# Macroscopic Model of Non-thermal Plasma Filament Based on Probabilistic Approach

Filip Zmeko[1], Eva Müllerová[1], Zdeněk Bonaventura[2],

[1] *Department of Power Engineering, Faculty of Electrical Engineering, University of West Bohemia, Pilsen, Czech Republic*

[2] *Departemnt of Plasma Physics and Technology, Faculty of Science, Masaryk University, Brno, Czech Republic*

Mathematical models that are based on kinetic and fluid approximations are traditionally used to evaluate various phenomena in non-thermal plasmas. However, the computational complexity of these models can be often very demanding [1], or even prohibitive in situations where it is necessary to resolve large spatial and extensive temporal scales to achieve convergent and physically consistent results.

We use a macroscopic probabilistic approach, see for example [2, 3, 4, 1], to model the propagation and branching of ionization waves, specifically focusing on predicting breakdown voltages in macroscopic electrode configurations. This approach enables direct comparison of statistically evaluated simulation results with experiments conducted under standardized conditions, such as defined in [5].

The macroscopic model used is based on the so-called Laplacian-growth-probability discharge model. This approach couples Laplace equation for electric potential $\varphi$

$$\Delta\varphi = 0, \tag{1}$$

with a probability for channel propagation

$$p_i = \frac{\varphi_i^{\eta}}{\sum_{j=1}^{n} \varphi_j^{\eta}}, \tag{2}$$

where $\varphi_i$ represents the electric potential at location $i$, and $\eta$ is the electric discharge branching parameter, for further details on the Laplacian growth model, see [6, 7].

The discharge channel is treated as a conductor with finite conductivity, and its propagation dynamics can be adjusted by varying several input parameters, such as the electric channel conductivity, or rate of discharge channel quenching.

By adjusting a set of these parameters, a macroscopic discharge model can be calibrated to mimic the desired macroscopic properties.

The probabilistic model combines the Finite Element Method (FEM) solver to solve the Laplace equation for the electric field and an iterative process for discharge channel propagation that consists of:

1) probability $p_i$ evaluation along already grown discharge tree,

2) cumulative probability calculation, i.e., sum($p_i$),

3) choice of propagation direction,

4) boundary condition implementation according to the electrode system and discharge tree morphology for the FEM solver, and

5) the electric potential $\varphi_i$ calculation.

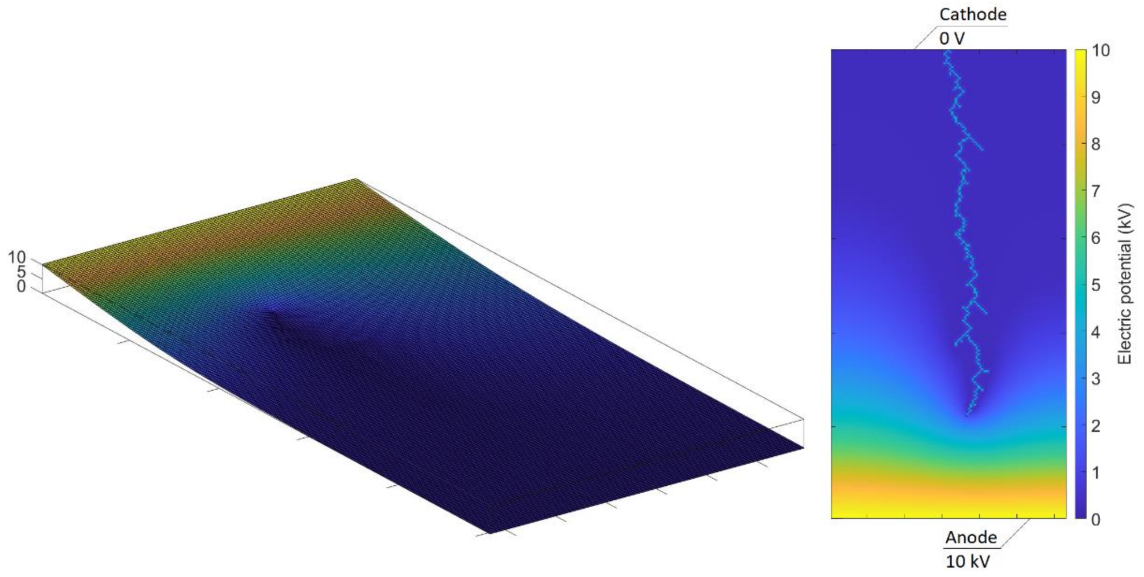

Fig. 1: The electrostatic potential (kV) for the zero-electric-channel-resistance approximation (left) and corresponding electric discharge path in 2D planar electrode system (right), created using [8].

Figure 1 shows a result of a discharge path obtained by the probabilistic model implemented in Matlab [8] for Cartesian 2D geometry. A zero channel conductivity is considered here with an applied voltage of 10 kV and a computational domain size of 1/6 cm by 1/3 cm.

This contribution will investigate the fine-tuning of the probabilistic discharge model parameters for the propagation of ionization waves in air at atmospheric and higher pressures. Our goal is to predict and statistically evaluate macroscopic parameters that are of crucial importance for electrotechnical applications, such as the probabilities of electrical breakdown under specific applied voltage waveforms.

Sweet spots and limitations of the macroscopic probabilistic approach will be discussed.

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