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TESTING OF LIQUID INSULATION USED IN HIGH VOLTAGE TRANSFORMER A MINI REVIEW

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Abstract: - Energy Mineral oil is used in all types of oil immersed power transformers to provide better cooling and to improve the insulation level. Moisture and prolonged electric stress leads the way for ageing in transformer insulation. It results in degradation of insulation properties and hindrance in uninterrupted operation. To avoid this, periodic condition monitoring is required to protect the transformer insulation. Transformer oil testing is necessary to determine the essential electrical, mechanical and chemical properties and to ensure the fitness of oil. In this paper the various critical properties AC breakdown voltage, DC breakdown voltage, Lightning Impulse breakdown voltage, PD inception voltage, Relative permittivity, dissipation factor, specific resistivity, volume resistivity, flash point, fire point, kinematic viscosity, Acidity was discussed. The measuring standards, instrument used for measuring purpose are listed and studied in simple manner. This paper would be help full for electrical engineering students to understand the basic concepts in testing of insulating oil.

Keywords— Nanoparticles, SEM ,TEM, AFM, Nano fluid

I. INTRODUCTION

Power transformer is a key component of electrical power network systems. It takes the role of voltage conversion and power transmission. The stability of power network systems depends on the safety of power transformers. Currently, large capacity power transformers are mainly oil-immersed. The oil plays the roles of cooling, insulation and etc. Therefore, improvement of the dielectric strength of transformer oil may considerably enhance the operating stability of the transformer and extend its lifetime [3]. Mineral oil is generally used as cooling and insulating fluid in oil filled electrical equipment. They are developed from petroleum crude stock after refining and distillation. The mineral oil contains a combination of basic hydrocarbon liquids, such as paraffin, naphthene, olefin and aromatic. Due to rising transmission voltage levels, it is very hard to for normal liquid insulation (mineral oil) to fulfill the need

of ultra high voltage transformers [2]. The breakdown mechanisms to describe the improvement in dielectric strength of Nano fluids were recommended [1-3]. The suspended nanoparticles in oil are considered to act as electron scavengers, transforming high mobility electrons to slow negatively charged particles based on the results of simulation model, so the initiation and migration of streamer is disrupted, and the breakdown strength is improved [4-6].

II. NANOMATERIAL CHARACTERIZATION TOOLS

The nanoparticle size was measured by the following methods they are:
Scanning Tunneling Microscope (STM)
Scanning Electron Microscopy (SEM)
Transmission Electron Microscopy (TEM)
Atomic Force Microscopy (AFM)

III.MINERAL OIL

Transformer oil (also known as insulating oil) is a special type of oil which has excellent electrical insulating properties and is stable at high temperatures. Transformer oil is used in oil-filled electrical power transformers to insulate, stop arcing and corona discharge, and to dissipate the heat of the transformer (i.e. act as a coolant) [12].Transformer oil is also used to preserve the transformer's core and windings – as these are fully immersed inside the oil. Another important property of the insulating oil is its ability to prevent oxidation of the cellulose-made paper insulation. The transformer oil acts as a barrier between the atmospheric oxygen and the cellulose – avoiding direct contact and hence minimizing oxidation. The level of transformer oil is typically measured using a MOG (Magnetic Oil level Gauge) [12].

There are two main types of transformer oil used in transformers. They are Paraffin based transformer oil and Naphtha based transformer oil [12].

Naphtha oil is more easily oxidized than paraffin oil. But the product of oxidation – i.e. sludge – in the naphtha oil is more soluble than the sludge from the paraffin oil. Thus sludge of naphtha-based oil is not precipitated in the bottom of the transformer. Hence it does not obstruct convection circulation of the oil, means it does not disturb the transformer cooling system [12].

Although Paraffin oil has a lower oxidation rate than Naphtha oil, the oxidation product (sludge) is insoluble and precipitated at the bottom of the tank. This sludge acts as an obstruction to the transformer cooling system [12].

IV. PROPERTIES OF MINERAL OIL

Transformer oil's primary functions are to insulate and cool a transformer. It must therefore have high dielectric strength, thermal conductivity, and chemical stability, and must keep these properties when held at high temperatures for extended periods. As transformer oil deteriorates through aging and moisture

ingress, transformer oil should, depending on economics, transformer duty and other factors, be tested periodically.

Power utility companies have a vested interest in periodic oil testing since transformers represent a large proportion of their total assets. Through such testing, transformers' life can be substantially increased, thus delaying new investment of replacement transformer assets.

Generally mineral oil grade –B is used for transformers and switch gears. The properties of mineral oil is listed below

A. Viscosity

Indicates fluidity, oil with lower viscosity has more fluidity which gives more cooling effect. Insulation and Dielectric strength: the insulation of transformer oil should be high, which is greatly reduced by the presence of moisture and dust particle presented in the work place. Dielectric strength should not be less than 30KV with 5.5mm standard gap.

B. Flash point

The temperature at which vapor above oil surface ignites spontaneously is termed as the flash point. Its value should not be less than 140°C.

C. Fire Point

The temperature at which the oil will ignite and continue burning should be about 200°C.

D. Purity

It should not contain impurities such as sulphur and its compounds. It will cause corrosion of metal parts and accelerate the formation of sludge.

E. Sludging

Sludging means the slow formation of semi-solid hydro carbons which may be acidic in nature also they block the passage of cooling oil. This is due to heat and oxidation. The remedy is use good insulating oil without content of sulphur or its components.

F. Acidity:

Among products of oxidation of transformer oil CO_2, volatile water, soluble organic acids and water. The presence of air and water can be reduced by using breather. The limiting value of acidity after oxidation is 0.4mg of KoH/g.

The insulating oil gets contaminated when presence of the following impurities shown in fig. 1. These impurities will reduce the dielectric strength of insulating oil or insulating strength of insulating oil.

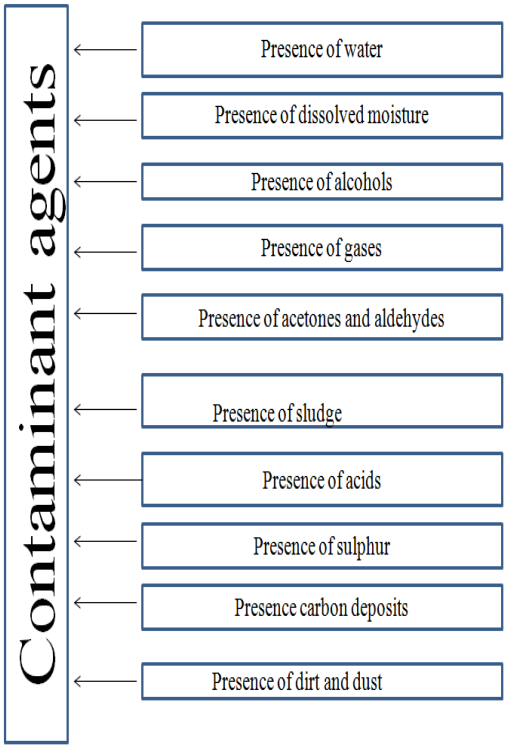


Fig. 1. Various Contaminant Agents

V. SAMPLE PREPARATION

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (or flea) immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid. The following fig. 2 shows the image of magnetic stirrer.

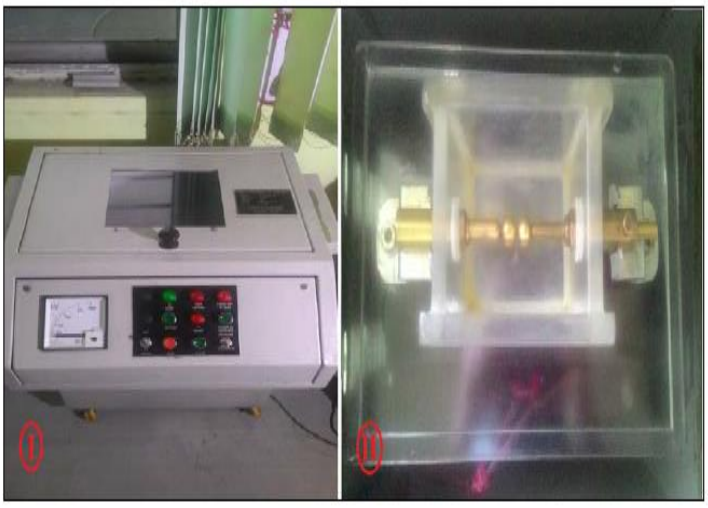
Fig. 2. Magnetic Stirrer

Nano fluids are prepared by dispersing the nanoparticles with base fluid (TOL) by magnetic stirrer or sonication process. The following fig. 3 shows the image of sample at sonication process.

Fig. 3. Image of sample at sonication process

VI. BREAKDOWN VOLTAGE TEST

IEC 60156, ASSTM D1816 and IS6792:1972 different testing standard was used in this test. It is the impartment test used to find out the insulation strength of mineral oil. A portable Jiantong oil tester was used to measure AC break down voltage. It consists of 220V/100KV step up transformer, Test cell with two spherical electrodes. High voltage is generated by using step-up transformer and applied between the contacts of electrodes at a rate of 2KV/s, the spacing between the electrodes was maintained at 2.5mm. The sparking between the contacts indicates the BDV strength. The measurements are taken by giving time delay of one or two minute between each successive measurement. The average of five values was taken as breakdown voltage. The BDV of mineral oil indicated the health of the transformer in electrical system. The BDV depends on pressure, temperature, humidity, nature of applied voltage, gap between the electrodes, contaminations and geometrical configurations of electrodes for a BDV testing system. The following fig.4 shows the BDV test kit and oil test cell.



(a) (b)

Fig. 4. 100kV BDV test Kit and Oil test cell

VII. CAPACITANCE TAN DELTA AND RESISTIVITY

In practice, the insulator cannot be made 100% pure. Also due to the aging of insulators, the impurities like dirt and moisture enter into it. These impurities provide the conductive path to the current. Consequently, an electric leakage current flowing from line to earth through the insulator has a resistive component.

Hence, it is needless to say that, for good insulator, this resistive component of electric leakage current is quite low. In another way, the healthiness of an electrical insulator can be determined by the ratio of the resistive component to the capacitive component. For good insulator, this ratio would be quite low. This ratio is commonly known as tanδ or tan delta. Sometimes it is also referred to as dissipation factor.

This testing instrument used to measure three important parameter in transformer oil - Tan Delta, Dielectric Constant and Resistivity of an insulating medium. Tan delta and Dielectric Constant balance with the aid of a synchronous and phase sensitive null detector. Resistivity with DC Voltage. The following fig. 5 shows the Image of Capacitance and Tanδ and Resistivity measurement kit.

Fig.5. Image of Capacitance and Tanδ and Resistivity measurement kit

VIII. IFT (INTERFACIAL TENSION) NUMBER

This Interfacial tension between the water and oil interface is the way to measure the attractive molecular force between water and oil. in Dyne/cm or milli-Newton/meter. Interfacial tension is exactly useful for determining the presence of polar contaminants and oil decay products. Good new oil generally exhibits high interfacial tension. Oil oxidation contaminants lower the IFT [12].

IFT instrument used for measuring under non-equilibrium condition, the Interfacial tension of mineral oil against water, which has been shown by practice to give reliable indication of the presence of hydrophilic compounds in transformer oil. The following fig.6 shows the image of IFT test kit.

Fig. 6. Image of IFT test kit

IX. DGA (DISSOLVED GAS ANALYSER)

DGA is the most sensitive and reliable loss prevention technique and it gives an early indication of abnormal behavior of transformer. This instrument measures the concentrations of dissolved gas or free gases in transformer oil and be interpreted to diagnose the condition of transformer oil filled electrical equipment in service and suggest future action. The following fig.7 shows the image of DGA test kit.

Fig.7. DGA test kit

X. WATER CONTENT (PPM)

This Moisture or water content in transformer oil is highly undesirable as it affects the dielectric properties of the oil adversely. The water content in oil also affects the paper insulation of the core and winding of a transformer. Paper is highly hygroscopic. Paper absorbs the maximum amount of water from oil which affects paper insulation property as well as reduced its life. But in a loaded transformer, oil becomes hotter; hence the solubility of water in oil increases [12]. 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 a sample for the test is critical. During oxidation, acids get formed in the oil the acids give rise to 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. We measure the water content in oil as ppm (parts per million unit)[12]. PPM Instrument used for the determination of water content in transformer oil unused or used insulating liquids with calorimetrically generated Karl Fischer regent. We can measure from 1 ppm to 1000 ppm. The following fig. 8. Shows the image of PPM measurement kit.

Fig.8. Image of PPM measurement kit

XI. FURAN ANALYSIS

This Test method is to determine the degradation of cellulose paper insulation. High Concentration or unusual increase in the concentrations of furanic compounds in oil may indicate cellulose degradation from aging or incipient fault conditions. The levels of furanic Compounds in oil relate to the average deterioration of the insulating paper. This Instrument used for the analysis of 2- Furfural related furan compounds resulting from the degradation of cellulosic insulation and found in mineral insulating oil samples taken from electrical equipment. The following fig.9.shows the image of Furan analysis test kit.

Fig.9. Image of Furan analysis test kit

XII. KINEMATIC VISCOSITY

This method describes a producer for the determination of the kinematic viscosity of liquid petroleum products, both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer. The dynamic viscosity can be obtained by multiplying the measured kinematic viscosity by the density of the liquid. Is a very important property which should be considered for determining the heat transfer rate. A low viscosity is most preferable since oil will be in circulation and it must fill the whole volume of the transformer. Viscosity measurements were done as per IS 1448-part 25:1970 using an Ostwald's viscometer. The following fig.10 shows the image of Karl Fischer viscosity meter.

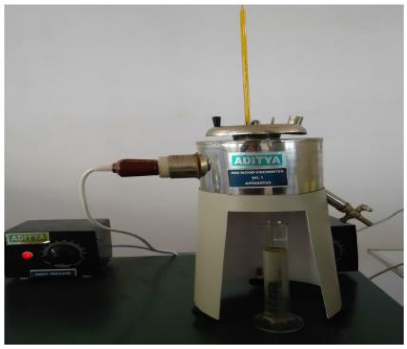


Fig.10. Karl Fischer viscosity meter

XIII. ACIDITY TEST (NEUTRALIZATION NUMBER)

This instrument used determination of acidic constituents in transformer oil. This acid number is used as a guide in the quality of transformer oil. The total acid content (acidity) was measured as per ASTM D 974. Acid number (mg of KOH/g) indicates contamination by substances with which the oil has been in contact or a chemical change in the oil from processes such as oxidation. A low total acid content determines an insulating oil is necessary to minimize electrical conduction and metal corrosion and to maximize the life of the insulation system. The following image shows the Acitiy test kit. This instrument used determination of acidic constituents in transformer oil. This acid number is used as a guide in the quality of transformer oil. The following fig.11. shows the image of acidity test kit.

Fig.11. Image of Acidity test kit

XIV. FLASH POINT

A. Flash Point

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 the application of flame under standard condition. Flashpoint is important because it specifies the chances of fire hazard in the transformer. So it is desirable to have a very high flash point of transformer oil. In general it is more than 140o(>10o) [12].

B. Pour Point

It is the minimum temperature at which oil starts to flow under standard test condition. Pour point of transformer oil is a valuable property mainly at the places where the climate is icy. If the oil temperature falls below the pour point, transformer oil stops convection flowing and obstruct cooling in a transformer. Paraffin-based oil has a higher value of pour point, compared to Naphtha based oil, but in India like country, it does not affect the use of Paraffin oil due to its 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 [12].

This instrument used for measuring the Flash Point by Pensky Martens closed cup tester of transformer oil, fuel oils, lubricating oils, suspension of solids, liquids that tend to form a surface film under test conditions and other liquids. The following fig. 12 shows the Fire and Flash Point measurement setup

Fig.12. Image of Fire and Flash Point measurement setup

CONCLUSIONS

High Voltage Transformers plays important role in electrical distribution system. The life time of these transformers mainly depends upon the insulation strength of mineral oil. Mineral oil testing is most important to determine the essential properties of insulating oil, to identity if certain oil is suitable for further use, to detect whether regeneration or filtration is needed, to reduce the oil costs, to prevent untimely failures and maximize the safety. In this paper characterization of nanotechnology tools, different types of testing like BDV test, capacitance, Tan delta, resistivity, acidity, IFT, Fire& Flash point test, Furan nalysis, DGA and PPM test were explained. The measuring standards, instrument used for measuring purpose are listed and were studied in simple. This paper would be help full for electrical engineering students to understand the basic concepts in testing of insulating oil.

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