Estimating the impact of VLF Frequency on Effectiveness of VLF Withstand Diagnostics

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Proof or withstand tests have been used for a very long time in the cable industry and find their origins in the well known routine tests carried out in accessory and cable factories. Experience shows that the most common voltage source used in service is the Very Low Frequency (VLF) approach. Although this test continues to serve the industry well and is described in detail in IEEE 400.2, when a Simple Withstand is implemented in the field users continue to raise concerns about the VLF frequencies: IEEE 400.2 discusses frequencies within the range 0.01 to 0.1 Hz. In most cases the need to move to lower frequencies is a result of needing to test longer (higher capacitance) lengths.

One of the useful studies (Moh, CIRED 2003) has suggested that lower frequencies are correlated with a reduced survival probability (Failure On Test {FOT} plus Failure In Service {FIS}): 87% and 75% for 0.1 Hz and 0.05 / 0.02 Hz, respectively. It may be hypothesized that this was because the defects in the cable systems inherently had higher breakdown strengths when tested at the lower VLF frequencies. However, it has been conjectured that this finding may not be due to the frequency of test, but to the reduced strength of longer lines where there is a higher likelihood of weakened links (joints, terminations, and/or degraded portions of cable) being present: the longer the chain the more weak links! Furthermore the rates do not change between 0.05 to 0.02 Hz. The practical importance of any such difference in test frequency is that, if correct, there may be a need to extend the test time to compensate for the lower frequencies ie the concept of a minimum number of cycles. To provide further information on this topic studies are needed where the test frequency is varied independently of the system characteristic. Furthermore it would be advantageous to conduct such tests on test objects with a consistent level of degradation; the focus of this presentation.

The study discussed in this presentation makes use of the well known Ashcraft Water Tree object to grow a series of Water Trees to a consistent range of lengths. These objects act as models for a degraded extruded cable. These objects are then subjected to VLF Withstand Tests at selected VLF frequencies (0.1 & 0.05 Hz). The electric stress at failure of these objects would provide an indication of the effectiveness of the selected frequency.

This paper will describe

- Industry Background
- Test Protocol (Ashcraft Water Tree Growth (EPR, WTR XLPE, XLPE), VLF Test (sinusoidal))
- Differences in breakdown strength (initial analyses) associated with the VLF Test Frequencies (Figure 1)

The breakdown data suggest that, for degraded extruded insulations:

- The hypothesis that the breakdown strength **is** higher at lower VLF frequencies is not supported
- The proposal that the hypothesized higher VLF breakdown strength at lower frequencies requires an increase in the test time is not supported
- The inference is that testing at lower frequencies (often required for testing longer lengths) is no less effective than tests at the more common 0.1 Hz

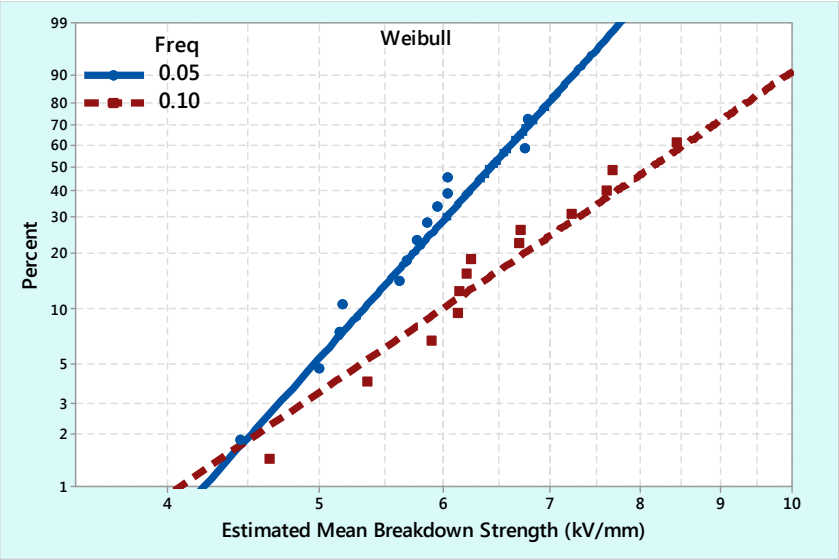

Figure 1: Estimated VLF Breakdown Strength of Ashcraft Objects containing Water Trees (Water Tree Lengths 3% to 14% of insulation thickness) at selected VLF Frequencie