Application of PDC Analysis to Identify Effect of Electrical Tracking On Conductivity of LLDPE-NR Nanocomposite

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Abstract. Polymeric nanocomposites are widely used for high voltage outdoor insulating application due to their good electrical performance. Recently, SiO_2, TiO_2 and MMT nanofillers are being used as filler because there are listed as main nanofiller commonly used in electrical engineering. Natural rubber (NR) was used because the nature of the interphase is found to affect viscoelasticity and it develops several interphases with the Linear Low-Density Polyethylene (LLDPE) matrix. One of the problems associated with outdoor polymeric insulators is tracking of the surface which can directly influence the reliability of the insulator. This paper presents the outcome of an experimental study to determine the conductivity level of the LLDPE-NR compound, filled with different amount of SiO2, TiO2 and MMT nanofiller using Polarization and Depolarization Current (PDC) measurement technique. LLDPE and NR with the ratio composition of 80:20 were selected as a base polymer. Results show that different compositions as well as the surface physical conditions affect the PDC measurement results.

Introduction

Tracking and erosion of the weather shed is one of the many problems that associated with outdoor polymeric insulators which can affect the power system reliability. The development of electrical tracking from the surface discharge activity related to the flow of leakage current on the surface of the insulator under contaminated and wet conditions. Research had been done on tracking and erosion of silicone/SiO2 nanocomposite by [1]. Other than that, a research had also been done to study the tracking and erosion resistance of polymeric silicone rubber insulator which is filled with micron sized alumina trihydrate (uATH) and nano sized alumina (nALU)[2]. Results shows that the resistance to high voltage arcing and resistance to tracking and erosion at very low filler contents have high improvement. This surface discharge phenomenon can produce arcs burn to the polymer insulator material and then created carbonized tracks in the long run. Effect on tracking and morphological properties of LLDPE-natural rubber compounds for surface tracking and erosion resistance had been investigated by researchers [3,4]. They observed the carbon track development of blends LLDPE-NR filled with or without ATH when electrical tracking and erosion test using the inclined plane tracking test. Among the non-destructive monitoring techniques, Polarization and

Depolarization Current (PDC) measurement is gaining popular due to its ability to assess the conductivity of HV insulations within the initial periods after a DC steps voltage application. Polarization and Depolarization Current test had been applied to LLDPE-NR Nanocomposite on normal condition without any defect [5-8]. This technique is very useful to estimate conductivity and moisture contents of the insulations.

Sample Preparation

Polyethylene nanocomposites were prepared by melt mixing at 170 ^{0}C using a Brabender mixer with chamber size of 50 cm3. The mixer has a high shear force and the screw speed was controlled at 35 rpm with the mixing time of 2 min. The polymer nanocomposites were finally prepared into circle shape with diameter of 7.5cm and the thickness of 3 mm by hot melt pressing at 1 tone pressure at 170 0C for 10 min with concentrations of nanofiller of 1, 3, 5 and 7 % wt respectively.

PDC Theory and Experimental Setup

A. Insulation Conductivity Concept

From the measurements of polarization and depolarization currents, it is possible to estimate the dc conductivity σ, of the test object. If the test object is charged for a sufficiently long time so that $f(t+t_c) \cong 0$, the dc conductivity of the composite dielectric can be expressed as[9-11]:

$$\sigma \approx \frac{\epsilon_o}{C_o U_o}\left[i_p(t)\text{-}i_d(t)\right] \quad (1)$$

Here, σ is the composite conductivity, ε_o is the relative permittivity, C_o is the geometric capacitance, U_o is the step voltage, $i_d(t)$ is the depolarization current, and $i_p(t)$ is the polarization current. All the obtained data are run and plotted using MATLAB. From the plotted figures, the trend and pattern of the conductivity will be determined, either an upward or a downward trend is expected.

B. PDC Measurement Technique

The polarization currents measurement is performed by applying a dc voltage step on the dielectric materials and depolarization current is measured by removing the dc voltage source incorporating with a switch which turn on to short circuit at the under tested objects. The dc voltage applied was 1000 V for about 10,000 seconds for polarization and depolarization time. The PDC measurement is shown in Fig.1. PDC testing was done at IVAT, UTM.

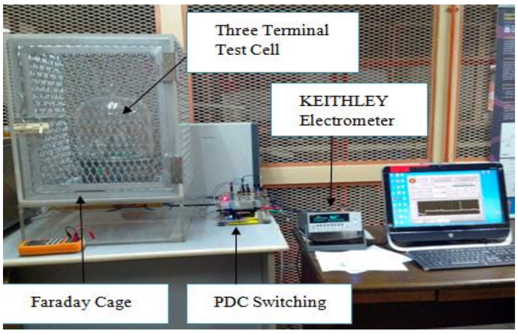

Fig.1: PDC measurement set up

C. Electrical Tracking Measurement Technique

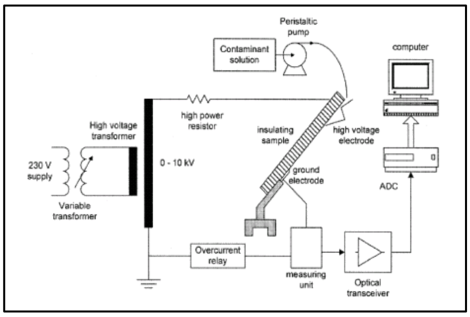

Fig.2: Schematic Diagram of IPT setup

Inclined plane tracking test is a standard test to evaluate the electrical tracking and erosion performances. The standards that being used is IEC 60587.The equipment was connected as shown in Fig. 2. The voltage stress was applied across the sample by using high voltage transformer. Contaminant of ammonium chloride equal to 1 gram together with de ionized water and non-ionic wetting agent such as Triton X-100 was flowed down through the specimen surface with the flow rate of contaminant solution of 0.10 ml/min.

Eight layer of filter paper are clamped between top electrode and sample as a reservoir of the contaminant. Duration of six hours test was conducted. Time-to-track test method was used which voltage applied to be fixed at 4.5 kV until six hours or breakdown occurred.

Results and Discussions

Conductivity Variation Analysis

This trend depends on polarization current and depolarization current values. Electrical tracking test affected the properties of sample. Electrical tracking develops from surface discharge activity associated with the flow of leakage current on insulator surface under wet and contaminated conditions. Arcs created from this surface discharge phenomenon burn the polymer insulator material and create carbonized tracks in the long run.Tracking test had given different carbon track effects and leakage current value for each sample. It is clearly shown that the tracking test affects the conductivity of the sample. Each of the samples has increased in conductivity because of tracking test that created degradation to the sample. This tracking phenomenon can result in the increment of leakage current as well as the development of carbon track.

Fig.3 shows the conductivity variations for sample R and sample group A after electrical tracking effects. It shows that, sample A1, A3 and A5 have lowest conductivity compared with others. These three samples almost give similar values. Surface material for sample A7 has been most degraded due to the electrical tracking which is similar to the outdoor ageing condition. The effects from the tracking test had contributed to highest conductivity. Fig.4 shows the conductivity variations for sample R and sample group B effects of electrical tracking. Sample B5 has lowest conductivity values.

Fig.5 shows the conductivity variations for sample R and sample in group C effect of electrical tracking. Lowest conductivity can be seen from sample C5 as compared to the other samples in group C. The degraded sample due to electrical tracking makes the moving charges increases and this can lead to a higher polarization current and conductivity.

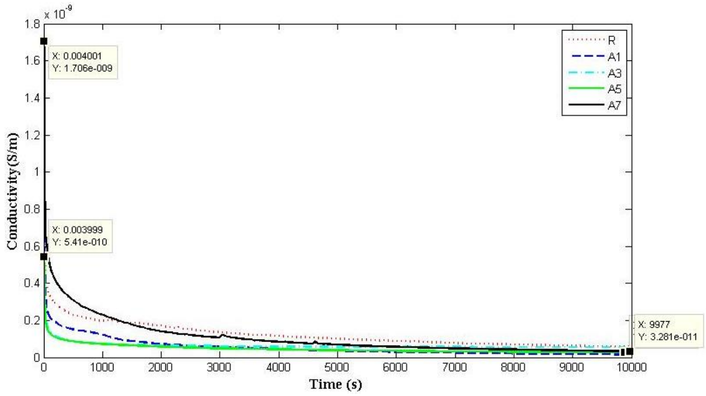

Fig.3**:** Conductivity variations for sample LLDPE-NR and sample LLDPE-NR/SiO_2 at different amount of nanofiller after electrical tracking test

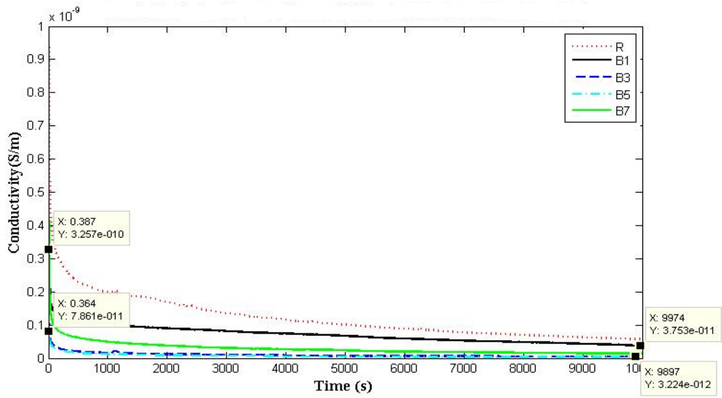

Fig.4: Conductivity variations for sample LLDPE-NR and sample LLDPE-NR/TiO_2 at different amount of nanofiller after electrical tracking test

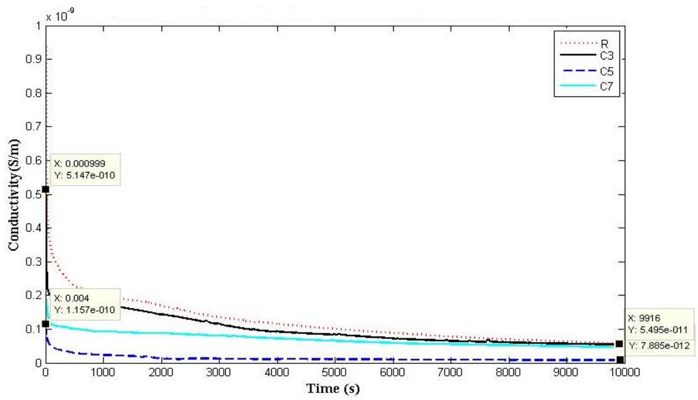

Fig.5**:** Conductivity variations for sample LLDPE-NR and sample LLDPE-NR/MMT at different amount of nanofiller after electrical tracking test

Based on the results, sample B5 has lowest conductivity value as compared with others. Sample with amount of 5 %wt TiO_2 nanofiller becomes the best sample.

Conclusions

Conductivity of pure LLDPE, LLDPE-NR/ and LLDPE-NR/SiO_2 samples with effect of electrical tracking has been studied in this paper. Based on the PDC measurement results, it was observed that sample LLDPE-NR/TiO_2 at 5 wt% (sample B5) has become the best sample among all sample in group A, B and C in term of lowest conductivity level of 3.224 x 10^{-12} S/m for effect of electrical tracking respectively. The hydrophobicity properties of TiO_2 nanofillers play a role and contribute to lowest conductivity. The trends of the conductivity variation were found to be dependent on the polarization and depolarization currents. These trends can be used to evaluate the condition of the insulation.

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