MEASURING THE MOISTURE CONTENT OF TRANSFORMER OIL USING THIN FILM CAPACITIVE SENSOR

ABSTRACT

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MD. FIROZ ALAM KHAN

Prof. Tarikul Islam
(Supervisor)

Prof. Shakeb A. Khan
(Co-Supervisor)

Department of Electrical Engineering
Faculty of Engineering and Technology
Jamia Millia Islamia
New Delhi

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Key words: Oommen's curve; Artificial Neural Networks (ANN); Transformer oil; Power transformer; Thin film capacitive sensor; Capacitance to frequency conversion, Capacitive sensor, Moisture measurement, Relaxation oscillator, Transformer ratio arm (TRA) bridge; Porous sensors, moisture sensing, Digital phase angle measurement and Detection circuit.

The existence of moisture in a transformer worsens the transformer insulation by decreasing its electrical, mechanical, and thermal strength. No doubts that many techniques have been developed to meet the task, but still none of these provide very good indication about the exact moisture level in the paper and oil insulation. This is because determination of moisture content in the paper and oil insulation is extremely difficult task when the transformer is in operation. The moisture in the oil-paper insulation is always in a very dynamic state, as there is a constant exchange of water between the oil and paper.

In the thesis an ANN based implementation of Oommen's curve to study the online estimation of moisture in paper insulation of transformer using temperature and moisture in oil as input is proposed. Oommen's curve is normally used to estimate the moisture content in transformer oil. A multilayer perceptron (MLP) feed forward network configuration with one hidden layer in addition to input and output layer is used. The implementation, analysis, and applications of the scheme for the online estimation of moisture are discussed in details. The results confirm that the estimated output of the ANN

follows the desired output of the Oommen's curve very closely. The implementation has the potential to diagnose the incipient fault in real time based on estimation of moisture in paper insulation.

Further an online moisture measurement scheme in a transformer oil using thin film parallel electrode capacitive sensor is developed. It consists of a nanoporous dielectric film in-between two metal gold electrodes. The sensor is designed and fabricated with porous alumina (γ-Al_2O_3) film dip coated by sol gel technique on a substrate of alumina. The sensor is sensitive, very fast, highly reproducible, low hysteresis and mass producible. It can withstand several harsh environmental conditions because of thermally and chemically stable alumina sensing film. The electrical characteristics of the thin film capacitive sensor with change in temperature and moisture in transformer oil are studied. The fabricated sensor has the potential to determine the online moisture in transformer at various temperatures.

For a prototype moisture measurement system of transformer oil, a suitable interface electronics circuit for the sensor has been developed. It is a linear, sensitive, and simple signal conditioning circuit designed using a transformer ratio arm (TRA) bridge for converting the capacitance change into frequency with high precision and accuracy for capacitive sensors. The circuit employs a relaxation oscillator in which the output frequency is linearly related to the capacitive unbalance of a TRA bridge. The design, analysis, and experimental results of the circuit and its application to a thin-film-based humidity sensor are reported. The experimental results confirm the theoretical value predicted. The circuit which offers the minimum parasitic earth capacitance effect has the potential for accurate monitoring of measurement parameters, particularly ppm-level

humidity. The simulation results for the effect of parasitic earth capacitances and ambient temperature on the output frequency have also been discussed. The pulse wave output of the circuit is interfaced with microcontroller for direct moisture display in ppm. The frequency sensitivity and nonlinearity of the sensor for the 0–110-ppm moisture range are found to be 10.94 Hz/ppm and 1.2%, respectively.

Finally, a digital moisture measuring instrument based on phase angle measuring technique with porous silicon (PSi) or porous alumina (PA) as capacitive moisture sensor is proposed. The interface circuit can measure digitally the phase angle change of the capacitive impedance of porous silicon or porous alumina sensor due to change in moisture concentration in terms of clock pulses. Based on phase detection principle, the technique is simple and provides good resolution and inherently digital readout. It is shown that the non-ideal effects such as, finite open loop gain of opamp and parasitic capacitance, offset voltage of comparators are negligible in the circuit. Its simplicity and compatibility with digital signal processing device makes it suitable for read out in a moisture system. The circuit is simple to hardware implement and uses few operational amplifiers and digital devices such as XOR, AND, BUFFER gates, COUNTER etc. The results show that the proposed circuit leads to higher accuracy by minimizing the errors caused by parasitic earth capacitance as well as offset voltage in the circuit. Simulation and experimental results are reported to confirm the effectiveness of the technique.

BRIEF PROFILE

Name: Md. Firoz Alam Khan.

Place of birth: Bokaro Steel City, Jharkhand.

Date of birth: 16/01/1977

Nationality: Indian

E-mail address: firozamu@rediffmail.com

Education:

I received Bachelor of Engineering degree from Aligarh Muslim University, Aligarh in Electrical Engineering and M. Tech. in Instrumentation and Control from Aligarh Muslim University, Aligarh. I have carried out my research work, on the topic of "Measuring the Moisture Content of Transformer Oil Using Thin Film Capacitive Sensor", at the Department of Electrical Engineering, Jamia Millia Islamia, New Delhi.