Influence of Electrode Configuration on AC Breakdown Voltages

K.L.Ratnakar[1], Dr. B. Rajesh Kamath[2]

[1]Professor in Electrical & Electronics Engineering, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India
[2]Dean (Academic), Professor and HOD of Electrical & Electronics Engineering, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India.

Abstract: **This paper deals with the breakdown strength of the insulation between the different electrode configurations in a closed chamber. The insulation between the electrodes is air and its breakdown voltage is 21.2 KV/cm in a uniform field or flux distribution. As we have tried with different electrodes like, pointed electrode, plane electrode, sphere electrode, rod electrode and Rogouski electrodes of different dimensions with respect to the common plate electrode as the bottom electrode in the arrangement. As the field distribution with the above electrodes is different the breakdown voltages are also of different values for each set of electrodes. It is observed that lower breakdown voltages for the electrodes where the field lines are concentrated and higher breakdown voltages for the electrodes with uniform field distribution. The breakdown voltage depends on so many factors like microscopic projections on the electrode surfaces, presence of small metallic particles on the electrode surface, atmospheric pressure and temperature, and the shape of the electrodes. In this paper all the other conditions are assumed to be of lower effect and shape of the electrodes has been considered as the top priority. The variation of BD voltage with respect to the gap length has been shown in a graph.**

Key words: **Types of electrodes, BD Voltages, Uniform and non uniform electric fields.**

I. INTRODUCTION

The reliability of High voltage equipment mainly depends on its ability to withstand the high voltage at which it is operating without getting discharged. The insulation may be vacuum, gaseous, liquid or solid materials. The insulation strength mainly depends on the media between the electrodes [1]. However in gaseous state will provide sufficient number of molecules in the intervening region between the electrodes. Yet in contrast to the liquid and solid dielectrics, there are too few molecules in gases to cause significant polarization effects and the electrical losses (dielectric loss) can be vanishingly small. Electrical strength proportional to the gas density, gases at high pressure show significantly higher dielectric strength compared to solids and liquid dielectrics [2]. In the present work before the chambers are filled with gas it is considered an empty chamber with electrode arrangement for finding the breakdown voltage for different electrodes. If the chambers are filled with gases, it will have high capacitance because permittivity is high compared with air or vacuum and so high dielectric stress, therefore it requires high voltage for breakdown. But when the media is filled with liquid or solid dielectric then it will have high value of relative permittivity and hence it requires high AC voltage for breakdown [3]. In fact high voltage engineering was evolved from a heritage of air insulated systems. Usually all such systems are exposed to a large volume of air of poorly controlled quality, in the sense that dust, insects, rain and in many cases birds and animals are an ever present contamination in the air insulation. Under such conditions design must be conservative and the theoretical withstand strength of the clean dry air is not a major factor in setting the design parameters. On the insulator surface, contamination can cause field distortions due to which the dielectric strength of the insulation get affected [4].The fundamental theoretical causes of breakdown are of little importance for practical designs which must operate reliably when exposed to the wide variety of pollutants and ambient conditions. In this paper we are considering the physical variations of the electrodes and their gap lengths between the electrodes.

II. EXPERIMENTAL SETUP

The following figure 1 shows the experimental setup for the tests carried with different electrodes. The plane electrode is taken as the bottom electrode. The top electrode is changed with different configuration electrodes such as pointed, plan, sphere, rod and rogouski electrodes. The test chamber is made up of Fiber glass material of square cross section. The flashover voltages for different air gaps are taken for each sample after fixing it as top electrode. By varying the gap in 5mm steps up to 40 mm gap the breakdown voltage experiment was carried and the readings were noted down. The average of three readings for each gap has been calculated and then taken as breakdown voltage. The AC breakdown voltages were applied and the results were tabulated.

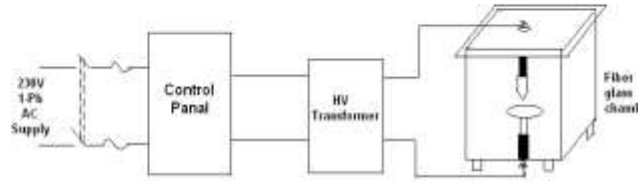
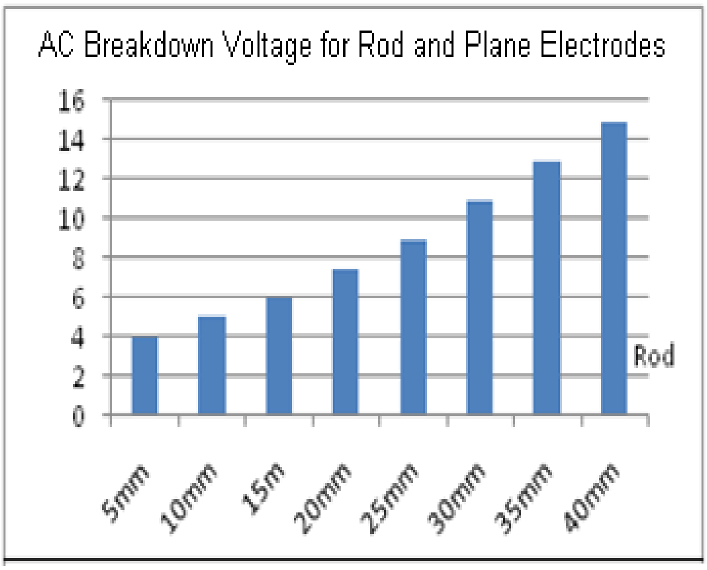
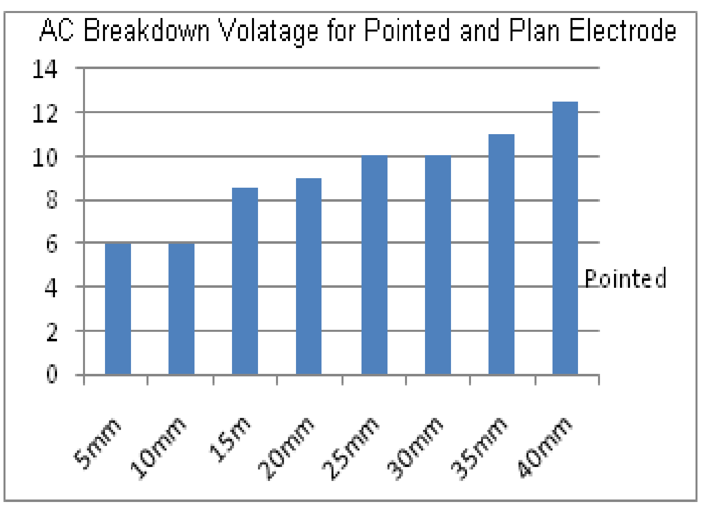


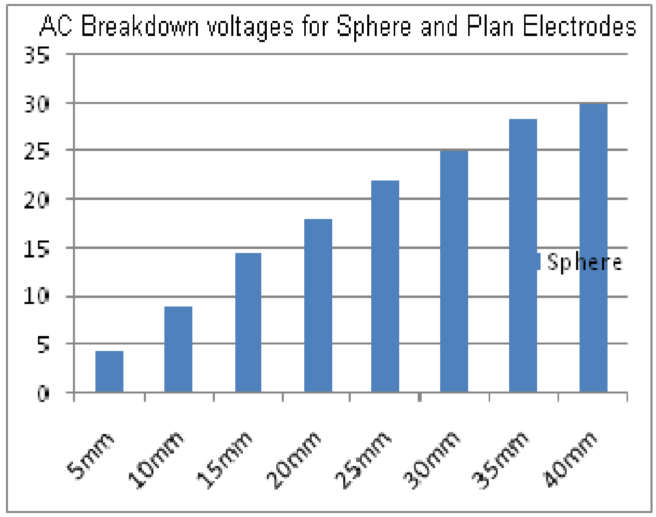
Fig 1: Breakdown voltage measurement circuit

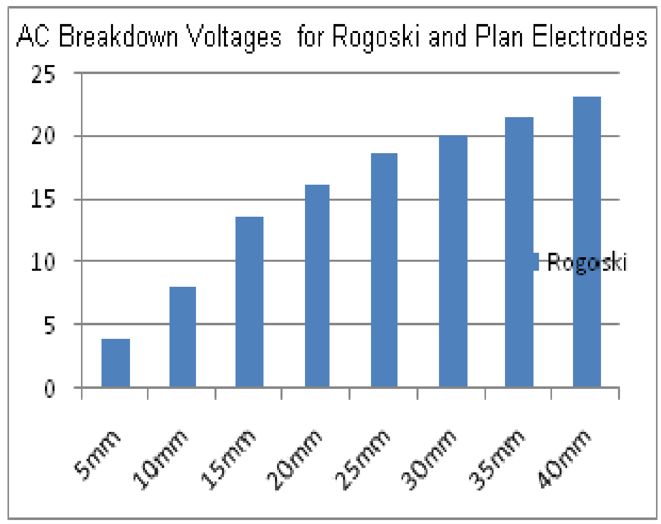
Table 1: Breakdown Voltages in KV for different Electrodes

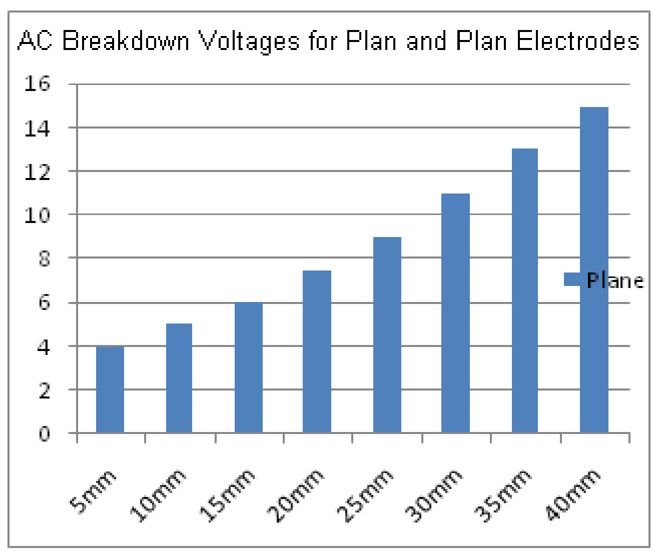
Electrode	5mm	10mm	15mm	20mm	25mm	30mm	35mm	40mm
Rod	4	5	6	7.5	9	11	13	14.9
Pointed	6	6	8.5	9	10	10	11	12.5
Sphere	4.5	9	14.5	18	22	25	28.5	30
Rogoski	4	8	13.5	16	18.5	20	21.5	23
Plane	4	5	6	7.5	9	11	13	14.9



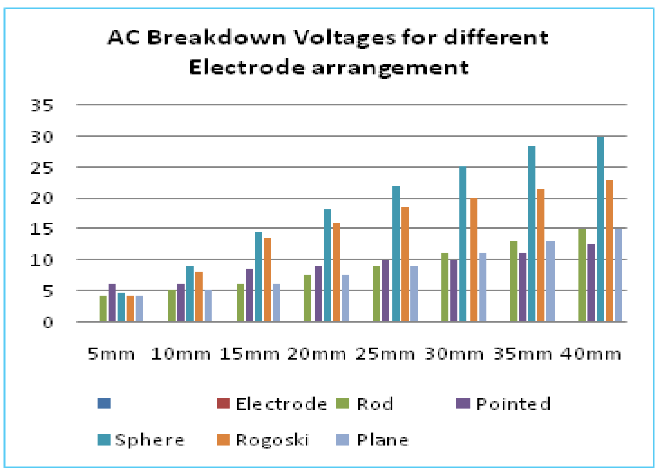




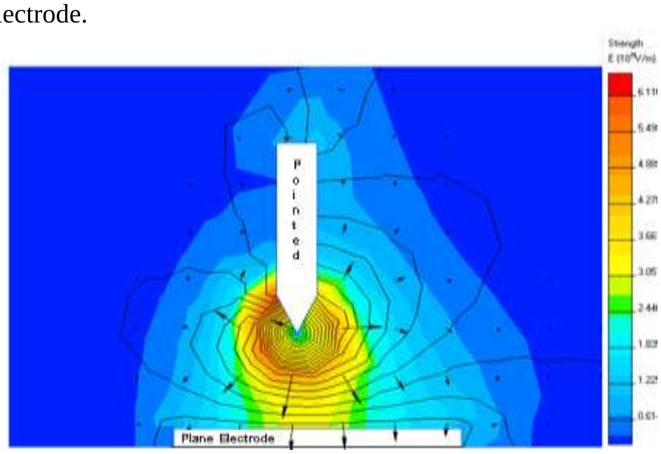




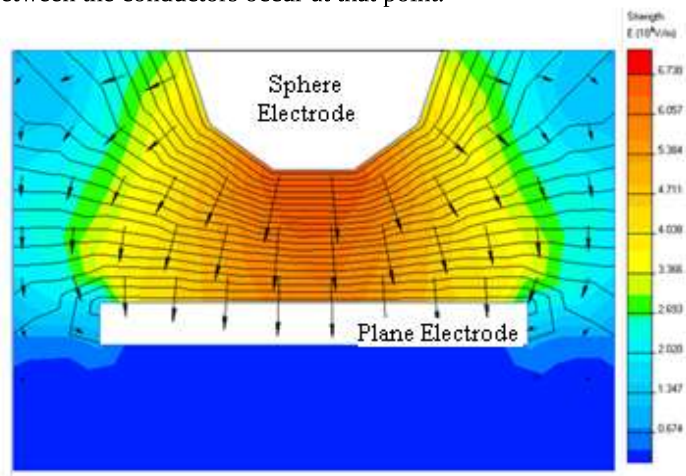
The above bar charts show at what voltage the breakdown has occurred in different electrodes. It is to be observed that all the breakdown voltages are in the units of Kilo Volts and also there is lot of variation in the breakdown voltages among the electrodes as the distance between them increases. It is clear that to breakdown the field intensity between the electrodes should reach the minimum voltage of 21.2KV/cm as the air is the media between the electrodes. The BD voltage also depends on the shape of the electrodes and their distribution of field lines. The BD occurs when there is concentration of field lines whose magnitude when reaches the BD value. The variation in the breakdown voltages for different electrodes is almost same when the gap is small, but the variation increases with the increase in the gap between the electrodes. In the case of sphere and rogoski electrodes the voltage required to breakdown is high. For the Rod electrode and Plane the breakdown voltage is almost the same and it is low as the concentration of field lines is more concentrated than spreading in all the directions. In the case of Sphere and Rogouski electrodes the field lines are more distributed than concentrating at the point and that is why it requires a high voltage to breakdown the gap.



The electric field lines between the pointed electrode and plane electrodes appear to be as shown in figure below. It clearly indicates that the breakdown occurs at the center as the entire field lines are more concentrated near the point of the top electrode.



The electric field lines between the sphere electrode and plane electrodes appear to be as shown in figure below. It clearly indicates that the electric field lines are more distributed over the entire surface area of the sphere and so it requires high voltage to breakdown the gap between the electrodes. Though the breakdown occurs at the center as the minimum distance between the conductors occur at that point.



III. RESULTS

From the above discussion of test results we can conclude that

1) The breakdown voltage mainly depends on the configuration of the electrodes.
2) The physical shape of the electrodes gives the variation in the breakdown voltages.
3) The breakdown voltages of a given set of electrodes depend on the distribution of electric field lines between them.
4) If the flux lines are more uniformly distributed then high voltages are required for the breakdown.
5) If the field lines are concentrated towards the electrode then the breakdown voltage is of low value.
6) The breakdown voltage also depends on the physical conditions of the chamber[5-7]
7) If the chamber is vacuumed then the breakdown voltages are more than what we have got.
8) If the chamber is gas filled then the breakdown voltages vary and with the increase in the pressure of the chamber, the breakdown voltage will also vary.
9) So the quantity of gas filled, in which ratio and what pressure will make the increase in the breakdown voltages of the setup.

REFERENCES

[1]. A Text book on High voltage Engineering by C.L.Wadhava.
[2]. A Text book on High Voltage Engineering by E. Kuffel and J. Kuffel
[3]. Choulkov V.V., “Effect of Electrode surface roughness on electrical breakdown in HV apparatus”, Dielectrics and Electric Insulation, IEEE Transactions, Volume 12, Issue 1, 2005, p98-103.

[4]. Byung-Taek Lee, Chang-Su Huh and Yong-Moo Chang, "AC Breakdown Voltage Characteristics Simulation of SF6/N2 in Non Uniform field and Extra High Voltage", the 4th International Power Engineering and Optimization conference, Shah Alam, Selangor, Malaysia, 23-24th June, 2010.
[5]. Subratha Karmakar, "An Experimental Study of Air Breakdown Voltage and its Effects on Solid Insulation", Journal of Electrical Systems, 8-2 (2012), p 209-217.
[6]. J. H. Colete and J. V. Merwe "The breakdown electric field between two conducting spheres by the method of images" *IEEE Transactions on Education*, Vol. 41, No. 2, May 1998.
[7]. I. Kitani, K. Edahiro, and K. Arii, "Spark breakdown in air / pp-film composite with point-sphere electrode system," *IEEE Trans. Electrical Insulation*, Vol. 25, pp. 393–398, 1990.

BIOGRAPHIES

Prof. K.L.Ratnakar was born in the year 1961 in Kakinada town of Andhra Pradesh. He got his B.Tech and M.Tech degrees in the year 1983 and 1985 from JNTU college of Engineering Kakinada. He has joined as Lecturer in Sri Siddhartha Institute of Technology, Tumkur in the year 1985 and he has grown in his profession along with his service to the height of Professor in Electrical and Electronics Engineering. He has authored a text book on **"Electrical Power Transmission and Distribution"** for third year B.E. students. He was a life member Indian Society for Technical Education MISTE and Institution of Engineers (India) M.I.E., professional bodies. He has presented 20 papers in national and international conferences. He has visited BRISBANE, Australia to present a technical paper in the International Conference in the year 2007.

Dr. B. Rajesh Kamath is a senior faculty of Sri Siddhartha Institute of Technology, Tumkur**,** and presently he is Dean Academic and Head of the Department of Electrical and Electronics Engineering. He has presented many technical papers in national and International conferences. He had been to San Francesco of USA, Dubai, Singapore for presentation of his research papers. He was Fellow of Institution of Engineers (India) F.I.E., life member of Indian Society for Technical Education MISTE. He also chaired many sessions in the national and International conferences.