COMSOL CONFERENCE
2015 KUALA LUMPUR

Modeling Of Degradation Mechanism At The Oil-Pressboard Interface Due To Surface Discharge

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Abstract

Surface discharge at the oil-pressboard interface has been classified as the most dangerous fault condition in power transformer because it results in catastrophic failure under normal operating conditions [1] and difficult to be detected [2]. Experimental works [3, 4] have shown that this failure mode that occurs at the oil pressboard interface results in creeping path (tracking) in the form of white marks and carbonisation of the oil and cellulose from the discharge source towards the earth electrode as shown in Figure 1. The formation of these degradation features are believed due to the drying out of the pressboard (forcing oil and water out of the pressboard pores). White and carbonised marks are conducting paths that can cause relatively small currents to flow bridging the high voltage and earth electrodes. The currents are insufficient to trip the protection system and can sometimes be visible in the form of full-gap discharges of arcing [5]. The degradation process can continue from minutes to months or even years under normal AC voltage operation until the creeping conductive path becomes an essential part of a powerful arc [6].

In order to understand the physical features of degradation on the pressboard surface as a result of surface discharge activity at the oil-pressboard, a model is developed using COMSOL Multiphysics on a 2-D axial symmetry plane. The model geometry has three media, i.e. the bulk oil region, transition region and bulk oil/pressboard region. In this work, three charge carriers, i.e. positive and negative ions and electrons are considered using charge transport equations to model the discharge streamer. These equations are coupled with the electrostatics and heat transfer equations to simulate the electric field distribution during the streamer propagation and to investigate the drying mechanism at the oil-pressboard interface respectively.

The simulation results provide a reasonable argument behind the formation of white and carbonised marks during the surface discharge experiment as a result of drying out process. Figure 2 shows the variation of temperature at the hottest spot on the pressboard surface. The result indicates that streamer branch on the pressboard surface causes significant increase in the temperature at that particular spot. The temperature increases beyond the temperature that may cause carbonisation of cellulose through dehydration and pyrolysis processes (less than 500 K) [7]. On the other hand, the cumulative energy density as a result of electrical power dissipation from the generated charges is illustrated in Figure 3. Correlation between Figure 2 and 3 suggests that the significant growth of energy dissipation causes the temperature to increase substantially to a certain magnitude. The moment when the energy increases steadily, the temperature starts to decrease gradually.

This work has confirmed the hypotheses about the localised nature observed in the experiment of surface discharge at the oil-pressboard interface, the development of white and carbonised marks on the pressboard surface. The simulation results have associated both degradation marks on pressboard

surface with high energy of long periods of partial discharge event that leads to thermal degradation at the oil-pressboard interface.

Reference

[1] V. Sokolov et al., "Effective methods of assessment of insulation system conditions in power transformers: a view based on practical experience," in Proceedings of the Electrical Insulation Conference and Electrical Manufacturing & Coil Winding Conference, Cincinnati, Ohio, USA, 1999, pp. 659-667.

[2] CIGRE Working Group 12.18: Life Management of Transformers, "Guidelines for life management techniques for power transformers," Draft Final Report Rev. 2, 22 June 2002.

[3] H. Zainuddin et al., “Investigation on the surface discharge phenomenon at the oil-pressboard interface,” in 17th IEEE International Conference on Dielectric Liquids, Trondheim, Norway, 26-30 June 2011.

[4] H. Zainuddin et al., “Partial discharge characteristics of surface tracking on oil-impregnated pressboard under AC voltages,” in IEEE 2013 International Conference on Solid Dielectrics, Bologna, Italy, 30 June - 4 July 2013, pp. 1016-1019.

[5] H. Zainuddin et al., “Characteristics of leakage current during surface disharge at the oil-pressboard interface,” in 2012 IEEE Conference on Electrical Insulation and Dielectric Phenomena, Montreal, Canada, 14-17 October 2012, pp. 483-486.

[6] A. K. Lokhanin et al., "Internal insulation failure mechanisms of HV equipment under service conditions," in CIGRE Report 15-201, 2002.

[7] D. F. Arseneau, "Competitive reactions in the thermal decomposition of cellulose," Canadian Journal of Chemistry, vol. 49, pp. 632-638, 1971.

Figures used in the abstract

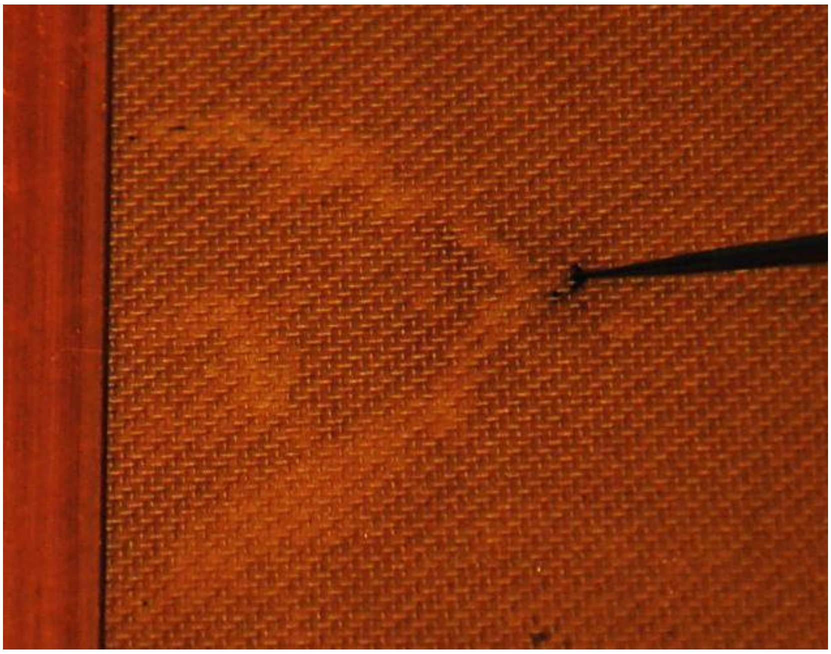

Figure 1: Pressboard surface with white and carbonised marks due to surface discharge experiment

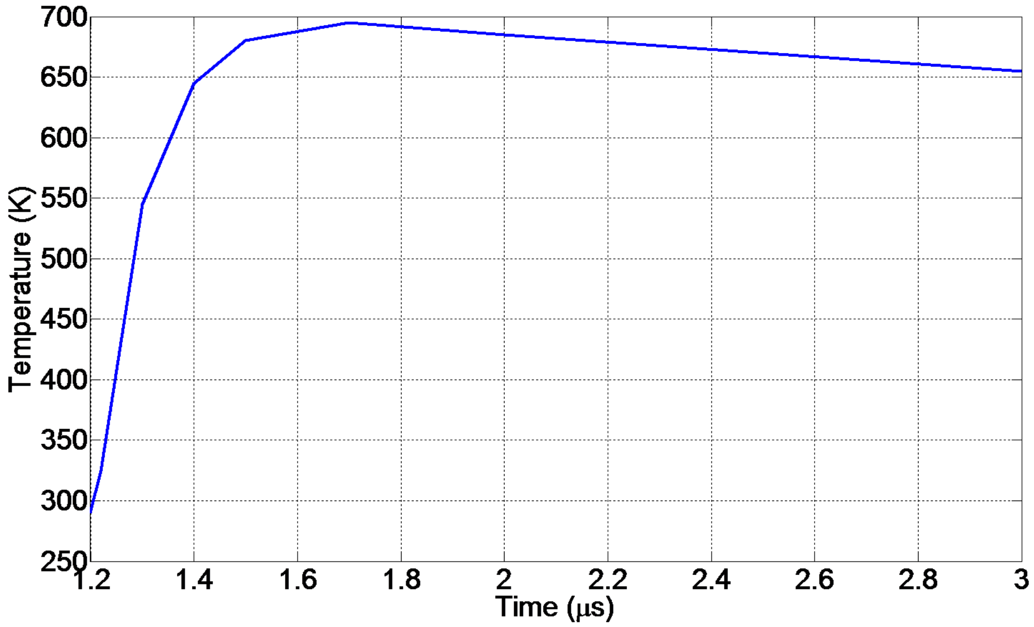

Figure 2: Simulated temperature variation at the hottest spot on pressboard surface

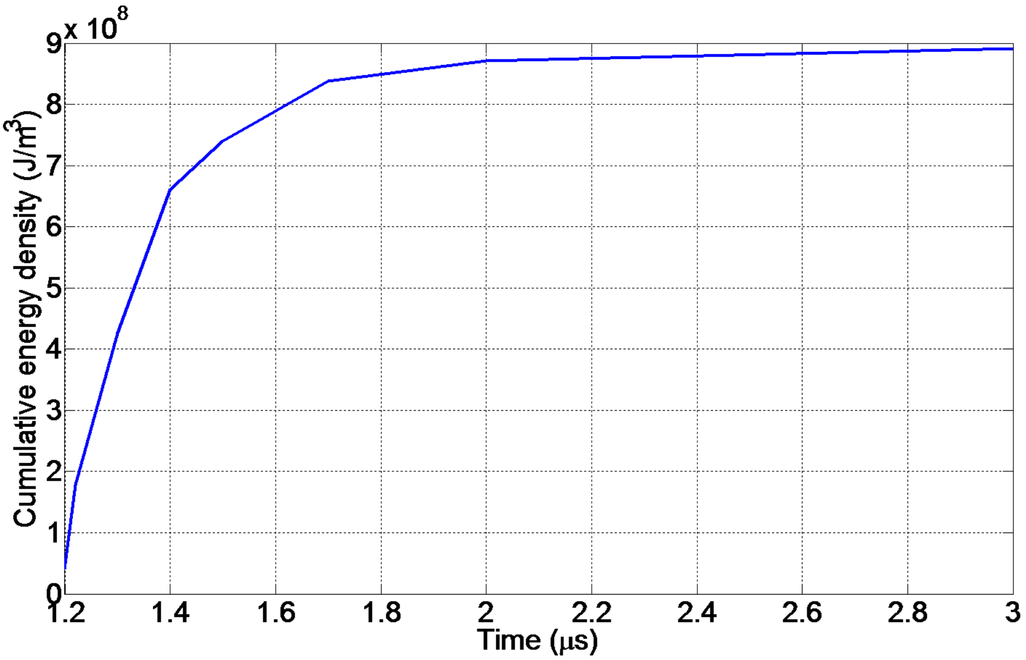

Figure 3: Cumulative energy density at the hottest spot on pressboard surface