Transformer loss measurement And Power generation using Heat Flux sensor based Thermoelectric Device

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Abstract:

Three phase transformers are the very important electrical equipment which are used in electrical power systems for step down and step up purpose. So it is essential to provide a better cooling system to it. The objective of this paper is to measure the heat loss accurately in transformer and to provide additional cooling system to it using a Thermo electric module. The thermo electric module is a sensor which acts as both actuator and sensor and it is used to measure the heat loss more accurately and to provide additional cooling to the transformer. Simulation is done using proteus software. It is shown that the conventional method for providing better cooling system has got many drawbacks. These demerits are overcome using the proposed technique. Improvement in cooling system of transformer is achieved and the transformer operates below its rated temperature.

Key words:

Cooling System, seebeck and peltier effect Thermo electric module, Transformer.

I. INTRODUCTION:

We know Transformer is an essential equipment in the power system and cost of the Transformer is also high. We need to protect the transformer from the overheating which may cause failure of Transformer and power system failure. As demand increase for the efficiency in Transformers, the need for accurate means of measuring the dissipative losses of Transformer also grows. Conventional techniques for measuring the heat dissipation include integration of the product of measured voltage and current waveforms, and use of insulated calorimetry chambers to measure the heat flow from Transformers. Also by calculating difference between input and output power in Transformers losses can be found out. Unfortunately, each of these techniques poses its own limitations and challenges. The above methods are used in measuring the transformer losses under linear conditions only. Forming the product of voltage and current waveforms requires highly accurate high bandwidth instruments. Calorimeter chambers can determine the heat dissipation by carefully measuring the coolant temperature and flow rate. Calorimeters can be used over a wide range of power ratings, with reported accuracy deviation of 6.2%. However, calorimeters are expensive to build and have

Significant limitations for measuring losses in Transformers and losses under transient conditions. Commercial heat sensors, such as the Schmidt-Boelter gauge or the Gardon gauge are designed for thermal radiation measurements, making them inappropriate for the intended application. In addition to measuring the total heat dissipation of Transformers, another related challenge has been to determine the distribution of the heat flow in the substrate and baseplate of high power modules. Finite element analysis has been successfully applied to predict this distribution in. However, experimental measurements to verify these predicted distributions are extremely rare in the literature. Opportunities to improve our understanding of this heat flow distribution will help to optimize the substrate and baseplate designs and to evaluate new power module package design features such as double-sided cooling. The objective of this paper is to present a new type of heat flux sensor that can accurately measure the dissipation of power converter components with planar heat transfer surfaces such as power semiconductor modules. These power components typically generate very high heat fluxes from small packages when they work under rated conditions. As a result, traditional heat flux measurement sensors inserted into the heat transfer path typically cause significant temperature rises inside the device which may degrade the loss measurement or even trigger device malfunctions under some circumstances. Thermoelectric coolers (also referred to in the literature as thermoelectric modules, TECs, or Peltier coolers) exhibit the property that their heat transfer ability can be changed by the amount of current flowing through them. If the relationship
between the TEC current and the heat flowing through the cooler can be appropriately controlled, thermoelectric cooler devices hold potential for being configured as very useful closed-loop heat flux sensors with low thermal resistance characteristics.

The measurement of a transformer’s losses and calculation of its efficiency is very well understood and applied in the power and distribution transformer industry. A Standard Test Method for Measuring the Energy Consumption of Distribution Transformers specify the testing procedure for the measurement of losses and the calculation of efficiency under linear loading. The measurement of No-Load Losses is made during an Open-Circuit Test and the measurement of Load Losses is made during a Short-Circuit Test. These measurements can be used to calculate efficiency as follows:

\[ \eta = \frac{P_{out}}{P_{out} + P_{loss}} \]

Where:
- \( \eta \) = Transformer Efficiency
- \( P_{out} \) = Output Power (Watts)
- \( P_{loss} \) = Transformer Power Losses (Watts)

II. LOSSES IN A TRANSFORMER:

a. No Load Loss:

No load loss or core loss appears because of time variable nature of electromagnetic flux passing through the core and its arrangement is affected the amount of this loss. Since distribution transformers are always under service, considering the number of this type of transformer in network, the amount of no load loss is high but constant this type of loss is caused by hysteresis phenomenon and eddy currents into the core. These losses are proportional to frequency and maximum flux density of the core and are separated from load currents. Many experiments have shown that core temperature increase is not a limiting parameter in determination of transformers permissible current in the non-sinusoidal currents. Furthermore, considering that the value of voltage harmonic component is less than 5%, only the main component of the voltage is considered to calculate no load loss, the error of ignoring the harmonic component is negligible. So, IEEE C57.110 standards has not considered the core loss increase due to non-linear loads and has supposed this loss constant, under non-sinusoidal currents.

b. Load Loss:

Load loss includes dc or Ohmic loss, eddy loss in windings and other stray loss and it can be obtained from short circuit test: \( PLL = PDC + PEC + POSL \). Here, \( PDC \) is Loss due to resistance of windings, losses in structural parts of transformer such as tank, clamps. The sum of PEC and POSL its value from the difference of load loss \( PTSL = PEC + POSL = PLL - PDC \). It should be mentioned that there is no practical or experimental process to separate windings eddy loss and other stray loss yet.

c. Current Loss in Windings:

This loss is caused by time variable electromagnetic flux that covers windings. Skin effect and proximity effect are the most important phenomenon in comparison to external windings, internal loss. The reason is the high electromagnetic flux intensity near the core that covers these windings. Also, the most amount of loss is in the last layer of conductors in wind to high radial flux density in this region.

The impact of lower-order harmonics on the skin effect is negligible in the transformer windings.

d. Ohmic loss:

This loss can be calculated by measuring winding of load current increases due to harmonic component, this loss will increase by of load current. It should be mentioned that there is no practical or experimental process to separate windings eddy loss and other stray loss yet. This loss can be calculated by measuring winding dc resistance and load current. If RMS value of load current increases due to harmonic component, this loss will increase by square of RMS.

e. Eddy Current Loss in Windings:

This loss is caused by time variable electromagnetic flux that covers windings. Skin effect and the most important phenomenon in creating these losses. In transformers windings, internal windings adjacent to core have more eddy current reason is the high electromagnetic flux intensity near the core that covers these. Also, the most amount of loss is in the last layer of conductors in winding, which is due flux density in this region perpendicular to field line. Order harmonics on the skin effect is negligible in the transformer can be used for calculating the eddy current loss too: \( R212-R2 \) standards, the amount of rated eddy current loss of windings is about 33% of total stray loss for oil-filled transformers. We can calculate. It should be mentioned that there is no practical or experimental process to separate windings. This loss is caused by time variable electromagnetic flux that covers windings. Skin effect and In transformers, in windings adjacent to core have more eddy current reason is the high electromagnetic flux intensity near the core that covers these.
winding, which is due order harmonics on the skin effect is negligible in the transformer.

f. Other Stray Loss:

Due to the linkage between electromagnetic flux and conductor, a voltage induces in the conductor and this will lead to producing eddy current. Eddy current produces loss and increases temperature. A part of eddy current loss which is produced in structural parts of transformers (except in the windings) is called other stray loss. Many factors such as size of core, class of voltage of transformer and construction of materials used to build tank and clamps. To determine the effect of frequency on the value of other stray loss, different tests have been fulfilled. The frequencies in the range of (420-1200 Hz).Thus this loss is proportional to the square of the load current and the frequency to the power of 0.8. Below equation can be used for calculating the other stray loss

\[
\text{POSL} = \text{PTSL} - \text{PEC}.
\]

III. PROPERTIES OF THERMOELECTRIC MODULE:

This module uses both seebeck and peltier effect. It works on the principles of Thermoelectric effect (seebeck and peltier effect). The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers.

The term “thermoelectric effect” encompasses three separately identified effects: the Seebeck effect, Peltier effect, and Thomson effect. Textbooks may refer to it as the Peltier–Seebeck effect. This separation derives from the independent discoveries of French physicist Jean Charles Athanase Peltier and Baltic German physicist Thomas Johann Seebeck. Joule heating, the heat that is generated whenever a current is passed through a resistive material, is related, though it is not generally termed as thermoelectric effect. The Peltier–Seebeck and Thomson effects are thermodynamically reversible, whereas Joule heating is not.

Thermoelectric module produces the voltage equal to

\[
V = S \cdot DT \quad \text{in volts}
\]

Where

- \(S\) - average seebeck coefficient in volts/°K.
- \(DT\) - temperature difference across couple in °(\(T_H - T_C\)).
- \(T_H\) - Temperature at hot junction.
- \(T_C\) - Temperature at cold junction

Current in the thermoelectric module is equal to

\[
\frac{S \cdot DT}{R_c + R_l}
\]

Where

- \(R_c\) - average internal resistance of TEC in ohms.
- \(R_l\) - Load resistance in ohms.

TOTAL HEAT INPUT TO COUPLE (\(Q_h\)):

\[
Q_h = (S \cdot T_H \cdot I) - (0.5I^2R_c) + (Kc \cdot DT) \quad \text{in watts}
\]

Where

- \(Kc\) - Thermal conductance of couple in W/°K
- Th - hot side of couple in °K

Efficiency \(\eta\) is given by

\[
\eta = \frac{V^2}{2Q_h}
\]
**WORKING PRINCIPLE:**

As the transformer core produces loss in the form of heat dissipation. That heat liberated is utilized by one junction of the TEC sensor and other junction is maintained cool. This temperature difference created in the TEC sensor produces voltage proportional to the heat difference applied to its surface. The voltage generated by this TEC sensor is the analog voltage which cannot be sensed by us. So amplification of the analog voltage is done by the inverting amplifier and its output is given to the Analog to Digital converter to convert analog voltage into a digital signal. Inverting amplifier is used because it has high dynamic stability, improved dc stability and better impedance matching. The digital signal is given to the microcontroller. The threshold limit is set by us in the microcontroller. If the microcontroller senses the voltage above the threshold limit it will switch on the exhauster fan to provide extra cooling for the transformer. The exhauster fan gets the voltage from the TEC itself. TEC uses another principle called peltier effect which is used for cooling the second junction of the TEC device.

**IV. SIMULATION OF ANALOG TO DIGITAL CONVERSION:**
RV1 and RV2 are the variable resistances connected in series. The voltage varies according to the variable resistance and it is given to the inverting amplification purpose. Here we use PIC16F877A micro controller. The output from the microcontroller is given to the LCD display and it displays the Voltage value. If it exceeds the threshold value then the microcontroller gives signal to the exhauster fan switch and additional cooling is provided to the Transformer.

Features of PIC16F877 microcontroller.

- It is a 8 bit microcontroller
- It has 40 pins.
- Out of 40 pins 33 pins are I/O pins.
- RAM -368 bytes.
- ROM -8K
- Data EEPROM -256Bytes.
- Temperature range in Celsius -40 to 125
- Operating voltage range in volts – 2 to 5.5

V. TEG MODULE AND ITS EQUIVALENT CIRCUIT:

VI. ADVANTAGES:

- It has many advantages compared to the conventional techniques. Conventional techniques need wattmeter or voltmeter to measure the power losses, which require careful observation. TEC sensor can measure the losses very accurately. Its accuracy deviation is only about ±2%.
- TEC is a sensor with low thermal resistance characteristics, which means it has high Thermal conductivity. The heat flow rate is very fast.
- Since it is a heat flux sensor the heat rate is divided uniformly by the surface area of the sensor to determine heat flux (Radiation+Conduction+Convection).
- TEC sensor not only used to measure the voltage. It also acts as a generator which generates DC voltage to exhauster fan which provide additional cooling for the transformer.

VII. APPLICATIONS:

It is used in Power electronic components loss measurement. It is used in CPU processors. The heat from the processor is utilized by the TEC sensor to generate voltage which is used for running the fan inside it. It is used in vehicles. The heat from the silencer is utilized by this TEC sensor to generate voltage which is used for the voltage for Headlights and indicator lights. It is used in the places where highly precise temperature control is needed. For example in Petroleum industries, Rubber industries etc….

VIII. CONCLUSION:

This project yields a new approach for measuring heat dissipation from Transformers using Thermoelectric devices. Reduces the impact of sensors on the operating temperature of the device under test. In future this technique can be implemented in vehicles. The new heat flux sensor makes use of the Peltier and Seebeck effects to operate the TEC devices as both actuators and sensors in a closed-loop control configuration. One of the special advantages of this approach is the ability to minimize the net thermal impedance of the heat flux sensor using active control techniques, thereby reducing the sensor’s impact on the operating temperature of the device-under-test. The measured performance characteristics of these TEC-based heat flux sensors are promising in terms of both steady-state accuracy and dynamic response.

IX. REFERENCES:


6. Rafael Palacios, Miguel A. Sanz-Bobi, Jost Villar, Antoni Arenas.


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