IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 2 (February. 2019), ||S (III) || PP 32-37

Comparative Analysis of Fault Detection in Transformers using different Fuzzy Membership Functions

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Abstract: To find out the incipient power transformer fault symptom diagnosis, various conventional and Artificial Intelligence (AI) technique based methods are used .This paper present comparison analysis of one of the most used artificial intelligence technique fuzzy logic using various membership function. Five gases namely hydrogen, ethane, methane, acetylene and ethylene values are taken from DGA results of 38 transformers conducted in PUNJAB STATE TRANSMISSION CORPORATION LTD. (PSTCL) Laboratory situated in Ludhiana. Ratios are chosen as inputs. Nine output codes for the different type of faults such as Partial Discharge of low energy, Partial Discharge of High energy, Low energy discharge, High energy discharge, thermal fault (<150^{O}C), thermal fault of 150-300^{O}C, thermal fault of 300-700^{O}C, thermal fault (>700^{O}C) and No fault condition are considered. The comparison results are used to intemperate /find the most suitable membership function in fuzzy logic to design Artificial intelligence based system.

Date of Submission: 15-02-2019 Date of acceptance: 04-03-2019

I. INTRODUCTION

Insulation is amajor part of transformer, which plays an important role inthe life expectancyofthe transformer. Transformerlifeis described based onthedesigned parameter with respect to normal operation and climate conditions. Tocalculate the performanceandaging of the equipment, insulation deterioration is amain indicator [1].

Most of the power transformers in power system, around the world are used beyond their designed life. Inthe absence of insulation deterioration measurement, lot of transformer failed, before reaching to their designed technical life. It is important to find the cause(s) of the insulation degradation with respect to age.

A large number of old transformers are still performing well in Punjab state,itis vitalto monitor the insulation behavior ratherthan replacing with new one. Thought load growthhas influence on the insulation degradation and increased it .The insulationdeterioration trend needs regularassessment. An accurate and scientific analysis of the insulation can suggest operating condition, de-rating of the transformer[3,4].

This could help in unit be proposed for relocation, subjected to less stress. Cost effective maintenance strategies can be developed which led to economical system design.

Condition monitoring provides vital information on the developing insulation problems and incipient faults results [5,6]. Thus early signs of any abnormality can avert the catastrophic failure.

II. TRANSFORMER OIL ASSESSMENT

Transformer oil assessment is mainly based on dissolved gas analysis (DGA), in particular Rogers Ratio method [7,8]. The gas ratios involved are C_2H_2/C_2H_4, CH_4/H_2&C_2H_4/C_2H_6..

This method is based on the thermal degradation principles. The validity of this method is based on correlation of the results of a much large number of failure investigation with the gas analysis for each case, but Roger's ratio method can give the ratio that do not fit into the codes. The value for the three key gas ratio corresponding are given in the table 1.0. These ratios according to Roger's are applicable to both gas taken from the gas space and gases extracted from the oil. The fault type has been chosen by combining some cases from the number of fault types originally suggested by Rogers.

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 Regarding the obtained codes and faults diagnosis are given in Table 1.0 and1.1.

Table 1.0: IEC code determination value

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

Table1.1: Fault Diagnosis using IEC codes

S. No	**Code** X Y Z			**Kind of Fault**	**Fault code**
1	0	0	0	No fault	F0
2	0	1	0	Partial discharge with low energy density	F1
3	1	1	0	Partial discharge with High energy density	F2
4	1 or 2	0	1 or 2	Partial discharge with low energy density	F3
5	1	0	2	Partial discharge with High energy density	F4
6	0	0	1	Thermal fault with temperature less than 150° C	F5
7	0	2	0	Thermal fault with temperature between 150°C to 300° C	F6
8	0	2	1	Thermal fault with temperature between 300° C to 700° C	F7
9	0	2	2	Thermal fault with temperature greater than 700° C	F8

III. FUZZY LOGIC SYSTEM

Fuzzy logic is a Boolean logic that is extendedTo handle theconcept of partial truth which isTruth value between "completely true" and "completelyfalse" values [11]. Precisely it is a multi-valueLogic that allow intermediate value to be defined between conventional values true or false, yes or no.

A fuzzy set allow for membership values to be set Between 0 and 1.The most powerful quality of fuzzyMembership is to dealt with linguistic variable orHedges (dense) like more or less, very, not very and Slightly. This allow human expression to express with more ease and more user /human friendly.itIs the vagueness of fuzzy logic that attract the humans towards it. Fuzzy logic has following advantage.

1. Solution to non-linear problems
2. Ability to handle linguistic variables
3. Rule reduction in fuzzy rule base

But it has disadvantage also:

1. Highly dependent on domain expert knowledge
2. Lack of information
3. Insufficient design methodology

IV. FUZZY LOGIC DEVELOPMENT FOR FAULT DIAGNOSIS

Rogers's ratio fuzzy logic System using IEC method

The fuzzy system for Rogers Ratio method consist of three gas ratio X,Y,Z as input variables. The output consist of faults. Grouping of fault is done which is shown in table 1.3. For each gas ratio there are two to four membership function which are classified as low, medium, high, very high according to membership interval is defined below:

X= 0, low u<=0.1	Y= 1, low u<0.1	Z= 0, low u<0.1
X= 1, medium .1<u<3	Y=0 , Medium 0.1<u<1	Z=1 ,medium .1<u<3
X= 2 ,High u>3	Z=2, high u>1	Z=2, High u>3

Fuzzy Rogers IEC Ratio

The 3-gas ratio range introduced by Ron Rogers, known as "Rogers Ratio", may not exactly provide the accurate range in reality. In practice, factors such as the loading history, transformer construction, oil volume, manufacturer and the weather condition may affect the ratio range as well. All these factors may affect the diagnostic of the transformer. As a result, a significant number of the DGA results may fall out of the listed codes of diagnostic conditions. In addition, the crisp sets used to classify the codes are not sufficient to handle the boundary conditions of the gas ratios especially when the values are closed to the threshold values of 0.1, 1.0 or 3.0. As a result, the classification for the codes of the gas ratio becomes contentious and less accurate diagnosis may occur. These restrictions entail the development of the Fuzzy Rogers Ratio diagnostic systems.

Identification of Fuzzy Input and Output Variable for Fuzzy IEC Ratio Method

IEC method uses the 3-digit ratio code generated from ratios of 5 fault gases which are H_2, CH_4, C_2H_6, C_2H_4 and C_2H_2 to determine 38 transformer conditions DGA results of these are obtained from PSTCL laboratory (Ludhiana) . Therefore, the structure for the Fuzzy Rogers Ratio system can be illustrated in Figure 1.0 where the three ratio codes are identified as the input parameter while the 9 interpretation results based on the difference combinationof ratio code are identified as the output parameter

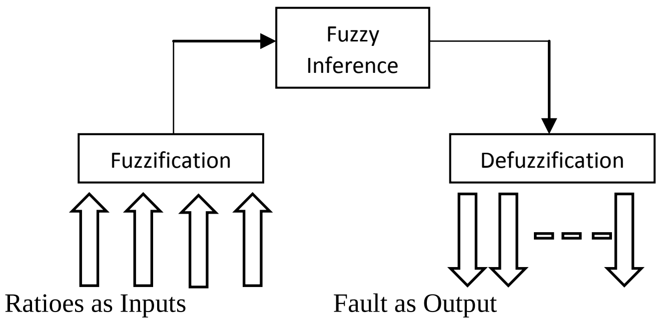
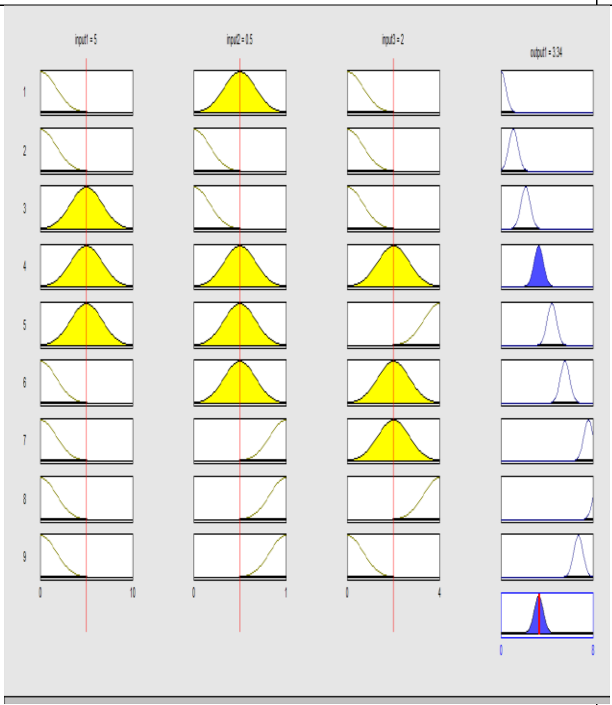
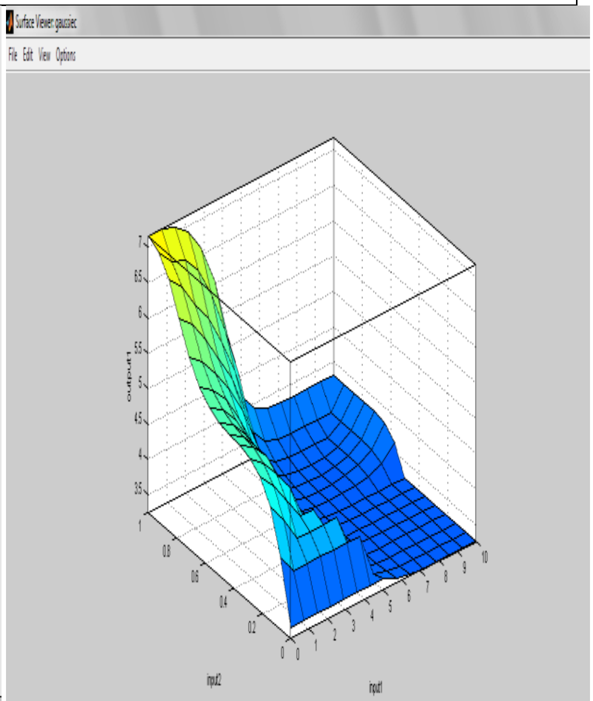
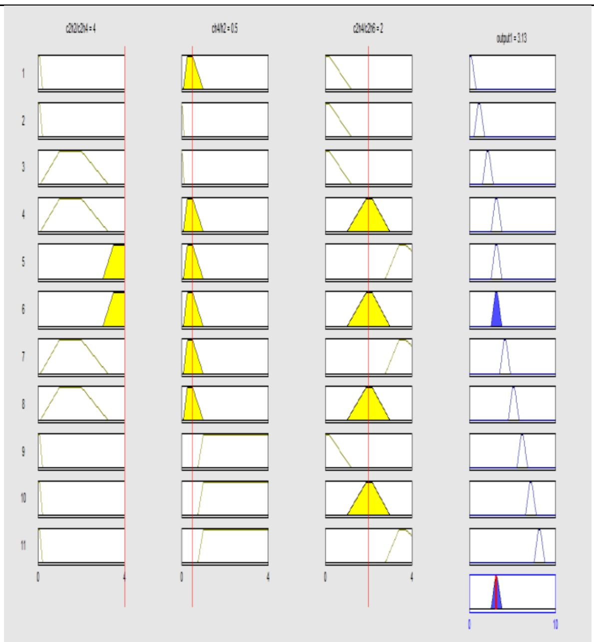
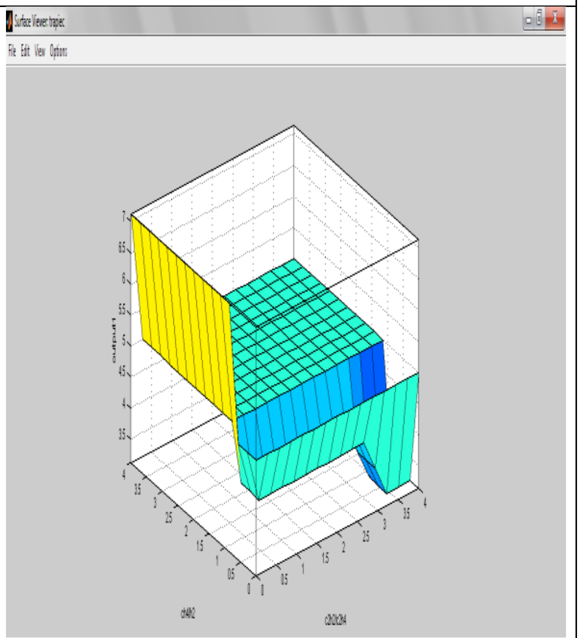


Fig.1.0:Input and output variables for the Fuzzy Rogers Ratio method.

The input and output parameter in Figure 1.0 are interpreted by using three type of membership function triangular, trapezoidal, Gaussian:

Rule Viewer	Surface Viewer
 **Fig.1.1:Rule viewer of Gaussian membership function**	 **Fig.1.2: Surface viewer for fault codes using GaussianMembership function**
 **Fig.1.3: Rule viewer of trapezoidal membership function**	 **Fig.1.4: Surface viewer for fault codes using trapezoidal Membership function**

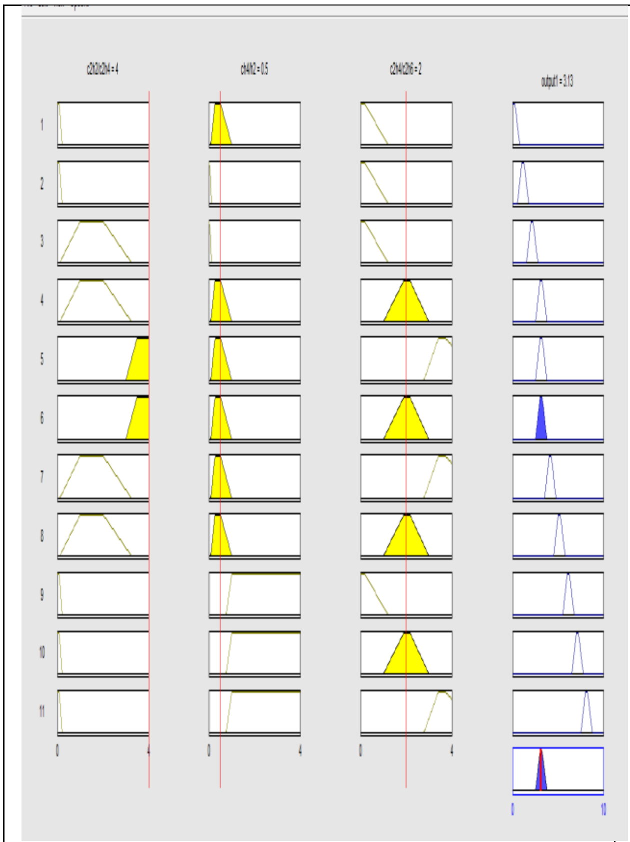


Fig.1.5: Rule viewer for fault codes using Triangular Membership function

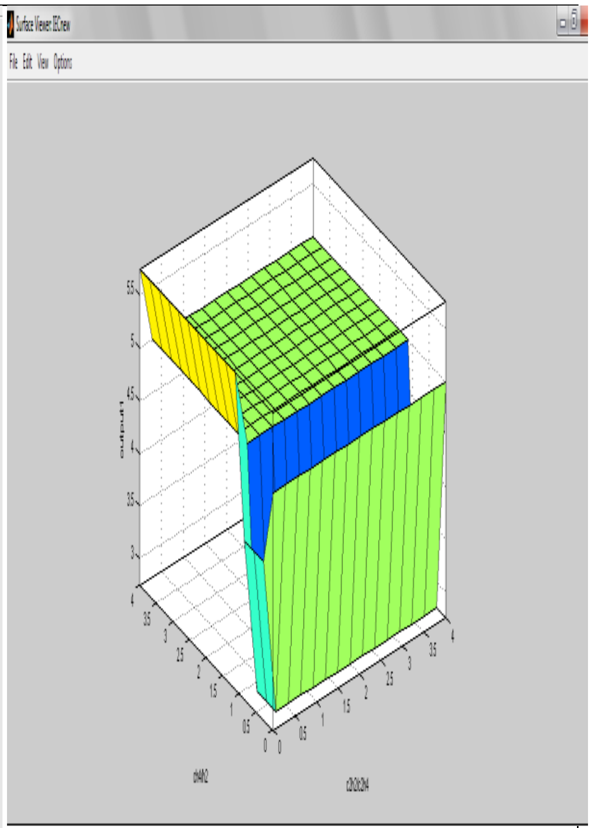


Fig.1.7: Surface viewer for fault codes using Triangular Membership function

Above figures show the rule viewers designed for various membership functions and surface viewers respectively. Based upon all these membership function designed all the 38 transformers DGA results were fed in Mat lab fuzzy inference system designed and compared with IEC ratio results. Comparative analysis is given below in Table 1.2

Table.1.2: Comparison of result of fuzzy logic using different membership function and IEC diagnosis

S.No	Fault diagnosis by Gaussian membership function	Fault diagnosis by trapezoidal member-ship function	Fault diagnosis by triangular member-ship function	Fault diagnosis by IEC method
1	F6	F6	F6	F6
2	F5	F4	F3	F3
3	F5	F4	F3	F3
4	F5	F4	F3	F3
5	F0	F6	F0	F0
6	F7	F7	F7	F5
7	F4	F0	F0	F0
8	F7	F6	F6	F6
9	F3	F5	F5	NO RES-ULT
10	F6	F6	F6	F6
11	F7	F8	F7	F8
12	F7	F8	F7	F8
13	F7	F5	F5	NO RES-ULT
14	F7	F8	F8	F8
15	F2	F0	F5	NO RES-ULT
16	F7	F8	F7	F7
17	F7	F8	F7	F7

18	F7	F8	F7	F7
19	F7	F8	F7	F7
20	F7	F8	F7	F7
21	F7	F8	F7	F7
22	F7	F8	F7	F7
23	F1	F5	F2	F2
24	F3	F5	F3	F3
25	F4	F3	F3	F3
26	F4	F3	F3	F3
27	F4	F4	F4	F4
28	F7	F8	F8	F8
29	F7	F5	F5	NO RES-ULT
30	F6	F6	F6	F6
31	F7	F5	F5	F6
32	F7	F8	F7	F7
33	F7	F8	F7	F7
34	F7	F8	F7	F7
35	F7	F8	F7	F7
36	F7	F8	F7	F7
37	F7	F8	F7	F7
38	F7	F8	F7	F7

V. CONCLUSION

From the above Table 1.2, it can be concluded that fault diagnosis by Fuzzy logic is nearest to actual fault diagnosis by using IEC methods based upon grouping of faults (Thermal, Partial discharge, Heating). Further, Triangular membership function is more accurate with 71.05% results matching with IEC methods and also giving results where conventional methods fails which results in increase in efficiency of system based on Fuzzy logic by approx. 10%.

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Amrinder Kaur. "Comparative Analysis of Fault Detection in Transformers using different Fuzzy Membership Functions." IOSR Journal of Engineering (IOSRJEN), vol. 09, no. 02, 2019, pp. 32-37.