Transient space charge phenomena in HVDC model cables

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In the development of polymer-insulated HVDC cable systems, space charge and conduction current are among the most important features to analyze. Space charge accumulation in the insulation drives the field distribution and directly impact on the performance of the cable. To have further information on the evolution of space charge, conduction current measurements under various electrical and thermal conditions are of great importance. Reversely, knowledge on space charge features brings understanding in conductivity behavior. The aim of this paper is to investigate the accumulation of space charge and charging current transients under various conditions of temperature and applied voltage in 1.5 mm-thick cross-linked polyethylene (XLPE) insulation of mini-cables by means of simulation and measurements.

Space charge measurements have been carried out on mini-cables by means of pulsed-electro-acoustic (PEA) method at room temperature and under temperature gradient of 10°C (T_{in} = 70°C, T_{ext} = 60°C) under DC applied voltage of -30 kV and -55 kV. Space charge results highlight enhancement of the field at the outer-electrode when combining thermal and electrical stresses. They also reveal systematic occurrence of a negative front of charges generated at the inner electrode that moves toward the outer electrode at the beginning of the polarization step. It is observed that the transit time of the front of negative charge increases, and therefore the mobility decreases, with the applied voltage. Further, the estimated mobility decreases when the temperature increases for the same condition of applied voltage.

Conduction current measurements were also performed on these model cables with applied voltage varying from 2 kV to 30 kV and temperature in the range from 30°C to 90°C. Current-voltage characteristics follow Arrhenius law and exhibit non-linearity with electrical stress. Furthermore, charging current measurements exhibit a peak during the transient. Such a short time increase of current may be correlated either to the transit of negative charges front (observed in space charge patterns) or to the association of field dependent conductivity and divergent field. Modeling of the phenomena based on conductivity vs. field and temperature has been achieved. A method has been derived to estimate non-linear conductivity as a function of field and temperature based on current measurements on mini-cables. The obtained model of conductivity enables finally to compute current transients under various temperatures and voltages and to address the origin of the front of charges.

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