To Study the Breakdown Voltage of Different Spacers

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ABSTRACT

The aim of this thesis work is to find the effect of breakdown voltage on solid insulation material (spacers) Polymethyl methacrylate (PMMA), Polytetrafluoroethylene (PTFE), Polypropylene (PP) and Polyvinyl chloride (PVC). In electrical power system HV power equipment is mainly affected by breakdown voltage. This over voltage is mainly caused by lightning strokes which helps to determine the safe clearance required for proper insulation level. To avoid this problem in HV power equipment, plane-plane and point-plane gap method is considered as one of standard methods. The plane-plane and point-plane gap method is not complex and accuracy is acceptable. The knowledge of the BDV of different solid insulating materials of different composite materials with various electrode configurations and thickness of spacers helps us to determine the insulation type and their strength in order to protect the equipment so that it works efficiently and to avoid failure.

1. INTRODUCTION

Over the past few years, many researches are done on BDV. Recent trend is towards introducing high voltage transmission lines with gas insulated systems, the existing spacers are inadequate to withstand such high voltages. There are many merits and demerits for this issue. One of the benefits is to produce HV for laser printer and cathode ray tube televisions, which has similarities to auto ignition for the spark plug to start the engine. The spark over can be seen if a HV transmission line is not properly installed at actual gap. The spacer materials will have variation in breakdown strength based on operating condition of system such as applied voltage and pressure of air/gas insulation. It can be harmful to human and can cause sparking. So, the technology is important and must be designed for safety. Also, there is a need for better solid dielectrics with good breakdown strength which reduce the size of high voltage equipment [1] [3].

Rapid development over recent years in the power sector has given the opportunity to electrical engineers to protect the electrical equipment for reliable operation. Therefore, it is important for today’s engineers to know different types of solid insulations and their properties to reduce the cost applications also keeping in mind safety considerations. Degradation of insulation of solid insulating material is one of the main problems of high voltage engineering. HV power equipment are mainly subjected to spark over voltage caused by lightning strokes and switching action. The plane-plane and point-plane electrode configurations are commonly used for this purpose.

In this research high voltage laboratory is used for measuring BDV. The application of spacer can increase the BDV [4]. For this purpose, four kinds of spacers namely Polymethyl methacrylate (PMMA), Polytetrafluoroethylene (PTFE), Polypropylene (PP), Polyvinyl chloride (PVC) with diameters of 25 mm, in two different high-voltage electrode configuration plane-plane and plane-point are investigated under normal temperature and pressure [5] [6]. These two electrode configurations are tested by using different spacer thickness with 5mm, 10mm, 15mm, 17.5mm and 20 mm. The effect of parameters such as electrode spacing and spacer material on BDV are determined for applied DC and 50 Hz AC voltages.

2. METHODOLOGY

The impact of spacer on BDV enhancement will be found for both DC and AC voltages are applied. Hence, four kinds of spacers namely Polymethyl methacrylate (PMMA), Polytetrafluoroethylene (PTFE), Polypropylene (PP), Polyvinyl chloride (PVC) with diameters of 25 mm in two different high-voltage electrode configuration plane-plane and point-plane are investigated [2]. This two electrodes configuration are tested by using different spacer length with 5mm, 10mm, 15mm, 17.5mm, 20 mm. The influence of different parameters such as gap between electrodes, uniform and non-uniform field electrodes and spacer materials on BDV will be investigated for applied DC and 50 Hz AC voltages. Various real time applications can be observed with respect to this research [7] [8] [9].

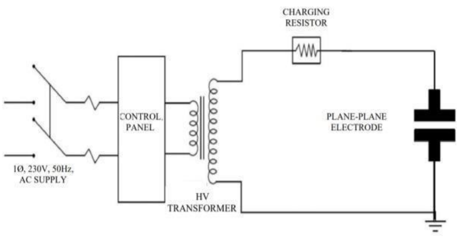

Figure 2.1 Circuit for the measurement of BDV under HVAC using plane-plane electrode

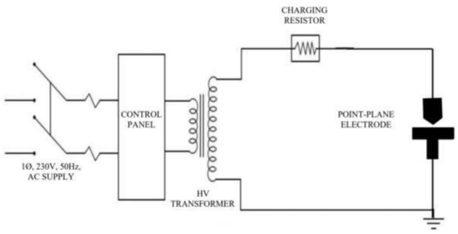

Figure 2.2 Circuit for measuring BDV under HVA Causing point-plane electrode

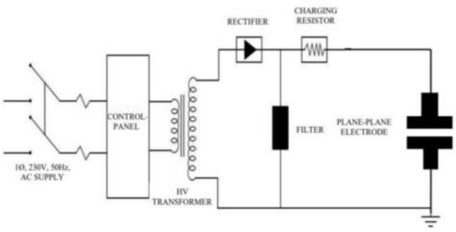

Figure 2.3 Circuit for measuring BDV under HVDC using plane-plane electrode

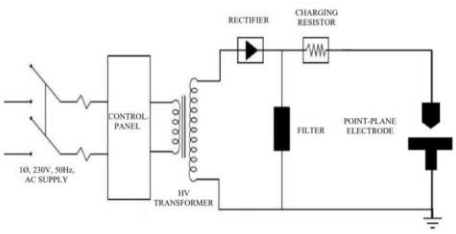

Figure 2.4 Circuit for measurement of BDV under HVDC using point-plane electrode

The circuit diagram for experiments to determine the breakdown voltages for different electrode configurations is shown in Figure 2.1, Figure 2.2 for AC and Figure 2.3, Figure 2.4 for DC. The electrodes are vertically arranged. 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 Aluminium with nickel coating and air acts as an insulating medium between two electrodes. The ac source used is 100 kV (RMS). An input voltage of 230 V ac is given to a step-up transformer. The secondary output of transformer is fed to the test object. The HV electrode is energized from the 50 Hz transformer with a power rating of 5kVA with a transformation ratio of 230V/100kV. The input voltage to the transformer can be in increased or decreased as per requirements of the experiments in steps of 1kV/sec. Required dc voltage can be obtained after passing the output voltage through a rectifier unit and a filter capacitor to reduce ripple. A charging resistor is used to control the current in the circuit. There is provision for tripping of electricalcircuit at the instant of breakdown. In addition, 100 kV ac and 140 kV dc breakdown equipment's were used for experiments requiring higher voltages. 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 protection in case of complete breakdown and prevent the high frequency current to the high voltage lead.

2.1 Control desk

To control and operate HVAC/HVDC test equipment control desk is used. The control panel consists of all the measuring instruments including the safety controlling switch such as mains switch, control switch (key), voltmeter, primary ON, secondary ON, primary OFF, secondary OFF, voltage regulation increase and decrease button, circuit breaker. All equipment under test is controlled by control panel. The desk contains operating and signal elements for the control circuit of the test equipment for warning and safety. It is fabricated of steel and stands on 4 wheels. The control panel displays the breakdown voltage at that particular gap distance between the electrodes.

2.2 Test setup

To conduct the breakdown test between the different electrode configurations, all the measuring instrument is referred to the test setup in the voltage laboratory. Experimental test setup is connected by using the circuit diagram.

2.3 Electrode arrangement

The types of electrode configurations for measuring HV are sphere-sphere, sphere-plane, rod-rod, rod-plane, point-point, point-plane and plane-plane. In this study two electrode configuration (plane-plane and point-plane) were used for the experimental study of different gap. The electrode is made of aluminium material and air acts as an insulating medium between these electrodes. Before the experiment is conducted, the two electrodes are cleaned to remove the dust particles residing over the surface. The behaviour of electric field is based on the nature of electrode configuration (uniform and non-uniform). Uniform electric field using plane-plane and non-uniform electric field using point-plane is produced as we apply the high voltage between the electrodes. The merits of plane–plane electrode arrangement is not influenced by polarity effect. However, there are many disadvantages such as very precise mechanical finish to the electrode is required, careful parallel alignment of the two electrodes and influence of dust brings in erratic breakdown of the gap. This is much more serious in these gaps as compared to sphere gaps as the highly stressed electrode areas become much larger. Hence, uniform field gap is generally not used for HV measurements. The electrode geometries used are 50 mm diameter Plane electrodes and 10 mm (60^o cone) Point electrode.

2.4 Different spacer materials used for study

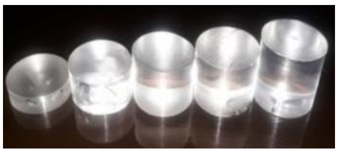

Figure2.5 PMMA spacer

Figure2.6 PTFE spacer

Figure2.7 PVC spacer

Figure2.8 PP spacer

Spacers are commonly used in air, oil and SF6 insulated systems both for mechanical support and insulation. The spacers are always weak links in the gas, solid and composite insulation systems and the breakdown is invariably by surface flashover across the spacer. Four cylindrical spacers made from PMMA, PTFE, PP and PVC materials are used for the investigation. Spacers of various lengths namely 5, 10, 15, 17.5 and 20 mm of diameter 25 mm are used for these experiments. Care is taken to see that spacer-electrode contact is firm so that there is no air gap between the two. It is possible to mount the spacers of different sizes by altering the electrode spacing. The photograph of the spacer materials used is shown in Figure 2.5, Figure 2.6, Figure 2.7and Figure

2.8. These materials are thoroughly cleaned. A clean and dry cloth is used for cleaning the surface. Thus, only clean and dry spacers and electrodes are used and they are handled with special surgical gloves to avoid direct contact with hands. These materials have good dielectric properties but their structural differences (spacer length) and dielectric constant make them give different results.

2.4 Spark over on spacer

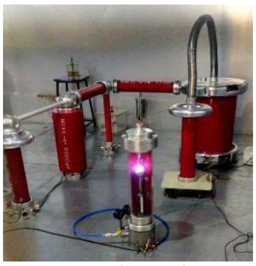

Figure 2.9 Spark over on surface of spacer between electrodes.

A spark gap shown in Figure 2.9 shows the arrangement of two conducting electrodes separated by a gap normally filled with gas e.g., air, designed voltage difference between the conductors exceeds the gap’s breakdown voltage, a spark forms drastically reducing its electrical resistance. Invariably, the breakdown observed with cylindrical spacers occurs on the surface along its length.

2.6 Precaution

1. The equipment must be grounded firmly.
2. The electrodes must be cleaned properly before fixing to the vessel.
3. Do not touch the equipment without grounding it with the discharge rod.
4. Before switch ON the supply, make sure the electrodes are properly aligned.

2.7 Standard operating procedure for measuring breakdown voltage

1. Install plane-plane/point-plane electrode at Measuring Spark Gap vessel and properly close the vessel cap. Make the electrodes properly aligned and zero

adjustment.
2. Now insert the spacer and adjust the gap between the electrodes by controlling the motor speed connected to the gear box of the movable electrode. (5mm, 10mm, 15mm, 17.5mm, 20mm)
3. Connections are made as per the circuit diagram for the required measurement of HVAC/HVDC breakdown.
4. For HVAC breakdown measurement the output terminal of the HV transformer is connected to the plane-plane/point- plane electrode through charging resistor. For HVDC breakdown measurement the output terminal of the HV transformer is connected to the plane-plane/point-plane electrode through silicon rectifier, filter and charging resistor. The other end of the supply is grounded.
5. After connections take discharge rod from the contact and keep at the corner and properly close the door.
6. Switch ON the mains switch (power supply).
7. Switch on the control switch (key) in control panel.
8. Switch ON the mains switch button at control panel (Green), observe the indication of mains ON.
9. Decrease 'voltage Regulation' to set primary to zero.
10. Press the 'Primary' ON button (GREEN) and the earthing switch stick will be down.
11. Press the 'Secondary' ON button (GREEN), the red light on the fence will glow. Slowly push the 'Voltage regulation' increase button and high voltage is applied between the electrodes until the spark over occurs.
12. Note down the readings of breakdown voltage.
13. Under HVAC breakdown, secondary will automatically turn off. Under HVDC breakdown, after breakdown occur decrease the 'Voltage regulation' and turn off both 'secondary' and then 'primary' OFF buttons (RED).
14. Switch OFF the main switch and wait for minimum 3 minutes.
15. Repeat the steps 8 to 14 to take average readings and for different values of spacer length adjustment.

3. RESULTS AND ANALYSIS

As previously mentioned, the main aim of this research is to observe the state of various solid spacer materials under the effect of breakdown voltage. In order to understand the effect of breakdown of solid spacers PVC, PP, PMMA and PTFE, experiments were carried out and data was obtained for different electrode configurations namely Plane-Plane and Point-Plane configurations with spacers length of 5mm, 10mm, 15mm, 17.5mm and 20 mm. These experiments were carried out to determine the BDV under AC, DC for comparison. The results obtained in the course of study are presented in the form of tables and graphs to highlight the various aspects of the study.

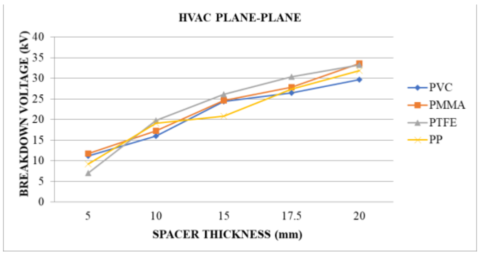

Figure 3.1 Variation of BDV of spacers with thickness using plane to plane electrode configuration under HVAC

Table 3.1 shows breakdown voltage with thickness of spacers using plane-plane electrode configuration under HVAC. Figure 3.1 shows the graph for variation of BDV with the thickness of the material for all spacers namely PVC, PMMA, PTFE and PP. The graph it shows that as the thickness of the spacer increases, the breakdown voltage increases. PP has the breakdown voltage lower than the PTFE and PMMA while PVC has the least breakdown voltage among the all.

Table 3.2 shows breakdown voltage with thickness of spacers using plane-plane electrode configuration under HVDC. Figure 3.2 shows the graph of variation for the breakdown voltage with the thickness of the material for all spacers namely PVC, PMMA, PTFE and PP. The graph shows that as the thickness of the spacer increases there is a considerable increase in its breakdown voltage. PMMA has higher breakdown voltage among the all. breakdown voltage with the thickness of the material for all spacers namely PVC, PMMA.

Table 3.3 shows breakdown voltage with thickness of spacers using point-plane electrode configuration under HVAC. Table 3.4 shows breakdown voltage with thickness of spacers using point-plane electrode configuration under HVDC. The graph shows variation for the breakdown voltage with the thickness of the material for all spacers namely PVC, PMMA, PTFE and PP. The graph shows that as the thickness of the spacer increases there is a considerable increase in its breakdown voltage. PP has the BDV lower than the PTFE and PMMA while PMMA has higher breakdown voltage among the all.

Table 3.5 shows breakdown voltage with thickness of PMMA using plane-plane electrode configuration under HVAC and HVDC. Figure 15 shows the variation graph of the breakdown voltage with thickness of PMMA under HVAC and HVDC. The graph depicts that PMMA is better insulating material at HVAC plane-plane electrode configuration.

Table 3.6 shows breakdown voltage with thickness of PMMA using point-plane electrode configuration under HVAC and HVDC. Figure 3.6 shows the comparison graph of the breakdown voltage with thickness of PMMA under HVAC and HVDC. The curve depicts that PMMA is better insulating material at HVDC point-plane electrode configuration. It is observed for all the cases that there is change in the BDV. It is observed that the spacers dielectric constant also has influence on observed result. On analyzing the graphs, as thickness of the material increases, the breakdown voltage for various spacers increases.

Table 3.1 Breakdown voltage of spacers using plane-plane electrode configuration under HVAC

Type of electrode configuration	Sl. No	Spacer Thickness (mm)	HVAC Breakdown Voltage (kV) Of Spacers			
			PVC	PMMA	PTFE	PP
PLANE-PLANE	1	5	11.19	11.76	7.012	9.23
	2	10	16	17.33	19.83	19.08
	3	15	24.35	24.64	26.16	20.81
	4	17.5	26.43	27.86	30.37	27.4
	5	20	29.73	33.58	33.28	31.91

Table 3.2 BV of spacers using plane-plane electrode configuration under HVDC

Type of electrode configuration	Sl. No	Spacer Thickness (mm)	HVAC Breakdown Voltage (kV) Of Spacers			
			PVC	PMMA	PTFE	PP
PLANE-PLANE	1	5	8.68	9.032	8.995	8.143
	2	10	12.68	17.36	13.45	16.08
	3	15	20.92	22.81	18.55	19.81
	4	17.5	23.88	23.52	22.57	20.4
	5	20	25.04	25.6	28.14	24.7

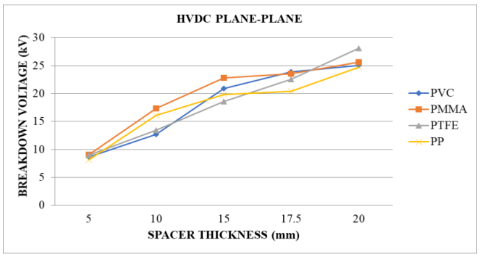

Figure 3.2 Variation of BDV of spacers with thickness using plane-plane electrode configuration under HVDC

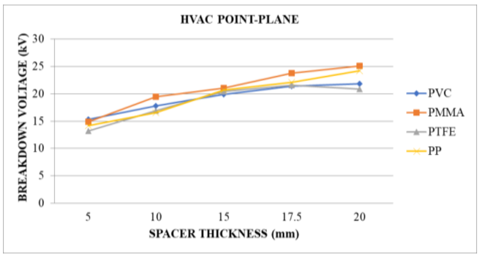

Figure 3.3 Variation of BDV of spacers with thickness using point-plane electrode configuration under HVAC

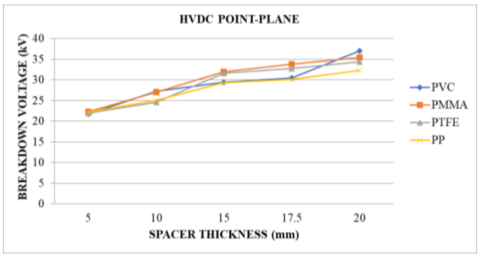

Figure 3.4 Variation of BDV of spacers with thickness using point-plane electrode configuration under HVDC

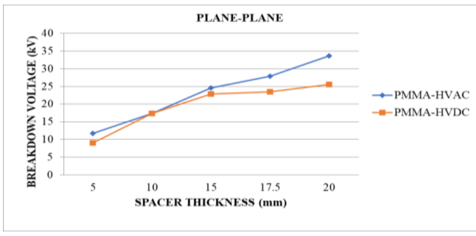

Figure 3.5 Variation of BDV with thickness of PMMA spacer under HVAC and HVDC plane-plane electrode configuration

Table 3.5 Breakdown voltage of PMMA using plane-plane electrode configuration under HVAC and HVDC

Type of electrode configuration	Spacer	Sl. No	Spacer Thickness (mm)	Breakdown Voltage (kV)	
				HVAC	HVDC
PLANE-PLANE	PMMA	1	5	11.7	9.03
		2	10	17.3	17.3
		3	15	24.6	22.8
		4	17.5	27.6	23.5
		5	20	33.5	25.6

Table 3.6 Breakdown voltage of PMMA using point-plane electrode configuration under HVAC and HVDC

Type of electrode configuration	Spacer	Sl. No	Spacer Thickness (mm)	Breakdown Voltage (kV)	
				HVAC	HVDC
POINT-PLANE	PMMA	1	5	14.88	22.29
		2	10	19.49	27.04
		3	15	21.087	31.985
		4	17.5	23.74	33.85
		5	20	25.057	35.46

4. CONCLUSIONS

Configurations have been investigated in this work. The plane-plane and point-plane electrode configuration are commonly used for this purpose. The effects of different parameters such as inter-electrode spacing, thickness of the spacer and dielectric materials on the breakdown voltage are investigated for applied 50 Hz AC and DC voltages. Hence the finding BDV of various insulating material provides major area of interest to the HV engineers and in particular to the high voltage engineers. Therefore, there is a possibility of developing solid insulating materials with excellent breakdown strength. It is observed for all the cases that there is change in the BDV. It is observed that the spacers dielectric constant also has influence on observed result. On analysing the graphs, as thickness of the material increases, the BDV for various spacers increases. It is also observed that PMMA has the higher breakdown voltage among the all spacers.

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