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Electric Discharges in Unsteady Air Flow

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Some evidences indicate higher probabilities of moving structures being struck by lightning compared to stationary ones and a few experiments confirmed an influence of the wind on electric discharge characteristics. In this presentation, we investigate numerically the impact of unsteady air flow on electric discharges by coupling fluid and discharge dynamics.

Two main physical mechanisms from which unsteady air flow might affect the electric discharge are considered. Firstly, the breakdown electric field is modified due to variations in air pressure. Secondly, the air flow affects the motion of charged particles. The momentum transfer between the neutral and charged particles can play a significant role in the motion of the charges around moving structures. Therefore, we have derived a fluid model based on the Vlasov-Boltzmann equation for the motion of ions, accounting for the effect of the air flow on the ion motion. We use the drift-diffusion equation for electrons. The model is validated by comparing swarm parameters with experimental results.

The equations are numerically solved using Ansys Fluent, a computational fluid dynamic tool based on the finite volume method. Fluent solves the compressible Navier Stokes equation for air flow, the drift-diffusion equation for electrons and the continuity, momentum and energy equations for ions. Furthermore, we have added Poisson's equation solver to calculate the electric field.

We will present our 3D model and will investigate the discharge characteristics in a point-plane electrode configuration with and without lateral wind and compare the results with previous experimental results. A recent experiment showed that positive coronas tend to tilt in the wind direction. The drift velocity of the electrons in the streamer is several orders of magnitude larger than that of the wind. Therefore, the mechanism behind this behavior of positive coronas is most probably related to ions motion. We will present a set of simulations showing the role of ions in the shaping of the discharge.