EXPERIMENTAL INVESTIGATIONS OF SURFACE DISCHARGE PHENOMENA AT SOLID-LIQUID INTERFACE OF POWER TRANSFORMER INSULATION SYSTEM

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THIRUMURUGAN C

(Roll No. D11045)

SCHOOL OF COMPUTING & ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY MANDI

HIMACHAL PRADESH-175005, INDIA

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Dedicated to my beloved parents

MR. CHANDRAKESAN ERUSAN

MRS. GEETHA CHANDRAKESAN

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Abstract

A power transformer is one of the important equipment in a electric power system. The breakdown in insulation is one of the main causes for the transformer failures. To increase overall dielectric strength, a composite insulation system (liquid and solid) is used in a power transformer. The composite insulation system reduces overall size and cost of a power transformer. Over the years, mineral oil has proven to be an excellent liquid insulation and cooling medium in power transformers. It is extracted from petroleum as a by-product. Mineral oil is still the most popular among liquid dielectrics used in power transformers. However, due to environmental and fire safety concerns, there has been a rise of interest in ester based liquids (synthetic ester and natural ester). Insulating papers are made from unbleached sulphate cellulose. Pressboard is nothing but the thick insulation paper of highest quality. Pressboard acts as solid insulation and gives mechanical support to windings.

Even though, a composite insulation is widely used in power transformers, the interface between liquid and solid insulation turns out to be a weak link. It is due to tangential component of electric stress along the interface between solid and liquid due to differences in the values of permittivity and various impurities. Moreover, there is always increased amount of free charged particles at the interface due to weak physical bonds. Furthermore, the microscopic unevenness of a Pressboard surface causes local field enhancement, thereby decreasing the overall dielectric strength. Partial discharge (PD) over a oil-Pressboard interface become one of the important reasons for failure of the high voltage power transformers. Therefore, surface PD detection, measurement and characterization is an integral part of power transformer diagnostic studies.

In this research work, a series of experiments were conducted to study the surface PD patterns in various combinations of oil-Pressboard insulation materials. The liquid insulation materials utilized in experimentation were mineral oil and synthetic ester, whereas the solid insulation materials were cellulose board and Nomex board. The partial discharge patterns were measured using PD detector. Initially, the sur-

face PD characteristics in various combinations of solid and liquid insulation materials were investigated using partial discharge inception voltages (PDIV), apparent charges (pC), and phase resolved partial discharge patterns (PRPD). Moreover, topography and composition of samples during surface discharges phenomena have been discussed using high resolution images and chemical composition obtained using Scanning Electron Microscope (SEM) and Energy dispersive spectroscopy (EDAX). Among all solid-liquid interfaces, synthetic ester-cellulose Pressboard have shown less surface PD activity.

Finally, PD characteristics of synthetic ester-cellulose Pressboard interface have been studied with impurities, viz., moisture (in oil and pressboard), conducting particles, and bubbles. In order to compare the influence of moisture on PD, separate measurements were taken for moisture in oil and moisture in Pressboard samples. Based on pC, PDIV, and PRPD measurements, observed that there is not much change in PRPD patterns of the moisture-in-board as compared with the moisture-in-oil sample. But with respect to the applied voltage, the number of repetitive pulses and PD magnitudes (pC) were high in the moisture-in-oil samples. The measurement PD patterns in oil/Pressboard with bubble are in good agreement with field results in the literature. From the PRPD, pC and PDIV values, it can be concluded that the Cu particles and bubbles tend to promote more surface discharges as compared to moisture-in-oil and moisture-in-Pressboard samples.

The purpose of the study is to investigate the suitability of synthetic ester as an alternative to mineral oil with various solid insulation material. The findings of this study will assist in understanding the behaviour of surface PD under various conditions and it would be of interest to asset managers considering the effects of such conditions in the transformer.

Keywords:Power transformers, oil-pressboard interface, partial discharges, apparent charge, partial discharge inception voltage.

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