

Biodegradable vegetable oil as an alternative insulation for transformers

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In high-voltage transformers, liquid insulation serves as both an insulator and a cooling agent. For many decades, transformer oil has been the traditional choice for this purpose. Despite its high quality insulating properties, mineral oil poses several environmental drawbacks. Researchers are exploring alternative insulating fluids for high-voltage applications, considering both environmental impact and insulating properties. With the increasing demands for better electro, physical and chemical properties of vegetable insulating oils used in high-voltage power transformers, enhancing these oils with nanoparticles has become a prominent area of research. The present study investigates groundnut oil (GO) and mustard oil (MO) as base fluids for insulation oil by incorporating zinc oxide (ZnO) nanoparticles. It analyses the effect of varying concentrations of ZnO nanoparticles on the electro-physical and chemical properties of the oils. The analysis reveals several significant enhancements in the properties of the oils when incorporated with ZnO nanoparticles. The result shows that the enhancement of the dielectric strength of the oil can withstand electrical stress without breaking down. Further, the impulse breakdown voltage, which evaluates the oil's ability to withstand high-voltage pulses, has significantly improved. The study observed a decrease in dissipation factors, representing reduced energy losses as heat within the oil, and a decrease in viscosities at high temperatures, implying improved fluidity and efficiency in high-temperature conditions. The interfacial tension improves, indicating better interfacial tension between the oil and water molecules. The findings suggest that vegetable oil-based nanofluids, with finer characteristics, have a high potential to replace traditional mineral oils.

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of the transformers. These liquid dielectrics minimize the sludge, internal short circuits and chemical contamination and function as coolants^{1,2}. Petroleum-based mineral oil has been used as a coolant in liquid-filled transformers for more than a century to guarantee the transformer's safe operation³. It has been widely used as the primary insulating medium in high-voltage equipment, such as transformers, cables, capacitors, circuit breakers, bushings, etc. due to its high mechanical strength and excellent dielectric properties⁴. For transformer insulation, it is crucial to find alternative insulating oils due to the drawbacks of this mineral oil, notably low moisture saturation, low fire and flash points, and non-biodegradability⁵. Vegetable oils (VOs) are biodegradable oils used as an alternative to mineral oil in transformer insulation. Vegetable or natural ester oils are obtained from biodegradable sources such as sunflower, rapeseed, coconut, palm oil, and so on^{6,7}. BIOTEMP was the first commercially available vegetable insulating fluid, patented by ABB, Inc. in the United States in September 1999. This vegetable fluid was primarily composed of oleic oil and is employed in distribution transformers. Waverly Light and Power in Iowa received another patent in 1999 for developing a transformer fluid based on soyabean oil⁷. Cooper Industries, Inc. of Milwaukee developed another vegetable-based transformer insulating fluid in 2000 known as Envirotemp FR3, which was created by combining various standard-grade oleic oils⁸.

Vegetable oils are subject to oxidation due to the high saturated fatty acid content, which impacts their physical, chemical and dielectric properties of transformer insulation. However, the characteristics such as viscosity, power, dissipation and cost are poor compared to mineral oil⁹. Therefore, it is necessary to enhance the VO's insulating qualities. The advantages of vegetable oils as transformer