

Performens and Analysis of Transformer Radiator with Different Types of Oils Using CFD

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ABSTRACT: A power transformer is the electrical device which is used for the conversion of electric energy in transmission and distribution network system for domestic and international energy transport and industry applications. The modern large and medium power transformers consist of oil tank with mineral oil for purpose of insulation and cooling by external radiator. In this work synthetic oils are used instead of mineral oil such as Palm oil, Coconut oil, Sunflower oil & Corn oil for cooling and insulation because of their biodegradability and high flash point properties. The radiator fin model is designed using **UG 8.0** and analysed in **CFD (Flow Vision)**. The results obtained from analytical method are close acceptance with CFD results. The out let temperature of mineral oil is 53.057 °C and among all the selected synthetic oil the outlet temperature of corn oil is 52.01 °C which is less than other synthetic oils. The analysis also shows that outlet temperature of radiator fin decrease for corn oil is 2.3% less than the conventional mineral oil. Further studies shown that the natural corn oil have good electrical, chemical properties as compared to the existing mineral oil & selected synthetic oils for transformer insulation.

KEYWORDS: Dielectric strength, vegetable oils & mineral oil.

I. INTRODUCTION

Transformer is a particularly profitable static machine working on the standard of mutual induction. It changes AC power in a circuit beginning with one voltage level then onto the following through inductively coupled electrical transmitters and is accessible in a variety of power ratings. The transformer principle was revealed by Michael Faraday in 1831 and it was William Stanley in the year 1886 that first developed a transformer for commercial use. It is the most efficient device in the power system with values of efficiency ranging up to 99.8%.

Large rated power transformers and distribution transformers form a major part of the today's power system network. However, the problem in large rating transformers is heat dissipation. More the heat is accumulated without being dissipated lesser is the life of the transformer. The insulating oil circulating inside the transformer absorbs heat from the interior of transformer through conduction and this heat is dissipated to the ambient through natural means or by cooling methods using suitable coolants. But there may be some areas inside the transformer where the oil might not reach properly or somehow the heat might not be dissipated properly, or heat dissipation is slow (or less) in comparison to heat generation, and hence gets accumulated. Such heat accumulation results in high temperature, which reduces the life of the transformer drastically.

Heat Generation in the Transformer:

A transformer has to be continuously in operation. By virtue of its construction, it has no moving parts and is a closely packed and sealed device. As a result, the dissipation of the generated heat inside the transformer is a rather difficult problem compared with any of the other machines.

This section presents a few thermal concepts related to generation and dissipation of heat. This is very important to analyse the thermal behaviour of transformers, or for that matter, any electrical device. Heat dissipation is a pronounced problem in transformers because transformers are enclosed devices and because transformers have no

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rotating parts which provide inherent ventilation. Any solid body with losses occurring in it generates heat inherently, because, any form of energy loss in a body is dissipated in the form of heat. The loss can be either magnetic loss, due to interaction of fluxes or hysteresis loss, or ohmic loss, due to the current passing through a conductor and the resistance being offered by it or mechanical loss, due to moving parts and the friction between the surfaces in contact.

Potential of natural vegetable oils as new dielectric fluid:

In view of the finding for the protecting liquid, the option should have the property of cooling the electrical equipment. Along with this line, the plant based oils are chosen. Recent research work and modern innovative work have idea on vegetable oils termed as "biodegradable oil" can discover mechanical applications.

Vegetable oils do not contain any sulphur, aromatic hydrocarbons, metals or unrefined petroleum deposit. The absence of sulphur means a diminishment in the development of corrosive downpour by sulphate discharges which can create sulphuric corrosive in our environment.

The vegetable oil which is completely qualifying as a dielectric liquid, its synthetic structure is critical. Rough vegetable oils extricated from oil seeds have dark colour and contain strong constituents, for example, proteins, filaments and fluid (fat and oil). Both fats and oil are triglyceride esters of unsaturated fats, yet fats contain a moderately high rate of immersed triglyceride and would stop to strong underneath room temperature.

Advantages to use vegetable Oils:

1. Reduced ecological effect, so if there should be an occurrence of a spill, no risky chemicals would need to be cleaned up and they have less poisonous quality to living life forms.
2. They are more secure, they have higher flash and fire focuses than most mineral based liquids what's more, and their danger to life forms and people is insignificant. .
3. Enhance economies in groups occupied with rural creation, since the source is that of renewable assets.
4. Non- poisonous quality
5. Biodegradability
6. Production of just adequate and generally safe warm debasement by-items
7. To be recyclable and promptly dispensable.

Table: 1 Properties of oils at 55 °C

Properties	Mineral oil	Corn oil	Sunflower oil	Coconut oil	Palm oil
Molecular weight (Kg/mol)	270	865.4	876.16	876.36	840.38
Density (Kg/m ³)	850.75	894.95	896	884.4	872.6
Viscosity (Kg/ms)	0.0068	0.01866	0.0193	0.0139	0.03215
Specific Heat capacity (Cp) (kJ/Kg K)	2.186	1.714	2.122	2.008	1.944
Thermal Conductivity (W/m K)	0.1156	0.164	0.164	0.1617	0.1699

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II. RELATED WORK

Vitaly A. Yatsevsky (1) the flow features has an influence on the thermal state of winding coils of the transformer with the natural cooling system. At such oil flowing, in different channels, the heat transfer coefficient varies within the limits of 50 to 100 W/ (m² K), and the radial component of velocity is changed over the range of $2.1e^{-4}$ to $2.2e^{-4}$ m/s. Thus the region with maximum temperature values is removed towards oil flowing along the coil radius.

Min-gu Kim et al (2) this paper presents prediction and experimental study on the cooling execution of radiators utilized as a part of oil filled power transformer applications with non-direct flow and direct-oil forced flow. Radiator temperature dispersion and cooling execution was predicted utilizing theoretical computations then approved using CFD simulation results. In the analysis, cooling limit was evaluated with the non-direct flow and the direct-oil-forced flow. For direct-oil-forced flow, the most extreme cooling limit was improved 20.1% more than non-direct flow. These outcomes confirm that the expectation and the evaluation of radiator cooling execution can be connected to design optimization of cooling mode for oil-filled power transformer applications.

Sadik Kakac et al (3) this paper summarized the vital distributed deals with Nano liquid properties, experimental and numerical heat transfer behaviours. In the simulations, two primary classifications were discussed in point of interest as the single-stage modelling which the combination of nanoparticle and base liquid is considered as a single-phase blend with steady properties and the two-stage modelling which the nanoparticle properties and behaviours are considered independently from the base liquid properties and behaviours.

The two-stage model can give the better perspectives in the Nano liquid flow field, following the solid and liquid stages are considered independently. The governing conditions for the single-phase model are straightforward for the new engineers and the less complicated model with the less time consuming. One may modify a few terms in the single-phase governing conditions to build accuracy of the computations.

The outcomes of related work is highlight the efforts in transformer cooling and the improvements of option dielectric liquids. The various types of products from vegetable sources utilized for dielectric coolants will be presented. The work offers a summary of improvement work on a consumable seed-oil-based dielectric liquid. It includes a foundation discussion of oils utilized, key properties correlation with other significant dielectric liquid types. Also this work has measured the properties of palmoil, sunflower oil, coconutoil, cornoil and mineraloil.

III. METHODOLOGY

3D model

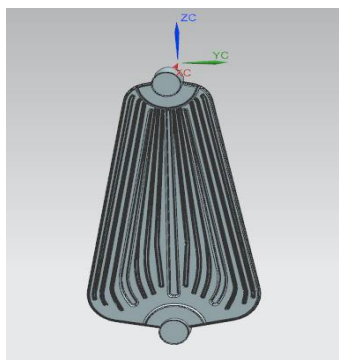


Fig.1: Transformer radiator fin

The above figure is a transformer radiator fin. Usually transformer radiator bank consists 10 or more than 10, for in this work single fin can be taken for simulation. This 3D model is designed in UG 8.0 modelling software. This

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fin is similar as elliptical shape due to which heat dissipation will be more. Length of the fin is 0.9 m, inlet & outlet tube diameter will be 0.09 m and thickness of the fin will be 0.02 m.

Steps followed in CFD analysis:

The 3D analysis of transformer radiator fin is done using Flow Vision software. The steps followed were as follows. In solver process 4 steps are involved, they are pre-processor, solver, postprocessor, viewport.

Pre-processor:

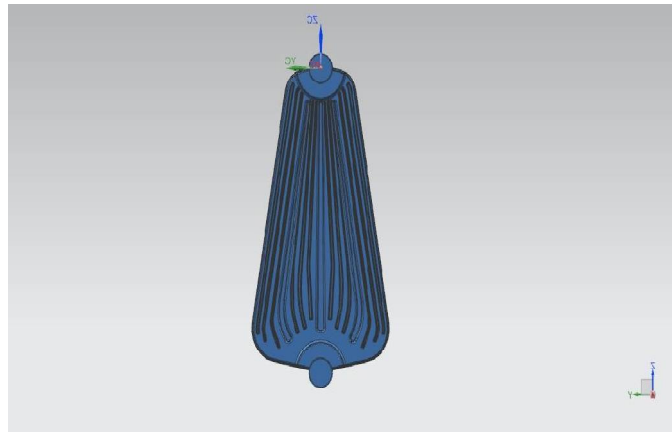


Fig.2: Imported model in flow vision software.

This is the first step and here we need to define the problem, assigning the initial conditions, boundary conditions. It starts with the importing the 3D stl or wrl file of cad model. In this, several steps is to be followed. Radiator fin analysis is the internal flow i.e. the oil flows inside the fin and it is exposed to the environment.

Steps in pre-processor:

- **General settings:** Here some initial reference values are to be specified like pressure, temperature, gravity etc.
- **Substances:** Here substances are to be loaded which are considered for analysis. We used oils as substance and properties of oils loaded according to that specified temperature.
- **Phases:** In this process a single phase or multi-phase is to be stated. We used the single phase.
- **Models:** Here model is created and assigning the phases to this model.
- **Objects:** Here all the parts which are needed to analyses are imported in this section only. Later we can assign as moving bodies or stationary bodies in sub region column.
- **Sub regions:** In this step, assign the model to this sub region which is created in the beginning. In this section we have to assign the boundary conditions.
- **Inlet Boundary condition:**
 - Type: Inlet/outlet
 - Velocity: Normal mass velocity
- **Outlet Boundary condition:**
 - Type: Free outlet

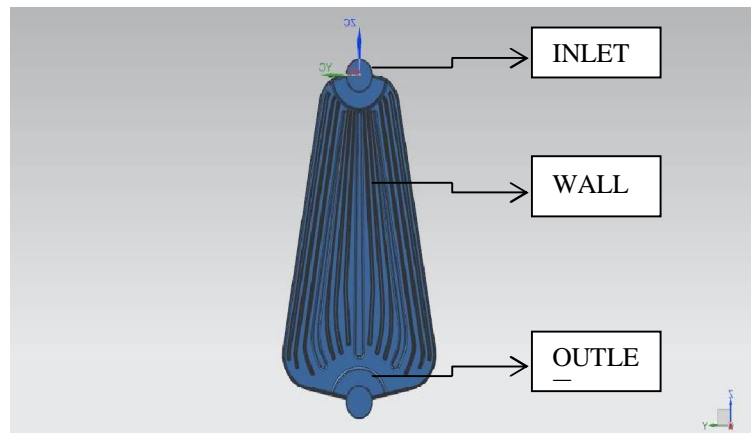


Fig.3: Indication of Boundary conditions for model

Formulas have to be used for calculations:

Rate of Heat Transfer (Q):

1. $Q = m \times C_p \times \Delta T$
2. $Q = h \times A \times \Delta T$

III.RESULTS AND DISCUSSION

The results obtained from the analytical and CFD are exhibited here in tabular column.2. lists the results obtained. The other properties are indicates that good properties ensure a good dielectric breakdown voltage of an insulating liquid. For example the moisture content of palm oil is 0.82(mg/kg) and the similar value for the break down voltage is 65(kV), similarly corn oil, coconut oil, sunflower oil and mineral oil as mentioned in table 1. But mineral oil still the breakdown voltage will be 52(kV) with moisture content of 1.2(mg/kg). So the critical factors that influence the breakdown voltage are the measure of suspended particles and the moisture content. The expense of vegetable oil is high camper to mineral oil.

The viscosity of a dielectric fluid is important property; subsequently this property should be seen in an unexpected way. The working temperature greatly influences the viscosity of a fluid inside the transformer tank, for example, the temperature differs considerably depending on loading, surrounding temperature and it rises excessively particularly during faults. It can be seen that at higher temperatures, the viscosity gets lower. This demonstrates there is an inverse relation between the viscosity and the temperature. The flash and fire points have demonstrated that the oil can securely be utilized even where the temperature is relied upon to be high the cut off expected for most applications is 100°C. The appearance and the relative density are in agreement with the breaking point of the standard.

The viscosity at various temperatures demonstrates suitability of the oil for dielectric use. The results figures show that the inner cooling duct oil has a higher temperature than the outer cooling duct. The following figure shows that the oil temperature in the radiator decrees rapidly. The most extensive cross areas at the cooling channel, close to the tank wall constitute a down comer and riser for the circulating oil. This is because of the effect hot oil going upwards while cold oil going downwards in the same wide cooling channel and the difference in pressure established by the thermo syphoning which seems to depend on the position of the core-windings as well as the cross section area of the cooling duct. The pressure decreasing along the length of the radiator fin as mentioned in table 4.3. On account of the thin cross area cooling pipes which are in the internal cooling conduits oil is going up which propose that the hot oil is directing to the top of the transformer tank.

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In order to validate this work, a comparison between numerical and CFD data is presented. The results obtained from analytical method are close acceptance with CFD results. The out let temperature of mineral oil is 53.057 °C and among all the selected synthetic oil the outlet temperature of corn oil is 52.01°C which is less than other synthetic oils. The analysis also shows that outlet temperature of radiator fin decrease for corn oil is 2.3% less than the conventional mineral oil. Further studies shown that the natural corn oil have good electrical, chemical properties as compared to the existing mineral oil & selected synthetic oils for transformer insulation.

MINERAL OIL:

Drop in Temperature:

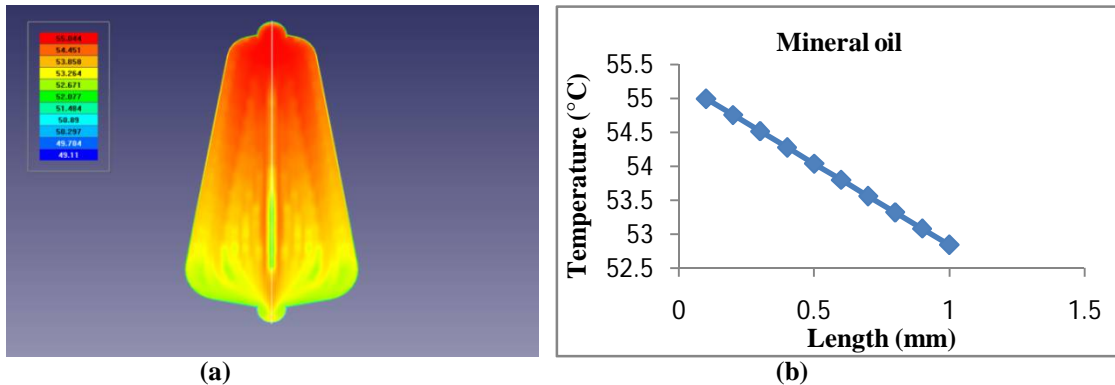


Fig.4 (a) Contour of temperature drop along the radiator length (b) Graph shows drop in temperature along the radiator length

The above figures show dissipation of mineral oil temperature along the length. Fig.4.a shows contour diagram of dissipation of temperature when contact with ambient temperature and fig.4.b graph shows gradually decreasing in temperature along the length.

COCONUT OIL:

Drop in Temperature:

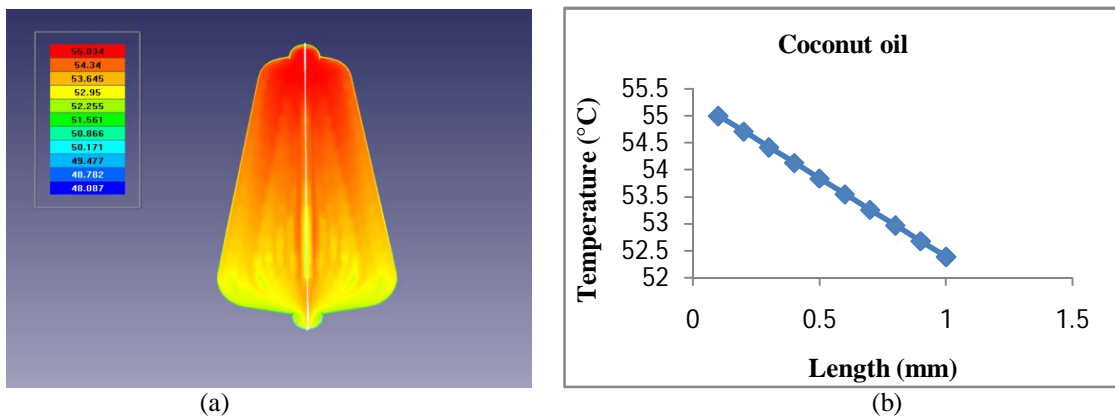


Fig.5 (a) Contour of temperature drop along the radiator length (b) Graph shows drop in temperature along the radiator length

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The above figures show dissipation of coconut oil temperature along the length. Fig.5.a shows contour diagram of dissipation of temperature when contact with ambient temperature and fig.5.b graph shows gradually decreasing in temperature along the length.

PALM OIL: Drop in Temperature:

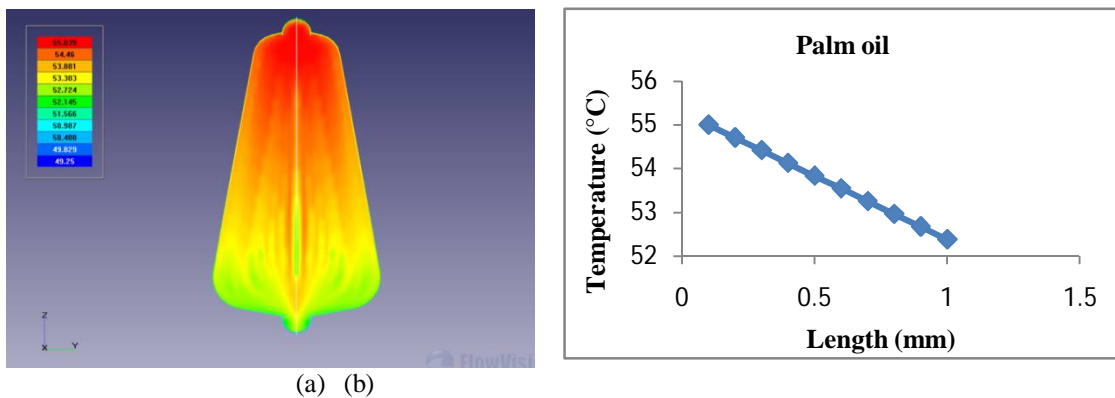


Fig.6 (a) Contour of temperature drop along the radiator length (b) Graph shows drop in temperature along the radiator length

The above figures show dissipation of palm oil temperature along the length. Fig.6.a shows contour diagram of dissipation of temperature when contact with ambient temperature and fig.6.b graph shows gradually decreasing in temperature along the length.

SUNFLOWER OIL: Drop in Temperature:

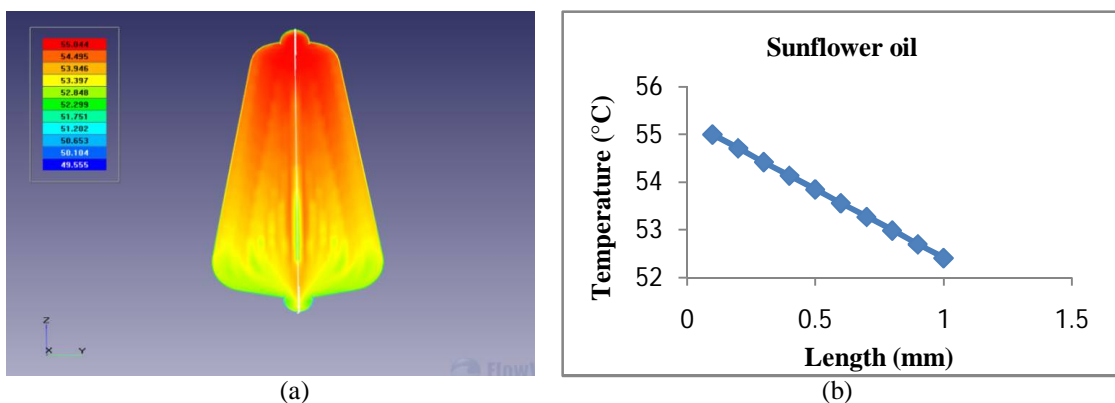


Fig.7 (a) Contour of temperature drop along the radiator length (b) Graph shows drop in temperature along the radiator length

The above figures show dissipation of sunflower oil temperature along the length. Fig.7.a shows contour diagram of dissipation of temperature when contact with ambient temperature and fig.7.b graph shows gradually decreasing in temperature along the length.

**CORN OIL:
Drop in Temperature:**

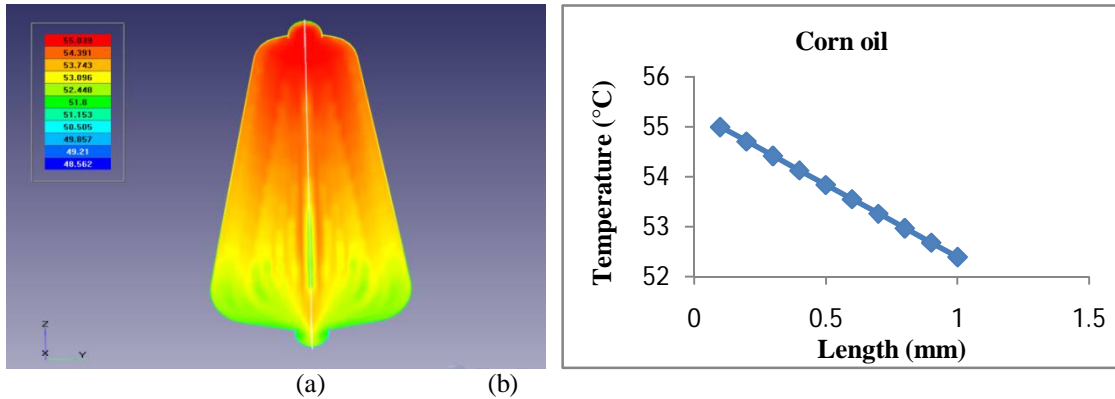


Fig.8 (a) Contour of temperature drop along the radiator length (b) Graph shows drop in temperature along the radiator length

The above figures show dissipation of corn oil temperature along the length. Fig.8.a shows contour diagram of dissipation of temperature when contact with ambient temperature and fig.8.b graph shows gradually decreasing in temperature along the length.

Table:2 Comparisons between analytical & CFD result shows drop in temperature (°C).

Oils	Analytical	CFD
mineral oil	53.057	52.6079
Sunflower oil	52.855	52.436
Coconut oil	52.81	52.38
Palm oil	52.71	52.13
Corn oil	52.01	52.10

The results obtained from analytical method are close acceptance with CFD results. The out let temperature of mineral oil is 53.057 °C and among all the selected synthetic oil the outlet temperature of corn oil is 52.01°C which is less than other synthetic oils. The analysis also shows that outlet temperature of radiator fin decrease for corn oil is 2.3% less than the conventional mineral oil.

IV.CONCLUSION

Today the world is seeing the time of a moving from the petroleum and mineral oils that are draining and ecologically unpleasant in transformer cooling and vegetable oils that are renewable and environmentally friendly. These renewable assets have great dielectric properties and are perfect for use with no danger and it will cools transformer more than the mineral oil. The business sector and regulatory pressures to diminish liability risk introduction of mineral-oil-filled circulation and power transformers are increasing. Also, there are requests to enhance

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equipment efficiencies and adopt more "earth-friendly" alternatives in our energy frameworks. Considering these outlook changes, the industry has been growing new transformer ideas. The properties of vegetable oil have been investigated against standards, and the outcomes illustrates that the selected corn oil has a good potential to be utilized as a dielectric liquid. The additional points of interest of vegetable oils in electrical equipment's are that they have great biodegradability, which is suited to corn oil as a good organic natural ester because the results obtained from analytical method are close acceptance with CFD results. The out let temperature of mineral oil is 53.057 °C and among all the selected synthetic oil the outlet temperature of corn oil is 52.01°C which is less than other synthetic oils. The analysis also shows that outlet temperature of radiator fin decrease for corn oil is 2.3% less than the conventional mineral oil. Further studies shown that the natural corn oil have good electrical, chemical properties as compared to the existing mineral oil & selected synthetic oils for transformer insulation.

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