Temperature and Electric Field Dependence of the Time Domain Dielectric Response of a Medium Voltage Cable Joint Stress Control Sleeve

Henrik **ENOKSEN**, Sverre **HVIDSTEN**; SINTEF Energy Research, Trondheim, Norway, henrik.enoksen@sintef.no, sverre.hvidsten@sintef.no

Mai-Linn **SANDEN**, Frank **MAUSETH**; Norwegian University of Science and Technology, Trondheim, Norway, mailins@stud.ntnu.no, frank.mauseth@ntnu.no

ABSTRACT

In this paper, the temperature and the electric field dependence of the time domain dielectric response of a virgin stress control sleeve commonly used in heat shrink joints has been studied. The result show that the conductivity of the stress control sleeve is strongly temperature dependent and that space charge phenomenon build up even at average fields less than 1 kV/mm. The space charge buildup also causes anomalous depolarization currents where the polarity is the same as that for the polarization currents, especially at the temperature above the melting peak of the material.

KEYWORDS

Heat shrink joints, nonlinear resistive electric field grading, time domain dielectric response.

INTRODUCTION

It has been shown that a significant number of medium voltage (MV) wet designed cable joints, and especially those installed in the 80s, suffer from overheating. Still, these joints seem to withstand the service conditions. It has been proposed that these joints have a very low electrical resistance, and that sections with such joints can be assessed by using a simple DC insulation tester [1]. The overheating is likely caused by too high contact resistance in the metallic connector in the joint. Due to the introduction of renewable energy sources, such as small hydro-electric power stations and on-shore wind power plants, the current loading of the existing distribution cable network will increase. This can in the future cause overheating in other joints that yet are not critical.

This paper is part of a work to elucidate the mechanisms causing the low insulation resistance of MV cable joints. As bad metallic conductor connections can result in local high temperatures that are most likely much higher than 90 °C during normal operation, the properties of a heat shrink stress control sleeve commonly used in such joints has been characterized at temperatures up to 150 °C. The main purpose of this paper is to examine if such high temperatures cause a critical change in the electrical properties of the stress control material. This could for instance be a critical change of the conductivity or the field grading properties at the high temperatures. Another example could be an irreversible change in the electric properties could also happen due to desorption of volatiles in the sleeve. Here, the electrical properties have been characterized by time domain dielectric response measurements at different temperatures and electrical fields.

THEORY

By applying a DC voltage across a dielectric material a polarization current will flow through the insulation due to the conductivity and the dielectric displacement. This current is expressed by

$$I_p(t) = C_0 U \left(\frac{\sigma}{\epsilon_0} + f(t)\right) \quad (1)$$

where C_0 is the geometric capacitance of the dielectric material, U is the applied voltage, σ is the conductivity, ϵ_0 is the vacuum permittivity, and $f(t)$ is the dielectric response function of the material [2]. After some time, the dielectric material is fully polarized and the contribution from the dielectric response function vanishes. Consequently, at this point, only a steady state conductive current flows through the material.

Short-circuiting the dielectric material gives rise to a depolarization current that flows in the opposite direction of the polarization current. The depolarization current can be expressed as

$$I_d(t) = C_0 U \big(f(t) - f(t + t_c)\big) \quad (2)$$

where $f(t + t_c)$ denotes remaining charges in the dielectric from previous voltage applying sessions. As there is no voltage applied during this period, the conductivity will not contribute.

Assuming $f(t + t_c)$ is small, Eqs. (1) and (2) can be combined to express the conductivity of the material as

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

where ϵ_0 is the vacuum permittivity [2].

The essential feature of the field grading material, like a stress control sleeve, is the field dependent conductivity (nonlinearity). At low electrical fields the conductivity is relatively low, but typically increases strongly from a low to a high conductivity value in a narrow electrical field region. Then the critical high field occurring at e.g. the termination of the insulation screen in cable joints and terminations can be reduced as space charges forms in the field grading material creating a counter field [3].

EXPERIMENTAL WORK

Test object

A commercially available heat shrink stress control sleeve was included in this study. The sleeve is normally used in medium voltage heat shrink cable joints. Here, the sleeve was installed by heat shrinking on a polytetrafluoroethylene (PTFE) rod with metallic electrodes. These electrodes were attached at each side as indicated in Fig. 1. The outer diameter of the test object