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

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ABSTRACT

Hipot or voltage proof tests have long been used to assure the health of cable systems in the factory and when commissioning. A recent concern with this approach is that there is no way to judge if the effect of dropping VLF frequency (required to test long lengths) has a significant and deleterious impact on the effectiveness of a Simple Withstand Test. This paper shows how this problem has been practically addressed with both Laboratory and Utility based studies. Both of these approaches conclude that there is no deleterious impact on the effectiveness of VLF testing at the lower end of the frequency band.

KEYWORDS

Diagnostic Techniques, Very Low Frequency (VLF), Water Treeing, Electrical Treeing, Withstand.

INTRODUCTION

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 (Figure 1). Although this test continues to serve the industry well and is described in detail in IEEE 400.2. However, 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) system lengths.

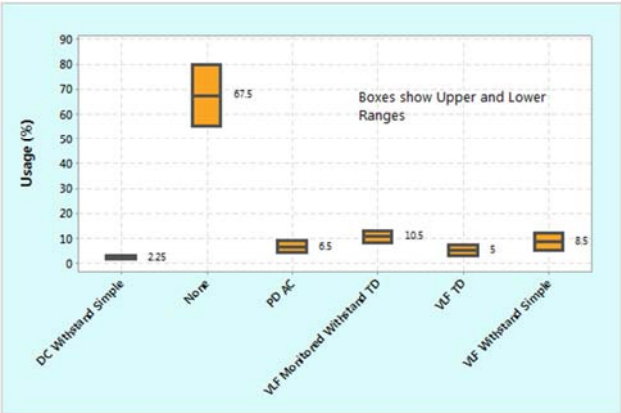

Figure 1. Results of a 2014 Study on the Use of Diagnostics on MV Cable Systems in North America

One of the useful studies [3] has suggested that lower frequencies are correlated (**Erreur ! Source du renvoi introuvable.**) 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, i.e. 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. Besides, it would be advantageous to conduct such tests on test objects with a consistent level of degradation; this is the main focus of this paper.

Table 1 Reported effect of VLF Frequency on Outcome of Simple Withstand Tests in Malaysia on 11 & 33kV System, Moh, CIRED 2003 [3

Test Frequency (Hz)	0.1	0.05	0.02
Performance (%)			
Survival	87	75	74
Fail On Test (FOT)	10	19	20
Fail In Service (FIS)	3	6	6

The study discussed in this paper takes two directions. The first 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 insulation. Subsequently, these objects are then subjected to VLF Withstand Tests at selected VLF frequencies of 0.1 Hz and 0.05 Hz. The electric stress at failure of these objects provides an indication of the effectiveness of the selected frequency. The second direction is an analysis of a well-defined long term Utility program where many of the VLF and cable system parameters (primarily length) are known; furthermore, the main elements of the program (time of voltage application and voltage level have remained constant).