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Dielectric Behavior of Insulating Material Under Transformer Oil

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Abstract: *In high voltage equipment liquid dielectric is used as coolant as well as an insulating medium. Measurements were made to assess the ac breakdown voltage in liquid dielectric with different electrode combination such as sphere-sphere,plane-plane,mushroom-mushroom,sphere-mushroom,sphere-plane,mushroom-plane.The breakdown voltage is function of electrode geometry and gap spacing length. In this paper special emphasis has been attributed to effect of solid dielectric leatheroid paper immersed in liquid dielectric under different conditions. The measured values are compared with those values under atmospheric condition. Also the effect of moisture and impregnation time of leatheroid paper in liquid dielectric here transformer oil is studied.*

Keywords: *Breakdown voltage, Leatheroid paper, Transformer oil, Composite Dielectric, Electrode*

1. INTRODUCTION

Liquid dielectrics are used as insulation media in high-voltage system. They can fill any space to be insulated. They can be easily circulated and they can be used to dissipate the heat generated in given system. Transformer oil is one of the most used insulating liquid for electrical insulating purposes. The most important electrical property of liquid insulation is its breakdown voltage .Breakdown voltage is affected by many factors such as electrode area, gap space electrode , geometry etc.

A study has been carried out to evaluate 1.Breakdown voltage of the transformer oil 2.Breakdown voltage of leatheroid paper 3.Effect of moisture on breakdown voltage of leatheroid paper 4.Effect of impregnation time for composite dielectric on its breakdown voltage .The data presented in this paper will contribute to understand dielectric property, breakdown voltage of transformer oil, leatheroid paper and combination of leatheroid paper and transformer oil. This lead to the selection of the desired insulating material to be used as insulation.

2. EXPERIMENTAL SETUP

2.1 AC Breakdown Voltage in Transformer Oil

Figure 1 shows various electrode geometries used for the breakdown voltage measurements in transformer oil. Different combinations of electrodes such as sphere-sphere, plane-plane, mushroom-mushroom, sphere-plane, etc. were used for obtaining the breakdown voltage of transformer oil with gap lengths varying from 0.5mm to 5.0 mm.

Figure 2 shows the automatic transformer oil testing kit used for measurement of breakdown voltage of transformer oil. Measurements are taken according to IEC 156 standard.

2.2 Breakdown Strength of Leatheroid Paper

Automatic transformer oil testing kit is also used for measurement of breakdown voltage of leatheroid paper. Different electrode combination of electrodes such as sphere-sphere, plane-plane etc. were used for obtaining breakdown voltage. Figure 3 shows the schematic of a mushroom-plane electrode combination mounted in test cell, with test sample sandwich between them. Electrodes are made up of brass. Electrodes were mounted horizontally in test cell. The applied voltage was 50 Hz A.C. supply. Automatic transformer oil testing kit can apply voltage up to 60 kV.

Sphere

Plane

Mushroom

Figure 1. *Various electrode geometries for breakdown voltage measurement in transformer oil*

Breakdown voltage of the leatheroid paper are obtained by considering insulating medium as air and transformer oil .

Figure 2. *Experimental setup with Automatic transformer oil testing kit*

2.3 Effect of Moisture on Breakdown Voltage of Leatheroid Paper

To study the effect of moisture on the breakdown voltage of leatheroid paper three conditions are considered

1) Initially the leatheroid paper kept in oven, then breakdown voltage is measured by considering air as insulating medium.

2) Initially the leatheroid paper is kept in oven, then breakdown voltage is measured by considering transformer oil as insulating medium

3) Initially the leatheroid paper is immersed in transformer oil, then it is kept in oven and after that the breakdown voltage is measured by considering transformer oil as insulating medium. Measurements are taken at different time for which paper is kept in the oven. To conduct this experiment mushroom-plane electrode combination is used.

2.4 Effect of Impregnation Time for Composite Dielectric on its Breakdown Voltage

Leatheroid paper is impregnate in transformer oil for 0 to 5 days. For this experiment mushroom-plane electrode combination is used and transformer oil as insulating medium in the test cell.

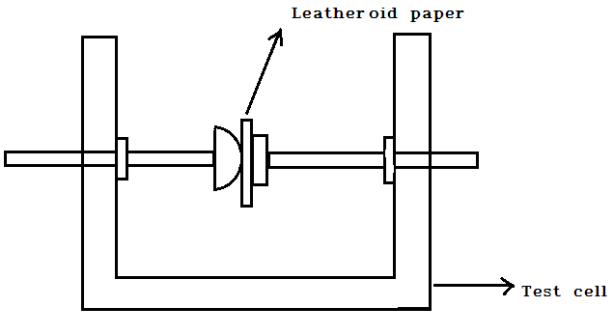

Figure 3. *Schematic diagram of mushroom-plane electrode arrangement*

3. RESULTS

Figure 4 shows the variation of A.C. breakdown voltage of transformer oil with gap length for different electrode combination. Each point of the curve is the average of 6 breakdown measurements.

The breakdown voltage of leatheroid paper is measured by using various electrode combinations at atmospheric condition i.e. air as insulating medium and when immersed in transformer oil given in table 1 and figure 5. The reported breakdown voltage values are average of 10 measurements.

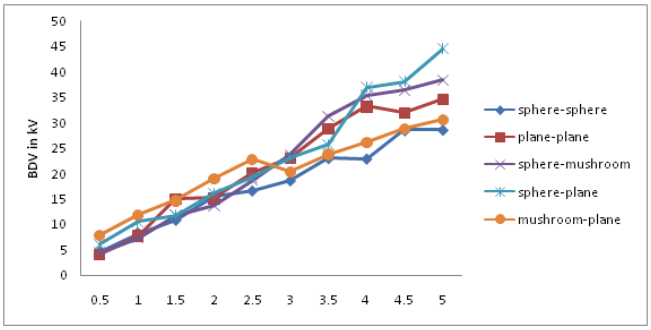

Figure 4. *Breakdown voltage of transformer oil with different gap spacing*

Table No. 1. *Comparison of breakdown voltage of leatheroid paper in air (without transformer oil) and with transformer oil*

Sr. No.	Combination of electrodes	BDV with air (in kV)	BDV with transformer oil (in kV)
1	Mushroom-Mushroom	2.31	3.09
2	Sphere-Mushroom	2.31	2.50
3	Sphere-Plane	2.36	2.62
4	Mushroom-Plane	2.28	3.56

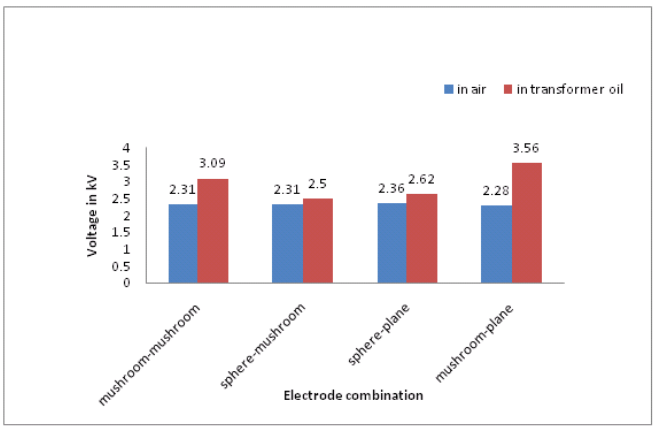

Figure 5 *Breakdown voltage of leatheroid paper with different electrode combination*

Figure 6 shows the effect of moisture when leatheroid paper is initially kept in the oven and then breakdown voltage is measured by considering air as insulating medium for different time figure 7 shows the effect of moisture when the paper is initially kept in oven before applying breakdown voltage by considering transformer oil as an insulating medium.

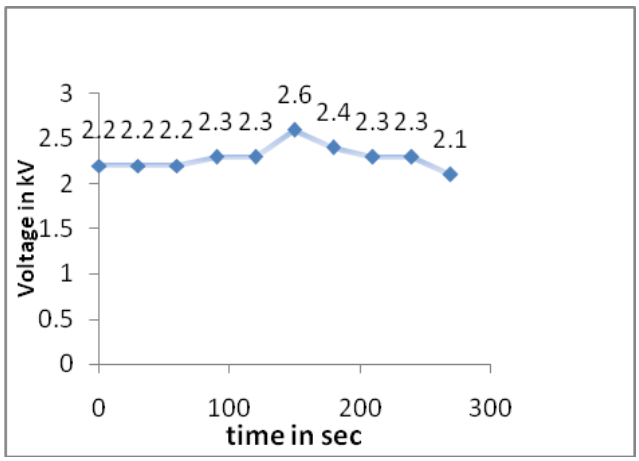

Figure 6. *Effect of moisture on breakdown voltage when leatheroid paper is kept in oven and breakdown voltage is measured in air*

Figure 8 shows the effect of moisture on the breakdown voltage of leatheroid paper when it is initially immersed in transformer oil, then it is kept in oven for removal of moisture and after that breakdown voltage is applied by considering transformer oil as an insulating medium. Figure 9 shows the effect of impregnation time on the breakdown voltage of leatheroid paper and transformer oil used in combination.

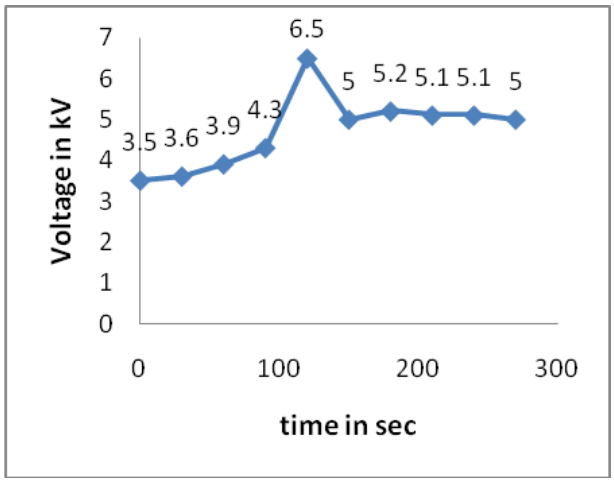

Figure 7. *Effect of moisture on breakdown voltage when leatheroid paper kept in oven and breakdown voltage measured in transformer oil.*

4. DISCUSSIONS

4.1 Ac Breakdown Voltage of Transformer Oil

The highest breakdown voltage of transformer oil was found to be 44.6 kV for sphere-plane electrode configuration while minimum breakdown voltage observed was 4.2 KV for plane-plane electrode combination (Figure 4). The other combination of electrode yielded intermediate values of breakdown voltage depending upon the field condition. It appears that breakdown voltage values are affected by gap length between the electrodes. It is observed that in transformer oil the breakdown voltage increases as the gap length increases. This effect is most pronounced in case of sphere-plane electrode combination. Hence it can be inferred that the breakdown voltage of transformer oil depends not only on gap length, but also on the electrode geometry.

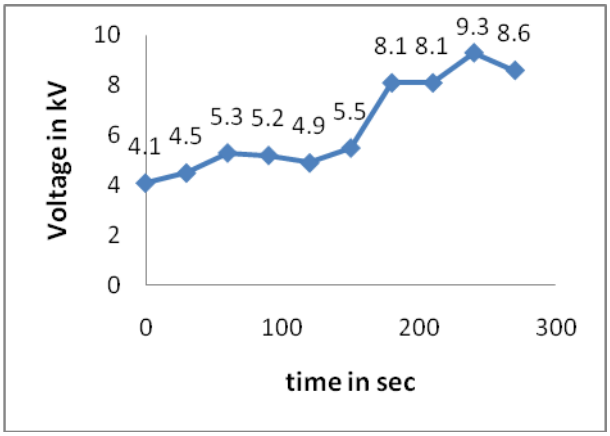

Figure 8. *Effect of moisture on breakdown voltage when leatheroid paper immersed in transformer oil then kept in oven and breakdown voltage is measured in transformer oil*

4.2 Breakdown Voltage of Leatheroid Paper

The breakdown voltage value of leatheroid paper in transformer oil is higher as compared to those values in air for different electrode combination we get different breakdown voltage value. Highest breakdown voltage is 2.56 kV for sphere-plane electrode combination and lowest breakdown voltage value is 2.28kV for mushroom-plane electrode combination when the insulating medium is considered as air. For insulating medium as transformer oil with leatheroid paper immersed in it, highest breakdown voltage is 3.56 kV for mushroom-plane electrode combination and lowest breakdown voltage is 2.50kV for sphere-mushroom electrode combination. From the table 1 it can be inferred that breakdown voltage of leatheroid paper is higher in transformer oil than that in atmospheric condition.

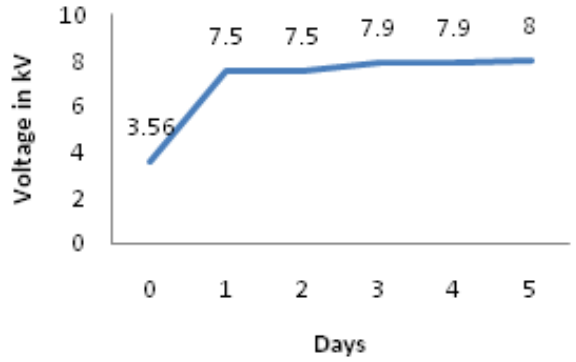

Figure 9. *Effect of impregnation time on breakdown voltage of leatheroid paper*

4.3 Effect of Moisture on Breakdown Voltage of Leatheroid Paper

Leatheroid paper is cellulosic insulation material and porous material it contains air bubbles. Due to these air bubbles present in leatheroid paper its breakdown voltage gets affected. Leatheroid paper is hygroscopic in nature so it can absorb moisture from atmosphere. By removing moisture from leatheroid paper its breakdown voltage is increased. When the air and leatheroid paper combination is kept in oven from 0 to 150 sec. the breakdown voltage increases from 2.2kV to 2.6kV. It was observed that after 150 sec. the leatheroid paper gets deteriorated and its breakdown voltage lowers to 2.4 kV from 2.6kV.

When breakdown voltage of leatheroid paper after removal of moisture measured in transformer oil same effect was observed .After 120 seconds paper gets deteriorated at 120 seconds .Breakdown voltage is 6.5kV but after 120 sec its breakdown voltage was 5kV at 150 seconds.

when the leatheroid paper is immersed in transformer oil then kept in oven and then again breakdown voltage test is performed under transformer oil we get highest breakdown voltage as 9.3 kV at 240 seconds but after 240 seconds we get 8.6 kV as breakdown voltage at 270 second.

Out of all three various experiments highest breakdown strength is observed when leatheroid paper is immersed in transformer oil and then moisture is removed by keeping it in oven after that breakdown voltage test is performed .This removes moisture from both transformer oil and leatheroid paper.

4.4 Effect of Impregnation Time for Composited Dielectric on its Breakdown Voltage

As leatheroid paper is porous material when it is impregnated in transformer oil by capillary action voids in leatheroid paper are filled by transformer oil. As the impregnation time increases, dielectric filling up cavities and voids thereby enhancing the breakdown voltage of leatheroid paper .It is observed that when leatheroid paper is impregnated with transformer oil for five days its breakdown voltage is 8.0kV.

Hence it can be observed from figure no. 9that breakdown voltage of leatheroid paper increases as it is impregnated with transformer oil.

5. CONCLUSION

In summary, the data presented demonstrate the behavior of liquid insulating material considering different gap spacing & electrode combination. Also the dielectric behavior of solid insulating material under liquid dielectric environment with particular reference to the effect on their breakdown voltage values is presented. The data presented and analyzed recommend the use of porous dielectrics of insulating high voltage equipments.

When gap between two electrode is increased breakdown voltage of transformer oil increases. Also when electrode combination changes at a particular gap length breakdown voltage of transformer oil is different. But effect of shape of electrode is not stronger as the effect of gap length.

Solid and liquid dielectric material combination is also studied. When leatheroid paper is separately used its breakdown voltage is lower as compared to those values when it is combined with transformer oil. It also has electrode shape effect for different shape of electrode; breakdown voltage of leatheroid paper is different in air and with transformer oil also. As leatheroid paper is porous material, after removal of moisture its breakdown voltage also increases. Out of all three various experiments highest breakdown strength is observed when leatheroid paper is immersed in transformer oil and then moisture is removed by keeping it in oven after that breakdown voltage test is performed .This removes moisture from both transformer oil and leatheroid paper. For this method it is observed that breakdown voltage of leatheroid paper is highest at 240 sec. and it is 9.3 kV but at 270 sec it decreases to 8.6kV.

Impregnation time of transformer oil also affect breakdown voltage of leatheroid paper. As the impregnation time increases up to certain days, breakdown voltage of leatheroid paper increases. For this case after five days of impregnation in transformer oil of leatheroid paper, breakdown voltage will increase from 3.56 kV at zero impregnation day to 8.0 kV at fifth impregnation day.

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