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Comparative Study of DGA Methods for the Incipient Fault Diagnosis in Power Transformer Using ANN Approach

Rajat S. Zade[1], Prof. Sagar Kudkelwar[2]
[1]M.Tech Student, [2]Head of Electrical Engineering Department
Department of Electrical Engineering,
Ballarpur Institute of Technology, Ballarpur, Chandrapur, Maharashtra, India

ABSTRACT
Power transformer being a major apparatus in a power system, monitoring of its in-service behavior is necessary to avoid catastrophic failures, costly outages. Power transformers are considered capital investments in the infrastructure of every power system in the world. Dissolved Gas Analysis (DGA) is an effective method for the early detection of incipient fault in power transformers. But the main drawback of the DGA ratio methods is that they fail to cover all ranges of data. The interesting results revealed by this study are serving as the underlying principle to carry out an ANN based insulation condition monitoring system. ANN approach is automatically capable of handling highly nonlinear input output relationships, acquiring experiences which are unknown to human experts from training data and also to generalize solutions for a new set of data.

Keywords: *Artificial Neural Network (ANN), Dissolved Gas Analysis (DGA).*

1. INTRODUCTION

Reliable and quality power is need of the hour for the economic development of a country. For providing reliable electrical energy, it is very necessary to have highly reliable associated electrical equipment. The transformer, being key elements in the transmission and distribution of electrical energy, improving its reliability is of utmost importance. Large oil filled electrical power equipments, such as transformers and reactors, is a critical element of an electrical power system. The reliability and continuous performance of these equipments is then vital key to the profitable generation and transmissions. To minimize the capital expenditure of the electrical power system, it is very common to operate these equipments at or close to the limits of their design parameters.

As one of the key pieces of equipment in a transmission and distribution system, the power transformer condition has a direct influence on the safety and reliability of a power system. Therefore, the online monitoring and offline test are vital for assessing power transformer conditions. Power transformers are the vital link of the power system. Monitoring and diagnosis techniques are essential to decrease maintenance and improve reliability of equipment. Power transformers are considered as most significant and vital element in the power delivery system. Due to highly competitive electrical energy market it is required to enhance the system's reliability and availability with cost effectiveness.

Up to now, some technologies, such as dissolved gas analysis (DGA), partial discharge (PD), and moisture analysis in transformer oil are widely used. Among these methods, DGA is a fast and economical method for detecting an incipient fault by utility engineers. It is well known that transformer faults, mainly in the form of overheating, arcing, or partial discharge, develop certain gaseous hydrocarbons, which are retained in the insulation oil as dissolved gases. The gas concentrations, generation rates, specific gas ratios, and the total combustible gas are important parameters for interpreting the result of DGA. Presently, a conventional ratio method and artificialintelligence (AI) method are the two major interpreting approaches.

The conventional ratio method mainly includes Rogers Ratios, Duval Triangle, and IEC Ratios, etc. Through calculating several ratios of key gas concentrations, the fault type is determined by interpretation schemes defined in advance. However, conventional ratios' boundaries are sharp, and it is unable to provide interpretation for every possible combination of ratio values. Thus, fuzzy-logic technology is introduced into a conventional ratio method to make ratios' boundaries vague. The fuzzy ratio analysis method is used to diagnose multiple incipient faults in power transformers. The deficiency is that its membership function is determined by practical experience or trial-and-error tests.

The detection of incipient faults in oil immersed transformers by examination of gases dissolved in oil, developed from original Buchholz relay application. The Gas Chromatograph (GC) is the most practical method available to identify combustible gases. GC involves both a qualitative and quantitative analysis of gases dissolved in transformer oil.

Artificial Neural Networks is a massively parallel-distributed processor, which have a natural tendency to acquire sufficient experimental knowledge and making it available for use. The ANN used in this methods are trained by Back Propagation Algorithm (BPA) with sigmoid function as non-linearity. Back Propagation Algorithm propagates the output error backward through the connections to the previous layer until the input layer is reached. In this paper ANN is applied to the DGA methods and results obtained are compared with the results of conventional DGA methods.

2. DISSOLVED GAS ANALYSIS:

Like a blood test or a scanner examination of the human body DGA can warn about an impendent problem, give an early diagnosis, and increase the chances of finding the appropriate cure. There are many methods in DGA. Some among them are Norms Method, Gas Ratio Method, and Key Gas Analysis. The detection of incipient faults in oil immersed transformers by examination of gases dissolved in oil, developed from original Buchholz relay application. The Gas Chromatograph (GC) is the most practical method available to identify combustible gases. GC involves both a qualitative and quantitative analysis of gases dissolved in transformer oil. As a result of faults the power transformer causes development of gases in oil. The gases developed are 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). As incipient faults causes gases dissolve in the oil, the technique of DGA was developed to detect in the early stage defects on insulation.

Among the available DGA techniques, the most used are the Key Gas methods, Doernenburg ratio, IEC ratio, Rogers ratio, Duval's Triangle method. The advantage of using ratio methods is that, they overcome the issue of volume of oil in the transformer.

A. Doernenburg Ratios Method:

This method calculates four gas ratios using dissolved gases of power transformer oil as plotted in Table 1. Taking these gas ratios ranges, it diagnosis the three types of fault conditions (i) Thermal decomposition , (ii) Corona and (iii) Arcing as shown in table 2. This method can calculate only three faults and it is very complex method.

Ratio 1 (RI)	CH4/H2
Ratio2 (R2)	C2H2/C2H4
Ratio3 (R3)	C2H6/ C2H2
Ratio4 (R4)	C2H2/CH4

Table1: Gas for Doernenburg Ratio Method

Diagnosis	R1	R2	R3	R4
Thermal decomposition	> 1.0	< 0.75	> 0.4	< 0.3
Corona(low intensity PD)	<0.1	Not significant	> 0.4	< 0.3
Arcing (High tensity PD)	0.1-1	> 0.75	<0.4	> 0.3

Table 2: The Fault Diagnosis According to Doernenburg Ratio Method

B. Rogers Ratio Method:

This method calculates faults by considering the ranges of four gas ratios, CH4/H2, C2H6/CH4, C2H4/C2H6 and C2H2/C2H4. The gas ratios are used to determine incipient failures. Table 3 shows codes for gas ratios used in this method and table 4 shows the Fault diagnosis according to Rogers ratio method.

Ratio Code	Range	Code
CH_4/H_2 (i)	<=0.1 >0.1,<1.0 >=1.0,<3.0 >=3.0	5 0 1 2
C_2H_6/CH_4 (j)	<1.0 >=1.0	0 1
C_2H_4/C_2H_6 (k)	<1.0 >=1.0,<3.0 >=3.0	0 1 2
C_2H_2/C_2H_4(l)	<0.5 >=0.5,<3.0 >=3.0	0 1 2

Table 3: Codes for Roger Gas Ratios

i	j	k	l	Diagnosis
0	0	0	0	Normal deterioration
5	0	0	0	Partial discharge
1-2	0	0	0	Slight overheating <150^{0}C
1-2	1	0	0	Overheating 150^{0}C -200^{0}C
0	1	0	0	Overheating 200^{0}C -300^{0}C
0	0	1	0	General conductor overheating
1	0	1	0	Winding circulating currents
1	0	2	0	Core and tank circulating currents, overheated joints
0	0	0	1	Flashover without power follow through
0	0	1-2	1-2	Arc with power follow through
0	0	2	2	Continuous sparking to floating potential
5	0	0	1-2	Partial discharge with tracking (note CO)

Table 4: The Fault diagnosis according to Rogers Ratio Method

C. IEC Ratio Method:

The Rogers Ratio Method fails to indicate all temperature range of decomposition. IEC ratio method derived from the Rogers method by eliminating C2H6/CH4 ratio. Three gas ratios CH4/H2, C2H4/C2H6 and C2H2/C2H4 are used to interpret the faults.

Ratio Code	Range	Code
l	<0.1 0.1-1.0 1.0-3.0 >3.0	0 1 1 2
i	<0.1 0.1-1.0 1.0-3.0 >3.0	1 0 2 2
k	<0.1 0.1-1.0 1.0-3.0 >3.0	0 0 1 2

Table 5: Codes for IEC Gas Ratios

l	i	k	Characteristic fault
0	0	0	Normal ageing
0	1	0	Partial discharge of low energy density
1	1	0	Partial discharge of high energy density
1-2	0	1-2	Discharge of low energy (Continuous sparking)
1	0	2	Discharge of high energy (Arc with power flow through)
0	0	1	Thermal fault <150^{0}C
0	2	0	Thermal fault 150^{0}C -300^{0}C
0	2	1	Thermal fault 300^{0}C -700^{0}C
0	2	2	Thermal fault >700^{0}C

Table 6: The Fault Diagnosis according to IEC Ratio Method

D. DUVAL TRIANGLE METHOD:

The Duval triangle method considers the three gases (i) methane (CH4), (ii) ethylene (C2H4), and (iii) acetylene (C2H2). Percentages of the total (CH4 + C2H4 + C2H2) gas are considered. The percentage of each gas are plotted on a triangular chart which has been subdivided into different fault zones as shown in Figure 1. The fault zone in which the point is located indicates the type of fault which is produced.

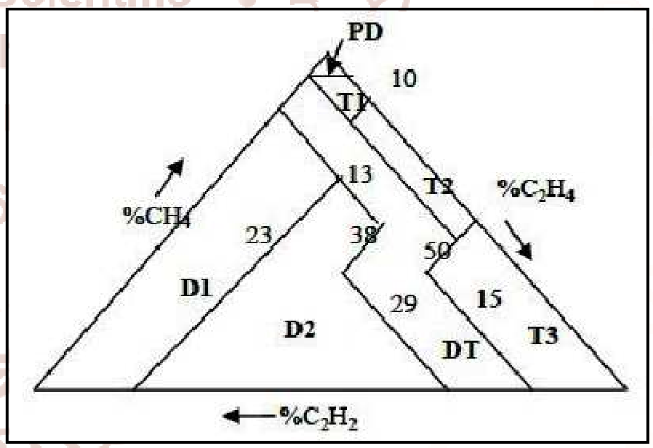

Figure 1: Duval Triangle

3. LIMITATIONS OF DGA:

In multi-class classification Fault interpretation can found to be a problem. Though DGA provides best interpretation of incipient faults, it fails during complex classification. When the value of gas ratio is near the threshold, it gives wrong diagnosis. The DGA methods cannot provide a completely objective and accurate results for all the faults since the number of possible code combinations exceed that of fault types. They do not always yield an analytical result and are not always correct. It requires other information such as the concentrations of the dissolved gases, their generation rates, specific gas ratios, and the total combustible gases in the oil to determine the types of fault. In this paper, an Artificial Neural Network approach is used to overcome the above drawback of ratio methods.

4. ARTIFICIAL NEURAL NETWORK:

Artificial neural networks, commonly referred to as neural networks are systems that are intentionally constructed to make use of some organizational principles similar to those of the human brain. They represent a promising new generation of information processing systems. Neural networks have a large number of highly interconnected processing elements (nodes or units). A neural network is a massively parallel distributed processor inspired by the real biological neuron in the brain; therefore, it has the ability to learn, recall, and generalize as a consequence of training patterns or data. Artificial Neural Networks (ANN) have become the subject of widespread interest, largely because of their wide range of applicability and the ease with which they handle complex and non-linear problems. The term neural network derives its origin from human brain which consists 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.

In this paper 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.

5. APPLICATION OF ANN TO DGA:

In this paper MATLAB software is used to construct ANN models. MLP neural networks are created separately for Rogers ratio method and IEC ratio method. The Multilayer Layer Perceptron (MLP) neural network is generated by using command *newelm*. Function *tansig* and *purelin* are used as transfer function. Figure 2 shows the Artificial Neural Network with five hidden layers. For the development of the neural network 200 sample datasets are used. 150 datasets are used for training purpose and 50 datasets are used for testing purpose.

To interact with MLP network the GUI is created using MATLAB. It provides the interfacing of user with network. Values of gases produced due to the faults are given as network input by using GUI as shown in figure 3. By using this panel the method to which ANN is applied is selected. The fault type window displays the type of fault.

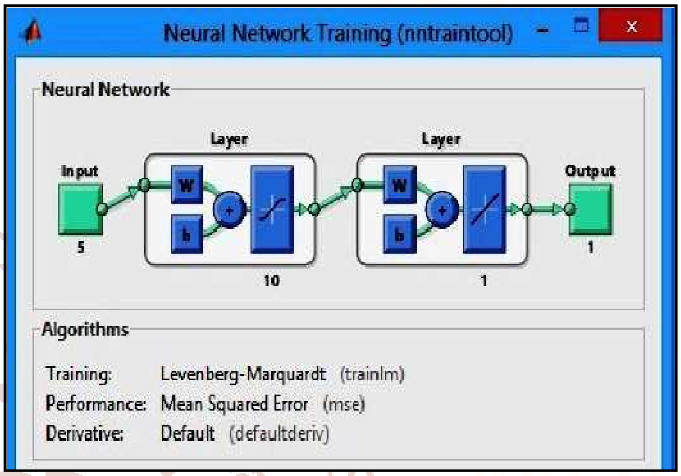

Figure 2: Artificial Neural Network

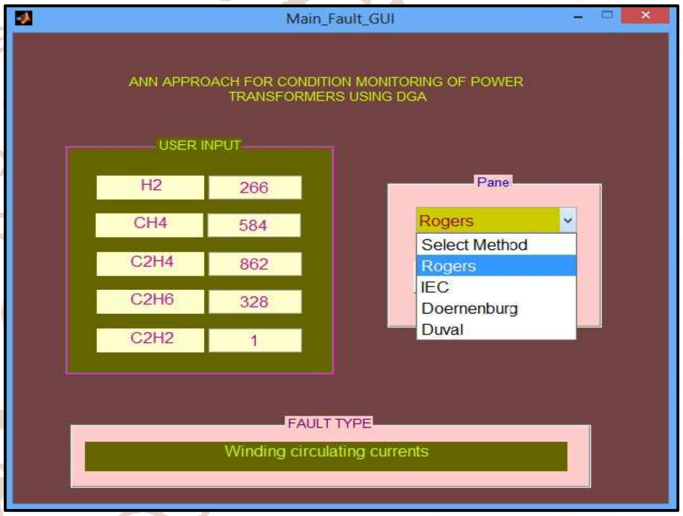

Figure 3: GUI panel

In figure 4 the errors are plotted with respect to training epochs. The error dropped until it fell beneath the error goal (the black line). At this point training is stopped. It shows the training performance of MLP network, it gives graphical analysis of neural network. Here best training performance is obtained at 7th epoch.

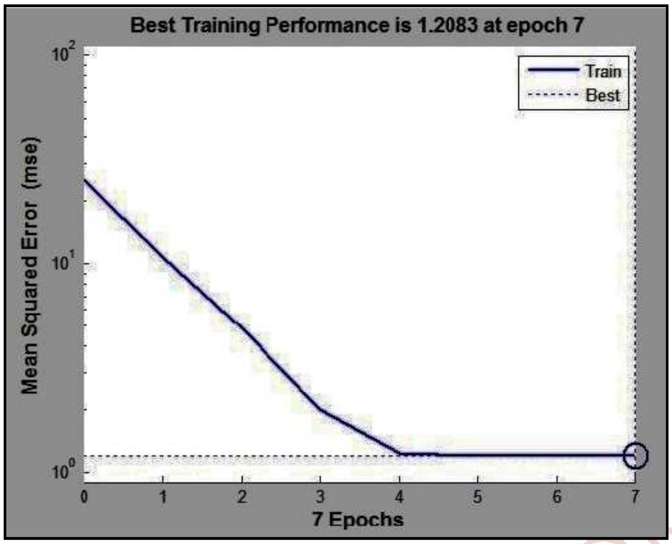

Figure 4: Training Performance

Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable, and the other is considered to be a dependent variable.

The regression is plotted using *Plot regression* command. The figure 5 shows the plot of regression target relative to output. It is used for function approximation. If the regression point is greater than 75% the result obtained are trustworthy.

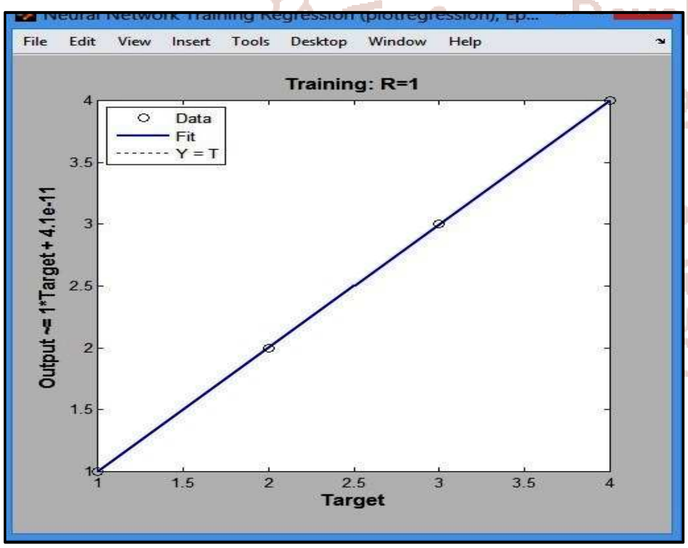

Figure 5: Regression Plot

6. RESULT AND DISCUSSION:

In this paper, data sets of two transformers are tested using Doernenburg ratio method, Rogers ratio method and IEC ratio methods shown in table 7 and 8. The ANN is applied to this method.

From table 9, Out of 13 datasets Rogers ratio method inconclusive at 1 condition, while IEC ratio method at 3 conditions, but when these methods are trained by means of Multilayer Layer Perceptron (MLP) neural network separately, it is found that performance of these ratio method get improved. It can be seen that the DGA method using ANN depicts improvement in performance than the single DGA methods.

Sr. No.	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO
1	2006	32	161	26	152	13
2	2007	40	165	30	160	186
3	135	188	72	195	0.001	519
4	179	191	82	210	0.001	415
5	169	234	82	274	5	483
6	199	205	85	225	0.001	425
7	201	226	90	230	0.001	430

Table 7**:** 20kV Alephata Make: BHEL 220/33KV 50 MVA, Year of Manuf.:200 D.O.C. 18/7/2003

Sr. No.	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO
8	329	49	54	370	5	126
9	154	328	401	978	8	290
10	28	85	132	684	0.001	114
11	36	47	82	415	0.001	142
12	15	20	70	320	0.001	152
13	14	21	72	325	0.001	162

Table 8: 132kV Kamthadi Make: Atlanta 33/22KV 10 MVA, Year of Manuf.:2005 D.O.C. 16/10/05

7. CONCLUSION

This paper presents the ANN approach for the systematic interpretation of incipient faults for power transformers. The Multilayer Layer neural network is developed and implemented for dissolved gas analysis in power transformer.

This proposed ANN algorithm applied to DGA has been tested by many real fault samples, and its results are compared with conventional DGA methods i.e. Doernenburg Ratio method, Rogers Ratio method and IEC ratio methods. The experimental results show that diagnosis accuracy of DGA methods using ANN is higher than conventional DGA methods for fault detection of transformer. ANN approach provides remedy on drawback of these DGA ratio methods. This method overcome the complexities and appears to be a promising approach to monitoring and diagnosis faults in power transformer.

Sr. No	Doerengburg Method	Doerengburg Method With ANN	Rogers Ratio Method	Rogers Ratio Method With ANN	IEC Ratio Method	IEC Ratio Method With ANN
1	Thermal decomposition	Thermal decomposition	No prediction	Partial discharge	Thermal fault >700°C	Thermal fault >700°C
2	Thermal decomposition	Thermal decomposition	No prediction	Partial discharge	Thermal fault 150°C-300°C	Thermal fault >700°C
3	Thermal decomposition	Thermal decomposition	Core and tank circulating currents, overheated joints	Overheating 150°C-200 °C	No prediction	Thermal fault 150 °C -300 °C
4	Thermal decomposition	Thermal decomposition	No prediction	Winding circulating currents	Thermal fault 150°C-300°C	Thermal fault 300 °C -700°C
5	Thermal decomposition	Thermal decomposition	No prediction	Core and tank circulating currents,	No prediction	Thermal fault >700 °C
6	Thermal decomposition	Thermal decomposition	Core and tank circulating currents,	Winding circulating currents	Thermal fault 150°C-300°C	Winding circulating currents
7	Thermal decomposition	Thermal decomposition	Winding circulating currents	Winding circulating currents	No prediction	Thermal fault 300 °C -700°C
8	No prediction	Corona (low intensity PD)	No prediction	Winding circulating currents	Normal ageing	Normal ageing
9	Thermal decomposition	Thermal decomposition	Winding circulating currents	Core and tank circulating currents,	Normal ageing	Thermal fault 300 °C -700°C
10	Thermal decomposition	Thermal decomposition	No prediction	Partial discharge	Thermal fault 150°C-300°C	Thermal fault >700 °C
11	Thermal decomposition	Thermal decomposition	No prediction	Core and tank circulating currents,	No prediction	Thermal fault >700 °C
12	Thermal decomposition	Thermal decomposition	No prediction	Core and tank circulating currents,	No prediction	Thermal fault >700 °C
13	Thermal decomposition	Thermal decomposition	No prediction	Core and tank circulating currents,	Thermal fault 150°C-300°C	Thermal fault >700 °C

Table 9: Results without ANN and with ANN

8. REFERENCES

1. A. Akbari, A. Setayeshmehr, H. Borsi and E. Gockenbach, "Intelligent Agent-Based System Using Dissolved Gas Analysis to Detect Incipient Faults in Power Transformers", *November/December — Vol. 26, No. 6, 0883-7554/07/$25/©2010IEEE.*
2. Bálint Németh, Szilvia Laboncz, István Kiss and Gusztáv Csépes, "Transformer condition analyzing expert system using fuzzy neural system", *978-1-4244-6301-5/10/$26.00 @2010 IEEE.*
3. Fathiah Zakaria, Dalina Johari and Ismail Musirin, "Artificial Neural Network (ANN) Application in Dissolved Gas Analysis (DGA) Methods for the Detection of Incipient Faults in Oil-Filled Power Transformer", *978-1-4673-3143-2/12/$31.00 ©2012 IEEE.*
4. Shishir Ranjan, P. Lakshmi Narayana, Mukesh Kirar, "Dissolved Gas Analysis based Incipient Fault Diagnosis of Transformer: A Review", *Impending Power Demand and Innovative Energy Paths - ISBN: 978-93-83083-84-8.*
5. Dr. D. V. S. S. Siva Sarma G. N. S. Kalyani, "Ann Approach for Condition Monitoring of Power Transformers using DGA"*0-7803-8560-8/04/$20.00©2004 IEEE.*
6. N. Yadaiah and Nagireddy Ravi "Fault Detection Techniques For Power Transformers",*1-4244-1291-9/07/$25.00 ©2007 IEEE.*
7. S. Qaedi, and S. Seyedtabaii, "Power Transformer Fault Detection Using Intelligent Neural Networks," *Proceedings IEEE TENCON02 0-7803-7490-8/02/0002002 IEEE.*

Author Profile

1. ***Mr. Rajat S. Zade****, received his BE from Datta Meghe Institute of Engineering, Technology and Research, Wardha and currently perusing. M.Tech (EPS) from Electrical Engineering Department, Ballarpur Institute of Technology, Ballarpur.*
2. ***Prof Sagar Kudkelwar****, received his BE from Government College of Engineering, Chandrapur and M.E. (EPS) from Government College of Engineering, Aurangabad, and currently working as Head of Electrical Engineering Department, Ballarpur Institute of Technology, Ballarpur..*