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E.6. Mise en évidence de fortes corrélations entre le développement de charges d'espace et la rupture diélectrique dans des isolants de câbles sous tension continue

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E.6. Evidence of a strong correlation between space charge build-up and breakdown in cable insulators under DC stress

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Résumé

Dans cet article on montre des corrélations entre le développement de charges d'espace, la croissance d'arborescences et le claquage dans du polyéthylène réticulé. On a utilisé la méthode de l'onde de pression pour suivre l'évolution de la distribution des charges en fonction du temps, sous contrainte continue, dans une géométrie de câble à isolant épais. On montre que pour certains systèmes isolants l'accumulation des charges d'espace peut augmenter localement le champ électrique à une valeur qui est plus de huit fois celle du champ appliqué, conduisant au claquage. Des analyses du matériau après décharge complétées par de la microscopie optique montrent la présence d'arborescences, le canal de décharge étant centré sur l'une d'elles. Les études d'évolution des charges d'espace permettent de comprendre le rôle de la charge d'espace dans les claquages sous contrainte continue. Cette compréhension permet la mise au point de techniques susceptibles de supprimer cet effet et donc de réaliser des câbles au polyéthylène réticulé pour le transport de courant continu.

Abstract

In this paper we present new evidence linking space charge build-up, tree growth and breakdown in XLPE. We have used the PWP method to monitor the charge distribution as a function of time under DC stress in a thick walled cable geometry. We show that for certain insulation systems the space charge build-up can increase locally the field to a value which is more than eight times the applied electric field, leading to breakdown. Post-mortem analysis followed by optical microscopy shows the presence of trees, the breakdown channel being centered on one of them. Studies of space charge evolution permit an understanding of the role of space charge in DC breakdowns. The understanding enables the development of technologies to suppress this effect and hence realize practical DC XLPE transmission cables.

Introduction

For many years experiments have suggested that there was an influence of a space charge build-up under electric stress, on the performance of insulators. Indeed such charges can strongly modify the internal electric field. It is well known for instance that charges of same polarity as that of the electrodes reduce the interfacial fields but increase the field in the bulk. On the contrary, charges of opposite polarity reduce the field in the bulk but increase the field at the interfaces near the electrodes. The increase of local field could be held responsible for breakdown phenomena[1-3]. Various approaches have been used to analyze this effect. A very direct one has been the application of non destructive techniques for the measurement of space charge distributions or electric fields inside insulators. Different methods can be used to obtain such information which use either the diffusion of heat or the propagation of a pressure wave in the sample.

In this paper we have used the pressure wave propagation method (PWP) to monitor the evolution of space charges as a function of time under DC stress in thick walled cable geometries. The insulator was made of cross linked polyethylene and the high voltage was applied until breakdown occurred. Post-mortem analysis shows evidence of a direct link between the space charge build-up and the breakdown.

The Experimental Method and Samples

Experimental Method

The principle of the PWP method has been described in detail elsewhere[4-6]. The impact of a laser pulse on a target produces a very short duration pressure pulse. The current flowing in the external circuit during the propagation of the pressure wave through the sample is directly related to the field or space charge distribution.

To get the electric field distribution $E(z)$ or the space charge distribution $\rho(z)$, a deconvolution may be applied to an integral equation, taking into account the attenuation and dispersion of the wave during its propagation in a sample. However, a rough image of the space charge distribution and the interfacial fields can be directly deduced from the measured