MULTISCALE MODELING OF PARTIAL DISCHARGES AND ELECTRICAL TREEING

BEATRICE CRIPPA, ANNA SCOTTI, AND ANDREA VILLA

Abstract. Electric power is a key component of the energetic system, and one of the main causes of ageing and deterioration of solid insulating components in the electric cables consists in Partial Discharges (PD). They are caused by the effect of high electrical fields acting on dielectric domains for a long time, leading to the formation of gas-filled fractures, in which charged particles are free to move and generate an internal electric field that contributes to the increase of the external one. This process gives rise to the Electrical Treeing, a self-propagating internal defect due to the interaction of PDs and the polymeric surface, that can be fully described by a coupled system of Partial Differential Equations (PDEs) [1]. The key aspects of this problem take into account the movement of charges in the gas-filled fracture and the evolution of the electric field and potential in both materials. The main drawback in this framework is the computational time needed for the numerical simulation of the problem, due to both the strong coupling among PDEs and the geometric complexity of the gas domain. Indeed, the crack produced by the Electrical Treeing consists of a ramification with very small diameter, compared to its length and the size of the dielectric domain, implying the need for a very fine mesh around and inside the defect for the 3D discretization. We can model this phenomenon as a coupled hybrid-dimensional 3D-1D problem, where the movement of charges in the gas is described by a system of one-dimensional diffusion-transport and pure transport equations, coupled with Maxwell's equation for electrostatics in both domains. This approach leads to a simpler geometry with much less degrees of freedom. Reducing the gas domain to a line is equivalent to considering a one-dimensional charge distribution, which produces a non-negligibile radial component of the electric fields. The correct treatment of this component when passing to the limit, together with the branched structure of the 1D domain, which allows the presence of bifurcations, were the main challenges in our work. We have derived the reduced-dimensional formulation of the presented problems and developed numerical schemes for their solution, based on Finite Volumes in 1D and mixed Finite Elements in 3D, in order to improve the performance of the numerical simulation of this physical phenomenon.

Keywords: mixed-dimensions, 3d-1d coupling, multiscale, electrical treeing **Mathematics Subject Classifications (2010)**: 65M08,65M60

References

[1] A. Villa, L. Barbieri, M. Gondola, A. R. Leon-Garzon and R. Malgesini A PDE-based partial discharge simulator *Journal of Computational Physics*, 345: 687-705, 2017.

MOX, Department of Mathematics, Politecnico di Milano, Italy
Email address: beatrice.crippa@polimi.it

MOX, Department of Mathematics, Politecnico di Milano, Italy
Email address: anna.scotti@polimi.it

Ricerca Sul Sistema Energetico (RSE), Italy
Email address: villa.andrea@rse-web.it