Long-term Effect of Rejuvenation Fluid on Water Tree Aged Cables under Electrical-thermal Stress

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ABSTRACT

To investigate the long-term effect of rejuvenation fluid in water tree aged cables, the dielectric properties and micro-structures were compared for rejuvenated and un-rejuvenated cable samples. The experimental result shows that water trees of rejuvenated samples are much shorter than that of un-rejuvenated samples, the dielectric loss factor of rejuvenated samples are also significantly lower than that of un-rejuvenated samples. Combining with the result of scanning electronic scope, the electric field distribution of the samples was analyzed. For the rejuvenated samples, the distortion of electric field is improved, and therefore the further propagation of water trees is effectively inhibited.

KEYWORDS

XLPE cables; Water tree; Rejuvenation; Electric field distortion.

INTRODUCTION

Water trees are regarded as the main reason of insulation degradation of XLPE cables in a moist environment [1-2]. Electrical performances of water tree aged cables would deteriorate significantly, and electrical trees are easy to initiate in water tree aged cables once under over voltages, which can eventually lead to breakdown of the cables [3]. Since the mid-1980s, a silicone injection technology has been utilized on cable rejuvenation to extend their service lives [4]. The technology is based on the siloxane rejuvenation fluid which can react with the water, thus consuming it in the water tree voids, in the meantime organic fillers are produced which can greatly promote the insulation performance of the cables [5]. However, rejuvenated cables would have to be subjected to continuing effects of electrical, thermal and environmental stress when they are put into service again. In order to understand the long-term effect of the rejuvenation fluid in the water tree aged cables, it is necessary to investigate the changes of their electrical properties and micro-structures under service conditions.

The rejuvenation mechanism of water trees has been reported and is continually developing [6-7]. In the previous researches of this paper, a new rejuvenation technology [8] based on the organic-inorganic compound is proposed, it has been confirmed that the technology has better effect on promoting the insulating performance of water tree cables. However, most of the literatures are focused on the short-term rejuvenation effect. In fact, the long-term safe operation of cables depends on the long-term effect of rejuvenation fluid on inhibiting water trees. Even though there have been publications [9-10] discussing the distribution of rejuvenation fluid in insulation layer of cables which are subjected to long-term electrical and thermal stress, there are rare reports about the changes of electrical properties as well as micro-structures of water trees. For the long-term performances of rejuvenated cables, there is still a lack of detailed experimental data and a physical model to explain it when they are subjected to service condition.

To investigate the changes of electrical properties and micro-structures of water trees in rejuvenated and un-rejuvenated cable samples, electric field distribution and micro morphologies of water trees are analyzed during long-term accelerated aging experiment.

EXPERIMENTAL SETUP

Sample Preparation

A XLPE cable with a rated voltage of 8.7/10 kV was cut into samples of 350 mm in length. The aluminium conductor was exposed 3 cm in length at one end of each cable. The outer-semiconductor layer on the surface was removed in 80 mm length at each end of the cable, as shown in Fig. 1.

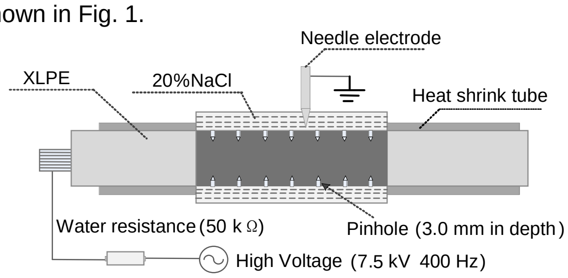

Fig.1: Accelerated aging experiment principle

Accelerated Aging Experiment

As shown in Fig. 1, the tested sample was subjected to an accelerated aging experiment which lasted for 4 weeks with a water needle electrode system. Pinholes with a depth of 3 mm were produced by the metal needle in the aging area in advance. The needle has a tip radius of 2.5±0.5 μm and a point angle of 10±1°. A water vessel was attached and produced with heat shrinkable tubes to ensure the aging area entirely immersed in the solution. A 7.5 kVrms voltage with frequency of 400 Hz was applied at the aluminum conductor of the cable, and a copper sheet was immersed in 20% NaCl solution as a grounding electrode.

Injection of Rejuvenation Fluid

To compare the changes of electrical properties and micro-structures, water tree aged samples were divided into two groups (8 samples for each group), namely group A and group B respectively. The samples of group B were subjected to injection with the injecting system of rejuvenation fluid in Fig. 2. The other half samples (group A) were kept un-rejuvenated.