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Novel Method for Prediction of Internal Condition of Transformer Using Fuzzy Logic

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***Abstract*: Transformer has vital role in the emerging electric Power Systems and is the one of the main equipments in the Power System. So monitoring and maintaining their healthiness is very essential, by monitoring Transformers periodically and taking required action results in increase of life of Transformers and also we can avoid secondary damages, electrical/mechanical hazards to human beings working near Transformers. If any problem is found while periodical testing /monitoring we can go for a planned shutdown which can save huge Generation Loss due to failure of Transformers in case of Generating Station. In general failure of Transformer can cause non availability of Generation/Transmission/ distribution for some time. So it is very necessary to monitor and take suitable action whenever any abnormalities are found in Transformers else it leads to failure of equipment further affecting the Power System Stability.**

***Keywords:* Transformer, condition monitoring, healthiness, Dissolved Gas Analysis (DGA), Fuzzy Logic.**

I. INTRODUCTION

A transformer is a static machine used for transforming power from one circuit to another without changing frequency. Power transformers have an important role in power flow in large power systems. Their better performance gives high efficiency and enhanced power transfer capability. However, various power transformer failures in the recent past have acquired much attention towards failure analysis. Transformers are reliable and offer trouble free service if they are monitored time to time by maintenance and operating engineers. There are many different maintenance actions, to be performed on a power transformer some of them are monthly basis, some other are quarterly, some are half-yearly basis and some of them are yearly basis. By doing these routine maintenance we can avoid failures to maximum extent which may be caused by internal faults, but some time external faults can cause severe damage to the transformer. In this paper Dissolved Gas Analysis (DGA) is used, wherein the transformer oil is tested for its gas composition. Composition levels of these gases are given as input to Fuzzy Inference System (FIS) to predict the condition of any given Transformer.

II. DISSOLVED GAS ANALYSIS (DGA)

DGA is the study of dissolved gases in transformer oil. Insulating materials within transformers and electrical equipment break down to liberate gases within the unit. The distribution of these gases can be related to the type of electrical fault, and the rate of gas generation can indicate the severity of the fault. The identity of the gases being generated by a particular unit can be very useful information in any preventative maintenance program. Online monitoring of electrical equipment is an integral part of the smart grid. When gassing occurs in transformers there are several gases that are created. Enough useful information can be derived from nine gases so the additional gases are usually not examined. The nine gases examined are:

- Atmospheric gases : hydrogen, nitrogen and oxygen
- oxides of carbon : carbon monoxide and carbon dioxide
- hydrocarbons: acetylene, ethylene, methane and ethane

Thermal faults are detected by the presence of by-products of solid insulation decomposition. The solid insulation is commonly constructed of cellulose material. The solid insulation breaks down naturally but the rate increases as the temperature of the insulation increases. When an electrical fault occurs it releases energy which breaks the chemical bonds of the insulating fluid. Once the bonds are broken these elements quickly form the fault gases. The energies and rates at which the gases are formed are different for each of the gases which allow the gas data to be examined to determine the kind of faulting activity taking place within the electrical equipment. Insulation overheating deteriorates the cellulose insulation.

- Oil overheating results in breakdown of liquid by heat and formation of methane, ethane and ethylene.
- Corona is a partial discharge and detected in a DGA by elevated hydrogen.
- Arcing is the most severe condition in a transformer and indicated by even low levels of acetylene.

Interpretation of the results obtained for a particular transformer requires knowledge of the age of the unit, the loading cycle, and the date of major maintenance such as filtering of the oil. The IEC standard 60599 and the ANSI IEEE standard C57.104 give guidelines for the assessment of equipment condition based on the amount of gas present, and the ratios of the volumes of pairs of gases.

After samples have been taken and analyzed, the first step in evaluating DGA results is to consider the concentration levels (in ppm) of each key gas. Values for each of the key gases are recorded over time so that the rate-of-change of the various gas concentrations can be evaluated. Table.1 indicates the normal limits (ppm) and action limits (ppm) of key gases. Any sharp increase in key gas concentration is indicative of a potential problem within the transformer.

Table.1 Key gases in DGA analysis

S.no	Gas	Normal Limits (ppm)	Action Limits (ppm)
1	Hydrogen (H2)	150	1000
2	Methane (CH4)	25	80
3	Ethylene (C2H4)	20	150
4	Acetylene (C2H2)	15	70
5	Ethane (C2H6)	10	35
6	Carbon dioxide (CO2)	10000	15000
7	Carbon monoxide(CO)	500	1000

Table.2 Interpretation from DGA and FIS results ranges

S.no	Gas detected	Primary Interpretation	Secondary Interpretation	FIS results ranges for fault indication
1	Hydrogen (H2)	corona effect	Arcing, overheated oil	0-1
2	Methane (CH4)		Arcing, serious overheated oil	1-2
3	Ethylene (C2H4)	Thermal fault, local or over heated oil	Corona, arcing	2-3
4	Acetylene (C2H2)	Electric fault like arcing and sparking	Severely over heated oil	3-4
5	Ethane (C2H6)		Thermal fault like corona & over heated oil	4-5
6	Carbon dioxide (CO2)	Cellulose decomposition		5-6
7	Carbon monoxide (CO)	Overheated cellulose decomposition		6-7
8	Overall Thermal fault due to Methane, Ethane and Ethylene			8-9

Dissolved gas analysis as a diagnostic technique has several limitations. It cannot precisely localize a fault. If the transformer has been refilled with fresh oil, results are not indicative of faults. These gases are to be isolated from the sample and analyzed quantitatively using gas chromatography process. This technique enables proper diagnosis of the transformer condition in service and can also suggest preventive measures. The quantities of gases generated from the transformer oil and their types help in identifying the various fault conditions.Table.2 gives interpretation of key gases obtained from DGA and FIS results ranges. Each fault has its own characteristic amount of energy. Elevated concentrations of gases may signal corona, discharge, overheating, arcing.

III. FUZZY LOGIC OVERVIEW

Fuzzy logic is a powerful technique for problem-solving with a wide area of applications. Fuzzy provides a very simple way to make definite conclusions from vague, ambiguous or imprecise information. In fact, fuzzy logic resembles human decision making with its ability to work from approximate data and find the solutions. Unlike classical logic, which requires a complete understanding of a system, exact equations, and precise numeric values, Fuzzy logic incorporates a way of thinking, like human which allows to model complex systems originating from our knowledge and experience. Fuzzy Logic allows expressing this knowledge with subjective concepts such as very hot, bright red and a long time, which are mapped into numeric ranges. Fuzzy Logic is conceptually easy to understand, robust and flexible system which can work on imprecise data. Fuzzy Logic control makes use of fuzzy rules. The procedure for creating a fuzzy controlled model is followed by following three steps.

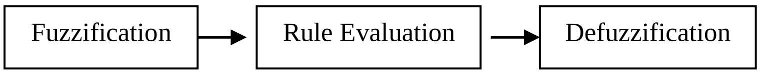

Fig a. Block diagram of Fuzzy Inference System (FIS)

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalued logical systems.

In Fuzzy Logic software, fuzzy logic should be interpreted as FL, that is, fuzzy logic n its wide sense. The basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution. Among various combinations of methodologies in soft computing, the one that has highest visibility at this juncture is that of fuzzy logic and neurocomputing, leading to neuro-fuzzy systems. Within fuzzy logic, such systems play a particularly important role in the induction of rules from observations. An effective method developed by Dr. Roger Jang for this purpose is called ANFIS (Adaptive Neuro-Fuzzy Inference System). This 999method is an important component of the toolbox.

Fuzzy logic is all about the relative importance of precision. In this sense, fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concepts of fuzzy logic relies on age-old skills of human reasoning. The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use.

IV. FUZZY INFERENCE SYSTEM MODELING

Figure.1 represents FIS editor showing 7-input variables and 1- output variable, Figures.2-8 represent the 7 input variables H_2, CH_4, C_2H_2, C_2H_4, C_2H_6,CO and CO_2 membership function plots for input variables. Figure.9 represents the membership function plot for the variable output i.e. internal condition and Figure.10 represents the rule view of input and output variables.

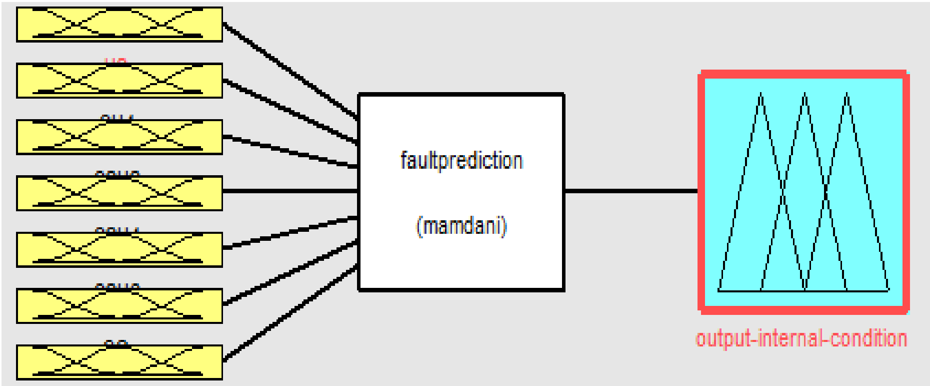

Fig1.FIS with seven Inputs and one Output

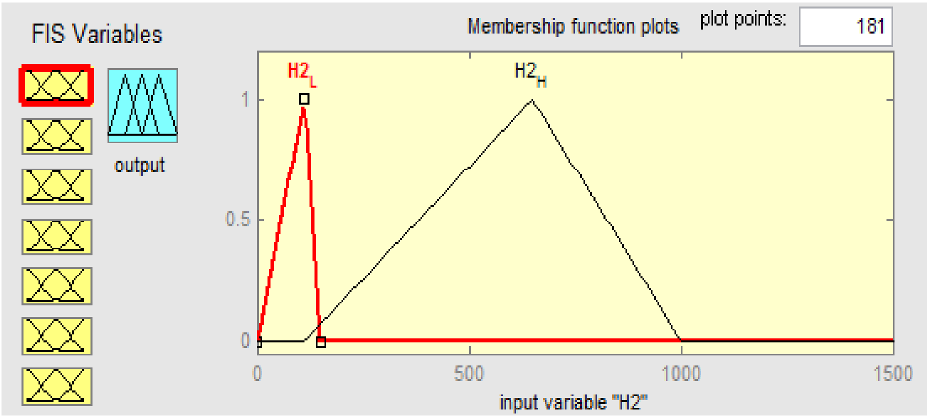

Fig2.FIS with MFs for Hydrogen Gas

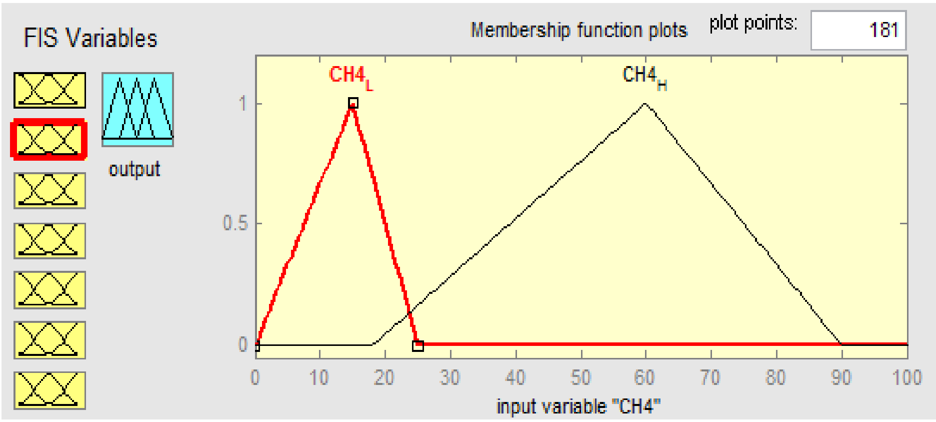

Fig3.FIS with MFs for Methane Gas

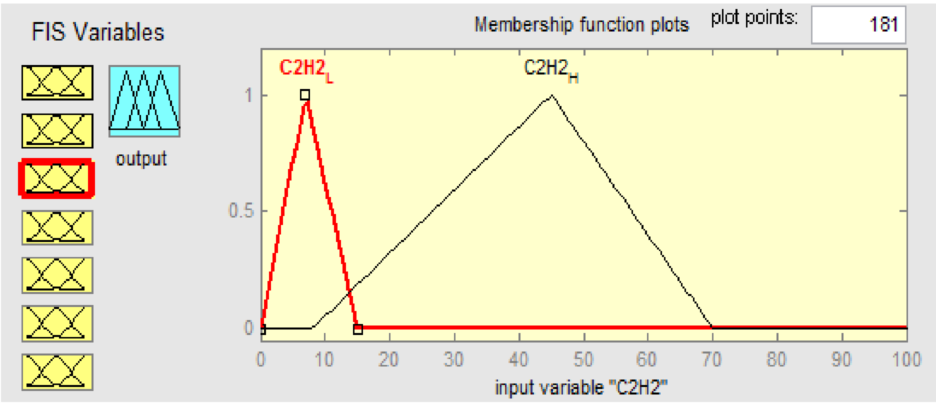

Fig4.FIS with MFs for Acetylene Gas

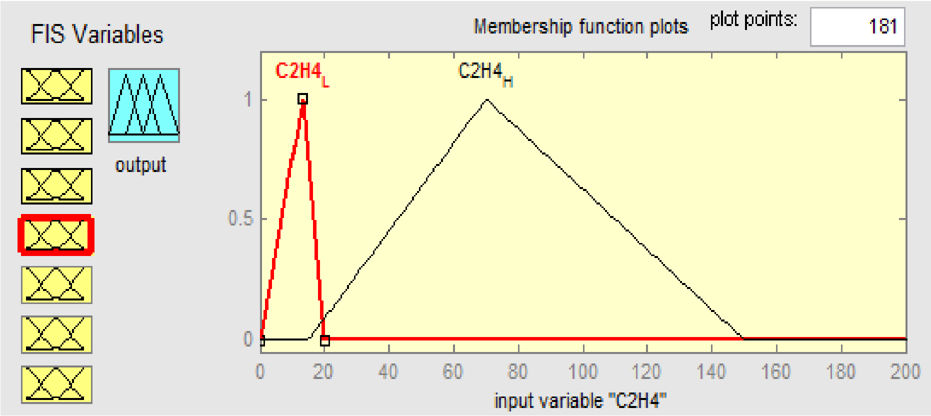

Fig5.FIS with MFs for Ethylene Gas

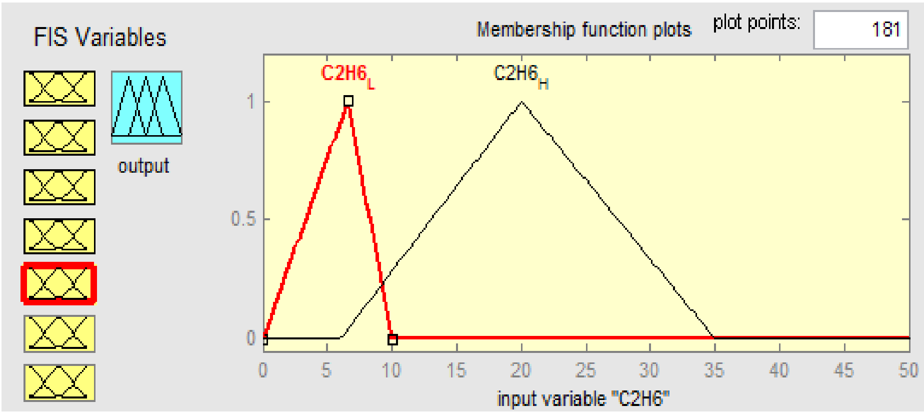

Fig6.FIS with MFs for Ethane Gas

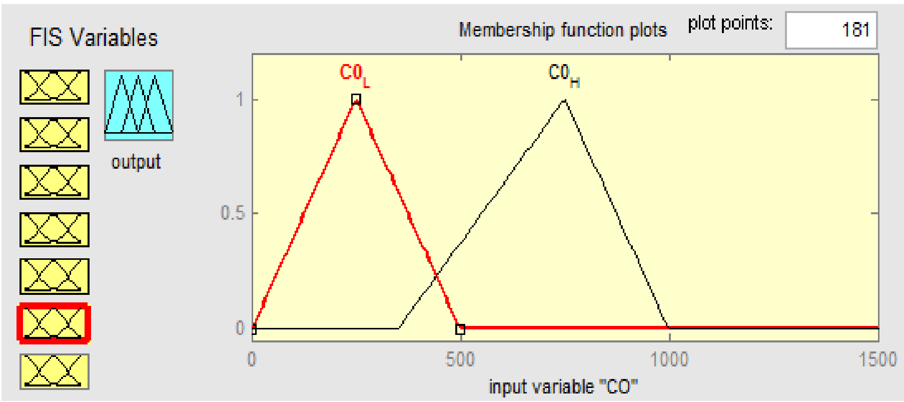

Fig7.FIS with MFs for Carbon Dioxide Gas

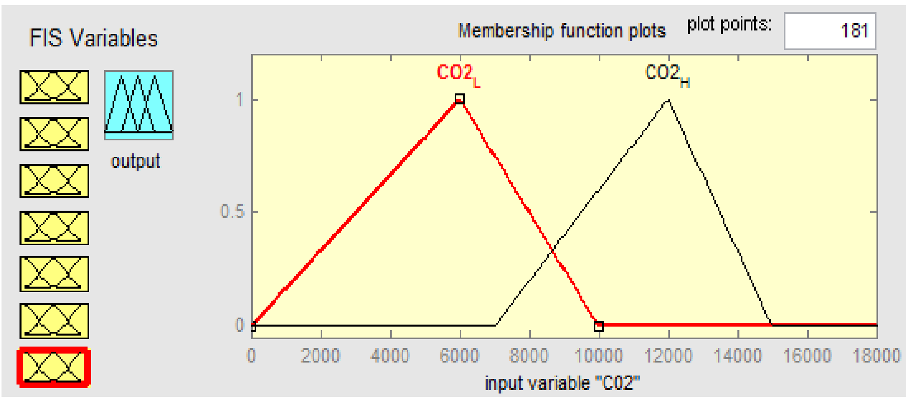

Fig8.FIS with MFs for Carbon Monoxide Gas

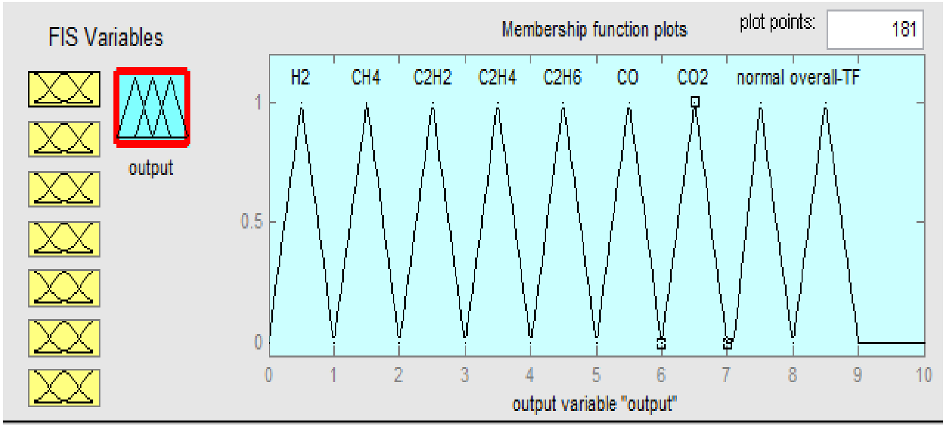

Fig9.FIS with MFs for 'output-internal condition'

V. RESULTS

Developed FIS has been used to evaluate the internal condition of a Transformer. It is very much clear from Rule Viewer that 8.5 is the output result. Referring to the 5th column of table.2 i.e.'**FIS results ranges for fault indication',** the output 8.5 lies between the range 8-9 which indicates Overall Thermal fault due to Methane, Ethane and Ethylene.

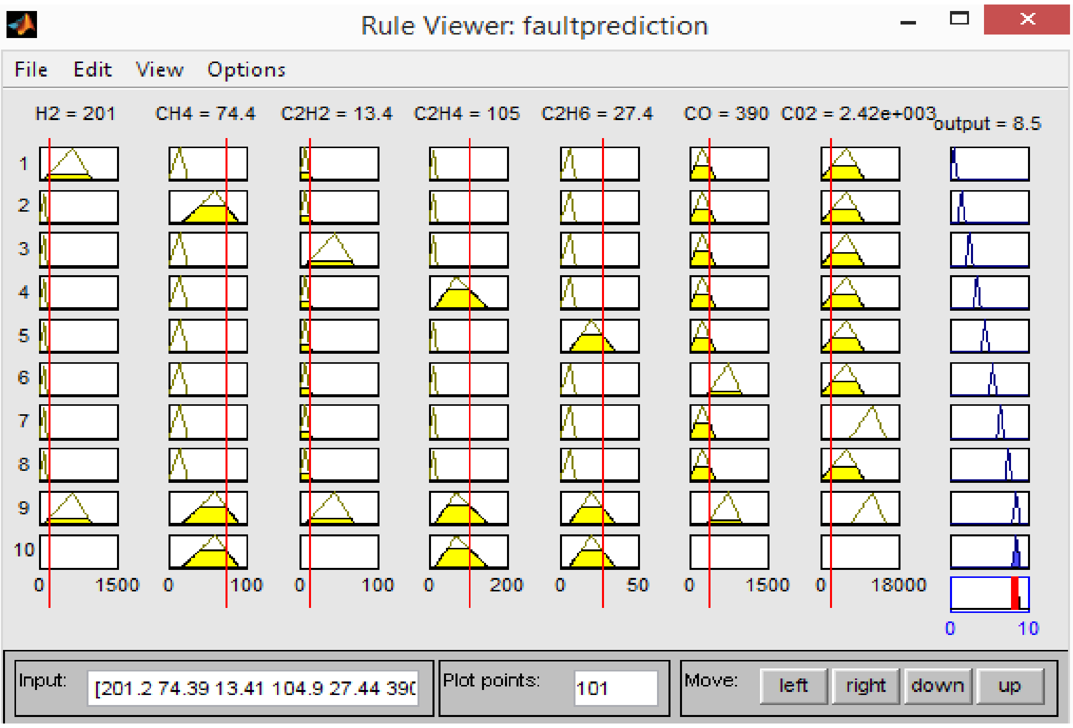

Fig10.Rule viewer indicating thermal fault

VI. CONCLUSION

In this paper a Fuzzy Inference System (FIS) is developed to know internal condition of any given transformer. The inputs to the FIS system are the key gases mentioned in the Table.1 and concentration levels of these key gases which are obtained from the DGA test of transformer oil are used for interpretation of fault types using developed FIS and results arrived are accurate.

In the developed FIS model only few cases are considered. So it is very much clear from the above analysis that we can easily predict the internal condition of any transformer. Once we know the concentrations of key gases, by using fuzzy logic tool we can come to know about healthiness of a transformer. After knowing the results we can take corresponding decision to clear the fault. In this case Fuzzy logic is used because of its Simplicity And Accuracy.

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