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Study of the effects of the temperature modulation on the lifetime of HV XLPE cables

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Ageing at constant temperature does not simulate cable operation, since cables are subjected to thermal cycles. Results obtained in 1999 on a 400 kV cable aged at IREQ (Canada) under heat cycles show clearly that this cable has a different behaviour from cables aged recently under constant temperature. In fact, thermal cycles seem to be beneficial to improve cable lifetime. But this aspect remains challenging to be quantified nowadays.

Scientists believe that during the lifetime of an AC cable, space charges may be generated and trapped in an insulation and could influence modifications/ageing of the product. One aim of our paper was to study the effect of the temperature in the insulation on the evolution of space charges. Under a constant and sufficient DC field, relationship between the temperature and the space charge density is relatively complex: indeed, the temperature can stimulate numerous processes, which act on the appearance of charges: charge injection from the electrodes, polarisation, and electrical conduction in the bulk. Such phenomena could be, to some extent, associated with the modification of the morphology of the insulation.

The objective of this study is to examine the ranges of temperatures which on the one hand promote the accumulation of space charge which can lead to a potential decrease of the cable lifetime, and on the other hand those ones where space charges release (evacuation) is favoured. A 150 kV AC cable was poled under 100 kV DC (maximum Laplace field: 7 kV/mm, which is relatively low) for 24 hours, then space charge and trapping sites features were approached using Thermal Step Method and thermo-stimulated currents measurements. As the traps depth varies within any polymer due to structure irregularities or changes, SAXS measurements were performed in order to point any evolution of the structure of the cable insulation submitted to severe cycling stress conditions at IREQ (851 thermal cycles at 95°C during 15327.5 hours, maximum field reached 27.5 kV/mm).

We observe, in particular, a higher space charge amount when the poling temperature is 60°C. On the other hand, the space charge trapping capacity falls abruptly at 70°C. We see also that annealing acts on the structure of the material and consequently on the trapping sites. In particular, annealing diminishes the space charge trapping at temperatures below 60°C. These behaviours are to be linked to the structure of XLPE (higher lamella thickness after the thermal treatment) and favoured molecular motion with increase of temperature.

It appears that the effect of temperature is very complex, and its consequences for the material are not all unfavourable. Further work is needed to support the positive thermal load on the behaviour of power cables.