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ON-SITE PARTIAL DISCHARGE TESTING OF DISTRIBUTION CLASS CABLES USING VLF AND POWER FREQUENCY EXCITATION

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ABSTRACT

The ongoing deregulation of the energy market has had up to now a strong impact on the maintenance strategies of most utilities. Especially, the increasingly service aged population of distribution class cables influences the reliability of the distribution network. Thus, field-testing is required to assess the severity of the degradation and to determine the cables, which require urgent replacement. Different methods are available for the high voltage excitation of the cables under test. The fixed frequency resonant test set running at 50/60Hz power-frequency offers a perfect match of the service condition, but such test sets are comparably heavy and costly. Other solutions, such as variable frequency resonant test sets, damped oscillating wave, or very low frequency (VLF) excitation offer more cost-effective testing solutions.

KEYWORDS

Partial discharge location, PD mapping, VLF, resonant test set, tan delta, field-testing.

INTRODUCTION

Partial discharge activity is a prominent indicator to assess the grade of degradation of high voltage equipment. The mapping of the partial discharge activity versus the cable length allows identifying cable partial discharge as well as weak accessories. However, strong differences exist between polymeric cables and mass-impregnated cables. Historically, partial discharge measurements on cables were increasingly applied since the change to polyethylene (PE) and later cross-linked polyethylene (XLPE) as insulation material for the majority of power cables.
Improved signal acquisition and processing made this technique also applicable to non-shielded field environments. However, care must be taken to adequately filter the high voltage source and to reduce pickup of ambient noise.

OCCURRENCE OF PARTIAL DISCHARGE

The solid and liquid insulation materials used for insulating power cables can tolerate an electrical field that exceeds by far the normal operational field strength typically applied with cables and other high voltage equipment. Thus, to enable partial discharge, it requires an imperfection that has a lower inception field, such as a gas inclusion, or, alternatively, which strongly increases the local electrical field within the insulation, as a sharp metallic inclusion, for instance. Both types of imperfections can happen during production, may remain undetected during initial testing, or evolve during service.
Partial discharge, an electron avalanche, requires a free initial electron that is being accelerated in the electrical field strongly enough to trigger the avalanche.
With the low-energy surface of an embedded spherical cavity in fresh polyethylene, no such free electron is available to have the partial discharge incepting, although the internal electrical field of that gas bubble is larger than the inception field (E_{Str}). Thus, no partial discharge occurs until such free electron is provided by de-trapping of space

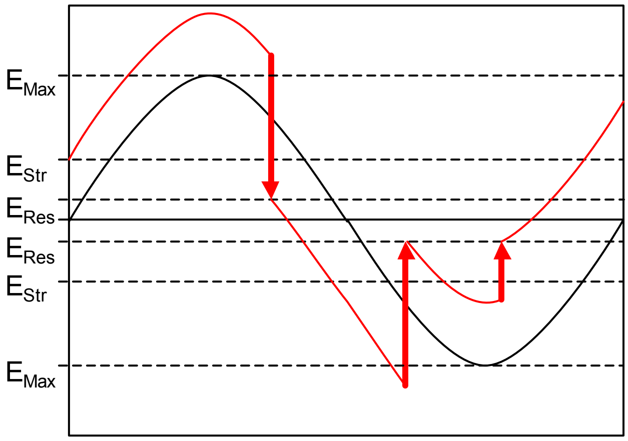

Figure 1: Internal E field with low electron availability

charges or by a photon of the natural radioactivity. This natural radioactivity – radioactive soil, gasses, cosmic photons – cause about $2 \cdot 10^{6}\ m^{-3} s^{-1}$ free electrons. Thus, the statistical delay to have a cavity discharge in fresh polymeric material incepting may reach several tens of minutes depending on the cavity's size.
Once this initial partial discharge impulse has occurred, the cavity's surface is polluted with electrons being kept with traps of comparably low energy levels. Thus, these electrons become available statistically depending on the material's properties. With fresh polyethylene (polypropylene, epoxy resin, etc.), this de-trapping time constant is in the range of tens of ms and above.
Figure 1 shows how the electrical field in the cavity reacts on the statistical delay caused by the de-trapping. Figure 2 shows a corresponding partial discharge pattern or so-called *j*-*q*-*n* pattern.

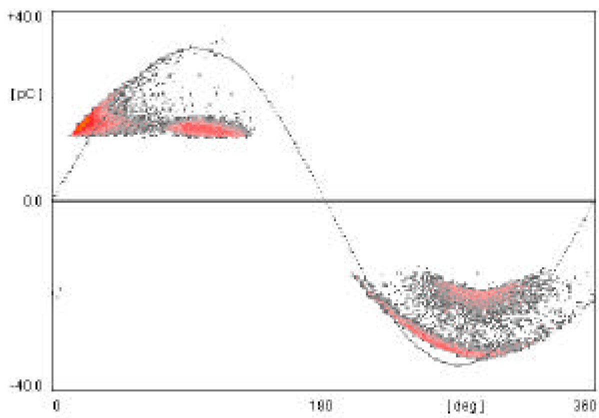

Figure 2: *j*-*q*-*n* pattern with low electron availability