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Improving the Dielectric Strength of Transformer Oil for High Health Index: An FEM Based Approach Using Nanofluids

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Abstract : As the world is moving towards extra-high voltage (EHV) and ultra-high voltage (UHV) power systems, the performance requirements of power transformers are becoming crucial to the system reliability and security. With the transformers being an essential component of a power system, low health index of transformers poses greater risks for safe and reliable operation. Therefore, to meet the rising demands of the power system and transformer performance, researchers are being prompted to provide solutions for enhanced thermal and electrical properties of transformers. This paper proposes an approach to improve the health index of a transformer by using nano-technology in conjunction with bio-degradable oils. Vegetable oils can serve as potential dielectric fluid alternatives to the conventional mineral oils, owing to their numerous inherent benefits; namely, higher fire and flashpoints, and being environment-friendly in nature. Moreover, the addition of nanoparticles in the dielectric fluid further serves to improve the dielectric strength of the insulation medium. In this research, using the finite element method (FEM) in COMSOL Multiphysics environment, and a 2D space dimension, three different oil samples have been modelled, and the electric field distribution is computed for each sample at various electric potentials, i.e., 90 kV, 100 kV, 150 kV, and 200 kV. Furthermore, each sample has been modified with the addition of nanoparticles of different radii (50 nm and 100 nm) and at different interparticle distance (5 mm and 10 mm), considering an instant of time. The nanoparticles used are non-conductive and have been modelled as alumina (Al_2O_3). The geometry has been modelled according to IEC standard 60897, with a standard electrode gap distance of 25 mm. For an input supply voltage of 100 kV, the maximum electric field stresses obtained for the samples of synthetic vegetable oil, olive oil, and mineral oil are 5.08×10^6 V/m, 5.11×10^6 V/m and 5.62×10^6 V/m, respectively. It is observed that for the unmodified samples, vegetable oils have a greater dielectric strength as compared to the conventionally used mineral oils because of their higher flash points and higher values of relative permittivity. Also, for the modified samples, the addition of nanoparticles inhibits the streamer propagation inside the dielectric medium and hence, serves to improve the dielectric properties of the medium.

Keywords : dielectric strength, finite element method, health index, nanotechnology, streamer propagation
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