Methods and Experience of Very Low Frequency (VLF) Diagnostic Testing to Support Asset Management of Critical MV Circuits

Jean Carlos HERNANDEZ-MEJIA; Josh PERKEL; Nigel HAMPTON; Georgia Tech-NEETRAC, USA,
jean.hernandez@neetrac.gatech.edu, joshua.perkel@neetrac.gatech.edu, nigel.hampton@neetrac.gatech.edu
JF DRAPEAU; Hydro Quebec-IREQ, CAN, Drapeau.Jean-Francois2@ireq.ca

ABSTRACT

Utilities find that the small footprint, ready availability of VLF (very low frequency) voltage sources, and well-established condition assessment criteria are beneficial when undertaking condition based maintenance. In this paper, the authors address the application of VLF diagnostic testing coupled with other complimentary techniques to support the asset management of critical Medium Voltage (MV) cable circuits. Circuits are considered critical when the risk of failure profile and related consequences are significantly different to traditional distribution applications. This situation is increasingly common and is not straightforwardly addressed in the current literature.

KEYWORDS

VLF, Diagnostic Testing, Asset Management, Condition Based Maintenance, Critical Infrastructure

INTRODUCTION

Utilities all over the world, and especially in North America, are facing a significant future challenge to maintain and renew their ageing assets [1]. Utility assets (like most equipment) degrade over time and eventually reach the point at which their performance is lowered sufficiently that they can no longer perform their intended functions. Equipment populations with assets that are far enough into this process produce service failures [2-6].

Effective asset management strategies require the availability of appropriate information on the performance of the assets themselves. In essence, the extra information comes from an effective diagnostic program whose results enable the utility to undertake “smart maintenance” in that only those assets that will likely impact the reliability in the near future receive some form of remediation.

To address this need for underground cable systems, voltage sources were developed during the last two decades that utilize AC frequencies in the range of 0.02-0.1 Hz [7, 8]. These sources provide an AC waveform from a unit that maintains the compact size of DC test equipment while avoiding the detrimental of DC on polymeric insulations.. These sources became known as Very Low Frequency (VLF) sources [3-11]. The possibility of augmenting the withstand capability with diagnostics such as dielectric loss and partial discharge further increases the usefulness [5, 8, 9].

Guidance on use and interpretation of the VLF technology is provided in the IEEE 400 – 2012 [7] and the IEEE 400.2 – 2013 [8] for both withstand and dielectric loss operations. This guidance is focused primarily on single diagnostics for conventional land distribution cable systems. The need for the use of coupled diagnostics on critical cable systems, where the risk profile is quite different to conventional distribution circuits, is not currently addressed in normal references. In this context, critical cable systems may be considered as those associated with

- long length subsea / river crossings,
- power plants, and
- life safety systems.

These applications are considered critical because their risk of failure profile and related consequences are significantly different to traditional distribution applications and require a number of extensions to the standard diagnostic testing paradigm.

This work considers these issues and uses a number of case studies to illustrate important differences and to describe the solutions employed. These include:

- Decision protocols – provision of interim outcomes to support implementation or cessation of tests.
- Diagnostic features – the circuit value supports a more in depth analysis.
- Maximizing the diagnostic power from coupled and /or complementary techniques. .

DEFINITION OF A CRITICAL CIRCUIT

The definition of a critical MV circuit will likely change from utility to utility; specific cases may require unique parameters to define whether the circuit is critical or not.

In this paper, the categories that are used to establish the criticality of a circuit are as follows:

- **Impact to the end customer**: this category includes circuits that support critical infrastructure (*e.g.* hospitals, airports, agencies, high profile customers, dense commercial/industrial/tourist areas, etc.).
- **Reliability**: This category includes circuits that may impact reliability indices (*i.e.* SAIFI and SAIDI).
- **Circuit Access/Location:** Circuits whose location and/or access are difficult (*e.g.* power plants, subsea applications, etc.).
- **Maintenance Strategy:** It some cases criticality is determined by the ability to address any issues on the circuit. There are cases where repair or replacement requires additional work or costs leading to prolonged downtime. It is also possible that for old or special circuits, replacements are simply not available.
- **Other:** Any other parameters that may arise for a particular case that cannot be covered by the categories described above.

In general, the definition of the criticality of a circuit may require more than one of the categories previously described. In terms of diagnostic testing, critical circuits can be further classified into three broad groups as follows:

- **New Critical Circuits:** These include new circuits that are *de facto* critical or new circuits replacing an existing critical circuit. In this group, the risk of failure under testing for voltages above the rated circuit