Effect of Metallic Particles on Breakdown Voltage of N_2 Gas in Uniform Field

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ABSTRACT

Performance of the metal particles is determined by the breakdown voltage in N_2 gas. The main factors which influence the breakdown in N_2 are the shape, size, and different angles for uniform & non uniform field. Present work is intended to study the effect of metallic particles on breakdown voltage in N_2 gas. Experiments have been carried out for different particles such as copper, aluminum & silver of 10 mm lengths are used under angle of 0°, 30°, 60°. Experimental results show that in copper and aluminium particles affect the insulation performance of N_2 more than that with aluminum particle.

***Keywords*—** Breakdown Voltage, N_2 Gas, Electrodes, DC Voltage

I. INTRODUCTION

There is a need for the larger amount of power generation, transmission and distribution networks in the world with the increase in the Industrial growth. Significant advances have been made in the design and development of high voltage Transmission and distribution. There is a need for compressed gas insulated system for transmission of bulk power with rated voltage above 800 kV. In the Gas Insulated Transmission Lines (GITL) and Gas Insulated Systems (GIS), the use of compressed SF6 gas as an insulating media in all the switchgears and circuit breakers has come into practice. SF_6 is an electro negative gas and it has dielectric strength three times that of N_2, the outstanding properties of SF_6 have resulted in its extensive use as an insulating gas in high voltage. On the other hand, it is a highly potent greenhouse gas due to its high global warming potential. Alternative insulating gases to replace SF_6 has been investigated in recent decade equipment.

Gas insulated substation have been major innovation in Power Transmission and distribution with proven reliability and maintenance free operation the gas insulated substation has its existence more than three decades the insulating material between the electrodes may be in solid, liquid and gaseous forms. These insulating materials will have variation in insulation strength based on operating condition of system such as applied voltage pressure of N_2 bubble in liquid and solid dielectrics.

These factors degraded the insulating materials under partial discharges takes place between the electrodes in the beginning of the gas insulated circuit breakers by insulated gas used was SF_6 alone but after the World Congress the environmentists have taken the objection to the usage of Sulphur hexafluoride gas as it is Greenhouse Gas Hence engineers start inventing the combination of SF_6, CO_2, N_2 etc. in different proportion in order to decrease the usage of greenhouse gas.

The electrical breakdown is used either by microscopic projection on electrode surface by free conducting particles and occurs as a result of process of ionization of gas molecule by free electrons. With this background keeping the need for gas insulated substation technology and to reduce SF_6 content in gas insulated substation this work has been carried out with the 100% of N_2. In this paper, an experimental study has been carried out to study the effect of metallic particles on breakdown voltage by considering plane-plane electrodes by varying the gap distance of 10 mm, 15mm ,20mm,25mm under angle of 0°, 30°and 60° respectively.

A. Breakdown Voltage in N_2

The breakdown in air (spark breakdown) is the transition of a non-sustaining discharge into a self-sustaining discharge. The buildup of high currents in a breakdown is due to the ionization in which electrons and ions are created from neutral atoms or molecules, and their migration to the anode and cathode respectively leads to high currents. Townsend theory and Streamer theory are the present two types of theories which explain the mechanism of breakdown under different conditions as temperature, pressure, nature of electrode surfaces, electrode field. Normally N_2 medium is widely used as an insulating medium in different electrical power equipment and overhead lines as its breakdown strength is 30kV/cm.

B. Types of Electrode Arrangement for Measurement of BDV

IEC 60052 sets four recommendations concerning the construction and use of standard N2 gaps for the measurement of peak values of some like alternating voltages of power frequencies, full lightning impulse voltages, switching impulse voltages and direct voltages are involving unusual problems that may not be familiar to specialists in the common electrical measurement techniques. These problems increase with the magnitude of the voltage, but are still easy to solve for voltages of some 10 kV only, and become difficult if hundreds of kilovolts or even megavolts have to be measured. The high voltage power equipment's have large stray capacitances with respect to the grounded structures and hence large voltage gradients are set up. A person handling this equipment's and the measuring devices must be protected against these over voltages. For this, large structures are required to control the electrical fields and to avoid flash over between the equipment and the grounded structures. Therefore, the location and layout of the equipment's. The electrode arrangements (Plane-plane) and circuits for measurement of high voltages and currents are shown.

Figure 1: Plane-Plane electrode arrangements with metal placed in angles 0°, 30°, 60°

II. EXPERIMENTAL ARRANGEMENT

The high voltage transformer is connected to the gas chamber through water resistor. Different electrodes are placed in gas chamber in their proper positions. Now the main supply is switched on from control panel. Voltage is increased using increase button from the control panel till the spark occurs. Distance between the electrodes in increased from 5 mm - 40 mm. Before placing the next different electrodes in the chamber, proper discharging is done through grounding rod. Test set up used for conducting experiments is as shown in Figure 2.

Figure 2: Test setup for HVAC

III. CIRCUIT DIAGRAM

Experiments for breakdown voltage in N_2 gas mixtures for different electrodes for different metals under different angles were conducted. The equivalent circuits are as shown below in Figure 3.

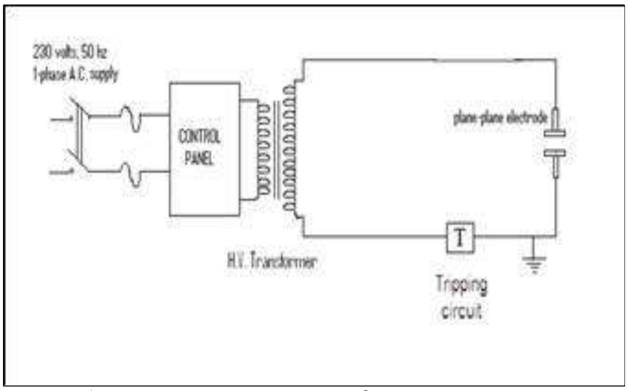

Figure 3: Circuit Diagram for HVAC System

IV. RESULTS AND DISCUSSION

To simulate the performance characteristic of the N_2 breakdown voltage (BDV) and maximum electric field between the conducting electrodes, two standard electrodes is taken into considered in this work. The main focus of the analysis is variation of breakdown voltage versus electrode gap with different diameters. This characteristic provides significant information on the withstanding capacity of the insulation to sustain the high spark over voltage. The N_2 breakdown voltage between the electrodes are measured by conducting the N_2 breakdown voltage in high voltage laboratory and corresponding BDV are calculated from the experimental depicted in Table 1 to Table 10. Variation of N_2 gas breakdown voltage of Aluminium metal, Copper metal and Silver metal for the Plane-Plane electrode combinations are shown

Table 1: N_2 breakdown voltage of Silver metal for the Plane- Plane electrode combination

SL No.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	10 mm	Silver	Plane-Plane	0°	25.102
2	15mm				41.456
3	20 mm				55.906
4	25 mm				67.503

Table 2: N_2 breakdown voltage of Silver metal of for the Plane-Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	15mm	Silver (10 mm)	Plane-plane	30°	9.013
2	20 mm				14.046
3	25 mm				19.193
4	30 mm				23.673

Table 3: N_2 breakdown voltage of Silver metal of for the Plane- Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	15 mm	Silver (10 mm)	Plane - Plane	60°	12.57
2	20 mm				20.33
3	25 mm				21.736
4	30 mm				27.28

Table 4: N_2 breakdown voltage of Copper metal of for the Plane-Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	10 mm	Copper	Plane - Plane	0°	15.213
2	15 mm				26.396
3	20 mm				37.64
5	25 mm				51.733

Table 5: N_2 breakdown voltage of Copper metal of for the Plane-Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	15 mm	Copper	Plane - Plane	30°	14.346
2	20 mm				20.16
3	25 mm				26.94
4	30 mm				33.625

Table 6: N_2 breakdown voltage of Copper metal of for the Plane-Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	20 mm	Copper	Plane - Plane	60°	21.73
2	25mm				28.05
3	30mm				33

Table 7: N_2 breakdown voltage of Aluminium metal of for the Plane- Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	10 mm	Aluminium	Plane -Plane	0°	34.06
2	15 mm				43.25
3	20 mm				55.69
4	25 mm				66.08

Table 8: N_2 breakdown voltage of Aluminium metal of for the Plane-Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle	Average BDV in KV (HVDC)
1	15 mm	Aluminium	Plane - Plane	30°	26.39
2	20 mm				32.92
3	25 mm				41.29
4	30 mm				45.33

Table 9: N_2 breakdown voltage of Aluminium metal of for the Plane- Plane electrode combination

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle in degrees	Average BDV in KV (HVAC)
1	20 mm	Aluminium	Plane – Plane	60°	30.21
2	25 mm				37.02
3	30 mm				42.00

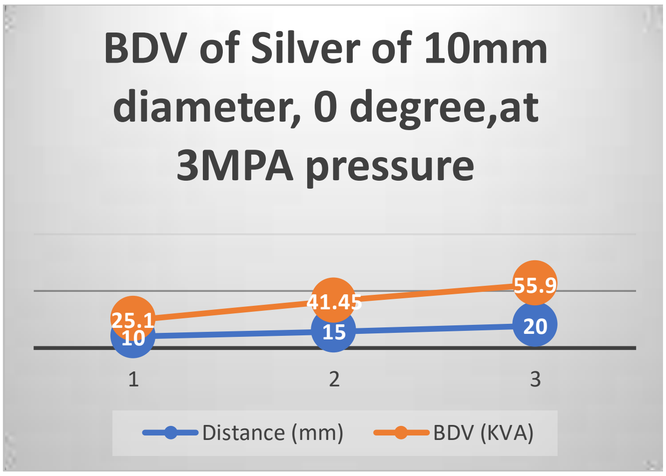

Figure 4: Variation of N_2 gas breakdown voltage of Silver metal for the Plane-Plane electrode combination (0°)

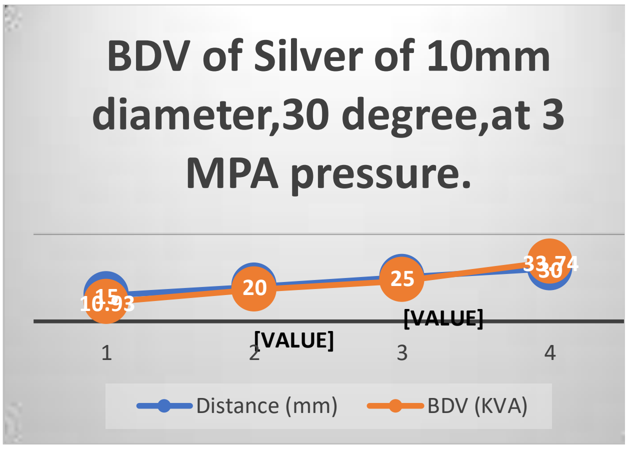

Figure 5: Variation of N_2 gas mixture breakdown voltage of Silver metal for the Plane-Plane electrode combination (30°)

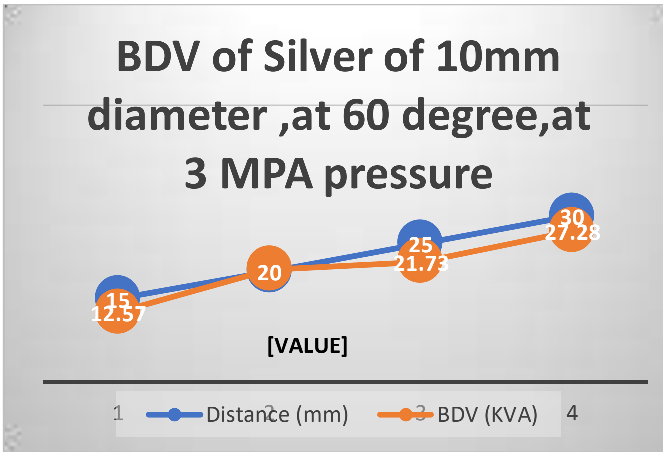

Figure 6: Variation of N_2 gas breakdown voltage of Silver metal for the Plane-Plane electrode combination (60°)

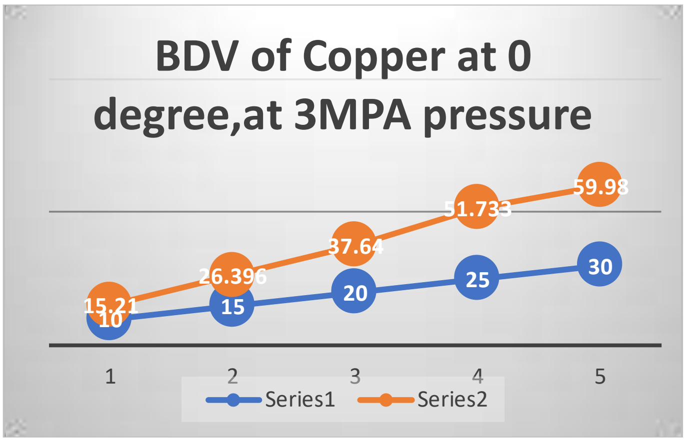

Figure 7: Variation of N_2 gas breakdown voltage of Copper metal for the Plane-Plane electrode combination (0°)

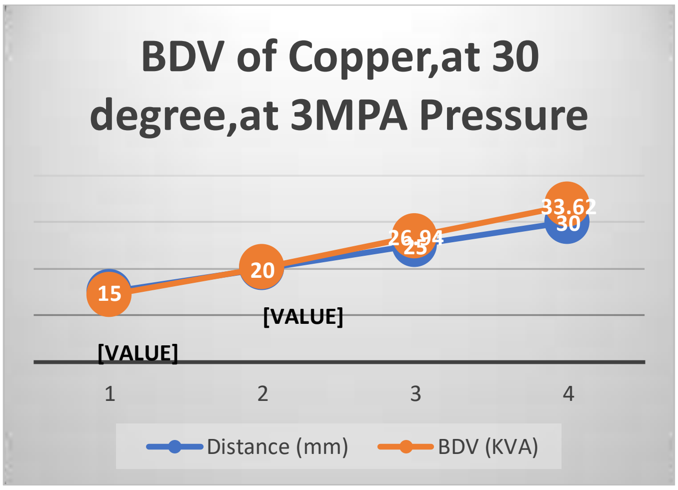

Figure 8: Variation of N_2 gas breakdown voltage of Copper metal for the Plane-Plane electrode combination (30°)

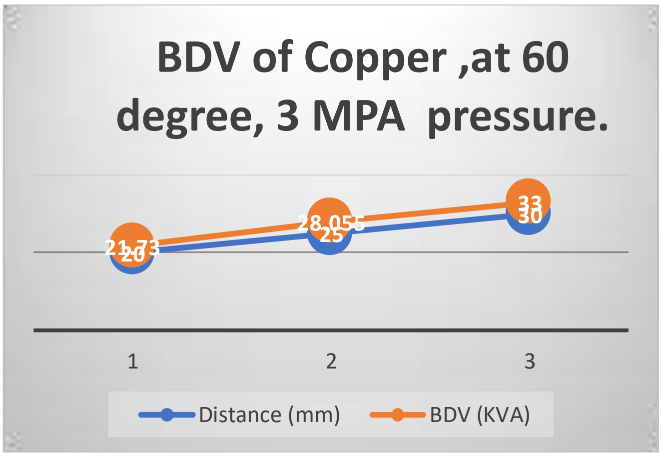

Figure 9: Variation of N_2 gas breakdown voltage of Copper metal for the Plane-Plane electrode combination (60°)

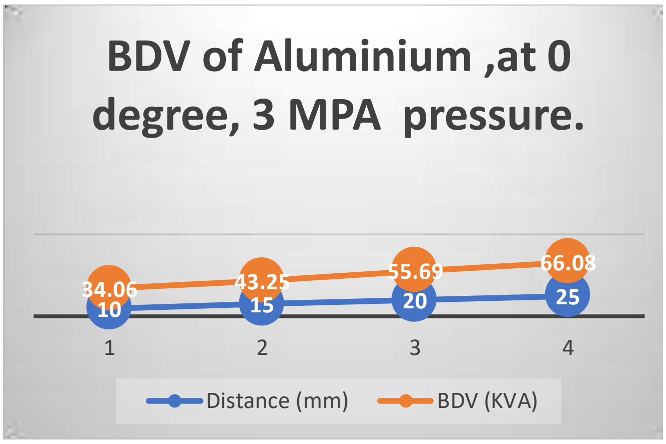

Figure 10: Variation of N_2 gas breakdown voltage of Aluminium metal for the Plane-Plane electrode combination (0°)

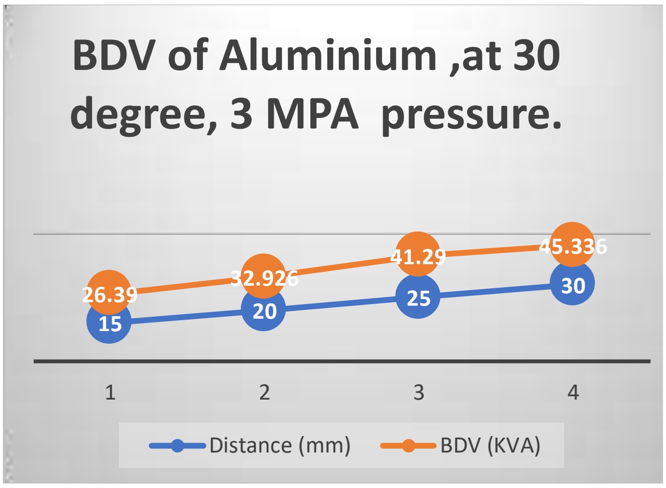

Figure 11: Variation of N_2 gas breakdown voltage of Aluminium metal for the Plane-Plane electrode combination (30°)

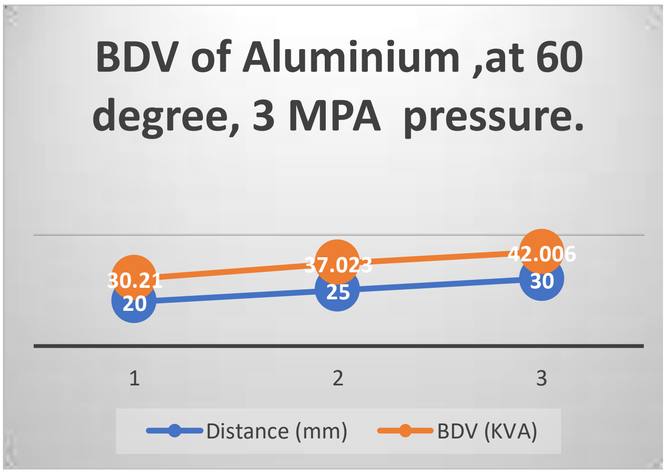

Figure 12: Variation of N_2 gas breakdown voltage of Aluminium metal for the Plane-Plane electrode combination (60°)

V. CONCLUSIONS

To simulate the performance characteristic of the N_2 breakdown voltage (BDV) and maximum electric field between the conducting electrodes, two standard electrodes is taken into considered in this work. The following conclusions are drawn based on above work

- Breakdown voltages of N_2 have been investigated in this work. In addition, the effect of metallic particle contamination has been studied under uniform field configurations
- The breakdown voltage mainly depends on the configuration of the electrodes, diameter of metal, type of the conductor
- If the field lines are concentrated towards the electrode, then the breakdown voltage is of low value.
- Experimental results were also analyzed in case of breakdown across different conductors with Plane-Plane combination of electrodes.
- It is concluded that with the increase of gap between electrodes, the breakdown voltage and electric field strength are increased and is inversely proportional to electrode radius.
- By looking at this graph we will get to know that which conductor is better. In this Aluminum is linearly increasing hence Aluminum is good & better than other conductors.

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