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DGA Interpretation of Oil Filled Transformer Condition Diagnosis

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DGA is one of the most recent techniques developed to diagnose the fault condition on oil filled insulation transformers. There are more than 6 known different methods of DGA fault interpretation technique and so there is the likelihood that they may vary in their interpretations. A series of combined interpretation methods that can determine the power transformer condition faults in one assessment is therefore needed. This paper presents a computer program- based system developed to combine four DGA assessment techniques; Rogers Ratio Method, IEC Basic Ratio Method, Duval Triangle method and Key Gas Method. An easy to use Graphic User Interface was designed to give a visual display of the four techniques. The result shows that this assessment method can increase the accuracy of DGA methods by up to 20% and the no prediction result had been reduced down to 0%.

Keywords: Dissolved gas analysis (DGA), Oil filled transformer, Fault analysis

1. INTRODUCTION

In mineral oil filled transformers, the degradation of the oil is a major concern [1]. Insulation materials degrade at higher temperatures in the presence of oxygen and moisture. The degradation from thermal stress affects electrical, chemical, and physical properties of the oil [2]. There has been a growing interest in the technique to diagnose, determine and decide the condition assessment of transformer insulation. This is primarily due to the increasingly aged population of transformers in utilities around the world [3].

Each of the known techniques has its own method of assessing the condition of transformers. Dissolve Gas Analysis (DGA) is one of the most recent techniques developed to diagnose the fault condition on oil filled insulation transformers.

There are more than 6 known different methods of the DGA fault interpretation technique so there is the likelihood that they may vary in their interpretations. This could lead to inconsistent conclusions on the condition of the transformer and thus it is necessary to arrive at a reliable decision on each transformer so

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Table 1. Common types of fault and key gases in DGA [5].

Operating Condition	Interpretations
Nitrogen plus 5% or less oxygen	Normal operation
Nitrogen, carbon monoxide, and carbon dioxide	Transformer winding insulation overheating; key gas is carbon monoxide
Nitrogen, ethylene, and methane - some hydrogen and ethane	Transformer oil is overheated; minor fault causing oil breakdown. Key gas is ethylene
Nitrogen, hydrogen, small quantities of ethane and ethylene	Corona discharge in oil; key gas is hydrogen
Same as #4; with carbon dioxide and carbon monoxide	Corona involving paper insulation; key gas is hydrogen
Nitrogen, high hydrogen and acetylene; minor quantities of methane and ethylene	High-energy arcing; key gas is acetylene
Same as #6 with carbon dioxide and carbon monoxide	High-energy arcing involves paper insulation of winding; key gas is acetylene

Table 2. Roger's ratio gas [5].

Ratio	Code
CH_4/H_2	1
C_2H_6/CH_4	2
C_2H_4/C_2H_6	3
C_2H_2/C_2H_4	4

as to take the correct and appropriate maintenance action. A series of combined interpretation methods that can determine the power transformer condition faults in one assessment is therefore needed.

In this paper, a computer program-based system for four DGA assessment techniques is presented and discussed because some of the methods are similar with near equivalent gas ratios [4]. The analysis of these diagnostic techniques on fault interpretation to determine a common comprehensive fault analysis is also presented. The four techniques are the Rogers Ratio Method, IEC Basic Ratio Method, Duval Triangle method and Key Gas Method. When they are used separately, they are likely to be less accurate than when combined.

The four diagnostic techniques above are presented separately and this is followed by the computer program and the analysis of the computer result to compare the fault interpretations.

2. TYPES OF DGA FAULT

Various diagnostic schemes have been developed for DGA interpretation. These methods attempt to map the relations between gases and fault conditions, some of which are obvious and some of which may not be apparent. The evaluation has been simplified by looking at key gases and the associated condition as discussed in Table 1.

3. DGA FAULT ANALYSIS TECHNIQUES

3.1 Roger's ratio method

This method uses the 4-digit ratio code generated from the 5 fault gases (H_2, CH_4, C_2H_6, C_2H_4, and C_2H_2) to determine 15 diagnosis rules for transformer conditions as shown in Tables 2 and 3.

Table 3. Roger's ratio code [5].

1	2	3	4	Ranges
0	5	0	0	<0.1
1	0	0	0	0.1 to < 1.0
1	1	1	1	1.0 to 3.0
2	2	2	1	>3.0
Diagnostic Code				**Fault**
0	0	0	0	No fault: normal deterioration
0	5	0	0	Partial discharge of low energy density or hydrolysis
1	5	0	0	Partial discharge of high density, possibly with tracking
0	5	1	0	Coincidental partial discharges and conductor overheating
0	5	0	1	Partial discharges of increasing energy density
1>2	0	0	0	Low energy discharge: flashover without power follow through
1>2	0	1	0	Low energy discharge: continuous sparking to floating potential
1>2	0	2	0	High energy discharge: arc with power follow through
0	0	1	0	Insulated conductor overheating
0	0	1	1	Complex thermal hotspot and conductor overheating
1	0	0	1	Coincidental thermal hotspot and low energy discharge
0	1	0	0	Thermal fault of low temperature range <150℃
0	0>2	0	1	Thermal fault of temperature range 100-200℃
0	1	1	0	Thermal fault of temperature range 150-300℃ overheating of copper due to eddy currents
0	1>2	2	0	Thermal fault of temperature range 300-700℃: bad contacts/joints (pyrolytic carbon formation): core and tank circulating currents

Table 4. IEC basic gas [5].

Ratio	Code
C_2H_4/C_2H_6	1
CH_4/H_2	2
C_2H_4/C_2H_6	3

Table 5. IEC basic code [5].

Case	Characteristic fault	1	2	3
PD	Partial discharges (see note 3 & 4)	NS[1]	<0.1	<0.2
D1	Discharge of low energy	>1	0.1-0.5	>1
D2	Discharge of high energy	0.6-2.5	0.1-1	>2
T1	Thermal fault t<300℃	NS[1]	>1 but NS[1]	<1
T2	Thermal fault 300℃<t<700℃	<0.1	>1	1-4
T3	Thermal fault t>700℃	<0.22	>1	<4

3.2 IEC basic ratio method

This method originated from the Roger's Ratio method, except that the ratio C_2H_6/CH_4 was dropped since it only indicated a limited temperature range of decomposition [6] as shown in Table 4 and 5. The faults are divided into nine different types.

3.3 Duval triangle method

This method has proven to be accurate and dependable over many years and is now gaining in popularity. The Duval triangle determines whether a problem exists as in Fig. 1 below. At least one of pre-requirement of L1 limit must fulfill, and increasing at a generation rate (G1 and G2) as shown in Table 6, before a prob-

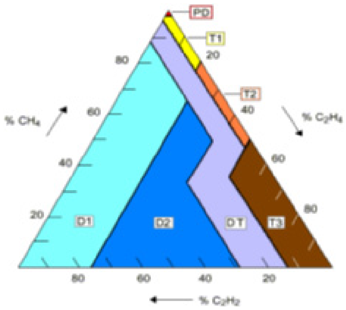

Fig. 1. Duval triangle legend [7].

Table 6. Duval triangle legend [7].

Legend
PD = Partial Discharge
T1 = Thermal Fault less than 300℃
T2 = Thermal fault between 300℃ and 700℃
T3 = Thermal fault greater than700℃
D1 = Low energy discharge (sparking)
D2 = High energy discharge (arcing)
DT = Mix of thermal and electrical faults

Table 7. Limit and generation rate per month [5].

Gas	L1 Limits (ppm)	G1 Limits (ppm/month)	G2 Limits (ppm/Month)
H_2	100	10	50
CH_4	75	8	38
C_2H_2	3	3	3
C_2H_4	75	8	38
C_2H_6	75	8	38
CO	700	70	350
CO_2	7,000	700	3,500
Where L1, G1 & G2 are gas limits indicating significant amounts of gas present in the transformer before the Duval Triangle method is validated			

lem is confirmed [7].

3.4 Key gas analysis

The Key-Gas analysis method could present damage levels of the power transformer and its cause by analyzing the levels of combustible gases. The gas levels for this method are given in Table .8. The method defines the level of damage by considering all of the total combustible gases, which can be classified in different ranges.

4. COMPUTER PROGRAM AND IMPLEMENTATION

The development tool used in the DGA fault interpretation computer program is given in Table 9 below.

4.1 Method of fault analysis classification

The fault interpretation results from each method are used in the main interface to determine the fault analysis classification by using a single fault analysis to find the common result. As seen in Table 10, each fault is represented by code (from F1-F6) as a conclusion from each method.

Table 8. Combustible gas in key gas analysis [6].

Gas	Normal	Abnormal	Interpretation
H_2	<150 ppm	>1,000 ppm	Arcing, Corona
CH_4	<25	>80	Sparking
C_2H_6	<10	>35	Local overheating
C_2H_4	<20	>100	Serve Overheating
CO	<500	>1,000	Serve Overheating
CO_2	<1,000	>15,000	Serve Overheating
N_2	1-10%	N.A	
O_2	0.2-3.5%	N.A>0.5%	Combustibles

Table 9. Development tools.

Function	Tool/Software
GUI application	Windows form API
Software platform	Microsoft.NET Framework 3.0
Operating System	Microsoft Windows XP/7
Programming Language	Microsoft Visual C#

Table 10. Codes of fault analysis classification [6].

Fault Code	Description
F1	Thermal fault at low temperature
F2	Overheating and Sparking
F3	Arcing
F4	Partial Discharge and Corona
F5	Normal
F6	No prediction

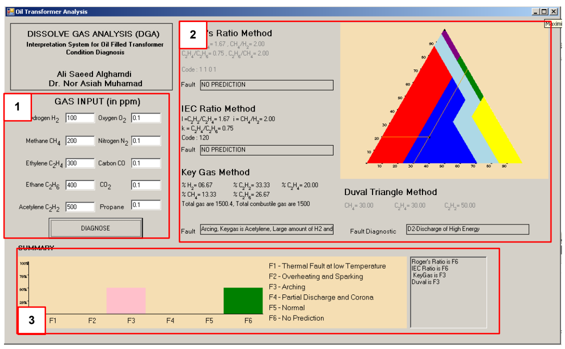

Fig. 2. The program GUI.

4.2 Implementation

The software is implemented in a single unit GUI as shown in Fig. 2 and performs the analysis after values have been entered and the user clicks the “DIAGNOSE” button.

5. RESULTS

After the software has been developed and tested with data which consists of 101 different oil gasses conditions, the results were compared with that of manual calculation. The data used are oil samples from oil-filled transformers under several conditions. The summary of the results are presented in Figs. 3 (accuracy analysis of program) and Fig. 4 (percentage prediction). The fault summary gives the percentage of accurate fault predictions obtained compared to the manual computation.

From the results, the software calculations indicate that the software validates the manual input calculations because it con-

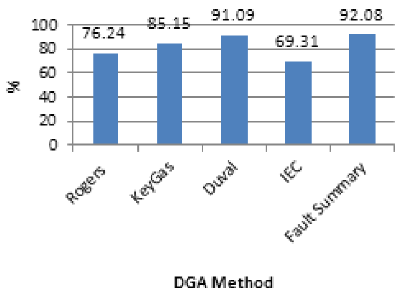

Fig. 3. Comparing accuracies of the 4 DGA techniques.

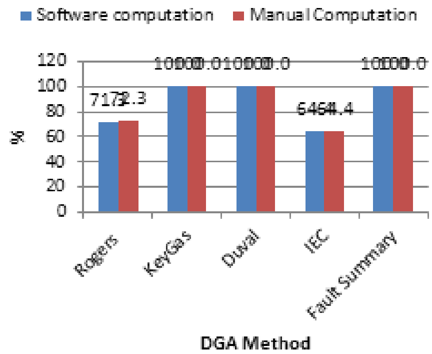

Fig. 4. Analysis of program and manual computations.

forms to most of the manual results obtained. Lack of method accuracy, and computation and data entry errors may be attributed to the differences noted in Fig. 4. The gas codes and ratios used to develop this computer software cannot be ruled out as a possible contributor to the observed difference in Fig. 4.

6. CONCLUSION AND DISCUSSION

The computer based oil insulation assessment software has been successfully developed. Analysis compared the accuracy and predicted results between each method utilizing both manual calculation and software calculation. The test concludes that the accuracy of fault-analysis classifications increased the accuracy of DGA methods by 20%. The no prediction result had been reduced down to 0% rather than using one single DGA method. The software also demonstrates that the DGA analysis faster since only the gas input data is required to arrive at a valid prediction.

6.1 Advantages and limitations

The advantages of using computer- based software for DGA analysis on oil filled insulation transformer are:

· It utilizes four methods to predict faults in transformer insulation oil in the same time
· It reduces the time to calculate and analyze oil-filled transformer faults by using DGA system.
· It gives better and more accurate results to confirm the transformer incipient fault.
· It reduces the human-error on interpreting the fault on DGA system.

6.2 Recommendation for further work

The use of four (4) methods of the DGA technique has fulfilled the requirement process to determine the fault type, but adding more DGA diagnostics is necessary. Accuracy is the main concern of fault analysis determination t. Although the accuracy in this developed system was sufficient, implementation of accurate algorithms are needed. The process of the fault decision in this computer- based software is based on a general percentage mechanism, where each of the methods has the same percentage of accurate predictions.

This research application in the real world will facilitate an easier fault prediction process in DGA analysis techniques. The implementation of online systems and continuous monitoring systems based on this computer- based software could be performed to improve its use in the real world. The use of online and monitoring systems have already shown that detailed on-site analysis is necessary for the management process of transformer [8,9].

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