

EXPERIMENTAL STUDY ON INFLUENCE OF POLLUTION LAYER THICKNESS AND POLLUTION SEVERITY ON THE POLYMERIC MATERIAL

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Abstract

The pollution performance of insulators has a significant impact on the reliability of the power system. Observation and research have revealed that all polymeric dielectrics are susceptible to deterioration under operating stresses, resulting in system failure. Polymeric materials have the property of hydrophobicity by which it gives better pollution performance. Transfer of Hydrophobicity may reduce under certain conditions resulting in failure of polymeric insulator. In this research work, an experimental investigation has been carried out on polymeric material to check if there is any influence of the pollution layer thickness on the hydrophobicity transfer property of polymeric material. Experiments with increasing pollution layer thickness and at various severity have been conducted to investigate the impact of pollution layer thickness and severity on the transfer of hydrophobicity of polymeric insulators. From the experimental findings, it can be inferred that the transfer of hydrophobicity may not happen for the pollutant thicknesses greater than 1mm and for higher severity. At the same time, hydrophobicity transfer occurs onto the polluted surface for lower severity and lower thicknesses of the pollution layer.

Keywords: Hydrophobicity, pollution severity, polymeric material, leakage current, layer conductivity.

1. INTRODUCTION

The pollution performance of insulators is crucial to the power system's reliability. Failures of transmission line insulators occur in the form of flashover due to pollution on the surface of insulators. These failures are in the form of surface flashover or surface deterioration. The main cause for these failures is the leakage current that flows under the moisture condition. The Leakage current that flows over the wet pollution layer cause dry bands. Scintillations across these dry bands occur at many places simultaneously that may result in a flashover, if it crosses the critical number of scintillations.

Field experience with polymeric insulators of about 40 years suggests that polymeric insulators can be used at higher severity. The main advantage of polymeric insulators is combating ambient pollution and easy maintenance [1]. Hydrophobicity can be lost due to corona and dry-band arcing activity occurring in contaminated and moist environments. As a result, their performance may be severely affected and lead to erosion and tracking, which in turn results in insulator degradation. It is very much necessary to understand the transfer of hydrophobicity on the surface, which is an early indicator of insulator degradation.

According to previous studies, the transfer of hydrophobicity in polymers is mostly due to a diffusion process in which low molecular weight

(LMW) polymer chains migrate to the surface of polymers, resulting in a low-energy surface [1,2]. To study the hydrophobicity behavior of polymer insulators, leakage current measuring systems [3] are generally used in laboratories and fields, however, no co-relation between hydrophobicity behavior and pollution layer thickness has been established for polymer materials at present. In this context, this research work focuses on whether there is an influence of pollution layer thickness and severity on hydrophobicity transfer onto the pollutant surface.

Uniform pollution layers of various thicknesses and conductivities were used to represent light, medium, and heavy polluted environments in this research work. The pollution layer thickness and severity were varied to see if the pollution layer thickness and severity had any effect on the hydrophobicity transfer property of the polymer material.

2. EXPERIMENTAL SETUP AND PROCEDURE

Three polymeric material samples, A (15x5x0.2) cm, B (15x5x0.3) cm, and C (15x5x0.6) cm as shown in fig 1 are considered for the experimental investigation, and tests were carried out in general accordance with the standards IEC60507 clean fog test method [4].

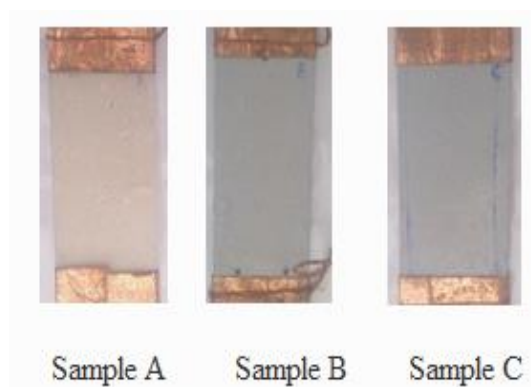


Fig. 1: Polymeric material samples

Tests were carried out on polymeric material after coating the pollutant layer as per the procedure described in [5]. An RMS voltage of approximately 1 kV was applied to the polymeric material samples placed within the fog chamber (40x40x40) cm in dimension and fog was generated inside the chamber. Throughout the process, the leakage current that flows on the sample's surface was monitored. Figure 2 illustrates the experimental setup used for the test.

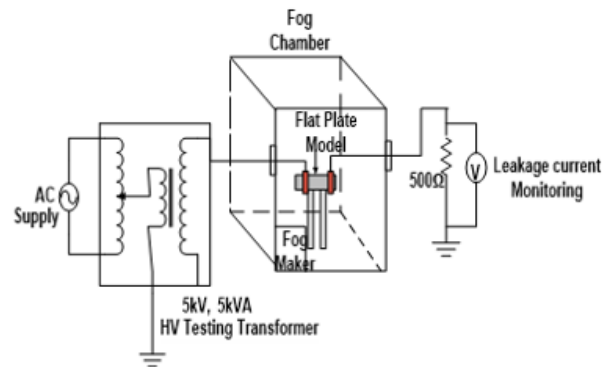
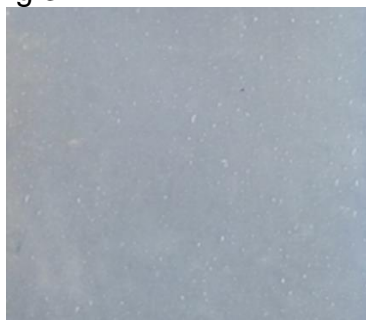


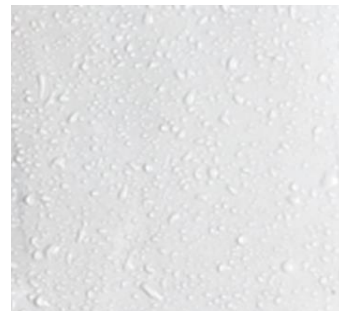
Fig. 2. Schematic diagram of a test setup

The fog was produced inside the chamber with the steamer, and the polymeric material samples were exposed to a steam-input rate around 0.016kg/m³/hr inside the chamber. The power supply is a 230V/5kV, 5 kVA transformer.

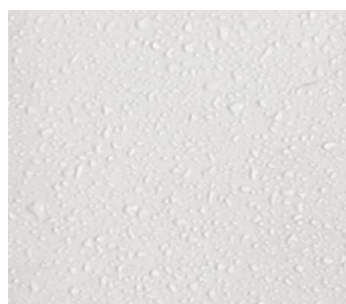
Polymeric material samples exhibited good hydrophobicity [HC1][6] before the test as shown in fig 3.



Sample A



Sample B



Sample C

Fig 3: Polymeric material samples exhibiting good hydrophobicity [HC1] before the test

The test specimens were artificially coated [5] and placed in a fog chamber and leakage current was monitored every 5 minutes up to 90 minutes. After the test, the polymeric

material samples lost their hydrophobicity property [HC4-HC5] but regained the hydrophobicity on the subsequent day [HC1-HC2] [6] as shown in figure 4

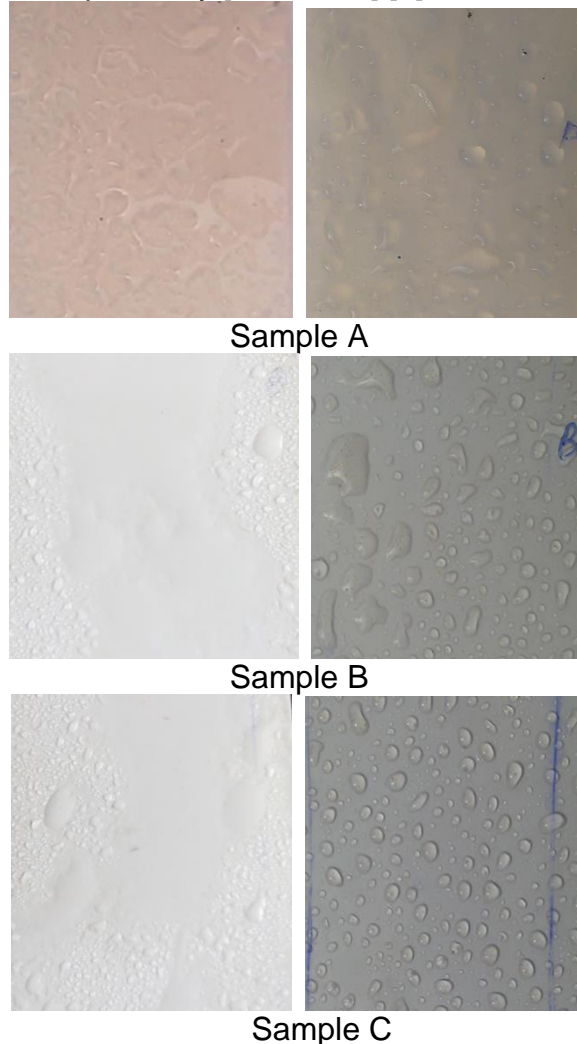


Fig 4: Polymeric samples exhibiting

a) loss of Hydrophobicity after the test [HC4-HC5]

b) Hydrophobicity recovery on a subsequent day [HC1-HC2]

At each layer thickness, experiments were performed to and the leakage current was measured during the tests. The maximum layer conductivity was used for comparing the transfer of hydrophobicity Uniform pollution layer thickness (t) of 0.16mm, 0.25mm, 0.5mm, and 1mm were obtained by using defined former thicknesses that defines the pollution layer thickness [5,7]. The dimension of the former is $12 \times 4 \times t$ cm, where t is the pollution layer thickness.

3. Results and discussion

Table 1 gives the results of the maximum leakage current and maximum layer conductivity recorded during the tests carried out on all three samples with and without coating on polymeric material for Layer conductivity $4.2 \mu\text{S}$ and SDD $0.035\text{mg}/\text{cm}^2$ [Slurry prepared at Volume conductivity $1.4 \text{ S}/\text{m}$]

Table 1: Max. Leakage current and Max. layer conductivity of polymeric material samples for different coatings for Layer conductivity $4.2 \mu\text{S}$ and SDD $0.035\text{mg}/\text{cm}^2$

Sl. No	Polymeric Material	Thickness of Coating	Max. Leakage Current (μA)	Max. layer Conductivity (μS)
1.	Sample A	Without coating	240	0.8
		0.16 mm	1241	3
		0.25 mm	789	1.9
		0.5 mm	739	1.8
		1 mm	1928	4.6
2.	Sample B	Without coating	158	0.38
		0.16 mm	168	2.6
		0.25 mm	485	1.2
		0.5 mm	1248	3
		1 mm	2183	5.2
3.	Sample C	Without coating	206	0.49
		0.16 mm	907	2.2
		0.25 mm	887	2.1
		0.5 mm	1444	3.5
		1 mm	2048	4.9

Figure 5 illustrates the Leakage current variation of polymeric material samples for different thicknesses of coating at SDD $0.035\text{mg}/\text{cm}^2$. From the graph, it can be seen that there is an increase in the leakage current and layer conductivity for a higher thickness of 1mm indicating transfer of hydrophobicity reduces as the pollution layer thickness increases. For the lower thicknesses, there occurs transfer of hydrophobicity onto the pollutant layer.

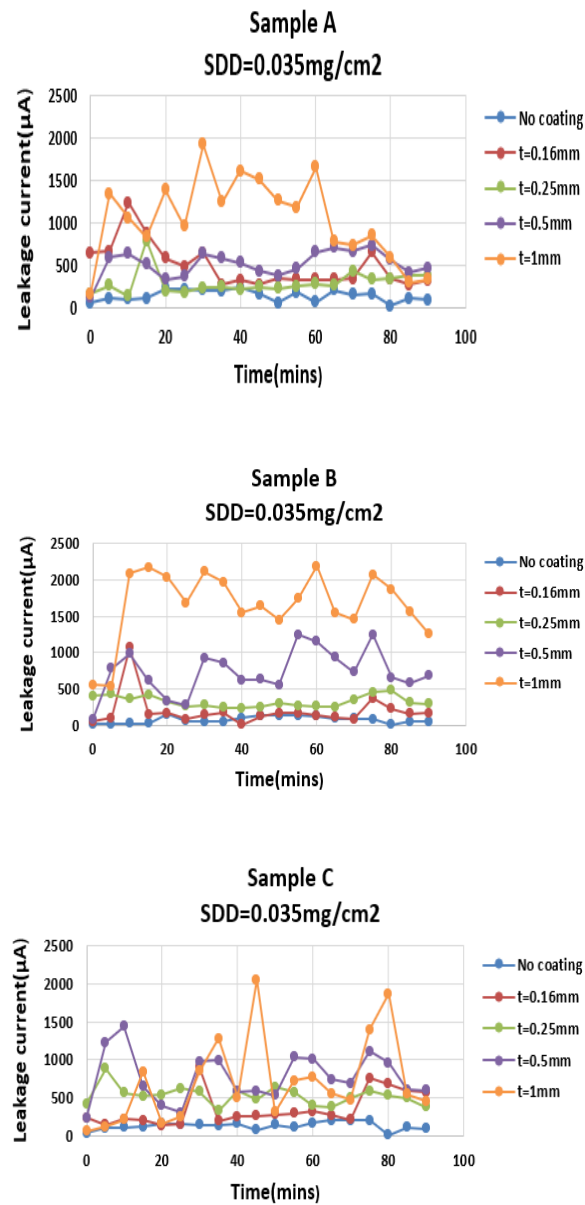
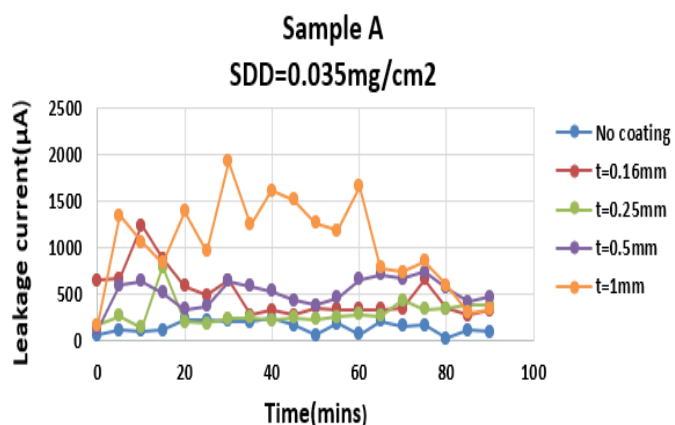


Fig 5: Variation of Leakage current of polymeric material samples for different thicknesses of coating at SDD 0.035mg/cm²

Table 2 gives the results of the maximum leakage current and maximum layer conductivity recorded during the tests carried out on all three samples with and without coating on polymeric material for Layer conductivity 20 μS and SDD=0.2 mg/cm² [Slurry prepared at Volume conductivity 8 S/m]

Table 2: Max. Leakage current and Max. layer conductivity of polymeric material samples for different coatings for Layer conductivity 20 μS and SDD=0.2 mg/cm².

Sl. No	Polymeric Material	Thickness of Coating	Max. Leakage Current (μA)	Max. layer Conductivity (μS)
1.	Sample A	Without coating	90	0.22
		0.16 mm	1910	4.58
		0.25 mm	1920	4.61
		0.41 mm	1890	4.54
		0.5 mm	1600	3.84
		1 mm	3640	8.74
2.	Sample B	Without coating	82	0.2
		0.16 mm	1466	3.39
		0.25 mm	1592	3.82
		0.41 mm	2910	6.98
		0.5 mm	11120	26.69
		1 mm	15900	38.16
3.	Sample C	Without coating	80	0.19
		0.16 mm	8500	20.4
		0.25 mm	1972	4.73
		0.41 mm	4694	11.17
		0.5 mm	2820	6.71
		1 mm	13760	33.02



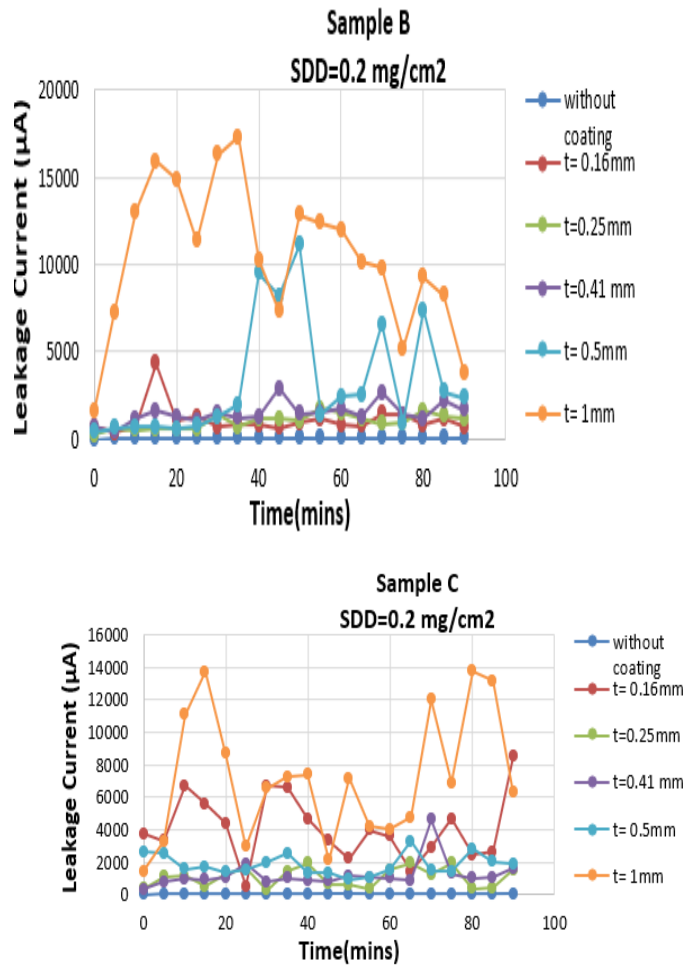


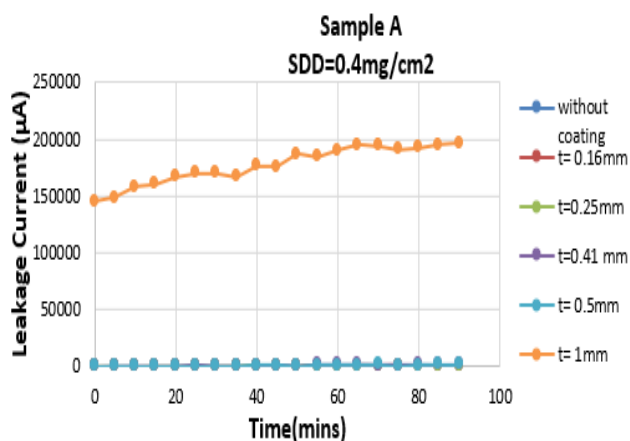
Figure 6: Variation of Leakage current of polymeric material samples for different thicknesses of coating at SDD 0.2 mg/cm²

Figure 6 illustrates the Leakage current variation of polymeric material samples for different thicknesses of coating at SDD 0.2 mg/cm². From the graph, it can be observed that there is an increase in the leakage current and layer conductivity for a higher thickness of 1mm indicating transfer of hydrophobicity reduces as the thickness of the pollution layer increases. But, for the lower thicknesses, there occurs transfer of hydrophobicity onto the pollutant layer for increased severity of 0.2 mg/cm².

The results of the maximum leakage current and maximum layer conductivity recorded during the tests carried out on all three samples with and without coating on polymeric material for Layer conductivity 37 µS and SDD=0.4 mg/cm²[Slurry prepared at Volume conductivity 16 S/m] are shown in Table 3

Table 3: Max. Leakage current and Max. layer conductivity of polymeric material samples for different coatings for Layer conductivity 37 μS and SDD=0.4 mg/cm^2

SI.No	Polymeric Material	Thickness of Coating	Max. Leakage Current (μA)	Max. layer Conductivity (μS)
1.	Sample A	Without coating	352	0.84
		0.16 mm	1078	2.59
		0.41 mm	432	1.04
		0.5 mm	3260	7.82
		1 mm	224000	537.6
2.	Sample B	Without coating	176	0.42
		0.16 mm	8920	21.42
		0.41 mm	1426	3.42
		0.25 mm	1666	4
		0.5 mm	2500	6
		1 mm	128800	309.12
3.	Sample C	Without coating	170	0.41
		0.16 mm	12600	30.24
		0.41 mm	7160	17.18
		0.25 mm	2780	6.67
		0.5 mm	9700	23.28
		1 mm	367400	881.76



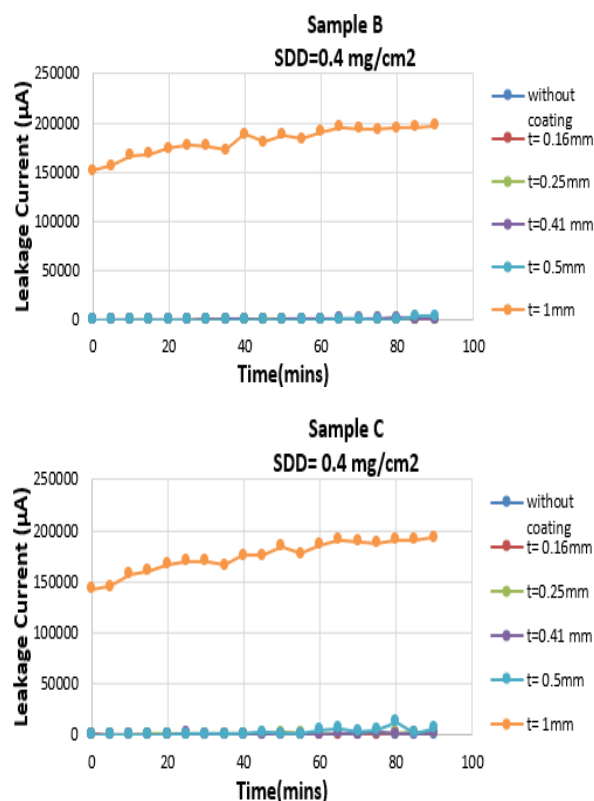


Figure 7: Variation of Leakage current of polymeric material samples for different thicknesses of coating at SDD 0.4 mg/cm^2

Variation of Leakage current of polymeric material samples for different thicknesses of coating at SDD 0.4 mg/cm^2 is shown in Figure 7. From the graph, it can be seen that there is an increase in the leakage current and layer conductivity for a higher thickness of 1mm indicating transfer of hydrophobicity reduces as the pollution layer thickness increases. For the lower thicknesses, there occurs transfer of hydrophobicity onto the pollutant layer for increased severity of 0.4 mg/cm^2 .

Summary

It may be concluded from the above experimental findings that increasing the thickness and severity of the pollution layer on the surface of polymer insulator samples can result in

- i. The variation in the leakage current occurs at various instants.
- ii. Vast difference between polymeric material without coating and with coating for all the severity
- iii. The leakage current and layer conductivity of pollutant material is much higher than the polymeric material without coating
- iv. The transfer of hydrophobicity was significant for the lower-thickness pollutant layer.
- v. For pollutant thicknesses greater than 1mm and at higher severity i.e., SDD= 0.4 mg/cm^2 , hydrophobicity transfer may not occur (Figure 7)

CONCLUSION

The test findings revealed that the change in layer conductivity happens at various intervals. The results indicate that there is a significant difference between polymeric materials that are uncoated and those that are coated. The results show that the layer conductivity of polluted material is significantly higher than that of polymeric material without coating. The increase in the severity has resulted in increased leakage current. The results also show that a pollutant thickness of 1mm draws more current throughout the test, showing that hydrophobicity transfer does not occur. Whereas pollutant layer thicknesses of 0.16mm, 0.25mm, 0.5mm, draws lesser current, implying that hydrophobicity transfer may occur at lower pollutant layer thicknesses

Based on the above results, it is possible to infer that conductivity increases for higher pollution thicknesses and higher severity for polymer insulator materials. Also, it can be seen that the transfer of hydrophobicity may not occur for pollutant thicknesses more than 1mm and at higher severity i.e., $SDD=0.4\text{mg/cm}^2$

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