International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 03, March 2016
www.ijirse.com
ISSN: 2454-9665

Study of Insulation Under Varying Field Conditions

M.U.Zuberi[1]& Aejaz Masood[2]

[1, 2] *Electrical Engineering Department, Aligarh Muslim University, Aligarh, (India)*

ABSTRACT

The results obtained by experimental investigations into breakdown characteristics of transformer oil, air and solids as insulation under homogeneous and non-homogeneous field conditions under alternating voltages (50Hz) stresses are reported in this work. To simulate homogeneous and non- homogeneous field conditions different electrode configurations were used to attain varying degree of uniformity. Also theeffect of gap length between the electrodes in transformer oil & air and that of thickness in case of solid insulation (Leatheroid, Presspahn and Krimpel sheet)on breakdown voltage under different field conditions is reported.

Investigations revealed that breakdown voltage of the insulation medium increases as the gap length between electrodes increases in case of transformer oil & air, the same being observed in case of solid insulation as the thickness of insulation is increased. Further investigations into breakdown characteristics of transformer oil, air and solids revealed that higher breakdown voltages of the insulating medium was observed under uniform field conditions than that in non-uniform fields.

Keywords*: *AC Voltages, Breakdown Voltage, Electric Fields, Solid Insulation,Transformer Oil

I. INTRODUCTION

High voltage transmission of electrical energy has made immense strides during the last decades and high voltage transmission system will be used increasingly in the near future. The diverse conditionsunder which a high voltage apparatus is used necessitate careful design of its insulation. The principal media of insulation used are gases, solid and liquidor a combination of these. These insulation materials are known to experience homogeneous as well as non- homogeneous field conditions[1-3].

The present work addresses to the investigations about the breakdown characteristics of transformer oil, air and solids as insulation under homogeneous field and non- homogeneous field conditions under alternating voltage stresses.

II. EXPERIMENTAL SETUP & PROCEDURE

II.1Electrodes

In order to simulate homogeneous and non- homogeneous field conditions Plane-Plane, Sphere-Sphere,Rod-Plane,Cone-Plane and Cone-Cone set of electrodes were used. Fig.1shows various electrode geometries used for the breakdown voltage measurements.

Different combinations of electrodes such as Sphere-Sphere,Plane-Plane etc. were used for obtaining breakdown voltage of transformer oil and air with gap lengths varying from 2.5 to 12.5mm.

II.2 Test Cell

Figure 2(a), 2(b) and 2(c) shows the experimental cell/schematic used to conduct the experiment for transformer oil, air and solid insulation respectively. For solid insulation and transformer oil the test cell made of Perspex

was used. For air, wooden stand was used as test cell as shown in Figure 2(b). The gap between the electrodes was adjusted by micrometer connected to one of the electrodes, the other electrode being fixed.

II.3 Experiment Samples

Transformer oil

-Breakdown strength 15kV/mm

-Relative permittivity 2.2-2.3

-Dissipation Factor 0.0005

-Maximum Permissible water content (in ppm) 50

Air

Breakdown Strength 30 kV/cm

Dielectric Constant 1.0059

Solid Insulation

Leatheroid: Thickness=0.19mm

Presspahn: Thickness=0.58mm

Krimpel: Thickness=0.23mm

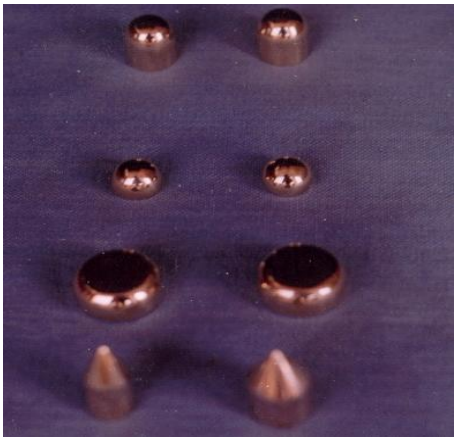


Figure 1

II.4 Conditioning of Samples and Electrodes

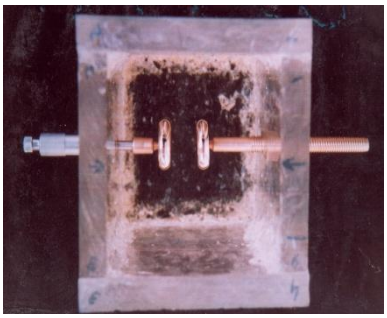
Transformer oil was filtered and dried under vacuum to remove air bubbles and moisture.No special treatment was given to solid samples.All the electrodes were thoroughly buffed and cleaned with alcohol before each set of experimentation.

II.5 Supply and Measurement of High Voltages

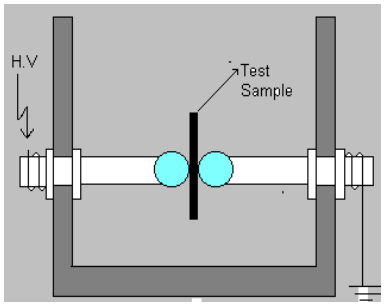
High voltages were obtained from a testing transformer of 30 kVA, 150 kV, 50 Hz rating which is discharge free upto 100kV. The voltages were measured using a voltmeter of lower rating connected at the primary side of the testing transformer. The corresponding high voltages were obtained from a calibration curve drawn using the sphere gap electrode system.

III. EXPERIMENT PROCEDURE

- All the electrodes were polished, buffed and cleaned with alcohol before experimentation.After each set of experiment electrodes were cleaned with alcohol and dried. The desired gap distance was adjusted using micrometer.Having mounted the desired electrode combination and adjusted gap distance, high voltage was applied till breakdown of the medium occurred. In each case five breakdowns were carried out and the average values were taken to obtain the results. In case of solids; the thickness of insulation in the gap was varied. While performing the experiments, temperature and pressure was also recorded.



(a)



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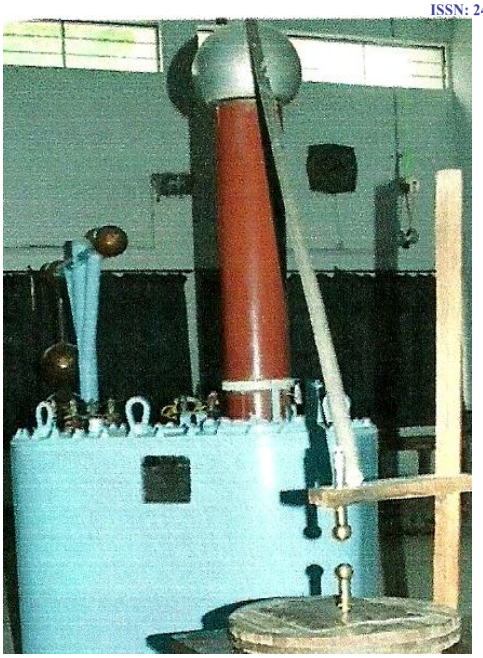


(b)

Figure 2.The experimental cell/schematic used for transformer oil, air and solid insulation.

IV. RESULTS

The measurements for study of breakdown characteristics of transformer oil using different combinations of electrodes and gaps (2.5-12.5mm) were made. Figure 3 shows the plot between the observed breakdown voltages for various combinations of electrodes and gap distance between electrodes (32 ºC; 742 Torr).

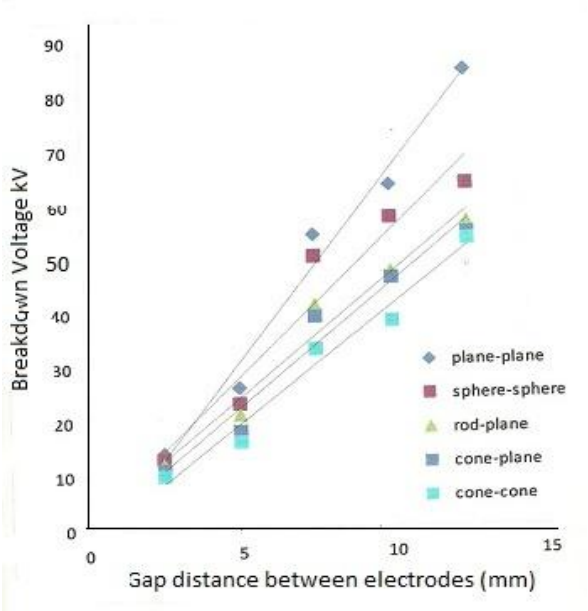


Figure 3. Plot between breakdown voltages and gap distance for transformer oil

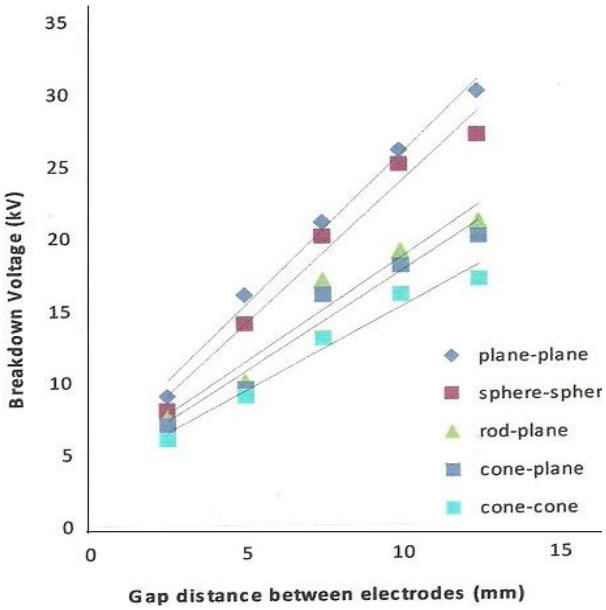
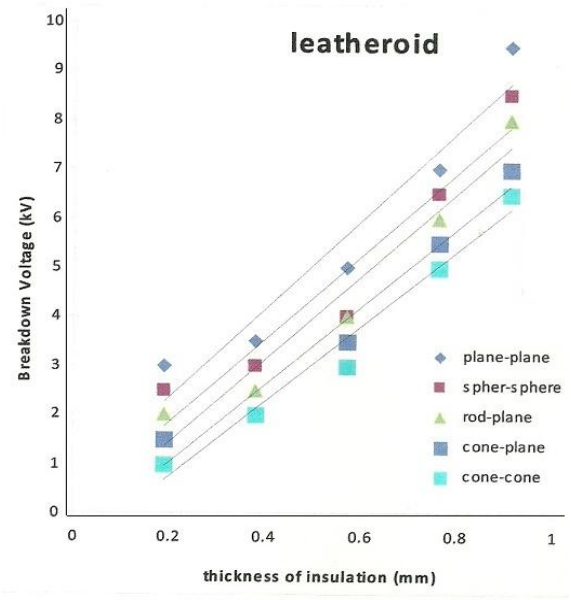
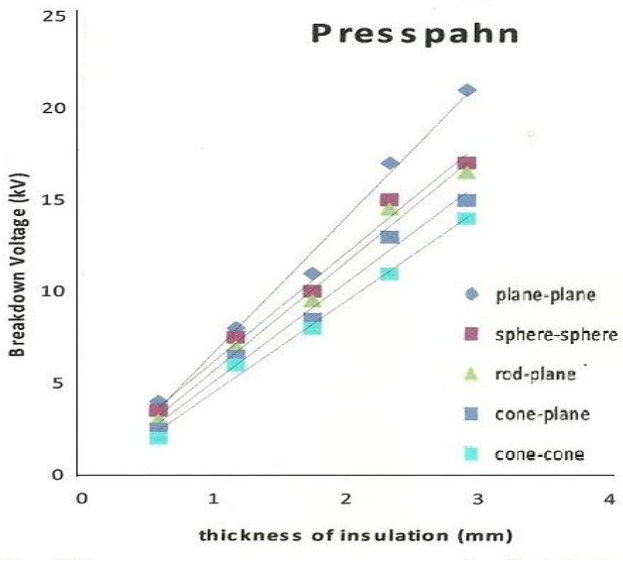


Figure 4. Plot between breakdown voltages and gap distance for air

Similarly the measurements for study of breakdown characteristics of air using different combinations of electrodes and gaps (2.5-12.5mm) were made. Figure 4 shows the plot between the observed breakdown voltages for various combinations of electrodes and gap distance between electrodes (32 ºC; 742 Torr).

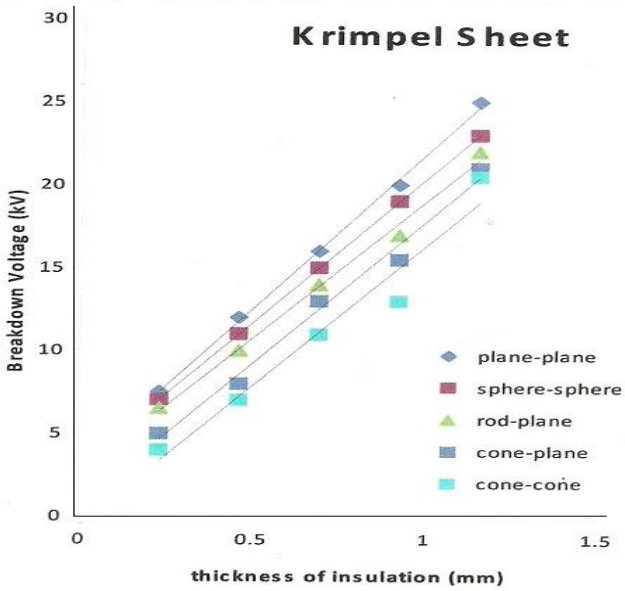
Figure 5(a)-5(c) shows the plot between the observed breakdown voltages for various combinations of electrodes and thickness of insulation for Leatheroid, Presspahn and Krimpel sheet respectively.(32 ºC; 742 Torr).





(a)

(b)



(c)

Figure 5. Plot between the observed breakdown voltages for various combinations of electrodes and thickness of insulation for Leatheroid, Presspahn and Krimpel sheet

V. DISCUSSION

Present study addresses the breakdown characteristics of transformer oil, air and solid insulants under five different electrode configurations simulating the uniform and non-uniform field conditions. Investigations reveal the following:

- Plane-Planeelectrode configuration simulates uniform fields; similar field conditions for sphere-sphere configuration may be assumed if the gap distance is small compared to the diameter of sphere. Higher breakdown voltage of the insulating medium (solid, liquid or gas) has been observed under the above said field configurations suggesting breakdown voltage is strengthened by degree of uniformity (Figures 3-5). For other electrode configurations the breakdown voltage of the insulating medium is low due to non-uniform field conditions. [4]
- Breakdown voltage of the insulation medium increases as the gap length between electrodes increases in case of transformer oil & air (Figures 3-4). Hence it can be inferred that the ac breakdown strength depends not only on gap length but also on the electrode geometry, a phenomena commonly observed in gases and other liquid dielectrics.[5]
- Breakdown voltage of solid insulation depends on the material, electric field conditions and thickness of insulation (Figure 5).[6-7]

VI. CONCLUSION

Investigations revealed that breakdown voltage of the insulation medium increases as the gap length between electrodes increases in case of transformer oil & air, the same being observed in case of solid insulation as the thickness of insulation is increased. Further investigations into breakdown characteristics of transformer oil, air and solids revealed that higher breakdown voltages of the insulating medium was observed under uniform field conditions than that in non-uniform fields.

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