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A Review on Utilization of Vegetable Oils as Transformer Oils

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Abstract - *In certain high-voltage equipment, minerals or synthesized oil is utilised in combination with sheet as the dielectric liquid. However, environmental concerns, a shortage of crude oil sources, and issues disposing of old oils have pushed researchers to work on renewable and biodegradable insulation applications. Transformer lubricants based on vegetable oil are quickly improving mineral oil-based solutions on the trade. They are effective since they outperform oil based experience and providing clear security and ecological benefits. The present state of vegetable oils as transformer oil, encompassing their manufacturing, treatment, and characterization, is discussed in this study.*

Key Words: Vegetable Oil, Biodegradable Oil, Renewable Materials.

1.INTRODUCTION

A transformer is among the most essential aspects of a power network since it converts voltage and transfers energy. For almost a decade, mineral oils have been utilised as a refrigerant and insulation [1]. Even so, owing to a scarcity of mineral oil origin, the long-term manufacturing of power transformer has been fiercely disputed around the globe. It is recognized worldwide that first-engendering mineral oil, which is typically made from petrochemicals, has restricted deposits and a number of other disadvantages, including non-biodegradability (mineral oil has a biocompatibility of less than 30%).[2-4].

Hundreds of billions of litres of shielding fluids are used in liquid filled transformers. They are available in three sizes: giant, moderate, and tiny.

Oil is used in both power and distribution transformers for insulating and conditioning. The dispersion smaller groups are far more common than larger models due to the fact that dispersion is far more widely dispersed by necessity, and therefore lower units hold considerably more flow in overall than large quantities. The most prevalent transformer fluid is oil, that has been utilized for over centuries.[5]. In transformers, vegetable oils are believed to be a good substitute for mineral oil. Vegetable oils are derived organically from grains as well as blooms. Several academics and businesses are studying vegetable oils in order to use them as shielding oils in transformers and to create an emissions atmosphere [6].

This paper provides a complete overview of the processes used to produce vegetable oil, as well as experimental research on various oils, characterisation, benefits, drawbacks, and problems faced by vegetable oil.

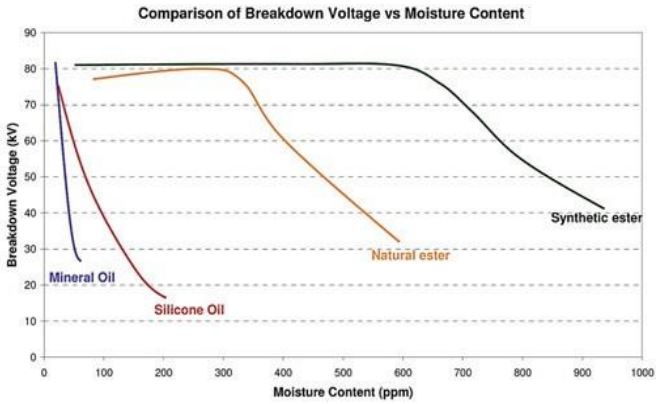

Fig -1: Breakdown voltage of impregnated cellulose

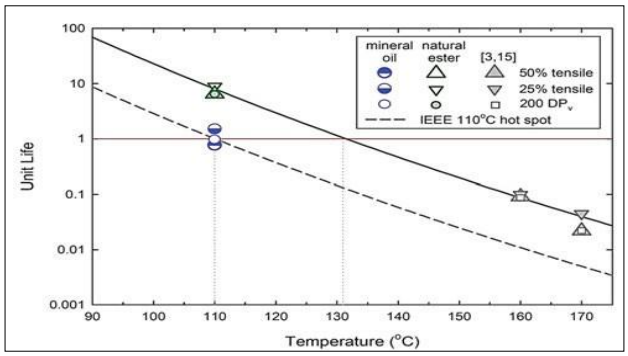

Fig-2: Comparison of unit life of transformer for oil and natural ester

1.1 Vegetable Oil as Transformer Oil

Triglycerides derived from plants are known as vegetable oils. Humankind have been using vegetable oils for ages. Vegetation oil that is fluid at ambient temperature is referred to as "vegetable oil." Triglycerides are found in vegetable oils.

While oil may be derived from a variety of plant components, economically, oil is derived largely from seeds.

Resulting from oxidative fragility, mineral oil used as transformer oil might produce hazardous chemicals.

Disposing and cleanup following equipment malfunction or spills is likewise a tough task. If a mineral oil transformer leaks or spills, it poses a significant environmental hazard.But at the other side, vegetable oil is a more environmentally friendly, recyclable, regenerative, inexpensive, widely

accessible, and secure insulating and refrigerating medium for transformers.

Table -1: Fire and flash points for various insulating fluids

Fluid type	Flash point °C	Fire point °C
Mineral oil	160 – 170	170 – 180
Silicone fluid	>300	>350
Low viscosity silicone fluid	268	312
Natural ester	>300	>350
Synthetic ester	>250	>300

Table -2 Fire classification of insulating fluids according to IEC 61100[7]

Class	Fire point	Class	Net calorific value
O	≤300°C	1	≥42 MJ/kg
K	>300°C	2	≤42 MJ/kg and ≥32 MJ/kg
L	No measurable fire point	3	<32 MJ/kg

1.2 Physical Properties

- **Viscosity**

The capacity to transmit heat through conduction is affected by the viscosity of the insulating liquid.
Greater fluidity would be predicted to lead to an increase hot spot degrees within the transformer because conduction conditioning is a significant heat disposal method in transformers.[8]

- **Point of Pouring**

The pour point refers to the temperature during which transformer oil will flow freely if the requirements are met. Pour point is a helpful metric for determining how transformer oil will function at low temperatures, especially when a transformer must be cold started at extremely low temperatures.

Vegetable oils have greater pour point than mineral oils generally in the range -15 to -25 C [9], test have revealed the successful cold start down to -30 C.

- **Operating Temperature**

The lifespan of the insulation paper is influenced by the working temperature of the transformer, which declines at rates depending on the insulation system and ambient. The findings of the practical tests show that utilizing vegetable oils instead of mineral oil allows a transfor-mer to function at a greater temperature. The heating of the transformer windings is monitored as a "hotspot" rather than an average. When examining at a processing location, a higher operating temperature equals more load on the transformer, which is an essential issue.

- **Water Absorption**

Table 3 shows the moisture absorption of various transformer liquids at room temperature, i.e. the total quantity of water content that a fluid can store without depositing free water. In all liquids, the absorption of free water rises with temperature. Natural esters oils can improve paper's thermal stability by removing more humidity from insulation system more efficiently than mineral oil, allowing for greater spot temperatures or longer equipment life.

Table -3 Water Solubility in transformer liquids

	Ester linkages	Approx water saturation at 23°C (ppm)
Mineral oil	0	55
Silicone oil	0	220
Natural ester	3	1100
Synthetic ester	4	2600

1.3 Production and Usage of Vegetable Oil

The investigators quickly realised that vegetable oils needed to be improved before they could be utilised as transformer fluid. The fluid in an enclosed transformer stays in the equipment for a long time (30–40 years when not replaced).

Some constituents of vegetable oil naturally deteriorate in a short amount of time. As the level of vividness goes from mono to tri unsaturation, the degree of un- saturation as an indicator of thermal convection becomes more unsteady.[16] Vegetable oil production is a multi-stage procedure. The first stage is to choose an appropriate oil, followed by purification to electrical grade. Ultimately, it is stabilised for the transformer's challenging environment.

2. Comparison of vegetable oil with mineral oil on the basis of performance

Mineraloil is made by distilling petroleum and then treating it with sulfuric acid at a refinery. It is used as a cooling insulating liquid in power transformers. The chemical composition determines the final properties of conventional

mineral oil. Vegetable oils, on the other hand, are a class of chemical molecules formed when an acid reacts with an alcohol. Vegetable oils are triglyceride-structured natural ester compounds made by chemically linking three fatty acids to a single molecule of glycerol. Vegetable oils are becoming more popular as a result of their benefits over mineral oils. Vegetable oils are much more environmentally friendly because of their great recyclability.

3. Advantages

The following are the advantages of using vegetable oil:-

3.1 Ecologically responsible and vulnerable area-appropriate

Vegetable oil - filled transformers have been among the most environmentally friendly options available in the market. International organizations such as the EPA (Environmental Protection Agency) and OSHA (Occupational Safety and Health Administration) do not regard the vegetable oil to be hazardous because it is manufactured from food-grade seed. It is non-toxic and recyclable, with a reuse and recycling of over 99 percent**.**

3.2 High-quality, long-term efficiency

The human health and the environment characteristics of vegetable oil is superior to that of traditional mineral oil. Because it is recyclable, spill containment methods are simple. It also has the tendency to accumulate moisture from aged paper, extending the paper's insulating life. These characteristics can extend the transformer's insulating life and allow it to withstand higher loads.

3.3 Product that is less combustible

Vegetable oil dielectric fluid is classed as a less-combustible dielectric refrigerant because of its high fire limit. As a result, fluid vegetable oil doesn't really add to an exterior fire, and the fumes are non-toxic.

3.4 Strengthening the agriculture sector

The growth of the vegetable oil sector would improve the indigenous agricultural economy of agrarian countries, particularly in rural areas, and will assist to bring down the cost of mineral oil imports.

3.5 Recyclable Fuel

Vegetable oil is a clean resource that may be made from discarded agricultural products and other feed stocks.

4. Technical issues and obstacles, as well as a research gap

(i) In terms of balancing price and quality, further investigations are needed to lower manufacturing costs, create low-cost feed stocks, and find prospective markets.

(ii) In order to improve manufacturing and consumer sentiment, sustained transformer effectiveness and endurance in a range of transformer kinds must be created.

(iii) The benefits of vegetable oil to mineral oil in terms of the environment must be promoted.

(iv)Additives for enhancing cold flow characteristics, preventing oxidation during storage, and material compatibility, among other things.

(v) An investigation of the impact of oxidized liquid on transformer durability and reliability.

- **Challenges**

The following are the key issues that hinder the usage of vegetable oil as transformer oil [1,10,11-15]:

(i) The rate of vegetable oil is influenced by the value of the feedstock.

(ii) Vegetable oil is difficult to store and handle.

(iii) Product homogeneity is determined by the supplier, feed stocks, and manufacturing techniques.

(iv) Transformer makers' approval on a separate problem.

(v) Vegetable oil must be available on a continuous basis before it can be used extensively in transformers.

The use of vegetable oil in transformers subjected to cold weather has proven a problem. The fluid might freeze at sub-zero temperatures if it didn't have any additives.

(vi)The use of vegetable oil in transformers subjected to cold weather has proven a problem. Even when depressants are added, the pour point of vegetable oils does not drop below -30C.The fluid might freeze at sub-zero degrees if it didn't have any additives.

(vii) Vegetable oil transformer units must be properly secured to prevent excess moisture from accessing the unit. Because of the possibility of air and moisture entering the sealed unit over its lifetime, an inadequate amount of antioxidants ought to be present.

5. CONCLUSIONS

Vegetable oils as transformer oil replacements have been the subject of extensive research in a number of nations. The use of vegetable oil as transformer oil has the potential to significantly minimize the global effect of mineral oils on the ecosystem. Vegetable oil fluid has been developed to meet contemporary demands for an ecologically friendly transformer fluid. Though environmental advantages are currently of considerable importance, in the future, when petroleum supplies run short, there might be severe shortages as early as the mid-twentieth century.

Fortunately, the foundation has already been set through the implementation of relevant transformer fluids.

Circuit breakers, tap shifters, wires, and capacitors are all conceivable uses for this liquid. Additional research and testing of these fluids for these purposes is required.

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