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Effect of Conducting Particle on Spacers in Air Insulated Systems

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ABSTRACT
Gas Insulated System (GIS) has been known to be reliable for more than 40 years. One of the reasons is because the active components are installed inside sealed-enclosures that reduce the environmental stress. Gas Insulated systems require solid insulating materials to provide mechanical support for conductors. Hence the spacers used in GIS should be precisely designed to realize more or less uniform field distribution along their surfaces. GIS occupy an important position in the power system. Insulating spacers are important parts in GIS. GIS have been used for many years as a means to provide safe and reliable high volt-age electrical systems. Normally, the problems connected with the use of these systems are few, especially when lower voltage levels are considered. However, the presence of metallic contamination can seriously reduce the insulation performance of a GIS. The aim of this work is to investigate the effect of conducting particle on spacers in air insulated system. The spacers used for study are Poly Methyl Metha Acrylate (PMMA) and nylon.

Keywords: *breakdown voltage, gas insulated system, spacers, conducting particle*

I. INTRODUCTION

The rapid urbanization and over population make expanding the transmission network very challenging due to the right of way problem and the limited amount of space available. There are also many issues with conventional air-insulated substations, including pollution by salt or dust, meteorological difficulties, and safety concerns. To overcome these problems, underground cable and gas-insulated substations (GIS) are needed to replace conventional transmission lines and substations.

The metal particle material affects the flashover voltage on spacer only under high gas pressure and high surface electric field of metal particle. The flashover voltage is almost the same when the iron or aluminum particle is attached, and is higher when the copper particle is attached [7]. GIS occupy an important position in the power system. Insulating spacers are important parts in GIS. The use of compressed gas as the insulating medium has made it possible to use compact equipment compared to that with air insulation [l-4].

The particle contamination on the spacers is one of the causes for the partial discharges which in turn cause the insulation failure. The particle contamination inside the GIS may occur because of the manufacturing process, from mechanical vibrations, moving parts of the system such as breakers. It can also be from the negligence during the maintenance inside the GIS or from corrosion or decomposition of the metallic products. A critical part in the development of GIS is support spacers. Surface flashover shows a strong sensitivity to metallic particle contamination of the spacer surface. A free conducting particle, moving near a spacer, under AC ramp voltages close to the particle crossing voltage, may initiate a breakdown [5]. Spacers are the weakest links in GIS, in addition to metallic particles. Spacers are used to support and insulate high voltage conductors in GIS. In the presence of a metallic particle, the breakdown strength of an SF6 test gap bridged by an alumina filled epoxy spacer is drastically reduced. The discharge always involves the particle [6].

The effect of conducting particle on spacers subjected to High Voltage is studied in Air Insulated system. The humidity did not influence the flashover voltage of the spacer as long there was no condensation. On the other hand, the gas pressure and the condition of the epoxy surface play significant roles in the flashover voltage [8].

In an electrical system, breakdown occurs when the insulation is lost. Insulation between electrodes can be solid, liquid, and gaseous. A breakdown strength of an insulation is determined by its ability to withstand a voltage. Various types of media, including solids, liquids, and gases, have been studied extensively in order to understand the breakdown phenomenon between electrodes. As per the International Electrotechnical commission (IEC), the standard electrode configuration used for the purpose are plane-plane, point-plane, rod-plane and sphere-plane.

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II. EXPERIMENTAL SET UP

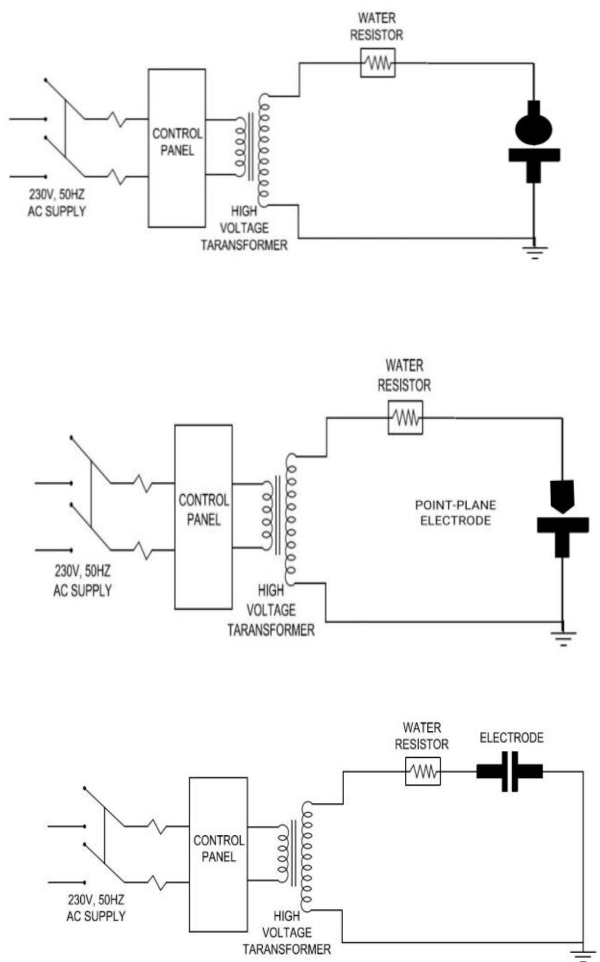

Figure 1: Measurement of breakdown voltage under HVAC

Figure 2: Laboratory setup for breakdown voltage measurement

The experiments conducted involved different electrode configurations, including plane-plane, sphere-plane, and rod-plane, with different spacing. Breakdown voltage (BDV) measurements were taken for High Voltage AC (HVAC) with and without conducting particle on the spacers. Two cylindrical spacers, Poly Methyl Metha Acrylate (PMMA) and nylon, were utilized in the experiments. Copper is used as conducting particle with dimension 10mm length and 1mm diameter.

The circuit diagram for the HVAC measurement setup is depicted in figure 1. The experimental laboratory setup is depicted in figure 2, providing an overview of the equipment used for conducting the experiments. These setups allowed for the accurate measurement of BDV under various conditions, facilitating a comprehensive understanding of the insulation performance of the tested materials and configurations. Experiments on BDV phenomenon on spacers with conducting particle were carried out in Air Insulated System subjected to HVAC. The conducting particle used was 10mm length, 1mm diameter copper wire.

III. RESULTS AND DISCUSSION

Table 1: Variation of BDV under ac with copper particle placed on spacers (Plane-Plane)

Electrode Spacing(mm)	BDV on PMMA spacer (KV)	BDV on PMMA spacer with copper particle (KV)	BDV on Nylon spacer (KV)	BDV on Nylon spacer with copper particle (KV)
5	10	6	7	4
8	14	10	14	11
10	15	10	16	10
12	18	13	20	14
15	22	18	21	17
18	24	20	23	19
20	27	21	26	21

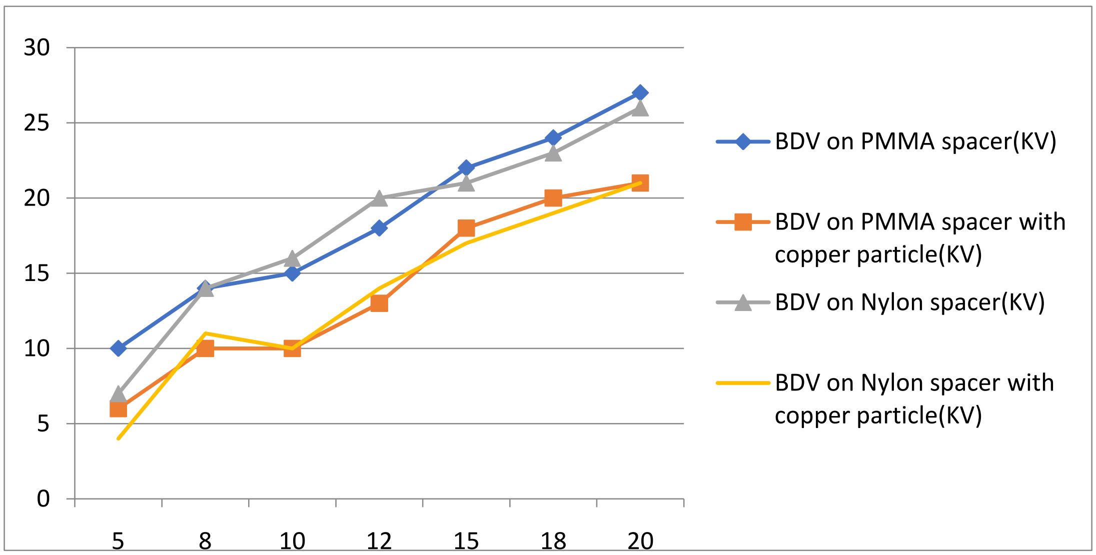

Figure 3: Variation of BDV under ac with copper particle placed on spacers (Plane-Plane)

Table 2: Variation of BDV under ac with copper particle placed on spacers (Sphere-Plane)

Electrode Spacing(mm)	BDV on PMMA spacer (KV)	BDV on PMMA spacer with copper particle (KV)	BDV on Nylon spacer (KV)	BDV on Nylon spacer with copper particle (KV)
5	11	6	11	7
8	12	8	12	8
10	14	10	15	11
12	16	12	16	12
15	18	15	17	14
18	19	17	18	16
20	20	18	20	18

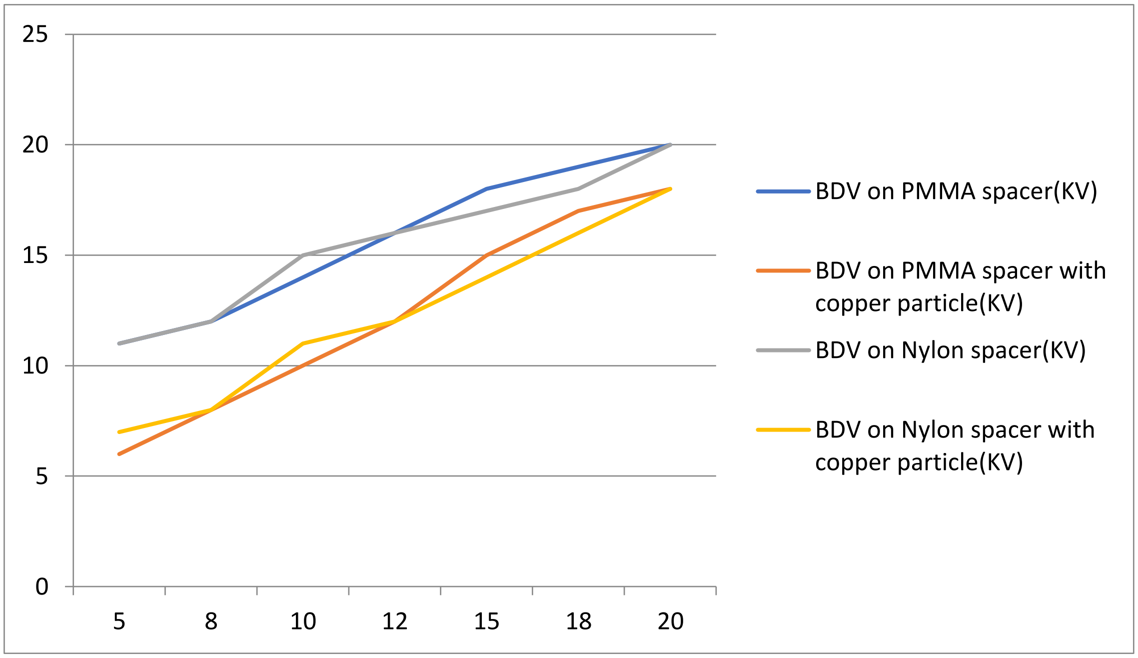

Figure 4: Variation of BDV under ac with copper particle placed on spacers (Sphere-Plane)

Table 3: Variation of BDV under ac with copper particle placed on spacers (Rod-Plane)

Electrode Spacing(mm)	BDV on PMMA spacer (KV)	BDV on PMMA spacer with copper particle (KV)	BDV on Nylon spacer (KV)	BDV on Nylon spacer with copper particle (KV)
5	17	11	21	15
8	20	14	20	16
10	18	16	21	16
12	20	17	19	16
15	21	19	22	18
18	22	20	23	18
20	22	20	22	19

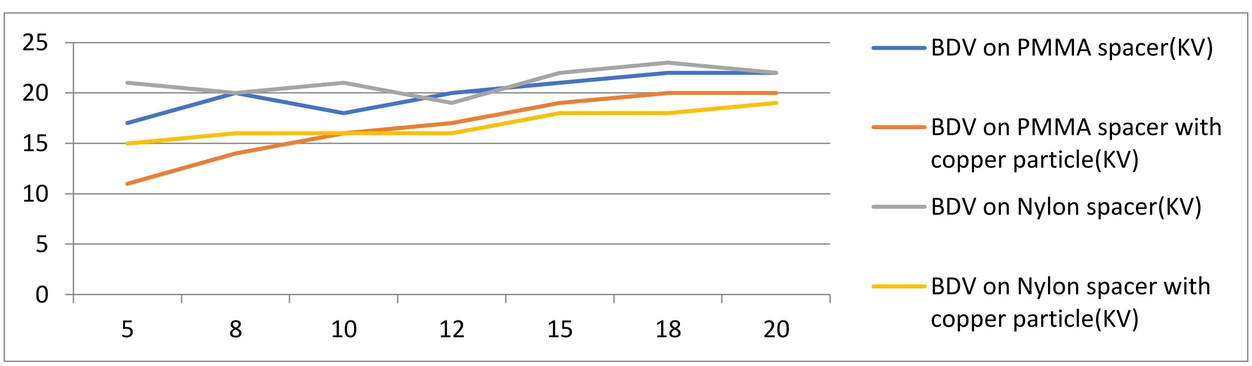

Figure 5: Variation of BDV under ac with copper particle placed on spacers (Rod-Plane)

The BDV in air with spacers is more with respect to that of particle on spacers subjected to HVAC. The BDV with conducting particles on spacers when subjected to HVAC increases gradually over the electrode spacing. The BDV characteristics of both nylon and PMMA spacers are almost same.

IV. CONCLUSION

Based on the observations from the experiments conducted with different electrode configurations (plane-plane, sphere-plane, and rod-plane) with conducting particle on spacer reveal that the breakdown voltage decreases when compared to that of without particle subjected to high voltage AC. The BDV phenomenon shows high for uniform electrode when compared to that of non-uniform electrode. The BDV of rod-plane electrode configuration is less when compared to that of sphere plane configuration. The conducting particle influences on the BDV subjected to HVAC. The experiments can be extended to study the BDV phenomenon on gaseous mixtures with conducting particle on spacers.

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