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B.8.3. Evaluation de l'état d'un câble par spectroscopie de propagation

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B.8.3. Assessment of cable condition by propagation characteristics spectroscopy (PCS)

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Résumé

L'évaluation in-situ de la constante de propagation en fonction de la fréquence (analyse spectrale) est proposée comme outil de diagnostic non destructif permettant de vérifier l'état de câbles en service. Des résultats comparatifs obtenus par les 3 méthodes suivantes sont présentés et commentés : (a) calcul, (b) mesures des impédances en circuit ouvert et en court-circuit, et (c) une méthode instrumentale, PCS, basée sur l'analyse par transformée de Fourier de la réflexion par une extrémité ouverte d'une impulsion de tension. Les spectres d'atténuation obtenus avec ces méthodes sur des échantillons de câbles neufs et vieillis sont utilisés pour mettre en évidence la possibilité d'employer la méthode PCS pour effectuer un contrôle du vieillissement des câbles. L'interprétation des modifications des différents composants d'un câble dues au vieillissement est discutée.

Abstract

In-situ evaluation of the wave propagation constant as a function of frequency (spectroscopy) is proposed as a non-destructive diagnostic tool for the assessment of the condition of cables in service. Comparative results obtained by means of the following three methods are shown and discussed: (a) calculation; (b) open-circuit and short-circuit impedance measurements and an instrumental method, PCS, based on the Fourier Analysis of a voltage pulse and its reflection from an open cable end. Attenuation spectra obtained with these methods for unaged/aged cable pairs are used to show the possibility of cable aging assessment by PCS. The significance of changes induced in the various components of a cable as a result of aging is discussed.

Introduction

As cables age in service, their ability to continue operating reliably needs to be periodically assessed by means of non-destructive diagnostic tests. Traditionally, cable users in North America have resorted to various overvoltage test methods, generally referred to as hipot tests. The most common of these remains the dc-hipot test which can be carried out with an inexpensive and relatively small voltage source. Elevated dc test voltages have been shown to induce, in certain aged distribution cables, conditions which tend to accelerate their subsequent deterioration under normal service conditions [1]. Very low-frequency (0.1 Hz) voltage is attempting to displace dc as a high voltage test source. As well, several diagnostic tests are presently envisaged to evaluate cables non-destructively in-situ. These include time-domain dielectric spectroscopy (TDDS) [2], partial discharge location (PDL) [3], evaluation of residual or return voltage [4], measurement of the dc-component of ac leakage current [5] and others. Some methods are indicated for power delivery cables and others for power plant applications. While some methods are effective in demonstrating and locating discrete defects, others are intended to monitor a general deterioration trend in entire cable lengths.

The University of Connecticut has been actively engaged in the development and implementation of three specific diagnostic techniques. Two of these, TDDS and PDL, are intended for the evaluation of discrete or localized deterioration. A third method, propagation characteristics spectroscopy (PCS), is intended as a general trend monitor and constitutes the subject of this paper.

As an electromagnetic wave set up by a short duration voltage pulse travels along a shielded cable, each frequency component of the wave undergoes an attenuation of its magnitude and a shift of its phase angle, according to the following relation:

$$E_x = E_o e^{-\gamma x} = E_o\, e^{-\alpha x}\, e^{-j\beta x} \qquad (1)$$

where E_o and E_x are the values of the wave at the origin and at a distance x, respectively, and γ is the propagation constant, a complex number expressed as:

$$\gamma = \alpha + j\beta \qquad (2)$$

The components α and β are the attenuation and phase constants expressed in Np/m (or dB/m) and rad/m, respectively. They constitute the wave propagation characteristics of the cable. The letter j represents $(-1)^{1/2}$. The PCS diagnostic method consists in evaluating these characteristics which can be indicators of deterioration.

The following three methods for determining the propagation characteristics will be described: (a) an analytical or calculation method based on the measured properties and dimensions of the cable components; (b) an experimental method based on the measurement of the open-circuit and short-circuit impedances (Z_{oc}-Z_{sc}) of a cable sample and (c) an instrumental method based