Progress in Engineering Application and Technology Vol. 3 No. 2 (2022) 481–489

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Thermal Analysis of Transformer in Distribution

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DOI: https://doi.org/10.30880/peat.2022.03.02.047
Received 23 July 2022; Accepted 07 November 2022; Available online 10 December 2022

Abstract: In engineering, transformers are used in a wide variety of applications, some of which include the production, transmission, and distribution of energy. It does this by using the principle of electromagnetic induction, which converts an alternating current (A/C) with a specific voltage into a direct current (DC) with a different magnitude. Therefore, the prediction of transformer temperature rising is important to avoid or decrease the probability of the damage to occur. This research aim to analyze the performance and output obtained from the thermal transformer's core simulation. This research has achieved by determine 3 materials use at core transformer, then conduct 3D modelling of core transformer. The 3D modelling was simulating by using Finite Element Method (FEA) to determine the most suitable material to use as core transformer. Actual experiment has been done by site visit, thermal camera was use as equipment to measure the thermal performance of core transformer. From the experiment, the temperature discrepancy between the simulation and the real data is anywhere between 0.5 and 1℃ when compared to the actual experiment.

Keywords: Transformer, Thermal Performance, 3D Modelling, Simulation, Thermal Camera

1. Introduction

1.1 Background Study

Thermal analysis is the study of how variations in temperature affect the material's inherent physical qualities. Transient thermal analysis involves calculating the temperature, heat storage, and several other thermal characteristics in a model as a function of time. A transformer converts an alternating current (A/C) of a particular voltage to a comparable current using the principle of electromagnetic induction. Life expectancy of a transformer depends on the thermal of the transformer. While the

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transformer operates, a portion of the electromagnetic energy is converted to heat energy, and the transformer produces energy loss in the winding and other components, which is then converted to heat.

A non-contact infrared camera detects infrared radiation (heat) and transforms it to an electrical signal, which is then processed to provide a thermal picture or video on which temperature calculations may be made. Heat detected by an infrared camera may be properly quantified or measured, allowing you to monitor and assess the severity of heat-related issues. In my research, more focus is on detecting thermal performance of a transformer in a substation using a thermal camera. This research will analyse the thermal performance with actual result to compare. Thermal camera specification use from the experiment will be compare with more efficient thermal camera specification.

1.2 Problem Statement

In a substation, transformers may be used to adjust the voltage levels between higher transmission voltages and lower distribution voltages, or to link two transmission voltages. Thermal monitoring of transformer is important to ensure the transformer is in good condition. If the temperature of the transformer is too high, it is indicative of a fault that can further damage the components inside the transformer if left unchecked. This increase of temperature also has the potential to shorten the transformer lifespan. Therefore, the prediction of transformer temperature rising is important to avoid or decrease the probability of the damage to occur. This study will analyze the temperature rises in windings and components inside transformer above ambient temperature by using Thermal 3D Modelling. This study also will predict the transformer temperature rise and determine the hotspot location of higher temperature that is important for industry and transformer used. The output from the model then will be compared with the actual measured data from industrial transformer. The measured data from industrial transformer was obtained by using thermal camera.

1.3 Objectives

The main objectives for this study are;

a) To determine materials of the core transformer.
b) To analyze the performance and output obtained from the thermal transformer's core simulation.
c) To compare the simulation output with the experimental data obtained by the thermal camera.

1.4 Scope of study

To fulfil the stated objectives, the scope of this project is as following:

a) Determine parameters from previous research and go site visit to company that have transformers.
b) In order to determine the core transformers' thermal performance, parameters will be used to simulate 3D modelling in SolidWorks.
c) Thermal performance simulations are created using 3D modelling in order to get the temperature of the core constituent and compare it to the real temperature measured during the site visit.

2. Methodology

This chapter focuses on the strategy that will be employed to accomplish the goals of this project. This chapter discusses the software and hardware development for this project. It also explains how the goals will be developed and achieved, as well as the techniques that will be employed.

2.1 Research Flowchart

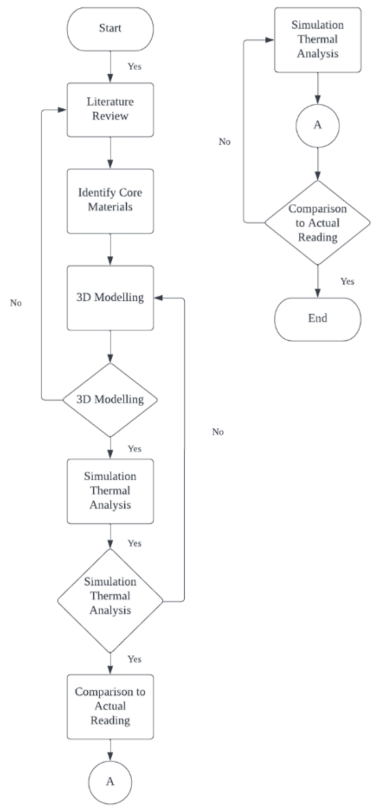

Figure 1: Research Flowchart

2.2 Research Flowchart Explanation

To achieve this research, a simulation has been made to make the process smooth and get like have been to be. This will begin to make studies from previous research related to research. This method will give the advantage of completing this research. The last study has stated the recommended idea to complete the research study.

From that, this research will proceed due to ideas that are recommended to add. After that, 3D modelling will be made using SolidWorks software. This 3D modelling dimension of the core transformer has been obtained from a previous study idea. This dimension is the same as the transformer for this research. Then, from 3D modelling, the thermal analysis simulation or FEA will be the simulated simulation. This research will study the core transformer's temperature, the core transformer's heat flow from minimum temperature to maximum temperature, and also the heat flux of the core transformer. After the simulation is complete, results due to simulation will be compared with the actual reading by using the thermal camera provided by the industry during the site visit at MMHE company. Moreover, the thermal camera specification that MMHE used will be compared with better thermal camera performance specifications.

2.3.1 Literature Review

Collecting data focused on a particular title is referred to as a literature review. Primary data and secondary research are the two sorts of sources that are used to obtain information. The key references are those obtained from conversations with the supervisor. Books, case studies, theses, journals, reports, and the internet are used to collect secondary data or information.

2.3.2 Materials Comparison

The core may be constructed out of a wide variety of materials. In transformers, magnetic fields may be contained more effectively thanks to the magnetic core, which is made of a material with magnetic permeability. For the sake of this study, will employ elements like:

1. Silicon Steel
2. Solid Iron
3. Alloy

2.3.2 Transformer Selection

For selecting a transformer, site visits to the industry were approached to get the suitable transformer to succeed in this research. Due to the site visit, Malaysia Marine and Heavy Engineering (MMHE) was chosen to get a transformer to be selected. For this research, transformer ONAF, 66kV/470V, was chosen as the transformer to this research.

2.3.3 3D Modeling Using SolidWorks

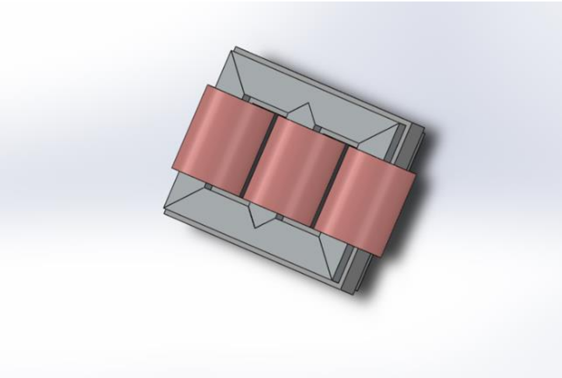

Figure 2: 3D Modeling Core Transformer

SolidWorks will be used to design the transformer's core. Using SolidWorks makes progress to development more effortless. SolidWorks also can make the drawing into 3D modelling to comply with the research's objective and scope. This 3D modelling is from the previous study because to get the specific detail dimension, only the factory that builds the transformer has the exact detail on the dimension of a core transformer.

2.3.4 Dimension 3D Modelling Core Transformer

Dimension of 3D modelling will be derived from the studies done in the past. Therefore, the same methodologies and dimensions were used in this research as were used in the previously cited work.

2.3.5 Simulation Finite Element Analysis (FEA) using SolidWorks

To run the simulation thermal analysis, the temperature is set in the 3D modelling, heat flux, and convection. From the simulation will get what should be in the actual result.

2.3.6 Thermal Camera

Thermal camera will be used to measure the thermal of the core transformer during the site visit. The thermal camera on MMHE is used to detect the thermal core of the transformer. This research will compare the specifications of the thermal camera used at MMHE company with the other thermal camera that will purpose in this research.

3. Results

For result, will explains the facts and conclusions reached by the thermal study performed on the transformer in distribution. The simulation detects heat transfer inside the core transformer by simulating the 3D modelling of the core transformer. After that, it will determine whether or not it successfully achieved the objectives outlined by this study's aim. During the site visit, a comparison will be made between the 3D modelling and the real reading utilizing a thermal camera. After that, a comparison will be made between the thermal camera performance during the site visit and the other thermal camera specification.

3.1 Heat Transfer at Core Transformer

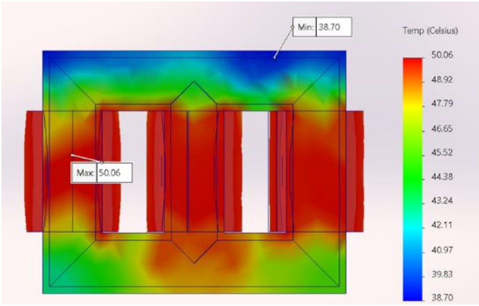

Figure 3: Heat Transfer of Silicon Material

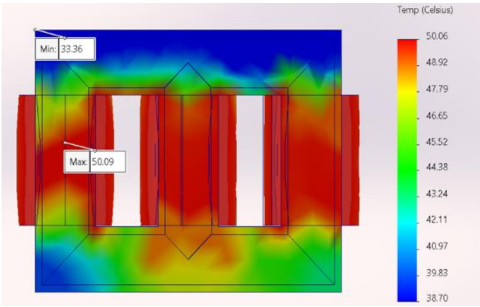

Figure 4: Heat Transfer of Solid Iron Material

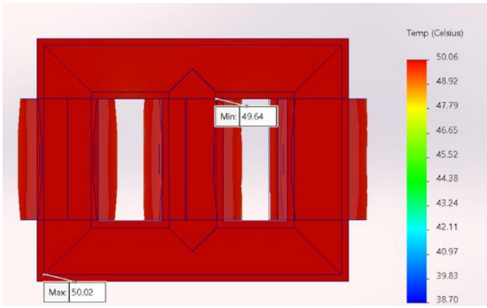

Figure 5: Heat Transfer of Alloy Material

The transformer's core is made out of steel, whereas the winding is made out of copper The temperature of the steel material can reach a maximum of 50.06 ℃ and a minimum of 38.70 ℃. Iron is shown as the material for the transformer core. The maximum temperature obtained from the simulation was 50.09 ℃, and the minimum temperature was 33.36 ℃. The alloy material was the last type of core transformer that was simulated throughout this investigation. The maximum temperature that could be obtained from the simulation was 50.0 ℃, while the minimum temperature that could be obtained was 49.6 ℃.

As on core transformer material made of steel and iron, the temperatures between products are not too far off in maximum and minimum temperature, but the temperature of the core transformer when made of alloy material is too high. Because of this consequence, the efficiency of the core transformer will decrease. Aside from that, the duration of the transformer's lifespan was determined by the thermal performance of the transformer. When the temperature of the transformer was high, the duration of the transformer's lifespan was constantly getting shorter.

3.2 Temperature Rising Graph of Core Transformer Materials

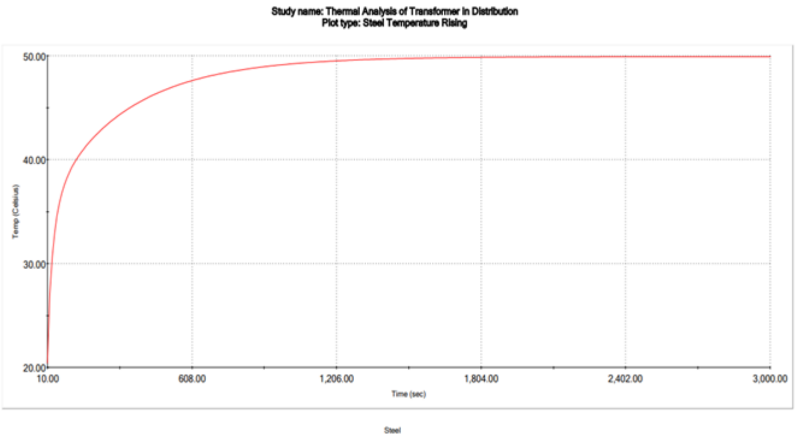

Figure 6: Temperature Rising Graph of Silicon Steel

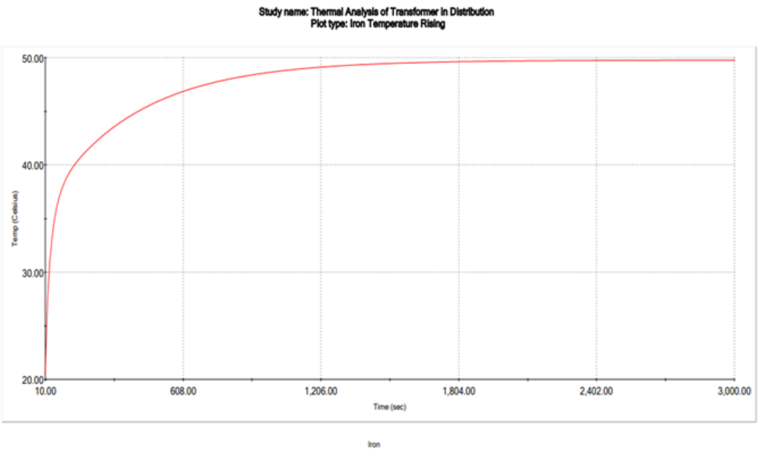

Figure 7: Temperature Rising Graph of Solid Iron

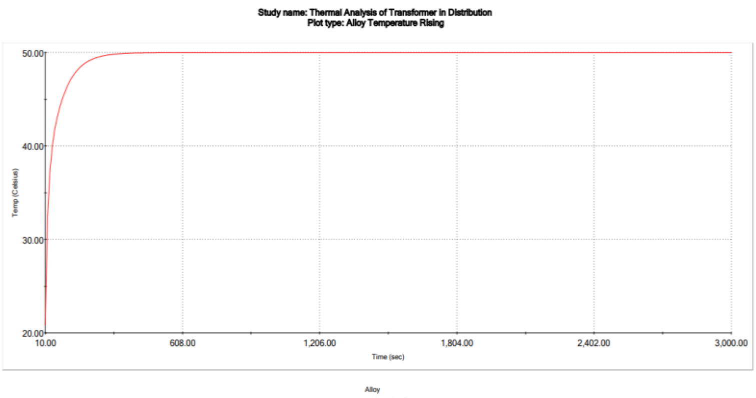

Figure 8: Temperature Rising Graph of Alloy

As the starting temperature of the core transformer is predetermined to be 20.00 °C, the chart depicts this value as the beginning temperature. After reaching 50.00 °C, the temperature did not change for the remaining 3000 seconds of the experiment. The inquiry simulation was completed in 3000 seconds since the longer it took to simulate the simulation, the longer it would have to be performed to represent reality truly. In Figure 8, the graph shows that alloy experiences the highest rate of temperature increase right from the start. This alloy material acts as a heat absorber whenever the magnetic induction operates when the transformer operates. As a consequence, in Figure 6 and Figure 7 of silicon steel and solid iron, the temperature rise from both materials is relatively comparable; nevertheless, the temperature increase from iron material was a little bit slower than that of steel. This demonstrated that solid iron is a better material than silicon steel for use as the core of a transformer.

Since thermal performance is such an essential factor for transformers, a comparison of materials that induce an increase in temperature was investigated. This is because the temperature of the transformer may be controlled before it undergoes maintenance if it develops a problem while being operated. If the temperature rises abnormally rapidly, the transformer can have some major issues. It is common knowledge that the transformer is an essential component of the electrical transmission system; hence, if anything goes wrong with the transformer, this will result in difficulties with the electric transmission to the load. The core of the transformer should be made of a substance that has a low-temperature rise and is made of the appropriate material.

3.3 Thermal Camera During Experiment

Figure 9: Thermal Camera Used During Experiment

The thermal camera used in this experiment is the same one the MMHE firm uses to ensure that the transformer at the site is under control. The MMHE firm has chosen the Fluke Ti32 as it is the thermal camera. The Fluke Ti32 can take a picture temperature of the core of a transformer and display it as a thermal image. At the same time, there are a few problems with the thermal camera when it comes to capturing the thermal performance of the core transformer. When the experiment started, the thermal camera had a minimal delay in capturing the thermal image of the core transformer. For the IR (Infrared) to detect any radiation that may be present on the item being measured, the hand must be held in a static position.

An experiment was conducted as a consequence of the simulation so that the results could be proven and compared with the investigation results. The experiment was carried out with a thermal camera, which was utilized to evaluate the thermal performance of the transformer. The experiment was done at midday, and it measured the surface temperature of the transformer that had been chosen by utilizing a Fluke Ti32 thermal camera. The thermal performance of the transformer is read by the image acquired by the thermal camera to be between 49.00 ℃ and 50.00 ℃, at an average temperature of 33.00 ℃. Figure 4.4 provides a reference for the results that were obtained.

The temperature simulation showed it could transport heat from 20.00 ℃ to 50.00 ℃ within 100 seconds. When compared to the actual experiment, the simulation and the actual data temperature difference is between 0.50 ℃ and 1.00 ℃.

3.4 Compared Simulation with Actual Experiment

Figure 10: Actual Result

An experiment was conducted as a consequence of the simulation so that the results could be proven and compared with the investigation results. The experiment was carried out with a thermal camera, which was utilized to evaluate the thermal performance of the transformer. The experiment was done at midday, and it measured the surface temperature of the transformer that had been chosen by utilizing a Fluke Ti32 thermal camera. The thermal performance of the transformer is read by the image acquired by the thermal camera to be between 49℃ and 50℃, at an average temperature of 33℃. Figure 3.8 provides a reference for the results that were obtained.

The temperature simulation showed it could transport heat from 20℃ to 50℃ within 100 seconds. When compared to the actual experiment, the simulation and the actual data temperature difference is between 0.50 ℃ and 1.00 ℃.

4. Conclusion

The main objective for the purpose project is to predict the thermal performance of transformer using simulation and propose efficient thermal camera that suitable to capture accurate thermal performance and give the best result on the thermal imager. During working on this research, a few problems were found. Compared to the actual experiment, the results from the simulation are not quite precise enough to be considered reliable. This is because the parameter of the simulation core transformer has been obtained via earlier studies. To find a solution to this issue, it is necessary to get the detailed parameter from the transformer manufacturer to make the simulation more realistic compared to the actual outcome.

Acknowledgement

The authors would like to the thank Faculty of Engineering Technology for its support.

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