Water Tree Propagation under Different DC Voltage Polarities: in the Presence of Harmonics

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ABSTRACT

To understand the influence of DC voltage polarity on propagation of water trees, a water tree accelerated aging experiment was performed on XLPE sheet specimens under five different types of voltages (four rectified voltages and sinusoidal voltage). An optical microscope was used to observe water tree morphology and measure water tree sizes of the specimens after 22-day aging experiment. The experimental results show that the morphology and sizes of water trees are strongly dependent on DC voltage polarity. As a result, a mechanism of ion diffusion is proposed to explain the propagation characteristics of water trees under different DC voltage polarities.

KEYWORDS

XLPE, water trees, DC voltage, polarity, ion diffusion

INTRODUCTION

HVDC XLPE cables have been widely used in new energy power generation, power supply dilatation in cities and island power transmission [1-2]. Even though water trees under DC voltage are initiated much slower than those under AC voltage, water tree propagation under DC voltage can be accelerated in the presence of harmonics generated by non-linear converters [3-4]. Different polarities in bipolar HVDC transmission systems can affect the space charge distribution and ionic diffusion in XLPE insulation, which can further result in different propagation characteristics of water trees [5-6].

The literature found that water trees under positive full wave rectified voltage and negative half wave rectified voltage were larger than those under sinusoidal voltage [7]. They presented a space charge injection model which could explain a part of the experimental results. Reference [8] found that the water absorption rate of PE under positive electric field was greater than that under negative electric field which could result in different characteristics of water tree propagation. Although many researchers had observed water tree characteristics under different DC voltage polarities, not all the properties of water tree propagation are thoroughly understood.

The diffusion of hydrated ions in the polymer plays an important role during the process of water tree aging. The ionic fluxes are different under different polarities. As a result, the numbers of water molecules driven into the polymer by ions are different under different polarities, which can result in different water tree propagation characteristics.

To understand the influence of DC voltage polarity on propagation of water trees in the presence of harmonics, water tree propagation characteristics in XLPE were investigated by utilizing four rectified voltages (e.g. positive half and full wave rectified voltages, negative half and full wave rectified voltages) and a sinusoidal voltage. According to the experimental results, a possible mechanism based on ionic diffusion is proposed.

EXPERIMENTAL SETUP

Specimen preparation

XLPE sheet specimens cross-linked according to industrial standards were used in the water tree accelerated aging experiment. Their electrical properties are similar to those of the industrial 10 kV cable insulation.

Fig. 1 shows the configuration of the specimen. The average thickness of the specimens was 3 mm, and a 25-mm diameter circular area was chosen as the aging region. 18 pinholes with depth of 1.5 mm were produced by the metal needle in the aging area in advance, which had a tip radius of 4.0±0.5 μm and a point angle of 17°±2°.

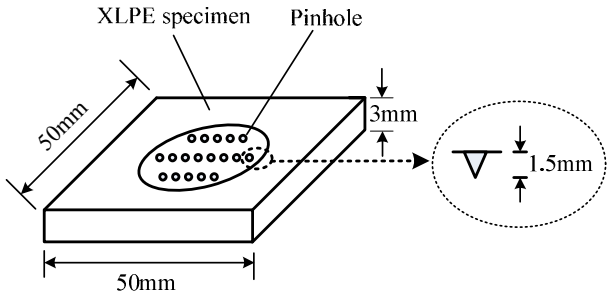

Fig. 1: Configuration of the specimen

Water tree aging setup

The experimental setup according to the IEC/TS61956 standard was used in the water tree accelerated aging experiment as shown in Fig. 2. The copper electrode in