ELECTRICAL TREES AND PARTIAL DISCHARGES DEGRADATION CHARACTERISTICS IN XLPE CABLE INSULATION AT HIGH TEMPERATURE

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ABSTRACT

Cross-linked polyethylene (XLPE) has become the widely used insulation for modern high voltage extruded cables, which is susceptible to treeing under the long term effect of electrical and thermal stresses. Combined with the methods of real-time microscope digital imaging and partial discharge (PD) continuous monitoring, we studied the effect of temperature on the electrical tree propagation and PDs degradation characteristics in XLPE cable insulation with the needle-plane electrode geometry at different power frequency 50 Hz voltages. It was found that the tree growth was accelerated greatly, and the PDs were more intensive at high temperature.

KEYWORDS

Electrical tree, Partial discharge, XLPE cable insulation, High temperature

INTRODUCTION

Cross-linked polyethylene (XLPE) has become the commonly used insulation for modern high voltage extruded dielectric cables, both for distribution and transmission system applications up to 500 kV, owing to its excellent thermal stability and electrical, mechanical properties. In common with any other polymeric insulating materials, the long-term deterioration and breakdown of XLPE subjected to AC voltage can usually be associated with the phenomenon of treeing [1]. Trees grown in a dry environment and a region of high electric field are referred to as electrical tree, which is one of the main causes for the failure of polymeric insulating materials used in high voltage cables. In some cases, electrical trees may be initiated from the semi-conducting layer protrusions, but they are usually initiated from voids [2] or water trees [3] in XLPE cable insulation.

Recently, with the rapid development of the cities and modern industries in China, the demand for electricity is growing at a fast rate, and the installation of the high voltage and extra high voltage XLPE cables (≥110 kV) is growing greatly. The electrical trees in high voltage XLPE cable insulation is more concerning to assure a secure and reliable supply of electricity [4~7]. However, the research of high temperature effect on electrical trees and partial discharges (PDs) degradation in XLPE cable insulation is not well concerned.

The temperature of conductor of power cable is at about 90 ^{o}C under the rated load, but the usual value is at 50-60 ^{o}C, as most of the cables in China are run in less load conditions. Therefore, from a practical viewpoint, electrical tree and PD characteristics at higher temperature are important for the polymer insulation. Combined with the methods of real-time microscope digital imaging and PD continuous monitoring, the electrical tree initiation, propagation and PDs degradation were investigated at high temperature for 64/110 kV XLPE cable insulation applied power frequency (50 Hz) voltage with the needle-plane electrode geometry. It was found that under the effect of different applied voltage levels, the electrical tree structures displayed the features of diversity, and the temperature was the dominant experimental parameter controlling the electrical tree propagation. The tree growth time at high temperature is shorter than the tree at room temperature under the same applied voltage. The tree structures changes with the increase of the experimental temperature. The PD patterns and PD parameters show that the PD activities at high temperature are more intensive, this is the reason to cause the tree growth rapidly at high temperature. For the electrical trees at high temperature under low voltage, the experimental results show that the intensive PD activities could accelerate the change of the channel conductivity, which cause the increase of the average tree growth rate.

EXPERIMENTAL

Sample Preparation

The outer semi-conducting layer and conductor of a new commercial high voltage XLPE cable, having an insulation thickness of 17 mm, were removed, after the mechanical process, leaving the inner semi-conducting layer with a thickness of 0.5 mm and the insulation with a thickness of 15 mm. The cable was cut into a series of pieces with a thickness of 5 mm. Most of the samples were cut into semi-circle to save cable.

The pin-plane electrodes geometry was used in experiments. The steel pin electrode (pin-tip radius 5±1 μm) was inserted slowly to give a pin-plane separation of 2±0.2 mm at temperature of 120~140 ^{o}C in a special heating mould. After annealing in the mould for 5~8 minutes to eliminate mechanical stress build up between the pin-plane regions, the sample was removed from the mould at 105 ^{o}C and cooled down to room temperature naturally. Each sample was observed for the existence of mechanical stress and void around the needle tip region by polarized light and transmitted light. The sample without the presence of mechanical stress and void was used in our experiments.

Experimental Setup

Figure 1 shows the experimental arrangement, consisting of a voltage regulator T_1, a YDTW-10/100 power frequency 50 Hz transformer T_2, a protection resistor R, a 1000:1 capacitive voltage divider, a 2000 pF coupling capacitor C_k , a RC detection impedance linked with