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A.6.4. Une technique optique pour la mesure in situ de la concentration de sous-produits de réticulation dans les câbles PR

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Résumé

Le polyéthylène réticulé (XLPE) a été utilisé dans les câbles de transmission et de distribution souterrains, à cause de ses faibles pertes diélectriques, de son haut degré de résistance et de sa bonne flexibilité. Les câbles en XLPE sont actuellement utilisés pour la transmission de puissances pouvant aller jusqu'à des tensions de 500 kV.

Cette communication décrit une nouvelle méthode optique non destructrice d'établissement de la concentration des sous-produits de la réticulation dans les câbles XLPE. Cette méthode comporte la détection et la mesure sur place de la thermoluminescence émise par les sous-produits de la réticulation, pendant la phase initiale de traitement par la chaleur du câble. On montre que la mesure de l'intensité de la thermoluminescence donne une indication directe de la concentration des sous-produits, qui peut être corrélée avec la résistivité diélectrique de l'isolant. Cette nouvelle méthode optique est également plus sensible que la spectrométrie de masse.

A.6.4. An optical technique for in-situ measurement of the concentration of the crosslinking by-products in XLPE cables

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Abstract

Crosslinked polyethylene (XLPE) has been employed in underground transmission and distribution cables because of its low dielectric loss, high degree of toughness and good flexibility. XLPE cables are presently used for power transmission at voltages up to 500 kV.

This paper describes a novel, non-destructive optical method of determining the concentration of the crosslinking by-products in XLPE cable. The method involves in situ detection and measurement of thermoluminescence emitted by the crosslinking by-products during the initial heat treatment of the cable. It is shown that the measurement of the intensity of thermoluminescence provides a direct indication of the byproduct concentration which can be correlated to the electrical strength of the insulation. Also, the new optical method is more sensitive than mass spectrometry.

Introduction

Extruded polyethylene has been used in underground high voltage cables for more than thirty years. Initially, its use was confined to distribution class cables; however, technological progress in materials handling and extrusion techniques have seen a gradual increase in its voltage and stress levels. At present, polymeric insulation is used in transmission class cables operating at voltages up to 500 kV.

In a power cable, a high current flows through the central conductor and the extruded insulation surrounding the conductor is subjected to high temperatures and a temperature gradient. To increase the resistance to thermal deformation and enhance dimensional stability the polymer is crosslinked. Chemical crosslinking by dicumyl peroxide is widely used but this method creates volatile crosslinking by-products such as acetophenone, cumyl alcohol and α-methyl styrene which may remain in the material for years.

Acetophenone, a diketone, is polar and can grade the electric field around points of electric stress enhancement but like other crosslinking by-products it is fugitive and exudes out of the polymer. Small quantities (2% by weight) of acetophenone increase the short term AC breakdown strength of crosslinked polyethylene (XLPE) cables [1]. On the other hand, the impulse breakdown strength of XLPE decreases with increasing amounts of crosslinking by-products in the polymer [2]. Also, acetophenone causes space charge to be trapped upon application of voltage and has been known to lead to chemically complex degradation products [3].

The operating and emergency temperatures of XLPE cables are 90°C and 130°C respectively but the insulation could be exposed to temperatures above 150°C during the preparation of in situ molding of cable joints. This generates water from cumyl alcohol which is one of the crosslinking by-products of dicumyl peroxide. When the cable cools the water condenses to form microcavities. The presence of such water-filled cavities could lead to water or electrical trees during cable operation thereby increasing the probability of eventual insulation failure. Hence, prior to installation, transmission class cables are subjected to thermal treatment in order to reduce the concentration of the crosslinking by-products to low levels. Once a metallic sheath has been installed on the cable the remaining by-products cannot easily escape and their effect on long term aging has yet to be established.

To determine the concentration of the crosslinking by-products in cable insulation, cumbersome and time consuming methods are presently employed. They involve