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Characterization of the dynamical structure of cable insulation

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Résumé

L' optimisation de la fiabilité des câbles moyenne tension est un problème d'actualité. Un vieillissement accéléré permet, après une période de deux ans, de déterminer la qualité des câbles. Cependant cette période d'attente est trop longue. Deux câbles, l'un satisfaisant le test, l'autre défaillant, ont été soumis à deux analyses thermiques. L'Analyse Enthalpique Différentielle, sensible à l'état cristallin a montré des évolutions différentes pour ces deux câbles au cours du test. Le Fluage ThermoStimulé, sensible aux différents domaines amorphes, a permis de différencier ces câbles avant le test et de suivre leur évolution pendant le vieillissement. Cette étude montre que ces câbles diffèrent par la mobilité moléculaire dans les interphases des domaines amorphes libres - cristallites.

Abstract

The search for a better reliability of medium voltage cables is current. Accelerated ageing, after a period of two years, allows to determine the cable quality. However, the waiting time is too long. Two cables, one fulfilling the test, the other failing, have been subjected by two thermal analyzes. Differential Scanning Calorimetry that is sensitive to crystalline states shows different evolutions for the two cables during the test. The Thermally Stimulated Creep that is sensitive to different amorphous domains, allows us to discriminate these cables before the test and to follow their evolution during ageing. This study displays that cables differ in the molecular mobility located at interphases between free amorphous domains and crystallites.

INTRODUCTION

From an economical point of view, it is crucial to know the resistance of a medium voltage (MV) cable to the propensity of the water treeing formation before laying them underground. Indeed, water treeing has been considered as one of the most important causes of failure in power MV cables with polymeric insulation [1].

Several years ago, a new insulating material was introduced in order to replace crosslinked Poly(Ethylene) insulation (XLPE) by using a low density Poly(Ethylene) (LDPE) initially copolymerized with Ethylacrylate. These resins lead to specific properties in respect to space charge for example [2].

Nevertheless, cables performed with the same base resin from different manufacturing processes have been found to give significantly different dielectric strengths during accelerated ageing test. Presently several accelerated tests such as mentioned in the Belgium specification (NBN C 33 - 323) are carried out on cable as quality criterion. Indeed, the typical ageing Long Duration Test (LDT), applied for cables with XLPE insulation for 15 kV up to and including 36 kV voltages, must be absolutely succeeded before acceptance of cable delivery. However, the major inconvenience of these accelerated tests is their long time consuming.

The aim of this work is to achieve a better knowledge of the manufacturing reliability in order to define, in a near future, a predictive test based on experimental procedures which can give an indication of the cable durability before completion the LDT.

The cable propensity to initiate water trees has been shown to be closely related to the polymeric structure of the cable insulation [3]. Since the physical structure is the only variable parameter, its characterization constitutes a key topic. The degree of crystallinity has been first invoked to explain changes of cables due to potential modifications under thermal treatment [4]. However, the evolution of the size and the number of cristallites may be an important factor. Moreover amorphous regions considered as responsible for many electrical properties must be also taken into account due to the high susceptibility evolution of the mobility of these domains under thermal treatment [5]. Two different thermal experiments have been used to characterize the physical structure of the polymeric insulation. Differential Scanning Calorimetry (DSC) allows us to investigate crystalline domains, and Thermally Stimulated Creep (TSCr) is more sensitive to the mobility of chains in amorphous domains. With both procedures, all structural parts of the cable insulation can be observed during ageing test.