Challenges Associated with the Interpretation of Dielectric Loss data from Power Cable System measurements

J. **Perkel** (1), J.C. **Hernández** (2), R. N. **Hampton** (1), J. F. **Drapeau** (3)**,** J. **Densley** (4), Y. **Del Valle (1)**
1 - NEETRAC, Atlanta, GA, USA, nigel.hampton@neetrac.gatech.edu, josh.perkel@neetrac.gatech.edu, yamille.delvalle @neetrac.gatech.edu
2 - Universidad de Los Andes, Mérida, Mérida, Venezuela, hmjeanc@ula.ve
3 - IREQ, Varennes, Québec, Canada, drapeau.jean-francois@ireq.ca
4 - ARBORLEC, Mississauga, Ontario, Canada, john@arborlec.com

ABSTRACT

Cable System Management requires an assessment of the health of the cables system. It is increasingly common for the assessment of aged cable systems to be made through the application of diagnostics measurements. A recent study has shown that VLF Tan Delta is perhaps the most commonly deployed cable system diagnostic. The practical use of this technique has been supported by the international standards IEEE400-2002 and IEEE400.2 (latest version). A key part of these standards is the guidance provided to a user that is detailed in the "Figures of Merit". These enable users to make practical improvements to the cable system. To aid these decisions a series of criteria have been developed. The benefit of the criteria described here is that the process is rational, reproducible and transparent. The outcomes are supported by a probabilistic assessment of service performance.

KEYWORDS

Diagnostic Techniques, Very Low Frequency (VLF), Tan Delta, Decision Tools

INTRODUCTION

The use of dielectric loss measurements to estimate the "health" of cable system assets is becoming increasingly common: a study in 2009 conducted by the authors showed that dielectric loss tests were the most commonly implemented proactive diagnostic in North America [1]. The measurement of the dielectric loss on cable systems in the field has been discussed by many authors for frequencies ranging from 0.01 Hz (VLF – very low frequency) to 300Hz (DAC – Damped AC) [1 - 9]. However, these discourses have tended not to address the practical methods that might be used to determine the levels which define the "health classes" e.g. condition assessment results as: no action required, action recommended, and others.

Therefore, this paper discusses the challenges associated with the interpretation of dielectric loss data from power cable system measurements at the different frequencies. The discussion is based on the following items or issues:

- Limitations of current methods and standards (i.e. IEEE Std. 400 Ed. 1).
- Collation of more than 3000 individual dielectric loss data from different cable systems in the field.
- Selection and discussion of traditional and novel diagnostic features such as absolute loss magnitude, changes in loss magnitude with voltage (Tip Up or Tip Down), temporal stability of loss magnitude for a specific voltage level, and stability of loss magnitude considering both time and voltage level.
- Interpretation of the local geographical context of loss data, e.g. effect of isolated high loss regions and neutral corrosion effects.
- Analysis of diagnostic features using Pareto principles establishes appropriate levels of performance for EPR, PILC & Polyethylene based cable system insulations.
- Assessment of the in service performance of the cable systems some years after the initial condition estimates.

VLF TAN DELTA MEASUREMENTS

Tan δ measurements determine the degree of real power dissipation in a dielectric material (dielectric loss). A comparison relates this measurement to a known reference value for the type of dielectric measured. A judgment establishes the condition of the tested circuit based on how much the dielectric loss differs from the reference value. Reference values can be based on:

- Values measured on adjacent phases (A, B, C),
- Values measured on cables of the same design and vintage within the same location,
- Values when new,
- Industry standards, or an experience library.

Tan δ is most powerful if the specific cable and accessory components under test are known. This allows for a direct comparison between the measured value and:

- The expected values for known materials / components,
- Previous measurements on the same circuit, or
- Baseline values.

Tan δ values are obtained by applying an AC voltage and measuring the phase difference between the voltage waveform and the resulting current waveform. Then this phase angle is used to resolve the total current (I) into its charging (I_C) and loss (I_R) components. The Tan δ is the ratio of the loss current to the charging current.

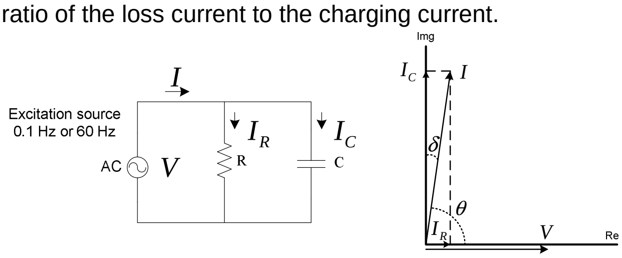

Figure 1: Equivalent Circuit for Tan δ Measurement and Phasor Diagram

Figure 1 shows an ideal equivalent circuit for a cable, consisting of a parallel connected capacitance (C) and a voltage dependent resistance (R). The Tan δ measured, at a frequency f and voltage V, is the ratio of the resistive