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

PE based insulation has been introduced in underground distribution cable systems up to 40 years ago. For this type of insulation, long term aging is a concern since 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 get 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 to the presence of very long water trees (typically vented) that may lead to the development of electrical trees.

The main purpose of this study is to clarify the influence of these types of aging on the actual electrical performance of the insulation and on the development of associated diagnostic features and values, 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 took place by having the cable samples immersed in tap water and energized at 5kV AC up to ~18000 h.

In order to get a portrait of the evolution of the aging condition of the insulation, the cable samples have been 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 that were used for step "b" were based on characterization of dielectric losses. Two methods were used: VLF tan delta diagnostic and Time domain spectroscopy (TDS).

Condition assessment through VLF tan delta was done using the following diagnostic features:

- Tan delta mean values @ 2kV (i.e. voltage corresponding to mean service stress - 1 Uo);
- Voltage dependence (Tip-up) (i.e. difference between TD @ 1.5 Uo and TD @ 0.5 Uo);
- Time stability @ 1 Uo (measured by standard deviation)
- Nonlinear voltage dependence (difference in "slope" for TD values between 0.5 and 1 Uo of tan delta ("Tip-up of the tip-up") and between 1 Uo and 1.5 Uo)

Condition assessment through TDS, which shows the evolution of dielectric loss vs frequency, was performed using an experimental device that has been developed at Hydro-Québec (IREQ). Diagnostic features for TDS include dielectric loss spectrum shape, voltage dependence and dielectric loss POL/DEPOL ratios @ 0.001 Hz.

The evolution of all these features will be shown and discussed through the various steps of the aging process.

Key words

Insulation, Dielectric, Water tree, VLF tan delta, TDS, Breakdown voltage, Weibull.