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Partial discharge characteristics of nanosilica biopolymer under AC voltage

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Abstract. The dielectric properties of LDPE-NR biopolymeric insulating materials can be improved by adding the silica nanoparticles in a certain percentage of weight into the composite. In the present study, four types of bionanopolymeric samples were prepared. To each sample, the nanosilica particles with a weight percentage of 1.5%, 3%, 4.5% and 6% a were added. To see the electrical characteristics, the four samples were placed under the AC high voltage for 1 hour and the partial discharge (PD) signals were recorded continouesly in that period of time. The results show that the number of positive and negative PD pulses for each silica sample after 60 minutes of testing was not the same for all samples. The that samples with a higher percentage of nano silica had fewer PD pulses. This indicates that nanosilica particles can improve the PD resistance of LDPE-NR insulation materials.

1. Introduction

Electrical insulation material that is widely used today is polymer-based insulation because it has some advantages compared to other materials [1] such as having water repellent properties, thermal properties, and good dielectric properties which are characterized by high penetrating stress levels. Also, polymer materials are also lightweight and simple in the manufacturing process [2, 3]. One of the inorganic polymer materials that have good electrical insulating properties is low-density polyethylene (LDPE) with a density of 0.91-0.925 gr / cm3 which can have short or long branches. LDPE has several advantages including strong mechanical properties, a bit translucent, high strength at low temperatures, resistant to chemical changes, can be made in the form of transparent thin films and has good electrical properties. To produce a polymer composite characterized by biopolymer, LDPE can be mixed with natural rubber (NR).

Natural rubber is a hydrocarbon compound containing a carbon atom (C) and a hydrogen ahom (H). Natural rubber has a general characteristic, namely a slightly dark brownish color, with a specific gravity of 0.91-0.93, the highest use temperature of 90^{o}C, softened at a temperature of 130^{o}C and decomposed at around 200^{o}C. SIR is an abbreviation of Standard Indonesia Rubber which is a technical specification of Indonesian production, one of which is determined by testing characteristics such as dirt, ash content, and PRI. SIR is divided into three categories, namely SIR 10, SIR 20, and SIR 50. To obtain a composite insulation material, nanosilica can be added to LDPE-NR which is the most commonly used nonsilicate ceramic material related to its high electrical resistance and resistance to thermal shock and corrosion. The boiling point of silica is 2230°C and melts in 1600°C-1725°C with a molar mass of 60,08 g mol^{-1}. Silica includes good heat and electricity insulators[4].

Mechanical, thermal, and dielectric properties of polymer materials can be improved by adding certain nano-sized particles called nanocomposite materials [5]. Nanocomposites can increase the resistance of insulating materials to partial discharge and thermal properties [6-8]. In its use as an insulating material, environmental conditions such as gases that fill cavities, pressure, humidity, and temperature have a significant influence on nanocomposite-based insulation [9]. For this reason, isolation resistance analysis such as partial discharge testing is necessary to diagnose the degradation rate of nanocomposite material [10-12]. Also, several congenital defects can affect the performance of the polymer material is in the form void defects, impurities (impurities), and protrusions (protrusion) on the surface of a semiconductor or a conductor and insulating polymer in the production process. These defects can result in high electric field strength (electrical stress) on the part of the defect and cause accelerated aging in polymer isolation polymer [13, 14].

The development of nanocomposite insulation materials requires a comprehensive study so that the phenomena possessed by the material can be fully understood [15]. In this research, partial discharge characteristics were examined in new nanocomposite materials made from LDPE-NR and nanosilica fillers. This study will examine the effect percentage weight of nano silica to partial discharge characteristic of low-density polyethylene (LDPE) and natural rubber (NR) biopolymer.

2. Experimental

In the present study, biopolymer non-composite materials were used by LDPE and NR with a fixed composition of 80:20 of the total sample weight. This composition applies to all bio-nanocomposite samples. Addition of nano silica is 1.5%, 3%, 4.5% and 6% by weight of LDPE-NR. The total sample weight in one treatment is 60 grams with a weight of LDPE is 48 grams and natural rubber 12 grams. The LDPE-NR mixture and silica were put into the mixing chamber simultaneously namely the rheomix machine at 150°C with a rotor rotation speed of 60rpm for 12 minutes. After this process is complete, the mixture is stored in an oven for 24 hours at 70°C. The next step of the insulation sample is molded using Hotpress Collin 300p in 4 phases.

Partial discharge (PD) measurements were carried out using a PD measurement system produced by Haefely Instrument type 9332. This testing equipment used a 9230 coupling capacitor series which was carried out on a test sample via a Z impedance using a high-voltage ball-field electrode.

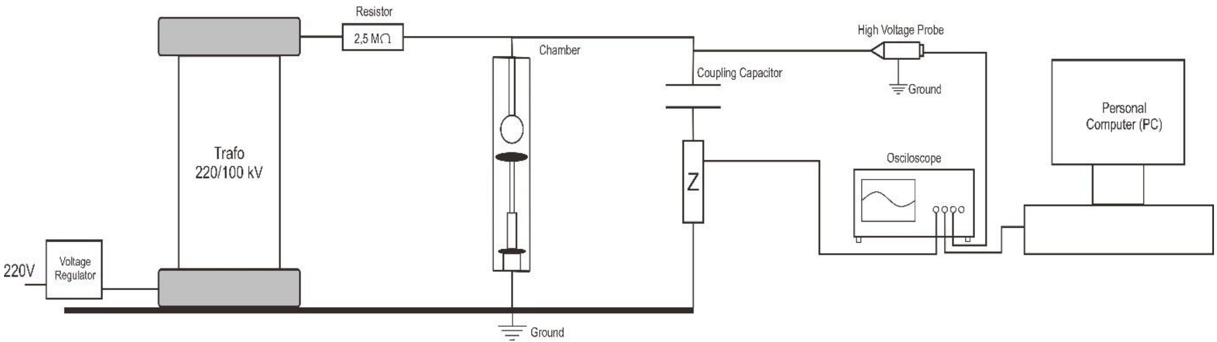


Figure 1. PD experimental setup.

3. Result and Discussion

3.1 PD Pulses

PD pulses can be represented in the form of a sequence of pulses in each cycle or the form of n-t patterns. Where n is the number or number of PD pulses that occur, and t is the time when PD occurs.

The number of pulses is seen in the positive cycle and the negative cycle of each silica variation. Figure 2 shows the characteristics of the number of PS pulses from the isolation samples of silica nanocomposites with various compositions at 28^{o}C. It can be seen that the number of PD pulses generally tends to decrease during the testing period both in the positive cycle and the negative cycle. In the early minutes, the number of PD pulses is the largest for all samples. The distribution of PD pulses is not the same for each cycle of data, for example, the PD pulses decrease after the initial minute but again rises in the case of a positive cycle of silica samples. In the positive cycle, silica 1 has the most number of PD pulses, and silica 4 has the least number of PD pulses, as well as in the negative cycle. In the positive cycle, the number of pulses of PS silica 1 decreased from 69 to 47, silica 2 decreased from 54 to 42, silica 3 decreased from 33 to 24, and silica 4 decreased from 29 to 22. In the negative cycle, the number of PD silica 1 pulses decreased from 89 to 60, silica 2 decreased from 73 to 42, silica 3 decreased from 52 to 36, and silica 4 decreased from 41 to 22. The addition of silica in the LDPE-NR composite can reduce the PD pulses.

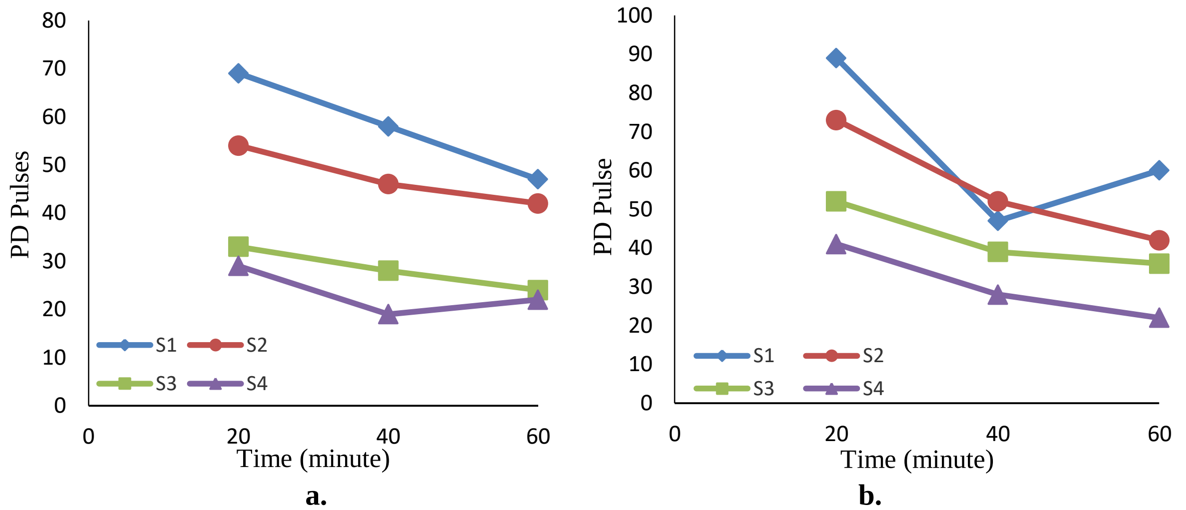
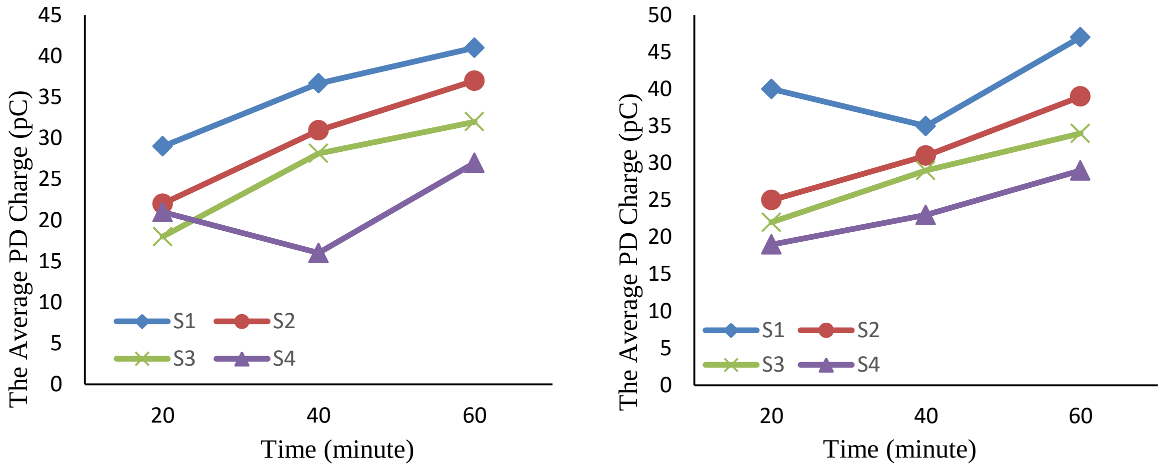


Figure 2. Characteristics of PD pulses at 28^{o}C; **a.** Positive Pulse, **b.** Negative Pulse

3.2 Average PD Charge

The average PD charge can be represented in the order of the average PD charge in each cycle or the form of an average Q-t pattern. Where the average Q is the average PD charge pulses, and t is the time when PD occurs. The average PD charge is seen in the positive cycle and the negative cycle of each silica variation. Figure 6 shows the average PD charge characteristics of PD from silica nanocomposite samples with various compositions at 28^{o}C for the time function. Seen the average PD charge tends to rise during the testing period both positive and negative cycle, but there is a decrease in the average of PD charge in the middle of the minute and back up in the next minute on positive cycle silica 4 and negative cycle silica 1. In the positive cycle average PD charge silica 1 rises from 29 pC to 41 pC, silica 2 from 22 pC to 37 pC, silica 3 from 18 pC to 32 pC, and silica 4 from 2124 pC to 27 pC. While the negative cycle, the average PD charge silica 1 increased from 40 pC to 47 pC, silica 2 from 25 pC to 39 pC, silica 3 from 22 pC to 34 pC, and silica 4 from 19 pC to 29 pC. The average PD charge silica 1 is larger, than the smallest is silica 4.



a. **b.**

Figure 3. Characteristics of average PD charge pulses at 28°C; **a.** Positive Pulse, **b.** Negative Pulse

4. Conclusion

The partial discharge testing of four compositions of bionanopolimeric composites samples was successfully carried out. It was found that the number of positive and negative PD pulses for each silica sample after 60 minutes of testing was not the same for all samples at different temperatures. It was also found that samples with a higher percentage of nano silica had fewer PD pulses. This indicates that nanosilica particles can improve the PD resistance of LDPE-NR insulation materials.

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