DEVELOPMENT OF AN EXPERT SYSTEM FOR DETECTING INCIPIENT FAULT IN TRANSFORMER BY DISSOLVED GAS ANALYSIS

Prof. N. K. Dhote
G.H.Raisoni College of Engg.,CRPF Gate No-3 , Digdoh Hills, Nagpur-16

Prof. D.M.Holey
G.H.Raisoni College of Engg.,CRPF Gate No-3 , Digdoh Hills, Nagpur-16

Prof. M.R.Ramteke
V.N.I.T., Nagpur

Keywords: Incipient Faults, Dissolved Gas Analysis and Expert system

Abstract Power transformer is a vital component of power system, which has no substitute for its major role. They are quite expensive also. It is therefore, very important to closely monitor it's in – service behavior to avoid costly outages and loss of production. Many devices have evolved to monitor the serviceability of power transformers. These devices such as Buchholz relay or differential relay respond only to a severe power failure requiring immediate removal of transformer from service, in which case, outages are inevitable. Thus, preventive techniques for early detection of faults to avoid outages would be valuable. A prototype of an expert system based on Dissolved Gas Analysis (DGA) technique for diagnosis of suspected transformers faults and their maintenance action are developed. The synthetic method is proposed to assist the popular gas ratio methods. This expert system is implemented into PC by using "Turbo Prolog" with rule based knowledge representations. The designed expert system has been tested for N.T.P.C., Talcher (India) transformer's gas ratio records to show its effectiveness in transformer diagnosis.

1 INTRODUCTION

Like any diagnosis problems, diagnosis of an oil-immersed transformer is a skilled task. A transformer may function well externally with monitors, while some incipient deterioration may occur internally to cause fatal problem in later development. Nearly 80 % of faults result from incipient deteriorations. Therefore, faults should be identified and avoided at earliest possible stage by some predictive maintenance technique.

DGA is very efficient tool for this purpose. Like a blood test or a scanner examination of the human body, it can warn about an impendent problem, give an early diagnosis and increase the chances of finding the appropriate cure. The operating principle is based on slight harmless deterioration of the insulation that accompanies incipient faults, in the form of arcs or sparks resulting from dielectric breakdown of weak or overstressed parts of the insulation, or hot spot due to abnormally high current densities in conductors, whatever the cause, these stresses will result in chemical breakdown of some of the oil or cellulose molecules consisting the dielectric insulation. The main degradation products are gases, which entirely or partially dissolve in the oil where they are easily detected at the ppm level by DGA analysis

2 DEVELOPMENT OF DIAGNOSIS AND INTERPRETATION

Oil degradation and other insulating materials e.g., cellulose and paper generally produce fault gases in transformers. Theoretically, if an incipient fault is present, the individual gas concentration, generating

K. Dhote N., M.Holey D. and R.Ramteke M. (2004).
DEVELOPMENT OF AN EXPERT SYSTEM FOR DETECTING INCIPIENT FAULT IN TRANSFORMER BY DISSOLVED GAS ANALYSIS.
In *Proceedings of the Sixth International Conference on Enterprise Information Systems*, pages 210-215
DOI: 10.5220/0002630302100215

rate and total combustible gas (TCG) are all significantly increased.

By using gas chromatography [4,6] to analyze the gas dissolved in transformer's insulating oil, it becomes feasible to judge the incipient fault types. The main gases formed as a result of electrical and thermal faults in transformers and evaluated by DGA are H_2, CH_4, C_2H_2, C_2H_4, C_2H_6, CO, CO_2. Their relative proportions have been co related through empirical observations and laboratory simulations, with various types of transformer encountered in transformer in service

Many interpretative methods based on DGA to diagnose the nature of incipient deteriorations have been reported. Even under normal transformer operational conditions, some of these gases may be formed inside. Thus, it is necessary to build concentration norms from a sufficiently large sampling to asses the statistics.

A Key Gas Method [2] based on thermodynamic considerations. The degree of chemical instauration of the gases formed is related to the energy density of the fault. Acetylene is thus mainly associated with arcing, where temperature reach several thousands degrees, Ethylene with the hot spot between 150 ^{0}C and 1000^0 C and Hydrogen with the "cold" gas plasma of corona discharges.

Dornerburg [1] developed a method to judge different faults by rating pairs of concentrations of gases, e.g., CH_4 / H_2, C_2H_2 / C_2H_4 with approximately equal solubilities and diffusion coefficients.

Rogers [2] established more competitive ratio codes to interpret the thermal fault types with theoretical thermodynamic assessments. This gas ratio method was promising because it eliminated the effect of oil volume and simplified the choice of units. Moreover it systematically classified the diagnosis expertise.

Table 1: IEC/IEEE codes for the interpretation of DGA results

C2H2/ C2H4	CH4/H2	C2H4/ C2H6	Range of gas ratio
0	1	0	< 0.1
1	0	0	0.1-1
1	2	1	1-3
2	2	2	Greater than 3
Characteristic Fault :			
0	0	0	Normal ageing
2	1	0	Partial discharge of low energy density
1	1	0	Partial discharge of high energy density
1-2	0	1-2	Continuous sparking
1	0	2	Discharge of high energy
0	0	1	Thermal fault of low temp <150 deg cel
0	2	0	Thermal fault of low temp between 150-300 deg cel
0	2	1	Thermal fault of medium temp between 300-700 deg cel
0	2	2	Thermal fault of high temp >770 deg cel

A very recent method, which gives more correct result about the interpretation of fault, is Evolutionary Fuzzy Diagnosis System, EFDS [7]. This method also uses three gas ratios. The ratios are scaled into symbolic codes. The advantage of this method is that if there is more than one fault developing at same time, this system finds out the all the faults with their possibility values.

The most widely used tool for this purpose is the IEC-IEEE [2] ratio method depicted in Table1. One drawback of this method in its present form is that a significant number of DGA results in service fall outside the proposed codes and cannot be diagnosed. Other methods that overcome this limitation have therefore been developed.

3 THE PROPOSED DIAGNOSTIC EXPERT SYSTEM

This study is aimed as developing a rule-based expert system to perform transformer diagnosis. The details of system are described below:

3.1 Expert System Structure

Expert system is one of the area of Artificial Intelligence (AI) which has moved out from research laboratory to the real word and is shown its potential in industrial and commercial application .An expert system is computer system which can act a human expert within one particular field of knowledge .The expert system embodies knowledge about one specific problem domain and possesses the ability to apply this knowledge to solve problem domain. Ideally the expert system can also learn from its mistakes and gain experience from its successes and failure. The system should able to explain the reasoning behind the way in which it has aimed at a particular conclusion.

An expert system comprises three base components.

1. Knowledge base
2. An inference engine
3. An user interface

The 'Knowledge Base' comprises a series of facts and rules about the particular problem area from which system draws its expertise. A fact is a clear concise statement, which expresses something, which is true within particular problem domain. A rule used in this system is expressed in If- Then forms. A successful expert system depends on a high quality knowledge base. For this transformer diagnosis system, the knowledge base incorporates some particular interpretation methods of DGA. In order to make use of the expertise which is embodied in the knowledge base. The expert system must also posses an element, which can scan facts and rules and provide answers to the queries given to it by the user. This element is known as 'Inference Engine'. The Inference Engine has the ability to look through he knowledge base and apply the rules to the solution of a particular problem. It is a component that generates new knowledge from base knowledge .It is, therefore, the driving force of the expert system.

The 'User Interface' is the means by which the user communicates with the expert system and vice versa. Ideally this interface should be as simple as possible so as to facilitate its use by the experienced users. That is an ideal expert system would allow the user to type his questions to the system in English. The system would then recognize the meaning of the questions and use its inference engine to apply the rules in the knowledge base to deduce an answer. This answer would then be communicated back to user in English.

3.2 The Proposed Diagnostic Method

Diagnosis is a task that requires experience. It is unwise to determine an approach from only a few investigations. Therefore, this study uses synthetic 'expertise method, with the experienced procedure to assist the gas ratio method. For the development of any expert system, there should be proper selection of a development tool. The different packages i.e., Expert system, Shell, Rule master, etc. can also be used for development, but these packages have their own limitations, since they use their own rules and instructions. But a computer language is more flexible and the user can develop his own methodology for the program formulation. So instead of using package, we can choose computer language for expert system development. The language chosen should be simple and declarative. 'Turbo prolog' has these facilities. One of the major advantages of prolog is that it has its own inference engine, which facilitates easy development of expert system. Therefore, prolog has been used for the development of proposed expert system.

3.3 Experienced Diagnostic Procedure

As shown in figure 1, the overall procedure of routine maintenance for transformer is listed. The core of this procedure is based on the implementation of DGA techniques. The gas ratio method is significant knowledge source. The Key gas method [2], Dornerburg [1], Rogers [2], IEC [2] and EFDS [7] approaches have been implemented together. The single ratio method is unable to cover all possible cases; other diagnostic expertise should be used to assist this method. Synthetic expertise method and database records have been incorporated to complete these limitations.

The first step of this diagnostic procedure begins by asking DGA for an sample to be tested, more important information about transformer's condition such as VA rating, Voltage rating, volume of oil in tank and date of installation of transformer must be known for further inference. If the transformer is not degassed after previous diagnosis, then probability of fault and rate of evolution of total combustible gases are found. If rate of evolution is normal, further diagnosis can be bypassed. Permissible limits for different gases are checked. For the abnormal cases, the gas ratio method is used to diagnose transformer fault type. If different diagnosis results are found from these ratio methods, a system diagnosis is adopted. After these procedures, different severity degrees are assigned to allow appropriate maintenance suggestions.

4 IMPLEMENTATION OF PROPOSED EXPERT SYSTEM

An expert system is developed based on the proposed interpretative rules and diagnostic procedure of an overall system. To demonstrate the feasibility of this expert system in diagnosis, the gases data are supported by 'NTPC, Talcher' have been tested. After analyzing oil samples, more than Ten years worthy gas records are collected. In the process of DGA interpretation, all of these data may be considered, but only data that have significant effects on diagnosis are listed in the later demonstration. From the expertise of diagnosis, normal state can be confirmed only by inspection of the transformer's normal level. In practice, most of the transformer oil samples are normal, and this can be inferred successfully on the early execution of this expert system. However, the success of an expert system is mainly dependent on the capability of diagnosis for transformers in question. In the implementation, many gas records that are in abnormal condition are chosen to test the justification of this diagnostic system. Amongst those implemented, two are listed and demonstrated

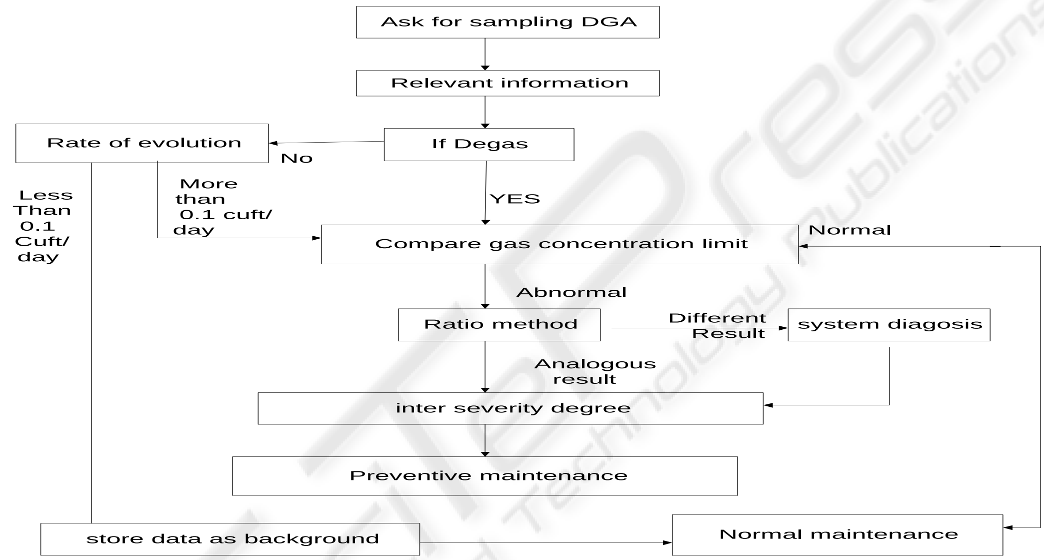


Figure 1: Procedure of proposed expert system

DATA:
TSTPS1, Date of installation: 12/03/90
200MVA, 400KV /21KV,
Volume of tank: 500 gallons.

Table 2: Concentration of gases in PPM.

Sample No.	Date of sampling	Whether Diagnosed	C2 H2	C2 H4	C H4	H2	C2 H6	CO	CO2
			Concentration of gases in ppm.						
1	29/07/96	Yes	0	3	2	2	8	0	25
2	25/12/96	No	35	105	490	383	53	88	589

Sample-1

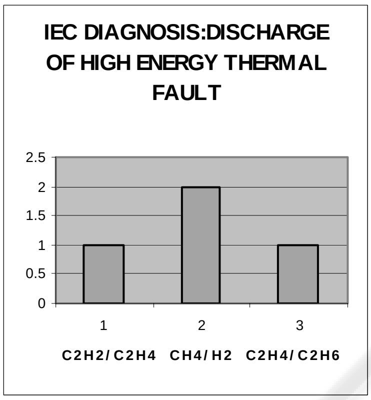
Results of Sample Implementation:

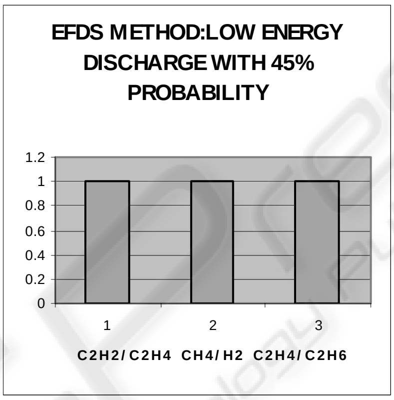
* All gases are within the safe level.
- Normal ageing of transformer.

Sample –2

Results of Sample Implementation:

Rate of TCG = 1.29 cu.ft. /day
Key Gas Method: Severe Overheating
Dornerburg Ratio: Thermal Decomposition.
Roger’s Ratio Method: Winding circulating currents
IEC Method: Discharge of high-energy thermal fault (300-700 deg .C)
EFDS Method: Low energy discharge with 45 % probability.
System Diagnosis: Low energy discharge





Recommendation of maintenance:

- Investigate immediately.
- Oil should be degassed.
- Retest oil within half month.

---

5 CONCLUSION

Prototype expert system is developed on a PC using ‘Turbo Prolog’. It can diagnose the incipient faults of the suspected transformers and suggest proper maintenance actions. System diagnosis is proposed to assist the situation, which cannot be handled properly by gas ratio methods. Results from the implementation of the expert system shows that the expert system is a useful tool to assist human experts and maintenance engineers.
The knowledge of this expert system is incorporated within the particular interpretative methods of DGA. The data base supported by NTPC, Talcher for about 10 years collection of transformer inspection is also used to improve the interpretation of diagnosis. The two examples presented are depicted from records and symmetry of test results is listed to justify them. This work can be continued to expand the knowledge base by adding any new experience, measurement and analysis techniques.

REFERENCES

E. Dornerburg, W.Strittmatter, Monitoring Oil Cooling Transformers by Gas Analysis, Brown Boveri Review, 61,pp 238-247,May 1974.

R.R.Rogers, IEEE and IEC Codes to Interpret Incipient Faults in Transformers, Using Gas in Oil Analysis, IEEE Trans. E.I., Vol. EI –13, NO.-5,pp 349-354,oct 1978.

M.Duval, Hydro-Qubec, It Can Save Your Transformer, IEEE Electrical Insulation Magazine, Vol.5, No.6, Nov/Dec 1989.

ASTM Method D 3612, Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography, 1979.

G.Belanger, M.Duval, Monitor for Hydrogen dissolved in transformer Oil, 'Hydran' Available from Syprotech Inc., Canada, IEEE Trans. on Electrical Insulation, Vol E1-12, No.-5,pp 335-340,1977.

H.Tsukioka, K.Sugawara, E. Mori, S.Hukumari, S.Sakau,New Apparatus for Detecting H2, CO, & CH4 Dissolved in Transformer Oil, IEEE Trans. Electrical Insulation, Vol. E1-18, No.4, pp 409-419, 1983.

Yann- Chang Huang, Hong-Tza Yang, Ching-Lien Hnany, Developing a New Transformer Fault Diagnosis System Through Evolutionary Fuzzy Logic, IEEE Trans. on Power Delivery, Vol.12, No2, April 1997.

ANSI / IEEE CS7.104-1978,Guide for the Detection and Determination of Generated Gases in Oil Immersed Transformer and Relating to the Serviceability of the Equipment.