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Stress control methods on a high voltage insulator: A review

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Abstract

This review article provides a comprehensive overview of the many factors that may enhance the level of electric field along the high voltage (HV) insulators, review of existing stress control methods and new promising technologies in stress control using advanced materials. In the first section, the factors that could possibly raise electric field stress around the HV insulators are discussed. Localized field enhancement, especially in the area close to the high voltage potential and ground potential will accelerate the degradation and subsequently causing pre-mature failure of the insulating material. Other than electrical field enhancement, mechanical stresses and environmental impacts also affect the performance of the high voltage overhead insulators. Consequently, multi-facet approaches are required to improve the HV insulators performance and reliability over their service life. In the second section, the existing stress control methods that include corona ring, combined insulation assembly and end-fitting design are reviewed. In the final section, a new promising technology of stress control using field grading methods (resistive and capacitive) is presented. Field grading material (FGM) is a new technology where the inorganic fillers are added to the insulation host matrices to enhance the mechanical and electrical performance of the insulation. FGM shows superior electrical performance compared to the conventional insulation material, which is also discussed in this paper.

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1. Introduction

A high voltage overhead insulator is providing isolation path, which insulates the live conductor from the electrical transmission and distribution tower. The HV insulators play vital parts in the transmission and distribution networks, which are used to transmit the electrical power to the consumers through the power system. The commercial needs for the high voltage lines started in 1880’s, which is the most cost effective technique to transmit the electrical energy over long distance. Since then, larger and more efficient overhead insulators are required to carry and support high voltage lines. The primary function of the high voltage insulators is to separate the live conductors from each other and from the utility pole. They also provide mechanical support for the high voltage insulator [1].

The glass and porcelain insulators have been used in the power utilities for over one century. These insulators have good resistance against environmental aging and they have been used in a wide range of applications. However, due to the hydrophilic surface of the ceramic material, the pollution performance of these insulators is poor. In the 1960’s, the polymer insulators, which are also referred to as composite or non-ceramic insulators, are introduced to the market. The non-ceramic insulators show many advantages over the conventional insulator, which make them more preferable than the porcelain and glass insulators. Furthermore, they have better hydrophobicity, lower leakage current, resistance to vandalism and higher mechanical strength [2].

The polymer insulators have some weakness, which must be taken into consideration during the insulator design. The life expectancy of the composite polymeric insulators is difficult to estimate and the reliability of the polymer materials is unknown. Based on field data, the polymer materials are susceptible to degradation under electric field stress, which may lead to early failure. Hence, the performance of the polymeric dielectrics must be tested and the electric field distribution along the overhead insulator must be studied. The existence of intermediate hardware also created nonlinearity of the electric field on the polymeric insulators when compared to conventional insulators. Hence, composite insulators have a certain level of stress field grading. Very high level of electrical field stress can cause electromagnetic pollution, perceptible noise, partial discharge for the system and accelerated aging of the insulator [3].

The fundamental of the electric field and the techniques of controlling the electric field strength and distribution must be considered, in order to understand the behavior of the insulation materials under the influence of AC/DC electric field. Electric field can be described as the electric force experienced by charge at any given point in the vicinity of the field. The electric force of the electric charge rises when the electric field is applied. Insulators, which are also called dielectrics, are materials where charges are not free to move through their body. However, there is no perfect dielectric because the dielectric consists some conductivity. When a high level of electric field applied over the dielectric, the insulator is heated up and conductive current will begin to flow. Hence, insulators must be tested to identify their withstand voltage level which is called “standard insulation level”. If the insulation material exposes to high electric stress over its critical electric field strength, then insulation failures in the form of corona, ionization, or electric arc will occur. These partial discharge activities will lead to an early breakdown. Electric field distribution also depends on many parameters including voltage waveform, insulator design, shape and materials of the electrodes, tower configuration and atmospheric conditions and pollution [4].

The following sections of this manuscript identify the factors that may increase the electric field strength along the high voltage (HV) insulators. The existing stress control methods and new technologies in stress control using advanced materials are discussed in more details.

2. Failure Factors of Insulation

The HV insulators are located at the top of the utility poles. After years of service in the field, the performance of the dielectric will degrade over time. For porcelain and glass insulators, defects such as cracks, surface tracking and structural damage will start to occur within the insulation materials. For the composite insulator, exposure to UV radiation may accelerate the aging of the polymer housing, which may lead to brittle and crack in the insulation structure.

As a result, the partial discharge will occur and leakage current will flow between the line conductor and the power pole through and over the surface of the insulator. Partial discharge (PD) of the high voltage overhead insulator can be defined as local electric stress on the surface of the insulator or inside the insulation materials. Chemical reactions,
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