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A Literature Survey on Biodegradable Oil as Transformer Insulating

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***Abstract*—The development of a vegetable oil based fully biodegradable dielectric fluid for use in electrical equipment is described. The starting material was a high oleic vegetable oil which was further purified and stabilized. A battery of evaluation tests and performance tests were conducted which confirmed the applicability of the fluid in equipment such as distribution transformers for prolonged use. The fluid belongs to the class of less flammable liquids due to its high flash and fire points. It is considered environmentally friendly due to its very high biodegradability. It is a possible alternative to the currently used fluids such as mineral oil and silicone which have low biodegradability.**

***Keywords*-Dielectric strength, Natural ester, Sanitation process, Antioxidants, Nan particles. etc**

I. INTRODUCTION

Transformers are key components of electrical power system network. It plays a vital role in every field of power system network like electrical power generation, transmission, and distribution.1 The majority of transformers depends on liquid dielectrics as an insulating material.2 The classification of insulating liquids. It prevents internal short circuit, protects the transformer from chemical attack, prevents sludge formation and acts as a cooling agent to remove heat when the transformer is being energized.3,4 The mineral oil obtained by fractional distillation and subsequent treatment of crude oil has been used as the liquid insulation for more than 75 years.5,6 It is also used in different electrical equipment other than a transformer, which includes different types of high voltage capacitors,7 switches, circuit breakers, tap changers and bushings etc.8 The purpose of this study is to provide information about different properties of various types of environment-friendly insulating oils which shows potential as regards application in the transformer.

1.1. History of transformer insulating liquid

History of transformer insulating liquid In 1892, \General Electric" started the use of first petrol embossed oils as an insulating liquid in the transformer. Commercial production of paraffinic-based mineral oil was started in 1899. Paraffinic-based mineral oil contained large quantity wax resulting undesirable high pour point. It also produced a large amount of insoluble sludge in subzero climate condition which lowered the viscosity and thus reduces heat transfer capacity. Later on paraffinic mineral oil was replaced by naphthenic oils which kept mineral oil as fluid at very low temperature but had the disadvantage of high flammability. Polychlorinated biphenyl (PCB) was first made in 1930,10 which overcame the flammability of naphthenic oils. But in early 1970, it was determined that PCB were no longer environmentally acceptable and hence new uses and production of PCBs have been banned.

1.2 CHARACTERISTICS OF NAPHTHENIC-BASED MINERAL INSULATING OIL

The molecular structures of the main components of the naphthenic-based oils are shown in Figure 1. Important features of naphthenic-based mineral insulating oil are summarized as follows.

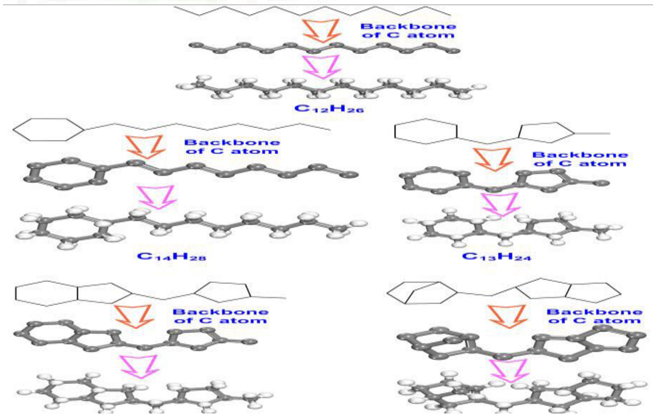

Figure 1. Main components of naphthenic mineral insulating oil

II. LITERATURE SURVEY

Muhamad, N. A., Phung, B. T., Blackburn, T. R., & Lai, K. X. (2009, September) In this work, the dielectric responsive function and the maximum conductivities of biodegradable and mineral transformer insulation oils were investigated. The experiment showed that even though biodegradable oil has a higher moisture level compared to mineral oil, this oil has a lower conductivity under all three different moisture levels. Its dielectric strength is higher than that of mineral oil. In tests at different moisture content, both oils had the highest conductivity in wet oil condition, followed by normal and lastly dried oil condition. However, in biodegradable oil, the maximum conductivity in the dried oil condition (head of the PDC curve) had almost the same value as it did in a normal condition.**[01]**

Azis, N., Jasni, J., Ab Kadir, M. Z. A., & Mohtar, M. N. (2014) Palm based oil is a good candidate as an alternative fluid for mineral oil in transformers. In term of viscosity, the performance of most of the palm based oil is comparable to other types of vegetable oils such as natural ester and synthetic ester. The acidity of palm based oil is slightly high compared to natural ester but for PFAE, the acidity is comparable to mineral oil. The oxidation stability for some of the palm based oil such as PFAE is good compared to other types of vegetable oils. However, further studies on the oxidation stability of other types of palm based oil are required in order to verify the performance. The flash point performance of palm based is not as good as natural ester and synthetic ester and requires extensive studies for further improvement.**[02]**

Jamail, N. A. M., Piah, M. A. M., & Muhamad, N. A. (2011, July) POC measurements can be used to determine the condition of H Vinsulation. P DC measurements r esults p resented suggest t hat hi gher moisture c ontents a nd 0 ther a geing condition s how h igher c onductivities 0 f both s olid and liquid insulations. This paper reviewed and does comparison results of POC conductivity for transformer, cabbie an d machine. From t he comparison results, it c oncluded th at the polarization and depolarization current results can b e used t 0 determine t he conductivity of solid and liquid insulations. The POC data are strongly influenced b y t he insulation conductivity. Higher values of polarization and depolarization currents can contribute to higher conductivity 0 f insulation.[**03**]

McShane, C. P., Rapp, K. J., Corkran, J. L., Gauger, G. A., & Luksich, J. (2001) We find that thermally upgraded Kraft paper ages considerably slower in the natural ester dielectric fluid than in mineral oil under the same thermal stress. Paper aged in the natural ester takes 5-8 times longer to reach the same end-of-life points as paper aged in mineral oil in sealed vessels at 170 C. Similar quantitative comparisons at the lower temperatures are not available, as the paper aged in the natural ester did not reach any standard end-of-life benchmarks within the 4000 hour test duration. Preliminary calculations based on these data estimate that at 110°C, the time to end-of-life should be at least 2 ½ times that of paper aged in mineral oil. We recommend that these results, along with additional data as it becomes available, be used to establish thermal aging equations and normal insulation life for thermally upgraded paper in natural ester dielectric fluids.**[04]**

Asano, R., & Page, S. A. (2013) Higher operating temperatures associated to natural-esterfluid different chemical composition and characteristics result in a different interpretation of the traditional tests used for condition assessment. For an acceptable transformer performance during factory tests and/or during the transformer lifetime, both mineral oils and natural ester fluids need to meet and maintain certain characteristics. Properties that directly impact the performance of the transformer should then remain stable over time and therefore be addressed in the design of the apparatus and monitored during the transformer lifetime to identify deviations and subsequently apply corrective actions..**[05]**

III. PROPERTIES OF MINERAL INSULATING OIL

3.1 Mineral Insulating Oil

In a mineral oil-immersed transformer, the insulation system of the transformer consists of mineral insulating oil and insulating paper. In normal operation of such a transformer, the oil-paper insulation system can be influenced by factors such as the electric field, thermal field, and force field. The physicochemical properties of the oil-paper insulation system gradually deteriorate over time. Therefore, these parameters can directly reflect the electrical properties of mineral insulating oil, such as the breakdown strength, dielectric constant, and conductivity. The changes of the above parameters of mineral insulating oil during operation of the transformer are analyzed in this section.

Mineral transformer oil				
Mineral based oil				
Property	**Value in metric unit**		**Value in US unit**	
Density at 60°F (15.6°C)	0.880 *10³	kg/m³	54.9	lb/ft³
Kinematic viscosity at 68°F (20°C)	22	cSt	22	cSt
Kinematic viscosity at 212°F (100°C)	2.6	cSt	2.6	cSt
Fire point	170	ºC	338	ºF
Pour Point	-50	ºC	-58	ºF
Flash point	160	ºC	320	ºF
Autoignition point	280	ºC	536	ºF
Specific heat	1860	J/(kg*	0.444	BTU/(lb*ºF)

capacity		K)		
Thermal conductivity at 20ºC (68ºF)	0.126	W/(m* K)	0.875	BTU*in/(hr* ft^2*ºF)
Thermal expansion at 20ºC (68ºF)	7.5*10^{-4}	ºC^{-1}	4.2 *10^{-4}	in/(in* ºF)
Breakdown strength	min.70	kV	min.70	kV
Dielectric dissipation factor at 90ºC (194ºF)	max. 0.002		max.0.002	
Permitivity at 20ºC (68ºF)	2.2		2.2	

3.2 BREAKDOWN VOLTAGE OF MINERAL INSULATING OIL

The electrical properties and thermal stability of insulating materials are closely correlated, and the electrical properties will deteriorate as the thermal stability of the insulating material decreases. Therefore, it is necessary to study the thermal stability of oil-paper insulation when researching its breakdown voltage. Moisture and temperature both strongly influence the aging process of the oil-paper insulation of transformers. Moisture severely affects the electrical properties of oil-paper insulation, accelerating its aging and shortening its service life [18–20]. For years, a large number of scholars have investigated the formation pathway of water in transformers and its influence on transformer performance. There are basically three states of moisture in insulating liquids, which are the dissolved state, emulsified state, and dispersed state. The moisture content in insulating oil can largely influence the electrical properties, that is, increase the electrical conductivity and dissipation factor and lower the electric strength of transformer oil [21].

3.2 Effect of Nanoparticles on the Breakdown Voltage of Mineral Insulating Oil

The decrease of the breakdown voltage is one of the most prominent problems during the aging of mineral insulating oil. Dariusz and Aksamit [66,67] modified new and aged mineral insulating oil with fullerene (C60) (Figure 6), and then measured the breakdown voltage of the modified mineral insulating oil samples. They found that the dielectric loss of the modified oil was lower, and its breakdown voltage remained higher during the aging process.

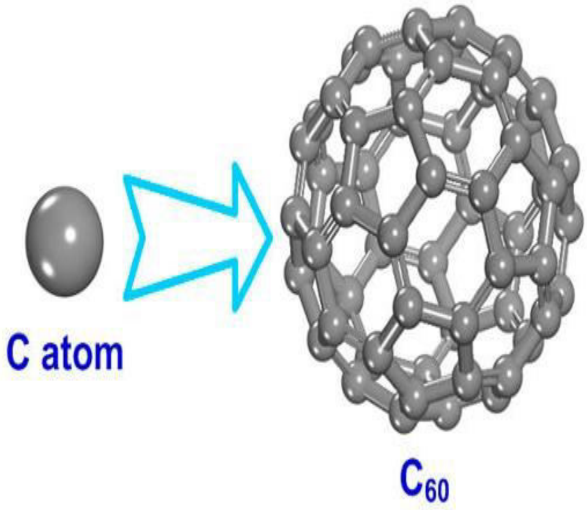

Figure 6. Molecular structure of fullerene (C60)

IV. PRODUCTION OF VEGETABLE TRANSFORMER OIL

In As for the production, the vegetable dielectric coolants can be broadly divided into two:

a. Synthetic Esters

Synthetic ester dielectric fluids, most commonly ploy (pentaerythitol) esters, have suitable dielectric properties [5, 9] and are significantly more biodegradable than mineral oil or HMWHs. Their high cost compared to other less-flammable fluids generally limits their use to traction and mobile transformers, and other specialty applications. Synthetic ester fluids have been used as a PCB substitute in compact railroad traction transformers since 1984 and in klystron modulators where their relatively low viscosity, high lubricity, and very low pour point properties justify the higher cost. Failure rates of traction transformers significantly decreased since replacing the scares with synthetic poly esters. The next is those available freely in nature and needs only some refining before application.

b. Natural Esters

Seed oil esters have been considered unsuitable for use in transformers, although past applications of rapeseed oil in capacitor applications hinted at considerable potential. Their susceptibility to oxidation has been a primary obstacle to utilization as a dielectric fluid. However, modern transformer design practices, along with suitable fluid additives and minor design modifications, compensate for this characteristic [10]. The application of natural esters in transformers can achieve a balance of desirable transformer and external environmental properties not found in other dielectric fluids. Attractive sources of natural esters are edible seed-based oils. Used mainly in foodstuffs, these agricultural commodity oils.

V. CONCLUSION

The main aim of this paper was to describe the step-by-step development of an alternative electro-insulating liquid based on natural esters grown in Central Europe. The oxidative stability and long-term AC voltage exposure were the criteria parameters for rapeseed oil selection in comparison with sunflower oil which was also pre-tested. Rapeseed oil contains a high number of saturated fatty acids which make the oil oxidation stable and thus usable in long-term applications. The original rapeseed oil had to be modified to meet the standards given by IEC 62770:2013. The percolation device was constructed. The acid number was significantly lowered by the oil treatment and acid number met the criteria given by IEC 62770:2013. The treated oil was also inhibited by the addition of DBPC in a concentration of 0.5 wt %. The modified rapeseed oil is ready for direct use in harmonized distribution transformers and it is protected by utility model number CZ 29982 with name ENVITRAFOL.

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