J Electr Eng Technol Vol. 9, No. 6: 2058-2064, 2014
http://dx.doi.org/10.5370/JEET.2014.9.6.2058

ISSN(Print) 1975-0102
ISSN(Online) 2093-7423

Intuitionistic Fuzzy Expert System based Fault Diagnosis using Dissolved Gas Analysis for Power Transformer

Geetha Mani† and Jovitha Jerome*

Abstract – In transformer fault diagnosis, dissolved gas analysis (DGA) is been widely employed for a long period and numerous methods have been innovated to interpret its results. Still in some cases it fails to identify the corresponding faults. Due to the limitation of training data and non-linearity, the estimation of key-gas ratio in the transformer oil becomes more complicated. This paper presents Intuitionistic Fuzzy expert System (IFS) to diagnose several faults in a transformer. This revised approach is well suitable to diagnosis the transformer faults and the corresponding action to be taken. The proposed method is applied to an independent data of different power transformers and various case studies of historic trends of transformer units. It has been proved to be a very advantageous tool for transformer diagnosis and upkeep planning. This method has been successfully used to identify the type of fault developing within a transformer even if there is conflict in the results of AI technique applied to DGA data.

Keywords: Power transformer, DGA, IFS, IEC gas ratio, Fault diagnosis.

1. Introduction

The distribution part in any electrical power system characterizes 70% of all the system, whereas the main part in any distribution system is the power transformers, so the power transformers are the most important key elements in any power system [1]. Electrical and thermal stresses within a transformer result in decomposition of its insulation. Hydrolytic, oxidative and thermal degradation take place within a transformer, and these harms can direct to service outages. Due to normal aging there are some gases present within the oil; the active and incipient faults increase the gas concentrations. The DGA results of the transformer oil can be used for giving advanced caution of rising fault. Several techniques have been developed to analyze the results of the gas chromatography; such as Dornenburgs ratio method, Rogers ratio method, Key gas method of IEEE std. C57.104, International Electro technical Commission (IEC) Method 60599, Duvals Triangle, CIGRE Regulations, and Nomograph method. Each of these methods suffers from some or the other problems. Even a failure of single power transformer may lead to long disturbances in supply, loss revenue and costly repairs. Several techniques both off-line (i.e. PD, transfer function, furan analysis of cellulose insulation, DP and recovery voltage measurements) and on-line (i.e. winding vibration, acoustic measurement of corona, temperature monitoring, gas in oil monitoring using Hydran and DGA) are available to assist in condition valuation of power transformers.

Among the available techniques, the DGA technique is rather simple, non-intrusive and also low-cost method. Though the conventional diagnostic techniques are depend on the gas ratios produced from one fault alone or from several faults, their prevailing nature is the same in a transformer [2].

If gases obtained from different fault in a transformer at a time are collected, then the relation between dissimilar gases becomes much complex which may not fit into the predefined codes, as the IEC(International Electric Committee) codes are well-defined only from certain gas ratios. If the gas ratio goes beyond the predefined boundaries, a sudden transition may occur in between 0, 1 and 2. When multiple fault is encountered in a transformer, then the gas ratio limit become ambiguous (fuzzy) [3]. For that reason, between different types of faults, the code should not change suddenly across the margins. Followed by the introduction, this paper explains dissolved gas analysis (DGA) and its interpret techniques IEC gas ratio and IFS in section II. In section 3, the proposed IFS-IEC faults diagnosis method is explained along with its membership and non- membership function. The data considered to perform the technique and the results obtained are illustrated in section 4 and concluded in section 5.

† Corresponding Author: Corresponding Author: Dept. of Instrumentation and Control Systems Engineering, PSG College of Technology, India. (geethamr@gmail.com)

** Dept. of Instrumentation and Control Systems Engineering, PSG College of Technology, India. (jovithajerome@gmail.com)

Received: April 3, 2014; Accepted: July 3, 2014

2. Preliminaries

2.1 IEC gas ratio method

Most of power transformers contain oil as it serves numerous purposes. It is an dielectric medium thus it can both transfer the heat and insulate simultaneously. The incipient faults happening in transformers give proof very early in their improvement stages through transformer oil gas analysis. By extracting the gases dissolved in the oil gas concentrations (in PPM) are obtained and by chromatography they can be separated. The gases that are usually found in the transformer insulating oil are hydrogen (H_2), carbon monoxide (CO), nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), ethane (C_2H_6), methane (CH_4), acetylene (C_2H_2) and ethylene (C_2H_4). The atmosphere is the prominent source of N_2 and O_2, for partial discharge is the prominent source forH_2, CO_2 existence in the oil is as a result of overheated cellulose, besides being a constituent of the atmosphere, overheated cellulose and air pollution is contributed by the presence of CO, whereas over heated oil is accountable for the presence of $C_2H_6$and CH_4, C_2H_2 due to arcing in the oil and C_2H_4 is present due to overheated oil. The faults are classified into primarily three type; arcing or discharge, partial discharge (PD) or corona, and thermal heating. Arcing leads to very high intensity of energy dissipation, whereas heating causes less intensity of energy dissipation and the least intensity of energy dissipation occurs with PD.

As per IEC/IEEE method, it is possible to evaluate four conditions, i.e. normal aging, thermal fault of several degrees of rigorousness, partial discharge (PD) and using three ratios CH_4/H_2, C_2H_2/C_2H_4, and C_2H_4/C_2H_6. Diagnosis of faults is accomplished through a simple coding scheme based on different ranges of ratios. Table 1 gives the range of IEC codes along with their concentration range for each gas ratios used by IEC/IEEE method.

Over a several decades the IEC codes has been involved in DGA and a lot of experience gathered all over the world to diagnose the emerging faults in a transformers [4]. Conventionally, the interpretations were all focused only on specific gas components like methane and hydrogen to determine the discharges in the oil. The ratios of certain gases, establishes more comprehensive diagnostic techniques [5]. The individual gases used to find each ratio and its allotted limits are shown in Tables (1) and (2). Once codes are then assigned accordingly to each gas ratio value, then the equivalent fault traced [4, 5].

Table 1. IEC Ratio Codes

Gas Ratios	Range of Gas ratio	Range code/IEC Code
C2H2/C2H4	<0.1	0
	0.1-1.0	1
	1.0-3.0	1
	>3.0	2
CH 4/H2	<0.1	1
	0.1-1.0	0
	1.0-3.0	2
	>3.0	2
C 2H4/C2H6	<0.1	0
	0.1-1.0	0
	1.0-3.0	1
	>3.0	2

Table 2. Fault classifications according to the IEC Codes

Fault type	C_2H_2/ C_2H_4	CH_4/H_2	C_2H_4/C_2H_6	INDEX
No Fault	0	0	0	F0
Partial discharges of low energy density	0	1	0	F1
Partial discharges of high energy density	1	1	0	F2
Discharges of low energy	1or 2	0	1or 2	F3
Discharges of high energy	1	0	2	F4
Thermal Fault of low temperature <150°C	0	0	1	F5
Thermal Fault of low temperatures 150-300°C	0	2	0	F6
Thermal Fault of medium temperatures 300-700°C	0	2	1	F7
Thermal Fault of high temperatures > 700 C	0	2	2	F8

Even though IEC code method is suitable for the valuation of transformer insulation, no quantitative indication for the probability of each fault is specified. In certain cases, the result obtained from DGA cannot be coordinated by the prevailing codes making the diagnosis ineffective [6]. During the presence of multiple faults in the transformer, the gases contributed from each fault mix up and the perplexing gas ratio becomes its results. The introduction of more effective analysis methods like IFS-IEC Fault Diagnosis overcomes the above mentioned problems.

2.2 Intuitionistic fuzzy systems

In 1983 K. Atanassov proposed the Intuitionistic fuzzy set (IFS), a generalization of the notion of fuzzy set [7, 8]. He introduced a new component degree of non-membership in the definition of these sets and studied the properties of a new object so defined. After the arrival of this new technique, its been widely used in huge number of notional and practical approaches. A fuzzy set generally have a degree of membership function, here in addition to this a degree of non-membership is also involved which requires its sum to be equal to or less than 1.The complementation of these two fuzzy set degrees into one is considered as a degree of uncertainty. The IFS objective is to expand the normal fuzzy sets. As opposed to a fuzzy set in X given by

$$B = \{(x, \mu_B(x)) | x \in X\}$$

Where, $\mu_B(x) : X \to [0, 1]$ is the membership function of the fuzzy set B, an Intuitionistic fuzzy set A is given by

$$A = \{(x, \mu_A(x)), v_A(x) | x \in X\}$$

Where, $\mu_A(x) : X \to [0, 1]$ and $v_A : X \to [0, 1]$ are such that

$$0 \leq \mu_A + \mu_B \geq 1$$

And $\mu_A(x); v_A(x) \in [0\ 1]$ denote a degree of membership and a degree of non-membership of $x \in A$, respectively. For each Intuitionistic fuzzy set in X, we will call

$$\pi_A(x) = 1 - \mu_A(x) - v_A(x)$$

A hesitation margin (or Intuitionistic fuzzy index) of $x \in A$ and, it expresses a hesitation degree of whether x belongs to A or not. It is obvious that $0 \leq \pi_A(x) \geq 1$, for each $x \in A$. As IFS being a generalized version of fuzzy system, the representation of imperfect knowledge can be done in a lot more ways in many real world problems.

3. Proposed IFS Based Transformer Fault Diagnosis

Both the membership function (μ) and also the non-membership function (υ) are to be incorporated into an intuitionistic fuzzy system. In the proposed method, the output of an IFS involves a linear combination of an traditional fuzzy system designed for the membership function along with an another traditional fuzzy system designed for non-membership function. The linearly combined IFS output can be obtained from

$$\text{IFS} = (1 - \pi)F_{Z_\mu} + F_{Z_v}$$

Where π represents intuitionistic index or hesitation margin, F_{Z_μ} represents the traditional output from a fuzzy system designed for membership function μ, and F_{Z_v} represents the output from a fuzzy system designed for non-membership function υ. The traditional fuzzy machinery mentioned in the previous section is used for computing then a weighted average is performed on its results to get the ultimate output of the IFS, this makes the technique more feasible.

3.1 IFS-IEC fault diagnosis

The fault diagnosis is based on the dissolved gases and their proportions comparative to Total Dissolved Combustible Gas (TDCG). The concentration of Hydrogen, Ethane, Methane, Ethylene, Acetylene, and Carbon Monoxide dissolved in oil are all summed up to represents TDGA. The absolute dissolved gas concentration (in PPM) and generation rates (PPM /DAY) are used to evaluate the rigorousness of any faults identified. According to [9], if the absolute level of TDCG is above 720 PPM and consists around 63% of ethylene, then there is a signal of overheated oil. If the TDCG generation rate to go beyond 10 PPM/DAY, then it is advised to have close observation. The concentration of every individual gas (PPM) for key gas method is shown in Table (3). Inferring from the Table (1), it is possible to code the three gas ratios (C_2H_2/C_2H_4, CH_4/H_2 and C_2H_4/C_2H_6) as 0, 1 and 2 according to their various ratio ranges. For better correlation of every individual gas ratio in the range to its corresponding IEC code Table (1) can be reordered as shown in Table (3).

Table 3. IEC Ratio Codes

Ratio-Code	Code 0	Code 2	Code 1
C_2H_2/C_2H_4	<0.1	<3	0.1-3
CH_4/H_2	0.1-1	>1	0.1>
C_2H_4/C_2H_6	1>	3<	1-3

The terms$R_{A1,}$ R $_{A2}$ and R_{A3} represents the ratio between acetylene and ethylene, methane and hydrogen, ethylene and ethane. The transformer fault can be identified better from combining the IEC codes of each individual gas ratio as mentioned in Table (2). For instance, the codes of gas ratio are obtained as R_{A1}=1, R_{A2}=1 and R_{A3}=0 then it is identified that transformer have No. 2 fault (i.e. Partial discharges of high energy density). The identified codes from the gas ratios involves the conventional AND and OR logics. For example, the second fault is symbolized as,

$$\mathbf{F2 = C_{One}(R_{A1})\ AND\ C_{One}\ (R_{A2})\ AND\ C_{Zero}(R_{A3})}$$

Where C_{One} (R_{A1}), C_{One} (R_{A2}) and C_{Zero}(R_{A3}) represents the code values obtained from the gas ratios R_{A1}, R_{A2} & R_{A3} respectively.Conferring to Table (3) their values can either be true (one) or false (zero). Accordingly, the fault F2 will also be either true (one) or false (zero) by the logic operations on the code. Also (α and β) are random probability (0 to 1) and the best value are (0.73 and 0.27) respectively (trail and error method).In IFS-IEC method, the membership functions μ_{ZERO} (R_{A1}), μ_{ONE} (R_{A1}), and μ_{TWO} (R_{A1}) are constructed for gas ratio $R_{A1.}$ The membership function includes three fuzzy sets Zero, One and Two which corresponds to the gas ratio codes 0,1 and 2 respectively. Similarly, the membership functions are designed for gas ratios $R_{A2}$and R_{A3} with the same three fuzzy sets. Every gas ratio R is recognized as a fuzzy vector, here it is illustrated for ratio R_{A2} as [μ_{ZERO} (R_{A2}), μ_{ONE} (R_{A2}), and μ_{TWO} (R_{A2})]. The input for Proposed Fuz-IEC method is obtained from the chromatographic. Data are utilized to diagnose one among the eight fault conditions. Five different gases Hydrogen, Ethane, Methane, Acetylene and Ethylene form three different features with their concentration ratios. The Methane-Hydrogen (MH) ratio,

Table 4. Fuzzy Specifications

Ratios	Formula	Fuzzy Membership functions with Range
Ratio (RA1)	Methane / Hydrogen	LOW : Any value below 0.1.
		MEDIUM : Between 0.1 and 1
		HIGH :> 1.0
Ratio (RA2)	Acetylene / Ethylene	LOW : Any value below 0.1.
		MEDIUM : Between 0.1 and 1
		HIGH : > 1.0
Ratio (RA3)	Ethylene / Ethane	LOW : Any value below 0.1.
		MEDIUM : Between 0.1 and 1
		HIGH :> 1.0

Acetylene-Ethylene(AE) ratio and Ethylene-Ethane (EE) ratio form that three features which makes input to the method. According to the membership intervals, these features are categorized as high (HIGH), medium (MED) and low (LOW). The membership interval ranges of the fuzzy input functions are tabulated in Table 4.

For the improved IEC method, the input classifications like R_{A1}=L, R_{A2}=M and R_{A3}=H provided with confidence factors are taken as the degree of membership of the gas ratio in fuzzy forms of the intervals shown in Table 4.

Then the rules implicit in Table 5 are applied to develop confidence factors for all the IEC diagnoses. We will consider for simplicity uniform trapezoidal membership function for the linguistic value low, medium and high of the input linguistic variable of IEC ratio method uses three ratios R_{A1}, R_{A2}, and R_{A3}.

The fuzzy membership functions for IEC code input classifications are shown in Fig. 2(a) for R_{A1}**,** Fig. 2(b) for R_{A2}, and Fig. 2(c) for R_{A3}. The input variable for the non-membership function of gas ratio R_{A1} and R_{A2} is shown in Figs. 3 & 4 respectively with the ranges for each linguistic value. It is obviously noted from Figs. 3 & 4, that in the gas ratio $R_{A\ 1\text{-}3}$ the membership and non-membership functions are not complementary to each other, which is because of the intuitionistic fuzzy system. The hesitation margin for both membership and non-membership function

Table 5. Knowledge Rule Base

		R_{A3}=LOW	R_{A3}=MED	R_{A3}=HIGH
R_{A1} - LOW	R_{A2}=LOW	F1	F1	F2
	R_{A2}=MED	----	F3	F3
	R_{A2}=HIGH	F4	----	----
R_{A1} - MED	R_{A2}=LOW	F0	F5	F5
	R_{A2}=MED	----	----	F3
	R_{A2}=HIGH	----	----	----
R_{A1}- HIGH	R_{A2}=LOW	----	F7	F8
	R_{A2}=MED	----	----	---
	R_{A2}=HIGH	----	----	----

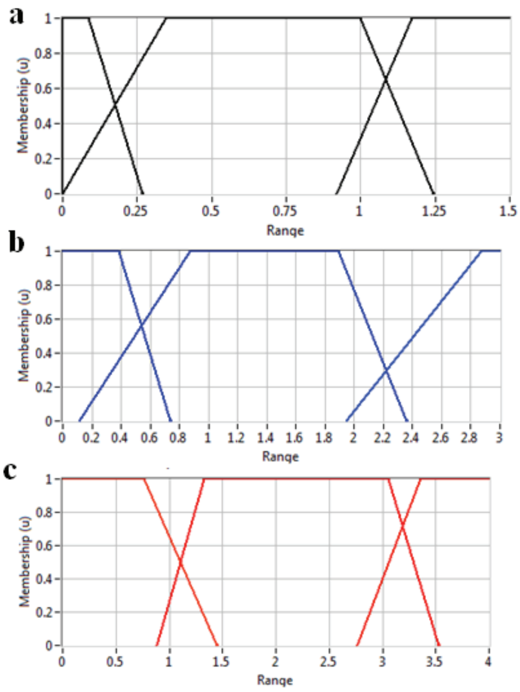

Fig. 2. Input Membership Functions for (a) Ratio 1 (R_{A1}) ; (b) Ratio 2 (R_{A2}); (c) Ratio 3 (R_{A3})

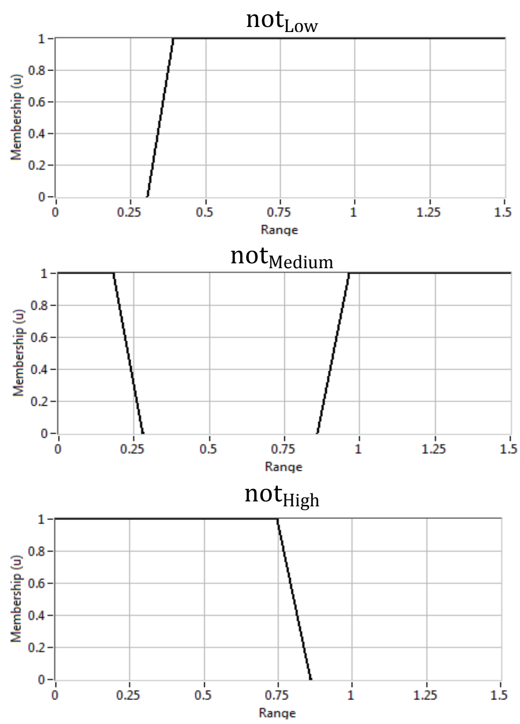

Fig. 3. Fuzzy Non-Membership Functions for Ratio 1 (R_{A1})

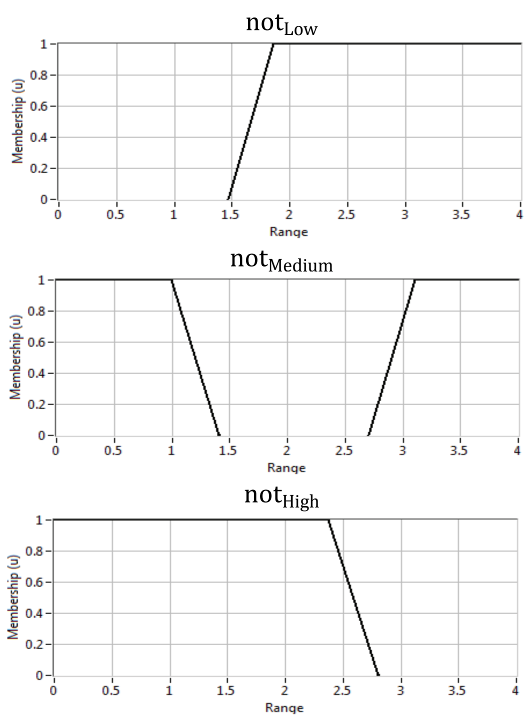

Fig. 4. Fuzzy Non-Membership Functions for Ratio 2 (R_{A2})

Table 6. Example (i) DGA data and Comparative Analysis

Sample no.	Date of sample	H_2	CH_4	C2H4	C2H6	C2H2	IEC/IEEE method	Proposed method	Comparison
1	8/19/1989	85	126	224	46	96	ND	Thermal and discharge	–
2	9/27/1989	142	118	193	31	92	F_4	Discharge thermal	Match
3	1/15/1990	300	45	101	17	225	F_4	Discharge	Match

Table 7. Example (i) DGA data and Comparative Analysis

Sample no.	Date	H_2	CH_4	C2H4	C2H6	C2H2	IEC/IEEE method	Proposed method	Comparison
1	Mar-01	31	39	82	43	3	F_7	Thermal	Match
2	May-01	14	44	75	36	0	F_7	Thermal	Match
3	May-02	11	55	212	53	3	F_8	Thermal and partial discharge	Match

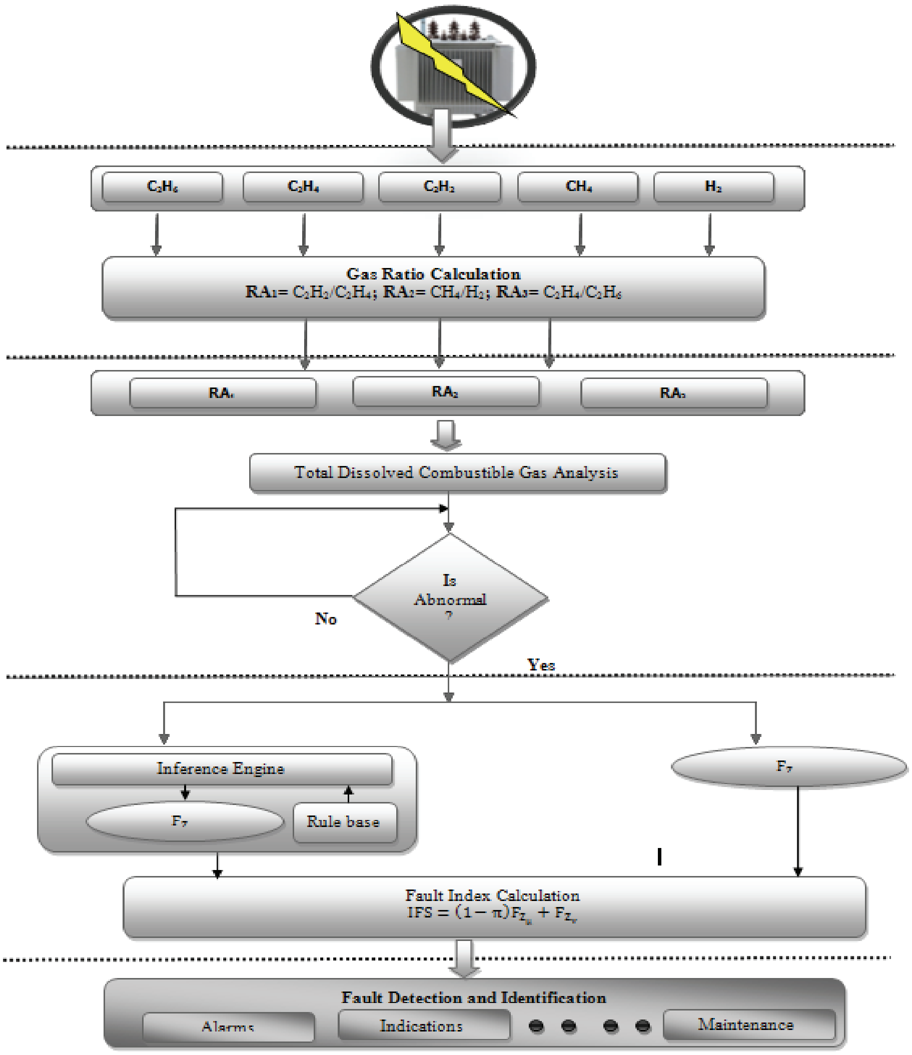

Fig. 1. Proposed Intuitionistic Fuzzy Expert System for Fault Diagnosis

is 0.05 and it is clearly shown in Figs. 2 and Fig. 3. Through Fuzzification R_{A1}, R_{A2}, and R_{A3} values are obtained the Table 5 is utilized as rule base. Similarly the fuzzified non-membership function ratios to the interpretation table can be accomplished by averaging all the fault conditions.

An IFS considers both the membership function μ and non-membership function υ for each gas ratio R_{A1}, R_{A2}, and R_{A3} had been obtained.

And the final result of the IFS is a linear combination of an traditional fuzzy system designed for the membership function μ for each gas ratio R_{A1}, R_{A2}, and R_{A3}along with an another traditional fuzzy system designed for non-membership function υ for each gas ratio R_{A1}, R_{A2}, and R_{A3}.The IEEE three key gas diagnosis table is utilized for fault diagnosis of transformer. In the traditional fuzzy systems, the conventional Boolean operations "OR" and "AND" are utilized to obtain the results of combining the codes. After merging the codes, If-then-else rule is employed to identify the faults according to the gas ratio conditions. If Then -Else rules can be used to determine the individual fault condition of the transformer.

4. Results and Discussions

As the information available about the history of the transformer and test data is really high, the possibility for correct diagnosis of the health of the unit is really high [1]. A baseline transformer test information should be established when the transformer is new or when possible afterwards. Launching such a reference point for gas concentrations in new or repaired transformers and tailed up by a routine monitoring program is an important element in the application of the traditional DGA methods. Monitoring the health of a transformer must be done on a routine basis and can start anytime, not just for new unit. The proposed method is applied to famous data of transformers published in literature [11] and those from the field.

Example (i): The transformer began operation in 1971 and the unit had affected by an arc tracing fault in August 1989. After repairing and degassing a special gas fingerprint of the transformer was designed. Table 6 provides the DGA samples and the relationship of the fault analysis by the proposed proof belief method with IEC/IEEE method. The IEC/IEEE method specified arcing fault for sample 1-3 while the fault type of sample1 could not be identified. The proposed method diagnosis a thermal fault and discharge in sample 2 and 3 correspondingly. The proposed method specifies that when the transformer was put away in service after repair there was re-development of an arc inside the Unit.

Example (ii): The 50 MV A, 11/110 kV, Generator Transformer had been in service for six years. The DGA results revealed an initial increasing trend and later become stabilized values making a definite prediction problematic. So, closer monitoring of the transformer was suggested. Table 7 gives the DGA data and the fault analysis by IEC/ IEEE method and the proposed method. The concentration of C_2H_4 was found to be increasing indicating a thermal fault emerging which is confirmed by the IEC/IEEE method.

By the proposed method occurrence of thermal fault is indicated in the samples and there is an increasing tendency of thermal fault level from the logged data, the initial accumulative trend of the thermal fault and also the accumulative weighed value propose that the transformer should be pulled out of service and internal assessment be carried out before the developing initial fault causes catastrophic blockbusting and breakdown of the Unit. It is observed that the proposed method can be used to observe the trend of fault development in a transformer over the period of time.

The above figure depicts the data logged when the transformer is at fault condition, then it is being used for fault detection and identification by Fuzzy IEC Expert system.

5. Conclusion

The non-destructive technique for fault evacuation of transformer can be done by monitoring gas in transformer. There are number of technique available to predict fault in transformer by analysis of DGA data, but no one technique are use to predict fault in transformer properly. The experimental results are studied by following techniques traditional IEC method, and IFS IEC key gas method. When the proposed method was applied to a transformer unit the results that were obtained for the available samples were consistent with the actual fault when the traditional methods are unable to do so. The improvements in the proposed method are due to the more truthful representation of the relationship between the fault type and the dissolved gas levels with fuzzy member ship function as shown in the results, where on top of determining the fault in transformer. Using the proposed method the decision regarding maintenance need not be dependent only on the operator/expert opinion but can be scientifically deduced using the proposed diagnostic method. Based on the degree of belief the transformer units can be ranked in order for decision making for routine maintenance / removal from service for preventive maintenance strategies.

References

[1] Dukarm, J. J, "Transformer Oil Diagnosis Using Fuzzy and Neural Networks", Canadian Conference on Electrical and Computer Engineering: Canada pp. 170-175, 1993.

[2] Rogers R. R., "IEEE and IEC code to interpret incipient faults in transformers using gas in oil analysis", IEEE transaction electrical Insulation, Vol. 13(5), pp. 349-354, 1978.

[3] Tang WH, Spurgeon K, Wu QW, and Richardson ZJ., "An evidential reasoning approach to transformer condition assessment", IEEE Trans on Power Deliv, vol. 19(4) pp. 1696-730, 2004.

[4] Spurgeon K, Tang WH, Wu QW, and Richardson ZJ., "Evidential reasoning in dissolved gas analysis for power transformers", IEEE Proc Sci Measur Technol vol. 152, pp. 110-7, 2005.

[5] Min Lee Hui, and Chang CS, "Application of Dempster-Shafer Theory of evidence for transformer incipient fault evidence", In 8th International conf. on advances in power system control, operation and

management, Hong Kong, pp. 1-6, 2009.
[6] Duval M, and Pablo A," Interpretation of oil in gas analysis using new IEC publication 60599 and IEC TC 10 databases", IEEE Electric Insul Mag, vol. 17 (2), pp.31-41, 2001
[7] Atanassov, K., E. Szmidt, and J. Kacprzyk, "On intuitionistic fuzzy multi-dimensional sets", *Issues in Intuitionistic Fuzzy Sets and Generalized Nets*, Vol. 7, 2008, 1-6.
[8] Atanassov, K., E. Szmidt, J. Kacprzyk, and P. Rangasamy, "On intuitionistic fuzzy multi-dimensional sets. Part 2. Advances in Fuzzy Sets, Intuitionistic Fuzzy Sets, Generalized Nets and Related Topics. Volume I: *Foundations, Academic Publishing House EXIT*, Warszawa, 2008, 43-51.
[9] Behjat V, Vahedi A, Setayeshmehr A, and Borsi H, Gockenbach E, "Sweep frequency response analysis for diagnosis of low level short circuit faults on the windings of power transformers: an experimental study", Int J Electric Power Energy Syst, vol. 42(01), pp. 78-90, 2012.
[10] Georgilakis P S., "Condition monitoring and assessment of power transformers using computational intelligence", Int J Electric Power Energy Syst, vol. 33(10), pp. 1784-5,2011.
[11] Geetha M, Jovitha J and Manikandan P, "Integrating Fuzzy IEC Expert System based Fault Diagnosis for Power Transformer Using Dissolved Gas Analysis", Journal of Electrical Engineering, vol. 14, no. 2, pp. 348-354, 2014.

Geetha Mani completed her Master of Engineering from Madras Institute of Technology (MIT), Anna University in Instrumentation Engineering. She is currently doing Ph. D at PSG College of Technology. She is working as Assistant Professor (Senior Grade) at Department of Instrumentation & Control Systems Engineering, PSG College of Technology. Her area of interests includes State Estimation, Fuzzy Systems and Advanced Process Control.

Jovitha Jerome received B.E. degree in 1979 from Madras University, India and M.E. degree from Bharathiyar University, India. She obtained D.Eng from the Asian Institute of Technology, Bangkok, Thailand. She has been teaching for 32 years at reputed institutions like the Government College of Technology, Coimbatore Institute of Technology, Coimbatore, India, and Sirinidhorn International Institute of Technology, Bangkok, Thailand. Presently she is Professor and Head of Instrumentation and Control Systems Engineering Department at PSG College of Technology, Coimbatore, India. Her research interest includes Distribution Automation, Power Systems Management and Virtual Instrumentation.