IDENTIFICATION OF TRANSFORMER INTERNAL FAULTS BY CONVENTIONAL & FUZZY THREE GAS RATIO METHOD

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ABSTRACT

Transformer is a main device of power system on which cost of electricity supply depends. Hence, to manage the life of transformers, to reduce failures and to extend the life of transformer, some preventive measures are being adopted. Power system reliability depends on the consistency of electrical equipment. DGA is most useful technique for fault detection in oil insulated transformer. Dissolved Gas Analysis (DGA) is the heart of on-line monitoring as it is a well-established method of transformer diagnosis. DGA techniques are simple, inexpensive, and widely used to interpret gases dissolved due to the deterioration of the insulating oil of power transformers and hence to diagnosis, possibility of various type of faults in power transformer. Different methods for detection are key gas method, ratio method. When more than one fault exists in a transformer, these methods sometimes fail to diagnose. IEC Three Ratio Method is widely used, but in many cases this method cannot accurately diagnose (such as no matching, multiple faults).This paper proposes the fuzzy three ratio method which overcomes the drawbacks of the conventional three-ratio method this paper first propose the fuzzy membership functions for codes "zero", "one", "two", then it transfer the conventional logic "AND" and "OR" used in IEC three-ratio method into fuzzy logic. Simulation proves the proposed method can overcome the drawbacks of the conventional three-ratio method that cannot diagnose multi-fault and no matching codes for diagnosis, thus, it greatly enhanced diagnosing accuracy. Also this paper present three fault type, partial discharges (PD), arc discharges, and thermal faults, Winding circulate current.

Keywords: *acetylene (C2H2) , carbon monoxide (CO), carbon dioxide (CO2), Dissolved gas analysis (DGA),ethylene (C2H4), ethane (C2H6),Key gases, hydrogen (H2), methane (CH4)*

INTRODUCTION:

Power transformer is major component of power system which has no substitute for its major role. Generally 80% faults occurs due to incipient faults. a transformer generally suffers from following types of transformer fault

1. Over current due to overloads and external short circuits
2. Thermal faults
3. Winding faults
4. Incipient faults

All the above mentioned transformer faults causes mechanical & thermal stresses inside the transformer winding and its connecting terminals. Thermal stresses lead to overheating which ultimately affect the insulation system of transformer. Deterioration of insulation leads to winding faults. Sometime failure of transformer cooling system, leads to overheating of transformer. So the transformer protection schemes are very much required. Incipient faults are internal faults which constitute no immediate hazard.

3.1 Dissolved gas analysis in transformer oil:
Dissolved gas analysis is a test used as a diagnostic and maintenance tool for oil-filled apparatus. Under normal conditions, the oil present in a transformer will not decompose at a faster rate. However, thermal and electrical faults can increase the rate of decomposition of the dielectric fluid, as well as the solid insulation. Gases produced by this process are of low molecular weight and include hydrogen, methane, ethane, acetylene, carbon monoxide, and carbon dioxide, and these gases get dissolved in the oil. Abnormal conditions in transformer can be detected early by analyzing the gases that get evolved within it.

2 Methods of interpreting fault using DGA:

1.Key Gas method
2.Ratio method
3.fuzzy three gas ratio method

2.1.Key Gas Method: In this method the concentration and gassing rates of the key hydrocarbon gases is monitored. The concentrations are expressed in ppm (parts per million). The normal operating concentration of these key gases according to IEC 599 is given in the following table.

Table No.1Dissolved gas composition

H_2	60-150
C_2H_2	3-50
C_2H_6	50-90
C_2H_4	60-280
CH_4	40-110

2. 2 IEC Ratio method: This method is the most widely used method for the fault interpretation.IEC ratio method is used as an industry standard. The widely used IEC ratio codes (Three ratios) are given below.

Table No. 2 IEC Codes

Gas Ratio	**Codes of different gas ratios**		
	C_2H_2/C_2H_4	**CH_4/H2**	**C_2H_4/C_2H_6**
<0.1	0	1	0
0.1-1	1	0	0
1-3	1	2	1
>3	2	2	2

Table No.3 Fault Classifications According to the IEC Gas Ratio Codes

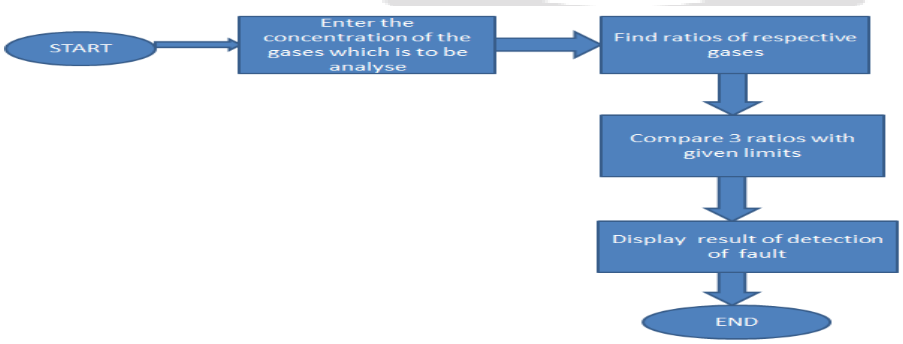
Sr. No.	Fault type	**C_2H_2/ C_2H_4**	**CH_4/H_2**	**C_2H_4/C_2H_6**
1	No fault	0	0	0
2	Partial discharges of low energy density	0	1	0
3	Partial	1	1	0

	discharges of high energy density			
4	Discharges of low energy density	1or2	0	1or2
5	Discharges of high energy density	1	0	2
6	Thermal fault of low temperature <150˚C	0	0	1
7	Thermal fault of low temperature 150˚-300 ˚ C	0	2	0
8	Thermal fault of medium temperature 300 ˚-700˚C	0	2	1
9	Thermal fault of high temperature >700 ˚C	0	2	2

2.2.1 The diagnosing steps based on Conventional Three Ratio Method:

Step1: From the DGA report of the input oil sample, provide the values of concentration of different gases like Hydrogen (H_2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4), and Acetylene (C_2H_2) in ppm.
Step2: Calculate three ratios R1 = Acetylene (C_2H_2) / Ethylene (C_2H_4), R2 = Methane (CH_4) / Hydrogen (H_2), and R3 = Ethylene (C_2H_4) / Ethane (C_2H_6).
Step 3: According to Table 5.2, each ratio is quantized to a classification code 0, 1, or 2.
Step 4: For the conventional logic IEC diagnosis "AND" and "OR" based conditional statements are constructed for decision making with reference to Table 5.3, and the fault type out of the 9 listed faults is determined.
Step 5: For any non-decision diagnosis, tenth decision of 'Not diagnosable' is used.
Step 6: Results are displayed in graph window for gas content in ppm, respective IEC code and IEC based Conventional Three Ratio Method decision.

Flowchart:



2.3 Fuzzy Three Gas Ratio Method: Through the combination of fuzzy logic and IEC Three Ratio method, this project puts forward Fuzzy Three Ratio Method. It fuzzi fies the coding boundary, thus overcomes the drawbacks of coding boundary sharp changing.

In the following, R1 is taken as an example to explain how to transfer IEC codes 0, 1, 2 into fuzzy set ZERO, ONE, and TWO.
The membership function of fuzzy set ZERO is:

$$\mu_{ZERO}(R1)=\begin{cases}1 & R1 < 0.08\\ e-50(R1-0.08) & R1 > 0.08\end{cases}$$

The membership function of fuzzy set ONE is:

$$\mu_{ONE}(R1)=\begin{cases}0 & R1 \le 0.08\\ 0.5+0.5\sin\big(25\,\Pi\,(R1-0.1)\big) & R1 \in (0.08, 0.12)\\ 1 & R1 \in (0.12, 2.9)\\ 0.5-0.5\sin\big(5\,\Pi\,(R1-3)\big) & R1 \in (2.9, 3.1)\\ 0 & R1 > 3.1\end{cases}$$

The membership function of fuzzy set TWO is:

$$\mu_{TWO}(R1)=\begin{cases}0 & R1 \le 2.85\\ e-12(R1-2.85) & R1 > 2.85\end{cases}$$

2.3.1 The diagnosing steps based on Fuzzy Three Ratio Method:

Step1: From the DGA report of the input oil sample, provide the values of concentration of different gases like Hydrogen (H_2), Methane (CH_4), Ethane (C_2H_6), Ethylene (C_2H_4)and Acetylene (C_2H_2) in ppm.
Step2: Calculate three ratios R1 = Acetylene (C_2H_2) / Ethylene (C_2H_4), R2 = Methane (CH_4) / Hydrogen (H_2), and R3 = Ethylene (C_2H_4) / Ethane (C_2H_6).
Step 3: Calculate the three fuzzy membership functions of each ratio based on equations listed in above section.
Step 4: As for the conventional logic "AND" and "OR" used in the conventional IEC diagnosis, replace "AND" by "min", "OR" by "max", the fuzzy diagnosing vector $F(i)$ where i = 1,2,…,9 represent i^{th} fault in Table 5.3 is determined by the following equations:

$F(1) = \min[\mu_{ZERO}(R1), \mu_{ZERO}(R2), \mu_{ZERO}(R3)]$
$F(2) = \min[\mu_{ZERO}(R1), \mu_{ONE}(R2), \mu_{ZERO}(R3)]$
$F(3) = \min[\mu_{ONE}(R1), \mu_{ONE}(R2), \mu_{ZERO}(R3)]$
$F(4) = \max(\min[\mu_{ONE}(R1), \mu_{ZERO}(R2), \mu_{ONE}(R3)]$
$\min[\mu_{TWO}(R1), \mu_{ZERO}(R2), \mu_{ONE}(R3)]$
$\min[\mu_{TWO}(R1), \mu_{ZERO}(R2), \mu_{TWO}(R3)])$
$F(5) = \min[\mu_{ONE}(R1), \mu_{ZERO}(R2), \mu_{TWO}(R3)]$
$F(6) = \min[\mu_{ZERO}(R1), \mu_{ZERO}(R2), \mu_{ONE}(R3)]$
$F(7) = \min[\mu_{ZERO}(R1), \mu_{TWO}(R2), \mu_{ZERO}(R3)]$
$F(8) = \min[\mu_{ZERO}(R1), \mu_{TWO}(R2), \mu_{ONE}(R3)]$
$F(9) = \min[\mu_{ZERO}(R1), \mu_{TWO}(R2), \mu_{TWO}(R3)]$

Step 5: Fault type out of the 9 listed faults is determined.
Step 6: Results are displayed in graph window for gas content in ppm, and Fuzzy Three Ratio Method decision [2].

3 RESULTS AND ANALYSIS:

3.1 Coventional three gas ratio method:

Amount of gas present in oil sample:

- Enter the value of concentration of Hydrogen gas in ppm H2 for the DGA sample :100
- Enter the value of concentration of Methane gas in ppm CH4 for the DGA sample :60
- Enter the value of concentration of Ethane gas in ppm C2H6 for the DGA sample :70
- Enter the value of concentration of Ethylene gas in ppm C2H4 for the DGA sample :120
- Enter the value of concentration of Acetylene gas in ppm C2H2 for the DGA sample :40

Roger Ratio

X = Acetylene C_2H_2 / Ethylene C_2H_4
X = 0.3333

Y = Methane CH_4 / Hydrogen H_2
Y = 0.6000

Z = Ethylene C_2H_4 / Ethane C_2H_6
Z = 1.7143

Output:

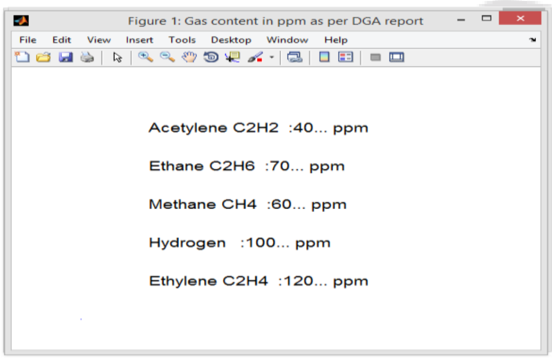


Fig 3.1.1:gas content in ppm as per DGA report

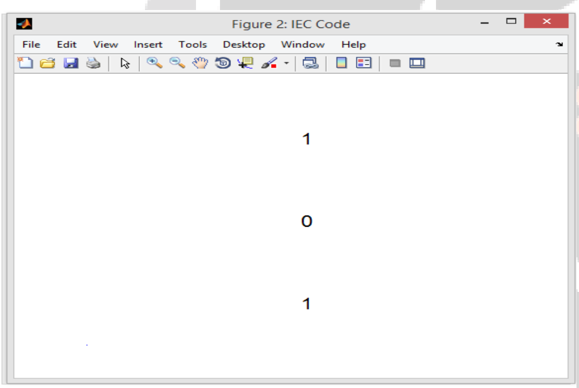


Fig3.1.2 IEC codes

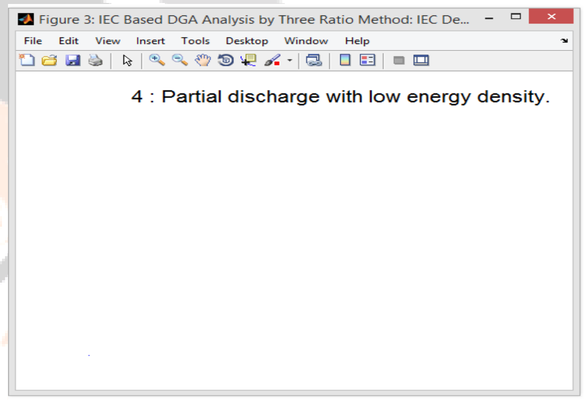


Fig3.1.3:IEC based DGA analysis by three ratio method

3.2 DGA Fuzzy three gas ratio method:
Amount of gas present in oil sample:

- Enter the value of concentration of Hydrogen gas in ppm H_2 for the DGA sample :50.5
- Enter the value of concentration of Methane gas in ppm CH_4 for the DGA sample :80.7
- Enter the value of concentration of Ethane gas in ppm C_2H_6 for the DGA sample :75
- Enter the value of concentration of Ethylene gas in ppm C_2H_4 for the DGA sample :150.8
- Enter the value of concentration of Acetylene gas in ppm C_2H_2 for the DGA sample :44.25

Three Ratios
X = Acetylene C_2H_2 / Ethylene C_2H_4

X =0.2934
Y = Methane CH4 / Hydrogen H2
Y = 1.5980
Z = Ethylene C2H4 / Ethane C2H6
Z =2.0107
Fuzzy Logic result of fault
Fuzzy output = 8

Output:

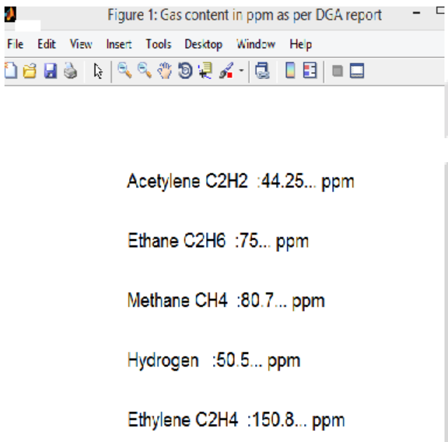


Fig 3.2.1:gas content in ppm as per DGA report

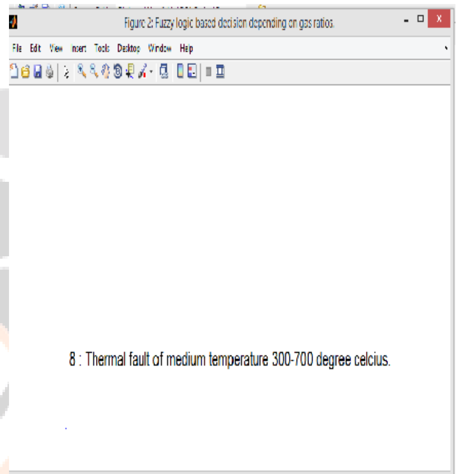


fig3.2.2:fuzzy logic o/p decision pending on gas content

4. CONCLUSION:

The Conventional IEC based Three Ratio Method developed and implemented for different sample cases in this project using MATLAB application software, and has been successfully used for the diagnosis of several faults in transformers. It has been proved that using the fuzzy diagnosis method, more detailed information about the faults inside a transformer can be obtained in addition to providing enhanced information for the maintenance engineer while remaining faithful to the original method.

The enhancements in the conventional IEC code method are due to the more realistic representation of the relationship between the fault type and the dissolved gas levels with fuzzy membership functions as shown in the output results, where in addition to determining the fault in transformer, the recommended and the advisable actions are demonstrated in the program for this method. Also, the multiple faults can be diagnosed using this method, while, it may not be possible for any conventional method.This project puts forward a transformer fault diagnose method based on Fuzzy Three Ratio Method. This method can overcome the drawbacks of the Conventional IEC Three Ratio Method such as: no decision, can't diagnose multiple faults. Simultaneously this method does not need to spend a lot of time for "learning", its programming is easy. Simulation results from practical generation and distribution transformer data show the program work well and the accuracy of the proposed method is much higher than the Conventional IEC Method.

5. REFERENCES:

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