C2.14

Elastic-wave methods for the measurement of space charge distributions : evolution and perspectives

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Résumé

Les méthodes de mesure élastiques représentent actuellement un outil puissant pour la détermination des distributions de charges dans les isolants. Elles sont non destructives et peuvent être utilisées à haute cadence. Dans cet article, nous montrons comment les résolutions spatiale et temporelle de ces méthodes sont continuellement améliorées. Par ailleurs, utilisées en complément d'autres techniques de mesures, elles permettent d'analyser plus précisément les processus chimiques et physiques mis en jeu dans les isolants.

Abstract

Elastic wave methods are now well established as a tool for the determination of the space charge distribution in insulators. They are non-destructive and may be operated at high repetition rates. In this paper, we will show that these methods are still pushing their limits in terms of spatial and temporal resolutions. They will also be a useful tool for understanding physical and chemical processes in insulators, in complementary measurements using others techniques.

Introduction

Breakdown phenomena and ageing of high voltage cables are directly related to the presence of strong electric field concentrations in localised areas of the insulator. Such situations can result from the build up of particular space charge distributions. In order to help choosing the proper materials and structures, various methods have been developed over the years to measure in a non-destructive way the space charge distributions in insulators. They involve current or voltage measurements under thermal, electric or mechanical stresses. One family of techniques now currently applied, uses the propagation of such a stress through the material under study. This perturbation is either transmitted to the sample from the outside, as in the so called PWP (Pressure Wave Propagation) [1,2,3,4], LIPP (Laser Induced Pressure Propagation) [1,2] or PIPP methods (Piezoelectric Induced Pressure Propagation) [3,4] or directly generated at the level of the charges to be measured as in the so called PEA (Pulsed ElectroAcoustic) [5] method. In this paper, we will consider only these methods which are physically very similar and we will discuss their evolution in order to solve new types of problems.

Indeed these methods are intensively used in simple configurations such is the case in planar and coaxial structures submitted to dc voltages. They can also be applied to help analyse and solve more complex problems. For instance, cables are mostly used under a.c. stress and not under d.c. stress. For this reason, it is of great interest to perform the space charge distribution measurements at high repetition rates. This allows to follow in real time the injection processes and the eventual accumulations which can take place either in normal operating conditions under fast varying applied voltages for instance at 50 or 60 Hz, or even as a result of qualification tests.

Another problem is associated with the development of trees or breakdowns initiated by a strong concentration of electric field, as can be the case near impurities of the material or defects of the electrodes. For such situations, the implementation of the methods requires either to focus the probe locally in the sample or to imagine configurations or geometries which allow for the use of conventional methods.

The progresses which have already been made in these directions and new developments of these methods will be discussed. In the last part of this paper complementary methods will be presented.

Principles of PWP and PEA methods

The Pressure Wave Propagation method

In the PWP method a pressure wave is transmitted to the sample and propagates at the velocity of sound. During this propagation the pressure wave moves the trapped charges in the insulator relative to adjacent electrodes. This slightly modifies the internal electric field. Under short-circuit conditions this electric field variation induces a current in the external measuring circuit. This current is proportional either to the space charge distribution in the insulator if the pressure wave is a short pulse or to the internal electric field in the case of a pressure step. The Figure (1.a) shows the principle of this method in the case of