

# Effect of Temperature, Water Content and Aging on the Dielectric Response of Oil-Impregnated Paper

A. Setayeshmehr<sup>1</sup>, I. Fofana<sup>2</sup>, A. Akbari<sup>1</sup>, H. Borsi<sup>1</sup> and E. Gockenbach<sup>1</sup>

<sup>1</sup>Institute of Electric Power Systems, Division of High Voltage Engineering, Schering- Institute  
Leibniz Universität Hannover, Germany

<sup>2</sup>Canada Research Chair, tier 2, on Insulating Liquids and Mixed Dielectrics for Electrotechnology, University of  
Quebec in Chicoutimi, 555, Boulevard de l'Université, G7H 2B1, Chicoutimi, Qc, Canada

**Abstract-** In this contribution, Fourier transform of dielectric responses from Polarization Depolarization Current measurements were investigated to evaluate temperature and aging effects on dielectric response of oil paper insulation system. Measurements of the dielectric response were performed at three temperatures and two aging conditions. To provide quantitative analysis from measurements, the current curves were decomposed into basic exponential functions. Attempts have been performed to correlate the physical condition of the insulation and the equivalent model parameters. The obtained results indicate the feasibility of using the relaxation time constants and coefficients to depict the temperature, water content and aging effects.

## I. INTRODUCTION

Condition monitoring of the insulation of transformers is an important issue since many transformers in electrical industries around the world are approaching the end of their design life. When power transformers fail, the fault can be traced usually to defective insulation. Since the quality of the insulation is a key element for reliable operation of a power transformer, condition monitoring can be utilized to attempt the prediction of the insulation condition and the remaining lifetime of a transformer.

Modern non-destructive, off-line techniques used by many engineers and researchers around the world include the Interfacial Polarization Spectra measurement by Frequency Domain Spectroscopy (FDS) and Polarization and Depolarization Current Measurements (PDC) [1-3]. However, their popularity has not been as well spread as anticipated due to the requirement of the expertise for their evaluation and analysis. In particular a number of factors need to be understood.

The main objective of this contribution is to report about the investigations concerning the time domain dielectric response (PDC) of an oil paper insulation system at different operating ranges of temperature, water content and aging. Measurements have been performed in laboratory, on some oil-impregnated pressboard samples. Temperature, water content and aging effects on the characteristic of the insulation system were investigated.

To obtain a quantitative data from PDC measurements for evaluating the temperature, moisture content and aging effects on the insulation, the polarization and depolarization currents were modeled with basic exponential functions. The

polarization and depolarization currents were fitted with five exponential functions. The results show a relation between the relaxation time constants and coefficients to the temperature, water content and aging.

## II. BACKGROUND KNOWLEDGE

The polarization and depolarization current indicated in the literature as "PDC" measurements is a non-destructive method for determining the condition off insulation materials in power equipments [1-3].

The measurement of PDC following a dc voltage step is one way in the time domain to investigate the slow polarization processes [1-4]. The dielectric memory of the test object must be cleared before the PDC measurement. The voltage source should be free of any ripple and noise in order to record the small polarization current with sufficient accuracy. The procedure consists in applying a dc charging voltage of magnitude  $U_c$  to the test object for a long time (e.g., 10,000 s). During this time, the polarization current  $i_{pol}(t)$  through the test object is measured, arising from the activation of the polarization process with different time constants corresponding to different insulation materials and to the conductivity of the object, which has been previously carefully discharged.

Then the polarization (or absorption, or charging) current  $I_{pol}(t)$  through the test object can be expressed by [2, 4 and 5]:

$$I_{pol}(t) = C_o U_c \left[ \frac{\sigma_o}{\epsilon_o} + \epsilon_{\infty} \delta(t) + f(t) \right] \quad (1)$$

where:

$C_o$  is the geometrical capacitance of the test object,

$U_c$  is the step voltage (charging voltage),

$\sigma_o$  is the DC conductivity of the dielectric material,

$\epsilon_o$  is the vacuum permittivity,

$\epsilon_{\infty}$  the high frequency component of the permittivity,

$\delta(t)$  the delta function arising from the suddenly applied step voltage at  $t = t_0$ .

$f(t)$  is the response function of the dielectric material.

The voltage is then removed and the object is short-circuited at  $t = t_c$ , enabling the measurement of the depolarization current (or discharging, or de-sorption)  $I_{dpol}(t)$  in the opposite direction, without contribution of the conductivity. The polarization current measurement can usually be stopped if the current becomes either stable or very low. According to the