ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Breakdown Characteristics of Ambient Medium in Presence of Barrier under Varying Field Conditions

Asim[1], Mohd. Waseem Khan[2]

M. Tech (High Voltage & Insulation Engineering), Dept. of Electrical Engineering, AMU, Aligarh, India

M. Tech (Power Systems & Drives), Dept. of Electrical Engineering, AMU, Aligarh, India

ABSTRACT:Rapid growth in power sector of nation has given the opportunity to power engineers to protect the power equipment for reliable operation during their operating life. It has been seen from the studies conducted by power engineers that one of the main problems in high voltage power equipment is the degradation of insulation.
In this paper it has seen that in a liquid insulation system of high voltage machine, the insulating capability in the available space can be improved by inserting an insulation barrier in the gap which alters the space charge distribution.
The ion formed in the zone depleted by the barrier and spread on its surface, forming surface charge carrier on the insulating barrier, thereby the field between the barrier and the ground electrode becomes uniform, leading to increase in the breakdown voltage. This improvement in the insulation strength is called the "Barrier Effect".
The result obtained by the experimental investigation into breakdown characteristics of transformer oil under inhomogeneous field conditions (Sphere-to-Cone electrode system) as well as moderately homogenous field conditions (Sphere-to-Sphere electrode system) under alternating (50 Hz) voltage stresses are reported in this work. The effect of gap length on breakdown in oil and the influence of electrode covering and barrier by solid insulators are also reported.

KEYWORDS: Barrier Effect, Space Charge Distribution, Electrode Configuration, Inhomogeneous Electric Field, Electrode Covering Effect.

I.INTRODUCTION

Dielectric strength of transformer oil is also known as breakdown voltage of transformer oil or BDV of transformer oil. Breakdown voltage is measured by observing at what voltage, sparking occurs between two electrodes immersed in the oil, separated by specific gap. Low value of BDV indicates presence of moisture content and conducting substances in the oil. High voltage transmission of electrical energy has made immense strides during the last decades, and also the high voltage transmission system will be used increasingly in the near future. For some of the equipment transformer oil/polymer will be the electrical insulation system. Therefore electrical breakdown characteristics of transformer oil may lead to spectacular consequences on the quality and reliability of high voltage networks. The insulation design of high voltage transformer can only be optimized if the electrical strength properties of the insulation system are precisely known. The main insulation materials used in a power transformer are oil, paper and pressboard. These insulating materials are known to experience homogeneous as well as inhomogeneous field conditions. Breakdown voltages of homogeneous and non-homogeneous field gaps known to be largely affected by inserting thin dielectrics "barriers" in the gaps; this is called barrier effect. Thus, it is of great interest to study the influence of such barrier effect on the breakdown voltage in transformer oil.It is well established that the breakdown of transformer oil somehow involves particles and other contamination particularly moisture. It was found that the removal of the large particles fromtransformer oil can raise the breakdown voltages. In particle initiated breakdown theories, it is assumed that the defects determine the breakdown stress and these are in fact the particles in the oil which migrate to the electrode by forces and initiate breakdown there. When the barrier is a thin insulating paper, it acts to control the space charge and it is thought of as a useful model to consider the dielectric because in this case, the space charge distribution is simple and it is possible to measure the space charge distribution quantitatively. The present work address itself to the investigations about the influence of barriers on the breakdown voltages in transformer oil for moderately homogeneous field (Sphere-Sphere electrode) and non-homogeneous field (Sphere-Cone electrode) system using 50 Hz, 150 kV ac test transformer.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

II.EXPERIMENTAL SETUP AND PROCEDURE

A. *Sphere-sphere electrode configuration:*

Test cell:The electrode were carried out in a vessel made of Perspex sheets, the internal dimension of the cell was 60mm 110mm 120mm high.
Electrode: The electrodes were polished sphere of 13mm diameter of brass and arranged horizontally with their axis 40mm above the bottom cell. The gap between the electrodes is to be adjusted by micrometer (least count 0.01) connected with one of the electrodes
experimental samples:

Species	Thickness (µm)	Density (gm/cm^3)
Polypropylene	14	0.8
Kraft paper	68	0.9
Polystyrene	184	1.05

Fig. 1 Arrangement for sphere-sphere electrode configuration

B. *Sphere-Cone electrode configuration*:

Test cell: The electrode were carried out in a vessel made of Perspex sheets, the internal dimension of the cell was 60mm 110mm 120mm high.
Electrodes:The cone electrode was formed from a solid brass of 15mm in diameter and7.5mm in height with rounded edges. The sphere electrode is made up of brass having a diameter of 13mm. The gap between cone electrode and sphere electrode were adjusted by a screw gauge attached to the electrodes.
Experimental samples: These are remaining same as in previous configuration.

Fig. 2 Arrangement of electrodes and insulating paper for Sphere-Cone electrode configuration.

Supply and measurement system:
*Supply and measurement of high voltage:*The high voltages were obtained from a testing transformer of 150 KV, 50 HZ,1 phase, 30 KVA rating.The voltages were measured using a voltmeter (accuracy ± 1%) connected at the primary side of the transformer, that read the low side voltage. The corresponding high voltages were obtained from a calibration curve drawn using the sphere-sphere electrode system using the diameter of 25 cm (IS-1876,1961)
Thickness measurement:The thickness of the barrier and electrode covering paper/polymer film was measured by a magnetic dial-gauge having an accuracy of 1 micrometer.
*Pressure and temperature measurement:*The pressure was measured by a barometer. The accuracy of pressure measurement was ± 0.50 torr. Wet and dry bulb thermometers were used to record the temperature in the laboratory. This can be made within the accuracy of ± 0.5 degree Celsius.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Electrode spacing and barrier spacing measurement:The electrode spacing was set by a micrometer having an accuracy of ± 0.01mm.The insulating paper/ barriers were placed in grooves. The vertical grooves were made on the two opposite side (wall) of the test cell with a gap of 2 mm.
Electrode conditioning:Before starting the experiment, all the electrodes was thoroughly cleaned, polished and finally washed with alcohol after every set of breakdowns the electrodes were brought out of the cell and thoroughly polished.
Experimental procedure:For both sphere–cone and sphere-sphere electrode systems, first the electrodes were polished and washed with alcohol and dried. The voltage was applied in accordance with BS: 148 or IS 335 till breakdownoccurred. In each case, seven breakdownswere taken and then the average value was used to draw the curves.

III.EXPERIMENTAL RESULT AND DISCUSSION

Experimental Observations:

A. *Sphere-Sphere Electrode Configuration*:
   (a) *Barrier Effect*: For the barrier effect the gap between electrodes was 10 mm at temperature 30°C (Dry), 27°C (Wet) and Pressure732 torr

S.N.	Barrier's location in mm.	Breakdown voltage (kV) rms		
		Polystyrenet=184µm	Kraftpaper t=68µm	Polypropylenet=14µm
1	0	56.4	48.5	58.4
2	2	52.2	45.4	55.2
3	4	62.6	57.6	68.3
4	6	64.4	60.4	75.4
5	8	60.8	55.3	69.4
6	10	58.5	50.4	64.5

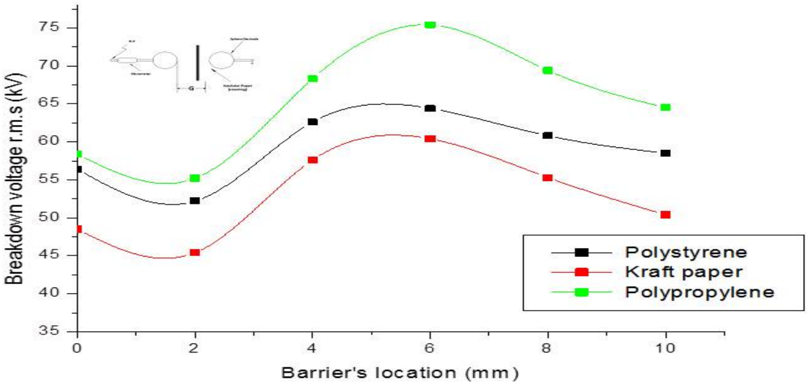

Fig.3Barrier effect for different types of materials for 10 mm gap

When the ac voltage is applied to one of the sphere electrode and other sphere electrode is grounded, the charges are liberated from the sphere electrode at high voltage, but they do not reaches the ground electrode because of the presence of barrier placed in between the two electrodes, and gets deposited on the insulating barrier. This gives rise to the stronger field on the grounded electrode side. It is evident from the figures that when the distance 'S' between the barrier and the ground electrode increases the breakdown voltage slightly decreases and then increases remarkably resulting in much higher breakdown voltage than that obtained with the covered ground electrode.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

(b) *Electrode Covering*: Electrode covering for different types of insulating materials at temperature 30°C(Dry),27°C (Wet) and Pressure 732 torr

S. N.	Electrode gap(mm)	Breakdown voltage (kV) rms			
		Bare ground electrode	Polystyrene t = 14µm	Polypropylene t = 184 µm	Kraft paper t = 68 µm
1	2	8.8	15.8	20.4	13.2
2	4	20.2	25.4	28.3	22.8
3	6	25.4	32.5	34.5	28.6
4	8	31.6	37.4	40.2	34.4
5	10	37.0	42.6	44.5	40.0

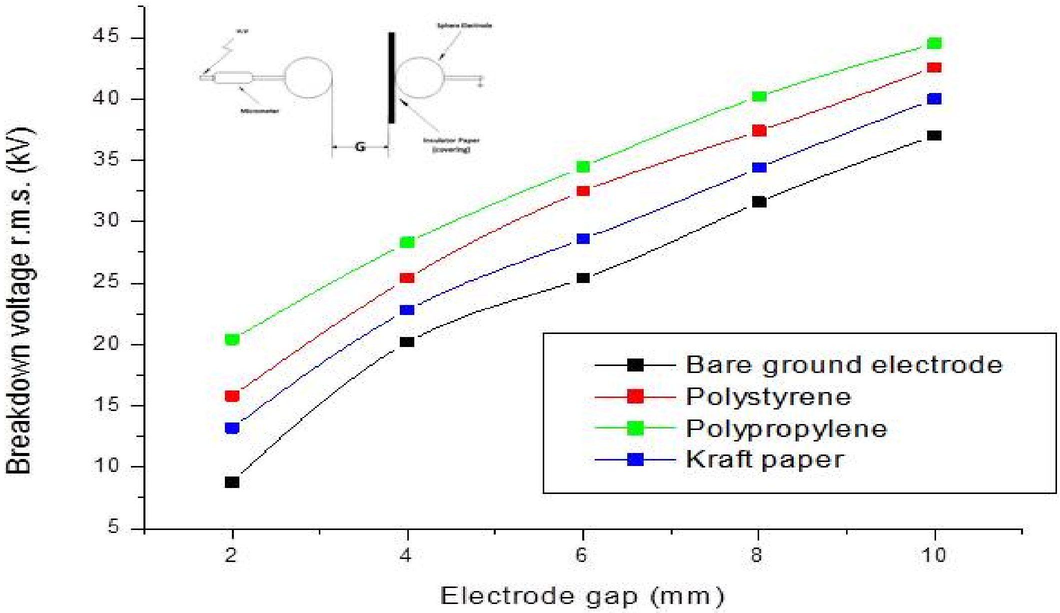

Fig.4 Effect of electrode covering with different types of insulating papers on breakdown voltage (under ac voltage)

The effect of covering the ground sphere electrode is shown in fig. for different insulating paper/polymer film. The breakdown voltage for polypropylene is higher than that of the Kraft paper and polystyrene. The breakdown voltage is higher with covering the ground electrode. This is because the streamers are generated from the high voltage electrode and initially it does not break the covered paper/polymer film.

B. *Sphere-Cone Electrode Configuration:*

(a) *Barrier Effect:* For the barrier effect the electrode gap were taken as 10 mm. The barrier distance 'S' with respect to ground electrode was varied and the breakdown voltage were recordedat temperature 24°C (Dry),20°C(Wet) and Pressure 742 torr

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

S.N.	Barrier's location (mm)	Breakdown voltage (kV)rms		
		Polypropylene t = 14 µm	Polystyrene t = 184 µm	Kraft paper t = 68µm
1	0	38.4	36.2	32.4
2	2	36.2	34.4	30.6
3	4	43.0	44.8	36.5
4	6	48.5	50.6	40.4
5	8	45.4	47.5	38.9
6	10	44.2	42.4	37.5

Figure below shows a plot of the breakdown voltage with respect to the barrier location for all the three types of barriers. However a comparison is not possible because the thickness of the barriers is not same though they have been tested. The variations of breakdown voltage with respect to the barrier location for 10 mm gap are given in fig. below. Explanation of the nature of graph will remain same as it was for previous configuration.

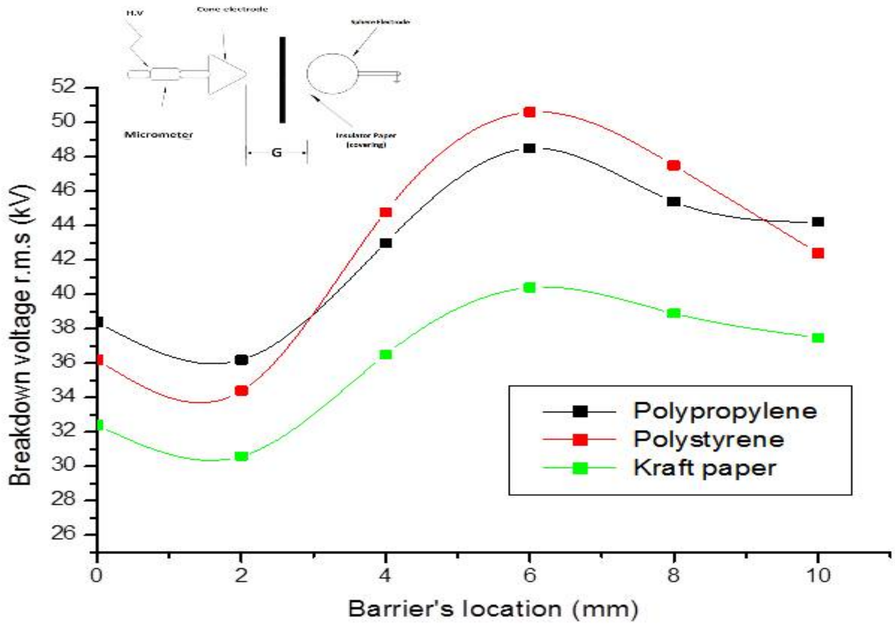

Fig.5 Barrier effect for different types of insulating materials for 10 mm gap

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

*(b) Electrode Covering Effect:*Electrode covering effect for different insulating materials at temperature 24°C(Dry), 20°C (Wet) and pressure 742 torr

S.N.	**Electrode gap (mm)**	**Breakdown voltage (kV)rms**			
		Bare ground electrode	Ground electrode covered with one layer of Kraft paper t=68 µm	Ground electrode covered with two layers of Kraft paper t=136 µm	Polystyrene covered ground electrode t=184 µm
1	2	10.3	13.8	15.6	16.4
2	4	20.7	26.4	27.4	29.2
3	6	28.8	33.6	35.6	37.2
4	8	32.3	36.8	38.8	40.3
5	10	36.4	40.5	42.4	43.5

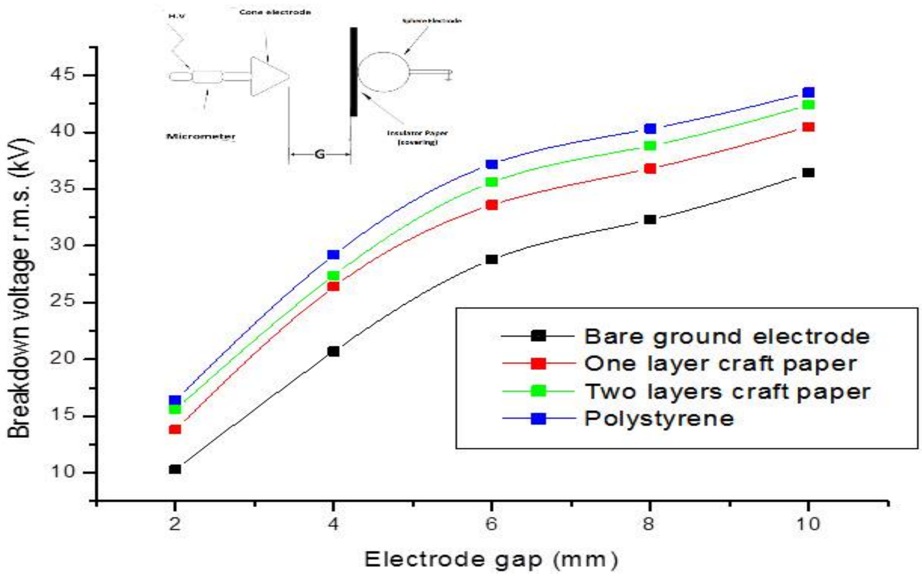

Fig.6 Effect of electrode covering with different types of insulating papers on breakdown voltage (under ac voltage)

The increase in the breakdown voltage in the case of covered electrode over that of bare electrode, as in the case of ac voltage is due to the fact that the breakdown is initiated at the cone tip and that the streamer does not initially break through the insulating layer covering the ground electrode

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

IV.CONCLUSION

1. The study of the barrier effect and electrode covering using a thin insulating paper is useful in analyzing the effect of space charge on the breakdown mechanism.
2. Electrodes covered with insulating paper film give higher breakdown voltage for transformer oil compared with those obtained with uncovered electrodes and this effect increases when two layers of paper are used.
3. When the distance between the insulating barrier and the ground electrode increases, the breakdown voltage slightly decreases and then increases reaching a higher value than for the case with covered ground electrode.
4. The barrier effect for the moderately uniform field i.e. sphere-sphere electrode configuration has similar variation as for the sphere-cone configuration.
5. The electrode covering effect for the sphere-sphere electrode configuration is linear in nature.
6. It is observed inclusion of barrier in the oil gap improves the breakdown strength of the gap, irrespective of the quality of the oil.
7. Use of polymer material as barrier has high breakdown strength of the gap.
8. In general, the barrier effect is high by placing the barrier in the middle of the oil gap, irrespective of the type of barrier.
9. The barrier acts as a geometrical obstacle against the direct propagation of discharge.
10. The optimal position of barrier is at about 20% of gap starting from the sharp electrode (i.e. cone).
11. The optimal position does not move when varying the thickness of barrier. However, the increase of barrier thickness leads to an increase in the breakdown voltage irrespective of the kind of barrier material.

REFERENCES

[1] BEROUALA., ZOUAGHIA.: 'Barrier effect on prebreakdown and strength of long oil gaps in the presence of insulating barrier'. IEEE Conf. on Electrical Insulation and Dielectric Phenomena, Minneapolis, 19–22 October 1997, pp. 660–663

[2] Kara A, Onal E, Kalenderli O, Mardikyan K, "The Effect of Insulating Barriers on AC Breakdown Voltage in Inhomogeneous Field", IEEE MELECON, May 16 – 19, Benalmadena (Malaga), Spain, 2006.

[3] K.H. Weber, H.3. Endicott, "Area effect and its external basis for the electric breakdown of Transformer oil" TAIEE Vol. 75, pp331-371, Jan.1956.

[4] M S Naidu, V Kamaraju, "High voltage engineering" Third edition.

[5] T.D. Eish and S. Ramadan, P.M. Radwan, "Influence of Electrode covering and barrier as breakdown phenomenon of Transformer oil", MEPCON-89, paper No. EE-14-83, pp 179-183, 1989.

[6] A.E. Lasts and S.Rusck, "Influence of barriers in the ac breakdown of Transformer oil", IEEE 1997 Power Engorge Winter meeting.

[7] S.A. Studniarz . The effect of barriers in the low field regions of non-uniform fields on oil breakdown. IEEE Trans. Power Appar. Syst. , 4 , 1568 – 1573

[8] Ekram Husain, Kamaluddin, Imtiyaz Ashraf, 4th International conference on properties and applications of dielectric materials, July 3-8, Brisbane Australia, 1994

[9] F. V. Topalis, I. F. Gonos, and I. A. Stathopulos, "Insulation properties of composite dielectric arrangements," Power and Energy Systems, vol.22, no.3,pp. 146-149, 2002.

[10] Frangiskos V. Topalis and Michael G. Danikas, "breakdown in air gaps with solid insulating barrier under impulse voltage stress".FactaUniversitatis, Elect. Energ. Vol. 18, Apr. 2005, 87-104