



## INVESTIGATION OF FLASHOVER VOLTAGE FOR EPOXY COMPOSITES FILLED WITH VARIOUS FILLERS

Mohamed. T. M. Mousa <sup>\*1</sup>, Loai. S. Nasrat <sup>2</sup>, Ziad. M. Ali <sup>2,3</sup>

<sup>1</sup> Main Department, Hydro Plant Power Generation Company, Ministry of Electricity, Aswan, Egypt

<sup>2</sup> Electrical Power & Machines Department, Faculty of Engineering, Aswan University, Aswan, Egypt

<sup>3</sup> Electrical Dept., College of Engineering at Wadi Addawasir, Prince Sattam Bin Abdulaziz University, KSA



### Abstract:

*Minerals fillers such as Magnesium Oxide (MgO), Alumina Trihydrate (ATH), Calcium Carbonate (CaCO<sub>3</sub>), and Silica (SiO<sub>2</sub>) were used to produce epoxy composite for high and medium voltage in electrical application. Effects of types and percentage weight of filler on flashover voltage properties of epoxy resin were determined. Cylindrical rod epoxy samples with different lengths (10, 20, and 30mm) and filler types have been prepared, these fillers with 30% percentage loading of epoxy samples by weight. Flashover voltage of composite material was measured under various environmental conditions, to check the accuracy the test was carried out for five times on each sample under the same condition. Results showed that flashover voltage of composite improved with epoxy/ATH filler at all lengths and conditions, also flashover voltage for samples in dry condition is higher than samples with other conditions at all filler and lengths.*

**Keywords:** Epoxy; Filler; Composite Materials; Flashover Voltage.

**Cite This Article:** Mohamed. T. M. Mousa, Loai. S. Nasrat, and Ziad. M. Ali. (2018). "INVESTIGATION OF FLASHOVER VOLTAGE FOR EPOXY COMPOSITES FILLED WITH VARIOUS FILLERS." *International Journal of Engineering Technologies and Management Research*, 5(9), 50-58. DOI: <https://doi.org/10.29121/ijetmr.v5.i9.2018.288>.

### 1. Introduction

Inorganic fillers in composites have become popular researches due to low cost and local availability. These fillers improve the mechanical, thermal and electrical properties of composites. Many researchers have used fillers to produce low-cost composites materials for various applications [1–3]. Magnesium Oxide (MgO), Alumina Trihydrate (ATH), Calcium Carbonate (CaCO<sub>3</sub>), and Silica (SiO<sub>2</sub>) are accepted fillers for electrical applications because of their high insulating properties. Fillers are widely used as a reinforcement material to improve the mechanical, electrical and overall properties such as stiffness, dielectric strength fire retardant and to prevent electrical discharge cause by void [4-6], these fillers were added to epoxy to increase the insulation's resistance [7-8].

The electrical and mechanical properties of composites are dependent on the filler's aspect ratio, interaction between fillers, composite matrix and also surface area. [9-11].

The epoxy resin is used as insulating material as well as structural material because it is cost effective. In recent times epoxy resin added with fillers finds major application as insulating material [12–15], The researchers are trying to understand the electrical, thermal and mechanical properties of epoxy nano composites insulating materials.

This study investigated the flashover voltage properties of epoxy resin filled with many filler types. The mentioned filler Magnesium Oxide (MgO), Alumina Trihydrate (ATH), Calcium Carbonate (CaCO<sub>3</sub>), and Silica (SiO<sub>2</sub>) were used in this study to enhance flashover voltage properties, this study aims to investigate the effects of filler loading and type on the flashover voltage properties of epoxy resin composites. Cylindrical rod specimens chemically were prepared from epoxy and many filler types have been tested to examine the flashover voltage properties of composites. In this study flashover voltage of composite specimens had been investigated in various condition dry, wet, and three concentration salinity conditions with three lengths for each condition.

## 2. Experimental Set-Up and Techniques

The samples were made from epoxy resin filled with and without fillers, the fillers used were Magnesium Oxide (MgO), Alumina Trihydrate (ATH), Calcium Carbonate (CaCO<sub>3</sub>), and Silica (SiO<sub>2</sub>). Specimens were fabricated as cylindrical rods having 1cm diameter and 10, 20, and 30mm lengths. Fillers in powder form have been added to epoxy resin with 30% load of weight, samples formed to be flat from all sides, epoxy resin structure shown in figure1, the specimens have been made chemically from epoxy.

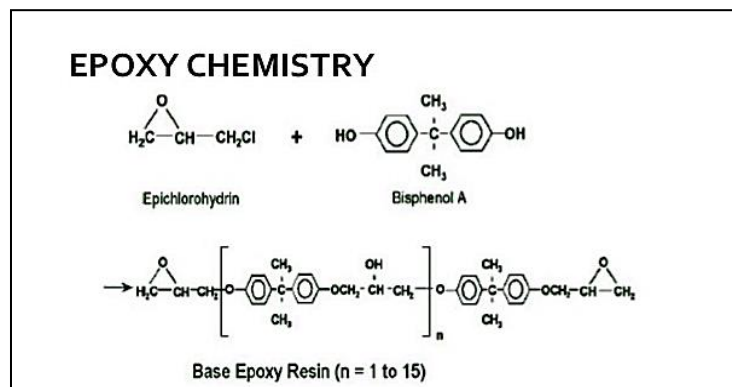


Figure 1: Epoxy resin structure

AC high voltage was obtained from a single phase auto transformer (100kV-5kVA). The test electrodes were made from copper with 10mm diameter. The specimens fixed between the electrodes in vertical form. The flashover voltage was measured for dry, wet, 30000 $\mu$ S/Cm salinity, 40000 $\mu$ S/Cm salinity, and 54000 $\mu$ S/Cm salinity conditions, and with three lengths of samples for each condition 10, 20, and 30mm. Simulation of condition was done by immersing the samples in the suitable solution (water on dray, and sodium chloride NaCl for salinity concentrations) for 24 hours at room temperature. After pollution was achieved on the samples they were tested in

high voltage laboratory as shown in figure 2. The high voltage between two electrodes increased gradually from zero by constant rate 2kV /sec until the flashover voltage (kV) occurs, each test has been done five times on each sample under the same conditions to check the accuracy of the results, the results gathered and tabulated in table form.



Figure 2: Flashover voltage test in high voltage laboratory

### 3. Results and Discussion

The flashover voltages results have been recorded and gathered in tabulated form for epoxy samples for each filler type (MgO, ATH, CaCo<sub>2</sub>, and SiO<sub>2</sub>) at all conditions (dry, wet, 30000, 40000, and 54000 $\mu$ S/Cm salinity) with three lengths 10, 20, and 30mm.

#### Dry Condition

Flashover voltage have been measured for epoxy sample without filler with three lengths on every condition dry, wet, 30000, 40000, and 54000 $\mu$ S/Cm salinity conditions.

The Effect of various filler types (no filler, MgO, ATH, CaCo<sub>2</sub>, SiO<sub>2</sub>), and given lengths (10, 20, and 30mm) on the flashover voltage performance with epoxy sample under dry condition is represented in figure. (3). This test has been done on epoxy samples with different fillers to measure the AC flashover voltage, this test repeated several times to ensure results, the odd values are taken into consideration to minimize error, the average flashover voltage is calculated and all practical results have been gathered and drawn.

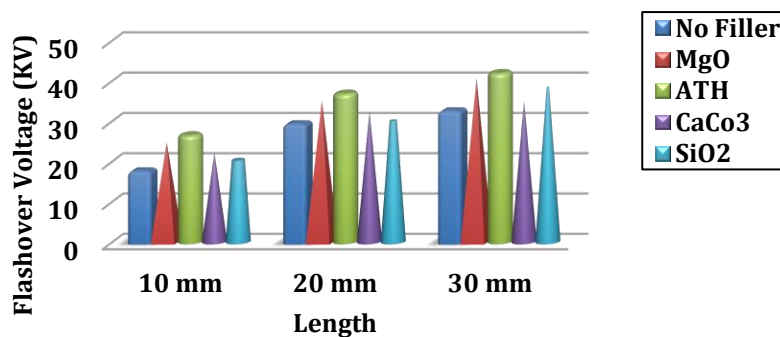


Figure 3: Flashover voltages of epoxy samples with fillers and lengths on dry condition

From above it is obvious that

- Flashover voltage for each filler type in Epoxy base increase with length, it means that while increase length sample for each filler type, flashover voltage increased to this sample.
- At 10mm length has max. flashover voltage is for ATH filler and min. value without filler.
- For 20mm length, max. flashover voltage is 37.31 KV for ATH filler while the min. is 29.91 with no filler.
- At 30mm length, optimum value for flashover voltage with ATH filler, but with no filler it have min. one.
- On dry condition, the best filler type with Epoxy base is ATH filler having max. value for flashover voltage at all lengths 10, 20, and 30 mm; but the lowest flashover voltage for Epoxy composite with no filler.

### Wet Condition

The aim for this test is to simulates the composite materials when they are subjected to rainy weather. This test has been done on epoxy samples with different fillers which has been immersed in water for 24hr, then they are wiped very well and then measure the AC flashover voltage. This test has been done to the all samples fifth times and the average has been taken, odd values were taken into consideration to minimize error, all these results have been plotted to be discussed and analyzed.

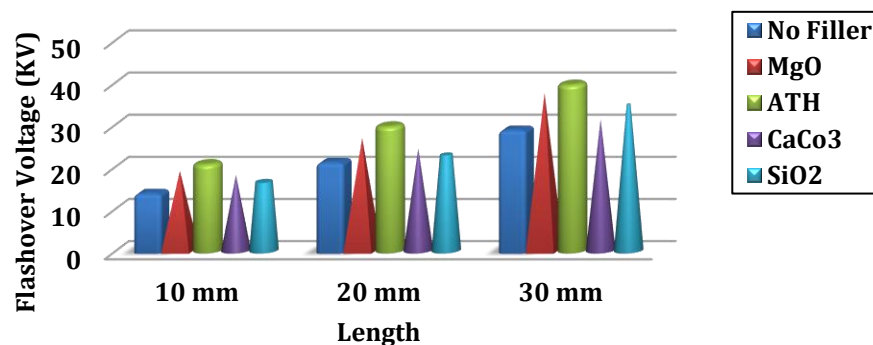


Figure 4: Flashover voltages for epoxy samples with fillers and lengths on wet condition

Figure (4) shows the below items:

- Flashover voltage for each filler type in Epoxy base increased with length.
- At 10 mm length has max. flashover voltage with ATH filler and min. value with no filler.
- For 20 mm length, max. flashover voltage is 30.11 KV for ATH filler while the min. is 21.56 with no filler.
- At 30 mm length, optimum value for flashover voltage with ATH filler, but with no filler it have min. one.
- On wet condition, the best filler type with Epoxy to be composite material is ATH filler which have max. value for flashover voltage at all lengths 10, 20, and 30 mm; but the lowest flashover voltage for Epoxy composite with no filler.

### Salinity Condition At 30000 Ms/Cm

This test simulates the composite insulators when they subjected in coastal places where the salt accumulates on the insulator surface. This test has been done on the Epoxy with different filler types samples, the samples are immersed in NaCl solution with 30000 $\mu$ S/cm concentration for 24hr and then clean very well then measure the AC flashover, this test has been done to all the samples many times and the average has been taken, odd values are taken into consideration, all results have been plotted and discussed.

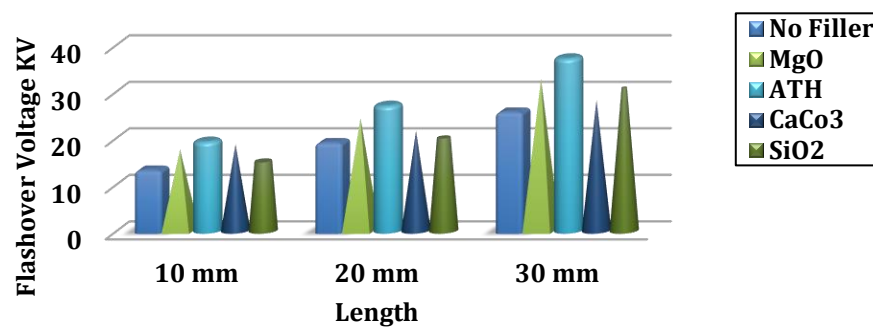


Figure 5: Flashover voltages for epoxy samples with fillers and lengths on 30000 $\mu$ S/Cm salinity condition

Figure (5) shows the following items:

- Flashover voltage for each filler type in Epoxy base increased with length.
- For 10 mm length, flashover voltage with ATH filler is max. and min. value with no filler.
- At 20 mm length, the flashover voltage is max. with 30.11 KV for ATH filler while the min. is 21.56 KV with no filler.
- The 30 mm length sample, optimum value for flashover voltage with ATH filler, but with no filler it have min. one.

On 30000 $\mu$ S/Cm salinity condition, the best filler type with Epoxy is ATH filler which have max. value of flashover voltage at all lengths 10, 20, and 30 mm wit 19.72, 27.46, and 37.63 KV respectively; but the lowest flashover voltage for Epoxy composite with no filler.

### Salinity Condition At 40000 $\mu$ S/Cm

Flashover voltage test on 40000 $\mu$ S/Cm salinity condition is simulate the composite insulators when they subjected in coastal places where the salt accumulates on the insulator surface. This test has been done on Epoxy with different filler types samples, the samples are prepared by immersing in NaCl solution with 40000 $\mu$ S/cm concentration for 24hr and then wept very well then measure the AC flashover for these samples, the reading was recorded, this test has been done to all samples many times and the average has been taken, the odd values are taken into consideration, all these results have been drawn and discussed.

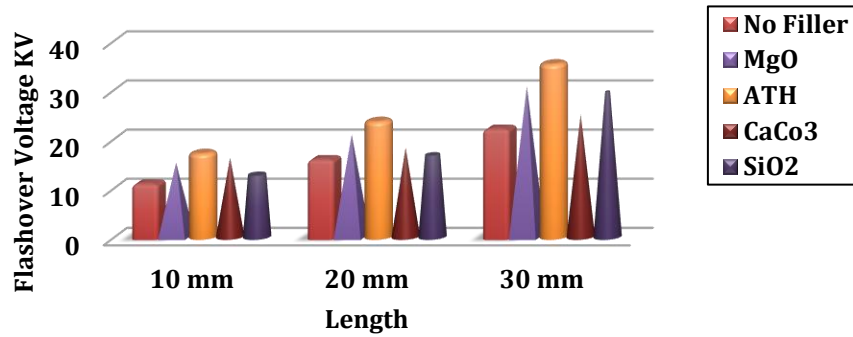


Figure 6: Flashover voltages for epoxy samples with fillers and lengths on 40000µS/Cm salinity condition

From figure (6) it is shown the following items:

- Flashover voltage for each filler type in Epoxy increase with length.
- For 10 mm length, flashover voltage with ATH filler is max. and min. value with no filler.
- At 20 mm length, the flashover voltage is max. with 24.01 KV for ATH filler while the min. is 16.33 KV with no filler.
- The 30 mm length sample, optimum value for flashover voltage with ATH filler, but with no filler it have min. one.
- On 40000µS/Cm salinity condition, the best filler type with Epoxy is ATH filler which have max. value of flashover voltage of 17.49, 24.01, and 35.71KV at 10, 20, and 30 mm lengths.

### Salinity Condition At 54000 µs/Cm

Flashover voltage test on 54000µS/Cm salinity condition is done to simulate the composite insulators when they subjected to coastal weather where salts accumulate on insulator surface. The test has been done on epoxy with filler types(no filler – MgO – ATH – CaCo<sub>3</sub> – SiO<sub>2</sub>) samples, the samples are prepared by immersing in NaCl solution with 54000µS/cm concentration for 24hr, then wept well and then measure the AC flashover for these samples. This test has been done to all samples several times and the average has been taken, the odd values are taken into consideration, all these results have been plotted to be easy discussed and analyzed.

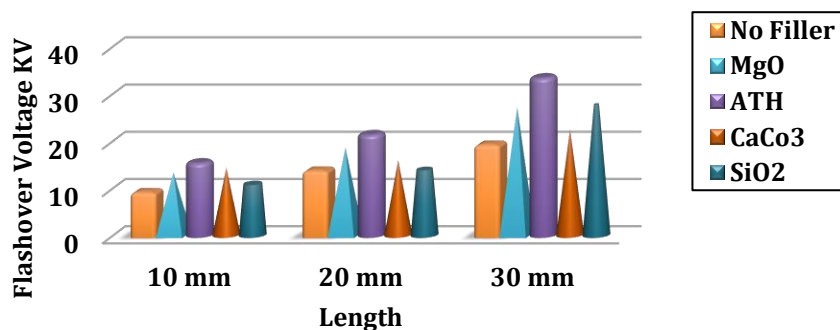


Figure 7: Flashover voltages for epoxy samples with fillers and lengths on 54000µS/Cm salinity condition



Figure (7) shows the below items

- Flashover voltage for each filler type in Epoxy increased with length sample.
- At 10mm length has max. flashover voltage with ATH filler and min. value without filler.
- For 20 mm length, max. flashover voltage is 21.81KV for ATH filler, while the min. is flashover voltage is 14.02KV with no filler.
- At 30 mm length, optimum value for flashover voltage with ATH filler, but with no filler it have min. one.
- On 54000  $\mu\text{S}/\text{Cm}$  salinity condition, the best filler type with Epoxy to be composite material is ATH filler which have max. value for flashover voltage at all lengths 10, 20, and 30 mm; but the lowest flashover voltage for Epoxy composite with no filler.

#### 4. Conclusion

This study has investigated the environmental effect on flashover voltage of epoxy composite. From the obtained results it can be noticed that: -

- 1) The values of flashover voltage for epoxy/ATH filler composite were reached a highest value (KV) than that of epoxy without ATH filler at all environmental conditions.
- 2) ATH filler give a highest value of flashover voltage with 42.41 KV on 30mm length under dry condition, while the lowest value was 9.67 KV for 10mm length on 54000 $\mu\text{S}/\text{Cm}$  salinity concentration condition.
- 3) Flashover voltage test showed that, the environmental condition leads to more changing of flashover voltage values, where dry condition has the highest value but 54000 $\mu\text{S}/\text{Cm}$  salinity has the min. one for the same length and filler type.
- 4) The best filler type which can be added to epoxy composite to give max. flashover voltage is ATH filler for all lengths and conditions, this is because it fills the pores, which make the surface more smooth and make surface leakage current is decreased.
- 5) Pure epoxy composite has a lower flashover voltage value than of composites containing other filler types at all lengths in the same condition.

#### Acknowledgement

The authors would like to thank the staff of High Voltage Laboratory at Electrical Engineering Dept. Aswan University, and National Research Center in Cairo where most of the samples preparation and experimental work were carried out. I gratefully acknowledge and thank my supervisors for helpful technical guidance, advice and encouragement throughout this work and making this research possible.

#### Author's Profile



**Eng. Mohamed Taha. M.** received the B.Sc. Electrical Engineering from Aswan university faculty of engineering, Aswan, Egypt in 2005 from., Aswan University, Egypt. He is working in Hydro Plant Power Generation Company (HPGC) in Aswan, Egypt as a Maintenance Engineer from 2009 till now. His research interests lie in the areas of analysis and developing electrical engineering models and applications, investigating composite materials usage in industrial application. mtahamm@gmail.com



**Dr. Loai. S. Nasrat** is a professor at Aswan University, Faculty of Eng., Elect. P&M Department. He has been actively involved in both basic and applied research in the area of HV engineering. His research interests include HV insulators, Nano polymeric materials, HV cables insulations, Aged oil transformer and environmental studies. Author and co-author of more than 60 papers on HV polymeric insulating materials, Nano insulating materials published in technical journals and proceedings of national and international conferences. Dr. Loai is a member in the Egyptian Sub-Committee of CIGRE and IEC.loaisaad@yahoo.com



**Dr. Ziad M. Ali** received the B.sc in electrical engineering from Assiut university, faculty of engineering, Assuit, Egypt, in 1998. He worked as a demonstrator in Aswan faculty of engineering, south valley university, Aswan, Egypt. Obtained M.sc degree from Assiut university, faculty of engineering in electrical engineering in 2003. worked as asstt. Lecturer in Aswan faculty of engineering obtained the PhD in 2010 from Kazan State Technical University, Kazan, Tatarstan, Russia. He worked assistant prof. since 2011 till 2016 in Aswan faculty of Engineering, currently worked as associated prof. in electrical dept. college of engineering at Wadi Addawasir, Prince Sattam bin Abdulaziz University, Saudi Arabia.

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\*Corresponding author.

*E-mail address:* mtahamm@ gmail.com