

Estimation of chemical changes of thermally aged XLPE cable insulator

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ABSTRACT

An actual XLPE cable was degraded thermally by conductor current heating. The insulating material of the cable was examined for chemical changes (IOT, crystallinity, and changes in chemical bonding) in order to investigate degradation mechanisms and diagnosis methods for XLPE cables with water-barrier design.

KEYWORDS

XLPE cable; Conductor current heating, Antioxidant; Crystallinity

INTRODUCTION

XLPE cables are widely used for supplying electric energy to cities. The amount of XLPE cable has been increasing year by year, owing to the replacement of oil-filled cable, as well. The water tree is the major degradation mechanism of XLPE cable.[1-2] Water-barriered XLPE cable is designed to prevent water tree degradation. This type of cable was introduced into actual power grid in Japan in the middle of 1980s and those cables introduced in early stage becomes more than 30 years in these days. Therefore, the degradation mechanism for the water-barriered XLPE cable should be investigated.

Water tree degradation is less possibility in water-barriered XLPE cable, thus its degradation could be oxidative degradation due to heat and exposure to oxygen. Thermal expansion and contraction of XLPE cable occurs through temperature changes due to load fluctuation under the operation. If the insulator hardens resulting in the oxidative degradation, it leads to difficulty in meeting thermal expansion and contraction of the cable conductor and induces crack in the cable insulator, which may cause the electrical breakdown.

The decrease of electrical insulation properties by oxidation was investigated in XLPE sheet specimens.[3] However, there is few report dealing on the oxidation degradation mechanism of XLPE in the cable core structure.[4]

In this work, an actual XLPE cable was exposed to thermal degradation by conductor current heating to simulate its operational conditions. The insulating material of the cable was examined for chemical changes in order to investigate degradation mechanisms of an XLPE cable with water-barrier design.

EXPERIMENTAL SECTION

The non-aged cable insulator was sampled from commercially available XLPE cable of water-barrier design. The thermally degraded cable insulator was sampled from the actual XLPE cable, which degraded thermally by conductor current heating to simulate its operating conditions.

DSC

Initial oxidation temperature (IOT) tests were performed in

a nitrogen atmosphere at room temperature to 80°C, and then under an oxygen atmosphere from 80°C to 300°C at 10°C/min using a PerkinElmer DSC8500 differential scanning calorimeter.

X ray diffraction (XRD)

XRD was measured on a Rigaku RINT TTR III with Cu K α radiation to obtain the crystallinity of the insulator. Scan speed was set at 2°/min from 5° to 50° as a scan range with a 0.02° step size.

FT-IR

The cable insulators were analyzed by an attenuated total reflection-Fourier transform infrared (ATR-FTIR) spectrometer (Thermo Fischer Scientific Nicolet iN10) fitted with a germanium crystal. Each sample was measured three times to obtain the average ATR-FTIR spectrum at the inner, middle, and outer parts, as shown in Fig.1, of the non-aged and thermally degraded insulators.

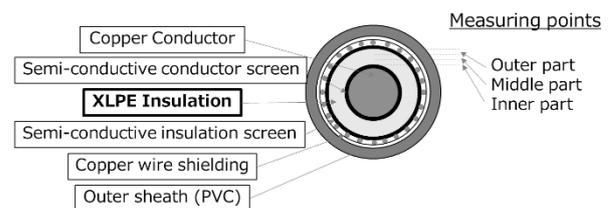


Fig 1. XLPE cable structure and measuring points.

RESULTS AND DISCUSSION

DSC, XRD, and FT-IR measurements were applied to the new and the thermally aged cable insulators.

Initial oxidation temperature (IOT)

Several methods for estimating the remaining antioxidant content of insulation are proposed, such as the oxidation induction time test and the initial oxidation temperature (IOT) test.[5] The IOT test measures the initial temperature of exothermic DSC peak under an oxygen atmosphere at a constant heating rate. The detected exothermic DSC peak is derived from the reaction in which the hydroperoxide (C-O-O-H, not a carboxyl group) bond, formed in the auto-oxidation of polymer, is cleaved into CO· and OH· radicals.[6] Antioxidant traps these radicals to terminate the subsequent oxidation reaction. However, if the remaining antioxidant content falls below a certain amount, the radicals cause the repeated oxidation reaction. Therefore, the aged polymeric sample with reduced antioxidant content has a lower IOT value compared to the new polymeric sample.