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A review of the influence of frequency on accelerated aging of PE and XLPE cables

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Résumé

Une revue de l'influence de la fréquence sur le vieillissement accéléré des câbles en PE et en PRC indique que la fréquence accélère l'arborescence. On n'a pas trouvé d'évidence expérimentale concernant une fréquence maximale. La même tendence est observée pour le vieillissement sec des câbles. Il n'existe aucun modèle théorique bien qu'il semble évident que le nombre de changement de polarité du champ électrique soit un facteur prépondérant. L'impact de cette observation sur de nouvelles procédures d'essais accélérés est discuté.

Abstract

A review of existing data on the influence of frequency on the accelerated aging of PE and XLPE cables is made. As a general trend, it was observed that high frequencies shorten insulation lifetime and increase vented water-tree growth. No evidence for a maximum frequency above which water-tree growth saturates was found. The influence of high frequencies on "dry" aging of extruded cables follows the same trends whatever the experimental conditions. No theoretical model actually describes all existing data, but there seems to be a relation between aging and the number of field cycles.

Introduction

It is well known that frequency is one of the main accelerating factors in the electrical aging of polymers, and this is particularly evident in accelerated water-treeing tests. However, most of the accelerated electrical aging tests are based on high electrical stress and temperature. Such tests are currently made under 60 Hz and they last several weeks (and often, several months); any reliable test reducing the time by a factor of 3 to 5 would therefore save very significant amounts of money. If it can be proven that high frequency tests give similar results than 60 Hz tests (but in shorter times) and thus accelerate the same mechanism of degradation, the tests accelerated by frequency rather than higher stress may correlate better with field performance.

Although the frequency influence has been empirically known for many years, there is not yet a formal equation relating insulation lifetime and frequency. Dakin [1] and Bahder et al. [2] have proposed aging models relating life and discharges frequencies but, to the best of our knowledge, they are not used (one because it is too crude and the other because it is too complex). In the aging models of Dissado and Montanari [3] and of Crine et al. [4], there is no explicit relation between life and frequency. Very recently, Dissado and Montanari [5] presented a preliminary model relating the aging time and the frequency; many improvements and many validation tests are needed to confirm the applicability of this theory to the electrical aging of cables in service. In fact, the electrical aging phenomena in polymers are still poorly understood. We have made a survey of existing aging data obtained at high frequencies and the most typical results are briefly reviewed in this paper. There are only limited data on the high-frequency electrical aging of various polymers [6-33] and most data was obtained in water treeing material tests [10-33], i.e. not with actual cables. There are several reasons for this limited amount of data for full size cables:

- There is no reliable theory correlating high frequency measurements to actual lifetime at power frequency.
- The optimal frequency for aging tests has never been established.
- There is no definitive standard for high-frequency life testing of cables.
- High frequencies sources delivering high voltage are not common and are relatively expensive.
- Full-size cable testing is expensive and it is usually reserved for standard homologation tests.

However, the few existing experimental results discussed in this paper clearly demonstrate that high frequency greatly accelerates the time to failure of cables or the water-tree growth rate. Thus, the development of a reliable model of accelerated electrical aging of polymers under high frequency may