Easy Evaluation of Streamer Discharge Criteria

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Abstract

In recent development of efficient power transmission systems two important trends influencing the engineering efforts are: (i) The steadily increasing voltage levels introduced to reduce resistive losses and (ii) Compacting, i.e. trying to make the equipment as small as possible. From an insulation point of view, however, these two requirements are conflicting in the sense that making clearance distances between conductors at different voltage levels smaller, while at the same time also increasing these voltage differences, obviously makes the occurrence of electric discharges and flashovers more probable. Avoiding this to happen clearly requires a very thorough design work; critical areas suffering from excessive stress must be identified followed by appropriate design modifications. Doing this by experiments is very time-consuming and expensive. Here, numerical simulations of the electric field distribution provide a highly useful tool. Unfortunately, it is not straightforward to translate the result from an E-field calculation into a statement whether a discharge or flashover will occur or not. In most cases a discharge will start, and possibly evolve, along an electric field line connecting the two conductors at different voltages. The appropriate quantity to use in the evaluation is the integral $S = \int \bar{\alpha}\, dl$, where $\bar{\alpha}$ is the local net ionization, being a function of the local electric field strength. The integral is performed along the particular field line under investigation and only where $\bar{\alpha} > 0$. If S exceeds a critical number, in the range 15 - 20, the total number of charges created will be sufficient to generate a so-called streamer, i.e. a self-sustained discharge. Provided the average field along the field line is sufficiently high a flashover can bridge the entire gap. These criteria are well established within classical gas discharge theory [1]. The ability to evaluate the above-mentioned criteria has previously been restricted to specialized software. In addition, it has only been possible to analyze a limited number of field lines at the same time. Using the Particle Tracing Module in version 4.3 of COMSOL Multiphysics such field line integrals can now be computed and analyzed in a more straightforward and flexible way. The implementation is simple and a large number of field lines can be evaluated simultaneously, both in 2D and 3D. Hopefully, this will result in a much faster and more reliable optimization process of insulation designs in high voltage equipment. In the present contribution we describe the way to apply the massless particle tracing technique in order to compute the integrals, as well as an example of how the results can be presented in an intuitive manner. Some applications involving 2D and 3D geometries are finally provided, for instance the case shown in Figure 1, Figure 2 and Figure 3, where a high voltage conductor is penetrating a cylindrical hole in a grounded metal wall.

Reference

[1] A. Pedersen et al., "Streamer inception and propagation models for designing air insulated power devices", IEEE Conference on Electrical Insulation and Dielectric Phenomena, Virginia Beach, USA, 19-21 Oct 2009.

Figures used in the abstract

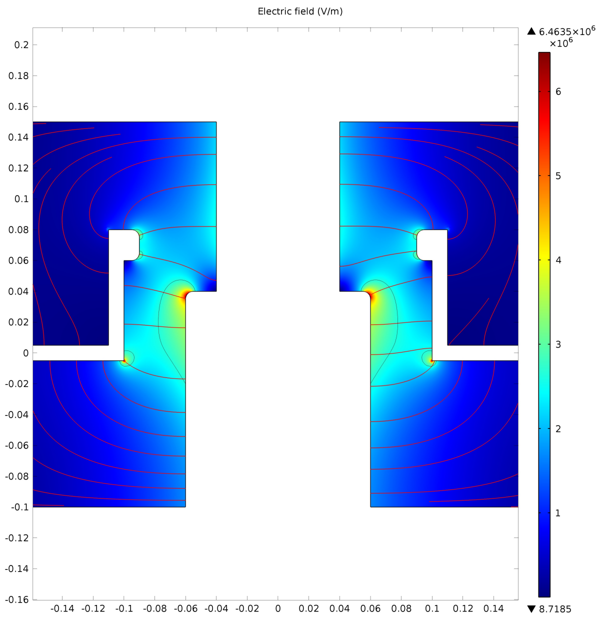

Figure 1: Axisymmetric model of a high voltage inner conductor penetrating a hole in a grounded metal wall. Electric field amplitude shown in colour and electric field lines in red. Grey curves limit areas with positive net ionization, $\bar{\alpha} > 0$.

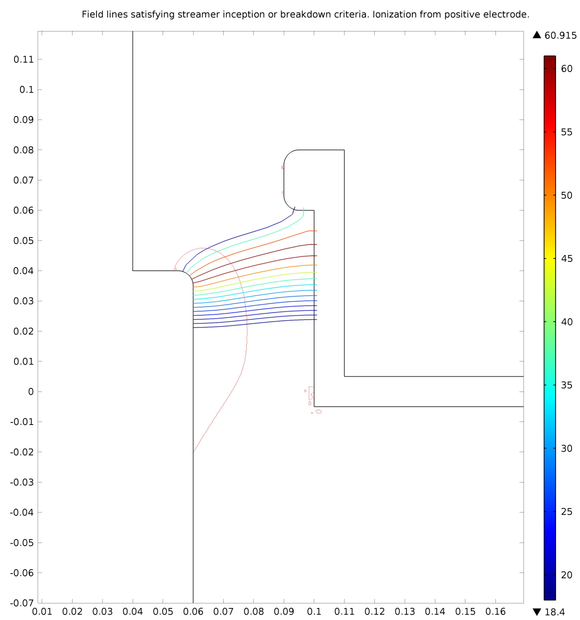

Figure 2: Field lines where a flashover starting from the inner, high voltage, conductor is probable. The area supplying positive net ionization is denoted by a red curve. Colour code denotes values of the streamer integral S.

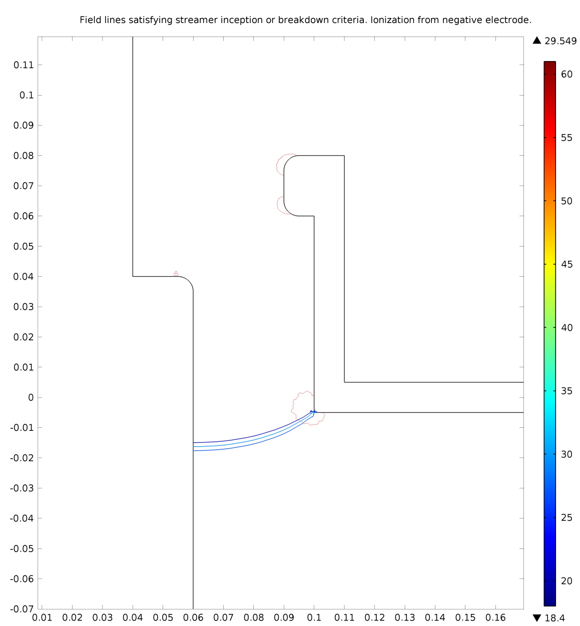

Figure 3: Field lines where a flashover starting from the grounded wall is probable. The areas supplying positive net ionization are denoted by red curves. Colour code denotes values of the streamer integral S.