A Comparison Between Half and Full Fins at Nanofluids in Transformers

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ABSTRACT: Power transformers characterize the biggest section of capital investment within the distribution substations as well as transmission. Additionally, outages of those transformers have a substantial economic influence on the functioning of an electrical network due to the fact that the power transformers are one of the utmost overpriced constituents in an electricity structure. A suggested thermal model for a distribution transformer is investigated. The temperature distribution in the three-phase transformer (250 KVA 11/.416 KV core type, mineral oil) was obtained using “COMSOL PROGRAM” after a 3D simulation utilizing a transient analysis in light of the Finite Element Method (FEM). Meanwhile, the suggested model is being used to examine the impacts of different types of oil on HOST. To test the effect of nanoparticles on heat transfer process, the insulation oil was changed with Nanofluids and hybrid nanofluids; For present work, can be concluded when add nanofluids (Al₂O₃, CuO, SiC) for oil of transformer under different concentration ratio (0.3,0.5,0.8,1,1.2,1.4 % wt) and add hybrid nanofluids (oil+ Al₂O₃+CuO), (oil+ Al₂O₃+SiC), (oil+ SiC +CuO) at different concentration ratio (1,1.2,1.4 % wt). The concentration of nanofluids show a direct influence on the temperature reduction for the studied cases. Finally it can be said, the proposed model was succeeded in simulating the distribution transformer, which is in good agreement with the experimental tests adopted for this work, and it could be used as a design tool with assist of COMSOL Multiphysics Package. The present model successfully accomplished for expecting the temperature distribution at any locations in the transformer when compared with practical measurement.

Keyword: Thermal model, concentration, distribution transformer, Nanofluid, hybrid.

Introduction: Power transformers characterize the biggest section of capital investment within the distribution substations as well as transmission. Additionally, outages of those transformers have a substantial economic influence on the functioning of an electrical network due to the fact that the power transformers are one of the utmost overpriced constituents in an electricity structure. Indeed, most of these transformers utilize oil and paper as the key type of insulation. Through the conversion process for the electricity power in a transformer, many types of losses are arising. These losses usually take
place at active parts (windings and core) of the transformer and then converted into heat. This heat spread throughout the transformer and then to the air by means of its insulation material such as minerals oil. But accumulation for this heat without efficient dissipation will cause deterioration in the transformer insulation paper and damage in their windings [1]. So, the temperature rise must be limited through safety rang, in order to increase the operational life of the distribution transformer. Earlier researchers have been studied the method for enhancing oil insulation performance by using different oil types as well as adding an active materials having high thermal conductivities. Özben 2015 [2] studied the flow and heat transfer in a transformer radiator filled with (ester, mineral and silicone) oils. The study investigated the thermal properties of transformers oils, it was found that the natural ester oil had the best pressure drop and heat transfer. Mushtaq 2017 [3] investigated the thermal behavior of electrical distribution transformer per the effect of using transformer oils, based nanofluids, as a cooling medium and an alternative to pure transformer oil. Different types of solid particles, total of four, (Cu, SiC, Al2O3 and TiO2) were used to constitute nanofluids with volume fractions (1%, 3%, 5%, 7%, and 9%). Results show that the overall cooling performance of the transformer was improved by the use of oil based nanofluids as a cooling medium in place of pure oil throughout the reduction in the temperature of the transformer and consequently increase transformer protection against breaking down. Lim 2015 [4] utilize CFD ANSYS-Fluent 15.0 simulation tool to implement 3D simulation to visualize transformer heat transfer performance based on the design of the designed transformer model. they used the graphite, CNT, and diamond nanofluids where the results indicate that they have superior heat transfer coefficient in comparison to transformer oil. Also, it is shown that graphite and CNT based nanofluids have lower temperature in the winding area compared to transformer oil alone. Ibtisam et al. 2016 [5] analyzed a suggested thermal model for a distribution transformer using ANSYS software. In the meantime, the effects of oil type on hot spot temperature (HST) are examined using the suggested model. The insulation oil was altered with Nano fluid in order to examine the effect of nanoparticles on the heat transfer process. 0.5% as a volume concentration of Nano particles (CuO and Al2O3) was used, where the maximum temperature decreased by 5%. Hasan M. I,(2017) [6]. Instead of pure transformer oil, a cooling fluid based on transformer oil-based micro encapsulated phase change materials suspension is employed with a volume concentration (5–25%) percent as a cooling fluid to enhance the cooling performance of transformers. In addition to its capacity to absorb heat due to melting, paraffin wax is an excellent electrical insulator and is employed as a phase change material to create the suspension.

So, the effects of oil types on the transformer temperature must be investigated. a thermal model was proposed to foresee this essential data before the real operations must be prepared In the scope of this study; temperature distribution in the transformer “- 250 KVA 11/416 KV core type” which was manufactured by Electrical Industries Company in AL WAZYRIA had been modeled in three dimensions with using Finite Elements package “COMSOL” as a reliable tool. The model can be used for obtaining the temperature distribution in the transformer at using different nanofluid concentrations with the mineral oil as a base fluid.

2. Methodology
2.1. Thermal Modeling
The FEM was employed in this work to solve the unsteady (3D) heat equation with internal heat generation and determine the temperature distributes for the active parts. Figure (1) shows a depiction of the transformer core’s adopted conditions. For the core which is exposed to internal heat generation (\(q\)), heat losses due to convection and radiation effect which is obscured in a medium with a temperature of \(T_\infty\).
To obtain the temperature variation inside the core, the general heat equation of conduction including internal heat generation is divided into core geometries. Initially, the core is depicted in Cartesian coordinates which represented in gray region in Figure 1. With this situation, the heat equation for constant properties (thermal characteristics) is:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q}{k} = \frac{\rho c_p}{k} \frac{\partial T}{\partial t}$$  \hspace{1cm} (1)

Where:
- $x, y$ and $z$ are the Cartesian coordinates.
- $T$ is the temperature.
- $r$ is the density.
- $k$ is thermophysical conductivity
- $c_p$ is the specific heat
- $t$ is the time

The three dimensional heat equations were employed in cylindrical coordinates and also with constant properties for the cylindrical region in the second example (copper windings in Figure 1). The following is the formula:

$$\frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 T}{\partial \phi^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q}{k} = \frac{\rho c_p}{k} \frac{\partial T}{\partial t}$$ \hspace{1cm} (2)

Where the cylindrical coordinates are $r$ and $\phi$.

Convection and radiation limit conditions assumed for the external surfaces of the core. Equation gives such boundary conditions (3):

$$-k \frac{\partial T}{\partial \eta} = h(T - T_\infty) + \sigma e(T^4 - T_\infty^4)$$  \hspace{1cm} (3)
Where: $\eta$ is the normal path, $\varepsilon$: emissivity of the surface along with $\sigma$ represent Stefan Boltzmann constant.

### 2.2. Free Convection Correlations

The average correlations for the iron silicon part's Free Convection ($\overline{h}$) were calculated using Barroso correlations [7]. First, Barroso ascertained Nusselt number $\text{Nu}_v$ for vertical plate which found in the iron silicon part side and the “$\text{Nu}_U$” and “$\text{Nu}_L$” for the horizontally positioned plate at upper and lower of core. These correlations for $\text{Nu}_v$, $\text{Nu}_U$, and $\text{Nu}_L$ are given by:

$$
\text{Nu}_v = \left( \frac{0.825 + 0.387 \text{Ra}^{1/6}}{1 + (0.492)^{1/6} \text{Ra}^{1/2}} \right)^2
$$  \hspace{1cm} (4)

$$
\text{Nu}_U = 0.15 \text{Ra}^{1/3}
$$  \hspace{1cm} (5)

$$
\text{Nu}_L = 0.27 \text{Ra}^{1/4}
$$  \hspace{1cm} (6)

Where, Prandtl number $\text{Pr}$, Nusselt number $\text{Nu}_v$ and Rayleigh number $\text{Ra}$ are used for the iron silicon part side, $\text{Nu}_U$ is used for upper surface and $\text{Nu}_L$ is used for bottom side. For winding part modeling, the coefficient of heat transfer was gained from correlations of cylinder obtained in [8]. The correlation is given by:

$$
\text{Nu}_c = \left( \frac{4\text{Pr}^2\text{Gr}}{36 + 45\text{Pr}} \right)^{1/5}
$$  \hspace{1cm} (7)

Where, $\text{Gr}$ is the Grashoff number.

$\text{Nu}_c$ represent Nusselt number of windings

$\overline{h}$ is obtained by equation (8) and as follows:

$$
\overline{h} = \frac{k_{\text{air}} \text{Nu}_v}{L_c}
$$  \hspace{1cm} (8)

Where $k_{\text{air}}$ is the thermal conductivity of the air is $L_c$ is the characteristic length of the side.

### 2.3. Numerical Solution

The levels of thermal diffusivity and thermal conductivity are determined by the core materials. Iron silicon, Kraft paper, and copper are among the materials used. To build a complete transformer, heat sources (core, winding), oil as a cooling fluid, insulating mineral, and an exterior tank were collected.

The heat conduction equation cannot be solved analytically because the transformer's geometries are not regular. As a result, numerical methods for solving partial differential equations (PDEs) should be used.

The key benefits of FEM are that it may be used to model any forms in any number of dimensions and that the material characteristics can be non-homogeneous (depending on location) and/or anisotropic (depend on direction). The way that the shape is supported (also called fixtures or restraints) can be quite general, as can be the applied sources (forces, pressures, heat, flux, etc.). The FEM provides a standard process for converting the governing energy principles or governing differential equations into a system of matrix equations to be solved for an approximate solution. For linear problems such solutions can be very accurate and quickly obtainable. In order to develop the thermal model, the points which were taken into consideration; Because oil is a dispersing media that does not create heat, there are no losses. As a result, there are no sources for oil elements. The heat dissipation from the tank to the ambient is represented by thermal resistances connecting the tank’s outside nodes to the
ambient at a temperature of 20°C. This means that the thermal model will anticipate a temperature rise beyond the ambient temperature and symmetry will be seen.

The thermal conductivity of copper and iron silicon, according to Bergman et al. [9], may be regarded constant across a wide temperature range. According to Liao et al. [10], the Kraft paper exhibits stable thermal condition for the range of 0 to 200 °C temperature. Bergman et al. [20] claim that the thermal conductivity of copper and iron silicon is constant across a wide temperature range. As a result, the thermal characteristics of Kraft paper can be considered constant. According to [9], the copper thermal conductivity is about 400 W/mK, 0.0890 W/m.K to the Kraft paper, and for iron silicon is 45 W/m.K.

The thermal diffusivity for the copper is 119.420 × E–6 m2/s, for the Kraft paper 0.07417E-6 m2/s and for the iron silicon is 17.58 × E–6 m2/s. The simulation presupposed that the assembly elements were in perfect contact. As a result, the thermal contact resistance was not taken into consideration. Partial discharges, polarization, and moisture are small insulation losses as compared to core and winding losses.

The governing equations are based on all of these assumptions:

Continuity:

\[
\frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0 \quad (9)
\]

X direction momentum

\[
\frac{\partial (\rho u^2)}{\partial x} + \frac{\partial (\rho uv)}{\partial y} + \frac{\partial (\rho uw)}{\partial z} = -\frac{\partial P}{\partial x} + \frac{\partial}{\partial y}\left(\mu \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu \frac{\partial u}{\partial z}\right) \quad (10)
\]

Y direction momentum

\[
\frac{\partial (\rho u^2)}{\partial x} + \frac{\partial (\rho v^2)}{\partial y} + \frac{\partial (\rho vw)}{\partial z} = -\frac{\partial P}{\partial y} + \frac{\partial}{\partial x}\left(\mu \frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial z}\left(\mu \frac{\partial v}{\partial z}\right) - \rho g \quad (11)
\]

Z direction momentum

\[
\frac{\partial (\rho u^2)}{\partial x} + \frac{\partial (\rho v^2)}{\partial y} + \frac{\partial (\rho w^2)}{\partial z} = -\frac{\partial P}{\partial z} + \frac{\partial}{\partial x}\left(\mu \frac{\partial w}{\partial x}\right) + \frac{\partial}{\partial y}\left(\mu \frac{\partial w}{\partial y}\right) \quad (12)
\]

Energy:

\[
\frac{\partial (\rho C_p T)}{\partial x} + \frac{\partial (\rho C_p T)}{\partial y} + \frac{\partial (\rho C_p T)}{\partial z} = \frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(k \frac{\partial T}{\partial z}\right) \quad (13)
\]

Where \(\rho\) is the density in (kg/m3), \(C_p\) the specific heat capacity in (J/(kg.K)), \(T\) absolute temperature in (K), \(u\) represent the velocity vector in (m/s), \(\rho C_p\) : conduction heat flux in (W/m2), \(P\) the pressure (Pa), \(\mu\) is the dynamic viscosity (kg/(m.s)) and \(k\) is the thermal conductivity (W/(m.K)). Then the mesh was established according to the field optimization. On the other hand, due to the size of the transformer, the number of elements is tremendously high. The mesh with 4,160,512 Tetrahedron elements was chosen. To solve for the nodes and produce a temperature profile, the program COMSOL Multiphysics was utilized. A mesh refinement test determined the mesh size. The results of
the test refinement are shown in Table 1. As a refinement parameter, the average temperature on the HV winding was used. The discretization was then completed by creating meshes as seen in Figure 2.

Table 1 presents the test refinement results.

| Test No. | Number of Tetrahedral Elements | Number of Tetrahedral Nodes | Average Temperature of HV Winding |
|----------|--------------------------------|----------------------------|-----------------------------------|
| 1        | 958467                         | 234702                     | 98.878                           |
| 2        | 2132258                        | 429090                     | 94.029                           |
| 3        | 3675689                        | 629210                     | 92.124                           |
| 4        | 4160512                        | 805920                     | 92.018                           |

Figure 2. The designed forms for (A): the geometric shape, (B): meshing.

3. Relation between Oil Properties and Temperature:

The oil temperature grew as heat was created in the transformer. As a result, oil parameters such as density (ρ), thermal conductivity (k), viscosity (μ), and specific heat (cp) will alter. The impact of temperature on oil characteristics is indicated in the following equations as oil temperature (Toil) [11].

\[
\begin{align*}
\text{cp} &= 807.163 + 3.58 \times \text{Toil} \quad \text{(14)} \\
\rho &= 1098.72 - 0.712 \times \text{Toil} \quad \text{(15)} \\
k &= 0.1509 - 7.101 \times 10^{-5} \times \text{Toil} \quad \text{(16)} \\
\mu &= 0.08467 - 4 \times 10^{-4} \times \text{Toil} + 5 \times 10^{-7} \times \text{Toil} \quad \text{(17)}
\end{align*}
\]

4. Physical Properties of the NanoFluid

Because to the action of, the thermal characteristics of the working fluids are altered. Nanoparticle concentration and fluid temperature influence nanoparticle characteristics. The concentration of Nano fluid volume is defined as [11]:

\[
\phi = \frac{\text{Vol}_{np}}{\text{Vol}_{e}} \quad \text{(18)}
\]

The viscosity is predicted by [5]:

\[
\mu_{nf} = (1 + 2.5\phi)\mu_f \quad \text{(19)}
\]

Nano fluid mixture thermal conductivity is determined by [11]:

\[
k_{nf} = \left(\frac{k_p + 2k_f + 2\phi(k_f - k_p)}{k_p + 2\phi - (k_f - k_p)\phi}\right)k_f \quad \text{(20)}
\]
The Nano fluid density is determined by [11]:

\[ \rho_{nf} = (1 - \phi)\rho_f + \phi\rho_p \]  
(21)

The Nano fluid specific heat is determined by [11]:

\[ (c_p)_{nf} = (1 - \phi)(c_p)_f + \phi(c_p)_p \]  
(22)

5. Result and discussion:

The results of the transformer temperatures distribution of a 250 kVA three-phase transformer using COMSOL program when add a nanofluids and hybrid nanofluids for oil of transformer Figure(3) show a temperature of core at full fins in transformer under different concentration of 0.3, 0.5, 0.8, 1.2, 1.4 % wt when using oil with different nanofluids (Al₂O₃, CuO, SiC). The result shows maximum temperature appear at (82-84)°C at 0.3%wt of concentration nanofluid SiC, CuO and Al₂O₃. The minimums temperature show at as at 1.4 %wt of concentration nanofluid for Al₂O₃, SiC and CuO respectively.

Figure (3) Temperature of core at full fins at nanofluids (Al₂O₃, CuO, SiC)

Figure(4) show a temperature of core at full fins in transformer under different concentration of 1.2, 1.4 % wt when using hybrid nanofluids (oil+ Al₂O₃+CuO), (oil+ Al₂O₃+SiC), (oil+ SiC +CuO). The result shows the minimums temperature show at as at 1 %wt of concentration nanofluid for at hybrid nanofluids (oil+ Al₂O₃+CuO), (oil+ Al₂O₃+SiC), (oil+ SiC +CuO) but the maximum temperature appear at 1 %wt of concentration nanofluid (oil+ Al₂O₃+CuO), (oil+ Al₂O₃+SiC)and (oil+ SiC +CuO) respectively.

Figure (4) Temperature of core at full fins at hybrid nanofluids (oil+ Al₂O₃+CuO), (oil+ Al₂O₃+SiC), (oil+ SiC +CuO)

Figure (5) show a temperature of H.V at full fins in transformer under different concentration of 0.3, 0.5, 0.8, 1.2, 1.4 % wt when using oil with different nanofluids (Al₂O₃, CuO, SiC). The result shows maximum temperature appear as at 0.3 %wt of concentration nanofluid SiC, and at 1.4 %wt of concentration nanofluid of CuO and Al₂O₃ . The minimum temperature show at as at 1.2 % wt of concentration nanofluid for SiC, Al₂O₃, and CuO concentration nanofluid respectively.
Figure (5) Temperature of H.V at full fins at nanofluids (Al$_2$O$_3$, CuO, SiC)

Figure (6) show a temperature of H.V at full fins in transformer under different concentration (1, 1.2, 1.4 % wt) when using hybrid nanofluids (oil+ Al$_2$O$_3$+CuO), (oil+ Al$_2$O$_3$+SiC), (oil+ SiC +CuO). The result shows the minimums temperature show at 1.2 %wt of concentration nanofluid (oil+ Al$_2$O$_3$+CuO) and (oil+ Al$_2$O$_3$+SiC and 1%wt at hybrid nanofluids (oil+ SiC +CuO). The maximum temperature appears at 1 %wt of concentration nanofluid oil+ SiC +CuO and at hybrid oil+ Al$_2$O$_3$+SiC, but nanofluids concentration 1.4% wt (oil+ Al$_2$O$_3$+CuO) and (oil+ SiC +CuO).

Figure (6) Temperature of H.V at full fins at hybrid nanofluids (oil+ Al$_2$O$_3$+CuO), (oil+ Al$_2$O$_3$+SiC), (oil+ SiC +CuO)

Figure (7) show a temperature of L.V at full fins in transformer under different concentration (0.3,0.5,0.8,1,1.2,1.4 % wt) when using oil with different nanofluids (Al$_2$O$_3$, CuO, SiC). The result shows maximum temperature appear as at 1.2 %wt of concentration nanofluid CuO and Al$_2$O$_3$ but at 0.3 %wt of concentration of SiC nanofluid. The minimum temperature show at as at 1 % wt of concentration nanofluid for SiC, Al$_2$O$_3$, and CuO concentration nanofluid respectively.

Figure (7) Temperature of L.V at full fins at hybrid nanofluids (oil+ Al$_2$O$_3$+CuO), (oil+ Al$_2$O$_3$+SiC), (oil+ SiC +CuO)
Figure (7) Temperature of L.V at full fins at nanofluids (Al₂O₃, CuO, SiC)

Figure (8) show a temperature of L.V at full fins in transformer under different concentration (1, 1.2, 1.4 % wt) when using hybrid nanofluids (oil + Al₂O₃ + CuO), (oil + Al₂O₃ + SiC), (oil + SiC + CuO). The result shows the minimums temperature show at as at 1 % wt of concentration nanofluid for at hybrid nanofluids (oil + Al₂O₃ + CuO), (oil + Al₂O₃ + SiC), (oil + SiC + CuO) but the maximum temperature appears at 1.2 % wt of concentration nanofluid (oil + Al₂O₃ + CuO), (oil + Al₂O₃ + SiC), (oil + SiC + CuO) respectively.

Figure (8) Temperature of L.V at full fins at hybrid nanofluids (oil + Al₂O₃ + CuO), (oil + Al₂O₃ + SiC), (oil + SiC + CuO)

Figure (9) show a temperature of oil at full fins in transformer under different concentration (0.3, 0.5, 0.8, 1, 1.2, 1.4 % wt) when using oil with different nanofluids (Al₂O₃, CuO, SiC). The result shows maximum temperature appear as at 1.2 % wt of concentration nanofluid CuO and Al₂O₃ but at 0.5 % wt of SiC respectively. The minimum temperature show as at 0.8 % wt of concentration nanofluid for CuO but at 1 % wt of concentration nanofluid SiC, Al₂O₃, and nanofluid respectively.

Figure (9) show a temperature of oil at full fins in transformer under different concentration (0.3, 0.5, 0.8, 1, 1.2, 1.4 % wt) when using oil with different nanofluids (Al₂O₃, CuO, SiC). The result shows maximum temperature appear as at 1.2 % wt of concentration nanofluid CuO and Al₂O₃ but at 0.5 % wt of SiC respectively. The minimum temperature show as at 0.8 % wt of concentration nanofluid for CuO but at 1 % wt of concentration nanofluid SiC, Al₂O₃, and nanofluid respectively.
Figure (10) show a temperature of oil at full fins in transformer under different concentration (1, 1.2, 1.4 % wt) when using hybrid nanofluids (oil+ $\text{Al}_2\text{O}_3$+CuO), (oil+ $\text{Al}_2\text{O}_3$+SiC), (oil+ SiC +CuO). The result shows maximum temperature appear at 1.4 %wt of concentration nanofluid oil+ SiC +CuO. As well as 1% wt of oil+ $\text{Al}_2\text{O}_3$+CuO and oil+ $\text{Al}_2\text{O}_3$+SiC. The minimum temperature shows at 1.4 %wt of concentration hybrid (oil+ $\text{Al}_2\text{O}_3$+CuO), (oil+ $\text{Al}_2\text{O}_3$+SiC) respectively, but at 1 %wt of concentration hybrid (oil+ SiC +CuO).
In the above section, the results of the conventional transformer temperatures distribution of a 250 kVA three-phase transformer are discussed, as well as when Nano fluids and hybrid Nano fluids are added for the transformer as an insulation oil and it can be seen that there is a significant reduction in the temperature of transformer active parts. This indicates that the transformer size can be reduced, which was achieved by halving the number of oil tank fins. This process will also improve the air ventilation between adjacent fins.

Figure (5.9) show a temperature of core at half fins in transformer under different concentration (0.3, 0.5, 0.8, 1, 1.2, 1.4 % wt) when using oil with different Nano fluids (Al$_2$O$_3$, CuO, SiC). The result shows maximum temperature appear as 81°C at 0.8%wt of concentration Nano fluid SiC, and in CuO at 0.3 % wt of concentration Nano fluid. As well as at 0.5%wt of concentration Nano fluid for Al$_2$O$_3$. The minimums temperature show at as at 1.4 % wt of concentration Nano fluid for Al$_2$O$_3$, SiC and CuO respectively.

Figure (5.10) show a temperature of H.V at half fins in transformer under different concentration (0.3, 0.5, 0.8, 1, 1.2, 1.4 % wt) when using oil with different Nano fluids (Al$_2$O$_3$, CuO, SiC). The result shows maximum temperature appear as at 0.3 % wt of concentration Nano fluid SiC, also at 0.3 % wt of concentration Nano fluid of CuO and Al$_2$O$_3$. The minimum temperature shows at as at 1.4 % wt of concentration Nano fluid for SiC, also 1.4 % wt Al$_2$O$_3$, and CuO concentration Nano fluid respectively.

6. Conclusions

For present work, can be concluded when add nanofluids (Al$_2$O$_3$, CuO, SiC) for oil of transformer under different concentration ratio (0.3, 0.5, 0.8, 1, 1.2, 1.4 % wt) and add hybrid nanofluids (oil+ Al$_2$O$_3$+CuO), (oil+ Al$_2$O$_3$+SiC), (oil+ SiC +CuO) at different concentration ratio (1, 1.2, 1.4 % wt). The concentration of nanofluids show a direct influence on the
Finally, it can be concluded that the suggested model was given a good result in simulating the thermal performance of the distribution transformer, which is in good agreement with the experimental tests adopted for this work, and it could be used as a design tool with assist of COMSOL Multiphysics Package.

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