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

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**Abstract**: The aim of the ARTEMIS [2] project was to develop a diagnostic system for assessing thermo-electric ageing of cross-linked polyethylene power cable insulation. It comprised eleven partners [1], including one raw material supplier, two cable manufacturers, three utilities and five universities. The scientific approach relied on the evaluation and the assessment of an ageing scenario in which the 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 main outputs of the project are described.

**Keywords**: Power cable, Diagnostic system, Electrical ageing, Synthetic insulation.

**Résumé**: L'objectif du projet ARTEMIS [2] était le développement d'un outil de diagnostic permettant l'évaluation du vieillissement thermo-électrique des câbles de transport d'énergie à isolation polyéthylène réticulé. Il regroupait onze partenaires [1], parmi lesquels un fournisseur de matière première, deux câbliers, trois utilisateurs de câbles et cinq universités. Dans le scénario de vieillissement envisagé, les charges d'espace piégées induisent des modifications locales de la structure du polymère jusqu'à un stade critique où se forment des vacuoles sièges de décharges électriques. Nous décrivons les principaux résultats du projet.

**Mots clés**: Câbles de transport, Diagnostic, Vieillissement électrique, Isolation synthétique.

## 1. Project objectives

Electric power transmission needs reliable high voltage AC (HVAC) power grids; there is a current trend towards an increase in buried links. This market evolution corresponds to a strong environmental pressure to reduce usage of overhead lines. The present technologies for the insulation of AC high voltage cables are cross-linked polyethylene (XLPE) and traditional paper-oil. The market for fluid-filled cables is declining due to higher dielectric losses, more maintenance, more complicated installation procedure and environmental reasons (risk of leakage). There is a growing need for extra-high voltage cables (400/500 kV), especially in urban or crowded areas corresponding to a stress level up to 16 kV/mm. The technical limitations of extruded high and extra high voltage cables are related to a lack of understanding of the degradation mechanisms. This is one of the reasons why the design stress currently employed for XLPE is lower than oil-filled cables, resulting in larger cables and thus higher installation costs. A reliable life model would make it possible to optimise the cable construction and thus make XLPE cables more competitive at the highest voltage levels. Some cables have been operating for over 20 years, with an expected 30 years life. There is a need for further life extension to 40 years for the cables. This requires an absolute need for reliable AC power cables. This target can only be reached through the development of an efficient Diagnosis System.

The ARTEMIS project was launched to answer some of these questions [3]. Its main objectives were:

- to assess the state of ageing of cable materials under combined thermo-electrical stresses,
- to develop a Diagnosis System to predict their remaining life time.

The main tasks of ARTEMIS comprise: development of a model of ageing and remaining life time based on characterisation of AC power cables, development of the Diagnosis System using the model and advanced characterisation techniques and retrospective evaluation using operating cables removed from service.

## 2. Theoretical background

Electrical failure of polymeric cables is normally due to growth of damage starting from weak points such as contaminants, protrusions and voids. Improvements in manufacturing technology have resulted in the reduction of their concentration and size making increased design field possible. In order to consider whether it is worthwhile investing further effort in improving manufacturing processes, it is necessary to understand the ageing mechanisms