CONDITION MONITORING OF THERMALLY AGED LOW VOLTAGE CABLES WITH POLARIZATION-DEPOLARIZATION CURRENT TESTING

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ABSTRACT

Polarization-depolarization current (PDC) measurements have been used to assess the condition of medium voltage (MV) cables, however to date little research has been done to apply this test method to LV cables and their unique designs and constructions. Recent research sponsored by EPRI evaluated the ability of PDC to monitor aging in thermally aged cables. In this paper the results obtained on thermally aged 24 conductor shielded and 3 conductor unshielded cables are presented. A variety of diagnostic 'metrics' derived from polarization and depolarization currents data were trended as a function of aging time and compared to traditional material property results.

KEYWORDS

Polarization-depolarization current, PDC, dielectric spectroscopy, FDDS, LFDS, chlorososulfonated polyethylene, Ethylene propylene rubber, XLPE, indenter modulus, density, OIT.

INTRODUCTION

The potential of frequency domain dielectric spectroscopy (FDDS) to assess the condition of aged low-voltage (LV) cables has been investigated by a number of research groups since the mid-1990s. EPRI Technical Report TR-105581: [1] and more recently the European Advance Project [2][3][4][5][6] highlighted the capability of this technique to track change in material properties as a result of aging. A few other independent studies have provided more insight into the potential of FDDS for LV cables condition monitoring. Chailan et al. demonstrated the applicability of dielectric spectroscopy to monitor thermal aging of EPR [7] and CSPE [8] materials. The method was also found to be able to detect changes in the insulation properties induced by irradiation [9, 10]. It should be noted that most of these studies focused on the characterization of material samples (e.g. single core insulated wires, thin films/slabs), rather than practical cable samples.

In a number of the studies just mentioned, very low frequency (below 0.1 Hz) FDDS results were found to be sensitive to the level of aging of the insulation under test. However, from a practical standpoint, tests conducted below 0.1 Hz take a much longer time, which may limit their applicability in the field. The use of time domain DC polarization / depolarization current (PDC) measurements can be complementary to FDDS, exhibiting some practical and scientific benefits [11]. Practically, PDC measurement data gathered in the time domain over fairly short periods of time (e.g. < 1000s) can be converted to the very low frequency domain (e.g. ~10^{-4} to 10^{-1}Hz), through a curve fitted Fast Fourier Transform (FFT) [12] or an approximating relation such as the Hamon approximation [13]. This approach is referred to as time domain dielectric spectroscopy (TDDS). Scientifically, PDC data (analyzed either directly in the time domain or through mathematical conversion in the frequency domain) includes information relating to both depolarization and polarization dielectric behavior, which can provide additional information regarding dielectric response phenomena. Aging studies focusing on PDC testing have shown the presence of diagnostic markers sensitive to medium voltage cable water-treeing / wet-aging insulation degradation [14, 15], and more recently to MV cable thermal aging [16].

This literature review highlights the benefits of using PDC testing to support the application of FDDS to assess the condition of LV cables in the fields. Recent EPRI sponsored research investigating the applicability of FDDS to monitor the condition of multiconductor LV cables, and also included evaluation of the PDC technique. The results summarized in this paper present data collected on thermally aged 24 conductors, shielded LV control cable and 3 conductors, unshielded power cables used in US nuclear power plants. Sensitivity of data collection to test configuration, test temperature, test voltage were also addressed in this study, however not all results are discussed in this paper.

EXPERIMENTAL

Cable Samples

The LV cables used for this study included:

- A 24/C cable manufactured in 1979 and rated 600V. Its construction includes 2 conductors #12AWG (3.31mm2), 22 conductors #20AWG (0.518mm2), ethylene-propylene rubber (EPR) with bonded chlorosulfonated polyethylene (CSPE) layer insulation, shield, CSPE jacket.
- A 3/C cable rated 600V. Its construction include 3 conductors #12AWG (3.31mm2) FR-XLPE insulation, CSPE jacket. A cross-sectional picture of both cables is provided in Figure 1.

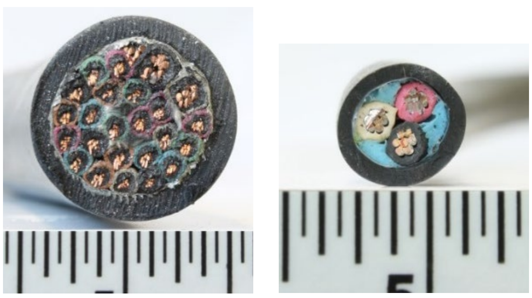

Figure 1 Cross-section of 24/C and 3/C cable samples.

Thermal Aging

Samples approximately 18.60m long were cut for the bulk aging experiment. Smaller 0.30m sections were also obtained for material tests, including individual wires