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Dissolved Gas Analysis of Transformer

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***Abstract*-The Dissolved Gas Analysis has been widely used by utilities throughout the world as the primarily diagnostic tool for transformer maintenance. The gas generated in mineral oil of power transformer can be monitored by all conventional methods, online DGA system and by application of various Artificial Intelligence practices. Assessment techniques for judging power transformer conditions and lifespan has been eye-catching. Dissolved Gas Analysis (DGA) has proved to be useful tool for diagnostic of incipient and potential faults in power transformers. This paper discusses pros and cons of the various DGA methods in practice and also deals with an experimental investigation carried out to study relation between gas generation and partial discharge. In the second part, a fuzzy logic based interpretation method (FLI), which is based on fuzzy set theory is described and implemented as an improved DGA interpretation method that provides higher reliability and precision of the fault diagnostics.**

***Keywords*- Transformer, Diagnosis, Dissolved Gas Analysis, Oil Contamination Analysis etc.**

I. INTRODUCTION

Dissolved gas analysis (DGA) of transformer oil is one of the most effective power transformer condition monitoring tools which can be facilitated to determine transformer criticality ranking. Insulating materials within transformers and related equipment break down to release gases within the unit. The distribution of these gases can be related to the type of electrical fault and the rate of gas generation can indicate the severity of the fault. The identity of the gases being generated by a particular unit can be very useful information in any preventative maintenance program. This technique is being used relatively successful throughout the world. Apparent advantages of fault gas can provide a) Advance warning of developing faults b) Determining the improper use of units c) condition checks on new and repaired units d) Convenient scheduling of repairs.

The methods used for the evaluating the ageing process and the deteriorating cellulose material are Dissolved Gas Analysis (DGA) of the transformer oil, the degree of polymerization measurements, Furan Analysis of the paper Analysis of dissolved gases has been a proven technique in use for the last 2-3 decades for monitoring the health of a transformer in service by sensing incipient fault well in advance before, even the buchholz relay operates. As the health of the oil implies the health of the transformer, the oil should be sampled and tested regularly to evaluate the oil condition and to determine the possible fault type. For achieving this transformer oil is evaluated by oil contamination test and four type DGA diagnosis method like IEC ratio method, Rogers ratio method, Key gas method and Dual triangle method.

II. DGA INVESTIGATION METHODS IN PRACTICE

Through application of DGA technique, fault gases dissolved in oil can be determined and interpreted. State of the art online monitoring systems by DGA have become highly advantageous and suitable to detect any abnormal increase of gas concentrations due to any incipient or potential fault developing in a power transformer. In some cases, DGA interpretation schemes may differ with respect to type and amount of identified faults.

That fact is for sure in conflict towards a reliable fault diagnostics. Most of the interpretation schemes are generally based on defined principles such as, gas concentrations, key gases, key gas ratios, and graphical representations. Some of the more applied interpretation schemes are IEC 60599, Key Gas Analysis, Roger and Doernenberg Ratio Methods, Duval Method and Gas Nomo graph Method. They are included into the IEEE Standard C57.104-1991.

1. Key Gas Method

The presence of the fault gases depends on the temperature or energy that disrupts the chemical structure of the insulating oil. This method detects faults by measuring individual gases rather than by calculating gas ratios. The significant and proportion of the gases are called "key gases" The key gases utilized to predict a specific problem are H_2 (Hydrogen) for corona in

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oil, C2H2 (Acetylene) for arcing, C2H4 (Ethylene) for severe overheating, CH4 (Methene) for sparking, CO (Carbond Monoxide) for overheated cellulose and C2H6 (Ethene) for local overheating. Permissible concentration of dissolved gases are as per.

2. Dorrnenburg Ratio Method

For convenient fault diagnosis, gas ratio methods use coding schemes that assign certain combinations of codes to specific fault types. The codes are generated by calculating ratios of gas concentrations and comparing the ratios with predefined values derived by experience and continually modified. A fault condition is detected when a gas combination fits the code for a particular fault.The Dorrnenburg Ratio method identifies faults by analyzing gas concentration ratios such as CH_4/H_2, C_2H_2/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4, which can be used to identify thermal faults, corona discharge and arcing. This method, which is specified in IEEE Standard C57.104-2008, characterizes dissolved gases of transformer oil. However, the method may obtain numerous “no interpretation,” results due to incomplete ratio ranges.

3. Roger’s Ratio Method

The most common gas ratio method is the Rogers ratio method, which distinguishes more thermal fault types compared to the Dorrnenburg ratio method. The Rogers method analyzes four gas ratios: CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4. Faults are diagnosed via a simple coding scheme based on ranges of the ratios. This method is effective because it correlates the results of numerous failure investigations with the gas analysis of each case. However, some ratio values are inconsistent with the diagnostic codes assigned to various faults in this method. Also, since the method does not consider dissolved gases below normal concentration values, a precise implementation of the method may still misinterpret data.

Table 1 Rogers Ratio codes.

Gas ratio	Ranges	Codes
CH4/H2	<0.1	5
	0.1-1	0
	1-3	1
	>3	2
C2H6/CH4	<1	0
	>1	1
C2H4/C2H6	<1	0
	1-3	1
	>3	2
C2H2/C2H4	<0.5	0
	0.5-3	1
	>3	2

4. Nomograph Method

This improves the accuracy of fault diagnosis by combining fault gas ratios and the concept of Key Gas threshold. By graphically presenting fault gas data, it simplifies interpretation of fault gas data. A nomograph is a series of vertical logarithmic scales for representing the concentration of individual gases as straight lines drawn between adjacent scales. The lines connect points representing the values of individual gas concentrations. Straight lines are diagnostic criteria for determining fault type. Fault types are identified by visually comparing the slopes of line segments with the keys at the bottom of the nomo graph.

Fault severity is indicated by the position of lines related to the concentration scales. The threshold value of each vertical scale is indicated by an arrow. For the slope of a line to be considered significant, at least one of the two tie points should exceed the threshold value. The fault is not considered significant if the tie point lies above a threshold value

5. Duval Triangle Method

The Dual triangle method concerns only three hydrocarbons gases: CH4, C2H4, and C2H2. Concentrations in ppm of the gases are expressed as percentages of the total of CH4+C2H4+C2H2 and plotted as a coordinated point of %CH4, %C2H4, and %C2H2 in a Dual triangle. Fault zones are divided into seven types, as shown in Fig.1. Six zones individual faults such as partial discharge, thermal faults, and electrical discharges. The seventh zone is a mixture of Electrical and thermal faults.[1].

In Dual triangle method following 7 Zones are Classified.

PD -Partial Discharge.

T1 -Thermal Fault less than 300°C.

T2 -Thermal Fault between 300°C and 700°C.

T3 -Thermal Fault greater than 700°C.

D1 -Low Energy Discharge (Sparking).

D2 -High Energy Discharge (Arcing).

DT -Mix of Thermal and Electrical faults.

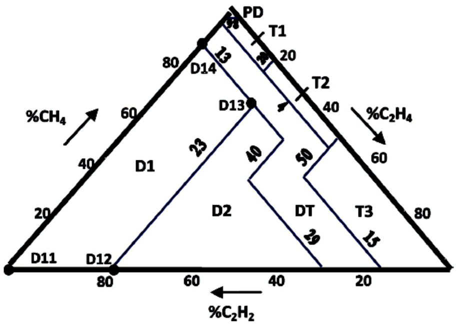

Fig. 1 Coordinate and fault zones of The Dual Triangle.

III. CASE STUDIES AND ANALYSIS

Numbers of transformer tested for oil contamination and dissolved gas analysis. Data of 1 transformer data chosen for analysis purpose. First oil contamination

1. Case Study No

Transformer Rating : 1.6 MVA
Voltage Ratio : 33KV/0.415KV

1.1 Table1 Oil contamination Test result is shown as per below.

Table 2 Oil contamination Test Results

BDV (KV)	45.4
Water content (PPM)	14
IFT (mN/m)	39
NN (mg KOH/g)	0.042
Resistivity (ohm-cm)	16.12
Flash point (°C)	149

From above test result it is found that all other test except dissipation factor test value is found within limit. Maximum dissipation factor value at 90 °C is 0.015 Max as per IS: 1866-2005. These test results indicate that the transformer oil is contaminated or deteriorated with water and other particles.

1.2 Table2 DGA Test result is shown as per below.

Table 2 DGA Test Result

Combustible Gases (ppm)			
CO	1088	C2H6	35
H2	2243	C2H4	185
CH4	24	C2H2	134

From above table-2 shows DGA test results for case study-1. Above data is analyzed by four different DGA analyses technique Key gas method, Dual triangle method, IEC ratio method and Rogers's ratio method. Total concentration of CO dissolved in the oil is 27.72 % and H2 is 62.62%. The high percentage of H2 indicates corona in oil and high percentage of CO indicates overheated cellulose.

Fig 2 Shows graphical representation of % dissolved gases concentration on the oil.

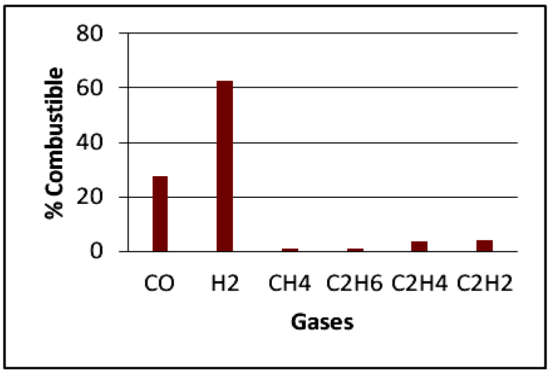

Fig.2 % Dissolved Gas concentration in Oil.

1.3 Table 3 shows the percentage of three gases in the Dual Triangle method.

Table 8 Combustible Gases (%)

Combustible Gases (%)		
CH4	C2H2	C2H4
9.02	44.23	46.81

IV. CONCLUSION

After study of the AI methods applied for the fault detection in transformers based on DGA methods, it has been found that these can be used to evaluate the condition of the transformer provided sufficient amount of reliable DGA data is available. Each of AI techniques and combination of two of these, in their own right has provided efficient solutions to incipient fault identification. The synergy of ANN and FIS can be a good solution for reliable results for predicting faults because one should not rely on a single technique when dealing with real –life application DGA is power fool tool for redacting of transformer incipient fault at early stages Transformer insulating oil is analyzed for prediction of transformer incipient fault at early stages. From that condition of power transformer is accomplished by two main methods. Oil contamination test indicates whether oil is contaminated or deteriorated. In oil contamination test dielectric strength, IFT, acidity, water content, resistivity and dissipation factor test preformed. After that DGA results analyzed by four different methods like Key gas method, Dual triangle method, IEC ratio method and Rogers ratio method.

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