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Test of polymers for high voltage DC cables

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Abstract: Results obtained from a series of tests conducted on planar samples, made from different polyethylene grades designed for implementation in high voltage DC cables, are presented.
Measurements of insulation currents vs. time, temperature and electric field were performed as well as space-charge measurements using the *Laser Induced Pressure Pulse* (LIPP) method. Special consideration was given to the decay in current, which can be observed after the application of voltage to the polyethylene specimen.

Keywords: HVDC insulation, space-charge, conduction mechanisms.

Résumé: Dans cet article, nous présentons les résultats obtenus sur une série d'essais effectués sur des échantillons plans de différents grades de polyéthylène destinés à la réalisation de câbles à haute tension courant continu (DC).
Des mesures de l'isolement en fonction de temps, de la température et du champ électrique ont été réalisées, ainsi que des mesures de charge d'espace par la méthode d'onde de pression par laser (LIPP). Une attention particulière a été apportée à la diminution du courant observée après l'application de la tension aux échantillons de polyéthylène.

Mots clés : « HVDC », isolement, charge d'espace, mécanismes de conduction.

1. Introduction

In our experiments, the problem associated with space-charge accumulation in polymeric DC cable insulation is being addressed. Based on earlier obtained insights, a number of promising polyethylene compounds were identified and some of these were subsequently selected to serve as candidates to be applied in the extrusion of DC test cables. In this work, we present the results obtained from measurements on samples made from three of these candidate materials. Measurements of insulation current versus time, temperature and electric field have been performed at electric field strengths ranging from 20 to 40 kV/mm and at temperatures between 50 and 80C. Space-charge measurements have been performed using the LIPP method at fields of approximately 20 kV/mm, which is the design field of the proto type cable. Measurements have been conducted both at room temperature and with an applied temperature gradient.

When devising a polymer with the sought after DC properties, it is important that the exact mechanisms at work in conduction and build-up of charge are adequately understood. One interesting aspect in relation to this is the decaying current, which is observed after a voltage has been applied to the sample. Simultaneously, a redistribution of space-charge can be observed inside the sample, leading to what is an apparently steady state condition. Another issue is the important question of what exactly determines the field and temperature dependency of the current and why the current continues to fall for considerable time; even after the space-charge distribution has come to an apparent steady state.

2. Materials and Test Procedure

Round planar samples of polyethylene have been used. The sample thickness chosen is 1 ± 0.1 mm and the diameter of the electrodes is 80 mm. Surrounding the low voltage electrode is a guard electrode, insuring that no surface current enters the measurement system.

Results obtained from measurements on three different material compositions are presented in this work. Polymer 1 is a cross-linked low-density polyethylene, containing a small amount of peroxide and no antioxidant. Polymer 2 is the same base polymer as polymer 1 but a slightly larger amount of peroxide and some antioxidant has been used. Polymer 3 is a very low-density polymer, containing approximately the same amounts of peroxide and antioxidant as polymer 2. In all three samples a commercially available polymer-based semiconductor has been used as electrode material.

Identical types of polymers have been used for both conductivity measurements and for LIPP measurements. The spatial resolution of the LIPP system is approximately 0.1 mm, allowing for a fairly accurate representation of the charge distribution inside the samples [3]. A well-tested and reliable measurement system has been used to conduct the space-charge measurements. An amplifier with a very low cut-off frequency and a high impedance input is used, resulting in direct measurements of the electric field in the sample. These results are then differentiated in order to obtain the space-charge distribution. The build-up and transport of space-charge in the samples are recorded by measuring the field distribution at different times after the application