PARTIAL DISCHARGE CHARACTERISTICS OF LOW-DENSITY POLYETHYLENE AND EFFECT OF NANOFILLER USING PULSE SEQUENCE ANALYSIS

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ABSTRACT This paper describes the partial discharge (PD) characteristics in leaf-like type of low-density polyethylene (LDPE) with nano-Magnesium Oxide (MgO) samples which were investigated using the pulse sequence analysis (PSA) method. This method enables to evaluate the individual sequences of PD events in data sets instead of just accumulated data sets as commonly used in investigations of PD characteristics with the conventional methods. The nano-MgO filler amount was 0, 1, 5, and 10%, respectively. The samples were loaded with a ramped AC-voltage 1.14 kV_{rms}/min up to 4096 PD pulses had occurred. The sensitivity was set about 16 pC. The results revealed that the discharge characteristics change during the growth of an electrical tree depending on sample types and filler amount.

1. INTRODUCTION

Polymeric insulating materials such as polyethylene, epoxy, silicone rubber, etc are widely used in electrical power insulation due to their advantages in electrical and mechanical properties. Partial discharge (PD) investigations in polymeric insulation materials have been performed since decades because the application of polymeric materials in electrical power insulation system increased. However, the PD characteristics during electrical treeing, the relevant degradation process in polymeric materials, is still of interest, because the analysis of PD processes is helpful to understand the degradation phenomena and thus can be used for improvement of the materials.

In this research work, PD characteristics in leaf-like type of low-density polyethylene (LDPE) with nano-Magnesium Oxide (MgO) samples were investigated using the pulse sequence analysis (PSA) method. This method enables to evaluate the individual sequences of PD events in data sets instead of just accumulated data sets as commonly used in investigations of PD characteristics with the conventional methods.

In our previous works, investigation on PD characteristics of neat polyethylene (PE) using PSA have been performed (Patsch, R., et. al., 2007a, Patsch, R., et al., 2007b, Arief, Y. Z., et al., 2007c)

2. EXPERIMENT

2.1 Sample Preparation

150 µm thick of leaf-like specimens were used in this research work. A tungsten wire with 50 µm in diameter is utilized as a needle electrode. The needle tip was formed by electrolytic polishing; its tip radius was 2 µm. The tungsten needle was sandwiched between two nanocomposite films and hot-pressed down to 150 µm in thickness. The specimen sheet was fixed between a slide glass and a cover glass by Aron Alfa adhesive (ToaGosei Ltd.). Aluminum foil was applied as a counter electrode at a distance of 0.4 mm from the tip of tungsten needle (Kurnianto, R. et. al., 2006).

The polymeric sample is low density polyethylene (LDPE) with different content of nanocomposite fillers, namely 0, 1, 5, and 10%, respectively. In this work, they are so called as NC0, NC1, NC5, and NC10, respectively.

2.2 Technique

The samples were loaded with a ramped AC-voltage 1.14 kV_{rms}/min up to 4096 PD pulses had occurred. The sensitivity was set about 16 pC. The pulse signals were automatically stored in a PC. The PD characteristics like discharge rate, phase of PD occurrence, voltage difference at which PD occurred, etc were observed.

The experimental setup for this work is shown in Fig. 1. The apparent PD charge is detected by a coupling device in the loop with the coupling capacitor Ck and sent to a PD detector. A band pass filter with a range 40-400 kHz was used in the measurement amplifier. Using an A/D converter, the PD signal is converted and stored in a PC. The time window for the measurement of the oscillating signal was set to about 51.2 μs with a pre-trigger time of 10%. Each sample was injecting the high voltage for thirsty times. Experimental results were analyzed using Pulse Shape and Pulse Sequence Analysis (PSA).

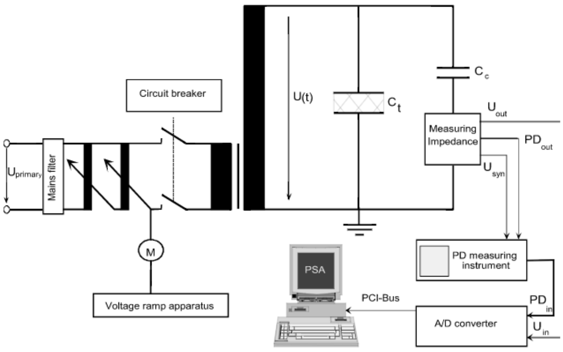


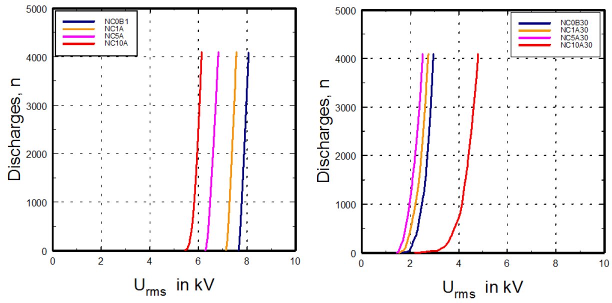
Fig. 1 Experimental setup for PD measurement.

3. ANALYSIS

Fig. 2 shows the PD charge occurrence number (n) for all sample types. As can be seen clearly from the figure, PD was occurred early in nanocomposite samples, while for neat LDPE, having partial discharge inception voltage (PDIV).

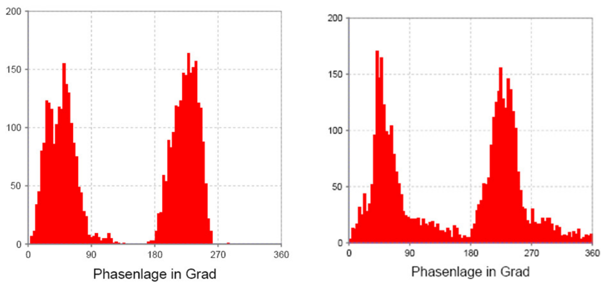
Figs. 3. 4, and 5 show the phase occurrence of PD charge for neat LDPE and LDPE added with MgO nanofiller. There is a slightly difference of phase occurrence at 1st measurement compared to 30th measurement for all sample types.

Fig. shows the discharge intensity in pC for neat LDPE and LDPE added with 10% of MgO nanofiller. It was found that the nanocomposite sample has lower discharge intensity compared to the neat LDPE sample.



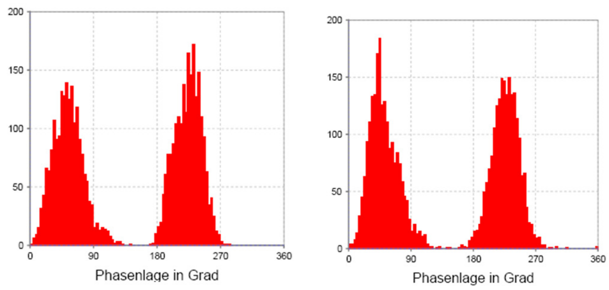
(a) 1st measurement (b) 30th measurement

Fig. 2 Discharge rate of applied voltage for all sample types.



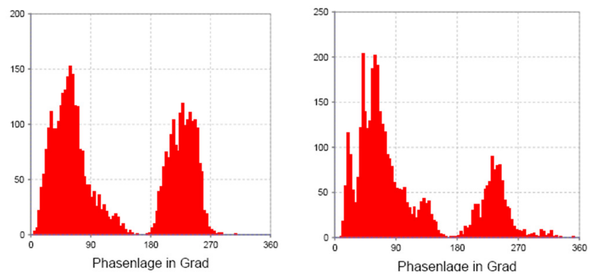
(a) 1st measurement (b) 30th measurement

Fig. 3 Phase occurrence of PD charge for neat LDPE sample.



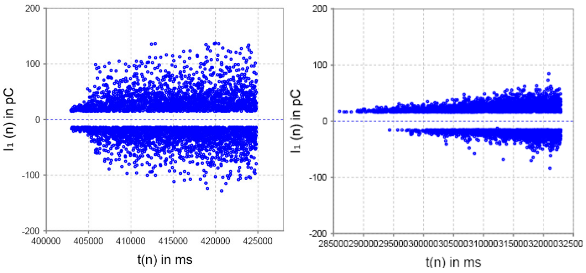
(a) 1st measurement (b) 30th measurement

Fig. 4 Phase occurrence of PD charge for LDPE added with 5wt% of MgO nanofiller sample.



(a) 1st measurement (b) 30th measurement

Fig. 5 Phase occurrence of PD charge for LDPE added with 10wt% of MgO nanofiller sample.



(a) neat LDPE (b) LDPE with 10wt% of nanofiller

Fig. 6 Discharge intensity in pC at 1st measurement.

In general for electrical treeing in polyethylene discharges occur in both polarities of the applied AC-voltage. For discharges in the positive half waves the magnitudes of the discharges are higher, show the ‘standard shape’, and in most cases only one discharge per half wave occurs. Discharges in the negative half waves are (in general) smaller; the first peak is usually ‘standard’, while in some cases the shape of the second peak may be changed. In some cases discharges occur with time differences in the region of some ten **µs**, and hence more than one discharge are found in the measuring window of about **50 µs** length.

For discharges in the negative half waves electrons are injected from the needle tip that move towards the flat electrode thus reducing the opposing negative field very quickly and thus consecutive negative discharges can occur in the same negative half wave. Only discharges at very high negative voltages are followed by a discharge in the following positive half wave. Discharges in the positive half waves of the applied voltage accelerate electrons towards the needle, thus leaving behind positively charges molecules. While the electrons enter the metallic needle, the positive charges generate a local electric field that modifies the electric field generated from the externally applied voltage. The field of the charged molecules does not change in the time scale of a few tens of ms (Arief, Y. Z, et. al., 2007c).

4. CONCLUSION

The results revealed that the discharge characteristics change during the growth of an electrical tree depending on sample types and filler amount. Furthermore the analysis suggested that space charges around the tip of the needle electrode generated by the PD events play an important role. Compared with the conventional evaluation method on the base of the phase angles of occurrence, the PSA has proven to be one of powerful tool to investigate PD and in order to gain a better understanding of the discharge phenomena in polymeric insulating materials and other insulation systems. Effect of electrical ageing gives a significant change in PD characteristic in PE

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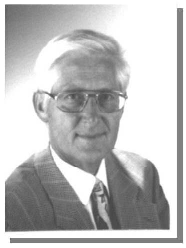

Rainer Patsch, was born in Lauban, Silesia, Germany in 1944. He graduated in 1969 as a Diplome-Physicist at the J.-W.-Goethe-University in Frankfurt, Germany. In 1980 he got his PhD in **Physics** from the University in Kassel, Germany. From 1969 to 1986 he was with the **Central Research Institute of AEG.** Main subjects of his work were basic studies on advantages and problems in the use of polymers in high voltage applications, e.g. the influence of electrical and water treeing in power cables, test methods and preventive measures. He was a **Full Professor** and head of the **Institute of Materials & Diagnostics in Electrical Engineering** at the University of Siegen, Germany (1986-2009). Fields of interest are the basic understanding of ageing and degradation processes in insulating materials in power equipment, especially under service and environmental conditions, and the development of **diagnostic** methods to **monitor the ageing of electric equipment**, especially with regard to the influence on reliability and service life.