Nonstandard High Voltage Electric Insulation Models

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Abstract

Introduction: Calculation of electric fields for designing high voltage (HV) insulation devices is believed to be state of the art. Usually parts of the Maxwell equations are solved for materials characterized by electric permittivity and resistivity. In some cases, these material properties depend on the electric field leading to nonlinearities. Sometimes heat transfer or further physical processes, like mechanics, must be included. Often, it is rather difficult to solve such multi-physics problems, particularly in realistic 3-dimensional geometries. However, the fundamental electrical model equations are generally known and are implemented almost ready-for-use in commercial simulation tools. One might thus come to the wrong conclusion that there is only limited challenge in physical modeling for electric insulation design. Use of COMSOL: Nevertheless, there still exists a set of important questions, where the appropriate fundamental model must be developed and mathematically formulated before simulation activities can start. Not always but often, the involved physics is related to boundary conditions. In any case, such nonstandard problems require that an appropriate simulation tool has a large flexibility in defining model equations, i.e., allows to define arbitrary types of degrees of freedoms, couplings between them, nonlinearities, and operations on variables. By using COMSOL, we discuss two such nonstandard problems, 1) dielectric withstand and 2) space charge injection, which are very important for R&D on modern HV insulation. Results: 1) In fact, the determination of dielectric withstand is the main reason for performing electric field calculations. An appropriate breakdown criterion must go beyond just prescribing a limiting field value. It consists of a sequence of nontrivial conditions associated with the formation and propagation of an electric spark, which finally has to bridge an electrode gap. We discuss, how one can model and simulate this with COMSOL, and determine the dielectric withstand voltage [1]. 2) In very high fields, particularly at direct current (DC) voltages, the electric fields can be strongly distorted by space charges, which are created at electrodes with electric field enhancements. The appearance of space charge depends on the contact physics, which must be modeled by appropriate boundary conditions. We show how unipolar space charge formation can be modeled and simulated with COMSOL, and how surface charging and self-focusing of the current results [2]. Conclusion: We re-emphasize the importance of a modeling flexibility of simulation tools for R&D. It allows to incorporate previously disregarded physical phenomena with nonstandard mathematical models. This is crucial whenever old technologies reach physical limits (which is, in HV engineering, due to the continuous trend of increasing voltage levels and decreasing size of devices), and/or when new technologies emerge (which is, e.g., due to the current technology-shift from alternating current (AC) to DC).

Reference

[1] T. Christen, Streamer Inception and Propagation from Electric Field Simulations, Conference on Scientific Computing in Electrical Engineering, SCEE 2012, Sept. 11-14, Zürich, Switzerland.
[2] T. Christen, FEM Simulation of Space Charge, Interface and Surface Charge Formation in Insulating Media, 15 Int. Symp. On HV engineering, 2007, Aug. 27-31, Ljubljana.