C6.10

Antioxidant concentration distribution measurement in XLPE cable insulation by PIXE Analysis, FTIR and UV spectroscopy

PARPAL J.L., GUDDEMI C., Hydro-Québec (IREQ), Québec, Canada
HINRICHSEN, Université de Montréal, Canada

Résumé:

Plusieurs études ont eu pour objet les propriétés diélectriques de l'isolation polyéthylène réticulé (PR) sous fort gradient de champ. D'après certaines études, l'ajout d'antioxydant peut impliquer des changements au niveau de la structure macromoléculaire du polyéthylène qui peuvent avoir une incidence sur la formation de la charge d'espace et donc sur la distribution du champ dans l'isolation du câble. Dans cet article sont présentés les résultats obtenus de l'analyse PIXE et des spectroscopies infrarouge et ultraviolet sur des échantillons de câbles PR dans le but de déterminer la distribution radiale de la concentration des antioxydants.

Abstract:

Numerous studies have addressed the dielectric properties of crosslinked polyethylene (XLPE) under very high electrical stresses. Some suggest that antioxidant additives could affect the morphological structure of the polymer, influence space charge formation and result in unacceptable electric stress distribution in the cable insulation. This paper presents the results of PIXE analysis, FTIR and UV spectroscopy measurements performed on aged and unaged transmission type XLPE cables in an aim to determine the radial concentration distribution of the antioxidant.

Introduction

Extruded polyethylene has proven to be an excellent insulating material, as shown by the recent development of XLPE cables at voltages up to 500 kV [1, 2]. However, polyethylene insulation subjected to excessive electrical, mechanical or thermal stresses shows rapid aging. One aging process originates from the reaction of polyethylene molecules with oxygen, which produces physical changes such as long-chain branching and cross-linking reactions [3]. This oxidation process can appear at the cable processing stage or during its use. In fact, the cable's stability against polyethylene oxidation depends as much on the manufacturing process as on its morphology (crystallinity, orientation) [3].

The most common stabilization method is to add an antioxidant. Antioxidants are typically large molecules comprising several different functional groups that delay oxidation and, hence, polyethylene aging. However, they are all polar to various degrees and not very soluble in polyethylene. Like many other additives, antioxidant will diffuse in the polymer while some can be lost by either surface evaporation or precipitation [4]. Diffusion of antioxidant additives has been observed not only in polyethylene films [5] but also from low density (LDPE) cable insulation [6, 7].

It has been speculated that the addition of antioxidants has a significant effect on the morphology of the polymer and, more specifically, on the presence of trapped charges in the bulk of the material [8]. Although defects, impurities and cross-linking by-products have a significant role on the space charge formation [9], the presence of antioxidant may well intensify the space charge concentration resulting in an electric stress enhancement possibly followed by electrical treeing.

This paper present the results obtained from characterizing the distribution of the antioxidant concentration in crosslinked polyethylene (XLPE) cable insulation. The transmission cable samples used were unaged or subjected to accelerated electrical aging with or without thermal cycling. The measurements were performed using Proton Induced X-ray Emission, Fourier Transform Infrared (FTIR) and Ultraviolet (UV) Spectroscopy.

Experimental

The study was performed on four different XLPE transmission cables and the diagnostic techniques listed in Table 1 to take the antioxidant concentration distribution measurements.

For the FTIR and UV spectroscopy measurements, 2.5-cm-wide ribbons were peeled from each XLPE cable on a lathe (typical thickness of 0.2 mm) and a small hole was drilled through the insulation to allow the number of layers peeled off to be counted and, thus, the radial position in the insulation to be determined. For the PIXE