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# Electrical aging and breakdown of crosslinked polyethylene cables

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**Abstract**: A model of dry electrical aging of extruded cables is briefly discussed. The model, without any adjustable constant, is based on two basic parameters : the activation energy and volume. It describes very well aging data obtained under constant temperature. The main objective of this paper is to show that the impulse and AC breakdown fields of actual XLPE cables can be directly related to the aging parameters deduced from dry aging tests performed on the same samples. From a practical point of view, this means that the aging characteristics at constant temperature of a given cable might be predicted from fast breakdown tests performed under at least three different voltage raise ramps. The practical implications and the remaining work to be done are also discussed.

**Keywords**: XLPE, dry aging, breakdown

**Résumé**: Un modèle de vieillissement accéléré à sec des câbles extrudés est présenté. Ce modèle sans aucune variable ajustable repose sur deux paramètres principaux, l'énergie et le volume d'activation. Il est montré qu'il décrit très bien les données expérimentales concernant les câbles PRC vieillis sous température constante. L'objectif principal de cet article est de montrer qu'il est possible de prédire les valeurs des champs de claquage sous impulsion et sous rampe AC à partir des résultats de vieillissement obtenus avec les mêmes échantillons et interprétés avec notre modèle. Cela suggère qu'il semble possible de déduire les caractéristiques de vieillissement à partir des résultats d'essais de rigidité diélectrique obtenus sous au moins trois rampes de voltage différentes. Les implications pratiques et le travail restant à faire sont brièvement discutées.

**Mots clés**: PRC, vieillissement sec, claquage

### 1- Introduction

Electrical aging of polymers is still poorly known although it has a major influence on the lifetime of extruded cables. Accelerated aging results are usually obeying a power law relation between aging time t and breakdown field F, such as $t = CF^{-n}$, where C and n are constants characteristic of the cable. Results plotted on log field vs. log time graphs are expected to fit a straight line. We have shown in previous work (1) that life extrapolations made from such graphs are, at best, dubious since the linear relation between log field and log time does not hold for long aging times (2) and it is not always evident at short aging times. In fact, results fit much better a semi-log plot between F and log t. We have proposed an aging model that describes very well actual accelerated aging data (1). There are few other models able to predict lifetime at the temperatures where most transmission cables operate (3-6). The Crine (1), Dissado and Montanari (3-4), and Lewis (5-6) models of aging predict the times to failure more accurately than the empirical inverse power law model that is currently used in cable design. Some of the models have constants that have to be determined experimentally, and it is likely that these constants will vary according to the extrusion conditions. The three models predict a threshold electrical stress, below which there is little or no electrical aging. Above the threshold stress, the times to failure decrease with increasing electrical stress. The Crine model predicts that the threshold stress is not well defined and that the aging rate changes to a very low but non-zero value below the threshold. Although some cables are operating successfully at ~15 kV/mm, and some have undergone prolonged aging tests at stresses greater than 20 kV/mm, there is concern that these stresses are above the threshold stress for aging. One objective of this paper is to show that weak bonds breaking occuring at a field higher than the critical (or threshold) field result in irreversible and fast aging.

Another objective is to show that it seems possible to directly relate aging and breakdown characteristics of the same XLPE sample using the proposed model. Obviously, the practical advantage would be very significant if the long and expensive aging tests could be replaced by fast and unexpensive breakdown tests. Among other things, this would considerably shorten cable design and acceptation