

## REVIEW ARTICLE

### USING SIMULATION PROGRAMS TO ESTIMATE PERFORMANCE OF NON CERAMIC INSULATORS AT SEVERE COASTAL SITES

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#### ABSTRACT

This paper presents an experimental measurement of ac 50 Hz flashover voltage (kV) of hydrophobic non-ceramic insulators to enhance electrical properties of polypropylene (PP) with respect to mechanical characteristics by adding inorganic fillers. Blends of polypropylene with various inorganic fillers such as: Alumina Trihydrate (ATH) and Silica (SiO<sub>2</sub>) are prepared with varying concentration rates and this is an attractive way to examine a new material combining the best properties of these two fillers. Each test was repeated five times on each sample under the same conditions to check the accuracy of the results. The impact of adding fillers to the polypropylene insulators on the flashover voltage is compared with the base case (no filler). Besides, the flashover voltage of each specimen under investigation is examined under various weather conditions such as dry, wet, salt wet (salinity 30000, 50000 and 60000 μS/cm) and 30wt. % nitric acid (HNO<sub>3</sub>). The tensile strength as a mechanical property has been determined throughout this work. The performance of (PP) samples shows a marked dependence on the concentration of filler. A MATLAB code has been created to give interpolated values between different percentages of inorganic filler.

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#### INTRODUCTION

Outdoor insulating bodies have traditionally been made out of glass or porcelain materials. The development and use of polymeric insulators started during the 1960s. Polymeric insulators are increasingly being used in both the distribution and transmission voltage ranges and are steadily capturing a wider share of the market (Gençoğlu, 2007). HV composite polymeric insulators are being accepted increasingly for use in outdoor installations by the traditionally cautious electric power utilities worldwide. The tremendous growth in the applications of non-ceramic composite insulators is due to their advantages over the traditional ceramic and glass insulators. These include light weight, higher mechanical strength to weight ratio, resistance to vandalism, better performance in the presence of heavy pollution in wet conditions, and comparable or better withstand voltage than porcelain or glass insulators. However, because polymeric insulators are relatively new, the expected lifetime and their long-term reliability are not known and therefore are of concern to users (Hackam, 1998). Environmental stresses such as heat, sunlight, moisture and contamination cause polymeric insulating materials to deteriorate both mechanically and electrically (Starr, 1991).

When these polymeric insulators are installed in coastal areas the salt and airborne particles are deposited on their surfaces and the pollution builds up gradually. Under dry conditions these deposits do not decrease the surface insulation strength, whereas in wet weather condition a conductive layer is formed which results in flow of leakage current which lead to occurring flashover voltage (Narayanan et al., 2014). Under polluted and wet condition, high leakage current may flow on the insulator surface. As the result a dry band arcing may take place and in the time it may degrade the insulator and initiate the insulator flash over leading to the failure of the lines. Several efforts may be taken to improve the insulator performance under polluted condition. They are increasing the number of insulator strings, modification of insulator design to increase the creep age distance and regular washing (Suwarno et al., 2012). By the action of the wind arrives at the insulators, being able to be placed in their surface. With the passage of time this layer will be thick enough to be dampened and to become conductor (Dhagat and Pachori, 2015). Fillers are used to fill the backbone polymer, which can increase the physical properties or provide certain processing characteristics. Extending filler is non-forcing material. It may be used to provide some desirable property. Alumina Trihydrate (ATH) is used in nearly all insulator compounds to impart a high resistance to electric tracking and inflammability. On the other hand, Silica, which is classified as semi-reinforcing filler,

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improves the physical properties (Ferreira *et al.*, 2011). In this work, cylindrical rod samples have been prepared from Polypropylene (PP) thermoplastic resin and with different concentrations of Alumina Trihydrate (ATH) and Silica( $\text{SiO}_2$ ) had been tested to examine the flashover voltage performance of composites. The ac (50Hz) flashover voltage of composite specimens had been investigated for different sets of samples at different conditions in this study. The dimension of sample has a 1cm diameter and 2cm length. The effect of adding inorganic fillers (ATH) and ( $\text{SiO}_2$ ) with various concentrations on the electric performance of PP samples have been studied throughout this work. MATLAB program (Curve fitting) was used to interpret the equation between different conditions.

## EXPERIMENTAL DETAILS

### A. Material Specimen

Specimens have been prepared from unsaturated Polypropylene polymer, having the transparent white color. Specimens were fabricated as cylindrical rods having 1cm diameter and 2cm length. Then the type of filler with the required quantity has been added to the above sample. Two types of filler have been used such as; Alumina Trihydrate (ATH) and Silica ( $\text{SiO}_2$ ). The different types of fillers have been used as a powder with different concentrations; the composition of the specimens is given in Table 1

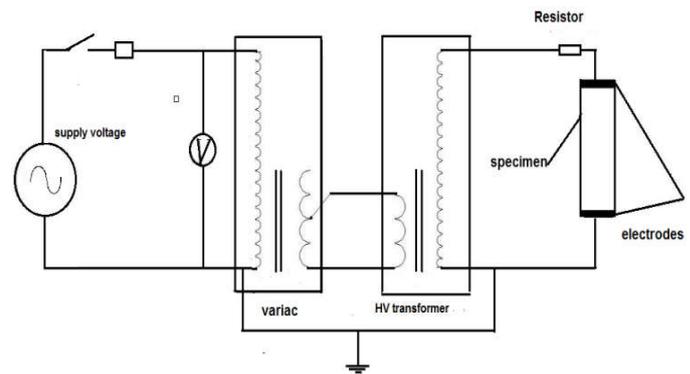
**Table 1. Composition of specimens with different concentrations of Alumina Trihydrate (ATH) and Silica( $\text{SiO}_2$ )**

Polypropylene by weight (%)	Concentration of by weight (%)
90%	10% (ATH)
80%	20% (ATH)
70%	30% (ATH)
80%	20% ( $\text{SiO}_2$ )
70%	30% ( $\text{SiO}_2$ )
60%	40% ( $\text{SiO}_2$ )

### B. Test Apparatus

The ac(50Hz) high voltage was obtained from a single phase high voltage auto transformer (100kV-5kVA). The output voltage of the transformer is controlled smoothly by a (0-220 V) variac regulating panel, the voltage applied to its primary winding. The high voltage set-up has been enclosed in an earthen cage. The power supply was connected in series with two electrodes. The electrodes were made of copper with 1cm diameter. The electrodes were fixed to the specimens, one at the top and the other at the bottom carefully to ensure a good contact. The experiments were carried out in a high voltage laboratory. The test characteristics of flashover are according to ASTM D-2303-64T. A schematic diagram of the experimental setup used in the work shown in the Fig. 1. The flashover voltage was measured under dry, wet, salt wet (salinity 30000, 50000, 60000  $\mu\text{S}/\text{cm}$ ) and 30wt. %nitric acid( $\text{HNO}_3$ ) conditions of composites with different concentration of ATH (10,20 and 30wt. %) and Silica(20,30 and 40wt. %). The contamination slurry was prepared by mixing an appropriate amount of sodium chloride in water. By immersing the sample in the slurry until contamination was applied on the sample. After pollution is achieved on the sample they were tested. 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 relation (equation) between different conditions was interpreted by the MATLAB.



**Fig. 1. Schematic diagram of flashover voltage test arrangement.**

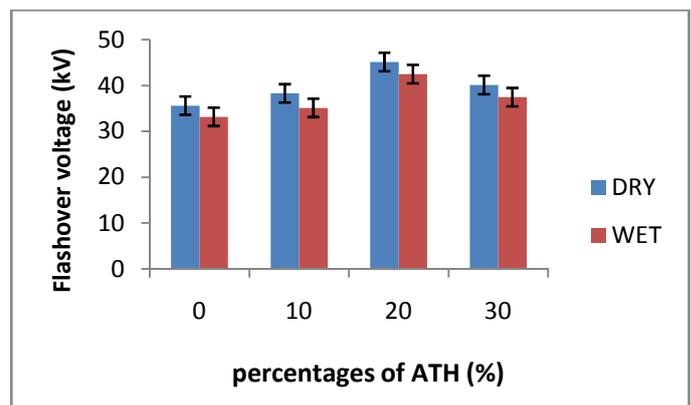
### C. Mechanical Test

Mechanical tests such as tensile strengths has been done to evaluate the mechanical performance of composite insulators according to ASTM D638 for tensile strengths, three identical specimens have been tested.

## RESULTS AND DISCUSSION

### A. Experimental Results of Flashover Voltage of PP with ATH Filler

**1-Flashover Voltage of Specimens under Dry and Wet:** The flashover voltage for PP with ATH filler samples was studied in different conditions (dry and wet) in different percentages of ATH (0%, 10%, 20% and 30wt. %). Figure 2 shows the comparison between flashover voltage and percentage of filler (ATH) for PP samples under (dry and wet) conditions.



**Fig. 1. Flashover voltage via the percentage of ATH in composite samples in dry and wet conditions**

In wet conditions for (zero filler), the flashover voltage of the samples decreased from 35.61 kV in dry case to 33.16 kV in wet condition. The percentage of flashover voltage losses is 6.9%. In wet for (10% ATH), the flashover voltage of the samples decreased from 38.27kV in dry case to 35.12kV in wet condition. The percentage of flashover voltage dielectric strength losses is 10.9%. In wet for (20% ATH), the flashover voltage of the samples decreased from 45.11kV in dry case to 42.47kV in wet conditions. The percentage of flashover voltage losses is 17.7%. In wet for (30% ATH), the flashover voltage of the samples decreased from 40.11kV in dry case to 37.11kV in wet condition. The percentage of flashover voltage

losses is 25.1%. It can be observed that, Flashover voltage of all specimens with different concentration of ATH increases by the increase of ATH percentage until 20wt. %. In wet condition, the values of flashover voltage decrease compared to dry condition. This is because of the water caused leakage current.

**2-Flashover Voltage of Specimens under Salt Wet:** Effect of ATH filler with different concentrations (10, 20, and 30wt. %) on the flashover voltage of composite insulators under salt wet (salinity 30000, 50000 and 60000  $\mu\text{S}/\text{cm}$ ) conditions. Figure 2 shows the comparison between flashover voltage and percentage of filler (ATH) for PP samples under conditions

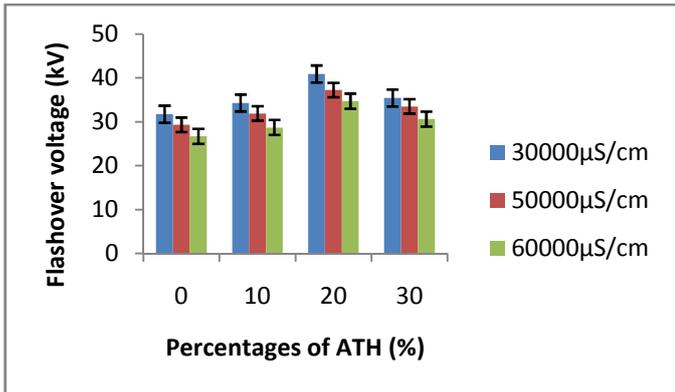


Fig 3. Flashover voltage of samples with ATH under salt wet (salinity 30000, 50000 and 60000  $\mu\text{S}/\text{cm}$ )

In salt wet (salinity 50000  $\mu\text{S}/\text{cm}$ ) conditions for ATH concentrations (0, 10, 20, and 30wt. %), the flashover voltage of the samples decreased from (31.73, 34.28, 40.89, and 35.41) kV in salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ) case to (29.31, 31.9, 37.23, and 33.5) kV in salt wet (salinity 50000  $\mu\text{S}/\text{cm}$ ) condition. The percentage of flashover voltage value for polypropylene sample in salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ) compared with polypropylene sample in salt wet (salinity 50000  $\mu\text{S}/\text{cm}$ ) of ATH filler is (7.6, 6.9, 8.9 and 5.4)%, respectively. In salt wet (salinity 50000  $\mu\text{S}/\text{cm}$ ) condition for ATH concentrations (0, 10, 20, and, 30wt. %), the flashover voltage of the samples decreased from (31.73, 34.28, 40.89, and 35.41) kV in salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ) case to (26.68, 28.7, 34.71, and 30.63) kV in salt wet (salinity 60000  $\mu\text{S}/\text{cm}$ ) condition. The percentage of flashover voltage value for polypropylene sample in salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ) compared with polypropylene sample in salt wet (salinity 60000  $\mu\text{S}/\text{cm}$ ) of ATH filler is (15.9, 16.3, 15.1 and 13.5)%, respectively. In salt wet (salinity 50000  $\mu\text{S}/\text{cm}$  and salinity 60000  $\mu\text{S}/\text{cm}$ ) conditions concentration of wt. % (NaCl) is higher than wt. % (NaCl) in salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ) so, contamination leads to consisting higher surface leakage current between two electrodes which leads to occurring flashover at lower values than salt wet (salinity 30000  $\mu\text{S}/\text{cm}$ ).

**3-Flashover Voltage of Specimens under Salinity 60000  $\mu\text{S}/\text{cm}$  and 30wt. % Nitric Acid:** Effect of ATH filler with different concentrations (10, 20, and 30wt. %) on the flashover voltage of composite specimens under salinity 60000  $\mu\text{S}/\text{cm}$  and 30wt. % nitric acid condition is shown in Figure 4. From this figure it can be seen that: The composite of polypropylene with ATH percentage of (0, 10, 20 and 30 wt. %) has a flashover voltage of (26.68, 28.7, 34.71 and 30.63) kV at sample salinity 60000  $\mu\text{S}/\text{cm}$ , the flashover voltage decreases to (24.78, 26.28, 32.98 and 27.41) kV at samples 30wt. % nitric acid condition, respectively.

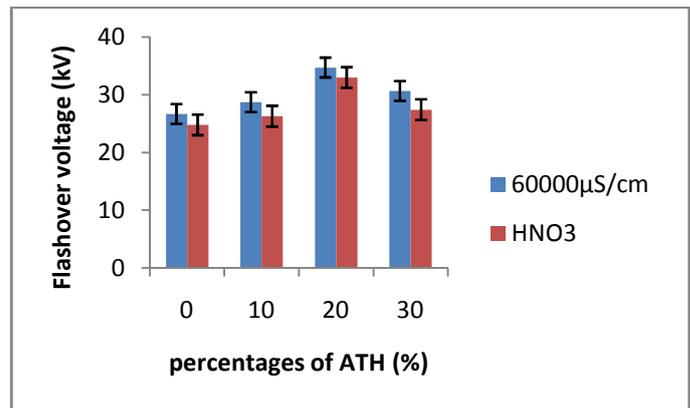


Fig 4. Flashover voltage of samples with ATH under salinity 60000  $\mu\text{S}/\text{cm}$  and 30wt. % nitric acid

The reduction percentage in the flashover voltage value for polypropylene sample in salinity 60000  $\mu\text{S}/\text{cm}$  compared with polypropylene sample in 30wt. % nitric acid condition is (7.12%, 8.4%, 4.98%, and 10.5%) for ATH concentration (0, 10, 20, and, 30wt. %), respectively. In 30wt. % nitric acid condition, surface leakage current consists between two electrodes. This leakage current results from nitric acid as this acid is very strong, this leakage current leads to faster flashover at small values if it is compared to condition under salinity 60000  $\mu\text{S}/\text{cm}$ .

## B. Experimental Results of Flashover Voltage of PP with SiO<sub>2</sub> Filler.

**1- Flashover Voltage of Specimens under Dry and Wet:** The flashover voltage for PP with SiO<sub>2</sub> filler samples was studied in different conditions (dry, wet) in different percentages of SiO<sub>2</sub> (0%, 10%, 20% and 30wt. %). Figure 5 shows the comparison between flashover voltage and percentage of filler (SiO<sub>2</sub>) for PP samples under (dry, wet) conditions.

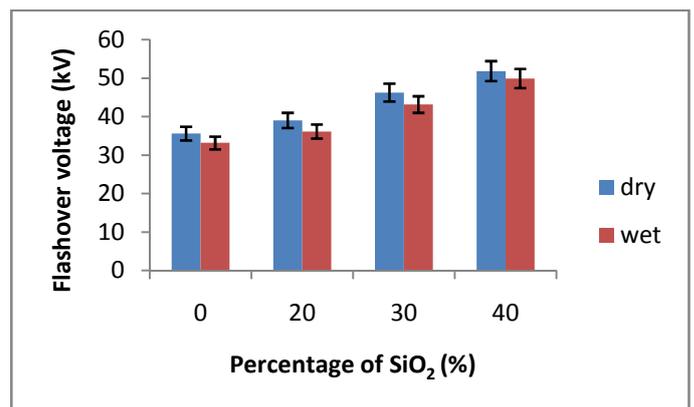


Fig 5. Flashover voltage of samples with SiO<sub>2</sub> under dry and wet condition

In wet conditions for (zero filler), the flashover voltage of the samples decreased from 35.61 kV in dry case to 33.16 kV in wet condition. The percentage of flashover voltage losses is 6.9%. In wet for (20% SiO<sub>2</sub>), the flashover voltage of the samples decreased from 39.1 kV in dry case to 36.14 kV in wet condition. The percentage of flashover voltage dielectric strength losses is 7.6%. In wet for (30% SiO<sub>2</sub>), the flashover voltage of the samples decreased from 46.26 kV in dry case to 43.13 kV in wet conditions. The percentage of flashover voltage losses is 6.8%. In wet for (40% SiO<sub>2</sub>), the flashover

voltage of the samples decreased from 51.78kV in dry case to 49.9kV in wet condition. The percentage of flashover voltage losses is 3.6%. It can be observed that, Flashover voltage of all specimens with different concentrations of SiO<sub>2</sub> increases by the increase of SiO<sub>2</sub> percentage until 30wt. %. In wet condition, the values of flashover voltage decrease compared to dry condition. This is because of the water caused leakage current.

**2- Flashover Voltage of Specimens under Salt Wet:** Effect of SiO<sub>2</sub> filler with different concentrations (20, 30, and 40wt. %) on the flashover voltage of composite insulators under salt wet (salinity 30000, 50000, 60000 μS/cm) conditions is shown in Fig.6.

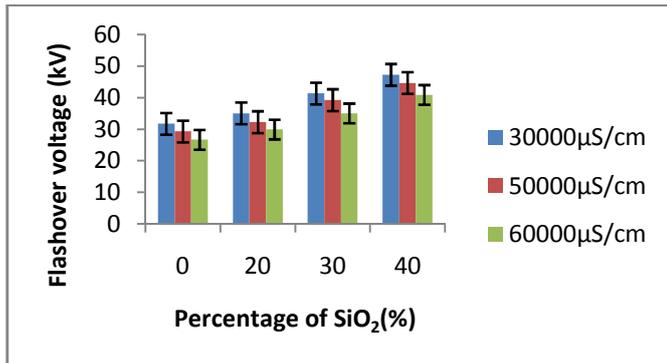


Fig 6. Flashover voltage of samples with SiO<sub>2</sub> under salt wet (salinity 30000, 50000, 60000 μS/cm) conditions.

In salt wet (salinity 50000 μS/cm) conditions for SiO<sub>2</sub> concentrations (0, 20, 30, and 40wt. %), the flashover voltage of the samples decreased from (31.73, 35.05, 41.34, and 47.24) kV in salt wet (salinity 30000 μS/cm) case to (29.31, 32.26, 39.22, and 44.66) kV in salt wet (salinity 50000 μS/cm) condition. The percentage of flashover voltage value for polypropylene sample in salt wet (salinity 30000 μS/cm) compared with polypropylene sample in salt wet (salinity 50000 μS/cm) of SiO<sub>2</sub> filler is (7.6, 7.96, 5.1, and 5.5)%, respectively. In salt wet (salinity 60000 μS/cm) conditions for SiO<sub>2</sub> concentration (0, 10, 20, and 30wt. %), the flashover voltage of the samples decreased from (31.73, 35.05, 41.34, and 47.24) kV in salt wet (salinity 30000 μS/cm) case to (26.68, 29.95, 35.03, and 40.91) kV in salt wet (salinity 60000 μS/cm) condition. The percentage of flashover voltage value for polypropylene sample in salt wet (salinity 30000 μS/cm) compared with polypropylene sample in salt wet (salinity 60000 μS/cm) of SiO<sub>2</sub> filler is (15.9, 14.55, 15.3, and 13.4)%, respectively. In salt wet (salinity 50000 μS/cm and salinity 60000 μS/cm) conditions concentration of wt. % (NaCl) is higher than wt. % (NaCl) in salt wet (salinity 30000 μS/cm) so, contamination leads to consisting higher surface leakage current between two electrodes which leads to occurring flashover at lower values than salt wet (salinity 30000 μS/cm).

**3- Flashover Voltage of Specimens under Salinity 60000 μS/cm and 30wt. % Nitric Acid:** Effect of SiO<sub>2</sub> filler with different concentrations (10, 20, and 30wt. %) on the flashover voltage of composite specimens under salinity 60000 μS/cm and 30wt. % nitric acid condition is shown in Fig 7. From this figure it can be seen that: The composite of polypropylene with SiO<sub>2</sub> percentage of (0, 20, 30 and 40 wt. %) has a flashover voltage of (26.68, 29.95, 35.03, and 40.91) kV at sample salinity 60000 μS/cm, the flashover voltage decreases to (24.78, 27.89, 33.68, and 38.19)kV at samples 30wt. % nitric acid condition, respectively.

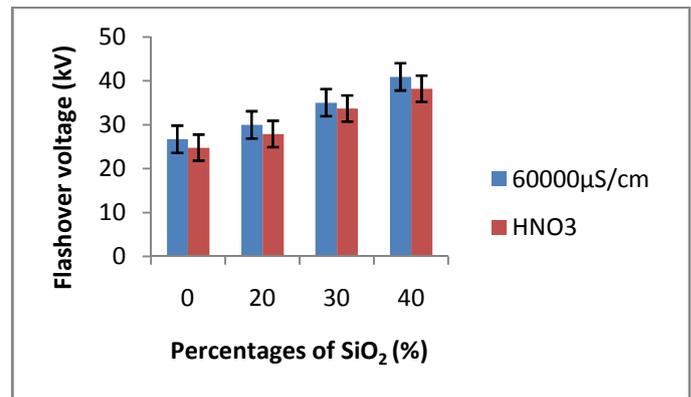


Fig 7. Flashover voltage of samples with SiO<sub>2</sub> under salinity 60000 μS/cm and 30wt. % nitric acid

The reduction percentage in the flashover voltage value for polypropylene sample in salinity 60000 μS/cm compared with polypropylene sample in 30wt. % nitric acid condition is (7.12, 6.9, 3.9 and 6.6)% for SiO<sub>2</sub> concentration (0, 20, 30, and 40wt. %), respectively. In 30wt. % nitric acid condition, surface leakage current consists between two electrodes. This leakage current results from nitric acid as this acid is very strong, this leakage current leads to faster flashover at small values if it is compared to condition under salinity 60000 μS/cm.

### C. Soft Program (MATLAB) Results in Flashover Voltage Test

Curve fitting methods allow you to create, access, and modify curve fitting objects. That allowed to like plot and integrate, to perform operations that uniformly process the entirety of information encapsulated in a curve fitting object. Figure 8 shows curve fitting for the flashover voltage results for the samples of ATH filler under dry condition. Where y is the flashover voltage (kV) under dry, x is the percentage of ATH in sample.

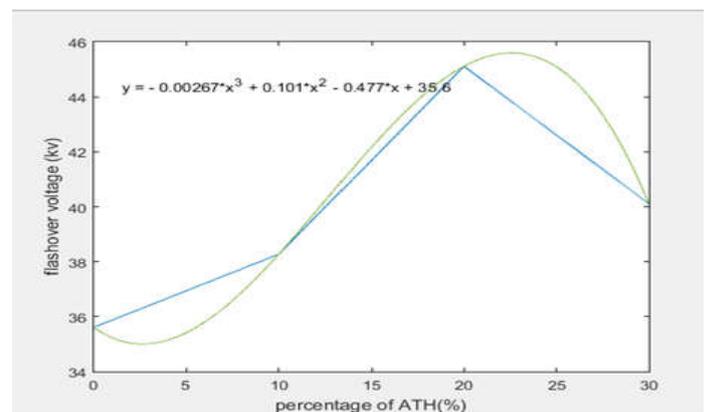


Fig 8. Curve fitting results for the Flashover voltage of samples with ATH under dry condition

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1 * X^3 + P2 * X^2 + P3 * X + P4$$

Coefficients

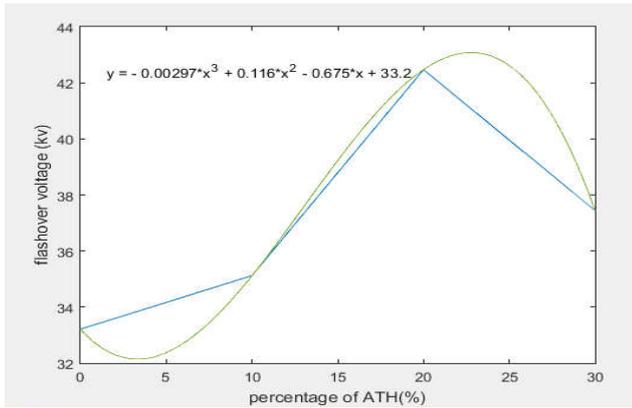
$$P1 = -0.00267$$

$$P2 = 0.101$$

$$P3 = -0.477$$

$$P4 = 35.6$$

Figure 9 shows curve fitting for the flashover voltage results for the samples of ATH filler under wet condition .Where y is the flashover voltage (kV) under wet, x is the percentage of ATH in sample.



**Fig 9. Curve fitting results for the Flashover voltage of samples with ATH under wet condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

Coefficients

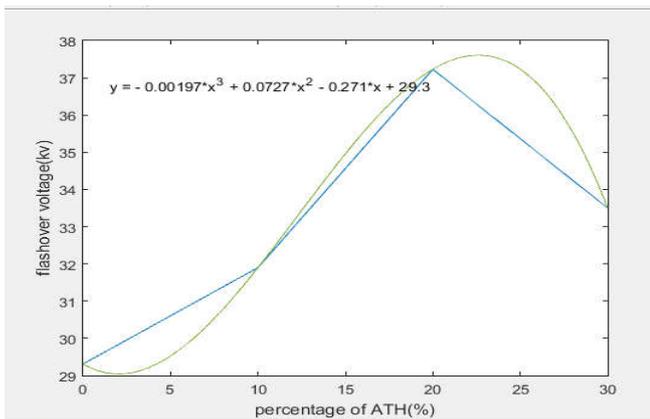
$$P1 = -0.00297$$

$$P2 = 0.116$$

$$P3 = -0.675$$

$$P4 = 33.2$$

Figure 10 shows curve fitting for the flashover voltage results for the samples of ATH filler under salinity 50000 μS/cm condition .Where y is the flashover voltage (kV) under 50000 μS/cm, x is the percentage of ATH in sample.



**Fig 10. Curve fitting results for the Flashover voltage of samples with ATH under salinity 50000 μS/cm condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

Coefficients

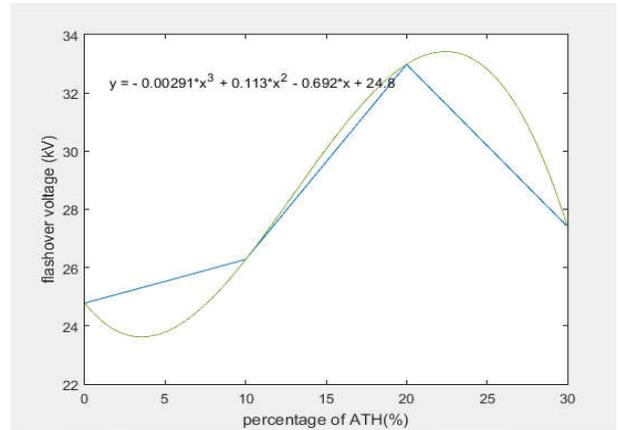
$$P1 = -0.00197$$

$$P2 = 0.0727$$

$$P3 = -0.271$$

$$P4 = 29.3$$

Figure 11 shows curve fitting for the flashover voltage results for the samples of ATH filler under 30wt. % nitric acid (HNO<sub>3</sub>) condition .Where y is the flashover voltage (kV) under 30wt. % nitric acid (HNO<sub>3</sub>),x is the percentage of ATH in sample.



**Fig 11. Curve fitting results for the Flashover voltage of samples with ATH under 30wt. % nitric acid (HNO<sub>3</sub>) condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

Coefficients

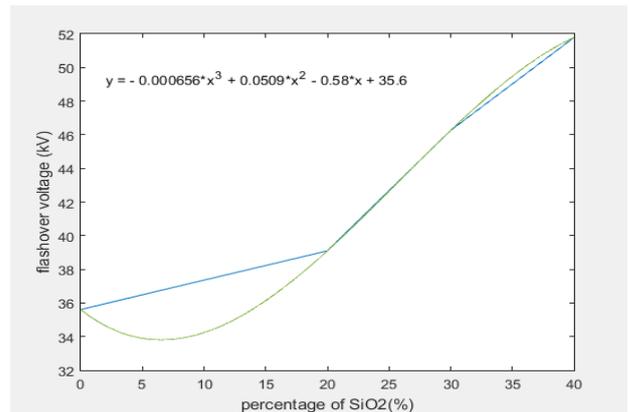
$$P1 = -0.00291$$

$$P2 = 0.113$$

$$P3 = -0.692$$

$$P4 = 24.8$$

Figure 12 shows curve fitting for the flashover voltage results for the samples of SiO<sub>2</sub> filler under dry condition .Where y is the flashover voltage (kV) under dry, x is the percentage of SiO<sub>2</sub> in sample.



**Fig 12. Curve fitting results for the Flashover voltage of samples with SiO<sub>2</sub> under dry condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

Coefficients

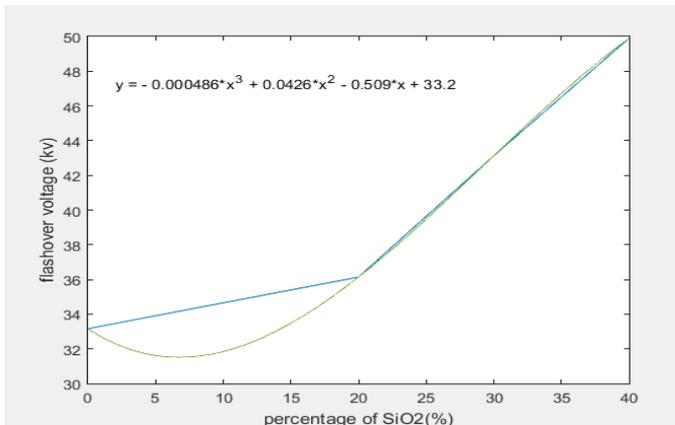
$$P1 = -0.000656$$

$$P2 = 0.0509$$

$$P3 = 0.58$$

$$P4 = 35.6$$

Figure 13 shows curve fitting for the flashover voltage results for the samples of SiO<sub>2</sub> filler under wet condition .Where y is the flashover voltage (kV) under wet, x is the percentage of SiO<sub>2</sub> in sample.



**Fig 13. Curve fitting results for the Flashover voltage of samples with SiO<sub>2</sub> under wet condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1*X^3 + P2*X^2 + P3*X + P4$$

Coefficients

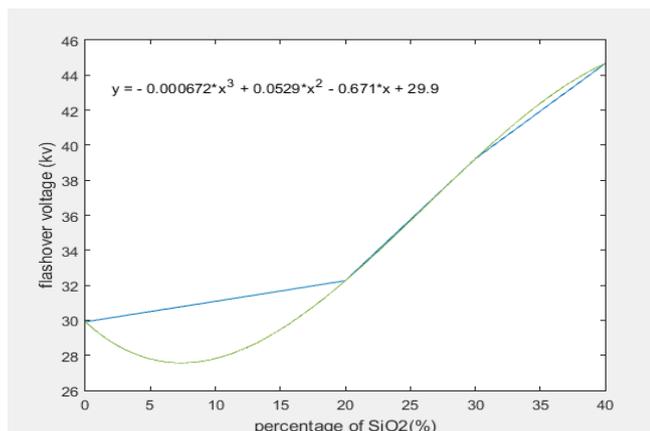
$$P1 = -0.000486$$

$$P2 = 0.0426$$

$$P3 = -0.508$$

$$P4 = 33.2$$

Figure 14 shows curve fitting for the flashover voltage results for the samples of SiO<sub>2</sub> filler under 50000 μS/cm condition. Where y is the flashover voltage (kV) under 50000 μS/cm, x is the percentage of SiO<sub>2</sub> in sample.



**Fig 14. Curve fitting results for the Flashover voltage of samples with SiO<sub>2</sub> under salinity 50000 μS/cm condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree polynomial equation as follow:

$$Y = P1*X^3 + P2*X^2 + P3*X + P4$$

Coefficients

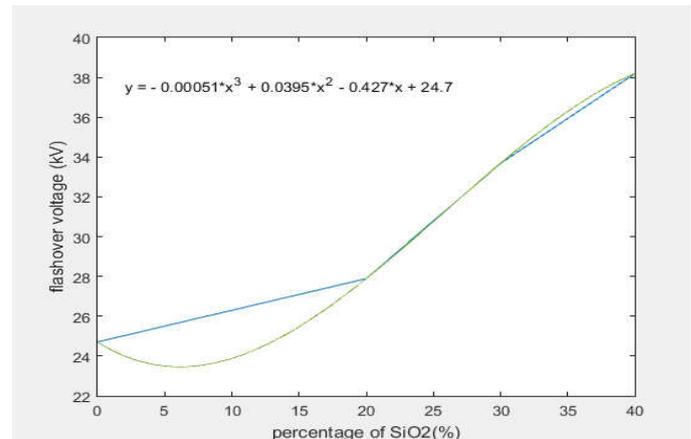
$$P1 = -0.000672$$

$$P2 = 0.0529$$

$$P3 = -0.671$$

$$P4 = 29.9$$

Figure 15 shows curve fitting for the flashover voltage results for the samples of SiO<sub>2</sub> filler under 30wt. % nitric acid (HNO<sub>3</sub>) condition .Where y is the flashover voltage (kV) under 30wt. % nitric acid (HNO<sub>3</sub>), x is the percentage of SiO<sub>2</sub> in sample.



**Fig 15. Curve fitting results for the Flashover voltage of samples with SiO<sub>2</sub> under 30wt. % nitric acid (HNO<sub>3</sub>) condition**

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup> degree equation as follow:

$$Y = P1*X^3 + P2*X^2 + P3*X + P4$$

Coefficients

$$P1 = -0.00051$$

$$P2 = 0.0395$$

$$P3 = -0.427$$

$$P4 = 24.7$$

## MECHANICAL RESULTS

### A. Tensile Strength Test Results for ATH and SiO<sub>2</sub> Filler

Tensile strength tests (TS) are carried out in order to illustrate the ability of samples to withstand the mechanical forces.

From Figures 16 and 17 it can be seen that:

The tensile strength (Kg/cm<sup>2</sup>) values of blank samples are lower than filled samples with different concentrations of ATH filler (10, 20, and 30) wt. %. The unfilled PP composite has a tensile strength value of 319.33 Kg/cm<sup>2</sup>, the value slightly increase to (321.67, 332, and 324.33) Kg/cm<sup>2</sup> with the addition of (10, 20, and 30) wt. % of ATH filler, respectively. The tensile strength value (319) Kg/cm<sup>2</sup> of PP without filler is lower than that of PP composite with SiO<sub>2</sub> filler, where this value increases to (351.67, 288.67, and 261.34) Kg/cm<sup>2</sup> with the addition of (20, 30 and 40) wt. % of SiO<sub>2</sub> filler, respectively. The increasing percentage of tensile strengths for ATH (10, 20 and 30%) is almost (0.8, 4.1 and 1.7%) respectively and for SiO<sub>2</sub> (20, 30 and 40%) is almost (5.9, 10.1 and 6.8%) respectively, with compared to unfilled PP specimens.

### B. Soft Program (MATLAB) Results in Tensile Strength Test

Figure 18 shows curve fitting for the flashover voltage results for the samples of ATH filler under condition .Where y is the flashover voltage (kV) under dry, x is the percentage of ATH in sample.

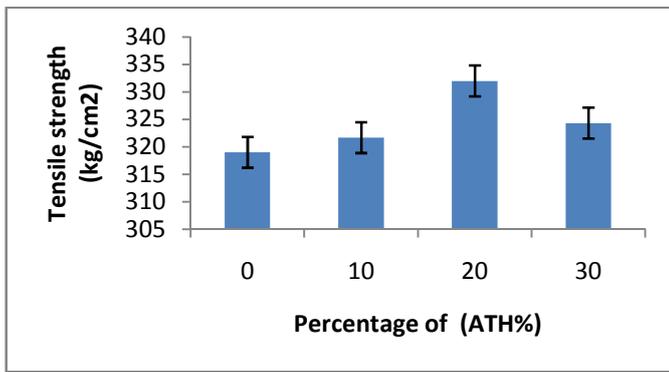


Fig 16. Tensile strength(kg/cm<sup>2</sup>) of samples with ATH under dry condition

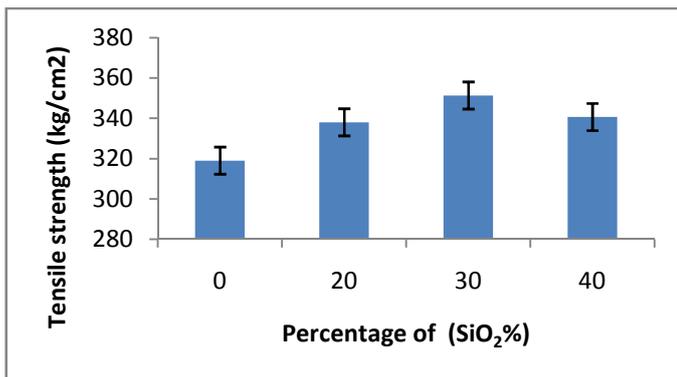


Fig 17. Tensile strength (kg/cm<sup>2</sup>) of samples with SiO<sub>2</sub> under dry condition

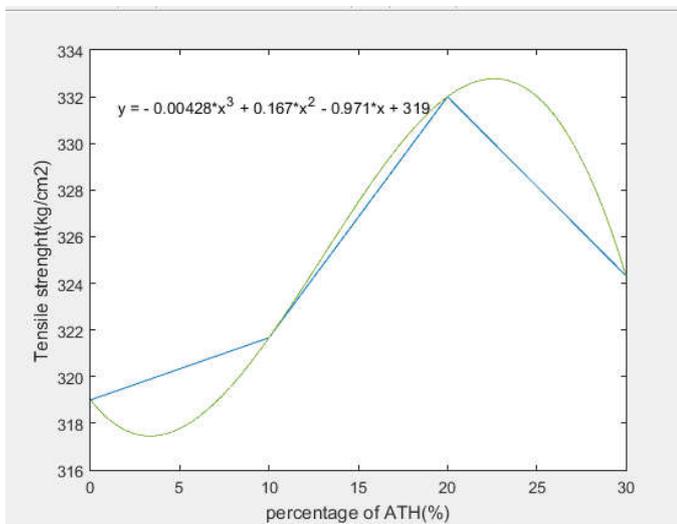


Fig 18. Curve fitting results for the Tensile strength (kg/m<sup>2</sup>) of samples with ATH under dry condition

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup>degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

- Coefficients  
 P1 = -0.00428  
 P2 = 0.167  
 P3 = -0.971  
 P4 = 319

Figure 19 shows curve fitting for the flashover voltage results for the samples of SiO<sub>2</sub> filler under dry condition .Where y is

the flashover voltage (kV) under dry, x is the percentage of SiO<sub>2</sub> in sample

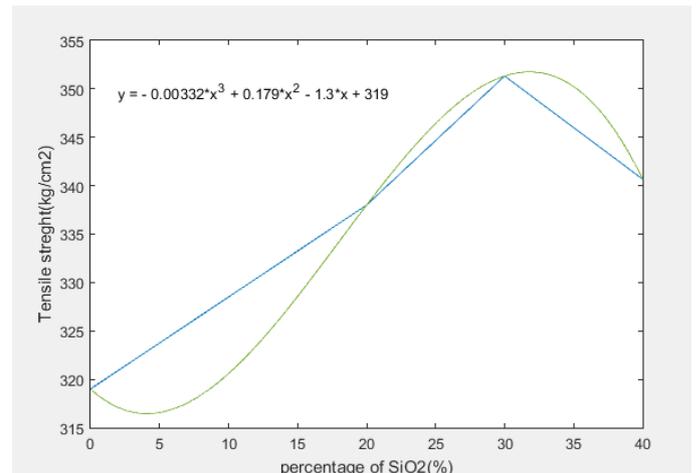


Fig 19. Curve fitting results for the tensile strength of samples with SiO<sub>2</sub> under dry condition

From the calculation of the program the best curve fitting for the data obtained can be represented by 3<sup>rd</sup>degree polynomial equation as follow:

$$Y = P1 \cdot X^3 + P2 \cdot X^2 + P3 \cdot X + P4$$

- Coefficients  
 P1 = -0.0033  
 P2 = 0.18  
 P3 = -1.3  
 P4 = 319

## CONCLUSION

This paper has concentrated on the environmental impact on the electrical performance of polymer insulators. The main conclusions that can be inferred from this work are:

- The type and percentage of filler has pronounced effects on the electrical and mechanical performance of Polypropylene (PP) composite insulators.
- There is a critical quantity of filler, which can be added regarding the quantity of Polypropylene (PP), and the appropriate percentage of SiO<sub>2</sub> reach to (40wt. %) in PP specimen gives the highest flashover voltage (51.81kV ) at dry condition.
- 3.The electrical performance of Polypropylene (PP) insulation materials under different conditions can be improved considerably by increasing the ATH filler content till a value around (20wt. %).
- Among the five conditions taken in this study (dry, wet, salinity 30000μS/cm, 50000μS/cm, 60000 μS/cm and 30wt. % nitric acid), the inclusion of nitric acid is the worst case where it causes faster flashover voltage (27.41kV).
- The mechanical properties of Polypropylene (PP) composites loaded with SiO<sub>2</sub> are better than other samples loaded with ATH.
- The unfilled Polypropylene has mechanical properties lower than other samples loaded with ATH (10, 20, and 30wt. %) and SiO<sub>2</sub> (20, 30 and 40wt. %) respectively.
- As a result of previous points, Polypropylene (PP) with SiO<sub>2</sub> composites has good electrical and mechanical properties if it is compare with ATH.

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