C2.13

Field distribution in HVDC cables : dependence on insulating materials

(see also B7.8.)

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Résumé

Les câbles haute tension à courant continu (HTCC) subissent un gradient électrique et thermique. La résistivité des matériaux d'isolation de ces câbles dépendant de la température et/ou du champ électrique, il en résulte une accumulation de charges d'espace dans l'isolant, qui modifie fortement le champ de Laplace. Récemment, des méthodes de calcul de la répartition du champ électrique dans les câbles HTCC à partir des lois théoriques de dépendance de la résistivité avec le champ et la température ont été mises au point.
Nous présentons des caractérisations de différents matériaux, potentiellement utilisables pour l'isolation de câbles HTTC, en terme de dépendance de la résistivité avec le champ et la température. Les gammes de mesure correspondent aux contraintes pouvant être subies par les câbles HTCC en service ou lors des qualifications.
A partir de ces résultats expérimentaux, nous montrons qu'un choix judicieux des matériaux d'isolation peut conduire à une réduction sensible du champ maximum subi par l'isolant pour une conception de câble et une tension données.

Abstract

A High Voltage Direct Current (HVDC) cable in service experienced a thermal and an electrical gradient. As far as the resistivity of the insulating material is temperature and/or field dependent, it results space charge accumulation in the insulating layer, which strongly distorted the Laplace field. Recently methods to derive the field distribution in HVDC cables from the theoretical laws of field and temperature dependence of resistivity have become available.
We present characterisation of several materials candidate for HVDC cable insulation, in terms of field and temperature dependence of the resistivity. The ranges of measurement correspond to stresses possibly applied on advanced HVDC extruded cables, during tests and during service life.
From these experimental data, it is shown that a pertinent choice of the insulating material should result in a significant reduction of the maximum electrical stress experienced by the insulating material for a given design and a given applied voltage.

1. Introduction

In a HVDC cable in operation, the temperature increases from sheath to core. As the conductivity of the polymers used in the insulating layer increases with temperature, it results a space charge accumulation which strongly distorts the Laplace field. Several authors [1-3] published recently mathematical methods to derive the field distribution in HVDC cables from theoretical laws of field and temperature dependence of resistivity.
In order to transform these theoretical results into practical use for a cable design, reliable data on resistivity at comparable field and temperature to those met in advanced HVDC cables, during service or during tests, are required, e.g. fields up to 100 kV/mm and temperatures up to 80 °C.
Up to now, limited data on polymers candidate for insulation of extruded dc cables were available [4]. They concerned resistivity measurements at fields lower than those potentially reached during cable testing.

2. Experimental procedure for high field measurement of resistivity

An electrode system with a rounded guard ring, minimising edge field enhancement was designed. This electrode system is placed in an oven and the temperature is measured in the vicinity of the sample.
A dc voltage, delivered by a highly stabilised Spellman voltage supply, is applied to the lower electrode. The current flowing through the central upper electrode is measured. The guard ring is also connected to earth but the current flowing through it is not measured.
Gold electrodes are deposed on the sample by cathodic sputtering under vacuum. The diameter of upper gold layer is 0.5 mm smaller than the diameter of the corresponding measuring electrode.