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Article

Dissolved Gas Analysis: A Proactive Approach for Recognization of Faults in Transformer using MATLAB GUI

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ABSTRACT

Transformer plays an important role in Power transmission network. For a reliable power supply utmost attention is required. The mineral oil employed is exposed to high thermal and electrical stresses and thus gasses are formed due putrefaction of the mineral oil. To reduce the failure in transformers diagnosis of mineral oil for faults needs to be carried out. The Dissolved Gas Analysis (DGA) is used for assessment of oil for liquified gases formed due to faults. DGA involves five classical methods Key Gas Method, IEC Ratio method, Rogers Ratio Method, Doernenburg Ratio Method and Duval triangle Method. This paper presents a MATLAB GUI for five classical methods with 93% accuracy when compared to reliable individual method of 83% accuracy.

Keywords: DGA, Mineral Oil, Transformer, Fault Analysis, MATLAB GUI

Introduction

The Transformer is a static device which transfers electrical energy from one circuit to another circuit. It consists of transformer oil with a primary function to insulate and cool a transformer. As the transformer plays a significant role in power transmission network, the oil must have high dielectric strength, thermal conductivity and chemical stabilities during its operation to avoid untoward incidences. The oil decomposes when fault occurs inside the transformer and thus liberates gas. These gases help in identifying the type and severity of fault. The cost of outages can be reduced by having a proactive approach in identifying the faults instead of a reactive approach. There are three different methods for gas identification viz. TCG, GBA, DGA. Out of these three DGA is the most reliable method for credentials of fault inside the transformer.

Formation of Gases in Transformer Oil

Gas is formed in mineral oil due to decomposition of cellulose and oil. Decomposition of cellulose and oil takes place due to thermal fault and electrical fault. Electrical faults occur due to Corona (Partial discharge) or Arcing (High energy discharge). Gases formed are CH4, H2, C2H6, C2H4, C2H2, CO2, CO etc. The percentage amount of gases formed in transformer depends on type of fault and its source of formation. Table 1[1,2] gives a dissolved gas concentration permissible limit which determines the health of the transformer.

Transformer Fault Diagnosis by Classsical Methods

One of the main advantages of Dissolved Gas Analysis over other gas identification methods is it gives early identification of incipient fault. Figure 1 shows the steps involved in DGA.[3]

Table 1.Dissolved Gas concentration limit

Gases (in PPM)	Normal	Caution	Abnormal	Danger
Hydrogen	100	101-700	701-1800	>1800
Methane	120	121-400	401-1000	>1000
Acetylene	35	36-50	51-80	>80
Ethylene	50	51-100	101-200	>200
Ethane	65	66-100	101-150	>150
Carbon Monoxide	350	351-570	571-1400	>1400
Carbon Dioxide	2500	2501-4000	4001-10000	>10000
TDCG	720	721-1920	1921-4630	>4630

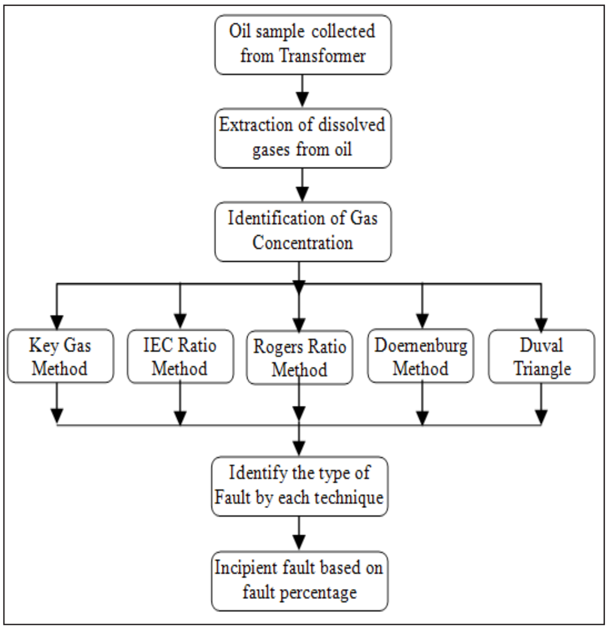
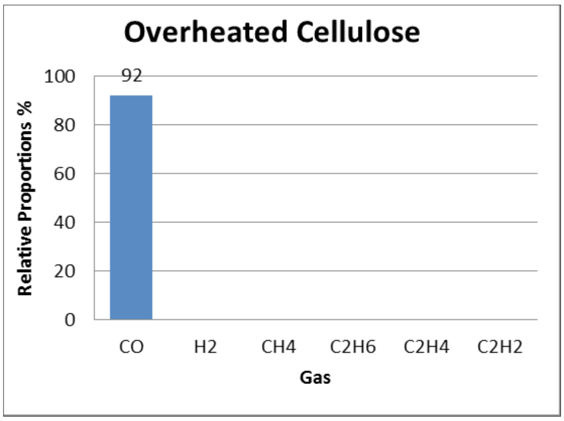


Figure 1.Combined DGA Techniques Flow Chart

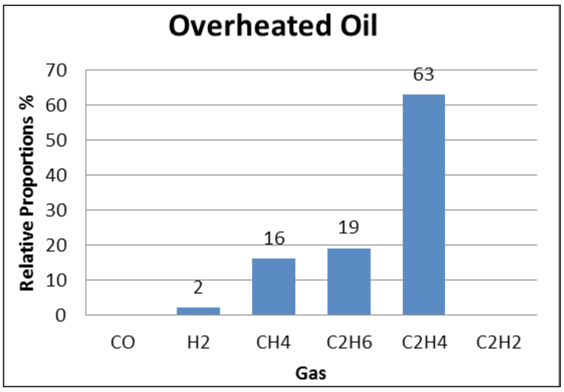
The oil sample is consisting of the transformer unit. From this oil sample, the dissolved gas is extracted. The concentration of dissimilar gases in ppm is evaluated from the extraction. The concentration values of different gases are analyzed for incipient fault by five classical methods viz. Key Gas Method, IEC Ratio Method, Rogers Ratio Method, Dornenburg Method, Duval Triangle. The incipient fault types is compared with all the five approaches and built on percentage, the final incipient fault is definite.

Key Gas Method

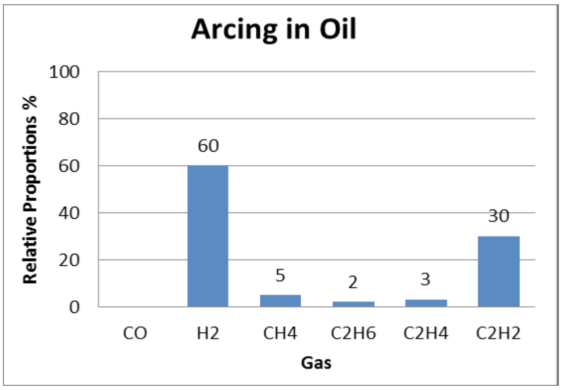
Key Gas method be contingent on the percentage of key gas liberated at the time of fault. Figure 2 shows dissimilar incipient faults grounded on quantity of gases unconfined inside the transformer.[4] When the gas crosses the limits, succeeding fault is the root cause.



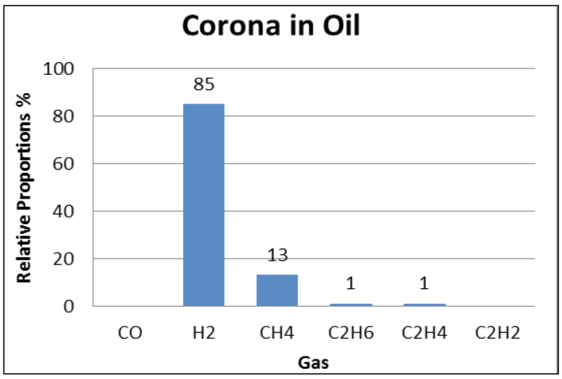
(a) Key Gas: Ethylene



(b) Key Gas: Carbon Monoxide



(c) Key Gas: Carbon Monoxide



(d) Key Gas: Carbon Monoxide

Figure 2.Key Gas Method with Four Faults

Rogers Ratio Method

As the term proposes this method diagnoses the fault with the help of gas ratios generated at the time of fault. The four gas ratios are CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4. One of the main compensations of this method is irrespective of the volume of oil it depends only on ratios of gas released. Table II shows codes for gas ratios. The value of each ratio is calculated, based on these four ratios range, code (0-5) is provided in Table II. Table III shows fault identified with reference to the ratio of gases with code. There are 12 possible causes of incipient faults as shown in Table 3.

Table 2.Gas Ratio Codes[4]

S. No.	Gas Ratios	Ratio Codes	Range	Code
1.	CH4/H2	i	<=0.1	5
			0.1-1.0	0
			>=1.0, <3.0	1
			>=3.0	2
2.	C2H6/CH4	j	<1.0	0
			>=1.0	1
3.	C2H4/C2H6	k	<=1.0	0
			>=1.0, <3.0	1
			>=3.0	2
4.	C2H2/C2H4	l	<0.5	0
			>=0.5,3.0	1
			>=3.0	2

Table 3.Different faults based on Rogers Ratio[5]

S. No.	i	j	k	l	Diagnosis
1.	0	0	0	0	No fault. Normal deterioration
2.	5	0	0	0	Partial discharge
3.	1-2	0	0	0	Slight overheating (<1500c)
4.	1-2	1	0	0	Overheating (1500c-2000c)
5.	0	1	0	0	Overheating (2000c-3000c)
6.	0	0	1	0	General conductor over heating
7.	1	0	1	0	Winding circulating currents
8.	1	0	2	0	Core & circulating currents (3000c-7000c)
9.	0	0	0	1	Flash over without power follow through
10.	0	0	1-2	1-2	Arc with power follow through
11.	0	0	2	2	Continuous sparking to floating potential
12.	5	0	0	1-2	Partial discharge with tracking

IEC Ratio Method

IEC ratio technique is resultant from the Roger's Ratio method. In this technique, ratio C2H6/CH4 was dropped as it exposed only partial temperature range at the time of decomposition in the transformer. Subsequent Table IV shows the IEC Ratio codes with gas ratio range and its code (0-2).[6,4]

Table 4.EC Ratio Codes[6,4]

S. No.	Gas Ratios	Ratio Codes	Range	Code
1.	CH4/H2	i	<0.1	1
			0.1-1.0	0
			>1.0	2
2.	C2H4/C2H6	k	<1.0	0
			1.0-3.0	1
			>3.0	2
3.	C2H2/C2H4	l	<0.1	0
			0.1-3.0	1
			>3.0	2

Table 5, shows fault identified with reference to the ratio of gases with code. There are nine possible causes of incipient faults as shown below.

Table 5.Different faults based on IEC Ratio[4,6]

S. No.	i	k	l	Diagnosis
1	0	1	0	Normal ageing
2	1	0	>0	Partial discharge of low energy density
3	1	0	1	Partial discharge of high energy density
4	0	1-2	1-2	Discharge of low energy
5	0	2	1	Discharge of high energy

6	0	1	0	Thermal fault (<150°C) heating
7	2	0	0	Thermal fault (150°C - 300°C)
8	2	1	0	Thermal fault (300°C - 700°C)
9	2	2	0	Thermal fault (>700°C) follow through

Dornenburg Ratio Method

This technique is based on ratios of four gases CH_4 / H_2, C_2H_2 /C_2H_4, C_2H_2 /CH_4 and C_2H_6 / C_2H_2 or six gases H_2, CH_4, C_2H_4, C_2H_2, C_2H_6 and CO. Through this method three types of fault can be analyzed i.e. thermal decomposition, corona and arcing.[7] This method is valid when the concentration of at least one of the gas H_2, CH_4, C_2H_4, or C_2H_2 must exceed twice the concentration limit. However, gases viz. C_2H_6 and CO must exceed the concentration limit. Table 6 shows the concentration limit of key gases.[8]

Table 6.Concentration limit for Dornenburg Ratio Method[8]

S. No.	Key gas	Concentration (PPM)
1.	Hydrogen (H2)	100
2.	Methane(CH4)	120
3.	Acetylene (C2H2)	35
4.	Ethylene (C2H4)	50
5.	Ethane (C2H6)	65
6.	Carbon monoxide (CO)	350

Table 7, gives the diagnosis for different gas ratio range and its subsequent fault.

Table 7.Diagnosis by Dornenburg Ratio Method[8]

Fault	(CH4/ H2)	(C2H2/ C2H4)	(C2H2/ CH4)	(C2H6/ C2H2)
Thermal decom-position	>1.0	<0.75	<0.3	>0.4
Partial Discharge (PD)	<0.1	Not significant	<0.3	>0.4
Arcing fault	>0.1 to <1.0	>0.01 to < 0.1	>0.3	<0.4

Duval Triangle Method

Duval Triangle method is one of the most accurate method when compared to other four approaches. This method is based on three gases CH_4, C_2H_4 and C_2H_2. The problem exists only if at least one of the hydrocarbon gases or hydrogen is greater or equal to L1 level. The gas generated must at the rate of G1 & G2 as shown in Table 8.[10,11]

Table 8.L1 limit and gas generation rates for Duval Triangle Method[10]

S. No.	Gas	L1 limits	G1 limits (ppm per month)	G2 limits (ppm per month)
1	H2	100	10	50
2	CH4	75	8	38
3	C2H2	3	3	3
4	C2H4	75	8	38
5	C2H6	75	8	38
6	CO	700	70	350
7	CO2	7000	700	3500

If the above conditions as declared in table 8, are content then the problematic happens. The percentage of each gas with total gas (CH4 + C2H4 + C2H2) is intended. This percentage of each gas is plotted on the triangular chart which is divided into six fault zones. The fault zone where the point is situated designates the type of fault produced in the transformer as shown in Figure 3.[10,11]

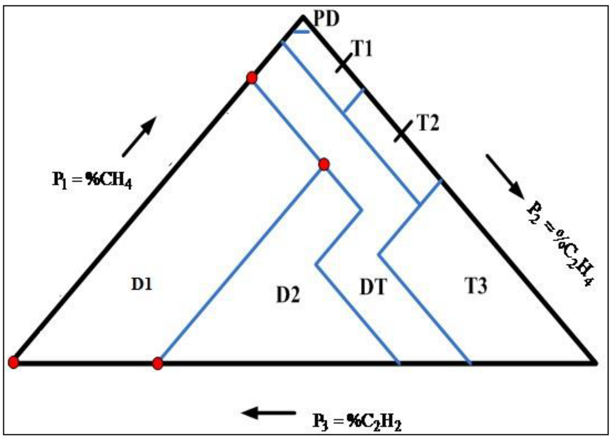


Figure 3.Duval Triangle

Combined DGA Analysis

As shown in Figure 1, in this method the key gas is analyzed by all the five methods which we have discussed, based on the percentage of fault diagnosed by each method the fault is determined. Table IX gives the codes for seven unalike faults.[6]

Table 9.Fault classification with codes[6,12]

S. No.	Fault	Code
1.	Thermal faults<300°C	F1
2.	Thermal faults 300°C-700°C	F2
3.	Thermal faults >700°C	F3
4.	Partial Discharge	F4
5.	Arcing	F5
6.	Normal Condition	F6
7.	No prediction	F7

Table 10.Mapping process of each fault with different diagnostic methods[6,12]

Method	F1	F2	F3	F4	F5	F6	F7
Key Gas	No prediction	Principal gas CO, C2H4	No predictio	Principal gas H2	Principal gas C2H2	<Limits	NO PREDICTION
Rogers	Slight over heating<150C,Over heating 150C-200C	General conductor overheating, core & circulating	Overheating>700 C	Partial discharge with tracking	Flash over without power follow, arc with power follow		
IEC	Thermal Fault <150C,thermal fault 150C-	Thermal Fault 300C-700C	Thermal Fault >700C	Partial discharge of low and high energy	Arcing and sparking	Normal	
Dornenburg	Slight Over heating	Thermal Decomposition	No Prediction	Corona	Arcing		
Duval	Thermal Fault <3000C	Thermal Fault 300C-700C	Thermal Fault >700C	Low energy discharged	PD s mix with electrical and		

The result of the combined analysis is showed on MATLAB GUI. The above codes are combined to make available the incipient fault based on the percentage of the fault 30 data of gases was analyzed for DGA by linking the results with specific approaches and combined DGA analysis.

Result and Conclusion

Using MATLAB GUI consequences for 30 data of gases from dissimilar papers were intended [6]. The outcome of the tested DGA is as shown in Table XI. It was experiential that the most accurate way is duval triangle method with 83% accuracy. Still, with combine DGA investigation, the percentage of accuracy is 93%. Thus, it is chosen to carry out combined DGA analysis, in its place of the furthermost precise individual Duval triangle technique for fault examination in case of internal fault in the transformer.

Table 11.Comparing percentage prediction of individual and combined DGA method

S. No.	Method	No. of Data tested	Computation		
			Results obtained	No Prediction	% Accuracy
1.	Key Gas	30	13	17	43%
2.	IEC	30	19	11	63%
3.	Rogers	30	23	7	77%
4.	Dornenburg	30	22	8	73%
5.	Duval	30	25	5	83%
6.	Combined DGA	30	28	2	93%

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