FAULT DETECTION TECHNIQUES FOR TRANSFORMER MAINTENANCE USING DISSOLVED GAS ANALYSIS

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Abstract

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 modelling of the transformer's reliability. There are standards available for this purpose the DGA interpretation should also be based on other information about the reliable particular transformer. This paper describes a realistic method for power transformers using readily available data. The method considers practical limitations on obtaining data and possible constraints on the parameters utilize IEC, IEEE. Dissolved Gas Analysis (DGA) is a widely used technique to estimate the condition of oil-immersed transformers. Incipient faults within the transformer may be detected by analyzing the gases which are dissolved in the transformer-oil. The objective of this paper is mainly to analyze available data from DGA, and investigate the types of fault. The calculation considers not only typical test results but also consist of specific mat lab programming for proper detection of faults from available data from DGA.

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.

TABLE I
CATEGORIZATION OF FAULT GASES

1. Corona	
a. Oil	H_2
b. Cellulose	H_2, CO, CO_2
2. Pyrolysis	
a. Oil	

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Low temperature	CH_4, C_2H_6
High temperature	C_2H_4, H_2(CH_4, C_2H_6)
b. Cellulose	
Low temperature	CO_2 (CO)
High temperature	CO (CO_2)
3. Arcing	H_2,C_2H_2(CH_4,C_2H_6,C_2H_4)

2. Types of Fault detectable by DGA

Fault conditions occur primarily from the thermal and electrical deterioration of oil and electrical insulation. Each combustible gas level will vary depending upon the fault process.

i. Arcing faults

Large amounts of hydrogen and acetylene are produced, with minor quantities of methane and ethylene. Arcing occurs through high current and high temperature conditions. Carbon dioxide and carbon monoxide may also be formed if the fault involved cellulose. In some instances, the oil may become carbonized.

ii. Corona

Corona is a low-energy electrical fault. Low-energy electrical discharges produce hydrogen and methane, with small quantities of ethane and ethylene. Comparable amounts of carbon monoxide and dioxide may result from discharge in cellulose.

iii. Sparking

Sparking occurs as an intermittent high voltage flashover without high current. Increased levels of methane and ethane are detected without concurrent increases in acetylene, ethylene or hydrogen.

iv. Overheating

Decomposition products include ethylene and methane, together with smaller quantities of hydrogen and ethane. Traces of acetylene may be formed if the fault is severe or involves electrical contacts.

v. Overheated Cellulose

Large quantities of carbon dioxide and carbon monoxide are evolved from overheated cellulose. Hydrocarbon gases, such as methane and ethylene, will be formed if the fault involved an oil-impregnated structure.

vi. Partial Discharge

The temperature plays a less important role in the chemical reaction occurring in the partial discharges since the vapour temperature in the discharge zone is not higher than 60-150°C. Hydrocarbon cracking in the partial discharges occurs as a result of excitation of molecules and their subsequent dissociation by collision with high energy electrons, ions, atomic hydrogen and also free radicals.

3. DISSOLVED GAS ANALYSIS (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:

- O_2 (Oxygen)
- CH_4 (Methane)
- N_2 (Nitrogen)
- C_2H_2 (Ethane)
- H_2 (Hydrogen)
- C_2H_4 (Ethylene)
- CO (Carbon Monoxide)
- C_2H_2 (Acetylene)
- CO_2 (Carbon Dioxide)

The DGA analysis is performed in four steps:

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

i. 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. The filled syringe is then sent to the laboratory for analysis.

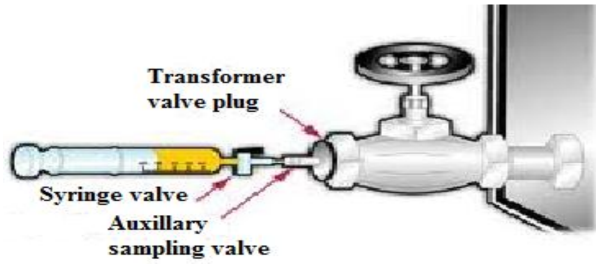

Fig. 1 Oil sampling by syringe

ii. 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.

iii. 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:-

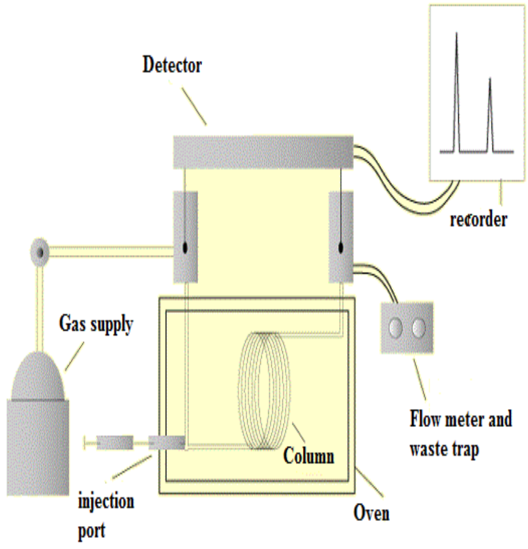

Fig. 2 Gas chromatography apparatus.

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.

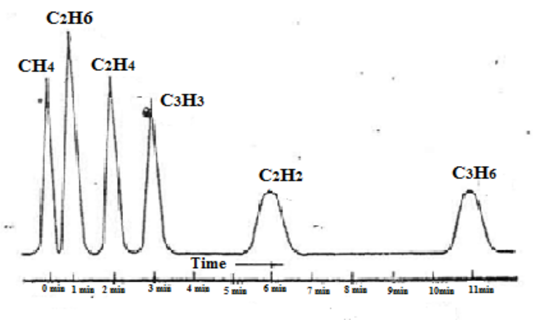

Fig. 3 Gas Chromatogram

4. METHODS FOR FAULT DETECTION

i. Key gas method

The most frequently used empirical methods are the key gas or interpretive method, based on establishing maximum threshold concentrations for each fault gas, can be applied without modification to the analysis of fault gases formed in load tap changers The Key Gas Method simply utilises relative percentages of the selected fingerprint gases to identify fault types. This method actually uses four characteristic charts which represent typical relative gas concentrations for four general fault types, i.e. Overheating of Cellulose (OHC), Overheating of Oil (OHO), Partial Discharge (PD) or Arcing, corona.

TABLE II

Permissible Gas Limits for Different Gases

Gas	Less than 4 Years in service	4-10 years in service	More than 10 years 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

ii. Roger's ratio method

The ratio methods are the most widely used technique. Roger, Dorenburg and IEC ratios are all used by utilities.Typically, three or four ratios are used for sufficient accuracy, such as the initial Roger's ratio method uses four ratios (CH_4/ H_2,C_2H_6/ CH_4,C_2H_2/ C_2H_4,C_2H_4/C_2H_6)to diagnose incipient fault conditions and a normal condition. 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:

TABLE III

Fault classification according to Rogers's Ratio Method

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

5. 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.

TABLE IV

Key gas analysis results

GAS	CASE I	CASE II	CASE III
CH_4	54	65	250
C_2H_6	21	40	950
C_2H_4	41	110	300
C_2H_2	130	40	190
CO_2	ND	145	2163
CO	550	210	210
H_2	200	130	750
Diagnostic Result	sparking , local and severe overheating faults	arcing, normal aging	arcing and severe overheating

TABLE V

Roger's Ratio analysis results

GAS	CASE I	CASE II	CASE III
CH_4	11646	69	43
C_2H_6	9901	44	40
C_2H_4	46976	39	50
C_2H_2	407	26	145
CO_2	1322	119	ND
CO	ND	23	148
H_2	348	110	750
Diagnostic Result	circulating currents and overheating of joints	normal aging	persistence sparking

6. CONCLUSION

Although the objectives set forth at the outset of this paper have been successfully achieved.In this paper complete study of the fault detection with the help of Dissolved Gas Analysis technique 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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