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ScienceDirect

Energy Procedia 117 (2017) 260–267

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Application of Surface Modified XLPE Nanocomposites for Electrical Insulation of High Voltage Cables- Partial Discharge Study

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Abstract

This paper presents the experimental results of PD test using IEC 60270 standard for 0-27.5 kV range with the PD characteristics of XLPE nanocomposites for un-modified, agglomerated and Octylsilane modified silica nanofillers using nano 1, 2, 3, 4, 5, 10 wt %. The unmodified and agglomerated nanocomposites show the lowest PD activity at nano 5 wt %. The surface modification of nanofiller helps to reduce the PD formation marginally due to improved nanofiller dispersion. Octylsilane surface modified XLPE/silica nano 3 wt % exhibits the lowest PD activity. To prove the further suitability of Octylsilane surface modified nanocomposites over unmodified and agglomerated nanocomposites, the discharge inception voltage (DIV) and breakdown voltage (BDV) have also been measured using IEC 60270 standard. The hypothetical theory has been proposed to explain the role of nanofillers in reducing PD activity and increasing DIV as well as BDV.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: Crosslinked polyethylene; nanocomposites; electrical insulation; partial discharge; morphology; surface modification

1. Introduction

The field of nanocomposite electrical insulations (nanofiller + electrical insulation) has gained a substantial attention of the researchers in recent years. The inclusion of nanofiller to the insulation material leads to the marginal improvement in its dielectric, electrical, thermal properties etc [1-5]. But, the agglomeration (or aggregation) of the nanofillers has questioned its reliability and application. The agglomerated nanocomposites have reported the

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1876-6102
Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.
10.1016/j.egypro.2017.05.130

adverse performances such as decreased breakdown strength and other unfavourable electrical performance. This type of behaviour biases the conclusion of different theories established to explain the role of nanofiller in the improvement of electrical, mechanical, thermal etc properties of nanocomposites. Recently, it has been found that the surface modification (generally by Silane agents) of the nanofillers acts as an adhesion between nanofillers and polymer matrix which improves the dispersion of nanofillers. This improves the dielectric properties such as AC and DC breakdown strength, electrical and water tree resistance while reducing the space charge, permittivity, dielectric loss etc [6-10]. Hence, this favours the application of surface modified nanofillers with base materials such as epoxy resin, polyvinyl chloride, XLPE etc. for electrical insulation.

XLPE is considered as a suitable insulation material for the high voltage transmission of electrical power. But, the increased voltage rating of XLPE based electrical cables has also increased the probability of formation of water tree, electrical tree, PD etc. inside the insulation. The inclusion of nanofillers improves the dielectric, electrical, thermal etc properties of the insulation materials. Recently, nanocomposite materials have been developed which procrastinate PD and avoid further consequences. The presence of nanofiller hinders the PD propagation inside the insulation. But, the dispersion of the nanofillers inside the polymer matrix plays a crucial role in this hindrance. The aggregation or agglomeration of nanoparticles has limited its application in the field of dielectrics and electrical insulation. To avoid the agglomeration, the nanofillers are modified using chemical coupling agent which improves the dispersion of the nanofiller considerably. Although the addition of nanofillers convinces its application in XLPE material to improve the foresaid properties, very less research in the field of PD has been carried out. The authors have already reported the PD study of XLPE/silica un-modified nanocomposites in [11]. In addition to this study, this paper presents the PD study agglomerated and Octylsilane modified XLPE/silica nanocomposites. It is expected that the agglomerated nanocomposites may deliver almost same performance as that of unmodified or virgin samples.

This paper is organized as follows: Section 1 explains the introduction to the PD and nanocomposite applications. Section 2 explains the methodology and characterization study of prepared nanocomposites. Section 3 & 4 comprises of experimental method followed and results of the testing. The enhancement attributed to the nanofillers is explained in Section 5 with the help of hypothetical theory.

2. Preparation and Characterization

XLPE/silica nanocomposites (nanosilica dimensions - 7 to 14 nm) are prepared using twin screw extruder and injection moulding for three cases using different mixing time and nanofiller as follow:

2.1. Case 1

PE granules with un-modified silica nanoparticles are mixed for 10 minutes and at 120 ^{0}C temperature. Dicumyl peroxide (DCP) is used as crosslinking agent. The nanocomposites prepared using this method are referred as unmodified nanocomposites.

2.2. Case 2

The multiple number of specimens are prepared for each wt %. It is evident from the microscopic observation that the nanofillers cannot be dispersed in homogeneous manner. Some of the specimens in each wt % show the agglomeration in the size of μm is observed as depicted in Fig. 1a and Fig. 1b.

2.3. Case 3

The same method is followed as in case 1 except the Octylsilane modified silica nanoparticles are used. Fig. 1c and Fig. 1d shows that the better (or ideal) dispersion of nanoparticles is achieved. In this case Octylsilane acts as a coupling agent between polymer matrix and silica nanoparticles. Hereafter, the nanocomposites prepared using this method are referred as Octylsilane modified nanocomposites.