Estimating MV Cable Endurance From Laboratory Qualification Data

Nigel **HAMPTON**, UL Solutions (USA) nigel.hampton@UL.com
Josh **PERKEL**, EPRI (USA) JPerkel@epri.com
Detlef **Wald**, Eifelkabel (CH) Eifelkabel@posteo.ch

ABSTRACT

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. It is often very difficult to access data with which to guide such assessments. This work describes a way in which end users and cable designers can use existing qualification test data to establish the relative endurance that they might expect from different cable materials. Moreover, it provides a means by which the minimum performance criteria can be compared to actual cable test performance at utility scale.

KEYWORDS

Reliability, Extruded Cable Systems, Endurance, Accelerated Water Tree Test

INTRODUCTION

New cables with extruded insulations are being installed in greater amounts to improve network reliability. [1] End users would like to understand the longevity they might expect from these assets when they are installed at utility scales. This need can be understood when recognising that failures adversely impact system average interruption duration index (SAIDI) and system average interruption frequency index (SAIFI) data, and represent considerable operations and maintenance costs. [2] Thus, anticipated life is a key factor in determining a cable system's total cost rather than its first cost. Obviously, the most convincing data would come from large, long-term accelerated ageing tests. [3] However, such tests are likely to be prohibitively expensive in terms of both time and space. Moreover, they would need to include joint and termination performance.

To date, end users and standardisation bodies have used small samples in either time to failure (IEEE) [3] or fixed time breakdown (CENELEC, ICEA) tests [4][5] to develop an understanding of the sensitivity of materials and designs to typical multifactor ageing stresses. Generally, fixed time tests are preferred, as they do not involve open-ended test programs and it is reasonably straightforward to define simple success criteria. A range of success criteria are applied to the fixed-time breakdown tests in an attempt to define a suitable level of acceptability. Often, these criteria have the goal of defining performance that is comparatively better than that of a previous generation of technology. Unfortunately, the results of such studies cannot be directly related to service endurance; the tests provide a breakdown strength when users wish to judge longevity in the field.

Early-generation extruded cable system service performance is well-documented with problems associated with water trees. These led to many improvements in design, manufacturing, materials, specification and testing. [1] The benefits of these developments are easily recognised through the elimination of early poor performance, with useful service lives extending past 20 years. [6] - [16] 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 of the qualifications [4][5] and model the impact of design elements on the life in service.

This paper discusses one practical solution to this problem as using data from already well-established test protocols that use breakdown tests for samples that are removed at selected ageing times (CENELEC — 50 Hz option, and AEIC / ICEA). [3] In this approach, these data are collated, and utility length and utility scale reliability are adjusted to provide suitable breakdown strengths at the fixed ageing times. These data are then used to establish suitable life curves. The outcomes will be described in the context of a "life statement," which covers the model assumptions, the probabilistic nature and the associated life.

ACCELERATED WATER TREE TEST (AWTT)

Since moisture ingress into the cable is almost inevitable in most practical installations, manufacturers of cables and compounds continually work to prevent and/or minimize contaminants and imperfections that can serve as water tree initiation sites. To evaluate the effectiveness of these efforts, various cable testing protocols have been designed to rapidly screen new compounds, manufacturing methods and cable constructions. AEIC and CENELEC standards for MV cables require power frequency ageing for one- or two-year long-term (shorter at 500 Hz) periods in water. The AEIC protocol qualifies the cable design / materials / CV line and provides important information on cable performance. Table 1 contains a summary of the AEIC tests.

Ageing test protocols are designed to accelerate water tree ageing and attempt to quantify its effect. Although these protocols are not designed to investigate degradation mechanisms, they can, if considered appropriately, provide significant useful information about cable performance. MV cable test protocols generally specify the use of short test lengths placed in water-filled tanks or tubes. An AC ramp or step breakdown test at selected times is typically used to assess the extent of ageing after the prolonged ageing program. The minimum criteria for AECI CS8 / ICEA 649 testing are set out in Table 2.

It is useful to note that due to cyclic conductor current heating in AEIC CS8 / ICEA S-94-649, the conductor temperature is considerably higher than the controlled insulation shield temperature in water (45°C). Furthermore, the "in-air" portions outside the water tubes will have a different and generally hotter temperature profile. Thus, care needs to be taken if directly comparing performances obtained in different test protocols.