Implementation of Ageing Laws and Cable Models to Estimate Service Life for MV Cable Designs using Laboratory Endurance Tests

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ABSTRACT

Investment in the distribution system continues, with a greater fraction than ever being directed at the use of underground cable systems. This is primarily due to the reported order of magnitude improvement in SAIDI and SAIFI with respect to overhead lines. Feedback from utility cable engineers consistently shows that the anticipated longevity of the cable system is the number one priority when deciding on which cable design to employ at their utility. Recent advances can be recognised with the almost 50% reduction in failure rate in the last 10 – 20 years. However, it is not clear what the longevity is and how much is contributed by the different elements of the cable design. This work uses laboratory data to detail the impact of design and installation / operating conditions.

KEYWORDS

Reliability, Extruded Cable Systems, Life Estimation

INTRODUCTION

Feedback from utility cable engineers consistently shows that the anticipated longevity of the cable system is the number one priority when deciding on which cable design to employ at their utility. Longevity is ranked significantly more highly than first cost or temperature rating etc. This finding can be understood when recognising that failures adversely impact SAIDI/SAIFI data and represent considerable Operations and Maintenance Costs. Thus anticipated life is a key factor in determining the total, rather than first, cost of a cable system.

Initial service performance of extruded cable systems is well documented and has led to many improvements in design, manufacturing, materials, specification and testing. The benefits of these developments are easily recognised through the non-reoccurrence of early poor performance, with useful service lives extending past 20 years. However, it is much more difficult to determine the anticipated life of a cable design and thus the benefits of a particular design element (jacket or WTRXLPE or supersmooth semicon etc). In principle, such lives could be determined from utility records. However, the volume and fidelity of records are not sufficient, in most cases, to support such analyses. Thus, the only recourse to garner these estimates is to return to laboratory test data and to model the impact of design elements on the life in service.

A multi-disciplinary team of experts drawn from utilities, manufacturers and academia examined the options and recognised that the most appropriate starting point was the Accelerated Cable Life Test (ACLT). The principle benefit was that the outcome of these tests were described in terms of time to a specified endurance for voltage / temperature / environmental acceleration; most usually mean life (B50). However, for practical cable designs these data are not directly usable as they are developed for short lengths of cable cores tested at elevated temperatures and voltages. Thus, the modeling activity needs to deconvolve these accelerating factors, which are used to make the tests to implement in practical timescales.

APPROACH

The approach used in this work was to collate the results of many public domain ACLT tests to model the impact of temperature, electrical stress and some elements of cable design. Algorithms were then constructed to scale test data on short cores to long cables in service using Life Expansion and Reduction Factors. The expansion and reduction factors for life are summarized:

- Life Expansion Factors
  - Lower voltages in service compared to test voltages
  - Lower temperatures in service compared to temperatures used in the tests
  - Use of jackets in service cables compared to jacketless cables used in tests
  - Lower load factors in service
  - Absence of water in the conductor interstices
- Life Reduction Factors
  - Longer lengths installed in service compared to the short lengths employed in lab tests
  - Higher volume of insulation used in service cables due to the larger conductor sizes compared to the relatively small conductors used in tests
  - Lower critical risk levels (B1 or B5) for cable failures considered by utilities compared to the mean lives (B50) considered by tests.

ACLT PROTOCOL

ACLT was initially proposed by Bob Lyle of Alcoa Cable Company [1]. Various compound manufacturers, cable manufacturers, and research laboratories adopted the aging program to evaluate cable core performance and to develop an understanding of how specific cable core designs perform. The test protocol including critical test parameters (i.e. sample, preconditioning, test conditions), techniques for measurement, control of the conditions and reporting were recommended in IEEE 1407 [2].

Compared to Accelerated Water Treeing Test (AWTT, a commonly used accelerated aging test qualification protocol), the principle benefit of using ACLT results for cable life estimation is that the data generated from ACLT is time-to-failure, the most relevant descriptor to a utility.

The disadvantage of ACLT is that the test duration is uncontrolled/undefined and sometimes can be too long to make economic sense or provide meaningful results in a timely manner. This is especially a problem when cables are expected to last longer with the advancement of modern cable technology. It thus becomes more and more difficult to fail a cable (i.e. require longer aging time) and less economical to conduct such a test. Sometimes,