Diagnostics of Degradation condition in Outdoor Polymeric Insulation Structures Using Neural Networks

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Abstract

In the present work, tracking phenomena has been studied with silicone rubber material under the AC and DC voltage, with ammonium chloride/Acid rain as contaminant. It is noticed that the tracking time depends on the conductivity and flow rate of the contaminant. The leakage current variation during tracking process categorized in to normal leakage current, surface discharge current and the current while tracking occurs. A diagnostic testing tool is suggested to monitor the surface condition of the insulator using Radial Basis Function Neural Network (RBFNN) technique using the leakage current. The methodologies adopted were detailed.

Introduction

Polymer materials are currently being used as high voltage outdoor insulation structures in distribution and transmission power systems because of their better dielectric properties,low weight and cost-effectiveness when compared to porcelain or glass insulators. When selecting the insulator, there are choices that encompass both material properties and design. There is an ever-increasing interest in the power industry worldwide to understand the degradation process and the performance characteristics of polymer insulating material in severe pollution conditions such as acid rain. The single largest problem yet to be overcome is the tracking and erosion of outdoor insulation structures.

Tracking, which is a peculiar phenomenon, occurs on the surface because of the creepage discharge resulting from surface contamination. It varies with surface field intensity, surface current magnitude and the state of discharge thereby induced, all of which are due to surface wetting and the degree of contamination. Once tracking occurs, the surface electrical insulation property is lost completely and it never recovers. In order to improve reliability and performance of insulation materials, the tracking phenomenon is being investigated worldwide.

Some polymeric materials, including silicone rubber and ethylene propylene diene monomer (EPDM), maintain their hydrophobic surface properties in the presence of pollutants over the surface of insulators. Most of the tracking studies carried out on polymer insulation are AC voltage[1,2]. In recent times, DC power transmission has become the preferred mode of power transmission and it has become necessary to understand the tracking phenomenon with insulation materials under DC voltages. In fact, due to greater accumulation of contamination over the insulators under DC voltages, the problem of tracking phenomena is even more severe compared to that with AC voltage, and the tracking phenomena under DC voltages have to be thoroughly understood.

Silicone rubber is used as a construction material for insulators. It provides hydrophobicity for a long time. With all this background knowledge, in the present work care has been taken to understand the tracking phenomena in silicon rubber materials by carrying out experiments according to IEC-587 [3], under AC and DC voltages, with Acid rain/NH_4C1 as contaminants. A separate experimental methodology has been adopted to understand the influence of acids on the surface condition of the polymeric material and on the tracking phenomena.

Experimental

In the present work, the tracking test was carried out following the IEC-587 test method [3]. The material used in the present work is silicon rubber. The gap distance between the top and the bottom electrode was adjusted to be equal to 50mm. A Schematic diagram of the experimental set - up and the electrode configuration used in the present work are shown in Fig.1 for DC voltages. If the sample is connected directly to the transformer without the rectifier circuit, the AC voltage test can be carried out. Acid rain and NH_4C1 solution were used as contaminants in the present study. The different flow rates were obtained using the control of the peristaltic pump. The composition of the acid rain could be obtained from our earlier paper [4].

The AC/DC voltage of 4.0 kv is connected to the top electrode and the bottom electrode is solidly grounded. The times to failure due to tracking are arrived at once the arc inception takes place near the bottom electrode and crosses two-thirds of the gap; otherwise the process lasts for six hours and the experiment is terminated. For the purpose of comparison, the study was carried out under AC voltages at the same voltage level. The pH value of the contaminant was measured using a Digital pH meter model DI 707 and the conductivity measured using a Lutron CD-4302.

Results and Discussion

Fig.2 shows the variations in tracking time of the virgin silicone rubber specimen under AC and DC voltages with NH_4Cl and the acid rain as the contaminant, at different conductivity levels. It is observed that no failure of specimen occurred due to tracking under the AC voltages with both the contaminants. It indicates silicone rubber insulation is an ideal structure for AC voltages. The filler content in the silicone rubber insulation is the ATH content, which act as an arc quenching agent thereby it keeps local temperature below the degradation level of silicone rubber. The filler is effective because they react either physically / and or chemically with the polymer to remove the degradation by products formed by the dryband arcing, from the surface of the material and hence prevents total degradation Under the positive DC voltage it is observed that the tracking is high compared to negative DC voltage. The variation in the tracking time is basically due to magnitude and duration of the leakage current flow over the surface of the insulation structure [5].

Fig.3 shows the variation in the tracking time of the silicone rubber specimen under the AC and DC voltages with NH_4Cl and acid rain as contaminant, at different flow rates. It is observed that under AC voltages, no specimen has failed in the specified time duration. Under the DC voltages, it is observed a drastic reduction in tracking time. This indicates that the local condition, which is a function of applied voltage and the degree of contamination, alters the characteristics of the material. Typical tracking formed zone pattern is shown in Fig.4

The RBFNN belongs to a class of neural networks known as feed-forward networks. These network have no feedback connection. Hence the relationship between the input and output is not a dynamic one. Representing an unknown function as a weighted sum of a family of basis function is a well known practise in the theory of interpolation. The Fourier series expansion of a periodic function and the polynomial expansion of a continuous function, as prescribed by Weierstrauss theorem, are examples of such representation. Functions that are radially symmetric around a centre were found to have some distinct advantage in multivariate interpolation [6]. An important example of such a function is the Gaussian function. The RBFNN is its most basic form consist of three layers: the imput, the output and the hidden layers. A three phase learning rule proposed by Moody-Darken has been used [7].

In the present work, to reduce the processing time, only first 10 components of the FFT are transferred to NN. The NN is trained using the FFT input and different condition as output (Such as surface discharge, local erosion and tracking). Initially the network is trained by applying signal from known sources, which are labeled according to their classifications.

Fig.5 shows the leakage current pattern measured during tracking process and its FFT patterns. It is observed under no discharge condition, only the supply frequency component was present. During erosion of the material fifth harmonic content is increased and at the time of tracking higher frequency components were observed.

The NN Results in the present study, at the time of training and the validation of results are given in Table - 1. Further data has to be acquired to train the neural network, to improve the performance of the methodology. It is realised that the RBF NN can be used as a diagnostic tool to understand the surface condition of the insulators.

Conclusions

The important Conclusion arrived at based on the present work are the following

- It is observed that the tracking time under the DC voltages is less compared to the AC voltage, irrespective of the type of the contaminant and the flow rate of the contaminant.
- It is observed the leakage current flow due to surface discharges have higher harmonic contents. While the tracking current have the fundamental frequency component high compared to the surface discharge current.
- It is demonstrated that the Radial Basis Function Neural Network technique is an ideal tool for condition monitoring of the surface condition of the insulators.

References

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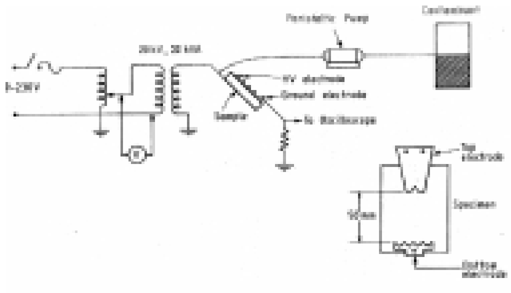

Fig.1 Experimental Setup

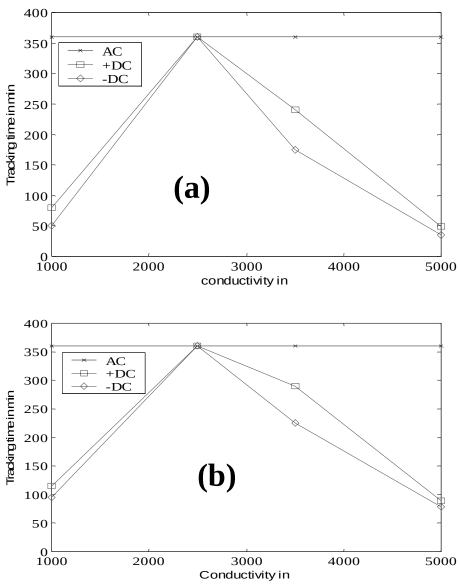

Fig. 2 Variation in tracking time with different contaminants
(a) NH_4 Cl (b) Acid Rain

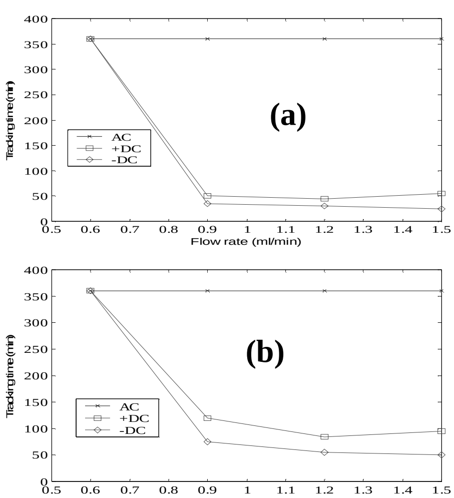

Fig.3 Variation in tracking time at different Flow Rate of the contaminant
(a) NH_4Cl (b) Acid Rain

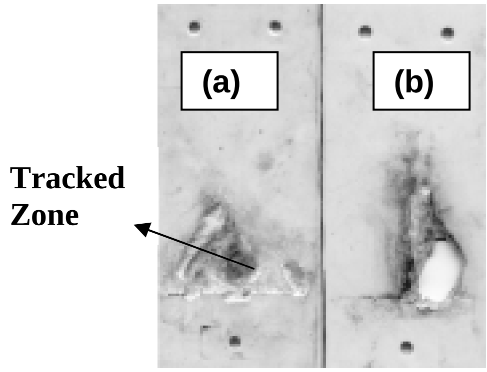

Fig.4 Tracking Formed Zone
(a) Tracked Zone (b) Local Erosion

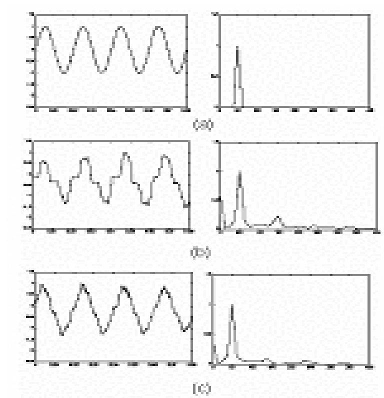

Fig.5 Leakage Current Measured and corresponding FFT plot obtained During Tracking Experiments

(a) Leakage Current at low voltages
(b) Surface Discharge Current
(c) Tracking Current

Table-1 Neural Network Results

Sl. no	Classification	A	B	C in %	Test result
1	Surface discharge	60	6	100	100
2	Local erosion	20	6	100	83.3
3	Tracking	22	6	100	100

A- No of patterns trained B- No of test pattern used C- Training Result