A.9.4. Effets thermique et électromécanique sur la rigidité diélectrique du polyéthylène haute densité sous champ électrique continu

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A.9.4. Thermal and electromechanical effects on dielectric strength of high density polyethylene under D.C. electrical field

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Résumé

Le comportement diélectrique des isolants solides utilisés dans les câbles d'énergie à courant continu dépend des conditions dans lesquelles ils sont destinés à fonctionner telles que la température, la pression, la nature du champ électrique appliquée (alternative, continue, ondes de choc...).
Nos résultats antérieurs obtenus sur le Polyéthylène Haute densité ont montré que la rigidité diélectrique ou le champ de claquage F_b diminue avec la température. Les mesures ont été effectuées sur des films de 100 µm d'épaisseur et dans la gamme de température de 30°C à 70°C.
Suivant nos hypothèses, la rupture diélectrique de ce matériau provient soit d'un effet thermique, soit d'un effet électromécanique. En utilisant les modèles classiques de claquage représentant, le premier, par l'équation générale de la chaleur et, le second, par la relation d'équilibre entre les contraintes d'origine électrostatique et la déformation d'origine mécanique, les résultats théoriques calculés et appuyés par des mesures complémentaires ont montré que le phénomène de rupture d'origine thermique est le plus probable. La contribution de ces deux processus semble correspondre mieux aux phénomènes réels apparaissant dans ce matériau.

Abstract

The dielectrical behavior of solid insulators used in D.C power cables depends on conditions in which they must be used such as temperature, pressure, nature of applied electrical field (AC, D.C, shock waves ...).
Our previous results obtained on High Density Polyethylene (HDPE) samples have shown that the dielectric strength F_b decreases with temperature. Measurements have been investigated on films of 100 µm of thickness and in the range of temperature 30 to 70°C.
Following our hypotheses, the dielectric breakdown of this material is issued from or a thermal effect or an electromechanical effect. By using classical models representing, the first, by the general heat balance equation and, the second, by the relationship between electrostatic force and mechanical deformation, calculated theoretical results and supported by complementary measurements have shown that thermal breakdown phenomenon is the most probable. The contribution of these two processes seems to correspond better to real phenomenon appearing in this material.

I. Introduction

One of important conditions in the utilization of power cable insulators is their reliability depending on their dielectrical behavior under different working conditions such as temperature, electrical field, pressure, etc.... In fact, following the type of stresses, dielectrical breakdowns in materials would be different. The breakdown origins can be electronic, electrochemical, thermal or electromechanical etc.... Among them, these last theories are often the most considered to explain breakdown of insulators when they are submitted to combined effects of electrical field and temperature.
From our experimental results obtained on HDPE films with temperature and pressure effects [1], we attempt to give an explanation on its variations. So that, the first hypothesis used is electromechanical process based on the Young's modulus of the material. The second hypothesis considered is thermal breakdown model initiated by the existence of an electrical conductivity which creates a thermal runaway leading to the breakdown of insulators.

II. Dielectrical breakdown models

Taking into account our possibilities for theoretical and experimental verifications, these classical theories are proposed to explain the decreasing of breakdown field versus temperature for samples submitted to the same parameters with other complementary measurements.

II.1. Electromechanical theory.

Following the application of an electrical field to soft polymers such as polyethylene, a mechanical deformation caused by Maxwell stress can be appeared [2]. This is due to a mutual colombic force resulting of the attractions of the charges on opposite electrodes. This mechanical stress can cause a considerable decrease in thickness of the dielectric from an original magnitude d_0 in the vicinity of breakdown fields.
The electrical attractive force causing compression is balanced, at equilibrium, by the elastic restoring force by the following equation :