On-site Condition Assessment of XLPE MV Cable Joints by Using an Insulation Tester

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ABSTRACT

In this paper, on-site time domain dielectric response measurements have been performed once a month on medium voltage XLPE cable links with heat shrink joints using a conventional 5 kV DC insulation tester. The main purpose of this work has been to examine the reproducibility of the measured currents. It is shown that both the polarization and depolarization currents remain approximately unchanged, and that they can provide robust criteria for cable condition assessment. It is advantageous to use the insulation tester before applying any other more advanced diagnostic techniques.

KEYWORDS

DC insulation tester, time domain dielectric response, MV XLPE cable, heat shrink joints

INTRODUCTION

It has been observed that many medium voltage (12 and 24 kV) cable sections with heat shrink joints can have a very low insulation resistance. This feature is typically observed in cross-linked polyethylene (XLPE) cables installed in the 80s, which constitutes about 30% of the Norwegian cable network. As the resistance values tend to be in the range of 0.1 – 10 GΩ, condition assessment by using very low frequency (VLF) tan δ testing at 0.1 Hz is not feasible [1]. Furthermore, by having such joints present in the cable link, the assessment can conclude that the cable is severely water tree degraded although the cable section is in a good condition.

The underlying motivation for this study is to propose a methodology based on using a simple DC insulation tester to assess the condition of cable sections including those with heat shrink joints. This is a simple measurement that is less time consuming than other commercial cable condition tests. Moreover, using an insulation tester requires little training which benefits utilities as they can perform the test themselves. This test is meant to indicate the course of action to be taken after test: For instance, are there any critical cable joints in the link, and should other more advanced diagnostic tests such as measuring partial discharges (PDs) be performed?

The purpose of this paper is to examine the reproducibility of the measured currents of cable links in service with joints having reduced insulation resistance. This is done by repeating measurements once a month and at the same time recording environmental factors such as the outside temperature. Some assessment criteria have been proposed which are based on the measurements of the polarization and depolarization currents at different voltages up to 5 kV DC. Examples of such criteria include the current magnitudes and the voltage dependence of the currents. The obtained data has been compared with measurements on the same type of joints performed in the laboratory using a sensitive dielectric response test set-up.

THEORY

Applying a DC voltage across the cable insulation gives rise to a polarization current due to the conductivity of the insulation and the dielectric displacement. This current is expressed by

$$\boldsymbol{J}(t) = \sigma \boldsymbol{E}(t) + \frac{d\boldsymbol{D}(t)}{dt} \quad (1)$$

where σ is the conductivity, $\boldsymbol{E}$ is the electric field, and $\boldsymbol{D}$ is the electric displacement field of the insulation [2]. After some time, all the molecules of the insulation have polarized and the contribution from the dielectric displacement vanishes. Consequently, at this point, only a steady state conductive current flows through the insulation.

When short-circuiting the cable insulation, the polarized molecules will relax to their original orientation/position. This creates a new current that flows in the opposite direction of the polarization current. As there is no voltage applied during this period, there is no contribution from the conductivity. This current is called the depolarization current. A typical behavior of the polarization and depolarization currents is shown in Fig. 1.

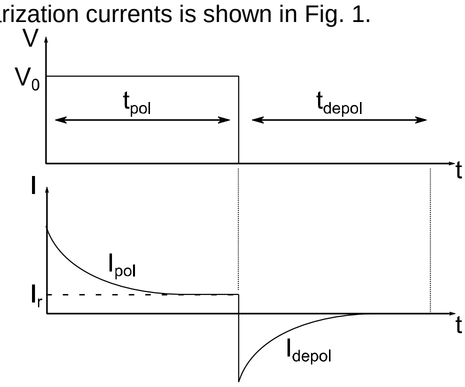

Fig. 1: Illustration of polarization ($\boldsymbol{I_{pol}}$) and depolarization currents ($\boldsymbol{I_{depol}}$) as a function of time.

The time dependence of the depolarization current follows a power law expressed by

$$I_d(t) \sim t^{-n} \quad (2)$$

where n is a positive number [2].

Having measured both the polarization and depolarization currents, it is possible to calculate an approximate value of the conductivity of the insulation. One approximation is

$$\sigma \approx \frac{\epsilon_0}{C_0 U}\left(I_p(t) - I_d(t)\right) \quad (3)$$

where ϵ_0 is the vacuum permittivity, C_0 is the geometric capacitance of the insulation, and U is the applied voltage during the polarization current measurement [2].