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Improving the long-term performance of composite insulators use nanocomposite: A review

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Abstract

Composite has been used as insulation material in the power transmission system for more than 50 years. The excellent mechanical and electrical properties make composite an ideal dielectric material for producing high voltage insulators. However, long-term application of the material in the field reveals the disadvantages of composite: vulnerable to erosion and tracking, low resistance to surface pollution and acid, degradation under heat radiation and early failure. Nanocomposite, which is made of polymer-based host matrix and nano-size particles, has been proven to have better mechanical and electrical properties than conventional composite. The improvements in the electrical properties of nanocomposite include higher breakdown strength, higher permittivity (depends on the type of the nano fillers) and better resistance to surface discharge. However, all of these studies are carried out on the newly made samples. Thus it is still largely unknown to the research community how nanocomposite performs over a long period of time under the influence of multiple stresses such as temperature, ultraviolet radiation, moisture, electrical stress and mechanical stress. Many long-term performance studies have been done on the conventional composite over the past few years. However, there are still lack of research works which dedicate to the long-term performance of nanocomposite. This paper provides a comprehensive review of researches that were carried out to study the long-term performance of nanocomposite. New multi-stress accelerated aging method will be presented in the later section of this paper and possible solutions that can overcome the problems of surface erosion and tracking using nanocomposite are also proposed.

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Keywords: Nanocompoiste; Long-term performance; Electrical properties.

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1. Introduction

This review paper is to provide an overview on the electrical behavior of nanocomposite and how nanocomposite can be used to achieve a better long-term performance compare to conventional composite. Composite has been used as insulation material in the power transmission and distribution system for more than 50 years. Composite has great mechanical properties and also excellent electrical properties which makes it an ideal dielectric material for producing high voltage insulators. However, after being adopted in the field for more than 50 years, the disadvantages of composite have been discovered: vulnerable to erosion and tracking, low resistance to surface pollution and acid, degradation under heat radiation and early failure.

Lewis [1] first introduced nanocomposite to power system or commonly known as nanodielectric as an electrical insulating material in 1994. It was strongly believed that the use of nanocomposite could lead to another revolution in dielectric material. Over the past 15 years, many researchers have observed improvements in electrical properties of nanocomposite [2-14]. Nanocomposite tends to produce higher breakdown strength than conventional composite. The change in permittivity of the nanocomposite is not significant but still slightly higher compared with conventional composite. The space charge measurement is also widely used in evaluating the performance of nanocomposite. Accumulation of space charge can be reduced by introducing nano-sized particles to composites especially at a higher temperature [22]. There are also not many previous studies found on the partial discharge measurement of nanocomposite. From the conclusions of all of these past studies, it is obvious that nano fillers can further improve the electrical properties of the conventional composite. However, all of these studies are performed on the newly made specimens. It is still largely unknown to the research community how nanocomposite performs over a long period of time.

Accelerated aging method is commonly applied to speed up the degradation of the specimens. Accelerated aging methods normally include aggravated heat radiation, humidity and ultraviolet radiation exposure to the specimens. These methods can be applied to simulate the aging of outdoor devices in the field. In the transmission and distribution systems, the high voltage insulators are not only aged by heat or humidity, but also the electric field enhancement and current created by the high voltage conductors. This paper provides a comprehensive review of researches that were carried out to study the long-term performance of nanocomposite. New multi-stress accelerated aging method will be presented in the later section of this paper. Multi-stress accelerated aging process allows us to simulate aging mechanism similar to the one experienced in the field. This paper also presents several possible solutions that can be used to overcome the problems of surface degradation, erosion and tracking in the long term.

2. Thermoset and Thermoplastic Nanodielectric

In the previous studies, various polymers have been used as basic material for synthesizing nanocomposite. The inorganic particles of nanometric size of low percentage weight (<20% wt) are dispersed in the host matrix. The nanodielectric can be considered as functional materials since the inorganic nano-size particles enhance the properties of the host matrix [21]. In general, the polymer host matrix or basic material can be basically divided into two categories: thermosets and thermoplastics.

2.1. Thermoplastic nanocomposite

The first thermoplastic nanocomposite was synthesized by Japanese researchers by polymerizing ϵ-caprolactam in the interlayer of montmorillonite yielding a nylon 6-clay hybrid [2]. Other polymers such as polypropylene and polystyrene are also used as basic material to synthesise nanocomposite [3, 4]. Polyethylene is one of the most studied composite dielectric materials due to the high dielectric strength, low electrical conductivity and remarkable mechanical property. J. Rong et al. presented a way to synthesis polyethylene/palygorskite nanocomposite via in-situ coordination polymerization approach in 200. In other works, low density polyethylene (LDPE), high density polyethylene (HDPE), ultra-high molecular weight polyethylene (UHMWP) and cross-linked polyethylene (XLPE) [5-8] have also been used as basic material to synthesise thermoplastic nanocomposite. Comparing with pure polyethylene, the nanocomposite samples were not only improving in mechanical [5, 6] and dielectric properties [5, 7, 8], but also slowing down the growth of electrical treeing inside the composite [9].