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Monte Carlo simulation of vacuum breakdown occurence statistics including the electromagnetic power flow dependence

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One of the most extensively studied characteristics of vacuum breakdown (VBD) is the conditioning process and the VBD occurrence statistics, in various systems, including Radio-Frequency (RF) accelerators and pulsed-DC large electrode systems. Despite the abundant data on the VBD statistics, drawing useful conclusions regarding the physical processes that determine various patterns within those data (e.g. long-term and short-term conditioning, pulse duration dependence, pulse width dependence, VBD separation distribution, etc), is extremely challenging. One of the main reasons is that the existing VBD models focus on the low-level physical mechanisms which render them unable to produce direct quantitative predictions that are comparable to the aforementioned experimental data.

In this work, we attempt to bridge this gap between theory and experiment by developing a Monte-Carlo model that simulates the occurrence of VBD in any high-field system, based on a few general assumptions. We model VBD occurrence as a two-step Markov chain process. The electrode surface is separated into small elements, each of which is described by a local field E, a power coupling impedance parameter Z, and a surface state parameter β. On each pulse, each surface element is randomly tested for the occurrence of thermal runaway. The probability of thermal runaway (TR) is a sharply increasing function of βE. The points for which TR occurred are randomly selected on whether this TR will develop into full VBD, which depends on E and the power coupling parameter Z of each point. The surface state parameter β of a point is updated after each pulse in a different manner, depending on whether nothing, TR, or VBD occurred.

Finally, we test the above method for various distributions of the simulation parameters, fitting them to reproduce well-known experimental conditioning curves and other VBD statistics.

Topic

Modeling and Simulations

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