



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS**

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SHORT ABSTRACT

This thesis presents the condition assessment of transformers filled with alternative dielectric fluids such as natural ester oil (NEO) and its nanofluids (NFs) by evaluating the oil properties. It also presents the development of a NEO modified with nanoparticles (NPs) with enhanced physicochemical, thermal and electrical performance for transformer application. The dissolved gas analysis (DGA) is performed to monitor the emission pattern of gases when the oil is subjected to thermal stress in a sealed beaker setup at 150°C. The classic Duval triangle, Dornenburg ratio, Rogers ratio and IEC method are applied to ascertain the type of incipient faults. The total dissolved combustible gases (TDCG) of the oils are done to examine the composition of combustible gases. To study of the ageing characteristics of the NEO, the frequency domain spectroscopy (FDS) is performed to obtain the dielectric parameters over a wide range of frequencies. The oil is subjected to thermal stress in an open beaker ageing test setup at 115°C for up to 500 hours, and samples are taken out at intervals of 100 hours for testing. A statistical model is developed to relate frequency, ageing duration and dielectric parameters based on the FDS results. The temperature dependence on the FDS characteristics of the dielectric liquids is also studied by considering semi-conductive titanium oxide (TiO₂) NP dispersed in the base fluids, in the frequency range of 10⁻³ to 10⁴ Hz and the temperature range from 30 to 90°C. The Cole-Cole double relaxation model is used to ascertain the number of relaxations in the samples. It is observed that the conductivity increases with increase in temperature for all the oil samples. A predictive analysis model is proposed using machine learning (ML) algorithms to predict the dielectric properties based on FDS. To understand the breakdown probability of the fresh and aged NEO and NEO-NFs, statistical analysis is carried

out on the AC breakdown voltage (ACBDV) data. The ACBDV tests are performed for all the samples and a comparative examination is done among them to estimate the behaviour of the new and aged oils. To understand the statistical behaviour of the ACBDV of the oil samples, normal, 2-parameter Weibull and 3-parameter Weibull distributions are considered and hypothesis testing with Shapiro-Wilk test and Anderson-Darling test is carried out. The goodness of fit using the correlation coefficient shows that all the 4 oil datasets follow a 3-parameter Weibull distribution quite well. As NEOs are being advocated for usage in transformer applications, a new NEO is developed in this work known as the Pongamia pinnata oil (PPO). The crude PPO is modified by the transesterification process and converted to pongamia oil methyl ester (POME) as the crude oil is not suitable for direct use because of its high viscosity, high pour point and acid number. To enhance the properties further, an insulating hexagonal boron nitride (h-BN) NP is used. The bulk h-BN NP of size 1 μm is exfoliated into 2-D nanosheets of size 50-100 nm subsequently to enhance the surface area of exfoliated h-BN (Eh-BN), which is then dispersed in the base fluid. The various thermophysical and electrical properties of NFs are also studied. The results of the POME are also compared with two more NEOs, one is the FR3 and the other is JAT and it is observed that the POME shows comparable results and thus may be used as a potential substitute to MO for transformer application.