Phased Propagation Characteristics of Water trees in XLPE Cables during the Accelerated Water Tree Aging Experiment

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ABSTRACT

To understand the propagation characteristics of water trees, this study reveals the mechanism of the microstructural changes of water tree on water tree propagation. Five groups of cable samples with pinhole defects were subjected to an accelerated water tree aging experiment for different aging time. The microscopic observation results show that the propagation rate of water trees is large in the initial stage and then decreases significantly in the stagnation stage, while increases again in the late stage. The microstructural changes of water tree itself is the fundamental reason for the changes of the propagation rates of water trees.

KEYWORDS

XLPE cable, water tree, propagation rate, stagnation, microstructural change, irregular, shape, electric field.

INTRODUCTION

Water treeing is one of the main reasons for the degradation of XLPE cable insulation [1]. With the increase in aging time, both the length and density of the water trees can increase [2]. However, due to the diversity of the aging conditions and the longevity of water tree aging [3], the propagation characteristics of water trees can be rather complex. Under different aging conditions, the morphologies and the propagation rates of water trees can vary significantly.

Generally, under different aging conditions, the water tree can have different propagation rates [3-5]. However, the propagation rate of water trees can be different under the same aging condition in different aging periods. In one specific aging period (which can be defined as stagnation period), the propagation rate of water trees can decrease considerably, and water trees nearly “cease” to propagate in length [8-10]. However, the cause for the changes of the propagation rate of water trees is still unclear.

The electric field can play a major role in the development of water trees, and the propagation rate of water trees is closely related with the electric field in the water tree regions [6]. From the existing researches [6-7], the electric field in water tree regions can change with the variation of the microstructure of water trees. For instance, with the increase in the density of water tree voids, the electric field can decrease at the water tree tips [6]. In addition, with the enlargement of the water tree voids, the electric field will decrease at the tip of the water tree void [7]. The changes of the microstructure of water trees and its influence on water tree propagation need to be further explored, if a deeper understanding of the propagation characteristics of water trees is to be obtained.

This study tries to reveal the role of the microstructural changes of water tree itself on water tree propagation. Based on the observation results of the microscopic morphologies of water trees in different aging periods, a simulation model of the electric field of water trees in different aging stages is constructed, and the mechanism of the microstructural changes of water tree itself on water tree propagation is revealed.

EXPERIMENTAL SETUP

Sample preparation and accelerated water tree aging experiment

An 8.7/10 kV XLPE cable (type: $YJLV_{22}3 \times 95$) was cut into short cable samples with a length of 500 mm. For each sample, the outer semiconductive layer was removed from both ends over 100 mm to ensure sufficient insulation distance, and a 50 mm long conductor was exposed at one end for connection to high voltage. A 250mm length in the middle part was chosen as the accelerated water tree aging region, where pinhole defects were produced. A syringe needle (curvature radius: 2.5 ± 0.5 μm) was inserted vertically into the semiconductive layer (at room temperature) in the water tree aging region to produce pinhole defects. The copper nose was connected to the exposed conductor for the connection to high voltage. Afterwards, heat-shrinkable tubes were placed on the exposed part of the insulation to hold the NaCl solution. Eventually, saturated NaCl solution (concentration: 26.5%) was injected into the tubes for the accelerated aging.

The samples were subjected to an accelerated water tree aging experiment under a voltage of 7.5 kV and a frequency of 400 Hz. In the aging, the frequency of 400 Hz was selected to accelerate water tree propagation. The sample and experimental setup are shown in Figure 1 for the accelerated water tree aging.

Five groups of short cable samples (from group G_1 to G_5) were produced by the above method. Then the five groups of cable samples were subjected to the accelerated water tree aging for 10, 20, 30, 60, and 90 days, respectively. From groups G_1 to G_5, the aging time increases successively.