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Diagnosis of Power Transformer by using Artificial Neural Network

Mahesh Yanagimath,Assistant Professor, Department of Electrical and Electronics Engineering, Hirasugar Institute of Technology, Nidasoshi. Email: maheshyanagimath.eee@hsit.ac.in
Dr. S.G.Ankaliki, Professor, Department of Electrical and Electronics Engineering, SDMCET Dharwad. Email: sgasdmee@rediffmail.com

Abstract— Power transformers are the heart of electric power distribution and transmission systems. They are always under the impact of electrical, mechanical, thermal and environmental stresses. They are one of the most critical and expensive components in power system. Due to the expensiveness of power transformer, the monitoring and maintenance of transformer condition becomes important. There exist various diagnostic methods to monitor transformer health condition. One of the technique called Artificial neural network (ANN) is used to diagnose and detect faults in oil filled power transformers based on Dissolved Gas in oil Analysis (DGA). By utilizing a feed forward ANN maximum accuracy can be achieved with the help of back propagation algorithm.This paper introduces the fault diagnosis system for power transformer using Artificial Neural Network (ANN).

Index Terms— Artificial Neural Network, Back Propagation, Power transformer, Dissolved gas analysis.

1 Introduction

Power transformer is one of the most critical and expensive components in power grid. Monitoring and maintenance of power transformer become an important task in many power utilities to enhance the financial and technical performances of power transformer. One of the important aspects in the monitoring and maintenance activities is transformer condition. The condition of the transformer can be used as a parameter to improve reliability, which enables the operator to develop effective maintenance and replacement strategies based on the condition of the transformer. The transformer condition is influenced by several factors such as chemical, electrical and mechanical parameters.

Various techniques were proposed to diagnose the health condition of power transformer. Dissolved Gas Analysis (DGA), Degree of Polymerization (DP) measurement, and Furan analysis are very commonly used by electric utilities.

Dissolved Gas Analysis (DGA) is the most common technique to diagnose the faults of transformer such as low and medium temperature thermal fault, high temperature thermal fault, discharge of low energy, arcing, and partial discharge. These faults are detected by analyzing the concentration of dissolved gases such as Hydrogen (H2), Methane (CH4), Ethane (C2H6), Ethylene (C2H4), Acetylene (C2H2), Carbon Monoxide (CO), and Carbon dioxide (CO2).

These gases tend to stay dissolved. According to the temperature reached in the area, the product of the oil decomposition change. Based on Dissolved Gas Analysis (DGA) gases can be detected and the concentrations of the gases, total concentrations of the combustible gases, the relative proportions of gases and gassing rates used to estimate the condition of the transformer and the incipient faults presented.

However, the DGA fails to estimate transformer end of life. Hence, another technique namely furan analysis is proposed. Furans are organic compounds in the transformer oil which are formed by degradation of paper insulation. By measuring the furan compounds concentration, remaining life of paper insulation can be estimated. Furans measurement is also related to the IFT and acid number.Another diagnosis technique which is usually used in the assessment namely insulation tests. The transformer insulation test includes insulation power factor test and excitation current test. Besides that, key gas method and ratio method have also been used to interpret the condition of transformer.

Currently, artificial intelligence technique is proposed to be used as a diagnostic tool for diagnosing the power transformer health. By using artificial intelligence, the rule can be generated automatically and the decision would be made. One of the benefits of artificial intelligence is to minimize the subjective perspective of the diagnosis.

Fuzzy logic and artificial neural network are the most commonly used artificial intelligence techniques for power transformer diagnosis. However, there is a significant difference between fuzzy logic and artificial neural network. In Fuzzy Logic, the rule of diagnosis has to be defined in advance and cannot learn directly from data samples, while the Artificial Neural Network can learn directly from data samples through a set of training samples and update the knowledge of diagnosis directly.

In this diagnostic method, all transformer parameters are involved with DGA parameter to determine the transformer condition. Besides that, ANN is used to represent primary and secondary parameter in transformer diagnosis.

In this paper we are proposing Artificial Neural Network for diagnosing transformer health condition. The Artificial Neural Network is used to diminish personal distraction of choosing transformer diagnostic methods which are available in various approaches. Using the proposed method, operator could determine condition of transformer from the measured data directly with no more calculation to obtain health index.

The usage of one of Artificial Intelligence type, namely multi-layer perceptron neural network with back propagation. It is used to detect the fault occurrence in the power transformer. It monitors the conditions of the transformer.

2. LITERATURE SURVEY

Manufacturers often define the anticipated life of power transformers to be 25 to 40 years. In the meanwhile multiple faults occur on the transformer. To determine these faults many techniques have been used such as DGA, Furan etc.

2.1 Dissolved GAS ANALYSIS [DGA]:

As a result of faults in the power transformer causes development of gases in oil. The gases developed are hydrogen (H2), methane (CH4), ethane (C2H6), ethylene (C2H4), acetylene (C2H2), carbon monoxide (CO), and carbon dioxide (CO2). As incipient faults causes gases dissolve in the oil, the technique of DGA was developed to detect in the early stage defects on insulation. The Gas Chromatography (GC) is the most practical method used for the identification of combustible gases. GC gives a qualitative as well as quantitative analysis of dissolved gases in transformer oil. Among the available DGA techniques, the most used are the Key Gas methods, Doernenburg ratio, IEC ratio, Rogers ratio, Duvals Triangle method. The advantage of using ratio methods is that, they overcome the issue of volume of oil in the transformer.

2.2 ARTIFICIAL NEURAL NETWORK [ANN]:

Artificial neural networks (ANN) are computing systems vaguely inspired by the biological neural networks that constitute animal brains. An artificial neural network is an interconnected group of nodes, inspired by neurons in a brain. ANNs are considered as nonlinear statistical data modeling tools where the complex relationships between inputs and outputs are modeled.

An Artificial Neural Network approach is used to overcome the drawback of DGA methods. The term neural networks derive its origin from human brain, which consist of massively, parallel connection of large numbers of neurons. Artificial Neural Networks attempt to model the structure of the human brain and are based on self learning. Its structure is highly parallel, resulting in the ability to self organizes to represent information and rapidly solve problems in real time.

A novel method Artificial Neural Network is applied to DGA for the interpretation incipient faults in power transformers. Fault interpretation can found to be a problem of multi-class classification. ANN automatically tune the network parameters, connection weights and bias terms of the neural networks, to achieve the best model based on the proposed evolutionary algorithm, which provides the solution for complex classification problems, since the hidden relationships between the fault types and dissolved gases can be recognized by ANN through training process.

One of the ANN class, namely Multi-Layer Perceptron with Back Propagation is proposed to estimate the health condition of a transformer. In the multi-layer perceptron, the neural network consists of several layer including input layer, output layer, and hidden layers. In the hidden layer, there exists an activation function. Whereas, Back Propagation is a learning algorithm which usually used by the perceptron to adjust the weight of nodes in order to obtain the target value. Figure 2.1 represents the multi-layer perceptron neural network.

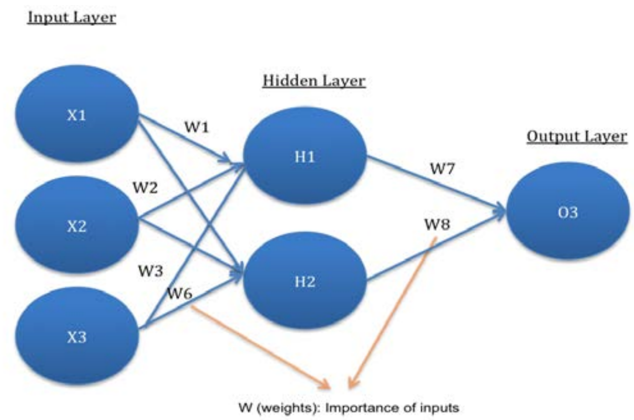

Fig 2.1 Structure of ANN

There are various fault detection methods, such as Roger Ratio, Doernenburg ratio or Key method, which are usually used in DGA diagnostic technique. These techniques work on the gases liberated by the transformer. But when transformer experiences multiple faults since, the generated gases from different faults are mixed up resulting in confuse ratio between different gas components. Due to this gaseous mixture DGA technique failed to diagnose transformer condition. This drawback can be overcome by using Artificial Intelligence such as, Artificial Neural Network (ANN) based on back propagation algorithm. The main objectives of the research work is

1) To study Conventional fault detection methods such as Roger Ratio or Doernenburg ratio which are used in DGA diagnostic technique.
2) To implement Artificial Neural Network for diagnosing transformer health condition.

3. METHODOLOGY:

A multi-layer perceptron neural network is implemented to the transformer health diagnostic mechanism which has 2-tiers of calculations. Accordingly, the proposed method is also designed by using 2-tiers of neural networks, as depicted in Figure 3.1. Transformer health parameters which are fed into the first tier input are DGA, furan, transformer power factor, age of transformer, operation and maintenance history. Each of combustible gasses involved in DGA analysis are considered as tier-1 input separately. The second tier is activated when the tier-1 result indicates the transformer condition of warning or poor. Transformer health parameters which are involved in the second tier are the measurement result of turn ratio test, short circuit impedance, direct current winding resistance, frequency response analysis (FRA) and degree of polymerization (DP).

The ANN in each tier is designed by using two hidden layers to increase the ability of information learning. Each hidden layer consists of several nodes which influence the performance of neural network. Hence, the number of nodes should be determined appropriately to increase the accuracy of ANN in respected hidden layers.

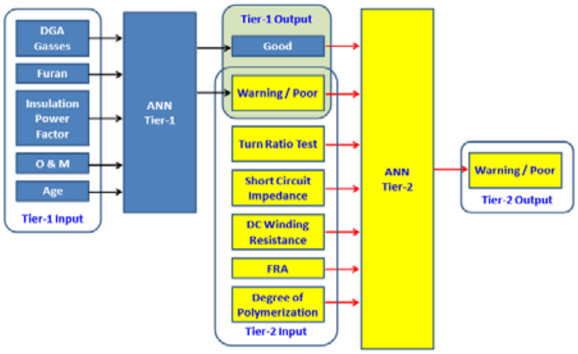

Fig 3.1 Two tier ANN

A multi-layer perceptron neural network is implemented to diagnose the transformer health mechanism which has back propagation calculations. The ANN is designed by using one input layer, hidden layer and output layer. Accordingly, the proposed method is designed by using neural network, as depicted in Figure 3.2. The transformer health parameters which are fed into the input are DGA gases such as Hydrogen, Ethane, Methane, Acetylene, Ethylene, carbon dioxide and carbon monoxide. Each of combustible gasses involved in DGA analysis are considered as input separately. The ANN output layer gives the output as good when there is no occurrence of fault. In the similar way if there is occurrence of fault the output is produced as warning or poor.

The ANN is designed by using hidden layer with back propagation increase the ability of information learning. The hidden layer consists of several nodes which influence the performance of neural network.

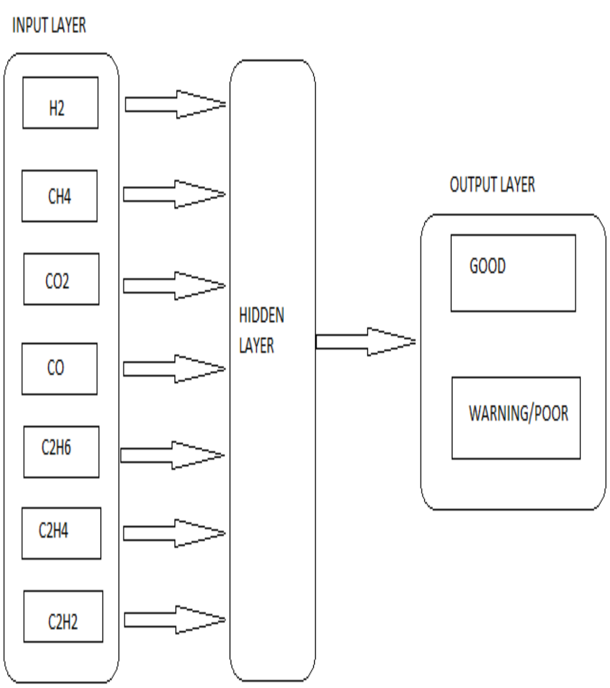

Fig 3.2. Sinle tier ANN.

4. Proposed ANN Design

One of the difficult tasks in applying ANN technique to any particular problem is to formulate the problem. The first step to formulate the problem is to find out what would be the inputs and outputs. After the inputs and output are defined, the next task is to incorporate hidden layers in the network. The selection of hidden layer is a matter of trial and error. However, it has been observed that in most applications, one hidden layer is sufficient. Finally the ANN with 3 hidden units are found to be the smallest structure with reasonably good result for this particular application of transformer protection. Associated with each neuron in the hidden layer and output layer is a transfer function. Usually nonlinear sigmoidal functions are used as the transfer functions. Once the ANN is designed it is required to train it. As mentioned, back propagation algorithm is used to train the network. The algorithm is described in the following section.

4.1 Back Propagation algorithm:

Back-propagation algorithm is most well-known and widely applied of the neural networks in use today. This algorithm iteratively process the set of training tuples and compares the networks prediction with the actual known target value. For each training tuple, the weights are modified to minimize the mean squared error between the networks prediction and actual target value. The modifications are made in the backwards direction from the output layer through each hidden layer down to the first hidden layer hence it is called backpropagation.

The back propagation net is a perceptron with multiple layers, a different threshold function in the artificial neuron, and a more robust and capable learning rule. Firstly it initializes the weights and biases in the network. And propagates the inputs forward by applying activation function. Then backpropagates the error by updating the weights and biases. Checks the error if it is very small then terminates the condition.

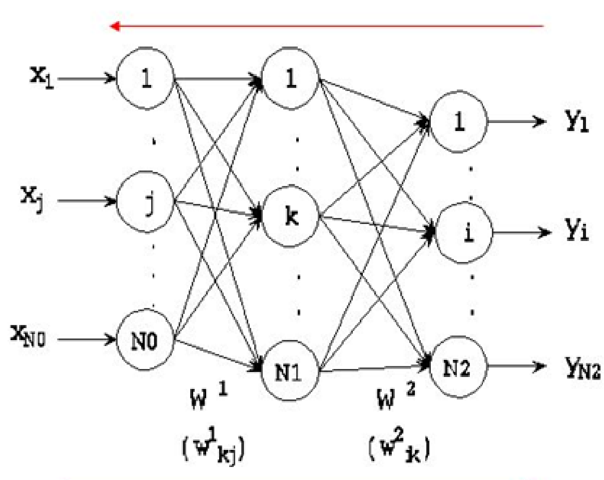

Fig 4.1. Back Propagation Algorithm

For each example in training set, first it computes the output signal and error corresponding to the output level. Then backpropagates the error back into the networkand stores the the corresponding delta values for each layer. Based on that it adjusts each weight by using the error signal and input signal for each layer.

5. CONCLUSION

This paper suggests the solution for possible improvement of power transformer protection using Artificial Neural Network (ANN). The design details of the ANN-based fault diagnosis system for power transformer have been presented. The proposed architecture of the proposed fault diagnosis system has the advantage of assigning one task to each ANN. The response of the proposed fault diagnosis system is fairly fast due to its parallel structure. This method would be more effective, robust and easy to implement.

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