# Laboratory Study of the Impact of Repeated VLF Withstand Test and Subsequent AC Operation on Service-Aged Cables

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## *ABSTRACT*

*VLF sources have proven effective for both withstand tests and diagnostic tests (partial discharge, dielectric loss) used to manage cable assets. Field studies confirm that overall VLF tests to the levels set out in IEEE 400.2 deliver practical improvements in reliability (fewer failures and longer times between failures) without initiating long-term problems. However, the field-based studies are not well-suited to investigating the impact of repeated testing, re-energization at power frequency and test parameters (voltage and time) outside the framework of IEEE 400.2. This study uniquely employed multiple long lengths (>70 m) of XLPE cables removed after more than 25 years of service to estimate the impact of a variety of VLF test parameters (1.8, 2.1 and 3.6 $U_0$, and 15, 60 and 120 minutes), plus multiple applications of VLF Simple Withstand testing.*

## *KEYWORDS*

Diagnostics, Reliability, Extruded Cable Systems, Endurance, Very Low Frequency

## 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. [1][2][3][7] Recent studies show that withstand tests are the most commonly implemented of the diagnostic tests based on the Very Low Frequency (VLF) approach (Figure 1).

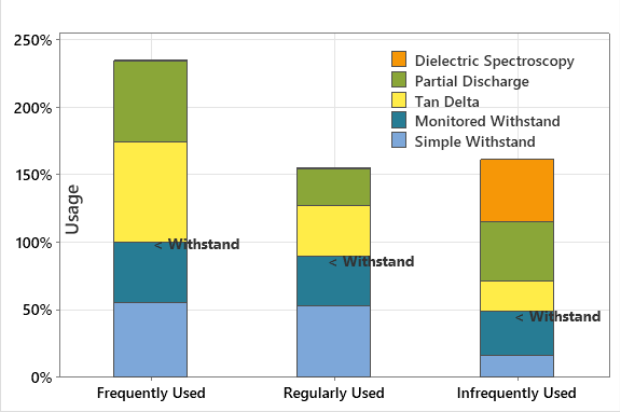


**Figure 1. Usage of VLF-based diagnostic techniques**

The majority (>90%) of VLF tests are conducted at a test frequency of 0.1 Hz. Laboratory and field studies [6] show that the VLF source frequency has a minimal impact on the breakdown strength of degraded cable insulations.

The withstand test has two parts: the initial ramp and the hold period. [7] The voltage exposure and hence the risk to which the cable system is exposed is determined by both the voltage level and the time of the application (Figure 2).

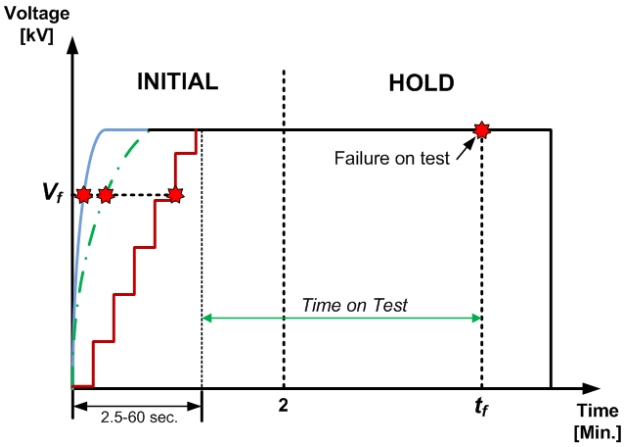


**Figure 2.Withstand test "initial" and "hold" phases**

The basic benefit of withstand tests is that they provide a practical way of providing the asset owner with assurance that the component can withstand a prescribed "over-stress." The results of these withstand tests are reported as either Pass or Not Pass. The unambiguous result alleviates the need to interpret a condition from the measurement data. This is a key benefit when it comes to implementing this approach in the field. Although the results are reported as either Pass or Not Pass, the outcomes can be used to categorise the cable system performance. As an example, failure at 2 minutes into a 2 $U_0$ test would be viewed as having poorer performance than a failure 10 minutes into a test at the same voltage level. Consequently, many practitioners and utilities record the details of the failures with the view that the withstand tests may be used to determine the "health" of their cable systems. [8][9] This form of field withstand tests may conveniently be defined as a "simple" test in that no property is monitored during the voltage application and the exposure/risk is determined by the voltage and time recipe. In this work, this structure is known as a "Simple Withstand"

Although the "Simple Withstand" test continues to serve the industry well; making up over half the withstand tests conducted, when a Simple Withstand is implemented in the field, users continue to be concerned by three issues:

- Prior to the test, there is no way to estimate the health of the cable system — hence, the risk of failure prior to the application of the proof voltage.
- There is no way to adjust the length (time) of the test — hence, the risk of the test either decreasing or increasing in length according to the quality of the cable system.
- There is no way to judge the quality of the pass should the cable system support the proof voltage — i.e., was