CHAPTER ONE

INTRODUCTION

1.1General Back Ground

In extended power systems, substation facilities have become both too complex and too large. Customers require the high quality offered by an electrical power system. However, some facilities have become old and often breakdown unexpectedly. Such unexpected failure may cause a break in the power system and result in loss of profits. Therefore, it is important to prevent abrupt faults by monitoring the condition of power systems. Among the various power facilities, power transformers play an important role in transmission and distribution systems. At present, it has been proven that the dissolved gas analysis (DGA) is the most effective and convenient method to diagnose the transformers [1].

Under normal conditions, the insulating oil and the organic insulating material in oil-filled equipment generate a small amount of gas caused by the gradual degradation and decomposition. The DGA approach identifies faults by considering the ratios of specific gas concentration. There are various methods based on DGA such as Dornenburg ratios, Roger ratios, IEC ratios, and etc. The DGA is a simple, inexpensive, and non-intrusive technique. The transformer oil provides both cooling and electrical insulation. It baths every internal component and contains a lot of diagnostic information in the form of dissolved gases. Since these gases reveal the faults of a transformer, they are known as Fault Gases. The DGA is the study of dissolved gases in transformer oil. The concentration of the different gases provides information about the type of incipient-fault condition present as well as the severity. Different methods Rogers, fuzzy, neural, key gas method, duval, dornenburg ratio etc. are available for fault detection using DGA data [1,6].

Under the abnormal condition in transformers, the insulation oil and the organic insulation material in oil filled equipment generate several gases such as hydrogen (H2), carbon monoxide (CO), acetylene (C2H2), methane (CH4), ethane (C2H6), ethylene (C2H4), carbon dioxide (CO2), and etc. The quantity of the dissolved gas depends fundamentally on the types of faults occurring within power transformers. By considering these characteristics, DGA methods make it possible to detect the abnormality of the transformers. More specifically, this method determines incipient faults in transformers according to the amount of gasses acquired from DGA. Here, the incipient faults include normal, alarm, fault, and danger. Also, this method makes it possible to identify the causes of faults represented as partial discharge, insulator degradation, arc discharge, low overheat and high overheat according to the concentration of special gasses. This diagnosis technique based on these categories has certain limitations. For example, in case of exceeding 400 (ppm) for the concentration of hydrogen, this method determines the fault as an alarm condition and identifies the cause of the fault as partial discharges. However, the transformer is assumed to be operating normally in case of 399 (ppm). Even though the difference between the two data is only 1 (ppm), the interpretations are completely different. This indicates a very crisp interpretation with respect to the boundaries. On the other hand, a specific gas is generated and accumulated in the oil as time goes on in spite of the normal condition. Therefore, the potential possibility and the degree of aging could be different even to transformers that are in normal condition. In fact, the amount of these gases indicates the potential for seeking a method for finding a faulted condition , this fault detection should be made periodically by means of DGA to maintain reliable operation of the transformers. Therefore, the variation of the existence and the concentration of the gasses with time must be taken into account for an accurate identification of the fault evolution and the aging reasons. powerful methodology for solving problems in nonlinear classification. The advantage of DGA is that the operation and test are performed at the same time, in addition to the fact that it is a simple and inexpensive diagnosis process [2,3].

1.2 Problem Statement

Under normal operating conditions of a transformer, the oil is subjected to a continuous oxidation process at slow rate. However, the oxidation process can abruptly accelerate due to higher-than-usual amount of energy dissipated by an electrical or a thermal fault in the transformer, leading to a sudden increase in the concentrations of certain hydrocarbon gases and other compounds. Thus, the condition of the transformer oil, which include concentrations of dissolved gases, presence of sludge particles, color etc. provides useful information about the technical state of the transformer and its malfunctioning.

1.3 Objectives

This research project is aimed at evaluating the factors affecting the dissolved gas analysis (DGA) through experimental investigations of the fault gas generation. Laboratory scaled models of the transformer oil tank including oil circulation piping system and high voltage system, which were used to simulate electrical and thermal fault, form the basis of the investigations. This research was further aided by the availability of more than one commercially available DGA techniques.

The specific objectives of this research project were defined as:

• Evaluation of factors affecting the gas-in-oil analysis, including gas extraction techniques, oil sampling and sample storage practices.

• Conduction of faults such as partial discharge (PD), arcing discharge (AD) and hotspot (HS) of various intensities by means of experimental setups designed to resemble fault conditions as in power transformers.

• Assessment of the fault gas generation triggered by electrical and thermal faults using DGA techniques that aimed at verifying the gassing behavior of oil under each fault type.

• Comparative analysis of different DGA interpretation schemes aimed at evaluating uncertainties involved in the application of fault interpretation schemes.

• Investigation of the diffusion process of fault gases from oil into the atmosphere through the open conservator tank, and the effect of circulation rate on the diffusion process.

1.4 Methodology

To identified the problem of the research, which is resulting from the oxidation of transformer oil, and by looking in the specialized reference in this domain, and then we have had practical experience in the "kilo ashra distribution station" and we take a sample of the oil transformer was tested device DGA and after that, the device is giving results on the screen came in the form of curves and these curves explain whether the converter by oil gases dissolved at a higher rate than normal or not, and the emergence of these gases raises the incidence of specific breakdowns if not corrected the problem; then after that we have identified the faults resulting from the emergence of those seven gases, called (hydrogen gas - carbon dioxide gas - first Alexad gas carbon - methane –alittlin gas – ethane gas) or part of this gas , and we have identified the procedures to be followed when the emergence of these gases in order to avoid damage and we indicate the most serious of which is “ethylene” and then finally place the appropriate solutions and recommendations to prevent such problems from occurring.

1.5 Project layout

This Project consist of five chapters as follows:

- ❖ Chapter One: Introduction.
- ❖ Chapter Two: Literature Review.
- ❖ Chapter Three: Dissolved Gas Analysis of Transformer Oil.
- ❖ Chapter Four: Experimental work.
- ❖ Chapter five: Conclusion and Recommendation.

CHAPTER TWO

LITREATURE REVIEW

2.1 Power Transformer

A transformer is basically a static electrical device that permits the transfer of alternating current (AC) or voltage between two electric circuits, based on the principles of electromagnetism and electromagnetic induction. The principle of electromagnetism states that an electric current passing through winding generates a magnetic field in the core.

The core of a transformer is represented in figure 2.1.

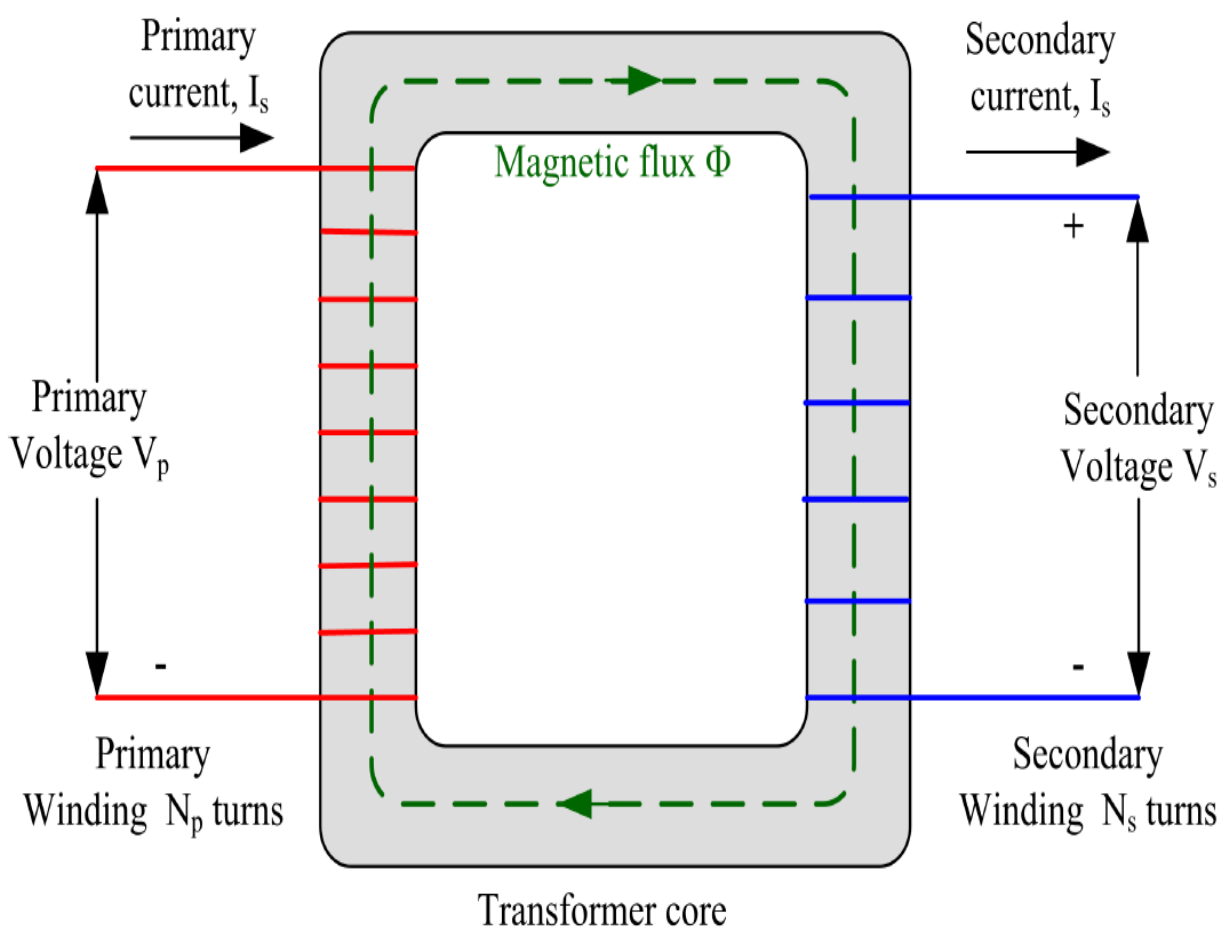

Figure 2.1: Core of a step-down transformer.

The principle of electromagnetic induction states that a variation of current in the primary winding will cause a change in the magnetic field which will induced voltage through the secondary winding.

A simplified concept of a transformer consists of two electrically insulated windings: primary and secondary windings, supported by an iron core. The windings are insulated from each other as well as from the core. The number of turns determines whether the transformer can be used for stepping-up or stepping-down of the voltage. In a step-up transformer the secondary winding has higher number of turns as compared to the primary winding, and in a step-down transformer the secondary winding has less number of turns as compared to the primary winding.

The voltage induced in the secondary winding follows the Faraday's law of Induction , which states, "the electromotive force in any circuit is directly proportional to the time rate of change of magnetic flux through the circuit".

2.1.1 Main parts of a transformer

A simplified schematic representation of a high voltage power transformer and its major technical components can be seen in the figure 2.2. A brief description of the components is shown in the following section.

- **Oil tank and its cooling system**

The oil tank is the outer part of a transformer, in which the core, windings and transformer oil are contained. Cooling collars are attached to the outer surface of the tank to achieve heat dissipation. For small transformers cooling is carried out through air circulation and heat radiation, however large transformers require adequate cooling system coolant substance.

This is usually achieved by circulating transformer oil through the windings and coolers.

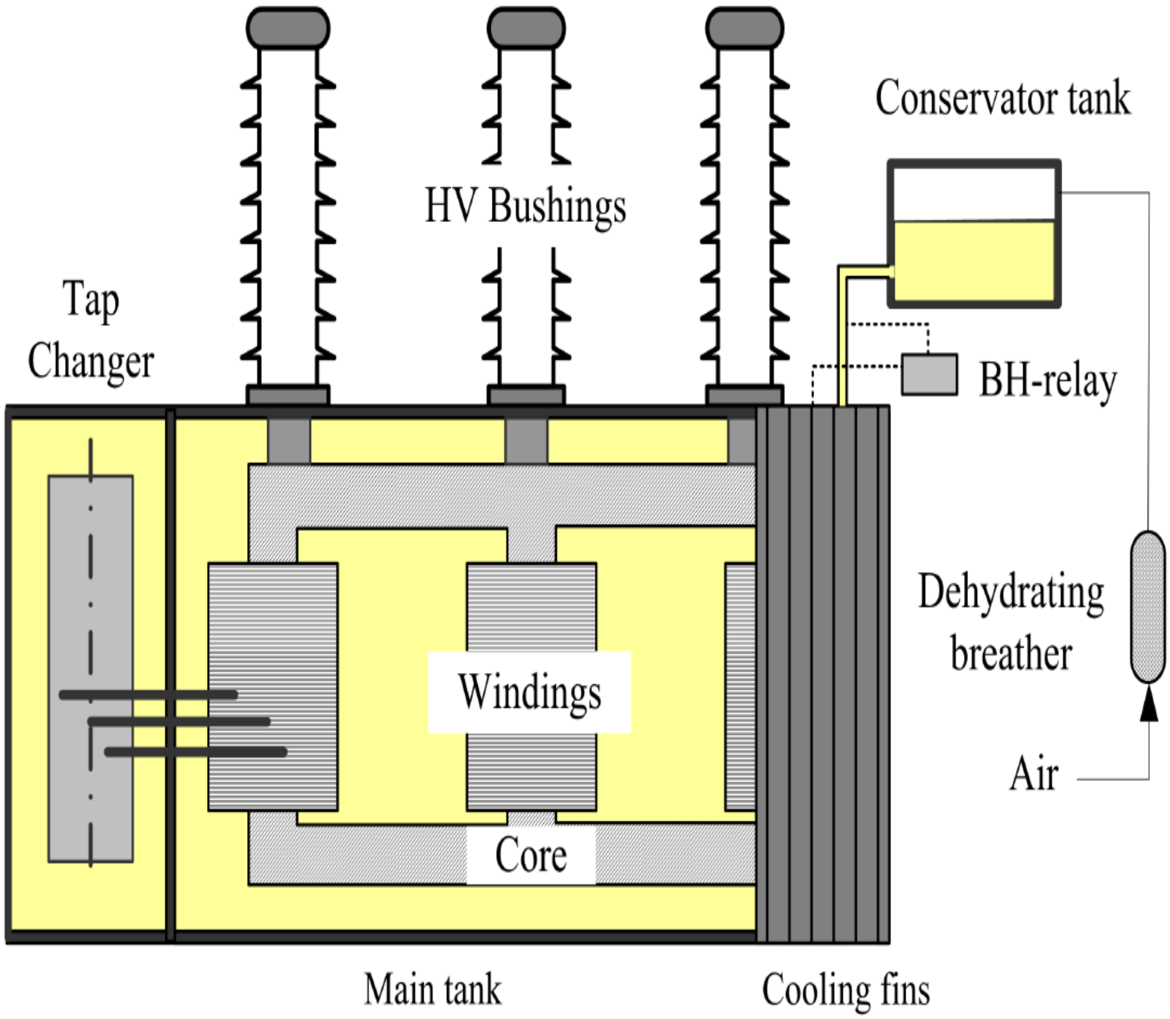

Figure 2.2: Schematic representation of a high voltage power transformer

- **The core**

It provides the main flux path for a magnetic field between primary and secondary windings. Generally the cores are constructed as hollow-core or shell-core of laminated steel layers insulated using varnish.

- **Windings**

These are coils of high conductivity copper or aluminum wrapped around the limbs of a core. The primary winding is connected to input network and the secondary winding is connected to output network. For the power transformers operating at high voltages, layers of winding are insulated using oil-impregnated paper and blocks of pressboard.

• **Tap changer**

Tap changers are external connections to the intermediate points along the primary and secondary windings, which allow the selection of a voltage ratio.

• **Bushing**

High voltage cables connecting a transformer to a network , are passed through bushing to insulate the cables from the main body of the transformer.

• **The conservator tank**

This tank is located on the top of the main tank and it is used to contain surge of transformer oil caused by thermal expansion. The tank has a breather, which is a glass vessel filled with silica gel to protect the oil from moisture and to allow the gases in oil to diffuse in to the atmosphere. Due to this system transformer behaves as an open-breathing system that allows gas exchange between the main tank and the surrounding environment.

• **The Buchholz relay**

Also known as a gas relay, is a safety device installed on the pipe connecting the main tank and the conservator. Under normal conditions the relay is completely filled with oil and it activates when the floats switch is displaced by certain accumulation of gas. This relay can switch off the transformer when a strong surge of oil flows to the conservator, or when the oil level falls down to dangerous levels.

• **Insulation materials**

It consists of cellulose paper wrappings around the windings and the transformer oil filling up the main tank. The general purpose of these materials is to insulate the different components of the transformer and to dissipate the heat produced due to thermal and electrical stresses[].

2.2 Mineral Oil

Although new systems are fluids are constantly being developed, mineral oil is the most common fluid in use today. Polychlorinated biphenyls (PCBs) are not acceptable to the Environmental Protection Agency (EPA) for use in transformers. Any reference to “oil” or “insulating fluid” in this section will be understood to mean transformer mineral oil. The manufacturer’s instructions and guidelines should be considered when dealing with fluids.

- Insulating fluid plays a dual function in the transformer. The fluid helps to draw the heat away from the core, keeping temperatures low and extending the life of the insulation. It also acts as a dielectric material, and intensifies the insulation strength between the windings. To keep the transformer operating properly, both of these qualities must be maintained.
- The oil’s ability to transfer the heat, or its “thermal efficiency,” largely depends on its ability to flow in and around the windings. When exposed to oxygen or water, transformer oils will form sludge and acidic compounds. The sludge will raise the oil’s viscosity, and form deposits on the windings. Sludge deposits restrict the flow of oil around the winding and cause the transformer to overheat. Overheating increases the rate of sludge formation (the rate doubles for every 10 “C rise) and the whole process becomes a “vicious cycle.” Although the formation of sludge can usually be detected by a visual inspection, standardized American Society for Testing and Materials (ASTM) tests such as color, neutralization number, interfacial tension, and power factor can provide indications of sludge components before visible sledging actually occurs.
- The oil’s dielectric strength will be lowered any time there are contaminants. If leaks are present, water will enter the transformer and condense around the relatively cooler tank walls and on top of the oil as the transformer goes

through the temperature and pressure changes caused by the varying load. Once the water condenses and enters the oil, most of it will sink to the bottom of the tank, while a small portion of it will remain suspended in the oil, where it is subjected to hydrolysis. Acids and other compounds are formed as a byproduct of sludge formation and by the hydrolysis of water due to the temperature changes. Water, even in concentrations as low as 25 ppm (parts per million) can severely reduce the dielectric strength of the oil. Two important tests for determining the insulating strength of the oil are dielectric breakdown and moisture content.

- The two most detrimental factors for insulating fluids are heat and contamination. The best way to prevent insulating fluid deterioration is to control overloading (and the resulting temperature increase), and to prevent tank leaks.
- Careful inspection and documentation of the temperature and pressures level of the tank can detect these problems before they cause damage to the fluid. However, a regular sampling and testing routine is an effective tool for detecting the onset of problems before any damage is incurred.

2.2.1 Mineral Oil properties

The oil must be certified by the manufacturer to have the following properties:

- Density: Specific gravity between .76 and .87
- Viscosity: < 34.5 cSt at 40^{o} C (< 172 SUS at 100^{o} F
- Color: >+30 Say bolt Color units
- Attenuation of light at 420 nm - The oil must be water clear. In particular, it must have an attenuation length of greater than 20 m for 420 nm (blue) light. That means that the amount of 420 nm light transmitted through a

1.8 m (6 ft) sample must be no less than 92% of that transmitted through an .2 m (8 in) sample.

- Long attenuation length over the wavelength range of 320 - 600 nm.
- High index of refraction and small dispersion over the wavelength range of 320-600 nm. The index of refraction and the dispersion (the change in index of refraction with wavelength) are usually functions of the density of the oil with both increasing with increased density. Impurities in the oil may have a small effect on the index, but may have a large effect on the dispersion.
- Small amount of scintillation light: Scintillation light is the isotropic light emitted when a charged particle passes through the material. In mineral oil, low scintillation light usually corresponds to a low level of aromatic or unsaturated impurities. In particular, while we need the oil stabilized with the antioxidant, Vitamin E, we would like to keep its concentration as low as feasible and Low reactivity with materials in our detector.
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- The index of refraction and the dispersion (the change in index of refraction with wavelength) are usually functions of the density of the oil with both increasing with increased density. Impurities in the oils may have a small effect on the index, but may have a large effect on the dispersion.

2.3 Transformer Faults

The IEC standard 60599 classifies the DGA detectable transformer faults into 2 categories: the electrical fault and the thermal fault. These two main categories can be further sorted into 6 types of transformer fault, according to the magnitudes of the fault energy: the electrical fault: partial discharge (PD), D1 (discharge of low energy) and D2 (discharge of high energy); the thermal fault: T1 (Thermal fault of low temperature range, T < 300 ºC), T2 (Thermal fault of medium temperature range, 300 ºC < T < 700 ºC) and T3 (Thermal fault of high temperature range, T >700 ºC).

2.3.1 Partial Discharge Fault

Partial discharge stands for the kind of discharge that only partially bridges the insulation gap between conductors/electrodes. The discharge May happen totally inside the transformer insulation or adjacent to the conductors. The PD around an electrode in gases is called corona, 29 commonly named as streamer.

Partial discharges, known as one of the most influencing reasons for insulator degradation, could lead to electric breakdown when they accumulate and propagate fully between two conductors. To avoid costly transformer failures, it is critically important to monitor the PD activities for early detection of the incipient of transformer fault. Dissolved gas analysis (DGA) is now the most widely used method to determine the condition of transformer insulation liquid as it is a non-destructive technique.

2.3.2 Electrical Sparking Fault

After decades of study, it is now generally accepted that the breakdown occurs after the streamers fully propagate through the gap of the electrodes. When the energy of dielectric breakdown is limited, it will act as small arcs which are named as sparking faults. In comparison with PD faults, sparking fault generate much more amount of fault gases under the same fault time and could be critical for transformer operation.

2.3.3 Thermal Fault

Sometimes bad connections when exclusive currents keep circulating in the conductor parts of the transformer, or leakage flux will lead to localized overheating. Thermal fault will change the transformer liquid performance by increasing the liquid temperature. In comparison with electrical type of transformer fault, thermal faults generate much more amount of fault gases under the same fault duration. Different types of fault gases will be formed under different temperature range; therefore, the fault gases could be used to diagnose the transformer fault temperature.

CHAPTER TREE

DISSOLVED GAS ANALYSIS

3.1 Dissolved Gas Analysis

Dissolved gas analysis (DGA) is known as one of the most widely used diagnosis tools of oil-filled transformers, it is noted as the non-interrupt test method which has already functioned for decades. Furthermore, DGA is also famous for the reliable fault forecast tool that is developed based on a vast amount of faulty oil-filled equipment in service and laboratory experiment results worldwide.

In general, DGA can be divided into 4 steps: collect oil sample, extract dissolved gas, gas chromatograph measurement and data interpretation. The oil sample collection is based on the international standard IEC 60567 which gives the recommended procedure for taking an oil sample from oil filled equipment. The oil sample collection is considered to be the first primary factor of a good DGA result; therefore, the recommended procedure needs to be followed carefully. The extraction of dissolved gas from the oil sample is the second step. The traditional vacuum method or the alternative vacuum pump method such as headspace and stripper methods are also available in IEC60567.

The last step will use the DGA results to interpret the transformer conditions. The international standards IEC 60599 and IEEE C57.104 provide many diagnosis tools for DGA results, such as the key gas method, the Roger ratio method and the Duval triangle method. Among all the diagnosis methods, the Duval triangle method seems to be the most popular one in fault prediction. However, because the interpretation methods are all developed based on the known transformer fault data, it may not be correct for some other cases, such as application of new ester liquids. The range and typical values of those interpretation methods might need to be changed as the database is updated.

3.2 Gas Formation

The transformer liquid consists of different hydrocarbon atomic groups like CH3, CH2 and CH. The molecular bond which is used to link the molecular group together, such as C-H and C-C bonds, will be broken when electrical or thermal energy is applied. Newly formed unstable radical or ionic fragments will recombine swiftly into gas molecules like hydrogen (H-H), methane (CH3-H), ethane (CH3-CH3), ethylene (CH2=CH2), acetylene (CH≡CH), CO (C≡O) and CO2 (O=C=O).

Different energy levels are required to break different kind of molecular bonds, as a result, different types and amounts of fault gases will be formed according to the severity and category of the transformer fault. The energy which is mandatory to crack the typical molecular bond inside the transformer oil is shown in Table 3.1.

Table 3.1.Bond Dissociation Energy.

Bond	C-C (CH3-CH3)	C-H (average)	C=H (H2C=CH2)	C=C (HC=CH)
Dissociation Energy(kj/mol)	356	410	632	837

Arcing, low energy sparking, PD and overheating are some of the common faults that could happen in the oil-filled transformers. Once any of these faults occurs, the insulation liquid will be decomposed and then a certain amount of combustible and non-combustible faulty gases will be formed. Generally speaking, there are 7 types of fault gases that could be generated after the transformer faults; they are hydrogen (H2), methane (CH4), ethane (C2H6), ethylene (C2H4), acetylene (C2H2), carbon dioxide (CO2) and carbon monoxide (CO).

Due to the different amounts of energy required to break different kinds of molecular bonds, the type and amount of fault gas generation vary and depend upon the magnitude of the fault energy. As a result, there exists a relationship between the fault type and fault gas generation which can be used to interpret the DGA results.

Figure 3.1 shows the diagram of the indicator gases related to each fault type

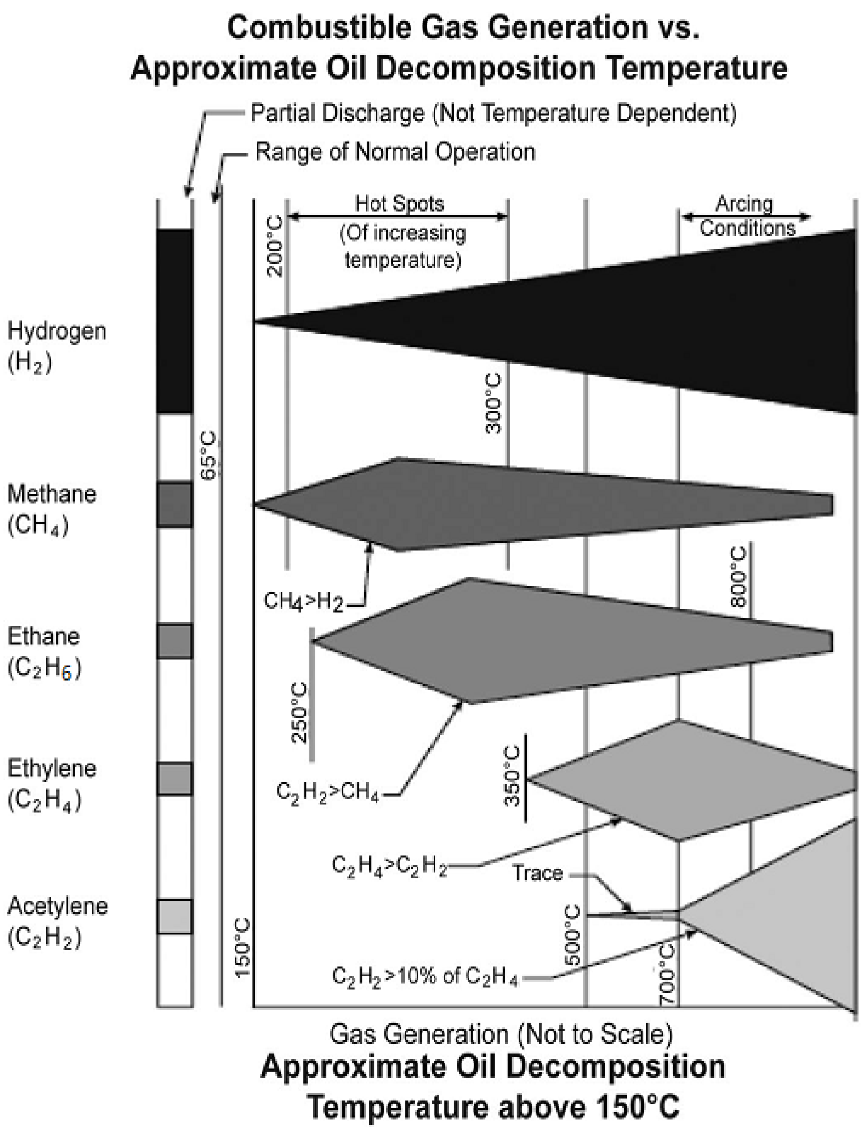


Figure 3.1 Diagram of Indicator Gases and Faulty Type and Severity Transformers Filled By Mineral Oil.

3.3 Classical Methods to Diagnose Transformer Faults

Based on DGA, many interpretative methods have been introduced to diagnose the nature of the incipient deterioration that occurs in transformers. Over the years, several techniques have been developed to facilitate the diagnoses of fault gases such as Dorneneburg method, Roger's ratio method Key gases method and Duval Triangle method.

3.3.1 Key gases method

The key gas method identities the key gas for each type of faults and uses the percent of th is gas to diagnose the fault [9]. Key gases formed by degradation of oil and paper insulation are hydrogen (H2), methane (CH4), ethane (C2H6), ethylene (C2H4), acetylene (C2H2), Carbon monoxide (CO) and oxygen (O2). Except for carbon monoxide and oxygen, all other gases are formed from the degradation of the oil itself. These gases are called “key gases” and are shown on Fig.3.2.

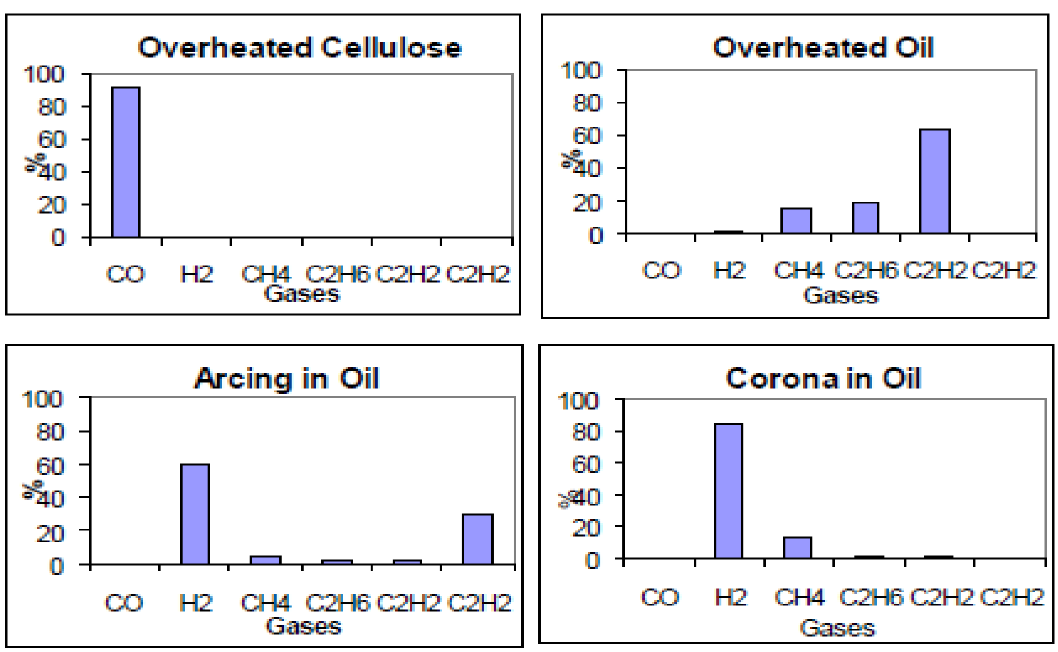


Fig3.2**:** Kay gas method and four typical faults.

Carbon monoxide, carbon dioxide (CO_2), and oxygen are formed from degradation of cellulosic (paper) insulation. Gas type and amounts are determined based on the kind of fault in the transformer, the severity and energy of the event. Events range from low energy events such as partial discharge, which produces hydrogen and trace amounts of methane and ethane, to very high energy sustained arcing, capable of generating all the gases including acetylene, which requires the most energy. The key gas method interprets the incipient faults in transformer according to some significant gases to assign four typical fault types.

3.3.2 Roger's ratio method

It is an additional tool that may be used to look at dissolved gases in transformer oil. The Rogers ratio method takes into consideration industrial experiences, laboratory tests, and further theoretical assessment. This method was further modified into an IEC standard. The original Rogers ratio method uses four gas ratios which are CH_4/H_2, C_2H_6/CH_4, C_2H_4/C_2H_6 and C_2H_2/C_2H_4 for diagnosis. The refined Rogers method uses two tables: one defined the code of the ratio, and the other defined the diagnosis rule. The ratio C_2H_6/CH_4indicated only a limited temperature range of decomposition, but did not assist in further fault identification. Therefore, in IEC standard 599, the further development of Roger's ratio method was deleted. Roger's ratio method and IEC 599 have gained popularity in industrial practices. However, it may give no conclusion in some cases. This is the "no decision" problem.

Table 3.2 shows the codes of roger’s method to diagnosis the fault in transformer.

Table 3.2: codes for Roger's method

CH_4/H_2	C_2H_2/C_2H_4	C_2H_6/C_2H_2	C_2H_2/CH_4	Diagnosis
0	0	0	0	Normal deterioration
5	0	0	0	Partial discharge
½	0	0	0	Thermal fault lower than 150°c
½	1	0	0	Thermal fault (150-200°c)
0	1	0	0	Thermal fault (200-300°c)
0	0	1	0	Overheating in the cables
1	0	1	0	Circulating currents in the windings
1	0	2	0	Circulating currents in the tank and the core, overheating in corrosions
0	0	0	1	Core
0	0	½	1/2	Corrosions discharges
0	0	2	2	Low intensity continuous discharge
5	0	0	1/2	Partial discharge involving solid insulation

3.3.3 Duval triangle method

The Duval Triangle was first developed in 1974 by Michel Duval using a database of about 1000 DGAs and transformer diagnoses results. Three hydrocarbon gases only (CH_4, C_2H_4 and C_2H_2) are used. These three gases are generated as a result of increasing the level of energy necessary to generate gases in transformers in service. The Duval Triangle is shown on Fig.3. 3 and the legend is on Table 3. In addition to the 6 zones of individual faults (PD, D1, D2, T1, T2 or T3), an intermediate zone DT has been attributed to mixtures of electrical and thermal faults in the transformer[E09532026.pdf].

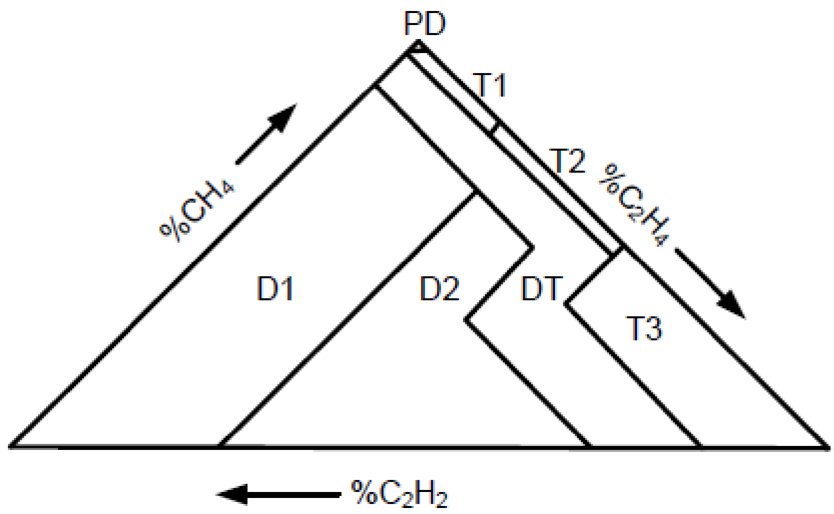


Fig.3.3**:** Duval triangle as a diagnostic tool to detect the incipient faults in transforme.

Table 3.3 legend of Duval triangle

Legend
PD=Partial Discharge
T1=Thermal fault less than 300̊c
T2=Thermal fault between 300̊c and 700̊c
T3=Thermal fault greater than 700̊c
D1=Low energy discharge (sparking)
D2=High energy discharge (arcing)
DT=Mix of thermal and electrical fault

3.3.4 Dornenburg ratio method

The Dornenburg method utilizes four calculated gas ratios to indicate a single fault type out of three general fault types. This procedure requires significant gases levels for the diagnosis to be valid. The four ratios and their diagnosis values are given on Table 3.2. Dornenburg method uses five individual gases or four -key gas ratios, which are: R1=CH4/H 2, R2=C2H2/C2H4, R3=C2H2/CH 4 and R4=C2H6/C2H2. Table 3.4 is used as a diagnostic ratio for Key gas method and Doernenburg method.

Table 3.4**:** Key gas ratio-Doernenburg .

	Ratios for key Gases			
	Main Ratio		Auxiliary ratio	
	CH4/H2	C2H2/C2H4	C2H6/C2H2	C2H2/CH4
Thermal Decomposition	>1	<.75	>.4	<.3
Corona(Low intensity PD)	<.1	Not significant	>.4	<.3
Arcing(High Density PD)	<1,>.1	>0.75	<.4	>.3

CHAPTER FOUR

EXPERIMENT WORK

4.1 Gas Chromatograph

Gas chromatograph is a type of chromatograph that is widely used in chemical analysis in order to separate and measure evaporable gas substances [40]. Figure (4.1) shows the diagram of gas chromatograph concept. As shown in Figure (4.1), the mobile phase flow, such as fault gases, is carried through the stationary phase which is used to retain the gas components. In the stationary phase, the weak retain substance will move faster while the strong retain substance will move more slowly. Consequently, different gas components will pass the stationary phase and reach the gas detector in different time ranges. Finally, the gas detector will give out the individual amounts of each gas according to the analysis time range [41].

4.2 Standard Gas

Standard Gas are typically used to calibrate gas chromatographs, enabling the composition of real refinery gases to be determined. This allows the user to calculate the carbon content and other physical parameters of the gas, thus ensuring compliance with carbon trading legislation.

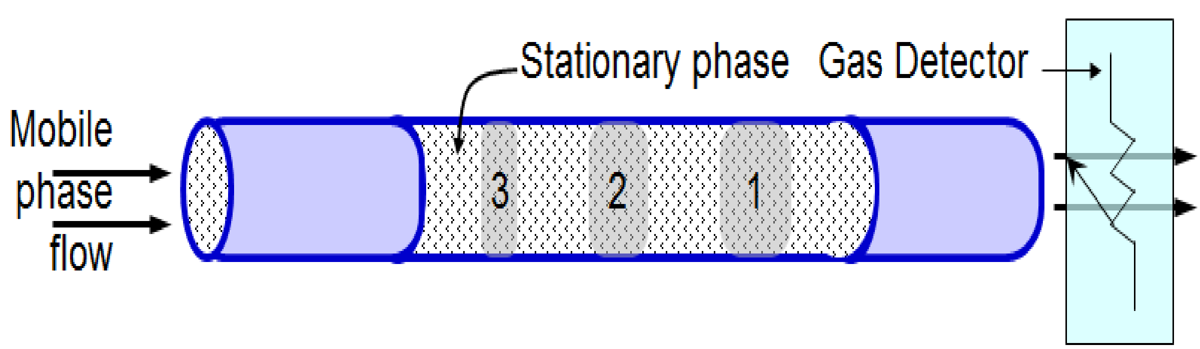


Figure 4.1 Gas Chromatograph Concept Diagram.

4.3 Normal values of dissolved gas

The mineral oil will contain normal values of dissolved gas which will indicate no incipient fault in the transformer. Normal value of each combustible gas and the total value of all gases are specified by IEEE std C57.104-1991 and described in the table 4.1. When the DGA results of all the 7 key gases are less than the normal values it can be concluded there was no incipient fault in the transformer.

Table 4.1 Normal values of DGA.

GAS	PPM
H2	100
CH4	120
C2H2	5
C2H6	65
C2H4	50
CO2	5000
CO	350

4.3 Pre-conditioning of the oil samples

Before starting the accelerated thermal aging process, the oil samples are preconditioned. First, the sample bottles or jars are cleaned before they are filled with oil. After taking some samples from the oil container, then the samples are vacuumed. This procedure is intended to reduce the humidity of the oil that may have increased during the oil storage in the container. New transformer oil are stored in containers. The imperfect bung closures and seals will allow the oil in the container to breathe air. Another reason is when we take the oil using the pump, it may introduce moisture to the oil too. The humidity content of the oil affects its dielectric properties, such as dielectric loss and breakdown stress. In order to study the aging effect on the dielectric properties, the humidity of the oil should be reduced as much as possible. For mineral oils, humidity tests show that it is necessary to reduce the humidity through the vacuum process before starting the aging process in the oven, because the humidity value of new mineral oil is around 18 ppm before the vacuum process, while it is reduced to 12 ppm after the vacuum process. For the ester oil which is used in this study, the vacuum process is not necessary as the humidity level is as low as 3 ppm even without the vacuum process and the oil does not show a measurable change of humidity after a vacuum process.

4.4 Experiment Steps

The sample to be tested is taken from the top valve of the transformer by 200 Ml, Then wash the bottle in which the sample is taken three times the oil to be analyzed to ensure that the same pure bug-free. During the sampling must take into account the environmental conditions (rain, dust, temperature ...... etc). Then another sample is taken from the above sample taken in with "injection" by 40 ml and then injected with argon gas by 5 ml and then placed in a shaking device. After that the gases formed by other taken injected smaller size. Which is taken to one mL of these gases and injected into the DGA device, Which separates the gases formed and displayed in the screen.

This view shows us made as curves and every curve gas are compared with the standard value of the gas; curves give us an indication of some of the problems and the kinds converter and whichever is the most dangerous and then later how to found solution or to avoid harm to the appearance of this gas.

4.5 Experiment Results

Table 4.2 DGA Result under normal condition (before fault).

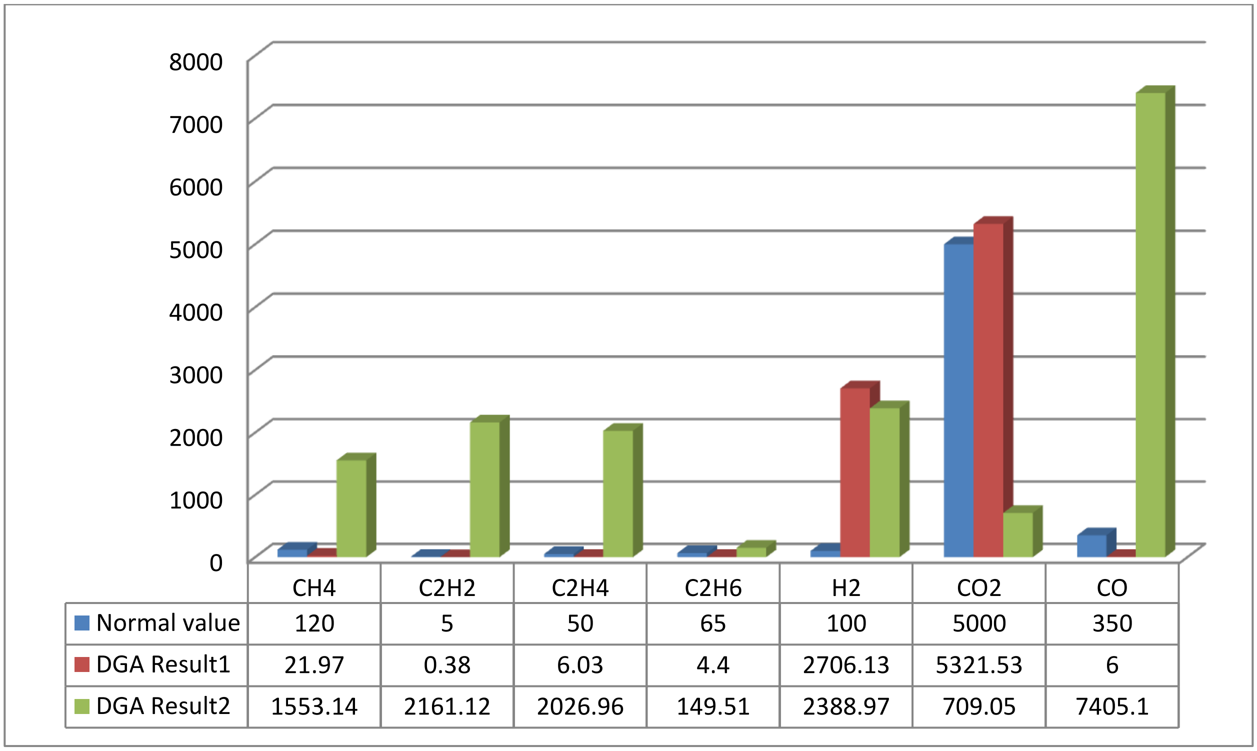
Gas	PPM
H2	2706.13
CH4	21.97
C2H2	0.38
C2H6	4.4
C2H4	6.03
CO2	5321.53
CO	6

Table 4.3 DGA under up normal condition Result (during fault).

GAS	PPM
H2	2388.97
CH4	1553.14
C2H2	2161.12
C2H6	149.51
C2H4	2026.96
CO2	709.05
CO	7405.10

4.4 Experiment Result Comparison and Discussion

The generation rate of fault gases for mineral oil tests under normal and up-normal operation condition of transformer are summarized in Figure 4.2. The normal value of this gases also summarized in figure 4.2.



	CH4	C2H2	C2H4	C2H6	H2	CO2	CO
Normal value	120	5	50	65	100	5000	350
DGA Result1	21.97	0.38	6.03	4.4	2706.13	5321.53	6
DGA Result2	1553.14	2161.12	2026.96	149.51	2388.97	709.05	7405.1

Figuer4.2 Experiment Result Comparison

It was observed that from the figure 4.2, the generation rate of fault gases is much higher than the normal value. Therefore, the generation rate of CH4 under fault is increased about 70 times of its value before the fault. Also C2H4 and C2H6 are increased about 337 and 33 times respectively. In Figure 4.2 it can be seen that the fault gas generation rate is increased with the increase of the fault temperature for mineral oil. It also shows that the CH4, C2H4, C2H2 and CO take up the most part of the total fault gases. Due to exceeds rate of H2, C2H2 and CH4 in the transformer oil , cause electric arc discharge in the transformer.

CHAPTER FIVE

CONCLUSION AND RECOMENDATION

5.1 Conclusion

Since about four decades, the DGA method has being gaining great attention as one of the most efficient and convenient methods for fault diagnostic in transformers. Thus, power agencies has joined forces with the oil diagnostic field in order to develop advanced measurement techniques for gas-in-oil analysis, as well as to improve statistical interpretation schemes used for the fault diagnostic.

- **Gas extraction techniques**

  Most of the gas-in-oil monitoring techniques cannot measured dissolved gases before extracting them from the oil, which is a very critical step of the DGA method. The dissolved gases need to be first efficiently extracted from the oil sample before feeding them to a gas analyzer, such as a gas chromatograph. Consequently, the efficiency of the extraction techniques has direct influence on the reliable quantification of dissolved gases and thus a proper fault diagnostic with the DGA method.

5.2 Recommendations

Based on the experience gained during these investigations, following suggestions can be pointed out for future research work and practical application of DGA,For the further investigations related to the fault gas generation and their evaluation by DGA, it is recommended to add other factors affecting the gas generation process, such as the presence of insulation paper, fluctuation of transformer voltage load and oil temperature.

5.3 Reference

[1] J.J Kelly, "Transformer fault diagnosis by dissolved gas analysis " IEE trans. On Industry application, vol.16, no.pp.777-782, Dec.1988.