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Analysis and Comparative Study of Theoretical and Practical Air Breakdown Voltages between Spherical Electrodes

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Abstract*— Growth in power sector of nation is a challenge for power engineers for the protection of sensitive power equipments and their reliable operation. The major challenges in high voltage (HV) power equipments include the quality and reliability of insulators used in power equipments. The HV power equipments are generally subjected to over voltage which may be caused due to thunder bolts or switching actions. These internal and external causes of over voltages determine the safe clearance requirements of proper insulation level. Normally air is the widely used medium as an insulator in different electrical power equipments as its breakdown strength is 30kV/cm. Therefore electrical breakdown characteristic of small air gap under the different applied voltages has its great significance for the design consideration of various air insulated HV equipment. In this paper, theoretical Breakdown Voltages (BDV) of different air gaps between spherical electrodes is compared to the practical values at normal temperature and pressure.
Keywords: High Voltage, Insulators, BDV, Spherical Electrodes

I. INTRODUCTION

To avoid the problems like over voltages and insulator poor quality in high voltage power equipments sphere gap method is considered as one of the standard methods for the measurement of peak value of AC and impulse voltages. This method is used for measuring breakdown voltage of insulating materials and chooses which material has more breakdown strength. The sphere gap method is less complicated and accurate enough. Air has been considered as the insulating medium between two spheres each of radius 5cm.

II. SPHERE-SPHERE ELECTRODE ARRANGEMENT

The sphere-sphere electrode gap is one of the standard methods for the measurement of peak value of AC and impulse voltages and is also used for checking the high voltage power equipments and other voltage measuring devices used in high voltage test circuits. In this, two similar aluminium spheres are separated by certain distance form a sphere gap with air medium. Also, care is taken such that the gap length between the spheres should not exceed a sphere radius. If these conditions are satisfied and the specifications regarding the shape, mounting, clearances of the spheres are met, the results obtained by the use of sphere gaps are reliable to within ±5%. It was suggested in specifications that the readings are to be taken in places where the ultraviolet radiation is low. Irradiation of the gap by radioactive or other ionizing media should be used when voltages of magnitude less than 50 kV are being measured or where higher voltages with accurate results are to be obtained.

Fig. 1 High Voltage Laboratory

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In this arrangement one sphere will be connected directly to earth. Low ohmic shunts like water resistance have to be connected between the sphere and earth in order to control heavy currents due to high voltage. The surfaces of spheres shall be cleaned and dried but need not be polished. In normal use the surfaces of spheres become roughened and pitted. The surface should be rubbed with fine abrasive paper and the resulting dust removed with lint-free cloth any trace of oil or grease should be removed with a solvent. Moisture may condense on the surface of the sparking points in conditions of high relative humidity causing measurements to become erratic. So the spheres are made with their surfaces are smooth and their curvatures as uniform as possible.

III. PRACTICAL ARRANGEMENT AND EQUIPMENT

For taking readings practically, two transformers each of capacity 50kV are cascaded to give 100kV capacity are taken. Standard spherical Electrodes of 5cm radius, control panel for safe application of voltage and earth rod for discharging the stores charges have been employed.

Fig. 2 Sphere-Sphere Arrangement

Fig. 3 Connection of Electrodes

IV. THEORETICAL STUDY OF AIR BREAKDOWN VOLTAGE

Measurement of high voltages and currents is a complex part and the equipments generally have large stray capacitance and large voltage gradient. High voltage equipments are protected against over voltages. The air gap distance between the spheres should not exceed the radius of the sphere. In short duration of time the breakdown voltage can be measured using this method. Sphere electrodes are made with many materials like aluminum, copper etc.

$$V = \frac{27.2\delta r\left(1+\frac{0.54}{\sqrt{\delta r}}\right)\frac{s}{r}}{0.25\left(\frac{s}{r}+1+\sqrt{\left(\frac{s}{r}+1\right)^{2}+8}\right)} \quad (1)$$

$$\delta = \frac{293b}{760(273+t)} \quad (2)$$

V. COMPARISON OF THEORETICAL AND PRACTICAL BDVS AND ELECTRIC FIELDS

In the table given below the gap between the spherical electrodes varies in the range from 0.5 cm to 3.0 cm and the corresponding breakdown voltage varied from 14 kV to 80 kV. It is also observed that the increase of sphere gap the air breakdown voltage is also increased. Earth rod is used before taking every reading for safety purpose and to earth the stored charges. The difference between theoretical and practical BDVs ranges from 2 to 4kV.

TABLE I
COMPARISON OF PRACTICAL AND THEORETICAL BDVS

S.No	Sphere Gap in cm		
1	0.5	14	16.33357
2	1.0	28	31.61459
3	1.5	42	45.91291
4	2.0	55	59.29481
5	2.5	68	71.82294
6	3.0	80	83.55632

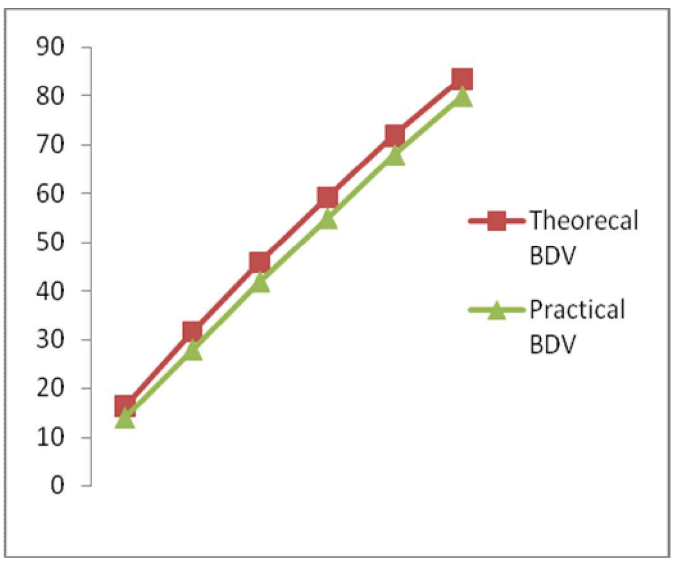

Fig. 4 Graphical Comparison of BDVs

VI. CONCLUSIONS

The breakdown voltage of different air gaps has been studied theoretically and practically in this paper. This comparative study can be further extended to electrodes of different shapes like two planes, two points, plane-point, sphere-rod etc. also for different gaps and mediums.

VII. ACKNOWLEDGMENT

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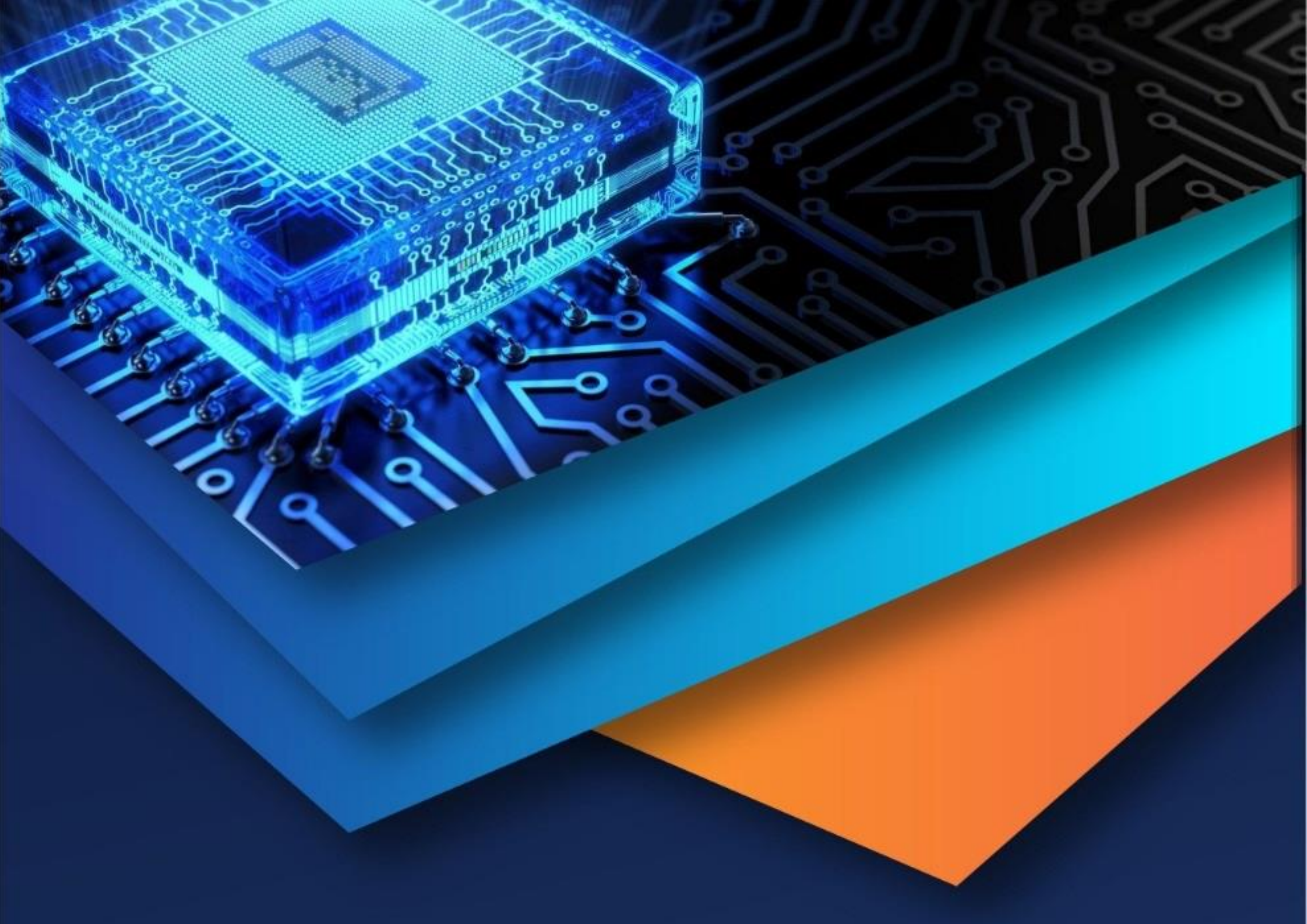

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