Modelling the Streamer Process in Liquid Dielectrics

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For many applications, liquid dielectrics are superior to solid or gaseous electrical insulation materials. Advantages of liquids include higher breakdown strength compared to compressed gases. When compared with solid dielectrics, their ability to circulate leads to better thermal management and easier removal of debris after breakdown. Liquid dielectrics are also better suited to applications involving complex geometries. Thus the electrical behaviour of dielectric liquids subjected to high electric fields has been intensively studied [1]. The interest arises from various applications that include pulsed power systems, energy storage, highvoltage insulation, development of acoustic devices and spark erosion machines.

Electrical breakdown of dielectric liquids is a very complex process that involves a succession of inter-correlated phenomena (electronic, mechanical, thermal, etc.). Moreover, experiments have shown that characteristic features of prebreakdown and breakdown phenomena greatly depend on experimental conditions (electrode geometry, shape and duration of applied voltage, liquid nature and purity, etc.). Rather than attempt to treat all phenomena associated with breakdown, it has been decided for the sake of clarity and brevity to restrict discussion in this paper to streamer processes occurring in mineral transformer oil.

Current research at the University of Southampton is mainly devoted to modelling the physical mechanism occurring within a needle-plane electrode geometry separated by mineral transformer oil, where breakdown is the result of the initiation and propagation streamer process. In previous research concerning gas discharge mechanisms, the implementation of the electro-hydrodynamic model has been validated in describing the streamer process [2]. Based on the treatment of liquid dielectrics as a dense fluid, the drift-diffusion equations of positive ions, negative ions and electrons are solved coupled with Poisson’s equation in this work. The finite element method based commercial software Comsol Multiphisics is used for numerical calculations. The streamer process simulation is modelled as a response to a negative pulsed voltage applied to the negative needle electrode. Estimations of the main features of the simulated streamers (such as field strength distribution, charge density, etc.) have been obtained and compared to experimental data published by other researchers [3]. The secondary process as a result of positive ion impact on the cathode is also discussed.

[1] A. Beroual, M. Zahn, A. Badent, et. al., “Propagation and Structure of Streamers in Liquid Dielectrics”, *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 14, no. 2, pp.6-17, 1998

[2] T. N. Tran, “Surface Discharge Dynamics: Theory, Experiment and Simulation”, *PhD Dissertation, University of Southampton,* 2010

[3] J. Devins, S. Rzad, and R. Schwabe, “Breakdown and Prebreakdown Phenomena in Liquids”, *Journal of Applied Physics,* vol. 52, no. 7, pp.4531-4545, 1981