Contamination Performance of High Voltage Outdoor Insulators in Harsh Marine Pollution Environment

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Introduction

This paper describes the results of an experimental investigation carried out to compare the contamination performance and surface degradation of outdoor insulators made from different polymeric materials. The tested insulators included silicone rubber (SR), ethylene propylene diene monomer (EPDM) and high density polyethylene (HPDE), which were used for reference.

The physico-chemical changes and electrical parameters were measured during the test to characterize the performance of each insulator. The analysis showed that the electrical performance of the insulators was significantly affected by the combined application of saline contamination and acidic cold fog. However, during clean cold fog application, the insulator material showed localized surface degradation while there was no evidence of serious dents and cracks.

Saline contamination with normal cold fog generated a reduction of flashover voltage equal to 40%. This reduction was more pronounced in acidic fog conditions – 85%. The scanning electron microscopy (SEM) and hydrophobicity results showed that surface degradation is more strongly correlated with acidic cold fog contents than those of normal cold fog. It was found that SR insulators perform better than EPDM and HPDE in harsh environments.

Polymeric materials are widely used in high voltage engineering applications because of their multiple performances and major advantages over ceramic and glass insulators such as lightness, high mechanical strength, enhanced pollution execution, and physico-chemical and dielectric characteristics

However, climatic and thermal degradation of polymer materials are still major drawbacks to their use. The typical problem with polymeric materials is the aging and deterioration of insulator weather shed material but not surface flashover. Outdoor insulators and substations equipment experience a harsh environment in the form of ultra violet radiations (UV), ash, dust, humidity , and, more importantly, saline contamination and acidic cold fog near the shoreline is a major problem experienced by many utilities worldwide. The insulator begins to deteriorate when the saline contamination deposited over the top and bottom surfaces of the insulator combines with humidity of the fog, dews and light rain.

Methods

Different types of polymeric insulators with leakage distance of 55 cm and dry arc distance of 29 cm were investigated. The electrodes were made of copper, 0.9 mm in thickness, and placed on polymeric surfaces, as shown in Fig. 1. The circular (point) electrode is connected to the H.V. source and the square one to the ground. The test voltage was produced by a 10 kVA, 100 kV, and 50 Hz transformer. The supplied voltage can be increased manually or automatically at a rate of 1 kV/s.

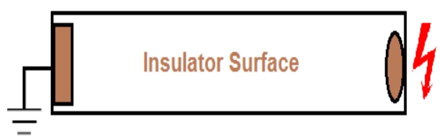

Figure 1. Shape of polymeric samples and electrodes.

The tests of polymeric insulation materials were carried out in an environmental chamber, as shown in Fig. 2, with adopted experimental setup for solid layer contamination deposition to simulate the natural climate condition near the shoreline. Acidic and normal cold fog was generated using the nozzle of a spray gun. The flow rate of fog was 3.0 $kg/h/m^3$

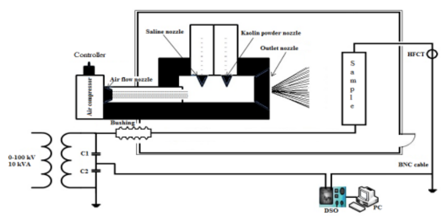

Figure 2. Experimental setup.

Table 1. Contents of acidic fog.

Ingredients	Contents (mg/l)
NH_4Cl	235
KCl	5.9
NaCl	25
$CaSO_4.2H_2O$	35.2
$MgSO_4$	29.5
HNO_3	170

Results

Surface Roughness

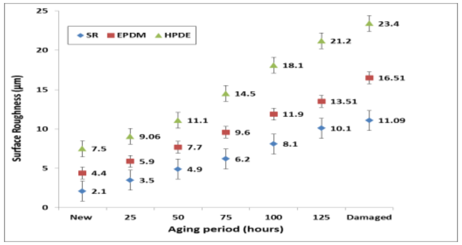

Figure 3. Surface roughness in acidic cold fog.

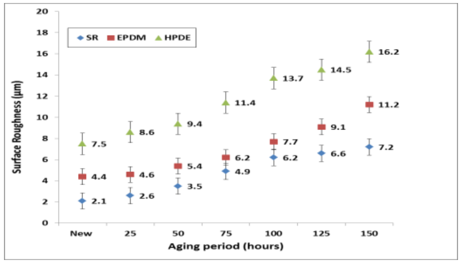

Figure 4. Surface roughness in normal cold fog.

Hydrophobicity

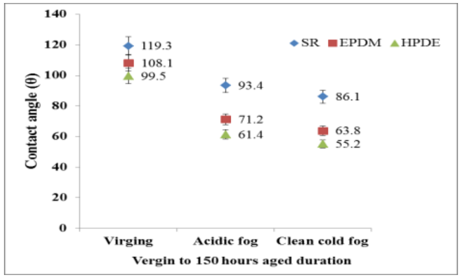

Figure 5. Contact angles of virgin and 150 hours aged samples of SR, EPDM and HPDE.

Surface Flashover

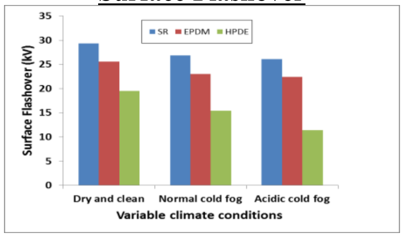

Figure 6. Surface flashover voltage (kV) Vs environmental conditions.

Scanning Electron Microscopy

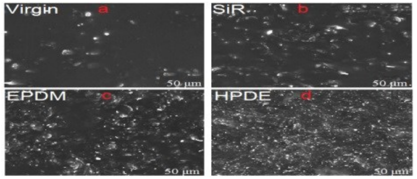

Figure 7. SEM picture in clean cold fog.

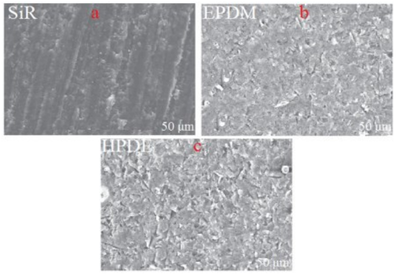

Figure 8. SEM picture in acidic cold fog.

Conclusions

Acidic cold fog has a large erosion and surface degradation effect on outdoor insulators. The impact of acidic cold fog was also found to be more intense than that of clean cold fog. SR material has better hydrophobicity and hydrophobicity transference than EPDM and HPDE. Also EPDM and HPDE insulators exposed to acidic cold fog and electrical discharges never recover their original hydrophobicity.