AGEING STUDY OF HIGH VOLTAGE INSULATOR WITH NANO FILLERS

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ABSTRACT

Silicon insulating materials with Nanofillers have attracted wide interest for enhancing electrical properties. In this work the experimental results of silicone rubber[SiR]nano based polymer outdoor insulators in salt fog ageing test based on IEC 62217 are presented. The specimen made of composite material by adding MgO and ZnO as Nano filler to Silicone Rubber as the base polymer with ATH. The samples prepared consists of Virgin without any nano filler as the reference , 10% MgO, 10% ZnO, 5% MgO, 5% ZnO nano-composite insulators. These five samples are kept in artificial salt fog chamber and aging test was conducted for a duration of 1000 hrs. Reduction of hydrophobicity, level of contamination are used as physical damaged inspection techniques were used to evaluate degree of surface deterioration. Differences in degree of surface deterioration were observed on all tested specimens just after salt fog test. It is observed that all the insulator withstood the test sample except with 10%MgO which have failed after 720 hrs of exposed to salt fog. All the samples performed well in inclined plane, tracking and erosion test. XRD on all samples before and after the test were carried out.

Keywords: Nano fillers, magnesium oxide, zinc oxid, hydrophobicity, Artificial Accelerated Salt Fog Ageing Test

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1. INTRODUCTION

Electrical insulation is the backbone of all electrical apparatus and power system networks. As the level of transmission voltage is increased, lightning, dynamic over voltages and performance of the exposed insulator under polluted conditions are the most important factors which is used to determine the insulation level of the system. Insulators in transmission lines are subject to different type of pollution under different environmental conditions. Under wet

condition due to light rain or fog and humid conditions cause flashover of polluted insulators and which leads to system outages. Hence, it is very much necessary to test the withstand capability of the insulators by artificial test methods.

It is well known that when the polluted layer of the insulator is moistened either by fog or light rain the leakage current flowing along the polluted surface of the insulator causes, drying and formation of dry bands. This disturbs the voltage distribution causing high voltages to appear across dry bands and cause partial arcs, also called scintillations. The early ageing is the main drawback of polymer insulators compared to conventional insulators. Polluted environments and those with high moisture levels in the environment, electrical discharges will develop on the surface of the insulation. In the long term, electrical discharges cause degradation of the polymer insulation in the form of electrical tracking and material erosion. To overcome the drawback of polymeric materials, micro/nano fillers are added. It is observed that, adding a few percent of nano-sized filler the properties of the original material can be drastically improved[3]. The main aim of this paper is to develop an insulator for high voltage application by adding MgO and ZnO nanofillers with SiR base material and experimentally studying its suitability for high voltage applications and to perform Salt fog ageing study on nano-composite based insulators under Ac excitation as per IEC 62217.

2. SAMPLE PREPARATION

The insulating material used for the experiment was prepared with MgO and ZnO as Nanofiller and Silicone Rubber as the base polymer[1]. The MgO preparation is easy, less time consuming and cheap in production as compared to other inorganic fillers. The ZnO nanofillers increase the relative permittivity and also the thermal conductivity of the composite[2]. It is considered as a better reinforcement filler for improving the mechanical properties of the silicone-rubber compound. Fig 1 and Fig 2 represents a SEM image of ZnO and MgO nanoparticles. These images substantiate the approximate spherical shape to the nanoparticles, and some of the particles exhibit agglomeration. It was observed that the size of the nanoparticle was around 1 microns.

Figure 1 SEM image of ZnO nanoparticles.

Figure 2 SEM image of MgO nanoparticles.

The fillers so prepared, were then mixed with silicone rubber to produce Nano-composites with desired concentration. For these samples, curing agents and colour are added rolled in form of sheets of 4mm thickness and then cut in the required shape and size as shown in Fig 3. These 4mm sheets are used for tracking & erosion test.

Figure 3 The samples SiR with nano fillers Composite of 4mm thick

The design of Composite insulator is as shown in Fig 4 generally consist of a fibreglass rod or hollow core for mechanical strength, external weather sheds made from either silicone rubber (SiR), EPDM or EPR metal fittings for attachment .

Figure 4 Design of Composite Insulator

The material was prepared by mixing the different concentration of nano fillers with SiR as the base polymer. The concentration of fillers were taken as percentage of the total weight of the base polymer. Total of five samples were prepared, a virgin sample without nanofiller was considered as reference. Silicon rubber based nano-composite insulators - Virgin, 5% MgO, 10% MgO, 5% ZnO, 10% ZnO, nano-composite insulators suitable for 11kV were prepared as shown in Fig 5.

Figure 5 SR insulators with nano fillers

3. EXPERIMENTAL SET UP

3.1. Inclined plane tracking and erosion test

Inclined plane tracking and erosion test is conducted on 4mm sample sheets prepared as per table 1. All the samples are tested as per IEC 60587 .

Table 1 The details of inclined plane tracking and erosion test.

Applied voltage	4.5kV
Distance between the electrode	50mm
Test duration	6hrs

All the samples have withstood the test of 6hrs. Not much tracking was observed on MgO and virgin samples but there was some tracking erosion on ZnO samples. Table 2 indicates the average depth of erosion and width of erosion on ZnO samples.

Table 2 Average depth of erosion and width of erosion

Samples	Average Depth of erosion	Average width of erosion
ZnO-10%	2.056mm	6079mm
ZnO-5%	0.864mm	4.32mm

HC levels from hydrophobicity test of all the five samples before and after tracking and erosion test are observed and are as shown in the table 3. It can be seen that there is no much change in the values even after 6hrs of tracking and erosion test. From table 2 it can be concluded that average width and depth of erosion is well within the acceptable limits.

Table 3 Hydrophobicity before and after tracking and erosion test

Samples	Hydrophobicity before test	Hydrophobicity after the test
MgO 10%	HC ₁	HC ₁
ZnO10%	HC ₂	HC ₂
MgO 5%	HC ₁	HC ₂
ZnO 5%	HC ₁	HC ₂
Virgin	HC ₁	HC ₁

3.2. Accelerated salt fog test

Five insulators were prepared and are numbered as shown in Table 4 was put in an ageing chamber for Accelerated ageing salt fog test for a duration of 1000hrs.

Table 4 Sample Insulators were numbered and then put in an ageing chamber

Sample.No	Material composition
1	SR with 10% weight of MgO
2	SR with 10% weight of ZnO
3	SR with 5% weight of MgO
4	SR with 5% weight of ZnO
5	Virgin SR insulator

The Details of Insulator Design are as given below

- Arcing distance: 190mm (I)
- Creepage distance: 346mm (A)
- Insulators weather sheds

$$I/A \leq 3$$

- NaCl content of water $8 \pm 0.4 \text{ kg/m}^3$
- Test voltage = $I/34.6 \text{ kV} = 10 \text{ kVrms}$

Allowed interruption

- for inspection 1hr (shall not be counted in test duration) → multiple
- For any break down 60hr (additional testing time of three times the duration of the interruption period shall be added) → once

Fig 6 and Fig 7 shows the test set up in an ageing chamber. Five insulators were mounted as shown. Insulators were exposed to continuous salt fog for a duration of 1000 Hours, leakage currents were monitored and tabulated.

Figure 6 Ageing chamber with four insulators with nano fillers and a virgin insulator.

Figure 7 Another view of the ageing chamber with insulators mounted for testing.

4. RESULTS AND DISCUSSION

Insulators made of HTV silicone rubber with ATH content having three different configurations, straight Shed, incline and alternate sheds, were tested continuously for 1000hrs in artificial salt fog chamber. Level of contamination, reduction of hydrophobicity were used as physical inspection techniques to evaluate degree of surface deterioration. On all the tested specimens differences in degree of surface deterioration were observed after 1000 hrs of salt fog test. All these samples are also tested for tracking and erosion and hydrophobicity test.

Insulators were put in an ageing chamber and was exposed to salt fog test NaCl content in water of 8 kg/m^3 and a voltage of 10kV rms was applied through out the test. Leakage currents were monitored at regular intervals and tabulated as shown in table 5.

Table 5 Leakage current after completion of 1000 hours of ageing.

Sample		Average Leakage current in μA
1	Sample with 10% MgO	Failed after 720Hrs
2	Sample with 10% ZnO	527.6
3	Sample with 5% MgO	543.6
4	Sample with 5% ZnO	422.2
5	Virgin sample	352.6

Plot of Leakage current with respect to the entire duration is plotted as shown in Fig 8 to Fig 12.

Figure 8 Plot of Leakage current with respect to the entire duration of 1000Hrs of sample with MgO 10%.

Figure 9 Plot of Leakage current with respect to the entire duration of 1000Hrs of sample with ZnO 10%.

Figure 10 Plot of Leakage current with respect to the entire duration of 1000Hrs of sample with MgO 5%.

Figure 11 Plot of Leakage current with respect to the entire duration of 1000Hrs of sample with ZnO 5%.

Figure 12 Plot of Leakage current with respect to the entire duration of 1000Hrs of virgin sample

It is observed that the average leakage current is approximately 400 μ A in sample 5 (virgin insulator under test) and in all other remaining insulators the leakage current during the test was around 600 μ A.

However MgO with 10% of nano filler failed after 720 Hours of accelerated ageing test. That particular insulator was removed from the chamber. Degradation of all the three sheds on the damaged insulator can be observed as shown in the Fig 13.

Figure 13 Damaged isolator MgO with 10% nano filler after 720 Hours of accelerated ageing test.

Table 6: XRD images of all samples before and after aging.

XRD analysis of all the samples before and after ageing are shown in the table 6. From the table it can be observed that after aging all the samples shows increase in crystallinity, except in 10% MgO and ZnO. Samples with 10% nano filler shows more impurity with background noise. It is also observed that insulator with 10% MgO as nano filler was removed from the test due to increase in leakage current and loss of mass.

This indicates lower concentration of nano filler is preferred. Optimization has to be done considering samples with lower concentration of nano fillers.

5. CONCLUSION

Virgin SR insulator, insulators with MgO and ZnO as nano fillers with a concentration of 5% and 10% were put to Accelerated ageing test for a duration of 1000 Hours. Inclined plane tracking and erosion test was carried out on 4mm thick samples as per IEC 60587.

All the five samples have passed tracking and erosion test.

Out of 5 insulators, insulator with 10% MgO as nano filler has failed and was removed from test after 720 Hrs. Hydrophobicity was regained after tracking and erosion. leakage current of all the samples during 1000 hrs of ageing test are within the limits.

From XRD analysis it can be concluded that lower concentration of nano filler performed better compared to 10% nano filler.

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