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Evaluation and modelling of thermo-electric ageing of XLPE insulated power cables: the ARTEMIS outcome

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The aim of the ARTEMIS[5] project was to develop a diagnostic system for assessing thermo-electric ageing of XLPE insulation of power cables. It associated 11 partners, among which one raw material supplier, two cable manufacturers, three utilities and 5 universities. The scientific approach relied on the evaluation and the assessment of an ageing scenario proposing that local concentration of trapped space charge drives local modifications of the polymer structure to a critical point at which voids were produced with a size sufficient to support partial discharges and electrical tree formation. The project structure was divided into different tasks with the objectives:

- to develop analytical expressions of the time to breakdown versus thermo-electric stresses,
- to age cables and peelings taken from cables under different field, temperature and time,
- to characterize any change of the material properties vs. ageing time and to correlate them with the ageing conditions in order to identify possible ageing markers,
- to develop a diagnostic system that can accommodate data associated with ageing.

The ageing model and life expression proposed for AC stress in isothermal conditions hold parameters (threshold values of field in particular) that have been inferred through specific, non-destructive tests. Molecular modelling was used to calculate the trap depth of positive and negative charges on features such as conformational and chemical defects in a polymer chain, or by-products of the cross-linking reaction. Numerical values show that chemical defects and by-products can provide efficient trapping centres. Several techniques have been selected to characterize the physical, chemical and electrical properties of the insulation at different stages of the ageing process, with a special focus on those techniques that give access to space charge related quantities (accumulated space charge, charge mobility, electroluminescence) and micro-cavities size and distribution (Optical Microscopy, Transmission Electron Microscopy, Scanning Probe Microscopy). Some analyses were also performed along the cable radius for different ageing times. It turns out that several measured quantities exhibited evolutions with time but these have not been convincingly associated with insulation degradation. It appears that the applied stress conditions for ageing cables (field up to 30 kV/mm for 6000 h at 90 °C) although higher than those of service conditions of XLPE cables were not severe enough to damage the insulation to a noticeable extent. Although a clear trend in the evolution of expected ageing markers was not observed, indications were obtained so as to support the ageing scenario at the basis of available ageing models, i.e. size and distribution of cavities evolve with time under stress. The structure of the ageing diagnosis system was designed as a general-purpose diagnostic tool, able to process any kind of data.

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[5] ARTEMIS: Ageing and Reliability TEsting and Monitoring of power cables: diagnosis for Insulation Systems, 5th Framework Program for Research and Technological Development of the European Union, project number BRPR-CT98-0724, 1998-2002.