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# Damage analysis and mechanical behavior of the low voltage overhead power cables dedicated to distribution network

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**Abstract.** Since the onset of electrical systems, electrical cable was the first physical support for passing an electric current to flow. Until now, the power cable is still valid and has undergone intrinsic more severe modifications to adapt with the electrical and environmental constraints.
However, mastering the reliability of overhead lines of electric power long distances through generally different parts of their relief (topography and altitude), climate (temperature, pressure, wind) their environment (industrial areas, coastal areas) has become increasingly important. Therefore, the equipment power transmissions are exposed to various constraints, among these, the degradation of connections and electrical aging weapons which are recognized as major factors causing the faults stored on airlines, and thus appear as very important factors in the quality and reliability energy transport.
The purpose of our work is to optimize the control performance of the ducts from the overhead electrical distribution networks generally and especially aging degradation. For this we will look at details of the various mechanisms and processes involved in the thermal aging of solid insulation in general and in particular synthetic sheaths. We then discuss the experimental part includes the cable and used test devices and complete the study by discussing results.

## 1 Introduction

Worldwide, overhead transmission lines are reaching their middle age, between 25 and 40 years old, and individual components are showing the first signs of deterioration. As a consequence, these components should be repaired and replaced as part of the normal maintenance routine [1,2]. In-service conductors are exposed to external loads and, to minimize the possible damages induced by wind, vibration dampers (known as spacer dampers) are positioned regularly on the transmission line by the use of clamps.

The conductors are subjected to maximum curvature near the clamps as well as compressive forces exerted by the clamping devices. Contact stresses in a clamping region can be divided into two categories: static and cyclic. Static stress is the sum of constant axial load (span weight), bending stress (change in curvature over the clamp), local clamping pressure and keeper pressure [3–5]. When the conductor is subjected to external tension, an internal torque is induced trying to unwind the conductor and, as a result, any variation in tension excites a tensional vibration mode, transmitting a torque to the support. Depending on the clamping force, the conductor can rotate in the support and cause fretting damage. Additionally, reversed-bending cycles of the conductor can be induced by wind near clamps and other fittings (maximum curvature) [2,3,6].

The overhead lines are affected by the wind-induced vibrations in two ways [1,7,8]:

- Aeolian vibration: caused by wind blowing over individual conductors, which induces high frequency vibration (between 10 and 40 Hz) due to the creation of vortices downstream of the conductor, promoting alternating bending stresses. It occurs at relatively low speeds for transmission lines, which are positioned normal to the prevailing wind.
- Sub-conductor oscillation (wake-induced vibrations): caused by wind-induced instabilities downstream of the conductor. Classical oscillation of a square quad bundle conductor results in the horizontally biased elliptical of the conductors at low frequencies of about 1 Hz, due to the interaction between vertical and horizontal wind-induced forces. The presence of a fitting during this oscillation promotes the flexing of the aluminum strands, which might promote fatigue or fretting failure after tens of millions of cycles.

Prediction of dielectric breakdown in the short or long term is difficult to do if we want to take into account all the parameters involved in the aging process. A large number of mechanisms have been implicated in the description of the process of damaging organic insulators and different approaches have been presented. Given the complexity of the process in question, several simplifications were made by different experts in the field. These simplifications are mainly related to specific properties of polymeric materials.

## 2 Degradation of overhead power cables

The cables must be a regular diagnostic whose main task is to verify the quality of their insulation defects (Figure 1). In this regard, the measurement of partial discharges is a technique that has proven its worth for many years.

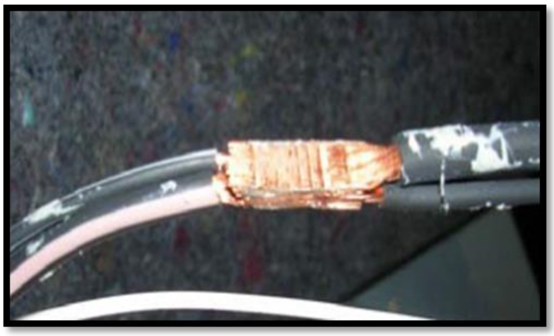

**Fig.1.** Tearing of the cable insulation

The airlines of power transmission drive long distances and cross through very different parts of their relief (topography, altitude, etc.), Climate (temperature, pressure, wind), and environment (industrial areas, coastal area).

Therefore, the equipment power transmissions are exposed to various stresses. Among them, pollution, slush and atmospheric icing insulators are recognized as major factors behind the recorded faults on overhead lines, and thus appear to be very important factors in the quality and the reliability of the power transmission. Insulators can indeed be covered with dust (but weakly conductive hygroscopic). Arcing can take birth in certain conditions, and grow to cause total bypass isolator (Figure 2).

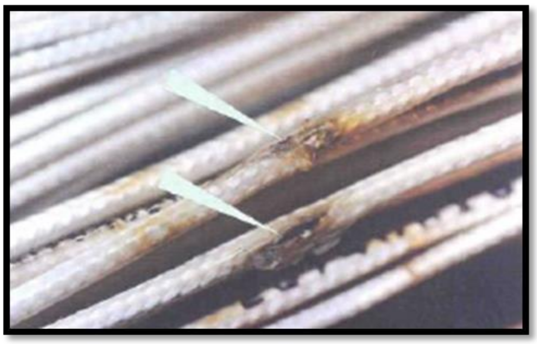

**Fig.2.** Degradation of the sheath (driver exposure to air)

In the literature, many works dealing with plenty degradation ducts from the power cables, for example, the breakdown of the insulation, called breakdown, this can occur following different mechanisms [9-11]. Propagation of electrical trees and modeling has been the subject of numerous studies. The most recent are those Dissado [12], Champion and Dodd [13-15] but studies have addressed this phenomenon in the 80 years [16-17]. Many studies relate the phenomena of partial discharges in organic insulators such as references [18-20]. These phenomena are well known but are already signed an advanced aging of the material.

## 3 Experimental parts

### 3.1 *Composition* and manufacture of studied cables

In this work, we will focus on the synthetic cables (Figure 3), the sheath and insulation is polymer. Generally, the insulation of the cable consists of three coaxial layers of plastic extruded into the center conductor (often called the cable core).


**Fig. 3.** Formation of a low voltage cable with XLPE insulated

Figure 3 illustrates the formation of a typical single-phase cable. From a purely technical point of view, we can distinguish two types of cables, those paper-insulated and those isolated cross linked polyethylene (XLPE cable). Inevitably, the insulation disposed around the conductor of a cable ages and degrades over time. Destruction, partial or complete of this insulation involves maintenance effort or worse cable replacement.

### *3.2 Preparation of test specimens*

The plates obtained in procedure will be cut into pieces form dumbbell (Figure 4) according to standard IEC 60811 [21].

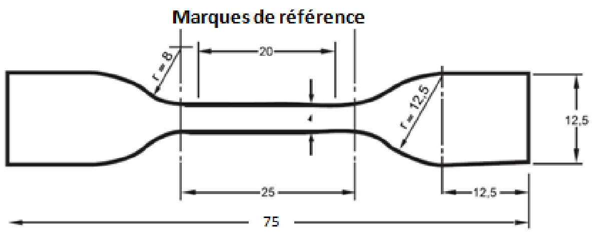


**Fig. 4.** Lap the insulating dumbbell [15]

Each test consists of a thin slice of the insulating envelope. The wafer is cut with a suitable device (sharp knife, razor, etc.). Along a plane perpendicular to the axis of driver specimens according to the desired dimensions.

### *3.3. Experimental*

The tests were conducted using an INSTRON (4301) equipped with a load cell of 100 Newton and locking jaws specifically adapted to the characterization of thin films (Figure 5).

For each aging time, 10 samples were analyzed in order to take into account the dispersion of results.

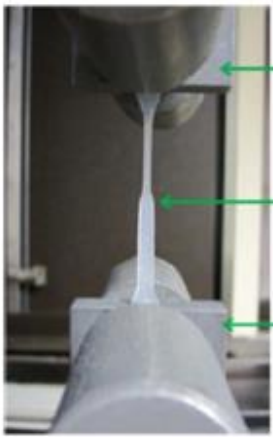


**Fig. 5.** Photograph of a tensile specimen during a uniaxial tensile test

The uniaxial tensile test was chosen to assess the effects of thermal aging on the mechanical properties of the polymer. Particular attention was paid to changes in two properties at break stress and elongation at break [22] (Figure 6).

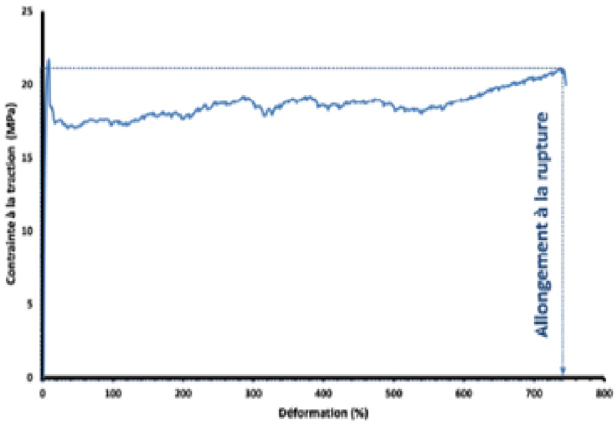


**Fig. 6.** Strain curve for the graphical determination of properties at break

## 4 Conclusion

The electrical conductors are among the most important component of overhead transmission and distribution of electrical energy they assured both the mechanical support of the parties brought to the low voltage electrical insulation with recent parts made in air or energized.

The use of lightweight cables, flexible, compact, highly reliable and resistant to various environments are the main constraints imposed by most industries.
First designed in copper and aluminum cable manufacturing has experienced through the years, a significant change, and in order to improve their performance whatever the weather and environmental conditions to which they are exposed. Indeed, disruption of electrical conductor can result in certain circumstances a major risk to the reliability and operation of the transmission of electrical energy by air.

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