THE DC AND AC INSULATING PROPERTIES OF MAGNETIC FLUIDS BASED ON TRANSFORMER OIL

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Magnetic fluids have been shown to provide both thermal and dielectric benefits to the power transformers. They can improve the cooling by enhancing the fluid circulation within transformer windings, as well as they can increase the transformer capacity to withstand lightning impulses [1]-[2], while also minimizing the efect of moisture on typical insulating fluids. The benefits of magnetic fluids may be utilized to design smaller, more effcient new transformers, or to extend the life or loading capability of existing units.
Since magnetic fluid experiences a magnetically driven flow unlike oil, the results of effcient heat removal with such fluid could be expected. However, the results showing the increased dielectric strength of magnetic fluid, compared with pure transformer oil, are surprising.
The presence of foreign particles has a profound effect on the dielectric breakdown strength of liquid insulators. Polarizable magnetic (e.g. magnetite Fe_3O_4) particles, which are of higher permittivity than the surrounding liquid, experience an electrical force directed towards the place of maximum stress. With uniform field electrodes the movement of particles is presumed to be initiated by the surface irregularities on the electrodes, which give rise to local field gradients. The accumulation of particles continues and tends to form a bridge across the gap, which leads to the initiation of the breakdown. The aggregation of magnetic particles in external magnetic field produced by the transformer windings influences the dielectric breakdown strength of a transformer oil based magnetic fluid.
However, Segal et al. [2] found out, that the presence of magnetic particles in transformer oil improved its dielectric properties by increasing the DC impulse breakdown voltage from 78 to 108 kV. In recent time the DC dielectric breakdown strength of transformer oil-based magnetic fluids was studied [3]. Now the motivation was to investigate the AC dielectric breakdown in magnetic fluids and to compare it with the previous observations.
Magnetic fluid used in experiments consisted of magnetite particles (mean magnetic diameter D_m=8.6 nm), surfacted by oleic acid, dispersed in transformer oil TECHNOL US 4000 (ε_r = 2.15). The volume concentration of magnetic particles was Φ=0.0025. The dielectric breakdown strength was measured by properly shaped electrodes of a uniform gap of electric field-Rogowski profile [4]. Two permanent NdFeB magnets produced the external magnetic field up to 50 mT, approximately uniform in the measured gap of electric field. The time development of the breakdown was measured with help of an inductive probe and a programmable oscilloscope with its own memory.
The development of the AC dielectric breakdown in magnetic fluid was compared with the development of the DC dielectric breakdovn. In the case of the DC dielectric breakdown the onset of measurable ionisation leads to complete breakdown of the gap. In the case of the AC dielectric breakdown various manifestations of luminous and audible discharges were observed long before the complete breakdown occurred.
The AC dielectric breakdown strength of magnetic fluid as a function of the distance between the electrodes in uniform electric gap was investigated for different values of magnetic field oriented parallel and perpendicular to the electric field. The comparison with the AC dielectric breakdown strength of pure transformer oil confirmed better dielectric properties of magnetic fluid in external magnetic field (Fig.1).

The measured DC nad AC dielectric breakdown strengths without magnetic field, compared with the DC and AC dielectric breakdown strengths of pure oil showed, that the the DC dielectric breakdown strength is higher than that of pure transformer oil and the AC breakdown strength remains comparable, but not worse (Fig.2).
Regarding to the better heat transfer, provided by magnetic fluids, their application in power transformers may lead to the improvement of the operation of these devices.

References:

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Figures:

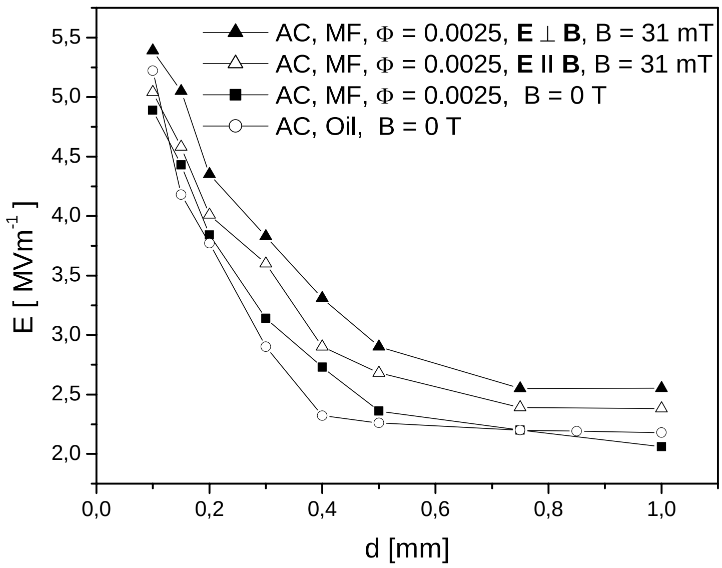

Figure 1: The AC dielectric breakdown strength vs. distance between the electrodes for magnetic fluid (Φ = 0,0025, Is = 1 mT) in B = 0, B‖E and B⊥E.

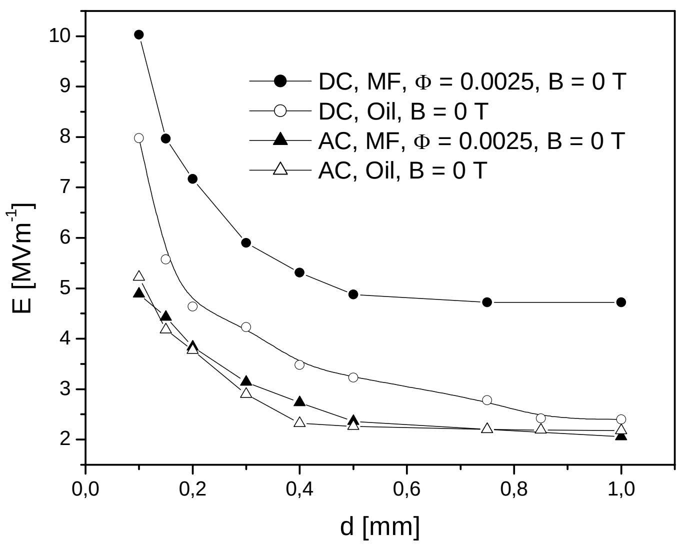

Figure 2: The DC and AC dielectric breakdown strengths vs. ditance between electrodes for magnetic fluid (Φ = 0,0025, Is = 1 mT) and pure transformer oil.