Effects of oxygen on the thermally accelerated degradation of actual XLPE cable insulation

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ABSTRACT

An actual XLPE cable insulation was exposed to thermal degradation under air and N_2 atmospheres to examine the difference of oxidative degradation process of the cable insulation. The initial oxidation temperature (IOT) measurements confirmed that the consumption of antioxidants under the N_2 atmosphere was progressive, although the decrease in IOT was slower than that under the air atmosphere. Additionally, although a sufficient amount of antioxidants remained in the XLPE samples degraded under the N_2 atmosphere, oxidation-derived peaks were observed in the IR spectrum, suggesting that the degradation mechanism under a N_2 atmosphere may differ from that under air atmospheric.

KEYWORDS

XLPE cable, Oxidative degradation, Antioxidant, FT-IR, IOT

INTRODUCTION

Crosslinked polyethylene (XLPE) cables are widely used to supply electricity to cities. The demand for XLPE cables has been continuously increasing over the years, which can be partly attributed to the need for replacing oil-filled cables. Water tree is a major XLPE cable degradation phenomenon, and is prevented by the development of water-barriered XLPE cable.[1-2] Such cables have been used in power grids in Japan for over 35 years. Therefore, there is a need to investigate other degradation mechanisms of water-barriered XLPE cables besides water tree.

The oxidative degradation due to heat and oxygen was focused on as a degradation mechanism other than water-tree degradation in XLPE cables.[3] Oxidative degradation of such cable is usually suppressed by antioxidants in cable insulations. Therefore, it is thought that the change in the residual degree of antioxidants can be used as an index of the start of oxidative degradation. On the other hand, the supply of oxygen from the outside cable is also considered to be suppressed in XLPE cables with the water-barrier layer. This is because the water barrier layer consists of thin metallic film adhered inside the outer sheath or metallic corrugated tube, which inhibits not only moisture invasion but also oxygen permeation.

In this study, samples of actual XLPE cable insulation were exposed to thermal degradation under air and N_2 atmospheres to examine the differences in oxidative degradation processes of the cable insulation. The N_2 atmosphere simulates an environment close to that of actual cable installations with water-barrier layers, and the air atmosphere was adopted to simulate under the condition that would accelerate oxidative degradation. Additionally, the temperatures for the thermally accelerated degradation tests were selected to be higher than the cable operating conditions in order to accelerate the degradation phenomenon of the cable insulation.

EXPERIMENTAL SECTION

Thermally accelerated degradation test for XLPE insulation samples

Two specimen of XLPE insulation samples with inner and outer semiconducting layers manufactured by different manufacturers were prepared from actual 66 kV XLPE cable (approximately 150 mm long with 9 mm thick insulation). Thermally accelerated degradation tests were conducted in an oven at 140°C under an air atmosphere. For the N_2 atmosphere test, the insulation samples of the XLPE cable was sealed in a N_2-purged metal vessel and the vessel was placed in an oven at 140°C. The thermally accelerated degradation tests were conducted for approximately 32 000 h and 29 000 h under air and N_2 atmospheres, respectively. These specimens were exposed to two kinds of chemical analyses mentioned below after certain time elapsed.

Differential scanning calorimetry (DSC) measurement

Differential scanning calorimetry (DSC) measurements were performed to obtain the initial oxidation temperature (IOT) of the samples. Samples (0.5 mm × 0.5 mm × 0.5 mm) were cut from the specimens, and 20 mg of the cut samples were placed in an aluminum pan for DSC measurement. The IOT analysis was performed under the N_2 flow at room temperature to 80°C, and then under the an oxygen flow from 80°C to 270°C at a heating rate of 10°C/min using a PerkinElmer DSC8500 differential scanning calorimeter.

Fourier transform infrared (FT-IR) spectroscopy

The insulation samples were analyzed using an attenuated total reflection - Fourier transform infrared (FT-IR) spectrometer (Thermo Fischer Scientific Nicolet iN10) equipped with a germanium crystal. Each sample of the non-aged and thermally degraded insulators was measured three times to obtain the average FT-IR spectra of the samples (Fig. 1).