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Transfer of Hydrophobicity of Polymeric Insulators for Various Pollution Severities

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Abstract: ***Polymeric insulators exhibit good performance under polluted conditions due to the unique property of hydrophobicity. However, the flashover of insulators occurs due to the development of leakage current under severe contamination. The initially hydrophobic surface of the insulator is lost when exposed to electric discharges or pollution. It is, therefore, necessary to understand the performance of insulators for different pollution severities when placed in actual service environment. The surface of the polymer insulator gets deteriorated as it ages but during the initial period of aging it is said that hydrophobicity exists even under polluted condition. This phenomenon is called hydrophobicity transfer. In this aspect, this work is carried out on polluted polymer insulators to understand whether hydrophobicity transfer occurs for various pollution severities. The experimental investigation was carried out to understand whether hydrophobicity persists for the lower thickness (<1mm) and 1mm coating of polymeric insulators. The results of the experiments are discussed in this paper. It can be observed from the results that conductivity rises to a higher value for a thickness of 1mm coating and an increase in the conductivity is not significant for less than 1mm coating. Based on the results it can be concluded that the hydrophobicity transfer may not occur for a higher thickness of pollution.***

Keywords ***: conductivity, leakage current, pollution, silicon rubber insulator***

I. INTRODUCTION

The safety and performance of electrical appliances mainly depend on electrical insulation. An electrical power source must maintain the progress and reliability to the concerned utility, thus substations and power lines must be designed such that they should be secured against overvoltages so that failures are as minimum as possible. The line conductors are electrically isolated from each other by using electrical insulators. Insulators should withstand high environmental and electrical stresses and should have excellent mechanical strength when they are placed in actual service

Glass and ceramic insulators are commonly used since transmission lines came into existence. The main problem with high voltage ceramic insulators is that the water runs freely on the surface of an incessant film. Under clean weather conditions, ceramic and glass insulators can withstand the power frequency voltage. When the insulator surface is covered by pollution, a leakage current develops which can cause a flashover, which eventually leads to the blackout. Therefore, the power supply reliability has to be improved and thus new composite insulators have been developed.

Polymer insulators are much lighter and offer higher performance than porcelain insulators. The other advantages of composite insulators are the best possible strength to weight ratio, good aging resistance, and high inherent fire resistance.

Polymer insulators ensure high quality, good mechanical and electrical properties under all environmental conditions. Though the polymer insulators are having very good properties, it has got the limitation that surface may deteriorate on long run. Therefore laboratory investigation on transfer of hydrophobicity on polymer insulators for various severities has to be carried out [1].

The silicone rubber materials have a unique property of transfer of hydrophobicity, which is a major cause of polymer insulators excellent pollution performance when contaminated. However, changes in insulator surface properties under operating conditions ultimately lead to a loss of hydrophobicity [2,3]. The insulators are susceptible to tracking, erosion and corona due to the formation of dry band arcs when there is a flow of leakage current, which leads to a transition to a hydrophilic state from a hydrophobic state [4]. It is very important to know the degree of hydrophobicity performance on the insulator surface. Therefore, it is necessary to determine the performance of the contaminated insulator that is failing in the transmission line.

There are various examinations accessible in literary works on the examination of the impact of contamination severities on the porcelain and glass insulators. However, exceptionally few studies are available on the contaminated polymeric insulators.

The hydrophobicity condition of the surface is closely related to the composite insulator's flashover performance under polluted conditions. Although hydrophobicity transfer to the exterior surface of silicone rubber insulators has been found to be slow, there is no need for completion to achieve the full effect [5,6]. For better polymeric insulators selection and their maintenance, further research on the hydrophobicity transfer properties of different contaminants should be carried out. As flashover of the contaminated polymer insulators happens at the working voltage, it is required to evaluate the severity of the contamination and the performance of the polymeric insulator[7]. The effectiveness of hydrophobicity is greatly influenced by the interaction of migrated compounds with the pollution particles in the bulk and on the surface.

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The physical morphology and natural chemical property of pollutants play an important role in the transfer of hydrophobicity.

Therefore a detailed tests on polymer insulator is very much required so as to assess whether transfer of hydrophobicity occurs at all thicknesses or not has to be ascertained [8,9].

The hydrophobicity transfer may decrease when the silicone content in pollution reaches the level of low molecular silicone content in the bulk of material [10]

In this paper, the uniform pollution layer for different conductivity and the thickness of the pollution layer were varied to simulate light, medium, and heavy polluted environments. A leakage current characteristic for the test samples A, B and C of polymeric insulators was studied under polluted environments. Conductivity and thickness of the pollution layer was varied to access the hydrophobicity transfer behavior using leakage current characteristics.

II. THE TEST SAMPLES & METHOD

A. Test Samples

Three polymer insulator samples A(14.9x5x0.2)cm, B(14.9x5x0.3)cm and C (14.9x5x0.6)cm were used in this experiment. Test samples considered for the experiments are as shown in Figure 1 where the pollution layer can be controlled by using former of different thickness [11].

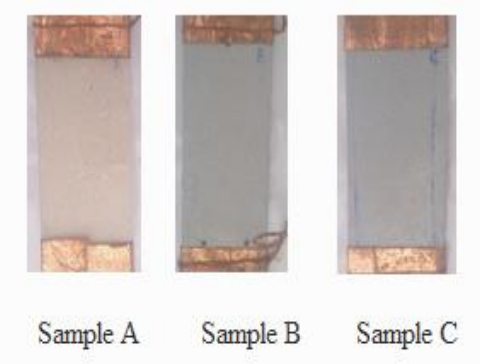

Figure 1. Test samples.

In this work, the behavior of leakage current is used to understand the hydrophobicity behavior of the polymer sample. The schematic diagram of the test setup carried out is as shown in Figure 2. Experiments have been conducted on the polymeric insulator samples and the leakage current is evaluated by recording the voltage across a series resistor [12].

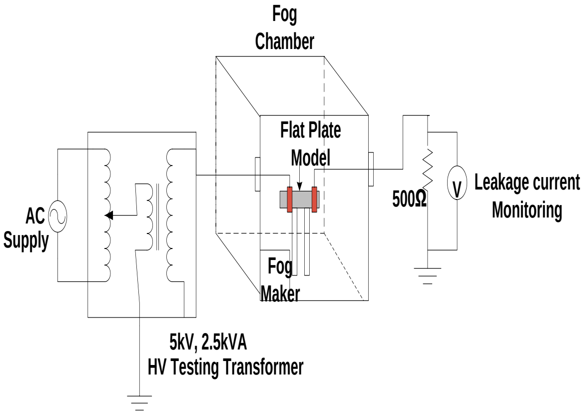

Figure 2. Schematic diagram of an experimental setup

B. Test Method

Generally, tests were performed according to the procedure of IEC60507 [13]. An RMS voltage of about 1 kV was applied to the insulator samples placed in the fog chamber (2mx2mx2m) in dimension and fog was generated inside the chamber. During the process, the leakage current that flows on the sample's surface was evaluated. Figure 3 shows the test setup used for the same.

Figure 3. Test setup

Using the steamer, the steam fog was generated in the chamber. The polymer insulator samples were subjected to a steam-input rate of about 0.016kg/m^3/hour inside the chamber. 230V/5kV, 2.5 kVA transformer is used for power supply.

C. Preparation of Slurry

The salt solution of the required conductivity was prepared [13]. Kaolin powder was then added to it so that it forms a thicker paste that can be applied on polymer surface. With a former of plastic sheet of various thicknesses, the pollution layer thickness can be controlled.

D. Pollution Layer Application

Different techniques have been found in the literature to apply and produce artificial pollution layers on polymer insulators. The thickness of the former then defines the thickness of the contaminant layer [11] as shown in figure 4. For various conductivities, the slurry was prepared in the form of a paste. Pollution for sample Insulators was then applied with the help of formers of different thickness 0.16mm, 0.25mm, 0.4mm, 0.5mm and 1mm to obtain different thickness of coatings. A solid knife edge was moved over the slurry which was coated on polymer surface in order to get uniformity of pollution layer as shown in figure 5. The insulator was dried under ambient conditions, after applying the pollution layer.

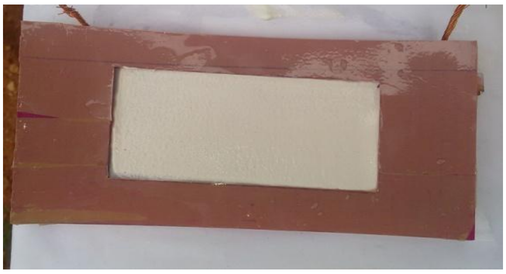

Figure 4. Sample with former

After drying, the polluted polymeric samples as shown in figure 5 were then placed in the fog chamber.

Periodically, applied voltage and the leakage current were measured for different thickness of pollution.

The ambient temperature of about 24±3°C was maintained in the laboratory during the whole test process

Figure 5. Pollution layer of thickness 0.25 mm using former made according to 2.3

III. RESULTS AND DISCUSSIONS

Tests were carried out to estimate the effect of layer thickness on the hydrophobic behavior in polymer insulators for various thicknesses of the pollution layer. Two sets of tests were carried out on each sample in three trials. The results of the leakage currents for samples A, B and C insulators for different coatings of the contaminant layer are shown in Table 1 and Table 2.

Table1. I set values of Leakage current for different samples A, B and C for different coatings

Sl.No	Insulator Sample	Thickness of Coating in mm	Max Leakage Current (mA) [RMS]		
			Trial 1	Trial 2	Trial 3
1.	Sample A	Without coating	2.176	0.09	1.704
		0.16	0.538	0.878	68.2
		0.25	1.042	1.292	8.77
		0.41	3.56	2.454	188
		0.5	143.2	3.12	1.66
		1	0.572	1.664	6.36
2.	Sample B	Without coating	0.176	0.082	0.158
		0.16	0.696	1.882	148.6
		0.25	0.896	0.498	4.52
		0.41	4.22	1.342	188
		0.5	228.6	3.34	3.46
		1	311.8	1.392	4.58
3.	Sample C	Without coating	0.618	0.078	0.206
		0.16	0.662	1.578	104
		0.25	0.868	1.224	7.52
		0.41	10.68	1.736	195
		0.5	217.6	2.64	11.36
		1	221.4	1.166	2.828

Table 2. II set values of Leakage current for different samples A, B and C for different coatings

Sl.No	Insulator Sample	Thickness of Coating in mm	Max Leakage Current (mA) [RMS]		
			Trial 1	Trial 2	Trial 3
1.	Sample A	Without coating	1.166	0.128	0.259
		0.16	6.54	0.564	0.652
		0.25	1.584	1.452	0.758
		0.41	1.38	0.432	1.856
		0.5	1.94	3.22	1.49
		1	186	198.2	196.2
2.	Sample B	Without coating	0.144	0.246	0.356
		0.16	1.398	8.92	0.754
		0.25	0.58	1.426	0.728
		0.41	.952	1.446	1.676
		0.5	1.092	1.882	1.136
		1	153.2	128.2	196.8
3.	Sample C	Without coating	0.204	0.378	0.567
		0.16	1.978	4.5	1.91
		0.25	8.42	7.16	2.298
		0.41	1.924	2.42	1.578
		0.5	1.17	1.656	12.86
		1	187.2	367.4	193.2

The results for different coatings of I set are shown in Figures 6 -8 and II set is shown in Figures 9 -11

IV

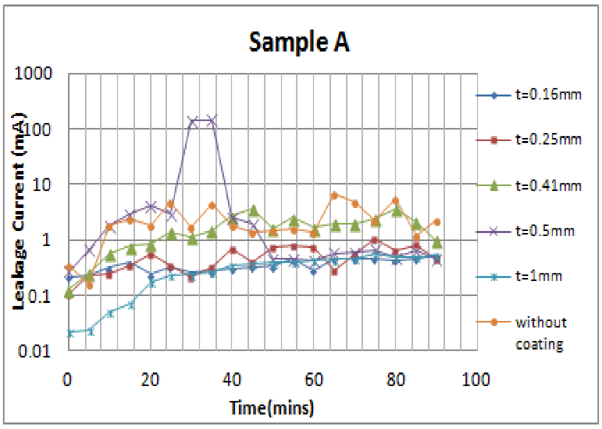

Figure 6a

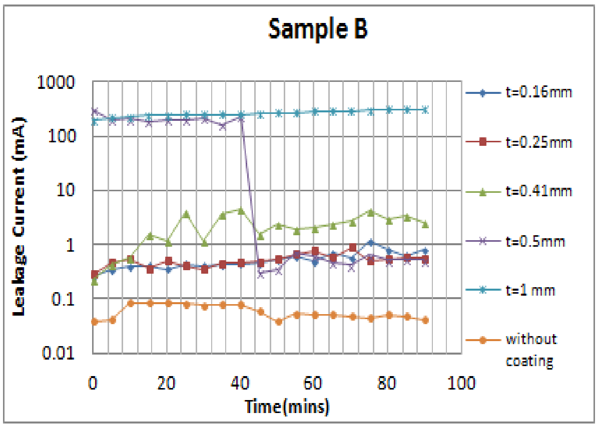

Figure 6b

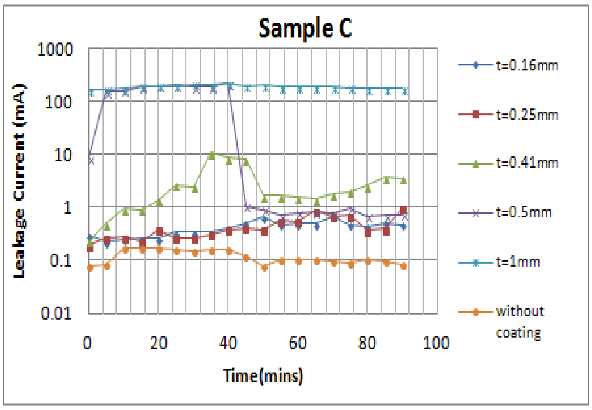

Figure 6c

Figure 6 a,b,c shows the I set leakage current variation of sample A, B & C insulator respectively in Trial 1

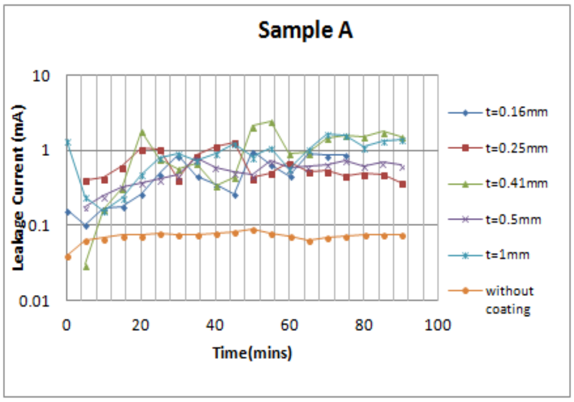

Figure 7a

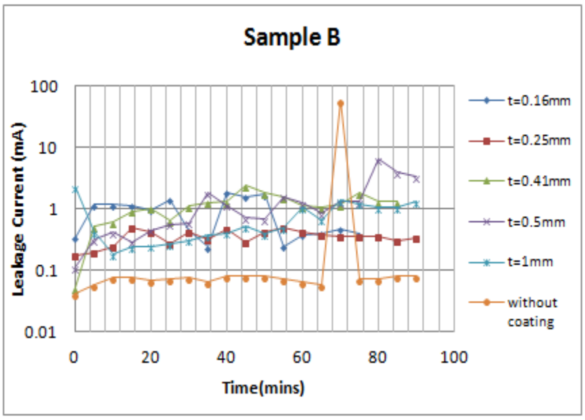

Figure 7b

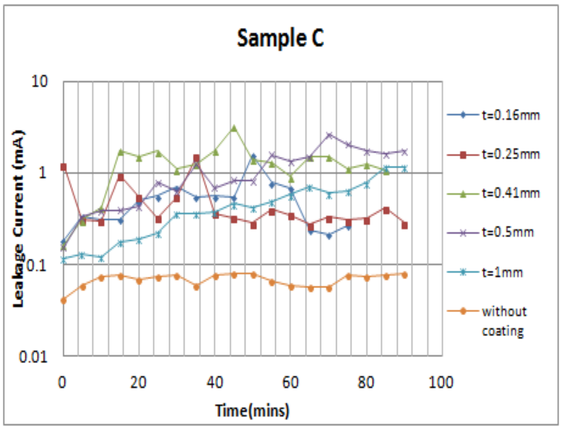

Figure 7c

Figure 7 a,b,c. shows the I set leakage current variation of sample A, B & C insulator respectively in Trial 2

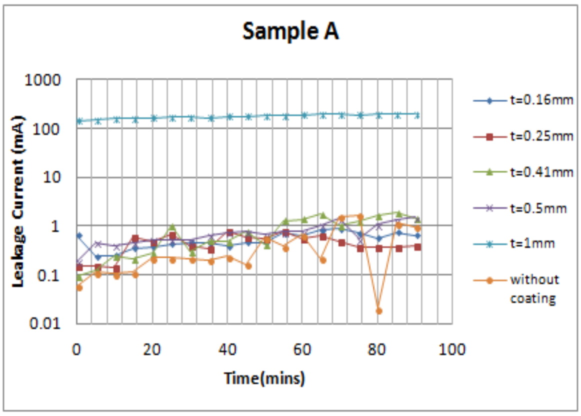

Figure 8a

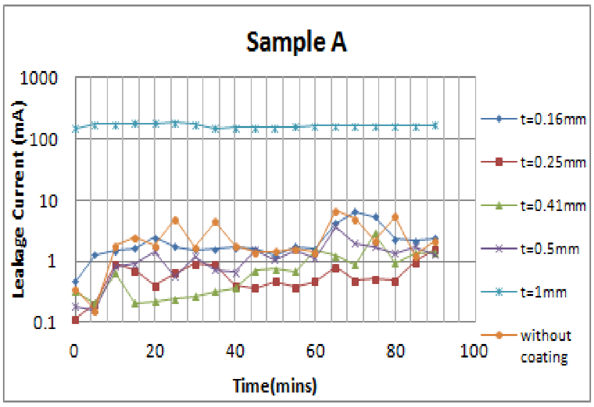

Figure 9a

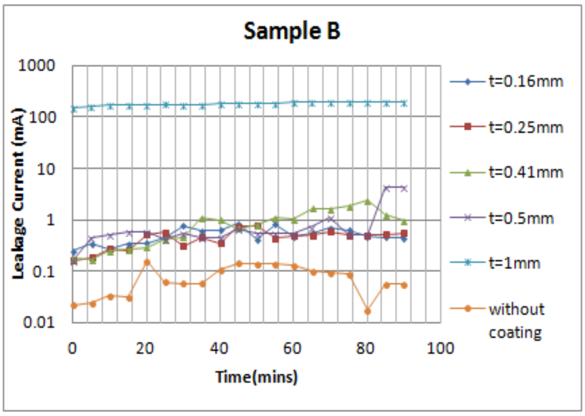

Figure 8b

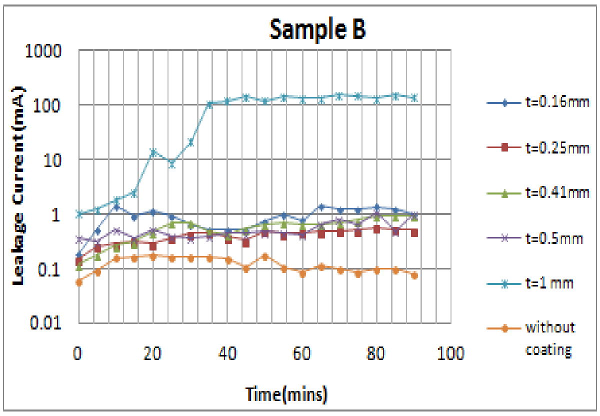

Figure 9b

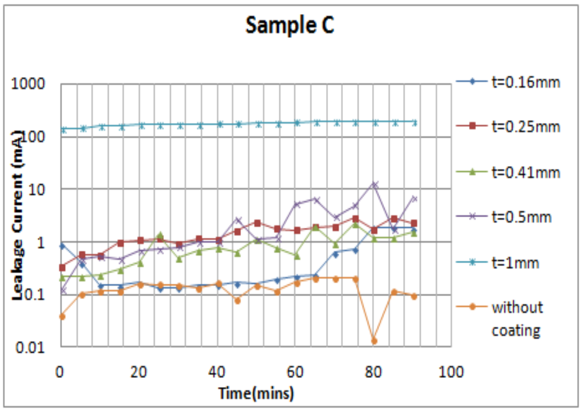

Figure 8c

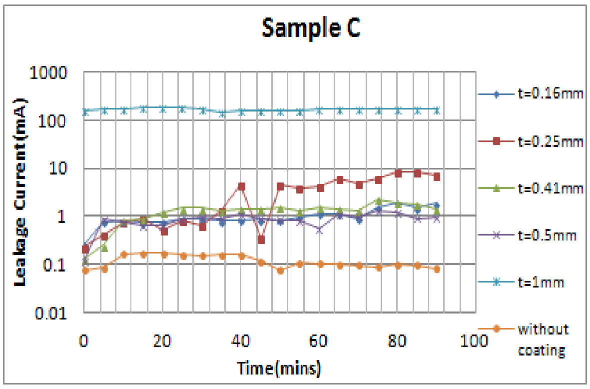

Figure 9c

Figure 8 a,b,c. shows the I set leakage current variation of sample A, B & C insulator respectively in Trial 3

Figure 9 a,b,c. shows the II set leakage current variation of sample A, B & C insulator respectively in Trial 1

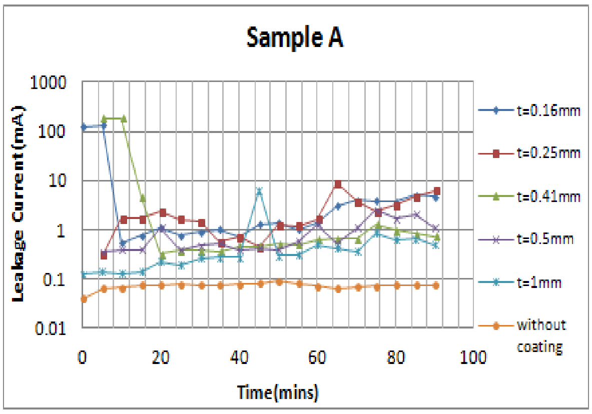

Figure 10a

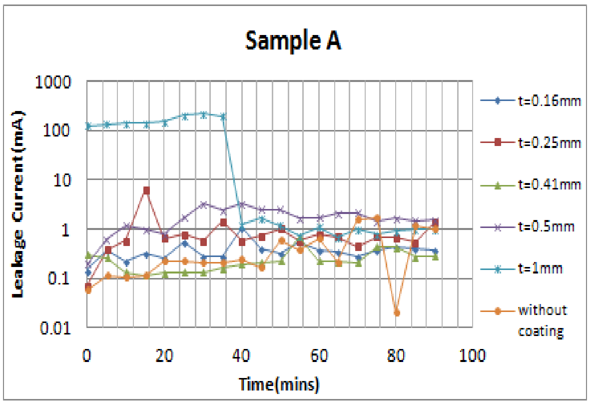

Figure 11a

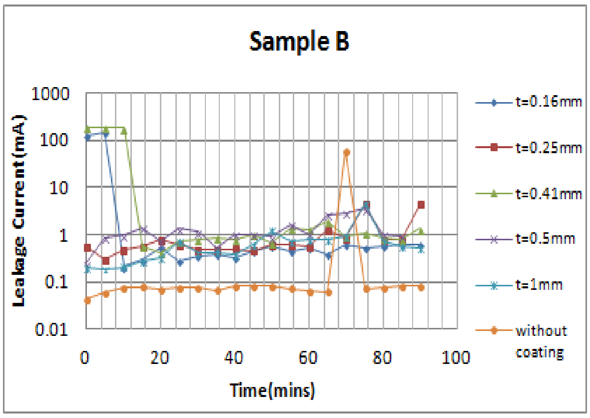

Figure 10b

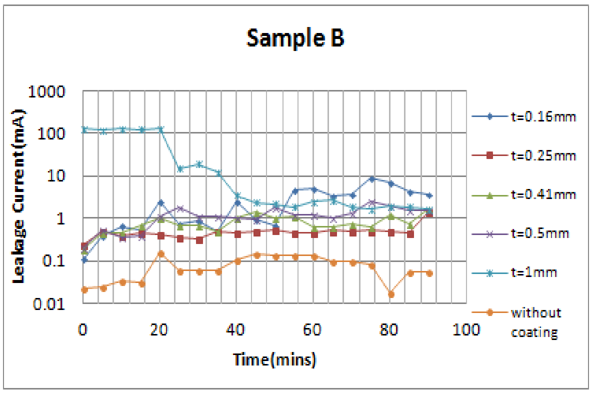

Figure 11b

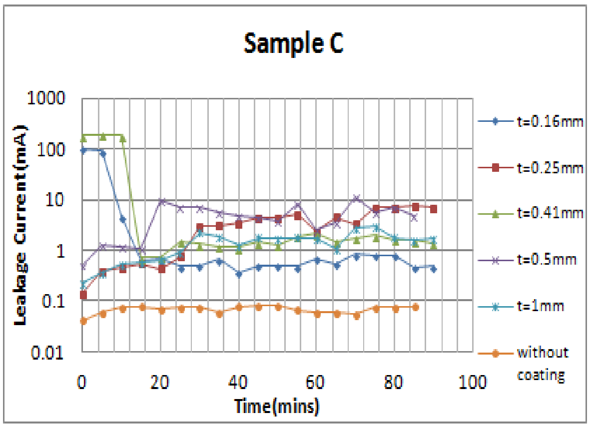

Figure 10c

Figure 10. a,b,c shows the II set leakage current variation of sample A, B & C insulator respectively in Trial 2

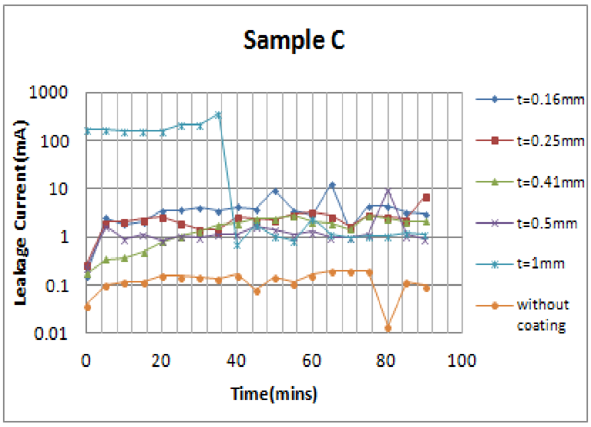

Figure 11c

Figure 11. a,b,c shows the II set leakage current variation of sample A, B & C insulator respectively in Trial 3

IV SUMMARY

From the above test results, it can be inferred that an increase in conductivity and thickness of the pollution layer on the surface of polymer insulator samples can result in

i. Current values being merged in a band of 0.1 to 1mA for thickness less than 1mm and increases upto 311.8 mA for I set and 367.4 mA for II set for 1mm thickness coating. (Figure 7 & Figure 9).
ii. But on repeating the experiments, it is observed that the same behavior is not seen because of formation of scintillations
iii. Scintillations carry away the pollution coating and dry zone will be more due to which the leakage current reduces and merges to band irrespective of thickness. (Figure 10 & Figure 11).
iv. The hydrophobicity transfer was effective for the pollution layer with lower thickness.

V.CONCLUSION

On the basis of experimental results, it can be concluded that the layer conductivity increases for both lower and higher thickness of pollution for polymer insulators. On repeating the experiments for the severity of 16 S/m, it can be seen that conductivity rises to a higher value for a thickness of 1mm pollution coating. On the other hand, for the pollution coatings less than 1mm, the increase in the conductivity is not seen much. However, on repeating the experiments, the same behavior is not observed for 1mm coating. This is because of the reason that the scintillations will take away some of the pollutants which result in the formation of the dry zone due to which conductivity reduces.

There was not much significant difference between the conductivities for all three types of insulator samples A, B & C. Additional research work needs to be performed to correlate the hydrophobicity of the polluted insulator to the variation in leakage current and consequently to correlate the thickness of the coating to hydrophobicity transfer

From the above work, it can be seen that the transfer of hydrophobicity may not happen for thicknesses greater than 1mm pollutants.

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REFERENCES

1. Muhammad Tariq Nazir, Jiang Xingliang, Shakeel Akram “Laboratory Investigation on Hydrophobicity of New Silicon Rubber Insulator under Different Environmental Conditions”, International Journal of Electrical & Computer Sciences IJECS-IJENS Vol: 12 No: 03.
2. F. Exl, J. Kindersberger. “Investigation of the Hydrophobicity Transfer Property of Polymeric Insulating Materials through Artificial Pollution Layers”, 2007 Annual Report Conference on Electrical Insulation and Dielectric Phenomena.
3. Wang Shaowu, Liang Xidong, Guan Zhicheng, Wang Xun “Hydrophobicity Transfer Properties of Silicone Rubber Contaminated by Different Kinds of Pollutants”, 2000 Conference on Electrical Insulation and Dielectric Phenomena.
4. Henrik Hillborg, Andrej Krivda, Lars E. Schmidt, Xavier Kornmann “ Investigation of Hydrophilic Pollution Layers on Silicone Rubber Outdoor Insulation”, 2010 Annual Report Conference on Electrical Insulation and Dielectric Phenomena.
5. Zhicheng Guan, Kang Niu, Gongmao Peng, Fuzeng Zhang, Liming WANG, Bernhard Lutz “Hydrophobicity Transfer Property of Silicone Rubber Material”, Vol 4, No 2, IEEE, July 2012.
6. D.A. Swift, C Spellman, and A. Haddad, “Hydrophobicity Transfer from Silicone Rubber to Adhering Pollutants and its Effect on Insulator Performance”, IEEE Transactions on Dielectrics and Electrical Insulation, Volume: 13, Issue: 4, Aug. 2006
7. HaifengGao, ZhidongJia, Zhicheng Guan1, Yingke Mao, Liming Wang1, Keneng Zhu “Evaluation of Electrical Insulation Properties on Aged Composite Insulators in Heavily Contaminated Areas” Conference Record of the 2006 IEEE International Symposium on Electrical Insulation.
8. Gutman and A. Dernfalk, “Pollution Tests for Polymeric Insulators made of Hydrophobicity Transfer Materials “.IEEE Transactions on Dielectrics and Electrical Insulation Vol. 17, No. 2; April 2010
9. Alexander Hergert Josef Kinderberger Christiane Bar, Ronald Barsch, “Transfer of Hydrophobicity of polymeric insulating materials for High voltage outdoor Applications”, IEEE Transactions on Dielectrics and Electrical Insulation Vol. 24, No. 2; April 2017
10. CIGRE 1999:Natural and Artificial Ageing and Pollution Testing of Polymeric Insulators
11. Florian Exl und Josef Kinderberger et al. ETG Fachtagung, “Round Robin Test for the Evaluation of the Hydrophobicity Transfer ability of Polymeric Insulating Materials” Grenzflachen in elektrischen Isoliersystemen vom 8. Bis 9, Marz 2005 in Hanau
12. Sunitha N.S, Dr. KN Ravi, Dr. R Prakash, Puspanjali “A Study on leakage current characteristics of Polymeric Insulators for different pollution layers”, IEEE, International Conference on Power and Advanced Control Engineering, ICPACE-2015
13. IEC 60507:2013 ‘Artificial Pollution Tests On High-Voltage Ceramic And Glass Insulators To Be Used On A.C. System’

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