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Comparative study of Breakdown Phenomena and Viscosity in Liquid dielectrics

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Abstract: Liquid dielectrics are extensively used in electrical apparatus which are operating in distribution and transmission systems. The function of electrical equipment strongly depends on the conditions of liquid dielectric. Liquid dielectrics are used is the most expensive components in power system apparatus like transformers and circuit breakers. A failure of these equipment would cause a heavy loss to the electrical industry and also utilities. Insulation failures are the leading cause of transformer failures and thus the liquid dielectrics plays a major role in the safe operation of transformers. One of the main cause for the failure of transformers is due to the presence of moisture. In this work, the life of insulating medium is estimated by comparing the Breakdown strength and Viscosity of different pure oils with that of the contaminated oils (which contains moisture) and also finding the alternative for mineral oil i.e. vegetable oils which are reliable, cost-effective and environmentally friendly even when they are contaminated.

Keywords: HV (high voltage), BD (breakdown), Breakdown strength.

I INTRODUCTION

A dielectric material is an electrical insulator that can be polarized by an applied electric field. When an insulator is placed in an electric field, they do not conduct, but only shift from their average equilibrium positions causing dielectric conduction. Because of this, positive charges are displaced toward the field and negative charges shift in the opposite direction. This creates an electric field that decreases the overall field within the insulator itself if a dielectric is composed of weakly bonded molecules, those molecules not only become polarized, but also reorient so that their symmetry axes align to the field[7].

Types of dielectric materials

- solid
- liquid
- gaseous

Liquid dielectrics

A liquid can be described as "highly compressed gas" in which molecules are very closely arranged. The movement of charged particles, their microscopic streams and interface conditions with other materials cause distortion in the undisturbed molecular structures of the liquids. A liquid is characterized by free movement of the constituent molecules among themselves but without the tendency to separate.

Phenomenon's such as Impact Ionization, Mean Free Path, Electron Drift and so on are therefore also applicable for liquid Dielectrics. They possess a very high Electric Strength and their viscosity and permittivity vary in a wide range.. We have considered two types of liquid here, one is pure liquids and the other is the liquid which contain moisture.

Breakdown in liquids dielectrics:

In highly purified liquid dielectrics, breakdown is controlled by phenomena similar to those for gasses and the electric strength is high (of the order of 1 MV/cm).. Effect of these impurities is relatively small for short duration pulses (1µs)[7]. However, if the voltage is applied continuously, the solid impurities line up at right angles to equipotentials, and distort the field so that breakdown occurs at relatively low voltage.

Breakdown in contaminated liquids:

Breakdown in contaminated liquids takes place by three mechanisms

- Suspended Particle Mechanism

- Cavitation and Bubble Mechanism
- Stressed Oil Volume Mechanism

Viscosity of liquids

Viscosity is an important property of all liquids. The internal resistance offered by a liquid to the flow of one layer of fluid over a next layer is called viscosity. This is due to the interrelation between the molecules of the fluid.

Types of viscosity

- Dynamic Viscosity
- Kinematic Viscosity
- Relative Viscosity

Kinematic viscosity

Kinematic Viscosity is traditionally measured by noting the time it takes liquid to travel through the orifice of the Kinematic Viscosity tube produces a fixed resistance to flow[6].

The time taken for the liquid to flow through the capillary tube can be converted directly to a Kinematic Viscosity using a simple calibration constant provided for each tube.

Moisture content:.

Water is a very undesirable pollutant to transformer oil and other insulators in a transformer. Firstly, considering moisture in Mineral oil, moisture makes the oil less thick with a lower boiling point than oil. Secondly, the paper winding, which is also an insulator and a dielectric in the oil transformer, is also adversely affected by moisture. The moisture slowly soaks the paper as the transformer oil contains moisture. A soaked paper, on transformer windings, decreases insulation, and thus the transformer's functioning and efficiency.

When the temperature has increased in the transformer environment, this very soaked paper again releases water into the transformer oil. This leads to oxidation, hence, increases the amount of acid and water. This causes oil quality reduction due to oil decomposition. This process is completely opposite in case of vegetable oils[1].

Effects of moisture on breakdown voltage of oils

The BDV of transformer insulation oils reduces as the moisture content increases [2, 3]. High moisture content coupled with dissolved gases that have pressures higher than the ambient pressure also leads to bubbling effect in transformers [2, 3]. Therefore monitoring of moisture in oil is a routine maintenance procedure [4]. The presence of moisture in insulation oils is one of the leading causes of electrical breakdown because it increases the ionic conductivity of the oil hence lowering the breakdown voltage [5].

Effects of moisture on viscosity of oils

Moisture content in the oil increases with increase in pressure , this in turn causes the increase in viscosity of oils . But transformer mineral oil having lower intermolecular forces its viscosity decreases as the moisture content increases. Whereas in case of vegetable oils being low molecular liquids have higher intermolecular forces , hence its viscosity increases .

Experimental procedure:

In this work the oils considered for study was Sunflower oil , Palm oil and transformer mineral oil . These oils were used both in pure form , also kept in a closed chamber for about 6 hours and increased the pressure from 26.7mmHg to 31.6mmHg.

Hence the moisture content in the oil got increased . hence these three types of oils both in pure form and also containing moisture were considered and compared to show which is the better dielectric.

Breakdown voltage test:

The BDV test conducted with spherical electrode is considered for statistical analysis and twenty breakdowns were acquired. In this test spherical electrodes were kept at distance of 2.5mm and the test chamber was filled with oil specimen. High voltage ac supply was slowly increased at a rate of 2kV/sec until breakdown occurs[6].

This test was carried out for both Pure and contaminated oil samples, at different electrode gap distances of 2.5 mm and corresponding breakdown voltage was recorded.

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Fig1: Breakdown test apparatus

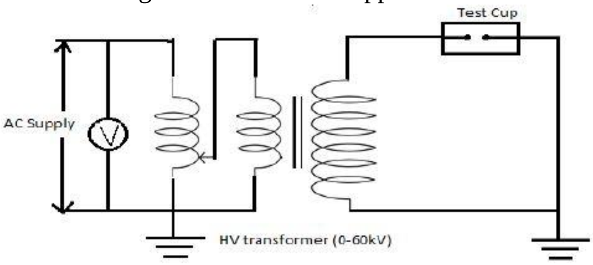

Fig1.1.Experimental setup for breakdown voltage measurement

Viscosity test:

Fig2: Cannon –Fenske viscometer

Fig3: Viscometer tube

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Fill the required liquid in the Cannon-Fenske viscometer Tube no. 100 (Direct type) to bulb marked at top close the tube hold the viscometer tube in the Viscometer-water-Bath apparatus and heat to 40^0 C and maintain the temperature for a period of 20-30 minutes the above process is done so that the oil will obtain the prescribed temperature during the testing after 30minutes open the tube and simultaneously start the stopwatch .Stop the stopwatch once the oil flow reaches the bottom of the mark in the bulb. Note the seconds on the stopwatch

The time taken for the liquid to flow through the capillary tube can be converted directly to a Kinematic Viscosity using a simple calibration constant provided for each tube.

Kinematic Viscosity Cst = (number of seconds) × (Standard factor of the bulb of the viscometer tube used for testing)

RESULTS AND DISSCUSSIONS

The breakdown voltages for different oils without moisture at a gap distance between the electrodes of 2.5mm are shown in Fig4.

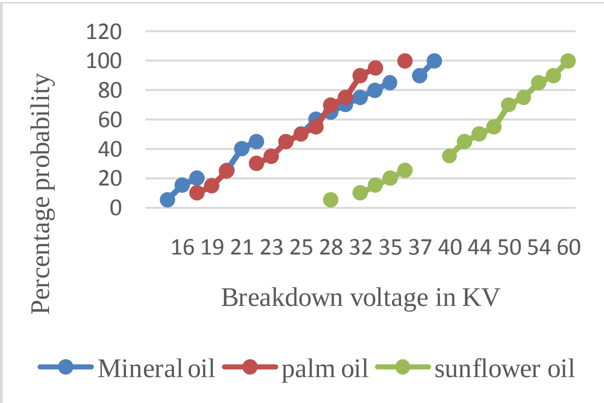

Fig4: Distribution of breakdown voltages at gap distance of 2.5mm for oils without moisture

The breakdown voltages for different oils which contain moisture at a gap distance between the electrodes of 2.5mm are shown in Fig6.

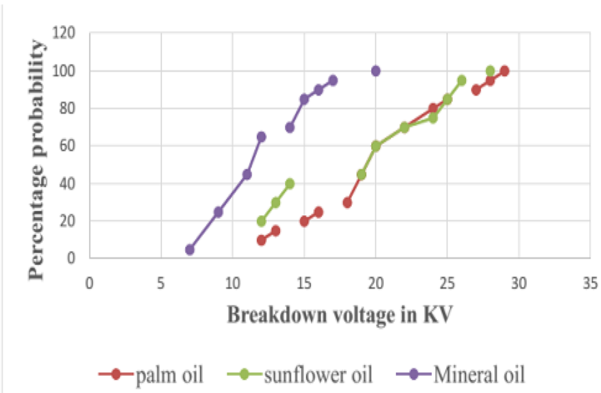

Fig5: Distribution of breakdown voltages at gap distance of 2.5mm for oils which contain moisture

From the above graphs we can say that the oils without moisture whose breakdown voltages starts from 15KV(Mineral oil), 17KV(Palm oil) and 28KV(sunflower oil) and oils with moisture whose breakdown voltages starts from 7KV(mineral oil), 12KV(Palm oil) and 12KV (sunflower oil). The presence of moisture in liquids reduces the breakdown voltages of oils and they breakdown very soon compared to pure liquids. Hence the oils without moisture are better dielectrics when compared to that of oils which contain moisture.

The breakdown strength of both oils without moisture and oils which contain moisture are shown in Fig6

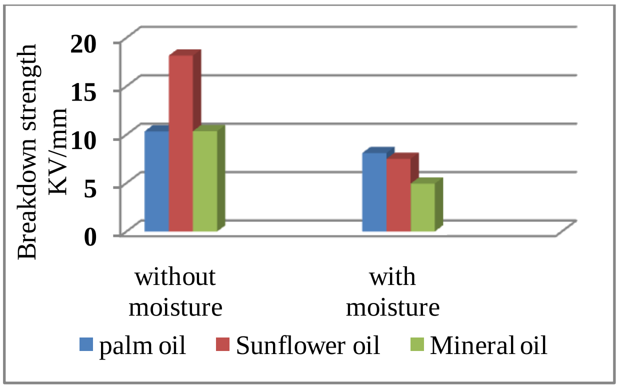

Fig6: Breakdown strength of different oils without moisture and oils which contain moisture

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From the graph we can say that the all Oils without moisture have better breakdown strength when compared to the breakdown strength of oils with moisture. For Oils without moisture, we can say that sunflower oil is a better liquid dielectric and for oils with moisture palm oil is a better liquid dielectric.

Viscosity test results:

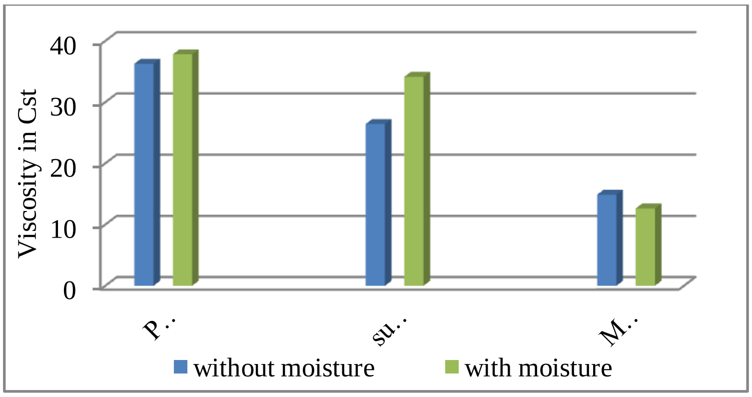

Fig7: Viscosity of oils without moisture and oils which contains moisture

For comparison, the viscosity of oils at 40^0c was considered here. This clearly shows that viscosity of oils increases for oils which contains moisture. This due to the intermolecular forces in the liquids. However compared to mineral oil, sunflower oil and palm oil shows higher viscosity when they contain moisture.

CONCLUSION

Insulation is one of the most important parts of high voltage instruments. Failure of insulation means failure of entire instrument, therefore it is necessary to pay attention to it. Here liquid dielectrics are the insulation system used .In this work the alternative for mineral oil is found that is vegetable oils which are better insulators. Since the presence of moisture in the oil is one of the main cause for the failure of insulation , we have proved that presence of moisture in the oil reduces the breakdown voltage and breakdown strength of oils and oils without moisture are better dielectrics when compared to oils with moisture . Vegetable oils are better dielectrics when they do not contain moisture as well as when they contain moisture .

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