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The effect of voltage reversal on space charge behaviour at high temperature in XLPE cable

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The renewed interest in HVDC transmission has led to many manufacturers worldwide investing in polymer insulated dc power cables. However, the electrical properties of polymer insulation, such as conduction and breakdown, are strongly affected by the presence of space charge within the bulk of the material under dc stress. With the accumulation of space charge, the electric stress distribution across the insulation may be greatly distorted. The electric stress enhancement will consequently lead to a premature failure of the cable at stresses well below the anticipated or designed values in an extreme situation. This issue had fascinated many researchers over the world to devote to the investigation of space charge accumulating mechanism, and some fruitful results have been achieved on the basis of research in film and plaque samples. Somehow, there are much less researches on the full size cables where the production process of the insulation, electric stress and temperature profile are fully reflected.

The research presented in this paper was carried out in a full size cross-linked polyethylene (XLPE) power cable using the pulsed electroacoustic (PEA) technique, in which the space charge evolution under reversed dc voltage polarity and different temperatures are measured and discussed.

It has been found that the build-up rate of space charge after the voltage reversal is faster than that in the initial stressing voltage although the final space charge profiles of two opposite polarities exhibited a "mirror effect". The faster rebuilding rate of space charge is considered as the result of electric stress profile distortion during the voltage polarity switch. The electric stress distributions were therefore calculated on the basis of the space charge measurement during and after the voltage polarity change to understand the space charge re-distribution.

Due to the stable distribution of space charge, the electric stress in the central insulation is significantly enhanced during voltage reversal. On the other hand, the stresses at the inner and the outer interfaces reduced respectively because the electric stress contributed by the previous heterocharge, which became a homocharge, counteracted the applied stress.

Space charge measurements at high temperature with and without temperature gradient across the cable insulation have revealed almost same space charge evolution phenomena except the lower charge density and faster decay rate.

The following conclusions may be drawn from the current research.

(1) At the stress level investigated, it was found that once the space charge is established in the cable insulation, its response to the external voltage change is slow. This is regarded as the risky moment for dc power cable insulation immediately after the polarity reversal as the electric stress is likely to have a complex distribution due to the presence of space charge.

(2) The rate of charge accumulation is affected by the new electric stress distribution when the voltage polarity is reversed. Space charge can be initiated in the region of higher electric stress.

(3) At high temperature, particularly in the presence of temperature gradient through the insulation, the temperature dependent conductivity leads to different electric stress distribution in some extent which in essence influences space charge initiation.