TEMPERATURE DEPENDENCY OF DIELECTRIC LOSS MEASUREMENTS AT 0.1HZ IN MEDIUM VOLTAGE POWER CABLES

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ABSTRACT

Laboratory-based experiments were performed to investigate how dielectric loss measurements of defect free XLPE power cable samples responded to changes in the insulation temperature. The results showed that tan δ values changed significantly and non-linearly as the temperature varied from 4⁰C to 65⁰C. The trend was consistent and independent of the test voltage and confirms similar findings by other researchers. The phenomenon is interpreted in terms of the hopping conduction model in polymers. Possible implications of these findings on in-situ tan δ diagnostic tests are discussed.

KEYWORDS

Tan δ; temperature dependency; non-linear relationship; diagnosis standards; 0.1 Hz test voltage, hopping conductivity.

INTRODUCTION

Dielectric loss factor (also known as tan δ) is now a popular diagnostic parameter in shielded power cables [1]. It is a measure of cable insulation power losses. Degradation of the cable insulation such as that caused by ageing, water trees, electrical trees or partial discharges manifest as increased tan δ. In diagnostic tests absolute values of the tan δ are compared with the anticipated values for new and aged cables (per cable type) as prescribed in standards such as the IEEE std 400™-2001 [2] and IEEE Std 400.2™-2004 [3]. Furthermore the degree of change in the tan δ as the test voltage is increased (tip up) is also used as an indication of the healthiness of the cable insulation.

Tan δ measurement is a global condition assessment of insulation. This is often a limitation in this method of cable diagnosis since in most cases specific location of defects may be desired. In that regard tan δ diagnostic tests are performed in conjunction with other condition assessment techniques such as partial discharge tests [4].

In line with the benefits of low frequency test voltages in power cable diagnosis, tan δ measurements are now widely performed using low frequency test voltages such as 0.1 Hz [4].

A literature survey shows that there has been sustained research work in how dielectric losses in polymer insulation depend on three key variables, namely: (a) test voltage frequency, (b) test voltage magnitude and (c) temperature of the insulation. The knowledge on the relationship between tan δ and test voltage characteristics (frequency and magnitude) has advanced to the extend of being recognised as diagnostic criteria in popular standards such as the Std 400.2™-2004 [3]. The same cannot be said about the influence of temperature on tan δ measurements. The IEC 60840:2004 standard [5] specifies that tan δ tests should be taken while the cable core conductor is at ± 5C⁰ to 10⁰C above maximum allowable temperature; this is presumably for factory tests. The IEEE Std 400™-2001 which is for field testing of shielded power cable systems, does not explicitly prescribe temperature conditions. Recent studies on tan δ by the likes of Hernàndez-Mejía et al [6,7] also unfortunately did not include tan δ – temperature dependency. It can therefore be generalised that standards and field experience reports on tan δ diagnosis are silent on how temperature influences the tan δ factor. On the other hand, literature on mainly laboratory based research, consistently reveals that dielectric losses significantly change with changes in the insulation temperature in most dielectrics.

Given that there are other factors that significantly influence cable temperature such as climatic conditions, type of backfill and ground temperatures, it is most likely that in practice, in situ tan δ tests can be performed at a wide range of cable insulation temperatures. A question therefore arises: to what extent are tan δ results compromised by taking measurements at different insulation temperatures?

This paper presents work on an investigation into the influence of temperature on tan δ measurements performed with a test voltage frequency of 0.1 Hz. The rest of the paper is structured as follows: firstly a summary review of sampled literature on the influence of temperature on tan δ measurement and then a description of the experimental procedure followed by results presentation and discussion.

A REVIEW OF RESEARCH KNOWLEDGE ON TEMPERATURE DEPENDENCE OF DIELECTRIC LOSSES

A summary of key findings in literature pertaining to research on how tan δ measurements depend on temperature is given in Table 1 below. A common 'golden thread' that runs throughout the findings of various researchers is that tan δ varies significantly and non-linearly with variations in temperature of the dielectric. The degree of variations and whether with peaks or not, and the location of the peaks depends on the dielectric types and the test voltage frequency.

The work reported in this paper seeks to contribute to this knowledge by performing tan δ - temperature dependence tests on cross-linked-polyethylene (XLPE) cable samples as presented in the experimentation section.