterns obtained from different power transformers having capacity from 6 MVA to 250 MVA of Maharashtra state transmission company Ltd. The desired error goal is set to 0.001, and is obtained in 208 training epochs as compared to 5000 epochs to get error goal of 0.012 in BP algorithm. After successful training, the weight matrices and biases are stored as files. The testing patterns are input from a data file and then the ANN is used to detect the faults [7]. Ten testing samples from different power transformers are tested. The testing patterns and corresponding results, comparative statement of fault diagnosis of transformers by various methods are listed in Table 1 and Table 2, respectively. This table clearly shows that the results of roger ratios, ANN diagnosis match for patterns number 1,4,8 only.

Table 2 Gases in PPM

Pattern	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2
1	48	43	3	75	81
2	318	337	57	583	641
3	338	32	1	32	50
4	114	1417	296	2096	0
5	2	4	3	4	0
6	21	34	5	47	62
7	37	75	126	5	0
8	59	339	42	392	1
9	13	10	4	13	0

Table 3 Comparison of fault diagnosis

Pattern	ANN Diagnosis	Roger's ratio Diagnosis
1	Arcing	Arcing
2	Arcing	Overheating
3	Partial Discharge	Arcing
4	Overheating	Overheating
5	Normal	Overheating
6	Arcing	No Identify
7	Normal	Overheating
8	Overheating	Overheating
9	Normal	Overheating

VII. CONCLUSION

The online monitoring of dissolved gas in transformer oil can diagnose the fault of transformer in time. Compare with this, the traditional monitoring method leads to the cost high, the reliability of power supply poor and worst of all, the method can't forecast the state of transformers in time.

In this discussion, the on-line monitoring device of dissolved gas in transformer oil typed HYDRAN is set as an example and the working principle and the properties of this kind of systems are introduced. Some common problems in using on-line monitoring devices are brought up and the settlement methods are described. This paper gives consultation to the maintaining of the on-line monitoring devices.
In this paper, a new transformer-fault-diagnosis-system has been proposed and implemented with online detection of gases develop in transformer oil to improve the conventional DGA methods. Theoretically, the ANN can be continuously train to represent any observable phenomena. The more complex the relationship is, the more training data are needed. The use of Adaptive Back-propagation learning algorithm reduces drastically the number of training epochs required for desired accuracy as compared to conventional Back-propagation algorithm.

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