Voltage Distribution In Metalized Film Cylindrical Capacitors

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Abstract

We narrow the consideration to HV cylindrical parts, typically with axial leads located on the opposite sides. They are tens of millimeters long, so at moderate frequencies of up to 10MHz they may be analyzed as lumped elements (not as transmission lines), although in some cases they may be regarded as Large HV Structures per definition of [3]. Voltage and current distribution (VCD) in metalized film capacitors was analyzed in an electrostatic approximation, namely using Electric Current interface, accounting for both conduction and displacement currents. First, a new analytical solution for VCD in capacitors with two highly resistive plates was derived. (Such a structure is a subset of metallized roll forming the actual capacitor.) It was compared to numerical solutions, both in field and circuit formulations, the latter using equivalent circuits; analytical and FEA solutions were a perfect match. Notably, the effective capacitance defined by the energy storage capability perspective decreases at higher frequencies, and the capacitance drop is more prominent at high metallization resistivity and large capacitance. The underlying mechanism is a significant voltage drop on the capacitor plates. Next, multisectioned parts with linear and nonlinear dielectric (biaxially oriented Polypropylene - BOPP) were analyzed on a COMSOL platform. The analysis showed that if the capacitor body sees temperature gradients the dielectric conductivity varies by orders of magnitude. Thus, voltage sharing between the capacitor sections may be compromised at dc voltage. The degree of nonuniformity stays uncertain in view of large uncertainty of all solid and liquid dielectrics conductivity dependence on the field and temperature, including BOPP. Yet, Multiphysics simulations do help with this difficult topic that is an inherent part of HV insulation design.

Reference

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[2] C. Yi, B. Zhang, C. Li, Q. Li, J. Hu and J. He, "Calculation of Current Distribution Inside the Metallized Film Capacitor Element at High Frequency," in IEEE Transactions on Dielectrics and Electrical Insulation, vol. 32, no. 1, pp. 127-135, Feb. 2025.
[3] Pokryvailo, A., ““Large” HV Structures: Transient Analysis of Voltage Distribution from First Principles”, Proc. 2018 IEEE Power Modulator and High Voltage Conference, Jackson Lake Lodge WY, 03 June 2018 - 07 June 2018, pp 306-311.
[4] G. I. Skanavi, Physics of Dielectrics, Region of Strong Fields, Moscow, GIFML, 1958, p. 258 (in Russian).
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Figures used in the abstract

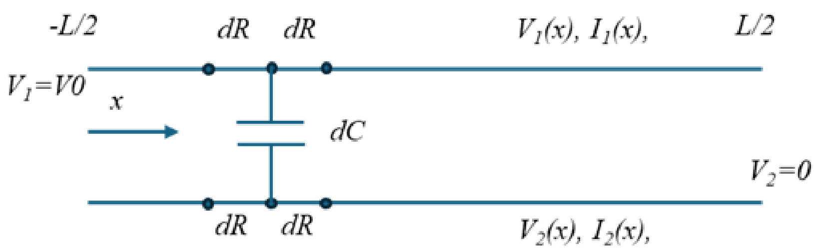

Figure 1 : To derivation of differential equations for two-plate capacitor. Note that currents I_1, I_2 flow in the same direction.

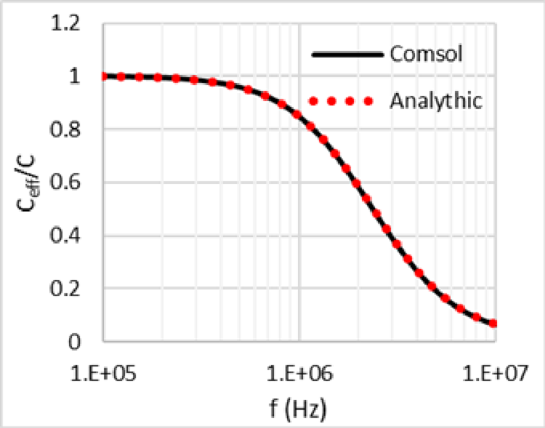

Figure 2 : Capacitance decrease with higher frequency.

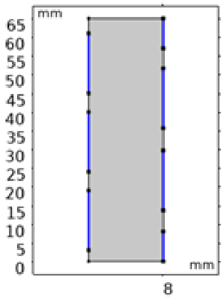

Figure 3 : A model of 6-section metalized film. Blue are the metallization plates (Top right point is at V0, bottom right point is gnd. dfilm=10um, not to scale).

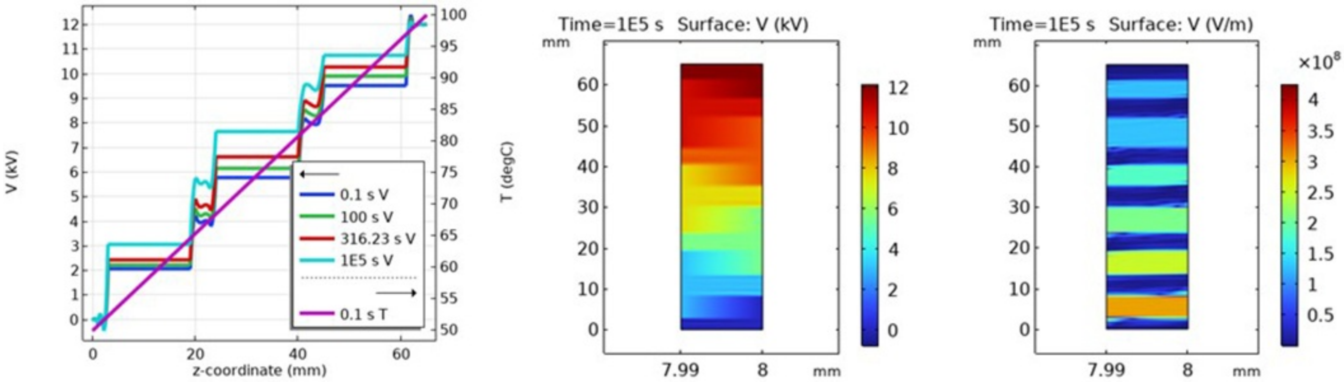

Figure 4 : Voltage and field distributions along the sections with temperature linearly increasing along a 6-section capacitor.