S. Saranya, Uma Mageswari, Natalya Roy, R. Sudha / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 3, May-Jun 2013, pp.592-595

Comparative Study Of Various Dissolved Gas Analysis Methods To Diagnose Transformer Faults

S. Saranya[1], Uma Mageswari[2], Natalya Roy[3], R. Sudha[4]
[4]VIT University, Vellore

ABSTRACT:

Dissolved gas analysis (DGA) is a reliable technique for detecting the presence of incipient fault conditions in oil immersed transformers. In this method the presence of certain key gases is monitored. The various analysis methods are : Rogers ratio, IEC ratio, Doernenburg, Duval triangle, key gas, artificial neural network (ANN) method. In this paper the various DGA methods are evaluated and compared. The comparative study is carried out from DGA data obtained from published papers. The key gases considered are hydrogen, methane, ethane, ethylene, acetylene.

INTRODUCTION:

Mineral oils is mixture of saturated hydro carbon paraffin whose general molecular formula is C_nH_{2n+2} with 'n ' in the range of 20-40. This oil acts as di electric medium and this heat transfer agent when used in transformers. During the occurrence of fault in the transformer, these gases are released within the unit. The rate of gas generation and its distribution indicates the severity of fault.

Fault may occur due to overheating, arcing, partial discharge, over heating in cellulose, etc. The fault gases are methane(CH_4),ethane (C_2H_6), ethylene (C_2H_4),acetylene(C_2H_2), hydrogen(H_2),carbon monoxide(CO),carbon di oxide(CO_2).non fault gasses are nitrogen(N_2),Oxygen(O_2). Depending up on the fault gas there are several technique to analyse the type if transformer fault.

METHODOLOGY:

The insulating oils breakdown to release small quantity of gases up on occurrence of fault. It is possible to distinguish fault such as partial discharge (corona), overheating, arcing, by means of DGA

1. Roger ratio method:

In this method four ratio CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4 are utilised. The code number that is generated can be related to a diagnostic interpretation as shown in Table 1,2 & 3.
Table(1):

CH_4/H_2	C_2H_6/CH_4	C_2H_4/C_2H_6	C_2H_2/C_2H_4	Diagnosis
0	0	0	0	If CH_4/H_2 is 0.1 or so → partial discharge, otherwise normal deterioration
1	0	0	0	Slight overheating – below 150 °C
1	1	0	0	Slight overheating – 150-200 °C
0	1	0	0	Slight overheating – 200-300 °C
0	0	1	0	General conductor overheating
1	0	1	0	Circulating currents and/or overheating joints
0	0	0	1	Flashover without power follow-through
0	1	0	1	Tap changer selector breaking current
0	0	1	1	Arc with power follow-through – or persistent sparking

Table 2.
C. E. G. B. Fault Gas Ratios.[4]

RATIO	RANGE	CODE
CH_4/H_2	≤ 0.1 > 0.1 < 1 ≥ 1 < 3 ≥ 3	5 0 1 2
C_2H_6/CH_4	< 1 ≥ 1	0 1
C_2H_4/C_2H_6	< 1 ≥ 1 < 3 ≥ 3	0 1 2
C_2H_2/C_2H_4	< 0.5 ≥ 0.5 < 3 ≥ 3	0 1 2

Table 3.
C. E. G. B. Diagnostics.

CODE				DIAGNOSIS
0	0	0	0	Normal
5	0	0	0	Partial discharge
1,2	0	0	0	Slight overheating < 150°C
1,2	1	0	0	Slight overheating 150 - 200°C
0	1	0	0	Slight overheating 200 - 300°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, no 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)
CO2 / CO > 11				Higher than normal temperature in insulation

2. IEC method:

This method similar to Roger's ratio method except that the ratios C_2H_6/CH_4 is excluded as it indicates only a limited range of decomposition. A detailed description of IEC method shown in table(4).

Table(4):

Range Of Ratio	Code		
	C2H2 / C2H4	CH4/ H2	C2H4/ C2H6
	R2	R1	R5
<0.1	0	1	0
0.1to1.0	1	0	0
1.0 to 3.0	1	2	1
>3.0	2	2	2

Different fault types can be identified by typical phenomena. Partial discharge of low energy density is observed by discharged in gas filled cavities from incomplete impregnation. Partial discharge of high energy density leads to perforation of solid insulation. Thermal faults are observed by overheating of insulation conductors.

3. Doernenburg Ratio Method:

In this method the gas concentration from ratio of CH_4/H_2, C_2H_2/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4 are utilised. The value of gases must exceed the concentration L1 when there is fault at the unit. Table (5) shows the key gases and their concentration L1.

Table (5):

Key Gas	Concentrations *L1* (ppm)
Hydrogen (H_2)	100
Methane (CH_4)	120
Carbon Monoxide (CO)	350
Acetylene (C_2H_2)	35
Ethylene (C_2H_4)	50
Ethane (C_2H_6)	65

To diagnose the fault the step by step procedure in this method is:

- Gas concentrations are obtained by extracting the gases and separating them by chromatograph
- If at least one of the gas concentrations (in ppm) for H2, CH4, C2H2, and C2H4 exceeds twice the values for limit *L1* (see table 7) and one of the other three gases exceeds the values for limit *L1*, the unit is considered faulty; proceed to Step 3.
- Determining validity of ratio procedure: If at least one of the gases in *each* ratio CH_4/H_2, C_2H_2/CH_4, C_2H_2/CH_4 and C_2H_6/C_2H_2 exceeds limit *L1*, the ratio procedure is valid. Otherwise, the ratios are not significant, and the unit should be resample and investigated by alternative procedures.
- Assuming that the ratio analysis is valid, each successive ratio is compared to the values obtained from table 8 in the order of ratio CH_4/H_2, C_2H_2/CH_4, C_2H_2/CH_4 and C_2H_6/C_2H_2

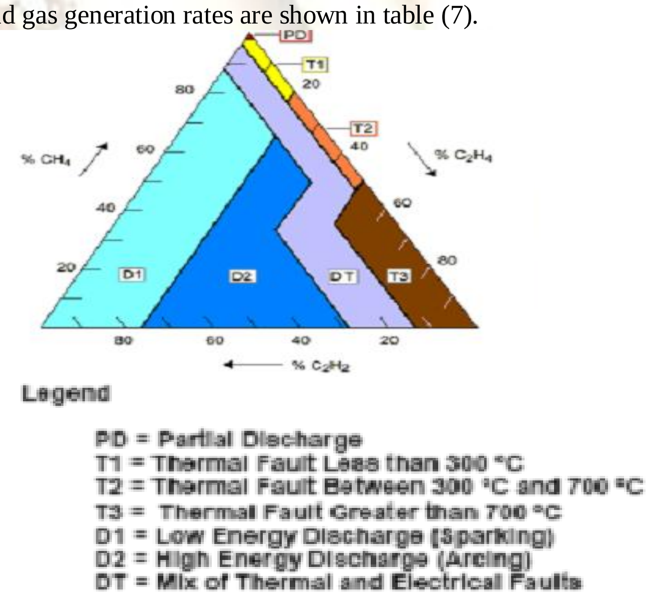
If all succeeding ratios for a specific fault type fall within the values (column) given in table(6), the suggested diagnosis is valid.

Table(6):

Suggested Fault diagnosis	1.thermal decomposition	2.corona(low Intensity PD)	3.arcing (high intensity PD)
CH4/H2	>1.0 >0.1	<0.75 <1.0	<0.3 <0.1
C2H2/C2H4	<0.1 <0.01	Not significiant	<0.3 <0.1
C2H2/CH4	<0.1 >0.01 <1.0 <0.1	>0.75 >1.0	>0.3 >0.1

4. Duval Triangle method:

This method was developed in 1960 by M.Duval. To determine whether the problem exists at least the one of the hydro carbon gases or hydrogen must be at L1 level or above , and the gas generation rate must be at least G2[]. The L1 level and gas generation rates are shown in table (7).



Table(7):

Gas	L1 limits	G1 limits (ppm per month)	G2 limits (ppm per month)
H2	100	10	50
CH4	75	8	38
C2H2	3	3	3
C2H4	75	8	38
C2H6	75	8	38
CO	700	70	350
CO2	7000	700	3500

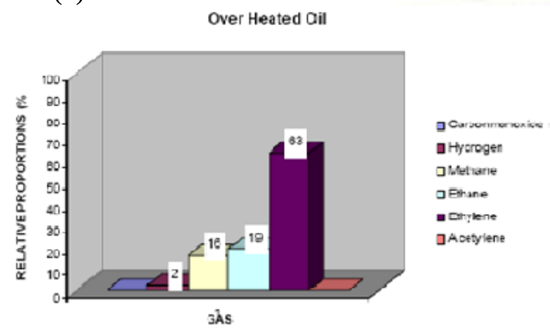
Once a problem has been detected, calculate the total accumulated Amount of the three Duval triangle gases (CH_4, C_2H_2, C_2H_4) and divide each gas by the total.

This will give the percentage of each gas of the total. Plot the obtained percentage of the total on the triangle to obtain the diagnosis.

5. Key Gas method:

The principle of the key gas method is based on the quantity of individual fault gases released from the insulating oil during the occurrence of a fault. In this method, individual gas is considered rather than the gas ratio for fault detection is calculated.

Table(8): Over Heated Oil Characteristic



Table(9): Overheated Cellulose Characteristic

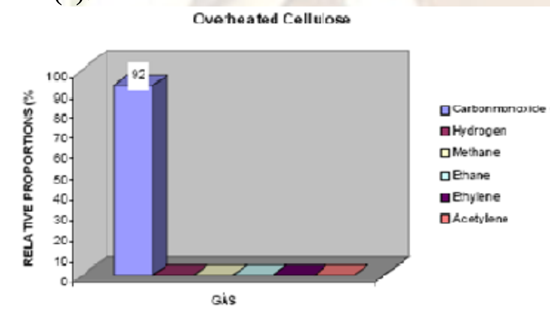


Table (10): Corona in Oil Characteristic

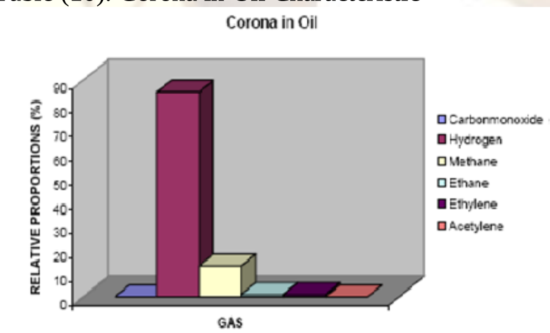
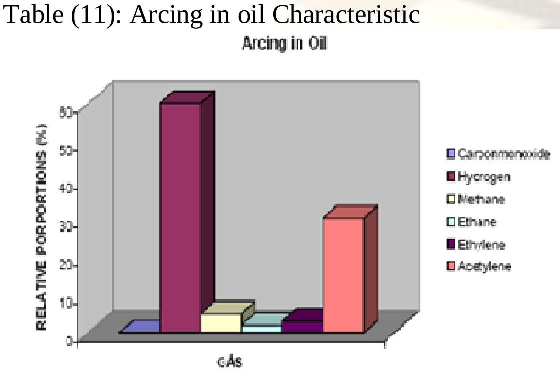
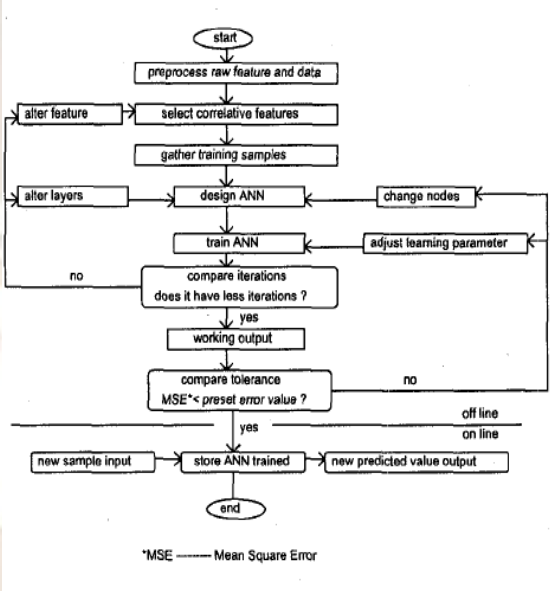


Table (11): Arcing in oil Characteristic



6. Artificial Intelligence:

The relationship between released gas and incipient fault condition is interpreted by ANN and is used to develop the gas- in- oil data. An ANN design includes selection of input, output, network topology and weighted connection of nodes. The network topology is chosen experimentally through a repeated process of optimization of the number of hidden layers. Figure () illustrates over all ANN design process with step by step adjustment to achieve desired structure. The back propagation learning algorithm used involves repeatedly passing the training sets through the neural network until it weights minimise the output error over the entire set. Once a process has done, the weights will be retained and ready for future use. New samples can be fed to this trained ANN to obtain the output readily.



Results and Conclusions:

The percentage of successful prediction and consistency are calculated using the following formulas:

$$S_{Fn} = \frac{R_{Fn}}{Number\ of\ cases\ of\ Fn} \times 100$$

$$C_{Fn} = \frac{\sum_{n=1}^{n=5} S_{Fn}}{Number\ of\ fault\ types}$$

where:

F_n = type fault code (n=1,2,3,4,5)

Method	F_1	F_2	F_3	F_4
Roger	Slight overheating <150°C Overheating 150°C-200°C Overheating 200°C-300°C	Conductor overheating Winding circulating current Core/tank circulating current.	Flashover. Arcing Continuous sparking.	PDs PDs with tracking
IEC	Thermal fault <150°C Thermal fault 150°C-300°C	Thermal fault 300°C-700°C Thermal fault > 700°C	Discharge of low energy Discharge of high energy	PDs of low energy density PDs of high energy density
Nomograph	Heating	Heating and Discharge	Arcing Arcing and heating	Arcing, heating and discharge Arcing and discharge
Doernenburg	Thermal decomposition with very high ratio 4	Thermal decomposition	Arcing	Corona
Duval	Thermal fault <300°C	Thermal fault 300°C-700°C Thermal fault > 750°C	Low energy discharge High energy discharge	PDs Mix thermal and electrical faults
Key Gas	Principal gas: CH_4 and C_2H_6	Principal gas: C_2H_4	Principal gas: C_2H_2	Principal gas: H_2

TABLE(13):

Method	Faults Code	Number of predictions (P)	Number of correct predictions (R)	% Successful prediction (S)	Consistency (C)
Roger	F_1	10	5	50%	45%
	F_2	13	13	39%	
	F_3	13	12	55%	
	F_4	9	8	57%	
	F_5	4	3	23%	
IEC	F_1	6	5	50%	60%
	F_2	26	26	79%	
	F_3	19	18	82%	
	F_4	9	9	64%	
	F_5	6	3	23%	
Nomograph	F_1	15	2	20%	74%
	F_2	24	23	70%	
	F_3	19	18	82%	
	F_4	20	14	100%	
	F_5	14	13	100%	
Doernenburg	F_1	3	2	20%	40%
	F_2	15	15	45%	
	F_3	9	8	36%	
	F_4	7	6	43%	
	F_5	8	7	54%	

From the results summarised in the table the following observations are made

- For f1 faults key gas and duval methods ds gave 100% successful predictions.
- For F2 faults key gas method gave 100% successful prediction.
- For f3 faults the IEC method gave the highest percentage of successful prediction at 82%
- F4 faults had the lowest percentage of successful prediction among all fault types.

F5 faults Duval Gas method gave 100% successful prediction. It can be observed that the most consistent method is the duval gas method followed by key gas method.

References:

1. Artificial neural networks applied to DGA for fault diagnosis in oil-filled power transformers: Mohammad Golkhah, Sahar Saffar Shamshirgar and Mohaammad Ali Vahidi.
2. An Artificial Neural Network approach to Transformer Fault Diagnosis. Y. Zhang, X. Ding, Y. Liu, P. J. GriffinThe Bradley Department of Electrical EngineeringVirginia Tech, Blacksburg, VA 24061-0111,USA
3. DiGiorgio, J.B. (2005) Dissolved Gas Analysis of Mineral Oil Insulating Fluids. DGA Expert System: A Leader in Quality, Value and Experience 1, 1-17
4. Chu, D. and A. Lux, On-line monitoring of power transformers and components: a review of key parameters. Electrical Insulation Conference and Electrical Manufacturing & Coil Winding Conference, 1999. Proceedings, 1999: p. 669-675.
5. Siva Sarma, D.V.S.S. and G.N.S. Kalyani, ANN Approach for Condition Monitoring of Power Transformers using DGA. 2004 IEEE Region 10 Conference, TENCON 2004., 2004. C: p. 444-447.
6. Yang, F. and Z. Liang, Comprehensive method detecting the status of the transformer based on the artificial intelligence. 2004 International Conference on Power System Technology, 2004. PowerCon 2004. , 2004. 2: p. 1638-1643.
7. Hongzhong, M., et al., Diagnosis of power transformer faults on fuzzy three-ratio method. The 7th International Power Engineering Conference, 2005. IPEC 2005., 2005.
8. Wang, M., A.J. Vandermaar, and K.D. Srivastava, Review of Condition Assessment of Power Transformers In Service, in IEEE Electrical Insulation Magazine. 2002. p. 12-25.
9. C57.104.1991, I., IEEE Guide for Interpretation of Gases Generated in Oil-Immersed Transformer, I. The Institute of Electrical and Electronic Engineers, Editor. 1992, The Institute of Electrical and Electronic Engineers, Inc p. 27.
10. FIST3-31, Facilities Instructions, Standards and Techniques Volume 3-31 Transformer Diagnostics. 2003, Bureau of Reclamation Hydroelectric Research and Technical Services Group Denver. p. 5-13.
11. Q.Su, et al., A Fuzzy Dissolved Gas Analysis Method for The Diagnosis of Multiple Incipient Faults in a Transformer. IEEE Transaction On Power System, 2000. 15(2): p. 593-59