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Simulation of Heat Transfer Characteristics on Palm Oil as Electrical Insulating Material Using Finite Difference Method

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***Abstract*—The purpose of this research work is to study the heat transfer characteristics of palm oil as insulating material using finite difference method (FDM). Analysis and investigations of several heat transfer characteristics of palm oil were performed to determine the heat transfer performance of this oil. The characteristics obtained is then compared to other insulating oils to determine the performance of the insulating material. The simulation was done using Computational Fluid Dynamics (CFD) software that uses finite difference method concept that could perform 2D simulation to visualize the heat transfer characteristics inside the design of 2D transformer model geometry. The winding temperature is set into initial condition under full load temperature. The fluids properties of insulating material such as density, viscosity, thermal conductivity and specific heat capacity are set as constant, respectively. The simulation is set to constant running time of 30 minutes with interval of 5 minutes. The heat transfer characteristics such as fluid temperature, winding temperature, velocity profile, density and viscosity, heat flux from the winding and heat transfer characteristics are defined as variables, respectively. The results shows significant decrease of fluid and winding temperature of a transformer with palm oil as insulating material and has better heat transfer performance than other vegetative oils.**

Keywords—heat transfer characteristics, vegetative-based oil, electrical insulating material, finite difference method, computational fluid dynamic.

I. INTRODUCTION

Transformer is a very important and essential electrical component in power distribution and transmission. Power transformer is an electrical machine that transfers electrical energy from one circuit to another either by stepping up the voltage or stepping down the voltage according to the needs. Basically, it is a device that changes voltage levels. There are many classes of transformer used in the distribution and transmission of power. Hermetic type of transformer is one of the many transformers that widely used in this world. Hermetic type transformer is a fully filled with oil where the oil expansion is compensated by deformable radiator fins [1-7].

For decades, mineral oil has been used in electrical power system for transformer oil. However, mineral oil possesses disadvantages where its application in electrical power system can cause environmental problems when accidents occur like oil spillage or transformer explosion due to the non-biodegradable and high flammability properties of mineral oils. To resolve this issue, the alternative insulating oils with biodegradable properties with good electric and chemical properties has been researched for potential insulating material that can replace the commercial oil.

Mineral oil is a petroleum-based oil. As oil petroleum sources becomes relatively low, vegetable or natural ester oil specifically palm-based oil becomes another option to replace the transformer oil. Looking into economics aspects, Malaysia is the one of main producer of palm oil which given the advantage to the economy growth of the country. Palm oil is categorized also as vegetable oil which they are popular because they perform better than products made from the commercial oil and have definite environmental and safety benefits [4]. A good type of insulating liquid must have good electrical properties which ensure the performance of the insulating material itself. The electrical properties for palm-oil such as the partial discharge magnitudes test, shows palm fatty acid ester (PFAE) are slightly lower than those of commercial mineral oil during aging period [5].

Heat produce in transformer generally occurs at the windings and core of the transformer due to power loss. The windings temperature may exceed 110℃ under full load or 80℃ rise above surrounding temperature in industrial standards [6]. In industry, analyzing the hot-spot temperature is a crucial to keep the life span of transformer. Hot spot temperature can