Dielectric Loss Evolution for Miniature Cables with PE Insulation through Various Stages of Degradation

Simon **BERNIER** (1), Jean-François **DRAPEAU** (1), Daniel **JEAN** (1)
1 – Institut de recherche d'Hydro-Québec, Varennes, Québec, Canada, bernier.simon@ireq.ca, drapeau.jean-francois@ireq.ca, jean.daniel@ireq.ca

ABSTRACT

The main purpose of this study is to clarify the influence of local and global aging on the actual electrical performance of the insulation and on the development of associated diagnostic values and features, along with the level of aging. The cables used for this study were miniature cables (RG-58) having an insulation thickness of ~1 mm. The aging was achieved by having the cable samples immersed in tap water and energized at 5 kV AC up to ~18000 h. The performance of these cables were assessed by measuring the dielectric response with two different methods (Very Low Frequency (VLF) and Time Domain Spectroscopy (TDS)); by visual inspection of the generated defects; and finally by breakdown voltage analysis.

KEYWORDS

Insulation, Dielectric, Water tree, VLF Tan Delta, TDS, Breakdown voltage, Weibull, Cable.

INTRODUCTION

PE-based insulation was introduced in underground distribution cable systems some 45 years ago. For this type of insulation, long term aging is a concern as it is well known that water treeing gradually develops when the insulation is exposed simultaneously to water ingress and service electric stress. As a growing proportion of XLPE extruded cables are considered to be reaching the end of their design service life, there is a need to gain a better understanding of the relation between diagnostic measurement results and the "actual" aging condition of the insulation. Insulation degradation can develop according to two processes: global and local. Global aging is related to the development of water trees while local ageing issues may be related to specific defects in the bulk of the insulation (e.g.: protrusions, contaminants, cavities) and/or to the presence of very long water trees (typically vented) that may lead to the development of electrical trees.

This study aims to investigate the effects of these two aging processes on the insulation performance and on the evolution of the various diagnostic features.

In order to get a clear picture of the evolution of insulation aging condition, the cable samples were assessed at regular intervals, typically every 1000 h to 2000 h. The following items were included in the condition assessment procedure:

a) Insulation performance, measured by residual AC breakdown voltage;

b) Diagnostic tests;

c) Material aging characterization, performed through systematic examination of water trees (bow-tie trees, vented trees) and electrical trees.

The diagnostics used for step "b" were based on the characterization of dielectric losses. Two methods were used: VLF tan delta diagnostic and Time Domain Spectroscopy (TDS). The evolution of diagnostic features associated to each of these methods will be illustrated and discussed through the various steps of aging process.

EXPERIMENTAL SETUP

Sample and aging set-up

PE-based insulation tested in this study was provided by miniature polyethylene cables (RG-58) samples. All cable samples were subjected to water ingress while a proportion of them was subjected to water tree aging. These miniature coaxial cables have an insulation thickness of 1 mm without the semi-conductive shield. The cable samples length was set to 20 meters. In this study, cable aging was performed by having them immersed in tap water and energized at 5 kVrms AC voltage. Such a voltage provided an electrical field having a mean value of 5kV/mm. For the purpose of this study, U_0 was determined as the voltage providing a mean electrical field equivalent to that present in MV cables operated in Hydro-Quebec 25 kV system (~2 kV/mm). Accordingly, U_0 was set to 2 kV. Under these circumstances, the 5 kV/mm mean stress used for aging corresponded to a value approximately 2.5 times greater than that of service stress.

Special terminations (stress cones) were placed on the end of the shield in order to reduce the tangentiel field at this point. Teflon tape was placed between the stress cones and the ends of the electrical shield as shown in Figure 1. The external jacket of the original coaxial cables was removed in order to facilitate water penetration within the bulk of insulation, which allowed the water-tree growth rate to increase.

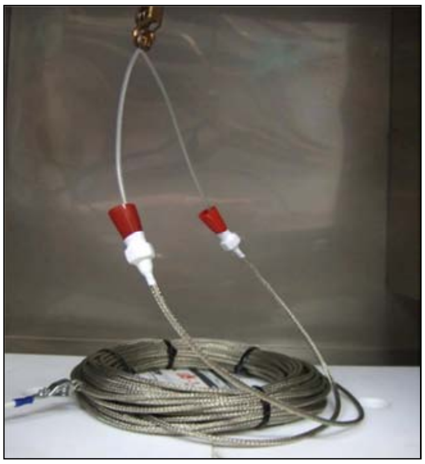

Fig. 1 : Miniature cable with the custom terminations

In order to achieve the water ingress into the PE insulation, all cable samples were immersed in water