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Effect of Breakdown Characteristics of Sf_6 /N_2 Gas Mixtures in Non-Uniform Fields

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***Abstract*— SF_6/N_2 gas mixtures are used to determine the performance of the metal particles by determining the breakdown voltage. The main factors that influence SF_6/N_2 breakdown are shape, size, and angles for uniform versus non-uniform fields. The goal of this research is to determine what the impact of metallic particles in SF_6/N_2 mixtures will be on the breakdown voltage. The experiments have been conducted on different particles such as copper, aluminum, and silver of 10 mm lengths under an angle of 0° and using non uniform field for AC voltage.**

Keywords*— *SF_6/N_2 gas mixtures; metallic particles; breakdown voltage; non uniform field

I. INTRODUCTION

The Economic development of any Country depends upon availability of electrical power at an affordable price. Availability of power is the foundation of Industrial growth which in turn contributes to the Economy of the Country. India is one of the faster growing economies of the world and ranks sixth in the power consumption after USA, China, Russia, Japan and Germany (Kumarappa and Monisha 2009). As per the Ministry of Power, Government of India, India has been able to achieve an economic growth rate of 8% per annum during last few years and is poised to achieve double digit growth rate. At the same time Industrial growth rate has been recorded over 9% rate consistently in last few years. The power sector at a glance "ALL INDIA" (Source CEA, July 2009) shows that the total installed capacity from different sources is 1,51,073.41 MW, of which 65% is from Thermal, 25% from Hydro, 3% from Nuclear and 8% from Renewable Energy Sources. The Indian government has set an ambitious target to add approximately 78,000 MW of installed generation capacity by 2012 (Kumar 2007). The total demand for electricity in India is expected to cross 950,000 MW by 2030. The Government of India also has an ambitious mission of power for all by 2012. This mission would require that our installed generation capacity would be at least 200,000 MW by 2012 from the present level of 151,073.41 MW. Power requirement will double by 2020 to 400,000 MW.

II. TYPES OF ELECTRODE ARRANGEMENT FOR MEASUREMENT OF BDV

IEC 60052 sets four recommendations concerning the construction and use of standard air 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 involves 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 equipments have large stray capacitances with respect to the grounded structures and hence large voltage gradients are set up. A person handling these equipments 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 equipments. There are various types of electrode arrangements and circuits for measurement of high voltages and currents. Those are,

i) Plane-plane
ii) sphere-Plane
iii) point-plane

Sphere-Plane:

A sphere-Plane electrode system (Figure 1) was designed and used for the measure the breakdown voltage and electric field in all types of insulating materials. This electrode arrangement is considered as a non-uniform field because the surfaces of both the electrodes are not similar. The maximum electric field in gap between the electrodes is,

$$Emax=0.9V_{max}/x_a$$

Figure 1: Sphere-Plane electrode arrangement.

where,
V is the voltage applied
X is the distance between the sphere and the plane
A is the radius of the electrodes

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Point-Plane:

In this arrangement the ground effect also affects the breakdown voltage of the rod-plate air gaps but in a quite different way than the Polarity Effect(Figure 2). The values of the breakdown voltage depend on the maximum value of the field strength in the gap between the electrodes, as well as the corona leakage current through the gap. According to the Polarity Effect the breakdown voltage is considerably higher in the arrangement with negative polarity on the rod because of the intensive corona effects. The ground effect the breakdown voltage is higher in the arrangement with the rod grounded because the maximum value of the field strength is lower. Ground effect is intense in small rod-plate air gaps, while the influence of the corona leakage current and the Polarity Effect appears in longer air gaps. This electrode arrangement is considered as a non-uniform field because the surfaces of both the electrodes are not similar.

Figure 2: Point-Plane electrode arrangement.

The average value of the field strength of an air gap is defined by equation,

$$E_{av}=V/G$$

The field factor (or efficiency factor) n is,

$$n- E_{max}/E_{av}-2G/(r.\ln 4G/r)$$

Table 1: Metallic Particle placed on the surface of the plane electrode with different diameter &angle (0°, 30°, 60°, & 90°)

Name of the Conductor	Diameter of the Conductor			Length
Copper Conductor	1 mm	2.5 mm	4 mm	10 mm
Aluminium Conductor	1 mm	2.5 mm	4 mm	10 mm
Silver Conductor	1 mm	2.5 mm	4 mm	10 mm

III. EXPERIMENTAL ARRANGEMENT

In AC output terminal of 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 setup for HVAC is as shown in Figure 3.

Figure 3: Test setup for HVAC

CIRCUIT DIAGRAMS:

Sphere-Plane:

Experiments for breakdown voltage in SF_6/N_2 gas mixtures for different electrodes for different metals under different angles were conducted. The equivalent circuits of sphere-plane and plane-point electrode are as shown below in Figures 4 and 5.

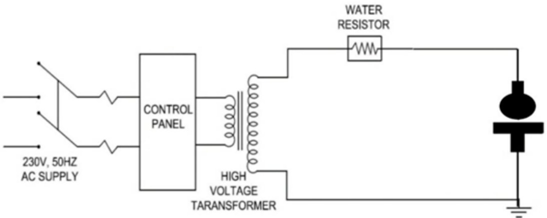

Figure 4: Sphere to Plane HVAC.

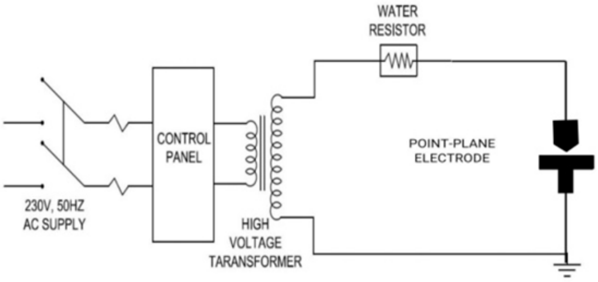

Figure 5: Point to Plane HVAC.

In this study two identical electrodes have been used for the experimental study of the short air gap. The electrodes are vertically aligned. The lower electrode which is above the ground plane is grounded where as the top electrode is connected with HV connector. The used plane electrode has a diameter of 50 cm and the electrode is made of Aluminum material with nickel coating and air is acting as an insulating medium between two electrodes. Before conducting the test the two electrodes are cleaned with carbon tetra chloride (CCl_4) so that it is free from floating dust particles, fibers. The upper electrode is connected in the high voltage terminal and the lower electrode is connected with the ground terminal.

Then the different metallic particles like copper, aluminum, and silver conductor of different diameter are placed on the lower plane electrode with different angles like (0°, 30°, 60°, and 90°). With the application of the high voltage between the electrodes, a non-uniform electric field is generated as the surfaces of the electrodes are not uniform. The HV electrode is energized from the 50 Hz transformer with a power rating of 5kVA with a transformation ratio of 230V/100kV. The applied voltage is raised to 75% of the estimated voltage and thereafter the voltage is raised 2% of the test voltage per second.

The test voltages are applied through the filter unit to isolate the noise of the transformer from the measuring circuit and current limiting device for protect in case of complete breakdown and prevent the high frequency current to the high voltage lead. At the inception of the breakdown the circuit is immediately disconnected from the supply and the breakdown voltage is recorded. A coupling device with connecting cable is associated with the measuring circuit for the measurement of the applied high voltages magnitude. The experimental study has been conducted for air breakdown test between the electrodes at normal temperature. For each 10 mm of gap between the electrodes, the air breakdown voltage is recorded in this study. The gap between the electrodes is varies from the range of 10 mm to 40 mm.

IV. RESULTS AND DISCUSSION

To understand the performance characteristic of the SF6 /N2 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 SF_6/N_2 breakdown voltage between the electrodes are measured by conducting the SF_6/N_2 breakdown voltage in high voltage laboratory and corresponding BDV are calculated from the experimental depicted in Table 2 to Table 8.

Table 3: SF_6/N_2 breakdown voltage of Aluminium metal of for the Sphere to 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 (Ø 1.5 mm)	Plane - Sphere	0°	29.63
2	30 mm				40.24
3	40 mm				47.79
4	50 mm				53.45

Table 4: SF_6/N_2 breakdown voltage of Aluminium metal of for the Point p to 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 (Ø 1.5 mm)	Plane - Point	0°	15.34
2	30 mm				18.93
3	40 mm				21.10
4	50 mm				25.26

Table 5: SF_6/N_2 breakdown voltage of Copper metal of for the Plane-Sphere electrode combination.

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle in degrees	Average BDV in kV (HVAC)
1	20 mm	Copper (Ø 1.5 mm)	Plane - Sphere	0°	34.81
2	30 mm				45.72
3	40 mm				51.32
4	50 mm				55.04

Table 6: SF_6/N_2 breakdown voltage of Copper metal of for the Plane-Point electrode combination.

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle in degrees	Average BDV in kV (HVAC)
1	20 mm	Copper (Ø 1.5 mm)	Plane - Point	0°	13.46
2	30 mm				21.08
3	40 mm				23.82
4	50 mm				28.57

Table 7: SF_6/N_2 breakdown voltage of Silver metal of for the Plane- Sphere electrode combination.

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle in degrees	Average BDV in kV (HVAC)
1	20 mm	Silver (Ø 1.5 mm)	Plane - Sphere	0°	29
2	30 mm				36.22
3	40 mm				46.78
4	50 mm				52.74

Table 8: SF_6/N_2 breakdown voltage of Silver metal of for the Plane- Point electrode combination.

SL NO.	Gap between Electrodes	Type of metal	Type of electrode	Angle in degrees	Average BDV in kV (HVAC)
1	20 mm	Silver (Ø 1.5 mm)	Plane - Point	0°	14.19
2	30 mm				19.17
3	40 mm				24.89
4	50 mm				28.58

From the Table 3-8, it was observed that as the gap distance increases the BDV of Silver material of diameter 1.5 mm under the angle of 0° in SF_6 /N_2 gas mixtures also increases in Plane –Point and Plane –Sphere Electrodes.

Comparison of materials with angle by a varying gap distance

Variation of SF_6/N_2 gas mixture breakdown voltage of Aluminium metal, Copper metal and Silver metal for the different electrode combinations are shown in Figures 6, and Figure 7 and decipatec in Table 9 and Table 10.

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Table 9: SF_6/N_2 breakdown voltage of Aluminium metal, Copper metal and Silver metal for the Plane-Sphere electrode combination

Type of electrode	Angle	Gap Distance (mm)	Material Type / Average BDV in kV		
			Aluminium	Copper	Silver
Plane-Sphere	0°	20	29.63	34.81	29
		30	40.24	45.72	36.22
		40	47.79	51.32	46.78
		50	53.45	55.04	52.74

Table 10: SF_6/N_2 breakdown voltage of Aluminium metal, Copper metal and Silver metal for the Plane-Point electrode combination

Type of electrode	Angle	Gap Distance (mm)	Material Type / Average BDV in kV		
			Aluminium	Copper	Silver
Plane-Point	0°	20	15.34	13.46	14.19
		30	18.93	21.08	19.17
		40	21.1	23.82	24.89
		50	25.26	28.57	28.58

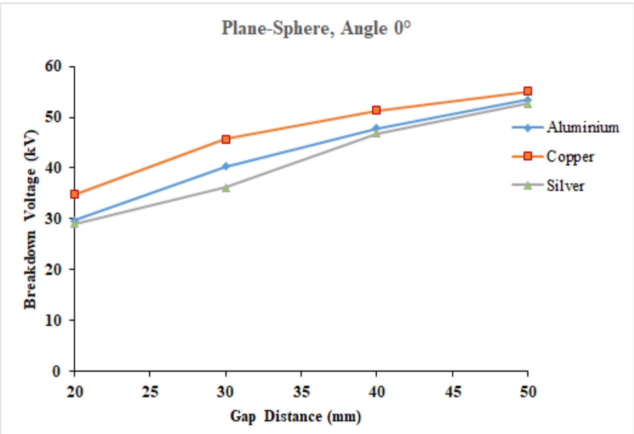

Figure 6: Variation of SF6/N2 breakdown voltage of Aluminium metal, Copper metal and Silver metal for the Plane-Sphere electrode combination.

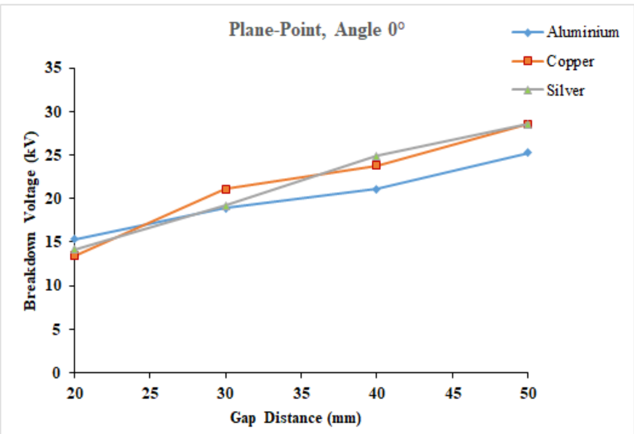

Figure 7: Variation of SF6/N2 breakdown voltage of Aluminium metal, Copper metal and Silver metal for the Plane-Point electrode combination

V. CONCLUSION

To simulate the performance characteristic of the SF6 /N2 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 SF_6/N_2 have been investigated in this work. In addition, the effect of metallic particle contamination has been studied under uniform, non-uniform field configurations. The breakdown voltage mainly depends on the configuration of the electrodes. 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 different 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 copper is linearly increasing hence copper is good & better than other conductors.

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