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Diagnosis of Power Transformer Depending on Dissolved Gas Analysis

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Dissolved Gas Analysis

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

GUI	Graphic User Interface
DGA	Dissolved Gas Analysis
TDG	Total Dissolved Gas
TCG	Total Combustible Gases
GBA	Gas Blanket Analysis
H2	Hydrogen
N2	Nitrogen
O2	Oxygen
H2O	Water
CO	Carbon Monoxide
CO2	Carbon Dioxide
C2H2	Acetylene
CH4	Methane
C2H6	Ethane
C2H4	Ethylene

LIST OF FIGURES

Figure 8.3: Result window- Identification of incipient faults of Transformer oil by comparing five diagnosis Methods

LIST OF TABLES

Chapter 1

INTRODUCTION

Overview:

Present chapter describes the introduction of project work. Also describes about main motivation of this work followed by main objectives. This chapter also describes the organization of thesis.

1.1 <u>Introduction</u>

In entire power transmission network transformer plays an important role, it transmits the power from one circuit to another circuit. So transformer protection attains much more attention in order fault free electric supply, maximize transformer life period and efficiency. Actually mineral oil treats heart of the transformer, it serves mainly insulation and cooling purpose but among that it is use to detect the fault gases dissolved in oil. The identification of specific gasses created in a transformer in administration is regularly the first accessible sign of a malfunction. If these faults are not correct, transformer may goes to failure. This is not encourage thing, it may cause to damage entire power transmission and not economical. Before failure of transformer, detection of fault is better option. So Dissolved Gas Analysis (DGA) is proved accuracy method to find faults. DGA mainly involves extracting or stripping of oil from the unit and subject to Gas Chromatography to extract the dissolved gases from oil [1]. The second step of DGA is detection of gas concentration levels using suitable methods like Flame Ionization detector, Thermal conduction detector (FID, TCD) and analyze for faults by using suitable diagnostic methods to find cause [2].

In this work, the condition based diagnosis system developed to combine five DGA classical methods-Keys Gas Method, Rogers Ratio Method, IEC Ratio method, Doernenburg ratio method and Duval triangle method. A feasible

MATLAB GUI conferred to give visual display of five methods. The result of this method shows overall DGA accuracy is more than 90% compared to 80% of most reliable individual method. DGA helps to diagnosis the present condition of the high voltage power transformer. Further, this method is also applicable to other oil filled high voltage power equipment for assessment of its condition during the operating service period of time.

1.2 Motivation

Dissolved *Gas Analysis* (DGA) has most proved accuracy method for condition assessment of power transformer. This gives prior information regarding mineral oil degradation level and generated dissolved gasses in mineral oil and concentration of dissolved gases by using Gas Chromatography. Taking the concentration of key gases (CO, CO_2, CH_4, C_2H_6, C_2H_2, H_2 and C_2H_4) incident faults identified by various classical techniques gives different conditions for the same sample unit. In this work considered the point, which discussed in above line and design combine of all five diagnosis methods for better accuracy results to diagnosis of incipient faults.

1.3 Thesis Main Objectives

☐ Analyze five classical diagnosis techniques to identify incipient faults in Transformer oil using 1. Key Gas method, 2. Rogers's Ratio Method, 3. Doernenburg Ratio Method, 4. IEC Ratio Method and 5. Duval Triangle Method

☐ Design combine five diagnosis methods of DGA for condition assessment of Power Transformer

1.4 Organization of Thesis

The entire thesis organization is as follows

Chapter 1: Deals with introduction of entire work follows by motivation and also discussed about main objectives of this work and finally organization of thesis are discussed.

Chapter 2: Deals with theory of transformer by talking about working principle of transformer then follows by use of power transformer and types of transformer and finally discussed about insulation materials used in transformer.

Chapter 3: Deals with introduction of insulating oil follows by types of transformer oil and finally discussed about properties of transformer insulating oil.

Chapter 4: Deals with gas formation in mineral oil, degradation level and factors Effect on mineral oil for dissolved gases.

Chapter 5: Deals with DGA interpretation techniques and the block diagram model design of DGA combined five methods and also it deals with one of the interpretation Technique -Key gas method.

Chapter 6: Deals with DGA interpretation techniques like Roger's ratio, IEC ratio, Doernenburg ratio methods and their codes representation for each method

Chapter 7: Deals with most accuracy DGA interpretation technique Duval's triangle method and its zones representation for all type of faults are discussed.

Chapter 8: Deals with mapping process of all type of faults to each diagnostic method. Finally conclude the type of fault exist by mapping of all faults to common indication to each method. A feasible GUI conferred to give visual display of five methods. The result of this method shows overall DGA accuracy is more than 90% compared to 80% of most reliable individual method.

Chapter 9: Deals with the general conclusions of the work done followed by future scope and references.

Chapter 2

INTRODUCTION OF TRANSFORME

Overview:

Present chapter describes the introduction of transformer. . This chapter also describes the organization of thesis.

2.1 Introduction

2.1.1 Definition of Transformer:

Electrical power transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings. It transforms power from one circuit to another without changing its frequency but may be in different voltage level.

This is a very short and simple definition of transformer, as we will go through this portion of tutorial related to electrical power transformer, we will understand more clearly and deeply "what is transformer ?" and basic theory of transformer.

2.1.2 Working Principle of Transformer:

The working principle of transformer is very simple. It depends upon Faraday's law of electromagnetic induction. Actually, mutual induction between two or more winding is responsible for transformation action in an electrical transformer.

2.1.3 Faraday's Laws of Electromagnetic Induction:

According to these Faraday's laws, "Rate of change of flux linkage with respect to time is directly proportional to the induced EMF in a conductor or coil".

2.2 Basic Theory of Transformer:

Say you have one winding which is supplied by an alternating electrical source. The alternating current through the winding produces a continually changing flux or alternating flux that surrounds the winding. If any other winding is brought nearer to the previous one, obviously some portion of this flux will link with the second. As this flux is continually changing in its amplitude and direction, there must be a change in flux linkage in the second winding or coil. According to Faraday's law of electromagnetic induction, there must be an EMF induced in the second. If the circuit

of the later winding is closed, there must be a current flowing through it. This is the simplest form of electrical power transformer and this is the most basic of working principle of transformer.

For better understanding, we are trying to repeat the above explanation in a more brief way here. Whenever we apply alternating current to an electric coil, there will be an alternating flux surrounding that coil. Now if we bring another coil near the first one, there will be an alternating flux linkage with that second coil. As the flux is alternating, there will be obviously a rate of change in flux linkage with respect to time in the second coil. Naturally emf will be induced in it as per Faraday's law of electromagnetic induction. This is the most basic concept of the theory of transformer. The winding which takes electrical power from the source, is generally known as primary winding of transformer. Here in our above example it is first winding.
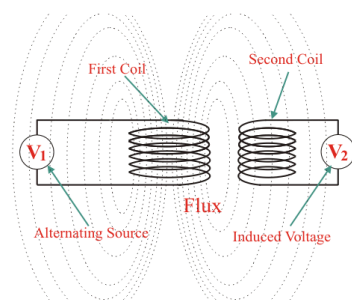
Figure2.1: Mutual induction between primary and secondary winding in the transformer

The winding which gives the desired output voltage due to mutual induction in the transformer, is commonly known as secondary winding of transformer. Here in our example it is second winding.
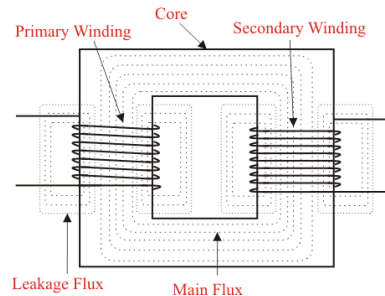
Figure2.2: Main components of transformer

The above mentioned form of transformer is theoretically possible but not practically, because in open air very tiny portion of the flux of the first winding will link with second; so the current that flows through the closed circuit of later, will be so small in amount that it will be difficult to measure.

The rate of change of flux linkage depends upon the amount of linked flux with the second winding. So, it is desired to be linked to almost all flux of primary winding to the secondary winding. This is effectively and efficiently done by placing one low reluctance path common to both of the winding. This low reluctance path is core of transformer, through which maximum number of flux produced by the primary is passed through and linked with the secondary winding. This is the most basic theory of transformer.

2.2.1 Main **Constructional** Parts of Transformer:

The three main parts of a transformer are:

1. Primary Winding of Transformer-
   Which produces magnetic flux when it is connected to electrical source.

2. Magnetic Core of Transformer-
   The magnetic flux produced by the primary winding, that will pass through this low reluctance path linked with secondary winding and create a closed magnetic circuit.

3. Secondary Winding of Transformer-
   The flux, produced by primary winding, passes through the core, will link with the secondary winding. This winding also wounds on the same core and gives the desired output of the transformer.

2.3 <u>Use of Power Transformer:</u>

Generation of electrical power in low voltage level is very much cost effective. Theoretically, this low voltage level power can be transmitted to the receiving end. This low voltage power if transmitted results in greater line current which indeed causes more line losses But if the voltage level of a power is increased, the current of the power is reduced which causes reduction in ohmic or I2R losses in the system, reduction in cross sectional area of the conductor i.e. reduction in capital cost of the system and it also improves the voltage regulation of the system. Because of these, low level power must be stepped up for efficient electrical power transmission. This is done by step up transformer at the sending side of the power system network. As this high voltage power may not be distributed to the consumers directly, this must be stepped down to the desired level at the receiving end with the help of step down transformer. Electrical power transformer thus plays a vital role in power transmission.

Two winding transformers are generally used where ratio of high voltage and low voltage is greater than 2. It is cost effective to use auto transformer where the ratio between high voltage and low voltage is less than 2. Again a single unit three phase transformer is more cost effective than a bank of three single phase transformers unit in a three phase system. But a single three phase transformer unit is a bit difficult to transport and have to be removed from service entirely if one of the phase winding breaks down.

2.4 <u>Types of Transformer:</u>

1. Step up Transformer and Step down Transformer - Generally used for stepping up and down the voltage level of power in transmission and distribution power system network.

2. Three Phase Transformer and Single Phase Transformer - Former is generally used in three phase power system as it is cost effective than later. But when size matters, it is preferable to use a bank of three single phase transformer as it is easier to transport than one single three phase transformer unit.

3. Electrical Power Transformer, Distribution Transformer and Instrument Transformer - Power transformers are generally used in transmission network

for stepping up or down the voltage level. It operates mainly during high or peak loads and has maximum efficiency at or near full load. Distribution transformer steps down the voltage for distribution purpose to domestic or commercial users. It has good voltage regulation and operates 24 hrs. A day with maximum efficiency at 50% of full load. Instrument transformers include C.T and P.T which are used to reduce high voltages and current to lesser values which can be measured by conventional instruments.

4. Two Winding Transformer and Auto Transformer - Former is generally used where ratio between high voltage and low voltage is greater than 2. It is cost effective to use later where the ratio between high voltage and low voltage is less than 2.

5. Outdoor Transformer and Indoor Transformer - Transformers that are designed for installing at outdoor are outdoor transformers and transformers designed for installing at indoor are indoor transformers.

6. Oil Cooled and Dry Type Transformer - In oil cooled transformer the cooling medium is transformer oil whereas the dry type transformer is air cooled.

7. Core type, Shell type and Berry type transformer - In core type transformer it has two vertical legs or limbs with two horizontal sections named yoke. Core is rectangular in shape with a common magnetic circuit. Cylindrical coils (HV and LV) are placed on both the limbs.
Shell type transformer: It has a central limb and two outer limbs. Both HV, LV coils are placed on the central limb. Double magnetic circuit is present.
Berry type transformer: The core looks like spokes of wheels. Tightly fitted metal sheet tanks are used for housing this type of transformer with transformer oil filled inside.

2.5 Insulation materials used in transformers:

Other than active materials, for example, copper and grain oriented silicon steel, a large number of ferrous, non-ferrous and insulating materials are used in power transformers. Optimum utilization of these materials according to their electrical, mechanical, physical, chemical and thermal characteristics is important for using an appropriate insulating material. The insulation class of a power transformer is decided on the test level of which insulation is capable of withstanding.

Transformer insulation is based on basic impulse insulation level together with voltage rating. Insulating media in up to 11KV transformer is mostly comprised of paper wrapped around the conductor in transformer coils, mineral oil and pressboard to insulate the coil from the ground. One basic requirement of all insulating materials is that they should be compatible with insulating oil and should not react with oil.

2.5.1 <u>The types of materials used for insulations are and their applications:</u>

1. Insulating Oil:

Insulation oil plays a very important in transformer insulation system. In low voltage transformer, for example, transformers used in the range of 12-1000V or low power rating transformers there is no need of insulating oil in such transformers. Heat dissipation is very low in low voltage transformers. In 11KV transformers, insulating oil has the important rule of acting as an electrical insulation as well as a coolant to dissipate heat losses. Transformer oil is basically obtained by fractional distillation and subsequent treatment of crude petroleum. So Transformer oil act as liquid dielectric and coolant and it is placed in a tank in which core of the transformer is placed.

2. Insulating paper:

Paper is a fabric made from vegetables fibers which are felted to form a web or sheet. The fibrous raw materials are obtained from plants including cotton, hemp, manila, straw, and coniferous trees. It attains a very high value of electric strength when emerged in oil under vacuum. "Craft insulating paper of medium air permeability" is used in layer winding insulation, condenser core of oil impregnated bushing. Craft insulating paper of high air permeability" is used in covering over rectangular copper conductor and continuously transposed copper conductor. "Crepe Kraft paper" is used in covering over flexible copper cable insulation of winding lead. "Press paper" is used as backing paper for axial cooling duct.

3. Pressboard:

Pressboard is a widely used insulating material for making a variety of components used in electrical, mechanical and thermal design of transformers. Pressboard id also made from vegetable fibers, whose cells contains much cellulose. The most difficult practical insulation in power transformers occur at the end of the windings and the lead outs from the windings. Pressboard molded components can be made to any required shape. Angle rings and caps are the widely used moldings. There are many kind of pressboards use in high voltage transformers but "soft pressboard –laminated" is used in 11KV transformers as a block washer, terminal gear cleat and support and spacer etc. "Pressboard molding from wet sheet or wet wood pulp" is used in angle ring, cap, sector, snouts, square tube, lead out, for insulating ends of winding, insulation between windings and numerous other applications.

4. Wood:

Wood based laminates are manufactured from selected veneers obtained from various timbers. The veneers are dried and partially or fully impregnated with natural phenomenon. The areas which required higher mechanical and lower electric strength, densities laminated wood is used for making a variety of insulation components like coil clamping ring, cleat, support, core and yoke etc.

5. Insulated copper conductor for winding:

Different type of insulated copper conductor windings are used in power transformers for example paper covered rectangular copper conductor, twin paper covered rectangular copper conductor bunched together, paper covered continuously transposed copper conductor, twin transposed copper conductor bunched together, twin rectangular copper bunched together and provided with a common paper strip between the two conductors and epoxy coated continuously transposed conductor. These are used to the winding space factor and mechanical strength of windings." paper covered rectangular copper conductor" is used for making different kind of windings. "Paper covered standard copper cable" is used for making lead and terminal. "Crepe paper covered flexible copper cable" is used for making lead and terminal required to be bent to a small radius. "PVC insulated copper cable-single and multi-core" is used to control wiring in marshaling box, nitrogen, sealing system.

6. Insulating tape:

Insulating tape is used for various taping purposes .For example cotton tape, cotton newer tape, glass woven tape, woven tape and phenol laminated paper base sheet. These tapes are used in taping, banding, core bolt insulation, places where required high strength and in banding of transformer cores.

Chapter 3

Transformer Oil

Overview:

Present chapter describes transformer oil. This chapter also describes the Types of Transformer Oil, Properties of Transformer Insulating Oil and how Collecting Oil Sample from Oil Immersed Electrical Equipment.

3.1 Introduction of Insulating Oil:

Insulating oil in an electrical power transformer is commonly known as transformer oil. It is normally obtained by fractional distillation and subsequent treatment of crude petroleum. That is why this oil is also known as mineral insulating oil. Transformer oil serves mainly two purposes one it is liquid insulation in electrical power transformer and two it dissipates heat of the transformer i.e. acts as coolant. In addition to these, this oil serves other two purposes, it helps to preserve the core and winding as these are fully immersed inside oil and another important purpose of this oil is, it prevents direct contact of atmospheric oxygen with cellulose made paper insulation of windings, which is susceptible to oxidation.

3.2 Types of Transformer Oil:

Generally there are two types of transformer Oil used in transformer:
1. Paraffin based transformer oil

2. Naphtha based transformer oil

Naphtha oil is more easily oxidized than Paraffin oil. But oxidation product i.e. sludge in the naphtha oil is more soluble than Paraffin oil. Thus sludge of naphtha based oil is not precipitated in bottom of the transformer. Hence it does not obstruct convection circulation of the oil, means it does not disturb the transformer cooling system. But in the case of Paraffin oil although oxidation rate is lower than that of Naphtha oil but the oxidation product or sludge is insoluble and precipitated at bottom of the tank and obstruct the transformer cooling system. Although Paraffin based oil has above mentioned disadvantage but still in our country it is generally used because of its easy availability. Another problem with paraffin based oil is its high pour point due to the wax content, but this does not affect its use due to warm climate condition of India.

3.3 Properties of Transformer Insulating Oil:

Some specific parameters of insulating oil should be considered to determine the serviceability of that oil.

Parameters of Transformer Oil:
The parameters of transformer oil are categorized as,

3.3.1 Electrical Parameter of Transformer Oil:

a. Dielectric Strength of Transformer Oil:
Dielectric strength of transformer oil is also known as breakdown voltage of transformer oil or BDV of transformer oil. Break down voltage is measured by observing at what voltage, sparking strands between two electrodes immerged in the oil, separated by specific gap. Low value of BDV indicates presence of moisture content and conducting substances in the oil. For measuring BDV of transformer oil, portable BDV measuring kit is generally available at site. In this kit, oil is kept in a pot in which one pair of electrodes are fixed with a gap of 2.5 mm (in some kit it 4mm) between them.

Now slowly rising voltage is applied between the electrodes. Rate of rise of voltage is generally controlled at 2 KV/s and observe the voltage at which sparking starts between the electrodes.

That means at which voltage dielectric strength of transformer oil between the electrodes has been broken down.

Generally this measurement is taken 3 to 6 times in same sample of oil and the average value of these reading is taken. BDV is important and popular test of transformer oil, as it is primary indication of health of oil and it can be easily carried out at site.

Dry and clean oil gives BDV results, better than the oil with moisture content and other conducting impurities. Minimum breakdown voltage of transformer oil or dielectric strength of transformer oil at which this oil can safely be used in transformer, is considered as 30 KV.

b. Specific Resistance of Transformer Oil:

This is another important property of transformer oil. This is measure of DC resistance between two opposite sides of one cm3 block of oil. Its unit is taken as ohm-cm at specific temperature. With increase in temperature the resistivity of oil decreases rapidly. Just after charging a transformer after long shut down, the temperature of the oil will be at ambient temperature and during full load the temperature will be very high and may go up to 90oC at over load condition. So resistivity of the insulating oil must be high at room temperature and also it should have good value at high temperature as well. That is why specific resistance or resistivity of transformer oil should be measured at 27oC as well as 90oC. Minimum standard specific resistance of transformer oil at 90oC is 35×1012 ohm–cm and at 27oC it is 1500×1012 ohm–cm.

c. Dielectric Dissipation Factor of Tan Delta of Transformer Oil:

Dielectric dissipation factor is also known as loss factor or tan delta of transformer oil. When an insulating material is placed between live part and grounded part of electrical equipment, leakage current will flow. As insulating material is dielectric in nature the current through the insulation ideally leads the voltage by 90°. Here voltage means the instantaneous voltage between live part and ground of the equipment. But in reality no insulating materials are perfect dielectric in nature. Hence current through the insulator will lead the voltage with an angle little bit shorter than 90°. Tangent of the angle by which it is short of 90° is called dielectric dissipation factor or simply tan delta of transformer oil.

More clearly, the leakage current through an insulation does have two component one is capacitive or reactive and other one is resistive or active.

Again it is clear from above diagram, value of $'\delta'$ which is also known as loss angle,
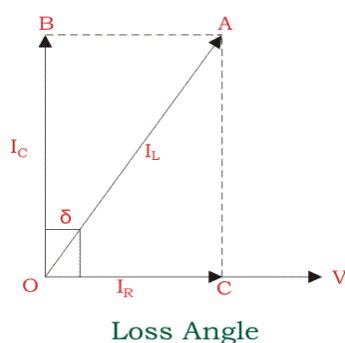
Loss Angle

Figure3.1: Diagram of loss angle

Is smaller, means resistive component of the current I_R is smaller which indicates high resistive property of the insulating material. High resistive insulation is good insulator. Hence it is desirable to have loss angle as small as possible. So we should try to keep the value of $\tan\delta$ as small as possible. High value of this $\tan\delta$ is an indication of presence of contaminants in transformer oil.

Hence there is a clear relationship between $\tan\delta$ and resistivity of insulating oil. If resistivity of the insulating oil is decreased, the value of tan-delta increases and vice versa. So both resistivity test and tan delta test of transformer oil are not normally required for same piece of insulator or insulating oil.

In one sentence it can be said that, tanδ is measure of imperfection of dielectric nature of insulation materials like oil.

3.3.2 Chemical Parameters of Transformer Oil

a. Water Content in Transformer Oil:

Moisture or water content in transformer oil is highly undesirable as it affects adversely the dielectric properties of oil. The water content in oil also affects the paper insulation of the core and winding of transformer. Paper is highly hygroscopic in nature. Paper absorbs maximum amount of water from oil which affects paper insulation property as well as reduced its life. But in loaded transformer, oil becomes hotter, hence the solubility of water in oil increases as a result the paper releases water and increase the water content in transformer oil. Thus the temperature of the oil at the time of taking sample for test is very important. During oxidation acid are formed in the oil the acids give rise the solubility of water in the oil. Acid coupled with water further decompose the oil forming more acid and water. This rate of degradation of oil increases. The water content in oil is measured as pm (parts per million units).
Water content in oil is allowed up to 50 ppm as recommended by IS–335(1993). The accurate measurement of water content at such low levels requires very sophisticated instrument like Coulometric Karl Fisher Titrator.

b. Acidity of Transformer Oil:

Acidity of transformer oil is harmful property. If oil becomes acidic, water content in the oil becomes more soluble to the oil. Acidity of oil deteriorates the insulation property of paper insulation of winding. Acidity accelerates thee oxidation process in the oil. Acid also includes rusting of iron in presence of moisture. The acidity of transformer oil is measure of its acidic constituents of contaminants. Acidity of oil is express in mg of KOH required to neutralize the acid present in a gram of oil. This is also known as neutralization number.

3.3.3 Physical Parameters of Transformer Oil

a. Inter Facial Tension of Transformer Oil

Inter facial tension between the water and oil interface is the way to measure molecular attractive force between water and oil. It is measured in Dyne/cm or mili-Newton/meter. Inter facial tension is exactly useful for determining the presence of polar contaminants and oil decay products. Good new oil generally exhibits high inter facial tension. Oil oxidation contaminants lower the IFT.

b. Flash Point of Transformer Oil

Flash point of transformer oil is the temperature at which oil gives enough vapors to produce a flammable mixture with air. This mixture gives momentary flash on application of flame under standard condition. Flash point is important because it specifies the chances of fire hazard in the transformer. So it is desirable to have very high flash point of transformer oil. In general it is more than 140o (>10o).

c. Pour Point of Transformer Oil

It is the minimum temperature at which oil just start to flow under standard test condition. Pour point of transformer oil is an important property mainly at the places where climate is extremely cold. If the oil temperature falls below the pour point, transformer oil stops convection flowing and obstruct cooling in transformer. Paraffin based oil has higher value of pour point, compared to Naphtha based oil, but in India

like country, it does not effect, the use of Paraffin oil due tits warm climate condition. Pour Point of transformer oil mainly depends upon wax content in the oil. As Paraffin based oil has more wax content, it has higher pour point.

d. Viscosity of Transformer Oil

In few wards, viscosity of transformer oil can be said that viscosity is the resistance of flow, at normal condition. Obviously resistance to flow of transformer oil means obstruction of convection circulation of oil inside the transformer. A good oil should have low viscosity so that it offers less resistance to the convectional flow of oil thereby not affecting the cooling of transformer. Low viscosity of transformer oil is essential, but it is equally important that, the viscosity of oil should increase as less as possible with decrease in temperature. Every liquid becomes more viscous if temperature decreases.

3.4 Collecting Oil Sample from Oil Immersed Electrical Equipment

Process of Collecting Oil from Oil Immersed Electrical Equipment Like Transformer. We collect oil sample for performing different tests on the oil to determine different physical, chemical and electrical characteristics of the oil. The sample is the representative of the oil inside the equipment. That is why; we take special care during collecting oil sample from the equipment. Otherwise surrounding atmosphere may affect the characteristics of the oil which may differ the outcome of the tests form the actual results.

The normal procedures of collecting oil from a transformer or other oil immersed electrical equipment are given in following points:

1. We should always take at least 1 to 2 liter of oil from bottom valve or oil sample valve (if available) depending upon the tests to be performed on that sample.

2. We should ensure that sampling is done by well experienced technical personnel.

3. We should not take sample of the oil in rainy, stormy, foggy, and snowy weather since it can affect the water contaminant of the oil. We should also avoid oil sampling in high atmospheric humidity for same reason.

4. We should use dry and clean containers preferably made of amber colored glass or clear glass or seamless stainless steel bottle. We can also use plastic bottle provided its suitability has been approved.

5. First we should run of some of the oil from oil sampling valve of the equipment to ensure the removal of any contaminants in the orifice of the valve.

6. Before toping up the bottle, we should rinse the sampling bottle with some oil

7. We should fill the bottle slowly and gently. We should allow the oil to flow against the wall of the bottle to avoid any formation of air bubble in oil so that no air can be trapped in the sample.

8. We should fill the bottle up to 95% of its capacity

9. Now we carefully close the bottle.

10. We must avoid any adhesive tape like thing at the cover.

11. Now, the bottle must be labeled with

   a. Name of the equipment from where sample is collected

   b. Rating of the equipment

   c. Serial No of the equipment

   d. Installed location of the equipment

   e. Other identifications of the equipment if required.

   f. Temperature of the oil at the time of collection

   g. Date of collection

   h. Identification of the sampling point (whether it is from top or bottom)

Chapter 4

GAS FORMATION IN MINERAL OIL

Overview:

This chapter mainly describes about literature review of TCG, GBA, DGA methods for gases identification. This chapter also describes total possible faults produced in mineral oil due to thermal and electrical degradation. Finally this chapter ends with block diagram representation of DGA combine design technique.

4.1 Gas Formation in Mineral Oil

The main cause for gas formation in mineral oil is cellulose and oil decomposition. When this degradation is occurred gases are produced like Carbon Oxides and Hydrocarbon Molecules.

   I. *Cellulose Decomposition "Paper"*
   The thermal degradation of cellulose mainly produced carbon oxides (CO, CO_2) and hydrogen or methane (H_2, CH_4) [2]. Due to thermal degradation in oil, carbon dioxide produced. The rate at which they are developed depends exponentially on the temperature and directly on the concentration of material at that temperature [11].

II. Oil decomposition

Mineral transformer oils are combination of hydrocarbon molecules and its general formulae is C_nH_{2n+2}, where n in the reach of 20 to 40. The deterioration forms for these hydrocarbons in thermal or electrical faults are more complex. The main reason

For generating the fault gases are breaking of carbon hydrogen and carbon-carbon bonds. These free radicals can mix with each other to form gases like hydrogen (H_2), methane (CH_4) and ethane (C_2H_6). Further decomposition in mineral oil develops such as ethylene (C_2H_4) and acetylene (C_2H_2) [12].

4.2 Interpretation of Gas Analysis

The main two causes of gas formation within an operating transformer are electrical and thermal degradations.

I. Thermal Faults

The decomposition of mineral oil from 150°C to 500°C generates low molecular
weight gases, such as methane (CH_4), hydrogen (H_2) and low quantity of higher molecular weight gases like ethane (C_2H_6), ethylene (C_2H_4) [18]. If decomposition of mineral oil increases more than 500°C generates large quantity of acetylene (C_2H_2). In
Case of thermal decomposition of paper insulation and other solid insulation produces carbon dioxide (CO_2), carbon monoxide (CO) [11].

II. Electrical faults

Two type of electrical faults are considered
1. Corona (or) Partial Discharge
2. Arcing (High Energy Discharge)

These faults mainly depend on intensity of energy dissipated per unit time per unit volume by the fault. Among all faults, most severe fault is arcing by developing acetylene and less severity fault is corona by producing large quantity of Hydrogen and Methane but if less severity fault was not correct, it leads to Arcing [14].

1. Corona (or) Partial Discharge

a. Partial Discharge means "The dielectric breakdown of some part of solid (or) liquid when impressed by high voltage". Here when the mineral oil of transformer is stressed by high voltage leads to production of several gases, discharges of cold plasma, bubbles (or) voids and with possible formation of X-wax in paper [12].

b. The approximate percentage of gases among all dissolved gases when partial

Discharge occurs is H_2=85%-90%, CO_2=1%-2%, CO=0.5%-1%,

CH_4=6 during partial discharge occurred in oil leads to develop H_2 gas and in cellulose is produce carbon oxides including H_2.

2. *Arcing*

a. Arcing in generally means "the electrical breakdown of a gas that developing ongoing plasma discharges, resulting current through normally non-conductive medium such as air" [18]. But in case of transformer severe energy dissipation

Occurs during arcing and it produces gases in the percentages approximately H_2=35%-40%, C_2H_2=35%-50% and remaining gases in very low volume.

b. In any fault associated with paper, produce gases like CO_2 and CO in very large quantity approximately 85%-90%.

%-10%, C_2H_6=6%-8% and very low quantities of ethylene and acetylene. Hence,

4.3 Literature Review

4.3 .1 Total Combustible Gases (TCG)

It is the first method proposed to detect the fault gases, the major advantage of this method is "it will detect fault gases very quickly compare to other methods and it is applicable to use in the field" [10]. But it has number of disadvantages

1. It can detect only combustible gases like (carbon monoxide, hydrogen, acetylene, methane and ethylene) and does not indicate non-combustible gases like (carbon dioxide, oxygen and nitrogen) [3].

2. This method is applicable only those have gas blankets and does not completely oil filled units of conservator type.

3. The most disadvantage of TCG is it can give only one concentration value of incipient fault and also not clearly identify which gases are actually present.

4.3.2   Gas Blanket Analysis (GBA)

During this method, the sample of the gas in the space above the oil is analyzed for its finding the incipient faults [16]. It can detect all of the individual components like C-H bonds and C-O bonds. However it suffers following disadvantage.

- The gases must be diffuses into the gas blanket only
- it is not suitable for field

4.3.3   Dissolved Gas Analysis (DGA)

It is the useful informative method for the detection of incipient faults and most used method now a day. DGA involves following steps [3].

1. Sample of the oil taken from the unit and extract the dissolved gases from oil.

2. Detect the gas concentrations and analyses by diagnostic methods (Key Gas and Ratio analysis methods) to find faults.

It is applicable to all type high voltage equipment like the gas blanket analysis method and it can detect all the combustible and non-combustible gases. The following are the advantages of DGA [14].

1. Advance warning of developing of faults.

2. Status check on new and aged mineral oil.
3. Convenient online scheduling of repairs.

4. Identifies degradation level before it leads to failure.

5. Monitoring of units under overload case.

6. Checking the improper use of units.

The main advantage of DGA method is "*it gives early identification of incipient faults*".

4.4   DGA Block Diagram

The steps involved in DGA is shown in following Figure 2.1

```
          ┌─────────────────────────────┐
          │    Oil taken from the unit   │
          └─────────────────────────────┘
                        │
                        ▼
          ┌─────────────────────────────┐
          │   Extraction of dissolved    │
          │        gases From the oil    │
          └─────────────────────────────┘
                        │
                        ▼
          ┌─────────────────────────────┐
          │     Identification of gas    │
          │      Concentration levels    │
          └─────────────────────────────┘
                        │
                        ▼
          ┌─────────────────────────────┐
          │  Analysis carried out to     │
          │  find the Type of incipient  │
          │            faults            │
          └─────────────────────────────┘
```
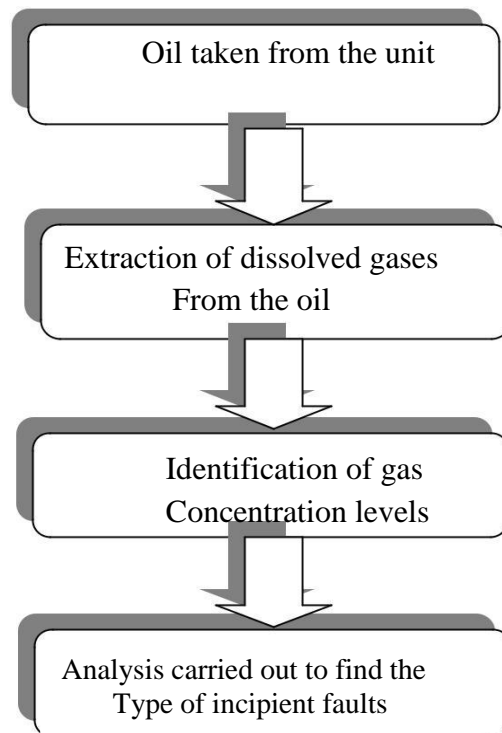
Dissolved   Gas   Analysis (DGA)   is a proved accuracy method   Figure 4.4: Flow Chart of DGA   to   find faults. DGA mainly involves extracting of oil from the unit and subject to Gas Chromatography to extract the dissolved gases from oil [6]. The next step of DGA is detection of gas concentration levels using suitable methods like Flame Ionization detector, Thermal conduction detector (FID, TCD) and analyze for faults by using suitable diagnostic methods to find cause. Figure 2.1 indicates the entire process of DGA [2]. In this work, the condition based diagnosis system developed to combine five DGA assessment classical techniques-Key Gas Method, IEC Ratio Method, Rogers Ratio Method, Doernenburg Ratio Method and Duval Triangle Method. A feasible MATLAB GUI conferred to give visual display of all five Methods at one window and this result gives cause to incipient faults, which kind of fault exist by individual method and finally compare all five methods to find exact incipient fault by taking their percentage. The result of this method shows overall DGA accuracy is more than 90% compared to 80% of most reliable individual method [7]. DGA helps

to diagnosis the present condition of the high voltage power transformer. The main reason for going combine five methods is "***none of the single method is giving all type of faults*** i.e. key gas method gives only two type of thermal faults and low energy discharge type faults by taking key gases, Ratio methods gives high thermal, partial discharge and arcing but not giving combination of thermal and electrical faults [10]. In case of Duval triangle method, it gives almost all possible faults except faults temperature $<150^0$c, if these low temperature faults are not corrected may be it leads to high temperature faults in future and perhaps increase to arcing also and these causes high damage to transformer. Normally by taking same sample unit different diagnosis methods gives different fault conditions, but in case of this combine DGA method gives result as only one common indication of fault by considering all individual methods faults. So it is giving prior intimation for occurring faults, hence by taking remedies for occurring incipient faults life period of power transformer is increased and failure percentage of transformer also decreased. Further, this method is also applicable to other oil filled high voltage power equipment for assessment of its condition during the operating service period of time.