Transformer Fault Diagnosis Based on DGA using Classical Methods

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Abstract- **During the last few years there has been trend of continuous increase in transformer failures. It is therefore necessary to diagnose the incipient fault for safety and reliability of electrical network. Various faults could occur in transformer such as overheating, partial discharge and arching which can generate various fault gases so in order to diagnose the fault DGA (Dissolved gas Analysis) is done. In this paper the proposed methods are used which is based on standards and guidelines of International Electro technical Commission (IEC), Central Electric Generating board (CEGB), and the American Society for testing and Material (ASTM). Fault diagnoses methods by the DGA technique are implemented to improve the interpretation accuracy of transformer.**

Keywords: Dissolved gas Analysis (DGA), Central Electric Generating board (CEGB), The American Society for testing and Material (ASTM), Institute of Electrical and Electronics Engineering (IEEE), International Electro technical Commission (IEC), British Standard (B.S.), Decomposition (Decomp).

I. INTRODUCTION

Transformers are the essential part of the electrical power system because it has the ability to alter voltage and current levels, which enables the power transformer to transmit and distribute electric power and utilize the power at economical and suitable levels. In electrical power system, voltage of electricity generated at the power plant will be increased to a higher level with step-up transformers. A higher voltage will reduce the energy lost during the transmission process of the electricity. After electricity has been transmitted to various end points of the power grid, voltage of the electricity will be reduced to a usable level with step-down transformer for industrial customers and residential customers. Since power transformer is vital equipment in any electrical power system, so any fault in the power transformer may lead to the interruption of the power supply and accordingly the financial losses will also increase. So it is of paramount importance to detect the incipient fault of transformer as early as possible. The following characteristics of oil were laid down in B.S.148:1959 the values stated being obtained by the testing method specified in the, appendices of the standard:-

Table I: Physical Properties of Transformer Oil

Characteristic	Limit
Sludge Value(max)	1.20%
Acidity after oxidation(max)	2.5 mg KOH/gm
Flash Point (closed) (min)	295° F (146.1°C)
Viscosity at 70°F(21.1°C)(max)	37 cS
Pour Point (max)	(-25.06°F) (-31.7°C)
Electric Strength, 1 minute (min)	40 kV (r.m.s)
Acidity(neutralization value) Total (max) Inorganic	0.05mg. KOH/gm Nil
Saponification Value (max)	1.00 mg. KOH/gm
Copper discoloration	Negative
Crackle	Shall pass test
Specific gravity	No Limit

Faults can be differentiated for their energy, localization and occurrence period. Along with a fault, there are increased oil temperatures and generation of certain oxidation products such as acids and soluble gases. These gases, hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), propane (C_3H_8), propane (C_3H_6), together with carbon monoxide (CO) and carbon dioxide (CO_2) are considered as fault indicators and can be generated in certain. The operating principle of transformer is based on the slight albeit harmless deterioration of the insulation that accompanies incipient faults, in the form of arcs or sparks resulting from dielectric breakdown of weak or overstressed parts of the insulation, or hot spots due to abnormally high current densities or due to high temperature in conductors. Whatever the cause, these stresses will result in the chemical breakdown of oil or cellulose molecules constituting the dielectric insulation

II. DISSOLVED GAS ANALYSIS

Thermal and electrical distributions in the operating transformer are two most important causes of dissolved gases in oil. The gases produced from thermal decomposition of oil and solid insulation are because of losses in conductors due to loading. Also decomposition occurs in oil and solid insulation is due to occurrence of arc. In case of electrical disturbances the gases are formed principally by ionic bombardment. The gases are generated mainly because of cellulose and oil insulation deterioration. In the normal operation of the transformer, gases such as Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4), Acetylene (C_2H_2), and Ethane (C_2H_6) and so on are released. In the existing methods, parts per million (PPM) values are determined for each gas in the oil along with a total value of combustible gasses. When there is an abnormal situation such as a fault occurrence, some specific gases are produced in greater quantity than in the normal operation. Thus, the amount of these gases in the transformer oil increases. The increase in the amount of gases results in saturation of the transformer oil and no further gas can be dissolved in oil. Therefore, when the oil is saturated, the gas is released from the oil. The amount of the dissolved gas is related to the temperature of the oil and the type of gas. The produced gas can be classified into three groups: polarization, corona, and arcing. These groups coming from the severity of the released energy during the fault are different. The largest and lowest amounts of the released energy are associated with the arcing and corona.

a) Polarization: In the transformer oil, the released gases at low temperature are CH_4 and C_2H_6, and at high temperature are C_2H_6, CH_4, C_2H_4, and H_2. In cellulose, the generated gases at low and high temperatures are CO and CO_2.

b) Corona: In corona, the produced gas in oil is H_2 and the released gases in cellulose are H_2, CO, and CO_2.

c) Arcing: In this case, the released gases are C_2H_6, CH_4, C_2H_4, and H_2.

In this method at first a sample of transformer oil is taken then the dissolved gases is extracted, separated and measured by means of chromatography. In order to interpret result of experiment data is produced is produced in suitable form to diagnose the fault. The different standard are used which are explained in following sections.

A. *Roger's ratio method I (IEC Standard)*

According to the IEC standards, the extended Rogers method is used to produce a three digit code. The code is determined based on the three gas ratios of C_2H_2/C_2H_4, CH_4/H_2, and C_2H_4/C_2H_6 as given in Table II.

Table II: IEC code determination Criteria

Gas ratio	Value	Code
X= C2H2/C2H4	X<0.1	0
	0.1<X<3	1
	X>3	2
Y= CH4/H2	Y<0.1	1
	0.1<Y<1	0
	Y>1	2
Z=C2H4/C2H6	Z<1	0
	1<Z<3	1
	Z>3	2

Table III: Fault Diagnosis IEC codes

Sl. No.	Code			Kind of fault	Grouping of fault
	X	Y	Z		
1	0	0	0	No fault	F1
2	0	1	0	Partial discharge with low intensity discharge	F2
3	1	1	0	Partial discharge with high intensity discharge	F3
4	1 or 2	0	1 or 2	Partial discharge with low intensity discharge	F2
5	1	0	2	Partial discharge with high intensity discharge	F3
6	0	0	1	Thermal fault with temperature less than 150°C	F4
7	0	2	0	Thermal fault with temperature between 150° C to 300° C	F5
8	0	2	1	Thermal fault with temperature between 300 °C to 700° C	F6
9	0	2	2	Thermal fault with temperature greater than 700°C	F7

B. *Roger's ratio method II. (CEGB Standard)*

In this standard, a four digit code is created using the Rogers method and four gas ratios of CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6, and C_2H_2/C_2H_4. From the obtained codes the faults are diagnosed.

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Table IV: CEGB code determination Criteria

Gas ratio	Value	Code
W=CH4/H2	W<=0.1	5
	0.1<W<1	0
	1<=W<3	1
	W>=3	2
X=C2H6/CH4	X<1	0
	X>=1	1
Y=C2H4/C2H6	Y<1	0
	1<=Y<3	1
	Y>=3	2
Z=C2H2/C2H4	Z<0.5	0
	0.5<=Z<3	1
	Z>=3	2

Table V: Fault Diagnosis using CEGB codes

S.NO	Codes W	X	Y	Z	Kind of fault	Grouping of fault
1	0	0	0	0	No fault	F1
2	5	0	0	0	Partial discharge	F2
3	1 or 2	0	0	0	Increase in temperature less than equal to 150° C	F3
4	1 or 2	1	0	0	Increase in temperature 150 °C to 200 °C	F4
5	0	1	0	0	Increase in temperature 200°C-300°C	F5
6	0	0	1	0	Increase in overall temperature in conductive parts	F6
7	1	0	1	0	Circulating currents in winding	F7
8	1	0	2	0	Circulating current between core and tank	F8
9	0	0	0	1	Spark with low energy discharge	F9
10	0	0	1 or 2	1 or 2	Spark with high energy discharge	F10
11	0	0	2	2	Continuous spark	F11
12	5	0	0	1 or 2	Partial discharge with tracking	F12

C. *Roger's ratio method III (ASTM Standard)*

In this standard a four digit code is generated based on the codes given in table using the Rogers method and the four gas ratios of C2H4/C2H6, C2H6/CH4, C2H2/C2H4, and CH4/H2 is considered.

Table VI: ASTM code determination criteria

Gas ratio	Value	Code
J=CH4/H2	0<W<0.1 0.1<W<1 1<=W<3 W>3	1 2 3 4
K=C2H6/CH4	X<1 X>1	0 1
L=C2H4/C2H6	Y<1 3<Y<1 Y>3	0 1 2
M=C2H2/C2H4	Z<0.5 3<Z<0.5 Z>=3	0 1 2

Table VII: Fault Diagnosis using ASTM codes

Sl. No.	Codes W	X	Y	Z	Kind of Fault	Grouping of fault
1	2	0	0	0	Normal	F1
2	1	0	0	0	Partial discharge	F2
3	3	0	0	0	Increase in temperature less than equal than 150 C	F3
4	4	0	0	0	Increase in temperature less than equal than 150 C	F3
5	3	1	0	0	Increase in temperature 150C-200C	F4
6	4	1	0	0	Increase in temperature 150C-200C	F4
7	4	0	1	0	Increase in temperature 200 C to 300 C	F5
8	2	0	1	0	Increase in temperature of conductor	F6
9	3	0	1	0	Circulating current in winding	F7
10	3	0	2	0	Circulating current between core and tank	F8
11	2	0	0	1	Spark with very low energy density	F9
12	2	0	1	1	Spark with high energy density	F10
13	2	0	1	2	Spark with high energy density	F10
14	2	0	2	1	Spark with high energy density	F10
15	2	0	2	2	Continuous spark	F11
16	1	0	0	1	Partial discharge with tracking	F12

III. DUVAL TRIANGLE METHOD

This method is more graphical method than ratio method. Duval triangle method uses concentration of the three key gases for the diagnosis of fault. These gases are CH4 (Methane), C2H4 (Ethylene), C2H2 (Acetylene).
The ratio of the gases is calculated using the expressions as below:

CH4% = (100 X) / (X+Y+Z)
C2H4% = (100 Y) / (X+Y+Z)
C2H2% = (100Z) / (X+Y+Z)

Where X = CH4 in p.p.m
Y = C2H4 in p.p.m
Z = C2H2 in p.p.m

These values are then plotted on the triangle. The point of interception falls into a zone in the triangle which depicts the fault in the transformer.

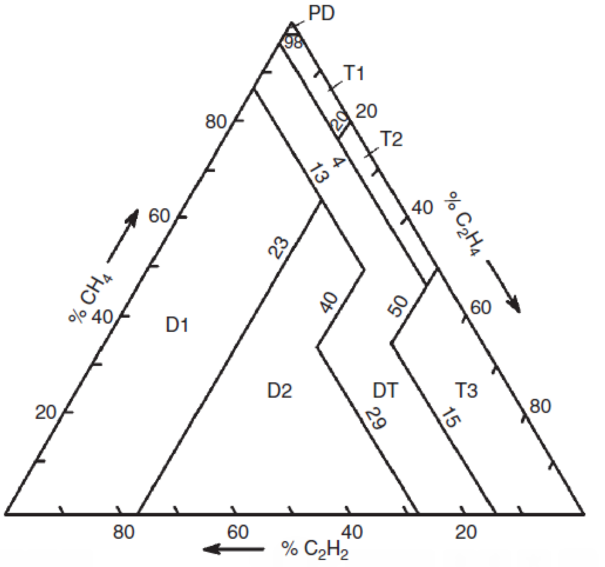

Fig I:
Where,
PD depicts Partial Discharge.
T1 depict thermal fault below 300°C.
T2 depict thermal fault between 300°C to 700°C
T3 depict thermal fault with overhauling.
D1 depicts low energy discharge (Spark)
D2 depicts high energy discharge (Electric Arc)
DT depicts a mix between thermal and electric faults.

IV. DOERNENBURG RATIO METHOD

This method utilizes the gas concentration from ratio of CH4/H2, C2H2/CH4, C2H4/C2H6, C2H2/C2H4.

Table VIII:Fault diagnosis using Doernenburg Ratio

M	N	O	P	
CH_4/H_2	C_2H_2/C_2H_4	C_2H_6/C_2H_2	C_2H_2/CH_4	Suggested Fault Diagnosis
>0.1	<0.75	>0.4	<0.3	Thermal Decomposition
<0.1 <0.001	>0.75	<0.4	>0.3	Corona (Low Intensity PD)
<0.1	<0.75	>0.4	<0.3	Arcing(High Intensity PD)

PROBLEM 1

DGA result of TATA STEEL, Jamshedpur (Tata Nagar).
Equipment: 15/18.75 MVA
Make BHEL
Rated Voltage: 420/220/33 KV
Rated current: 434/526.6/837.03 Ampere

Table VIII: DGA result of Transformer

FAULTY GASES							
Sl. No.	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	CO_2
1	178	506	176	583	11.7	151	1844
2	315	865	510	2062	1	233	4851
3	383	1040	534	2315	2	233	4851
4	380	363	308	1700	61.5	48	1683
5	279	192	255	746	0	136	2831
6	695	1340	629	2720	2.5	335	5655
7	253	174	233	718	0	98	2477
8	5239	40972	6101	7784	233.9	588	5222
9	173	161	79	417	9.5	21	1000

ROGER'S RATIO									
Fault Gases(ASTM STANDARD)									
	Ratio				Codes				Fault
S. No.	W	X	Y	Z	W	X	Y	Z	Kinds of Faults
1	2.84	0.347	3.312	0.020	3	0	2	0	Circulating current bet. core & tank
2	2.74	0.589	4.0431	0.00048	3	0	2	0	Circulating current bet. core & tank
3	2.715	0.513	4.335	0.00086	3	0	2	0	Circulating current bet. core & tank
4	0.955	0.848	5.5194	0.03617	2	0	2	0	No Result
5	0.688	1.328	2.925	0	2	1	1	0	No Result
6	1.928	0.4694	4.324	0.00091	3	0	2	0	Circulating current bet. core & tank
7	0.687	1.339	3.0815	0	2	1	2	0	No Result
8	7.82	0.1489	1.2758	0.030	4	0	1	0	No Result
9	0.93	0.4906	5.278	0.0227	2	0	2	0	No Result

Table IX: Diagnose of fault by IEC method

ROGER'S RATIO							
Fault Gases(IEC STANDARD)							
	RATIO			CODES			
S. No.	X	Y	Z	**X**	**Y**	**Z**	Kinds of Faults
1	0.02	2.84	3.312	0	2	2	Thermal fault with temp >700°C
2	0.0004	2.74	4.04	0	2	2	Thermal fault with temp >700°C
3	0.0008	2.71	4.33	0	2	2	Thermal fault with temp >700°C
4	0.0361	0.95	5.51	0	2	2	Thermal fault with temp >700°C
5	0	0.688	2.92	0	2	1	Thermal fault having temp b/w 300 & 700°C
6	0.0009	1.928	4.32	0	2	2	Thermal fault with temp >700°C
7	0	0.679	3.081	0	2	2	Thermal fault with temp >700°C
8	0.030	7.82	1.275	0	2	1	Thermal fault having temp b/w 300 &700°C
9	0.022	0.93	5.27	0	2	2	Thermal fault with temp >700°C

Table X: Diagnose of fault by ASTM method

Table X1: Diagnose of fault by CEGB method

ROGER'S RATIO									
Fault Gases(CEGB STANDARD)									
	Ratio				Codes				Fault
S. No	W	X	Y	Z	W	X	Y	Z	Kinds of Faults
1	2.84	0.347	3.312	0.020	1	0	2	0	Circulating current bet. core & tank
2	2.74	0.589	4.0431	0.00048	1	0	2	0	Circulating current bet. core & tank
3	2.715	0.513	4.335	0.00086	1	0	2	0	Circulating current bet. core & tank
4	0.955	0.848	5.5194	0.03617	0	0	2	0	No Result
5	0.688	1.328	2.925	0	0	1	1	0	No Result
6	1.928	0.4694	4.324	0.00091	1	0	2	0	Circulating current bet. core & tank
7	0.687	1.339	3.0815	0	0	1	2	0	No Result
8	7.82	0.1489	1.2758	0.030	2	0	1	0	No Result
9	0.93	0.4906	5.278	0.0227	0	0	2	0	No Result

Table XII: Diagnosis of fault using DUVAL Triangle method

DUVAL TRAINGLE METHORD				
	PERCENTAGE			FAULTS
Sl. No	%CH4	%C2H2	%C2H4	TRANSFORMER FAULT DIAGNOSIS
1	45.84	52.82	1.06	Thermal fault with temp >700° C
2	29.54	70.42	0.03	Thermal fault with temp >700° C
3	30.98	68.96	0.059	Thermal fault with temp >700° C
4	17.08	80.01	2.89	Thermal fault with temp >700° C
5	20.46	79.53	0	Thermal fault with temp >700° C
6	32.98	66.95	0.061	Thermal fault with temp >700° C
7	19.50	80.49	0	Thermal fault with temp >700° C
8	83.63	15.88	0.477	Thermal fault below 700° C
9	27.40	70.97	1.617	Thermal fault with temp >700° C

Table XIII: Fault Diagnose of fault by Doernenburg ratio method.

DOERNENBURG RATIO					
	RATIO				FAULT
Sl. No	M	N	O	P	TRANSFORMER FAULT DIAGNOSIS
1	2.84	0.020	15.04	0.023	Thermal Decomp
2	2.74	0.00048	510	0.0011	Thermal Decomp
3	2.715	0.00086	267	0.00192	Thermal Decomp
4	0.955	0.03617	5	0.169	Thermal Decomp
5	0.688	0	N.R.	0	Thermal Decomp
6	1.928	0.00091	251.6	0.00186	Thermal Decomp
7	0.687	0	N.R.	0	Thermal Decomp
8	7.82	0.030	26.08	0.005708	Thermal Decomp
9	0.93	0.0227	8.31	0.0590	Thermal Decompo

V. CONCLUSION

In this thesis the analysis of dissolved gas of transformer is used to diagnose the fault in the transformer using Rogers's ratio through IEC, CEGB, ASTM standards parallel with DUVAL triangle and Doernenburg method. These techniques are implemented for better decision on the power transformer state and classification of power transformer fault using dissolved gas analysis as input data. It is presented here that how one technique is superior over the other for diagnosing the fault of the transformer in the most convenient manner. This shows great promise in that a number of faults likely to cause future trouble in service have been detected, although in each case the transformer had satisfactorily passed the routine tests. The technology presently exists and is being used to detect and determine fault gases below the part per million levels. However there is still much room for improvement in the technique, especially in developing the methods of interpreting the results and correlating them with incipient faults.

REFRENCES

[1] Bhalla ,Deepika., Kumar Bansal, Raj. and Gupta, Hari Om(2008).” *Transformer Incipent fault diagnosis based on DGA using fuzzy logic*” Internal Journal 2008.

[2] IEEE Std C57.104-199, 1992, "IEEE Guide for the Interpretation of Gases Generated in Oil Immersed Transformers". *IEEE Press*, New York

[3] Rogers R. R., 1978, "IEEE and IEC code to interpret incipient faults in transformers using gas in oil analysis ", IEEE transaction electrical Insulation., ,Vo.13,No.5, 349-354

[4] 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

[5] Dornerburg, E. and Strittmatter, W, “*Monitoring oil cooling transformers by gas analysis”*, Brown Boveri Review, vol61, May 1974, pp. 238-247.

[6] Duval, M., 1989, "*Disssolved gas analysis, It can save your transformer*", IEEE Electrical Insulation Man., Vo.5, No.6, 22-27.

[7] Gradnik, K. M., “*Physical-Chemical Oil Tests, Monitoring and Diagnostic of Oil-filled Transformers*.” Proceedings of 14th International Conference on Dielectric Liquids, Austria, July 2002

[8] Haupert ,T. J., Jakob, F., and Hubacher, E. J., 1989, "*Application of a new technique for the interpretation of dissolved gas analysis data*" 1lth Annual Technical Conference of the International Electrical Testing Association, 43-51.

[9] Herbert G. Erdman (ed.), *Electrical insulating oils*, ASTM International, 1988 ISBN 0-8031-1179-7, p.108.

[10] Hooshmand R., Banejad M., 2006 "Application of Fuzzy Logic in Fault Diagnosis in Transformers using Dissolved Gas based on Different Standards", World Academy of Science, Engineering and Technology,No.17.