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Theoretical and experimental study of space charge under DC polarisation up to breakdown in power cable insulator

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Résumé

Les mesures de charges d'espace par la méthode d'onde de pression dans le Polyéthylène Basse Densité, soumis à une tension continue jusqu'au claquage, sont présentées. Les résultats montrent la formation de cette charge d'espace et son évolution avec le champ appliqué. On constate la présence d'homocharges au voisinage de chaque électrode. Pour expliquer ces phénomènes, on propose le modèle théorique basé sur l'injection de type Schottky au niveau des électrodes avec le mécanisme de transport par hopping dans le volume du matériau en tenant compte du processus de piégeage bipolaire.

Abstract

Measurements of space charges in Low Density Polyethylene (LDPE) have been carried out under dc voltage up to electrical breakdown using the Pressure Wave Propagation (PWP) method. Results have shown that the space charge build up exhibits an evolution with increasing voltage. In the aggregate, we can observe homocharges which dominate in the vicinity of each electrode. An attempt has been made to explain these space charges phenomena by proposing a model based on the bipolar injection of Schottky's process with the hopping mechanism transport in the bulk taking into account the bipolar carrier trapping phenomenon.

1 .Introduction

Since it was affirmed that space charge could cause very serious damage of electrical cable insulation under high voltage dc stress, different advanced techniques [1-4] for the direct probing of its distribution were realized to understand the physical mechanisms of its formation and development in order to avoid or retard the risks of breakdown. This paper deals with measurement and analysis of space charges in LDPE up to electrical breakdown.

2 .Experimental apparatus

Figure 1 shows the experimental apparatus of space charge measurement with PWP method. A pressure pulse is generated by the impact of a short duration laser pulse on the specimens (9 ns). The propagation of this wave changes the amount of induced charges on the electrodes, creating a current in the external circuit. This current is mathematically analyzed for obtaining the space charge distribution. The laser is Quantel Nd YAG 781 with 127 to 450 mJ energy. A Tektronix TDS 620 numerical oscilloscope is used to record the data. The applied dc electrical stress is given by a ± 300 kV dc voltage generator with a voltage rise rate of up to 10 kV/s and a stability of the output voltage about 3 %.
The samples used in our experiments are 150 mm diameter and 1 mm thick Low Density Polyethylene delivered by the manufacturer with semi-conductive electrodes playing the role of targets (500 µm thick, 20 mm diameter). These electrodes are hot pressed to about 130°C on both sides of the sample to prevent any change in acoustic impedance between the target and the sample. A 300 mm sheet is added to the sample to avoid surface flashover.

The applied voltage was raised in 20 kV steps of 2 hours duration up to electrical breakdown. For voltages greater than 80 kV, the measurements were executed in a Rhodosil oil path. The temperature of tests was 25 °C.