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Artificial Intelligent Tools for detecting incipient faults in transformer using Dissolved Gas Analysis

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Abstract – *The Power Transformer is one of the very important assets in a transmission grid. It's breakdown may cause hindrance in the transmission and distribution operation. Thus it is very important to detect the incipient faults in transformer as soon as possible. There are various conventional methods for detecting these faults; Dissolved Gas Analysis is one of the reliable techniques. This paper presents the application of Artificial Neural Network (ANN) in detecting incipient faults in transformer. The ANN model was developed using historical data to classify three transformer fault scenario based on amount of hydrocarbon gases. The gas ratios are based on Doernenberg's ratio method. The test results indicate that the ANN design yields a very satisfactory result and can make a very reliable conclusion to pin point transformer's condition based on the combustible gas ratios.*

***Key Words*: Artificial Neural Network, Dissolved Gas Analysis, Doernenberg's ratio method, transformer.**

1. INTRODUCTION

The subject of transformer maintenance is very important as it affects the electric grid economically and also reduces grid efficiency. It is very important that the grid should be able to provide uninterrupted power supply to the consumers. For such a power supply it is required that the transformer should be reliable. Hence it is a very important issue to diagnose transformer faults as soon as possible. The cost associated with the repairing of damaged transformer can be greatly reduced by such efficient detection.

Transformers are in constant operation and so they are subjected to electrical, mechanical and thermal stresses. These excessive stresses lead to the degradation of insulation. The carbon-carbon and carbon-hydrogen bonds break and active hydrogen atoms and hydrocarbon atoms are produced. These atoms combine with each other and lead to the formation of gases such as Hydrogen (H_2), Carbon Monoxide (CO), Methane(CH_4), Ethane(C_2H_6), Carbon Dioxide (CO_2), Ethylene (C_2H_4), Acetylene (C_2H_2). Gas chromatography is used to detect these gases. Types of faults occurring in transformer are determined by the concentration of the gases. There are mainly three types of faults that cause liberation of faulty gases: Partial Discharge, Arcing and Overheating.

There are many techniques for monitoring the insulation condition of the transformers such as Dissolved Gas Analysis (DGA), Furan Analysis, Partial Discharge monitoring, temperature monitoring. Among all these techniques, Dissolved Gas Analysis is one of the most reliable techniques to detect incipient faults in transformers. DGA can be used to give advance warning of developing faults so that we can take necessary steps to avoid complete breakdown.

Several methods are available for the Dissolved Gas Analysis such as the Rogers' ratio method, Doernenberg's method, Duval Triangle method, IEC method, Key gas method. These methods do not involve any calculations and interpretation is based on vast experience. To overcome this drawback various Artificial Intelligent techniques are available to analyze incipient fault in transformer such as Artificial Neural Network (ANN), K-Nearest Neighbor (K-NN). In this paper Artificial Neural Network (ANN) is applied to detect incipient faults in transformer. ANN consists of small units like neurons which are connected to each other through synapses and have their own weights (synaptic strength). The Artificial Neural Network is inspired from our biological nervous system. ANN consists of characteristics like clustering, non-linear mapping, pattern recognition, robustness, high speed information processing. ANN possesses the property of self learning, self-updation, self adaptation. The network after being properly trained can be used for solving unknown problems. Multilayer feed forward back propagation network is used in this study. It consists of input layer, hidden layer, output layer. The hidden layer functionally maps the input model to the output model.

2. METHODOLOGY

2.1 DATA COLLECTION & PREPARATION

The historical data of the combustible gases was collected from the website of Wilmigton university. The data consists of values of combustible gases like Hydrogen (H_2), Methane(CH_4), Ethane(C_2H_6), Ethylene (C_2H_4), Acetylene (C_2H_2). The four ratios of gases are used as input and three transformer conditions as output.

The table below shows the input fed and the targeted outputs

	Ratios for Key Gases			
	Main Ratio		Auxiliary Ratio	
	CH_4/H_2	C_2H_2/C_2H_4	C_2H_6/C_2H_2	C_2H_2/CH_4
Thermal Decomposition	>1	<0.75	>0.4	<0.3
Corona(Low intensity PD)	<0.1	Not significant	>0.4	<0.3
Arcing (High Density PD)	<1>0.1	>0.75	<0.4	>0.3

Table 2.1: Doernenberg's ratio method

The data is interpreted on the basis of the Doernenberg's ratio method. The data is first normalized and then fed to the network.

2.2 ANN model

In this paper, the MATLAB software was used for constructing the Artificial Neural Network model. The Multilayer feed forward network was used, as it is the most popular architecture and can be applied to this scope of work. We have used 10 hidden layer, one input layer, and one output layer.

The ANN model produces the output based on the input and targeted output. While developing ANN model, there are many factors that are needed to be taken into consideration such as learning rate, network configuration, transfer function, number of hidden layers. Generally they are all decided referring to previous studies.

Developing ANN consists of two parts: training and testing

a) Training stage

During this stage, the network is fed with the four gas ratios as the input and the three transformer conditions as output. The training stage is most important while designing an ANN. The parameters like learning algorithm, architecture design may affect the performance of ANN. Problems of over fitting and under fitting may occur. If the network has the capacity of memorizing the network but cannot classify the new data sample then it is said to be over fitted. Early stopping can be used to avoid over fitting. If smoothing of the network output is carried out then bias becomes too large and generalization error may occur.Data is divided into three subsets; training set, validation set, testing set.

The training set is used to calculate the gradient and update the network's weights and biases, while validation set is used to check the condition of training stage.

b) Testing stage

During testing stage a new set of data samples is fed to the network to check its performance of training stage. At testing stage, the network is evaluated using regression analysis. The correlation between the inputs and targeted outputs is analyzed using regression coefficient. If the value of R is close to 1, then it can be said that the network is well trained.

The Graphical User Interface (GUI) is used for interaction between the user and the developed network. On entering any record number from 1 to

215, the GUI accepts the input automatically and displays the type of fault.

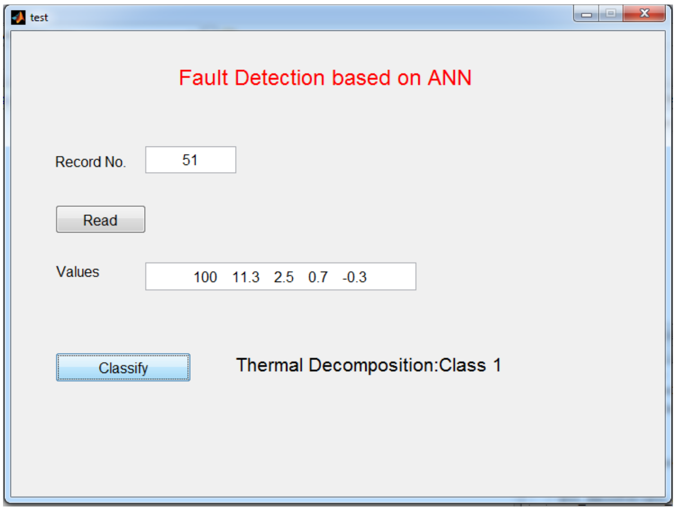

Figure 2.1: The GUI model

2.3 K-NN CLASSIFIER

The purpose of the K Nearest Neighbours (K-NN) algorithm is to use a database in which the data points are separated into several separate classes to predict the classification of a new sample point

In general we start with samples of data, of which the data points are known. Then we have to be able to predict the classification of the new data point based on the known classification and predictions of the given database. That is why, the database is known as our training set, since it trains us what objects of the database look like. We consider choosing the classification of a new observation based on the classifications of the observations in the database which it is "most similar" to.

We have experimented with three values of K which are K=1,3,5. The accuracy varies for different values of K.

3. RESULTS AND DISCUSSION

The network was trained using 215 data samples out of which 129 samples were used for training and 86 samples were used for testing. The training algorithm 'trainlm', Levenberg Marquardt (LM) was used as it is the best and fastest training algorithm.

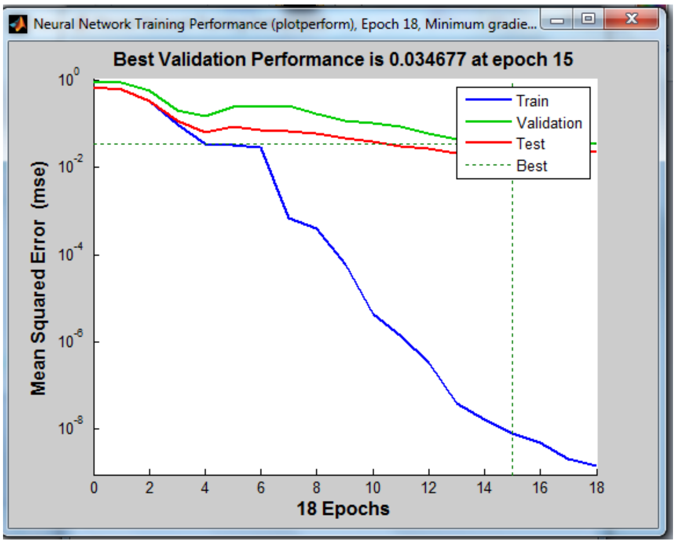

Figure 3.1: Performance during training stage

The figure 3.1 shows the performance of network during training stage.

Performance of the trained network was tested during testing stage. The values of regression coefficient were checked and found near to 1.

The figure shows the linear regression of the network response and the targeted output.

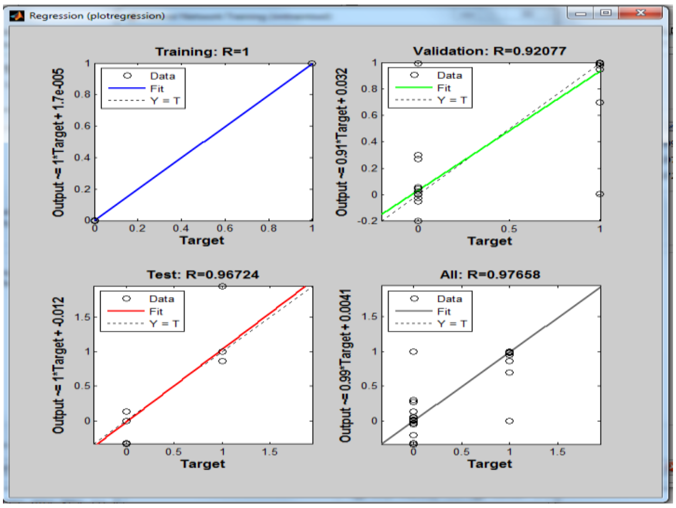

Figure 3.2: Regression analysis of MLP

The regression factor for the three values of K was checked and the best value of K was decided.

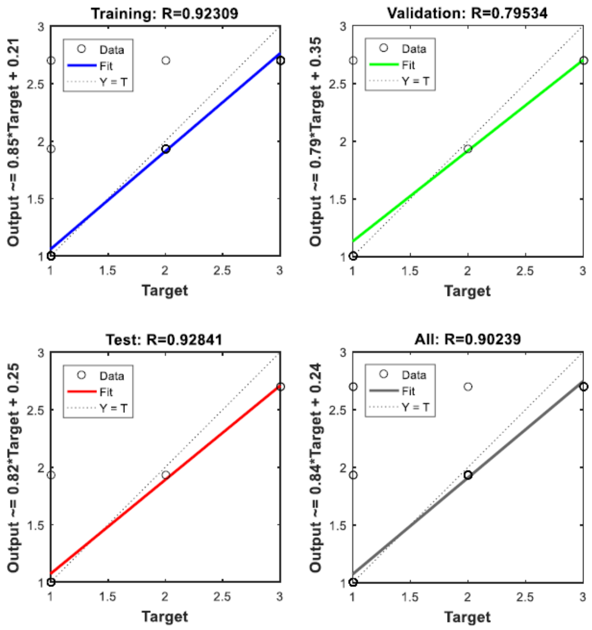

Figure 3.3: Regression analysis of KNN

After successfully training and testing the network, the best network is selected. The best Artificial Intelligent tool can be used to predict incipient faults in transformers. The results of Multilayer Perceptron network using feed forward back propagation and Levenberg-Marquardt training algorithm and the K-NN network were compared and the MLP network was found to be better.

4. CONCLUSION

A model of Multilayer Perceptron Artificial Neural Network was successfully developed and tested to predict incipient faults in transformers using four gas ratios using Doernenberg's ratio method. The K-NN classifier was also tested using the same ratio method. The accuracy of the network is verified by testing the network using unknown sample data in the testing stage. Hence the incipient faults are successfully predicted using developed network.

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