Transfer function approach of the Debye model for estimating paper moisture in a power transformer

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Abstract. In the event of a power transformer failure, the utility could experience an interruption in its power supply. Many factors, including winding deformations, insulation deterioration, transient and overloaded conditions, etc., can lead to this kind of failure. This research explores the relationship between polarisation and depolarization current (PDC) measured from the oil impregnated paper insulation of a high voltage (HV) power transformer to reveal data about the state of the insulation used in these devices. Paper insulation in a power transformer has been documented to age in a non-uniform fashion. Popular models that can model non-uniform ageing include the conventional Debye model (CDM). In the current study, we employed CDM to foresee the performance of oil-impregnated paper insulation. Further, dielectric loss tan and overall insulation conditions have been explored, with the largest magnitude of Z evaluated from the transfer function (TF) of the CDM model impacting most to the insulation condition and projected moisture present in the insulation paper.

Keywords. Power Transformer, CDM, Transfer Function, Dielectric loss tangent, and Paper Moisture (PM).

1. Introduction

To facilitate the transfer of electricity from one circuit to another, without altering the frequency of the current, a power transformer is an integral part of the power grid. Insulation breakdowns between the windings have been identified as the primary cause of transformer failures. The breakdown of the insulation, excessive voltage, transient events, and overloaded circumstances are the primary causes of this [1-5]. Frequent condition checks on transformers are necessary to prevent problems like turn-to-turn faults (TTFs) in the transformer's windings, which can lead to catastrophic faults and ultimately the transformer's complete failure if not addressed in time.

Over the past few decades, it has become clear that deformed transformer windings are the primary cause of power transformer failure. About 35% of transformer failures, according to statistical data given by CIGRE, are caused by winding deformation. Short circuit current is influenced by winding deformations including hoop buckling, hoop tension, and internal and external forces, which in turn leads to poor insulation conditions and ultimately transformer failure [6-7]. Power transformers can't be easily replaced, therefore utilities need to keep an eye on them to prevent a catastrophic breakdown that would cause an outage. Measurement of dielectric responses is one the popular, vital, and well accepted method to diagnosis insulation condition of power transformer [3]. In early stage of 90's, Return voltage method (RVM), degree of polymerization (DP), dissolve gas analysis (DGA) were used to diagnosis insulation condition conditions [8-9]. all these methods having their own restriction and imitations. In this paper, Recorded PDC data for different grid connected transformer (GTs) has been used to computed transfer function using Debye model and estimated paper moisture to know the insulation conditions of power transformer.

2. Studied System:

2.1. Transfer Function of Conventional Debye Model (CDM)

In an electrical circuit when an electric field is applied, a current start flowing into the circuits by means of alignment of dipole in the direction of electric field called as polarizations current, whereas when electrical field removes the alignment of dipole gets relax and return to its original state called as depolarization current. These PDC recorded for different GTs and used to compute parameters associated with Debye model of individuals GTs [10]

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