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Conditioning Monitoring of Transformer by Dissolved Gas Analysis by Matlab with Case Studies

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Abstract:
Reliable operation of transformers largely depends o n a lifetime of insulating system. Due to the complexity of the power transformer design, operational and maintenance policies, it is impossible to accurately predict the expected life of a transformer. Consequently, power system operators have to depend on various condition monitoring and condition assessment techniques available to determine plant condition and remnant life. This paper deals with dissolved Gas Analysis (DGA) which is a widely used technique to estimate the condition of oil-immersed transformers. The measurement of the level and the change of combustible gases in the insulating oil is a trustworthy diagnostic tool which can be used as indicator of undesirable events occurring inside the transformer, such as hot spots, electrical arcing or partial discharge. The objective of my study is mainly to analyze available data from DGA, and investigate data that may be useful in quantitative modeling of the transformer's reliability. The experimental results showed that the application of faults occurring in transformer oils increased the concentration of combustible gases such as hydrogen, methane, ethane, ethylene and acetylene, etc. Dissolved gas analysis were done using Key gases, Roger's ratio The calculation includes condition ratings, weighting factors, and assigned scores for specific condition parameters by using mat lab programming.

Keywords: *DGA, key gas analysis, roger's ratio, fault detection techniques, chromatography, Matlab.*

1. Introduction

Condition monitoring is the process of monitoring a parameter of condition in machinery, such that a significant change is indicative of a developing failure. It is a major component of predictive maintenance. The use of conditional monitoring allows maintenance to be scheduled, or other actions to be taken to avoid the consequences of failure, before the failure occurs. Transformer is one of the most important and critical component of electricity transmission and distribution system. In service, transformers are subject to electrical and thermal stresses, which can cause the degradation of the insulating materials. The degradation products are gases, which entirely or partially dissolve in the oil where they are easily detected at the ppm level by dissolved gas analysis. Transformer oil sample analysis is a useful, predictive, maintenance tool for determining transformer health. Along with the oil sample quality tests, performing a dissolved gas analysis (DGA) of the insulating oil is useful in evaluating transformer health. It is generally accepted that the incipient electrical failures inside the winding of the power transformer are responsible for gas evolvement of the mineral insulating oil generally called gassing. The cause of incipient failures is currently attributed to local overheating which generates hot spots as well as points of excessive electrical stress that produce partial discharges. DGA allows gases to be extracted from oil and their subsequent chemical decomposition to be determined. Based on variable amount of components identified in the blend such as N_2,O_2,CO, CO_2 ,CH_4, C_2H_6,C_2H_4 ,C_2H_2 , several diagnostic methods have developed to establish the nature of the incipient failures and the risk it poses to the service reliability of the unit.

2. Dissolved Gas Analysis

Decomposition of gases in oil and paper insulation of transformers caused by faults depends on temperature of faults. Various faults produce certain gases and the percent of some gases have been found to indicate fault types, such as overheated oil and cellulose, corona in oil and arching in oil. DGA is widely used in diagnostics of the transformer condition. In this method a sample of the oil is taken from the unit and the dissolved gases are extracted. Then the extracted gases are separated, identified, and quantitatively determined. The main advantage of the DGA technique is that it detects the gases in the oil phase giving the earliest possible detection of an incipient fault. This advantage alone outweighs any disadvantages of this technique. DGA Is a widely used technique to estimate the condition of oil-immersed transformers. The measurement of the level and the change of combustible gases in the insulating oil is a trustworthy diagnostic tool which can be used as indicator of undesirable events occurring inside the transformer. The DGA technique detects gas in parts per million (ppm) dissolved oil by the use of gas extraction unit and a gas chromatograph. It checks whether a transformer under service is being subjected to a normal aging and healthy or whether there are incipient defects such as hot spots, arcing, overheating or partial discharge. The most commonly measured gases are:

(i). Hydrocarbons and hydrogen
Methane CH_4
Ethane C_2H_6
Ethylene C_2H_4
AcetyleneC_2H_2
Hydrogen H_2
(ii). Carbon oxides
Carbon monoxide CO
Carbon dioxide CO_2
(iii). Non-fault gases
Nitrogen N_2,Oxygen O_2

2.1. Steps for DGA Analysis

- Oil sampling
- Extraction of all the gases in the oil sample.
- Separation of gases (gas chromatography).

2.1.1. Oil Sampling

Sampling of oil is carried out using apparatus and methods. The most appropriate container is a gas-tight glass syringe of suitable capacity and fitted with a three-way sampling cock. Oil samples shall be representative of the bulk of the oil in the equipment. Oil samples shall be taken from the main oil stream: points outside the main oil stream shall be disregarded. To prevent oxidation the samples shall be shielded from direct light by wrapping the container in aluminium foil or by storing in an opaque enclosure. The procurement of representative sample of oil from a transformer is very important and the sample should be collected and transported in such a way that the gases dissolved in the oil are not subject to any changes. Sampling by syringe, as shown in figure shown below, is probably the most popular technique although other techniques are also available. Oil samples are usually taken at the bottom of the tank, from the drain valve, but also for special purposes, at the top from the radiators, or the gas relay. filled syringe is then sent to the laboratory for analysis.

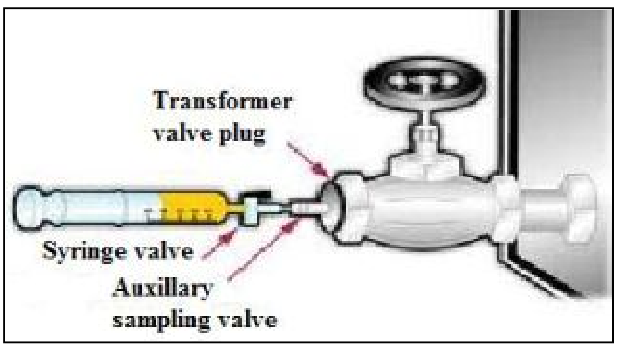

Figure 1: Oil sampling

2.1.2. Extraction of Gases

After collecting a reprehensive sample the important step is the extractions of gasses from the oil unless complete extraction can be achieved the results obtained cannot be relied upon. Considerable difficulties can be encored in procuring assembly should fulfill the following given conditions.

i. High vacuum must be must be used throughout the apparatus.

ii. The apparatus must be designed in such a way that it must be checked carefully that vaccum collection ratio is achieved for the given sample. To avoid gas losses until the time of extraction the oils were tapped into amber coloured glass bottles filled to the brim without air space and allowed only minimum gas extraction apparatus permits degassing of the oil at a temperature of 100 degree having two limbs of equal volume was designed to be connected and injected on to gas sampling valve the gas sampled can be collected and injected on the gas chromatograph with a gas tight syringe directly .The efficiently of gassing was tested by repeating the degassing procedure on the each component gas in the sample extracted

2.1.3. Gas Chromatography

Gas Chromatography was first demonstrated experimental in 1906 by michel .tswett a russian botanist on the basis of difference as an analytical technique for separating compounds on the basis of difference in affinity for stationary and mobile phases.Gas chromatography is basically a technique for effecting a separation of the various constituents of a gas mixture in gas chromatography the separation of components in a mixture is achieved by the difference in property of the components to be adsorbed to the different extents in the column .the component which is held most strongly to the column elutes at the end the gas sample to be analyzed is made to flow via inert carrier gas through a column packed with a specific material which interact with each constituent of the gas mixture to a varying degree .the varying rate of interaction of each gas mixture results in various velocities of the individual gases as they flow through and emerge from the column .it is identified by an appropriate detector whose output is recorded on a chart in the form of peaks : each gas peak corresponding to a different constituent of the original gas mixture. The gas chromatographic apparatus consist of a gas steam supplied by gas cylinder a sample injection port, a chromatographic column a detector and a strip chart recorder .The apparatus is as shown:-

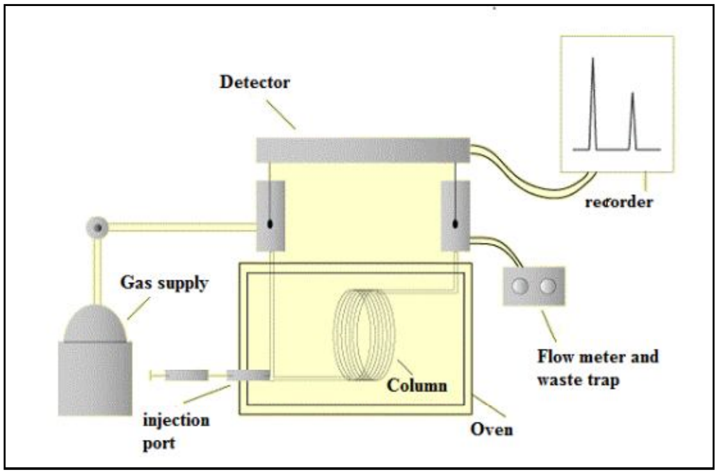

Figure 2: Gas chromatography apparatus

A Chromatogram is the plot of the detector response which measures the change of composition of the column effluent against time or volume of the carrier gas. The chromatogram may be of two types via, differential and integral depending on whether it measures the instantaneously concentration in the effluent of the gas or of the total amount of the sample accumulated form the beginning of the analyses. The peak which is generally a Gaussian Peak (bell shaped) is a portion of the chromatogram which is recorded on the detector while the component emerges from the column. Integral chromatogram is usually manually plotted in which the vertical axis represents the amount of the sample accumulated in mV.

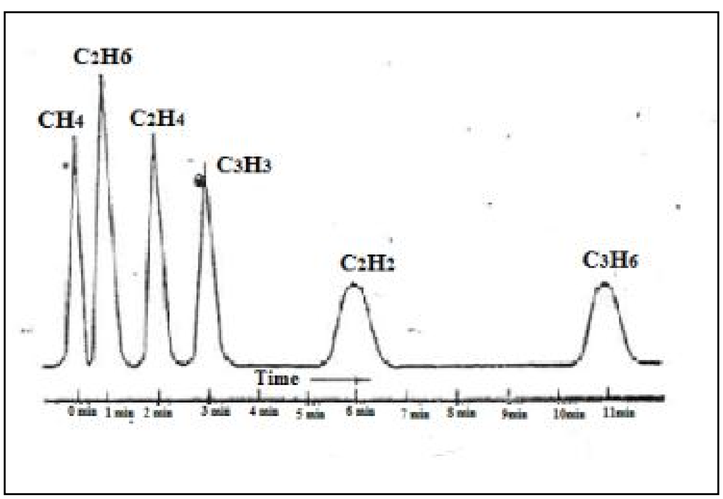

Figure 3: Gas Chromatogram

3. Fault Detection Techniques

3.1. Key Gas

Key Gas method becomes applicable to transformer with developed faults where absolute values of key gases are considered. The key gases are acetylene, hydrogen, ethylene and carbon monoxide. Following table illustrates the nature of faults, when key gas is abnormally high.

KEY GAS	NATURE OF FAULT
Acetylene C2H2	Electrical arc in oil
Hydrogen H2	Corona , partial discharge
Ethylene C2H4	Thermal degradation of oil
Carbon Monoxide	Thermal ageing of oil

Table 1: Key gases

GAS CONTENTS		NATURE OF FAULT
MAJOR	MINOR	
Ethylene	Ethane	Thermal Decomposition
Methane	Hydrogen	(Hot Spots)
Hydrogen Methane	Acetylene Ethylene Ethane	Electrical Discharge (Except Corona)
Hydrogen	Methane Ethane	Internal Corona
Carbon Monoxide		Cellulosic insulation decomposition
Carbon Dioxide		Cellulosic insulation decomposition

Table 2: Various Types of Faults Depending on the Gas Composition

On the basis of the history, we have developed a table for the maximum threshold concentrations of the fault gases which has been given below.

Gas	Less than 4 Years in service	4-10 years in service	More than 10years in services
Hydrogen	100-150	200-300	200-300
Methane	50-70	100-150	200-300
Acetyiene	20-30	30-50	100-150
Ethylene	100-150	150-200	200-400
Ethane	30-50	100-150	800-1000
Carbon monoxide	200-300	400-500	600-700
Carbon dioxide	3000-3500	4000-5000	9000-12000

Table 2: Permissible Gas Limits for Different Gases

3.2. Roger Ratio Method

The ratio methods are the most widely used technique. Roger, Dorenburg and IEC ratios are all used by utilities. First the four ratios CH_4/H_2, C_2H_6/CH_4, C_2H_2/C_2H_4, C_2H_4/C_2H_6, are found out on given values, then depending upon these ratios faults are detected on the bases of following tables:

CH_4/H_2	C_2H_6/CH_4	C_2H_4/C_2H_6	C_2H_2/C_2H_4	Evolution
0	0	0	0	**If CH4/H2 <0.1, then partial discharge otherwise normal deterioration**
1	0	0	0	Slight overheating below 150*C
1	1	0	0	slight overheating 150*C- 200*C
0	1	0	0	Slight overheating 200*C 300*C
0	0	1	0	General conductor overheating
1	0	1	0	Circulating currents, overheated joint
0	0	0	1	Flashover without power follow through
0	1	0	1	Tap changer selector breaking current
0	0	1	1	Arc with power follow through or persistent sparking

Table 3: Standards for Roger Ratio

4. MATLAB

It is a programming environment for algorithm development, data analysis, visualization, and numerical computation. Using MATLAB, you can solve technical computing problems even faster compared to the traditional programming languages. This programming helps to find automatic results from the data obtained from the procedure used in dissolved gas analysis. It helps to obtain accurate type of fault at its initial stage of occurrence.

Gas	Case i 4yrs	Case ii 6yrs	Case iii 10yrs
CH_4	54	69	43
C_2H_6	21	44	40
C_2H_4	41	39	50
C_2H_2	130	26	240
CO_2	ND	119	145
CO	550	23	ND
H_2	200	110	148
FAULTS	circulating currents and overheating of joints	normal aging	persistence sparking

Table 4: Key gas result analysis

Gas	Case i 4yrs	Case ii 6yrs	Case iii 10yrs
CH_4	54	69	43
C_2H_6	21	44	40
C_2H_4	41	39	50
C_2H_2	130	26	240
CO_2	ND	119	145
CO	550	23	ND
H_2	200	110	148
FAULTS	circulating currents and overheating of joints	normal aging	persistence sparking

Table 5: Roger's Ratio analysis results

5. Conclusion

Although the objectives set forth at the outset of this thesis have been successfully achieved .In this dissertation work complete study of the fault detection with the help of Dissolved Gas Analysis have been done. The conclusion is that proposed method of Dissolved gas analysis is more effective and more intelligent than existing method in which all the calculations were done manually. By trending the dissolved gas levels, problems can be identified and evaluated further before they cause a catastrophic failure of the transformer as detailed knowledge of operation state of transformer is required as one of the fundamental conditions of electric power network operation. This knowledge also enables transformer operation with minimum risk of unexpected failure. With the help of new effective method using matlab programming language we can directly get the complete information about the health of the transformer.

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