TIME DOMAIN SPECTROSCOPY (TDS) AS A DIAGNOSTIC TOOL FOR MV XLPE UNDERGROUND LINES

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ABSTRACT

A Time Domain Spectroscopy (TDS) measuring device has been developed at IREQ as a diagnostic tool to assess the water-tree aging of MV XLPE underground cables. The diagnostic is based on the dielectric losses obtained by TDS measurements in polarization and depolarization. The results of TDS measurements on a total of 15 Hydro-Québec's lines show that the dielectric losses do not correlate with the number of years in service and losses are mainly due to joint degradation.

KEYWORDS

MV XLPE cables and accessories, water-tree aging, diagnostic tool, dielectric spectroscopy in the time domain

INTRODUCTION

The demand by electrical power utilities for condition-based maintenance and for diagnostic tools to assess the degradation of underground cable system insulation is increasing. With the growing number of assets aged 30 years or more, there is also a need to prioritize in which order underground lines should be maintained or replaced.

In the case of MV XLPE underground cable systems, the insulation is prone to water-tree degradation unless it has a water barrier to prevent water infiltrating. Although every one agrees that water treeing will potentially affect the dielectric performance of the insulation, there is no clear understanding of how it will affect the expected material lifetime. The models developed to date are not useful and the reported failure statistics are too insufficient to be able to extrapolate the degradation level of the insulation and the remaining life of the cable insulation because they cannot take into account the so-called TEAM (temperature, electric stress, ambient conditions, mechanical stress) factors. The lack of reliable diagnostic methods available to characterize global insulation aging also complicates the replacement decision.

In order to assess the water-tree degradation of Hydro-Québec's MV XLPE underground cable system, a project was launched at IREQ to determine the potential of Time Domain Spectroscopy (TDS) as a diagnostic tool. The TDS measuring device developed at IREQ was used to assess the water-tree aging on more than 25 cable sections that had been removed after being in service between 15 and 34 years. The tests performed on cables between 40 m and 350 m long (without accessories) showed a good correlation between the global (water-tree) aging and the amplitude of the dielectric losses in depolarization [1]. Once this correlation was well established, field measurements were taken on 15 Hydro-Québec lines (ranging from 1.1 km to 8.2 km and 8 to 45 joints). The results obtained on these lines showed that the dielectric losses do not correlate with the number of years in service. In several cases, lines commissioned more than 30 years ago even showed dielectric losses close to those of new lines. These results are in good agreement with those obtained from residual breakdown voltage and maximum water-tree length measurements on approximately 45 cable sections recuperated from the network. Indeed, contrary to what was expected, the minimum residual breakdown voltage for cables in service for 30 years ranged as high as between four to eight times the service voltage and the maximum water-tree length (bow-tie) was approximately equivalent to 30% of the insulation thickness [1].

Following the TDS field measurements on lines, several cable sections were recuperated (when feasible) and sent to IREQ for further investigation (residual breakdown voltage, water-tree length and TDS losses). Investigating the TDS dielectric losses on these particular cable sections provided key data for getting a proper interpretation of line losses. In fact polarization and depolarization losses measured on underground lines are the result of a combination of losses coming from cable sections, joints and terminations. Previous studies showed that the contribution of the accessories could be significant, even to the point of dominating that of the cable sections [2-4].

EXPERIMENTAL

TDS is an off-line, non-destructive and efficient method for measuring dielectric losses of polymeric insulation. The principle is shown in Figure 1. The dielectric losses are calculated in the low-frequency range between 10^{-1} Hz and 10^{-4} Hz from the polarization and depolarization current values measured with the TDS device. The computer-controlled TDS device developed at IREQ can measure polarization and depolarization currents with a sensitivity of 10×10^{-9} A and 1×10^{-12} A, respectively. The circuit is schematized in Figure 2.

A field version of the TDS device developed at IREQ was installed in a small vehicle, Figure 3. TDS measurements are performed by applying the voltage to the line terminations either in outdoor (indoor) substations or directly