Investigation of Transformer Oil Exposed to the Atmosphere

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Abstract-*The transformers oil acts as a insulation but also it is used for cooling of the transformer. It carries away the heat generated in the transformer. It is highly important that the properties of transformer oil are maintained so that they do not change in due course of time. But the properties of the oil change when exposed to the atmosphere because of the ingression of moisture, dust, etc. In this project, an attempt has been to study the change in properties of transformer oil when it is exposed to the atmosphere. The degradation of oil is measured by the change in the electrical properties of the oil as breakdown voltage (BVD), tan delta and part per million (ppm).*

Two Sample of oil is taken and exposed atmosphere for 65 days. The properties are regularly monitored and the change is noted. The correlation between these parameters and the number of days for which the oil is was kept open is plotted. It could be concluded that the breakdown voltage of oil reduces when exposed to atmosphere while tan delta and ppm increase. The maximum changes in the properties are observed in the first 6 days exposure. Less change in the properties are observed after 6 days, this is because the oil start saturating and moisture absorption capacity of oil is reduced. In 65 days of exposure, the dielectric strength of oil reduces by 40% of its initial value.

Index terms- Transformer oil, Investigation, Atmosphere.

I. INTRODUCTION

Insulating materials are used for insulating the conductor from the atmosphere. There are so many types of insulators in which liquid is also used as an insulator. Therefore in transformer the oil is used for insulation and heat dissipation.

Transformer oil needs to be tested periodically to ensure that it is still fit for purpose. Testing sequence and procedures are by various international standards by American Society For testing And Material (ASTM)

II. Necessity of oil testing:.

As transformer oil is an important factor for protection of transformer winding, also used for heat dissipation inside the tank. it is important to investigate the healthy condition of transformer oil with respect to its properties. This paper deals with such investigative test s used to study the properties and the experiment on the sample taken to calculate the healthy condition of transformer oil. with deterioration in healthy condition of transformer oil when exposed to atmosphere causes bubble formation, atmospheric changes , surface breakdown and tracking effect in transformer oil.

Before investigating it important to discuss the properties standard required for healthy insulating material. Based on the properties the investigative test can be carried out in order verify the healthiness of the insulating material. Transformer oil properties are discussed in

this paper and investigative test are perform on variable sample to judge the healthiness of insulating material.

Low viscosity is the ease with which convection flow can be induced clearly is very dependent on the viscosity of the fluid and it is therefore very important. Resistance to oxidation is the neutralization value of Transformer oil increases on getting oxidize. The neutralization value must not go beyond 0.4mg KOH/ gm. after oxidization and total sludge after oxidization must be not more than 0.1 % of the weight of oil used. Sludge is a poor conductor of heat, sludge deposited over the Transformer parts leads to poor heat dissipation. It blocks the flow of oil in the ducts and impaired cooling. Therefore once sediments of perceptible sludge are detected oil is considered not usable.

Dielectric strength of Transformer oil the dielectric breakdown voltage measurement of the electrical stress that the insulating oil can withstand without failure. This property is measured by applying the voltage through the oil sample between two electrodes under a certain prescribed condition in the oil. The dielectric strength of Transformer oil is also known as Breakdown Voltage (BDV) of Transformer oil. The specific resistance of transformer oil is with an increase in temperature the resistivity of oil decreases rapidly. The resistivity of the insulating oil must be high at room temperature. Also, it should have good value at high temperature as well. That is why specific resistance of resistivity of Transformer oil should be measured at 27°C as well as 90°C.

III. Investigative test on transformer

In this paper investigative test regards to effect of atmospheric changes over transformer oil is tested and verified following are the investigative test setup.

Moisture content is a Testing sample of Transformer oil gives the content of moisture/water in it, due to the presence of this moisture the dielectric constant of oil is reduced. Any increase in moisture content will decrease the insulating property of oil. Water in solution is normally determined by chemical means and is measured in parts per million (ppm).

Dielectric strength is the dielectric breakdown voltage is the measurement of the electric stress that insulating oil can withstand, without failure. This property is measured by applying a voltage through the oil sample between two electrodes under certain prescribed conditions in the oil. Power Factor- The Power Factor is the valuable screening test. It is the ratio of true power to Apparent power. If the new oil has a power factor greater than 0.05% it indicates a significant power loss, because the oil may be contaminated with water, oxidation products, or other polar contaminants. Effect of oxidation-The effect of oxygen moisture contamination is one of the most obvious causes of deterioration in the insulating quality of Transformer oil. This contamination can be eliminated by purification. A less Rapid, but more serious characteristic deterioration if the formation of acid and sludge, which is caused by oxidation. Thus the exclusion of oxygen is of prime importance. In open breather Transformers, the oxygen supply the almost unlimited and oxidative deterioration is much faster than in sealed Transformers. Atmospheric oxygen is not the only source of oxygen available for the oxidation of insulating oil; water also serves as a carrier of Oxygen and Leaky gaskets constitutes a real hazard, causing both oxidation and moisture contamination. The rate of oxidation also depends on the temperature of the oil; the higher the temperature, and the faster oxidative breakdown. This point to the importance of avoiding overloading of Transformers, especially in Summer time. Oxidation results in the formation of acid in the insulating oil which in turn, contributes to the formation of sludge.

The effect of temperature on moisture-The amount of moisture that can be dissolved in oil increases rapidly as the oil temperature increases. Therefore, insulating oil purified at to higher temperature may lose a large percentage of its dielectric strength on cooling, because the dissolved moisture is them becomes an emulsion.

Effect of contamination is solid and metal particles in oil-Solid particles in suspension in insulating oil affect the dielectric strength, depending on concentration, type, and size. Particles counting with automatic laser particle counter have become simple. A particle size distribution lists the size and amount of different particles. The particle in insulating oil settles rapidly and in only about an hour, all particles larger than 50 Micron are deposited. Smaller particles take more time. This means that sample must be agitated before PSD (particle size distribution) analysis.

Humidity-Various types of humidity are as follows:

Relative humidity is defined as the ratio of vapour pressure at a temperature to the saturation vapour pressure at the dry bulb temperature. It should be kept in mind that for calculating relative humidity, saturation vapour pressure is taken at dry bulb temperature and not at wet bulb temperature.

Specific humidity is defined as the mass of water vapour present in the kg per kg of dry air.

Absolute humidity- it is defined as the amount of water vapour present in a unit volume of air. It is usually expressed in kilograms per cubic meter.

A principle of tan Delta test-

A pure insulator when connected across line and Earth, it behaves as a capacitor. In an ideal insulator, as an insulating material which acts as a dielectric too, it is 100% pure, the electric current passing through the insulator, only have capacitive component. There is no resistive component of the current, flowing from line to earth through insulator as an ideal insulating material, there is 0% Impurity. In the pure capacitor, the capacitive electric current leads the applied voltage by 90° in practice; the insulator cannot be made 100% pure. Also due to the aging of the insulator are the impurities like dirt and moisture enter into it. These impurities provide a conductive path to the current consequently, leakage electric current flowing from line earth through insulator has also the resistive component. Hence it is needless to say that, for good insulator, this resistive component of leakage electric current is quite low. In another way, the healthiness of an electric insulator can be determined by a ratio of the resistive component to the capacitive component for good insulator this ratio would be quite low. This ratio is commonly known as Tan δ or tan Delta. Sometimes it is also called as dissipation factor (DDF).

The resistive components I_R are in phase with the voltage on the x-axis. The inductive component IL lags capacitive component I_C. As the capacitive component of leakage electric current IC lead system voltage by 90°, it will be drawn along the y-axis.

Now total leakage current I_L (I_C +I_R) makes an angle δ with the y-axis.

Now from the diagram above, it is cleared; the ratio I_R to I_C is nothing but tan δ

Thus, tan $\delta=I_R/I_C$

Where, I_R – Resistive component

I_C- Capacitive component

This tan δ angle is known as a loss angle.

IV. Oil testing-

When the oil is kept open to atmosphere, it contaminates and the properties of the oil change because of the ingression of moisture, dust particles etc. To study these, two samples of oil are taken and the electrical parameters of oil such as breakdown voltage, dielectric dissipation factor, and PPM are regularly monitored. Two tanks filled with oil is taken as exposed to the atmospheric condition. These tanks are so covered that dust, dirt couldn't enter but at the same time provide sufficient ventilation to the oil. These oil samples are

taken into glass bottles as per the quantity required for different testing. The test performed on the oil that is breakdown voltage test (BDV), tan delta test and water content test breakdown voltage is performed to check the dielectric strength of the oil: Tan Delta test is performed to check the loss angle of oil: water content test is performed to check water in oil in parts per million (ppm) initially the fresh oil was tested and reading was noted, then after the changes in the property irregularly monitor for 65 days. The relation between the deterioration of properties and the number of days is studied. It was observed that in the first 6 days of exposure, the dielectric strength of oil drastically decreases.

V. Breakdown voltage test setup

This is to test of the dielectric strength of Transformer oil. The sample is taken in electrolysis pot and a voltage difference is applied between anode and cathode of the pot. The difference between the two plates is 2.5 mm. The voltage near which the oil losses its insulation property, that voltage is called BDV.

Precaution to be taken while performing BDV-

Before putting the oil for testing the cell was thoroughly cleaned by rinsing with the test oil. Immediately after this, the sample was poured down slowly in the test cell to avoid air Bubbles forming. After each break down the oil was gently stirred, so as to keep away the carbon particles between the electrodes.

Procedure-

The Transformer oil is filled in the vessel of the testing device in which a pair of electrodes is fixed with a gap of 2.5 mm between them. A voltage is applied to the electrodes and is continuously increased up to The breakdown voltage which is control at a rate of 2KV/s the voltage at which sparking starts between the electrodes is observed.

Fig 1: Break down voltage test

At a certain voltage, level breakdown occurs in an electric arc, leading to collapse of the test voltage. And instant after ignition of the arc the test voltage is switched off automatically by the testing device. Ultra-fast switch off is highly desirable, as the carbonization due to the electric arc must be limited to keep the additional pollution as low as possible.

The Transformer oil testing device measures the root mean square value of The breakdown voltage. After the Transformer oil test is completed, the insulation oil is stirred automatically and the test sequence performs repeatedly.

As a result of the breakdown voltage is calculated as the mean value of the individual measurements. A minimum breakdown voltage of Transformer oil or dielectric strength of Transformer oil at which this oil can safely be used in the transformer is considered as 30KV.

VI. Water content test setup

Water content testing by Karl Fischer titration

Karl Fischer titration is an analytical technique to measure the amount of water contained in various samples, which may be solid, liquid or gas episode. This method was originally developed in the 1930s by German chemist Karl Fischer.

Karl Fischer titration is based on a 1:1 reaction between iodine and water in the presence of sulphur dioxide and a base.

K-F titration can be summarized into a series of steps-

Add reagent ("titrant") to a burette. The reagents include alcohol.SO_2, a base, and I2.

Add sample solvent to the titration vessel. Bring stirring the vessel.

Zero instruments by titrating unwanted moisture in the system.

Add the weighed to the titration vessel.

Being adding reagent from burette while starring.

When the endpoint is reached, the electrode will detect no change in current upon addition of more Reagents.

By knowing how much titrant was added, the water content can be calculated

Normally, the K-F instrument does the calculation and reports the result as "% water" or "Parts 3per Million" (PPM).

The Karl Fischer reaction

K-F titration involves two reactions-

In first reaction an alcohol. Sulphur dioxide (S02) and a base (RN) react to form

$CH_3OH+SO_2+RN= [RNH] SO_3CH_3$ (1)

In the second reaction, the alkyl sulphite facts with iodine (I2) and the water from the sample

fig 2: Karl Fischer titration kit

$[RNH]SO_3CH_3 + I2 + H_2O + 2RN = [RNH] SO_4CH_3 + 2[RNH]I$ (2)

Since water and I2 are consumed in equimolar amounts in reaction 2, if you know the amount of I2 consumed, you know the amount of water that was present in the sample.

VII. Dielectric dissipation factor (Tan Delta) test setup

It is also known as a loss factor. It is measured of the dielectric nature of oil. For a perfect dielectric when applied with a sinusoidal AC voltage, the current flowing through it should lead the voltage by 90 °. But it is not in the case in reality. The angle by which it is short of 90° is called as loss angle.

Fig 3: Tan delta test

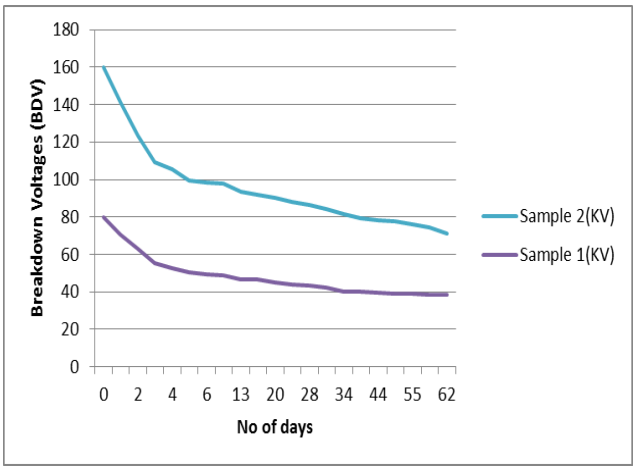
Method of tan Delta test

The cable, winding, current transformer, potential Transformer, Transformer, the bushing on which tan Delta test or dissipation factor test to be conducted, its first isolated from the system. A very low-frequency test voltage is applied across the equipment whose insulation is to be tested. First, the normal voltage is applied, if the value of tan Delta appears good enough, the applied voltage is raised 1.5-2 times of normal voltage of the equipment. Tan Delta controller unit takes a measurement of tan Delta values. A loss angle analyser is connected it and Delta measuring unit to compare tan Delta value at normal voltage and higher voltages and analyses the result.

VIII. Results of tests:

Results of Breakdown voltage test-

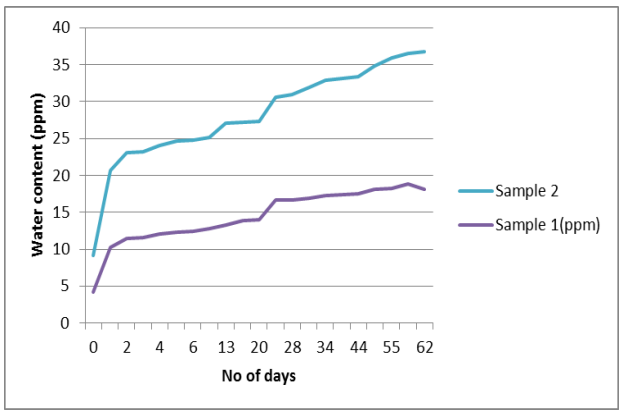
From above graph the dielectric value of sample 1 and sample 2 vs. Number of days are plotted. For first 6 day of exposure both the sample have approximately same breakdown voltage this is because both the sample is kept under same condition and temperature and the dielectric value drastically reduces and after that there is consistency in there reading as the oil saturates. It shows that as the number of days increased, the breakdown value of oil decreases from 80 Kv to 32.4 Kv for sample 1 and 80 Kv to 27.2 Kv for sample 2 i.e. 60%. This is due to ingression of moisture in the oil.



Graph 1: Breakdown voltage vs. No. of days

Results of water content test-

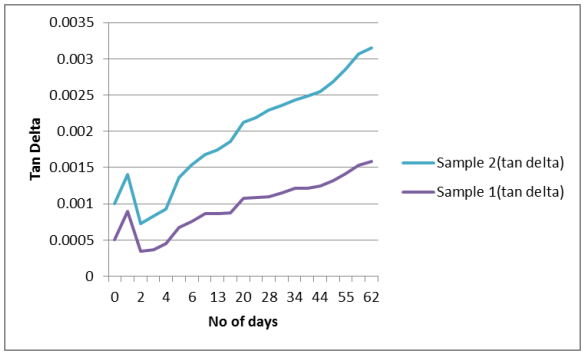
The moisture content of oil of sample 1 and sample 2 vs. Number of days are plotted. It shows that as the number of days increases, the moisture content of oil also increased from 4.25 ppm to 22.39 ppm for sample 1 and 4.91 ppm to 22. 64 ppm. For sample 2. This is due to ingression of moisture in oil due to change in atmospheric condition.



Graph 2: Water content (ppm) vs. No of days

Results of Tan Delta test

From above graph shows the tan delta of oil of sample 1 and sample 2 vs. Number of days are plotted. It shows that as number of days increase, tan delta of oil increase from 0.0005 to 0.00211 for sample 1 and 0.0005to 0.00373 for sample 2. This is due to ingression of moisture in the oil.



Graph 3: Tan delta vs. No. of days

IX. Conclusion-

The breakdown voltage is reduced due to change in the oil properties by 40% of initial value when, similarly the loss angle also increased, also water content in the oil also raised due to the ingression of moisture in it. Moreover, it is also observed that the change in the first 6 days is maximum; the dielectric strength of oil is reduced by 61%. Less change in the property for observed after 6 days this is because the oil starts saturating the moisture absorption capacity of oil is reduced. The graph indicates the deterioration properties with increasing the number of days. Thus, it is seen that the dielectric strength of oil in 65 days is reduced by 48%.

X. References

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