By using Practical Reading to Perform Incipient Fault Diagnosis of Transformer Oil using Dissolve Gas Analysis Based on Fuzzy Three Gas Ratio Method

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Abstract—The most common internal fault diagnosis method of power transformer is Dissolved Gas Analysis (DGA) [1-4]. It is a sensitive and reliable technique for the detection of incipient fault condition within oil-immersed transformers. There are a number of methods developed for analyzing these gases and interpreting their significance. These methods are, Roger gas ratio, IEC gas ratio and Duval Triangle[3]. Here we used fuzzy three ratio method to resolve the fault diagnosis problems for oil-filled power transformer. In fuzzy three-ratio method, we considered that the drawbacks of the conventional three-ratio method lie in: when the ratio crosses the coding boundary, code changes harply, but in reality the boundary should be fuzzied. Based on this assumption, this paper first propose the fuzzy membership functions for codes “0”, “1”, “2”, then it transfer the conventional logic “AND” and “OR” used in IEC three-ratio method into fuzzy logic and put forward the diagnosing steps of this method. Simulation proves the proposed method can overcome the drawbacks of the conventional three-ratio method can’t diagnose multi-fault and no matching codes for diagnosis, thus, it greatly enhanced diagnosing accuracy. In the aspects of experimental work done I have taken data from oil testing lab vidyut bhavan Nagpur.

Key words: Power Transformer, Fuzzy Logic, Dissolved Gas-In-Oil Analysis (DGA), Three-Ratio Method

I. INTRODUCTION

Transformer is most essential equipment of electrical engineering which transform electrical power from one circuit to other. It’s fault may cause the interruption of power supply. So it is important to diagnose fault in regular basis. When there is an overheating or discharge fault occur inside a power transformer, it will produce several different gases in the transformer oil, so dissolved gas-in-oil analysis (DGA) is the most commonly used method to diagnose power transformer fault. There are so many diagnosis methods like roger’s ratio, duval triangle method, IEC three ratio method, fuzzy five ratio method, fuzzy three ratio method. In this paper I had used practical reading which I have been taken from oil testing unit of vidyut bhavan, nagpur, Maharashtra. In this Laboratory Dissolve Gas Analyzer releases different type of gases which is placed in burn transformer oil. These gases are H₂, CH₄, C₂H₆, C₂H₄, C₂H₂, CO, CO₂. Ratio of these gases detecting the category of fault. This experimental objective achieved by two methods IEC three ratio method & Fuzzy three ratio method and compare both of them from actual type of fault[1-2].

II. DISSOLVE GAS-IN-OIL ANALYSIS METHODS

Conventional Three Gas Ratio and Fuzzy Logic based Fuzzy Three Gas Ratio methods are studied and implemented using MATLAB application software. These methods are described below:-

A. Conventional Three Gas Ratio Method:

Fault gases in transformers are produced by degradation of transformer oil or other insulating materials, e.g.: cellulose and paper. When discharge or overheating occurs, the oil around the fault will decompose into specific gases, which dissolve in the oil. Different fault types are therefore reflected by the different compositions of the gases-in-oil.

In IEC three-ratio method [1-2] the relevant coding definition and fault type classification shown in table1 and table2.

The diagnosing steps based on Conventional Three Ratio Method.

1) Step1: From the DGA report of the input oil sample, provide the values of concentration of different gases like Hydrogen (H₂), Methane (CH₄), Ethane (C₂H₆), Ethylene (C₂H₄), and Acetylene (C₂H₂) in ppm.

2) Step2: Calculate three ratios R1 = Acetylene (C₂H₂) / Ethylene (C₂H₄), R2 = Methane (CH₄) / Hydrogen (H₂), and R3 = Ethylene (C₂H₄) / Ethane (C₂H₆).

3) Step 3: According to Table 1, each ratio is quantized to a classification code 0, 1, or 2.

4) Step 4: For the conventional logic IEC diagnosis “AND” and “OR” based conditional statements are constructed for decision making with reference to Table 2, and the fault type out of the 9 listed faults is determined.

5) Step 5: For any non-decision diagnosis, tenth decision of ‘Not diagnosable’ is used.

6) Step 6: Results are displayed in graph window for gas content in ppm, respective IEC code and IEC based Conventional Three Ratio Method decision.

B. Fuzzy Three Gas Ratio Method

Through the combination of fuzzy logic and IEC Three Ratio method, this project puts forward Fuzzy Three Ratio Method.[1-3] It fuzzifies the coding boundary, thus
overcomes the drawbacks of coding boundary sharp changing.

C. The fuzzification of the three-ratios
According to Table 1, three gas ratios, R1 = Acetylene (C2H2) / Ethylene (C2H4), R2 = Methane (CH4) / Hydrogen (H2), and R3 = Ethylene (C2H4) / Ethane (C2H6); can be coded as 0, 1, and 2 for different ranges of ratios.

According to Table 2, specific codes of three gas ratios correspond to specific fault. For instance when, transformer is diagnosed as no.8 fault, R1 = 0, R2 = 2, and R3 = 1. In the IEC code diagnosis, actually the conventional logic AND and OR are used. For example: R1 = 0 AND R2 = 2 AND R3 = 1, through conventional logic operation, will be either one (true) or zero (false). This method holds that the drawback of the conventional IEC method lie in that when gas ratio change across coding boundary, the code change sharply between 0, 1, and 2. In fact, the gas ratio boundary should not be clear (i.e. fuzzy).

In this method, IEC codes 0, 1, 2 are replaced by fuzzy sets ZERO, ONE, TWO, each gas ratio can be represented by a fuzzy vector \([ \mu_{\text{ZERO}} (R), \mu_{\text{ONE}} (R), \mu_{\text{TWO}} (R) ]\), where \(\mu_{\text{ZERO}} (R), \mu_{\text{ONE}} (R), \mu_{\text{TWO}} (R)\) are the membership function of the fuzzy set ZERO, ONE, TWO.

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.

1) The membership function of fuzzy set ZERO is:
\[
\mu_{\text{ZERO}} (R1) = 1 \text{ R1} \leq 0.08 = e^{-50(R1-0.08)} \text{ R1} > 0.08 
\]

2) The membership function of fuzzy set ONE is:
\[
\mu_{\text{ONE}} (R1) = 0 \text{ R1} \leq 0.08 = 0.5 + 0.5 \sin (25 \Pi (R1 - 0.1)) \]
\[
= 1 \text{ R1} (0.08, 0.12) \]
\[
= 0.5 - 0.5 \sin (5 \Pi (R1 - 3)) \]
\[
R1 \epsilon (2.9, 3.1) = 0 \text{ R1} > 3.1
\]

3) The membership function of fuzzy set TWO is:
\[
\mu_{\text{TWO}} (R1) = 0 \text{ R1} \leq 2.85 = e^{-12} (R1 - 2.85) \text{ R1} > 2.85
\]

Figure 1, 2, and 3 are the representation of fuzzification process of code 0, 1 and 2 for R1.

Similarly, the three fuzzy membership functions for R2 can be obtained as follows:
4) The membership function of fuzzy set ZERO is:
\[
\mu_{\text{ZERO}} (R2) = 0 \text{ R2} \leq 0.08 = 0.5 + 0.5 \sin (25 \Pi (R2 - 0.1)) \]
\[
R2 \epsilon (0.08, 0.12) = 1 \text{ R2} (0.12, 0.9) \]
\[
= 0.5 - 0.5 \sin (5 \Pi (R2 - 1)) \]
\[
R2 \epsilon (0.9, 1.1) = 0 \text{ R2} > 1.1
\]

5) The membership function of fuzzy set ONE is:
\[
\mu_{\text{ONE}} (R2) = 1 \text{ R2} \leq 0.08 = e^{-50} (R2 - 0.08) \text{ R2} > 0.08
\]

6) The membership function of fuzzy set TWO is:
\[
\mu_{\text{TWO}} (R2) = 0 \text{ R2} \leq 0.85 = e^{-12} (R2 - 0.85) \text{ R2} > 0.85
\]

Similarly, the three fuzzy membership functions for R3 can be obtained as follows:
7) The membership function of fuzzy set ZERO is:
\[
\mu_{\text{ZERO}} (R3) = 0 \text{ R3} \leq 0.9 = e^{-50} (R3 - 0.08) \text{ R3} > 0.85
\]

8) The membership function of fuzzy set ONE is:
\[
\mu_{\text{ONE}} (R3) = 0 \text{ R3} \leq 2.85 = 0.5 + 0.5 \sin (25 \Pi (R3 - 1)) \]
\[
R3 \epsilon (0.9, 1.1) = 1 \text{ R3} (1.1, 2.9) \]
\[
= 0.5 - 0.5 \sin (5 \Pi (R3 - 3)) \]
\[
R3 \epsilon (2.9, 3.1) = 0 \text{ R3} > 3.1
\]

9) The membership function of fuzzy set TWO is:
\[
\mu_{\text{TWO}} (R3) = 0 \text{ R3} \leq 2.85 = e^{-12} (R3 - 2.85) \text{ R3} > 2.85
\]

The diagnosing steps based on Fuzzy Three Ratio Method
1) Step1: From the DGA report of the input oil sample, provide the values of concentration of different gases like Hydrogen (H2), Methane (CH4), Ethane (C2H6), Ethylene (C2H4) and Acetylene (C2H2) in ppm.
2) Step 2: Put gases concentration in fuzzy logic model.
3) Step 3: Calculate the three fuzzy membership functions of each ratio based on equations listed in above section.
4) 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 2 is determined by the following equations. [1-2][3][5]
\[
F(1)=\min[\mu_{\text{ZERO}}(R1), \mu_{\text{ZERO}}(R2), \mu_{\text{ZERO}}(R3)]
\]
\[
F(2)=\min[\mu_{\text{ONE}}(R1), \mu_{\text{ONE}}(R2), \mu_{\text{ONE}}(R3)]
\]
\[
F(3)=\min[\mu_{\text{TWO}}(R1), \mu_{\text{TWO}}(R2), \mu_{\text{TWO}}(R3)]
\]
\[
F(4)=\max[\min[\mu_{\text{ZERO}}(R1), \mu_{\text{ZERO}}(R2), \mu_{\text{ZERO}}(R3)], \min[\mu_{\text{TWO}}(R1), \mu_{\text{TWO}}(R2), \mu_{\text{TWO}}(R3)], \min[\mu_{\text{ONE}}(R1), \mu_{\text{ONE}}(R2), \mu_{\text{ONE}}(R3)]
\]
\[
F(5)=\min[\mu_{\text{ONE}}(R1), \mu_{\text{ZERO}}(R2), \mu_{\text{TWO}}(R3)]
\]
\[
F(6)=\min[\mu_{\text{ONE}}(R1), \mu_{\text{ZERO}}(R2), \mu_{\text{ONE}}(R3)]
\]
\[
F(7)=\min[\mu_{\text{ZERO}}(R1), \mu_{\text{TWO}}(R2), \mu_{\text{ZERO}}(R3)]
\]
\[
F(8)=\min[\mu_{\text{ZERO}}(R1), \mu_{\text{TWO}}(R2), \mu_{\text{ONE}}(R3)]
\]
\[
F(9)=\min[\mu_{\text{ZERO}}(R1), \mu_{\text{TWO}}(R2), \mu_{\text{ONE}}(R3)]
\]

5) Step 5: Compile fuzzy model & membership function to determine type of fault
6) Step 6: Fault type out of the 9 listed faults is determined.
7) Step 7: Results are displayed in graph window for gas content in ppm, and Fuzzy Three Ratio Method decision [1-3].
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Table 2: Classification of Fault Type through IEC Three-Ratio Method

<table>
<thead>
<tr>
<th>No</th>
<th>Fault type</th>
<th>Codes of the ratios</th>
<th>IEC Three Ratio Method</th>
<th>Fuzzy Three Ratio Method</th>
</tr>
</thead>
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<td>No fault</td>
<td>0/0/0</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>Partial discharge of low energy density</td>
<td>0/1/0</td>
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<td>Partial discharge of high energy density</td>
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<td></td>
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<tr>
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<td>Discharge of low energy</td>
<td>1or2/0/1 or 2</td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>Discharge of high energy</td>
<td>1/0/2</td>
<td></td>
<td></td>
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<td>6</td>
<td>Thermal fault of low temperature&lt;150 C</td>
<td>0/0/1</td>
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<tr>
<td>7</td>
<td>Thermal fault of low temperature150~ 300 C</td>
<td>0/2/0</td>
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<td>8</td>
<td>Thermal fault of medium temperature300~700 C</td>
<td>0/2/1</td>
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<td>9</td>
<td>Thermal fault of high temperature&gt;700 C</td>
<td>0/2/2</td>
<td></td>
<td></td>
</tr>
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</table>

III. FUZZYFICATION MODEL

IV. RESULTS & SIMULATIONS

In order to determine the accuracy & less time consumption of the fuzzy three ratio proposed in this paper, I have taken 13 samples with actual fault type already known are collected from viduyt bhavan. Simulation is then carried out by using MATLAB. The diagnosing steps & model are mention in section III. Simulation results are shown in table 3. From the table 3 it can be seen that among these 13 samples, IEC method has fails to correctly diagnose of fault. From the table 4, we can say that the accuracy of fuzzy three ratio method is more then the IEC three ratio method. & programming section is absent with the help of small model and fuzzy member ship function window find out the fault. This method is less time consuming.

V. CONCLUSION

In this paper I carried experimented actual data from oil testing lab & using two methods for finding type of fault. In between both methods Fuzzy three ratio method gives more accurate & precise result. This method is less time consuming never required any kind of programming section. For finding fault type I have taken thirteen samples for diagnosis of fault type out of nine type of fault. Fuzzy three ratio is less time consuming then IEC three ratio method.

SN | Hydrogen H2 | Methane CH4 | Ethane C2H6 | Ethylene C2H4 | Acetylene C2H2 | Actual Fault Type | IEC Three Ratio Method | Fuzzy Three Ratio Method |
---|-------------|-------------|-------------|--------------|---------------|-------------------|-----------------------|-------------------------|
<p>| 1  |             |             |             |              |               |                   |                       |                         |</p>
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Table 3: DGA Sample and Diagnosis Results by Different Method

REFERENCES


