Experimental Study on Surface Ageing of Polymeric Insulator

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Abstract -
Polymeric insulators are widely used due to their excellent hydrophobic nature. Hydrophobicity gets affected due to surface degradation. The major environmental factor that affects the surface characteristics of the polymeric insulator is the deposition of contaminated water droplets on the surface of the insulator. In the present work, the effect of salinity of water droplets representing the contaminated water and the number of droplets on the surface of the polymeric insulator are experimentally studied. The behavior of flashover voltage due to the above factors was observed and a conclusion was drawn on how the flashover voltage behaves with an increase in salinity and also with the increase in the number of water droplets on the surface of the insulators. This study has resulted in an important conclusion that even though flashover is close to the surface, they occur at a lower value of voltages with the increase in salinity and number of droplets of water. This causes surface degradation and hence results in surface ageing of the material.

Keywords - *flashover voltage, hydrophobicity, polymeric insulator, salinity, water droplets.*
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1. Introduction

Initially, insulators made of ceramic and glass were employed. Since the beginning of high-voltage transmission, these insulators have been utilized in electrical equipment such as transformers, CT, PT, support insulators, isolators, etc. Transmission lines with voltages ranging from low to high employ these insulators. The performance of the insulation is important for a reliable power supply. Frequently referred to as ceramic insulators, porcelain insulators can withstand compressive or tensile stresses and have a longer lifespan. It has been in use for more than 110 years, and this ceramic insulation has a very long lifespan. Ceramic insulators currently have a lot of problems, while having a longer lifespan. Their main disadvantages are their weight and performance in a polluted environment. Every country wants to industrialize; therefore, environmental pollution is growing and causing flashovers across ceramic insulators. The length of the surface is not linearly correlated with the increase in transmission voltage as a result of the pollutant flashover that occurs on the ceramic insulator's surface. As a result, under conditions of medium and heavy pollution, a transmission system with a voltage higher than 220kV cannot operate with a ceramic insulator. Transmission companies apply measures like washing the insulators, increasing leakage distance, using multiple insulators, applying grease on the insulator surface, and applying Room temperature vulcanizing (RTV) coating on ceramic insulators, or using new polymeric insulators. Researchers felt it is necessary to invent a different insulation material, and as a result "polymeric insulators" were introduced in the 1960s. The polymeric insulator has more advantages than ceramic and glass insulators as well as good performance in a polluted environment, lightweight, easy to handle, free maintenance, and much lower cost, etc. Because of these properties, composite insulators have gained worldwide popularity and are replacing the usual ceramic and glass insulators[1]. Polymeric materials have hydrophobicity properties, which is a significant benefit for polymeric insulators. Even in wet environments, the hydrophobicity property of the insulator surface avoids the development of polluted water films on the insulator's surface which helps to suppress leakage current[2]–[5].

Polymeric insulators have a very good pollution performance due to their hydrophobic property. But it deteriorates due to electrical and climatic stress under wet and polluted conditions. The deterioration changes due to flashovers, scintillations, corona, arcing, ultraviolet radiations, heat, etc.[6]–[22]. This results in surface degradation of the insulator. To understand the surface behavior of polymeric it is necessary to understand the arc characteristics between the water globules on the polymer surface. Therefore, they are deliberately placed on the surface of polymeric material and arcing characteristics are studied

The failure modes of an insulator are chalking and crazing. Most of the failure modes are due to surface degradation. This surface degradation is a consequence of arcing on the polymeric surface. Though the polymeric surface is hydrophobic, depending on the distance between globules and the stress between the globules causes arcing between the water droplets. This arcing is very close to the polymeric surface and hence degrades the material. This may even cause erosion of material in a long run [23]–[33].

Therefore, it is necessary to understand the fundamental process of arcing between globules and find a solution to Eschew the arcing between the water globules.

A series of experiments were conducted by placing water globules on the polymeric surface between electrodes under electrical stress.

An experimental study was conducted with 3 water globules placed between the electrodes. Voltage was applied between the electrodes and the behavior of the water globules was monitored by varying the voltage. The study was also conducted with 9 water globules. These experiments were conducted to understand the behavior of the water globules and study the arcing process across the globules.

2. Specimen Preparation and Experimental procedure

Tests were conducted on three polymeric samples S1, S2, and S3. The dimensions of the samples used for testing are 150mmX50mmX6mm in size. The source used for testing consists of an autotransformer that supplies a step-up transformer of 230V/50kV, 5kVA rating from a 230V ac source. The water droplets placed on the insulating specimen were made conducting by dissolving salt into it. Two salinity levels chosen are 5 grams of salt per liter of water (5 g/L) and 10g of salt per liter of water (10 g/L). Water globules were arranged on the insulator specimen with 3 and 9 globules. These globules are placed on the insulator specimen with help of a liquid dropper. Figure 1 shows the arrangement of 3 water droplets at the center of the specimen. The distance between the centers of the adjacent droplets is about 12mm. Figure 2 shows the arrangement of 9 water droplets at the center of the specimen. The distance between the centers of the adjacent droplets both horizontally and vertically is about 12mm

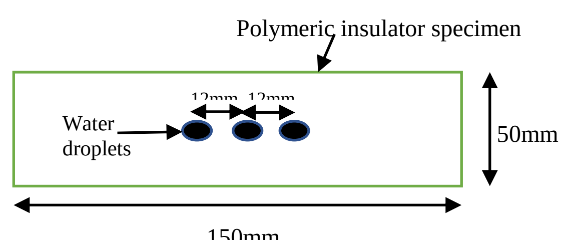

Figure 1: Arrangement of 3 droplets of water on the specimen

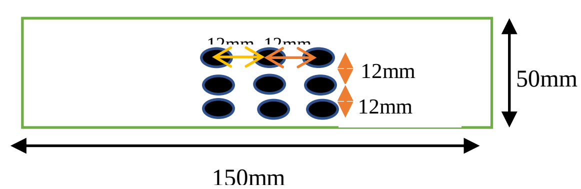

Figure 2: Arrangement of 9 droplets of water on the specimen

Water droplets were placed on the insulator material with 3, and 9 globules as shown in Figure 3 and Figure

4 respectively. The copper wire is wound around the insulator sample to act as the electrodes as shown in Figure 3. The water with two salinity levels viz., 5 g/L and 10 g/L were prepared.

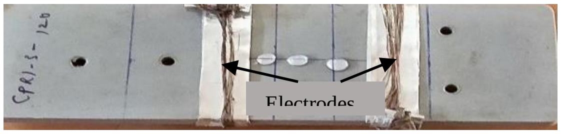

Figure 3: Photograph of the specimen with 3 droplets of water and electrodes for field application.

The circuit is set up for applying the required voltage on the polymeric material as in Figure 5. Voltage is supplied to a step-up transformer, 230V/50kV, through an auto-transformer, 0-230V. The high voltage is then applied to the specimen.

Figure 4: Photograph of the specimen with 9 droplets of water and electrodes for field application.

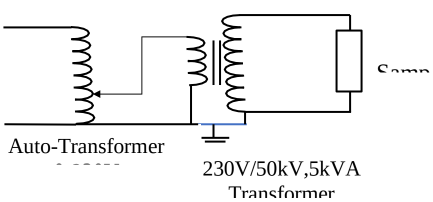

Figure 5: Circuit setup for applying a voltage to the specimen

The experimental setup for applying voltages on the insulator material is shown in Figure 6. The input to the auto-transformer was 230V. A reduced voltage from the auto-transformer was applied to the primary of the step-up transformer(230V/50kV). The high voltage was applied to the insulator sample through electrodes.

Figure 6: Experimental setup for measuring surface characteristics

The high voltage from the step-up transformer was applied to the insulator sample through electrodes. The high voltage applied was kept at a particular value and the behavior of water droplets was observed. After a few minutes, the voltage was slowly raised till the flashover occurs. The flashover voltage was recorded. This process was repeated thrice, i.e., three trials on all the samples viz., S1, S2, and S3, and the flashover voltages were recorded. The recorded values were tabulated for two salinity levels, viz., 5 g/L and 10 g/L. Table 1 and Table 2 show the flashover voltages for the case of 3 droplets and 9 droplets of water at 5 g/L. Table 3 and Table 4 show the flashover voltages for the case of 9 droplets of water at 10 g/L salinity.

3. Results and Discussion

The photographs in Figure 7 and Figure 8 show the specimen after flashover for the case of 3 and 9 droplets of water for 5 g/L of salinity. It can be observed that the water droplet joins together and bridge the gap between the droplets across the electrodes hence losing the hydrophobicity property.

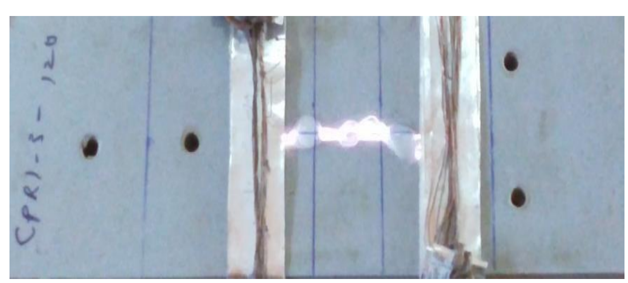

Figure 7: Polymer insulating material specimen after flashover for the case of salinity level5g/L and 3 droplets of water

Figure 8: Polymer insulating material specimen after flashover for the case of salinity level 5 g/L and 9 droplets of water

Flashover voltages recorded during experimentation are tabulated in Table 1 for 3 droplets and 5 g/L salinity, and in Table 2 for 9 drops at 5 g/L salinity.

Table 1: Salinity level 5 g/L and no. of droplets=3

Sample No.	Flashover voltage in kV		
	Trial-1	Trial-2	Trial-3
S1	17	10	15
S2	17	8	5
S3	22	20	7

Table 2: Salinity level 5 g/L and no. of droplets=9

Sample No.	Flashover voltage in kV		
	Trial-1	Trial-2	Trial-3
S1	18.5	15	14
S2	19	18	17
S3	17	12	12

Table 3 gives the flashover voltages at 10 g/L salinity and 3 droplets of water and Table 4 for 9 droplets and 10 g/L salinity.

Table 3: Salinity level 10 g/L and no. of droplets=3

Sample No.	Flashover values in kV		
	Trial-1	Trial-2	Trial-3
S1	20	14	16
S2	20	19	6
S3	18	14	13

Table 4: Salinity level 10 g/L and no. of droplets=9

Sample No.	Flashover values in kV		
	Trial-1	Trial-2	Trial-3
S1	18	13	12
S2	19	14	13
S3	13	11	10

3.1 Behavior of flashover voltage.

From recorded values of flashover voltages in Table 1 and Table 2, a plot of flashover voltage v/s trial number for 5 g/L salinity and 3 droplets of water and 9 droplets of water for all the three samples S1, S2, and S3 is shown in Figure 9 and Figure 10 respectively.

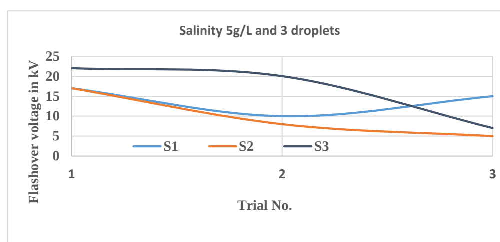

Figure 9: Flashover voltage at 5 g/L salinity and 3 droplets of water.

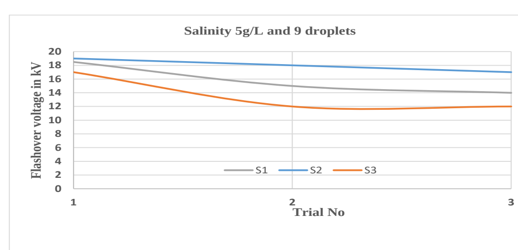

Figure 10: Flashovervoltage at 5 g/L salinity and 9 drops of water.

It can be observed from Figure 9 and Figure 10 that for all three samples at a single salinity of 5 g/L flashover voltage decreases as the number of trials increases for both the cases of 3 and 9 droplets of water. This indicates that subsequent flashovers in the actual conditions in the field occur at a lower voltage. This indicates that the surface characteristics get affected as the flashovers increase resulting in surface ageing.

Also, it can be observed from Figure 11 and Figure 12 that for all three samples at a single salinity of 10 g/L flashover voltage decreases as the number of trials increases for both the cases of 3 and 9 droplets of water. This indicates that subsequent flashovers in the actual conditions in the field occur at a lower voltage. This indicates that the surface characteristics get affected as the flashovers increase resulting in surface ageing.

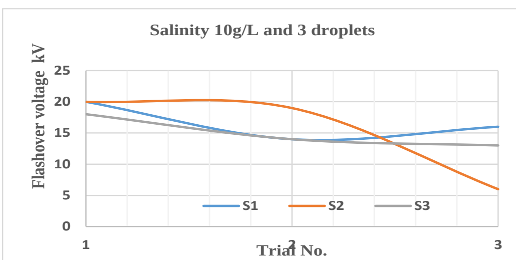

Figure 11: Flashovervoltage at 10 g/L salinity and 3 drops of water.

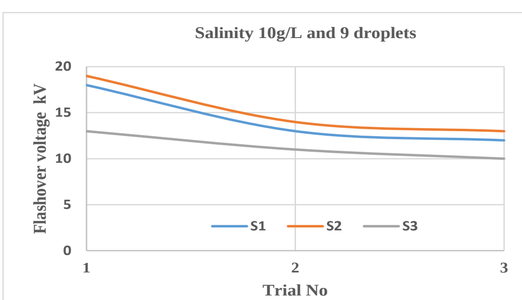

Figure 12: Flashovervoltage at 10 g/L salinity and 9 droplets of water.

From Figure 11 and Figure 12, for all three samples at a single salinity of 10 g/L flashover voltage decreases as the number of trials increases for both the cases of 3 and 9 droplets of water. This indicates that subsequent flashovers in the actual conditions in the field occur at a lower voltage. This indicates that the surface characteristics get affected as the flashovers increase.

4. Conclusion

The experiments were conducted to analyze the factors affecting the surface ageing of the polymeric insulator material. From the results, it was evident that the salinity level has a considerable influence on the voltage level at which the flashover on the surface of the insulating material occurs. It was observed that an increase in salinity level decreases the voltage level at which the flashover occurs.

Further, the number of droplets on the surface of the insulating material also influences the voltage level at which the flashover occurs. An increase in the number of droplets also decreases the voltage at which the flashover occurs. This indicates that as there is more pollutant droplet deposit on the insulating surface the lesser voltage at which the flashover occurs. Hence increasing the surface ageing process of the insulating material.

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