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Topic of Research : **Condition Monitoring of Oil Immersed Transformer Based on Dissolved Gas Analysis (DGA)**

Keywords: Transformer oil, DC sensor, COMSOL Multiphysics, sensitivity, moisture,2-Furfuryldehyde(2-FAL), Zinc Oxide (ZnO) Polyvinyl Alcohol (PVA), Polydimethylsiloxane (PDMS); ANN, Binary Classifier, DGA , Weighing Factor.

FINDINGS:

The findings of this thesis present a comprehensive investigation into the real-time condition monitoring of oil-immersed transformers, with an emphasis on enhancing diagnostic accuracy using soft computing techniques. It employs an ANN-based multistage binary classifier to enhance the diagnostic precision of the conventional IEC method. A key contribution is the development and implementation of an interdigitated capacitive (IDC) sensor system designed to detect insulation degradation by-product, particularly 2-Furfuraldehyde (2-FAL) and moisture, which are critical indicators of transformer health. The study involved both simulation and fabrication of IDC sensors for detecting high-dielectric constant contaminants in transformer oil. Capacitance measurements were used to evaluate sensor performance, with simulations conducted using COMSOL Multiphysics software, confirming the feasibility of the sensor design.

In this study, a fault diagnosis model is developed using Artificial Neural Networks (ANN) in MATLAB, utilizing the 'Neural Net Fitting' Toolbox. The model performs multi-stage binary classification of faults in accordance with IEC 60599, based on chemically weighted Dissolved Gas Analysis (DGA) data. The classification process is carried out in a sequential manner, identifying fault types step-by-step: Fault/No Fault (F/NF), Electrical/Thermal (ELEC/THR), Partial Discharge/Discharges (PD/D1D2), Thermal Faults (T1T2/T3), and Low/High Energy Discharges (D1/D2). To evaluate the model's effectiveness, fault gas data from the TC-10 database is used, and the Mean Square Error (MSE) is calculated for each classification stage. The binary classification of faults for chemically weighted DGA data shows superior performance over non weighted DGA data with outstanding performance accuracies.

Additionally, to enhance sensitivity, a comb-type capacitive sensor was explored for detecting insulation degradation by-products in transformer oil. Simulations were conducted using COMSOL Multiphysics software, ZnO and Al_2O_3 as sensing materials. Among the tested configurations, the sensor utilizing ZnO as the sensing layer demonstrated the highest normalized capacitance and superior sensitivity for both 2-Furfuraldehyde (2-FAL) and moisture detection. Performance of comb type capacitive sensor is better in comparison to IDC sensors in terms of sensitivity.

Furthermore, the fabricated IDC sensors used ZnO as the sensing material, and it was found that increasing the number of sensing electrode fingers reduced both capacitance and sensitivity. Among the various configurations tested, the double-sided (DS) 1-1-1 configuration exhibited superior sensitivity to 2-FAL and moisture. The sensors showed greater responsiveness to 2-FAL, with moisture detection characterized by linearity and minimal nonlinearity errors. Further optimization through changes in sensor geometry and material composition led to improved sensor performance, resulting in a low-cost, efficient solution suitable for online monitoring of transformer insulation.

IDC (Interdigitated Capacitive) sensors were developed using PVA and PDMS as selective sensing films for the detection of moisture and 2-Furfuraldehyde (2-FAL) in transformer oil. The sensors were designed in two distinct configurations (1-1-1) and (1-3-1) each comprising three electrode structures: Single Side (SS), Single Side with Shielding (SSWS), and Double Side (DS). In the (1-1-1) configuration, sensor performance was evaluated for SS, SSWS, and DS structures across contamination levels range from 0 to 60 ppm of moisture and 2-FAL. The sensors were designed using PVA for moisture detection and PDMS for 2-FAL detection. Simulation and experimental studies focused on the change in capacitance as the key response indicators. Among all variants, the DS structure in the (1-1-1) configuration exhibited the highest sensitivity for detecting both moisture and 2-FAL, demonstrating its superior performance for insulation health monitoring.

In conclusion, this study improving sensor structure and materials enhances the detection of insulation degradation in transformer oil. Calibration and use of specific sensing films address the challenge of distinguishing between 2-FAL and moisture. Customized IDC sensors demonstrate effective sensitivity for targeted detection. ANN models using weighted DGA data provide superior fault classification compared to non-weighted data.