Voltage Holding Prediction Model (VHPM): a novel technique for breakdown probability evaluation in complex medium and high voltage devices in vacuum

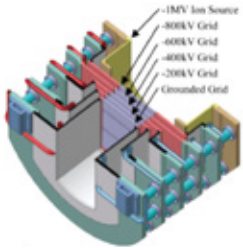
The Voltage Holding Prediction Model (VHPM) is aimed at improving the design of high-vacuum complex electrostatic devices, extensively used in many research and industrial areas, with respect to the simple analysis of the electric field distribution. This is done by the adoption of a probabilistic approach, combined to a more advanced breakdown physical model, that defines a new breakdown variable W, depending upon electric field and voltage applied.

It was developed for the design of the electrostatic accelerator of the Neutral Beam Injector for the International Thermonuclear Experimental Reactor (ITER), with the challenging requirement of withstand 1 MV in a very tight high vacuum environment, and at a later time adopted for the optimization of Siemens medium voltage Vacuum Circuit Breakers (VCB). The VHPM has the twofold advantage of allowing on one hand to identify the most critical regions of the considered geometry, which can be more prone to breakdowns, on the basis of the above mentioned criterion, and on the other hand to identify an univocal probabilistic relation with respect to the voltage applied. It is implemented in the numerical code CAFE, that uses two complementary electrostatics geometric formulations, allowing the convergence to a very precise solution of the electric field distribution, and include a suitable post processing tool for the efficient tracing of charged particle trajectories, as required by the probabilistic model adopted. This last one is assumed to follow a two-parameters Weibull distribution, depending on the experimentally obtained Weibull parameters m and W0 and on the cumulative contribution of all the possible trajectories obtained by the numerical model, weighted by their corresponding breakdown variable W.

This method has indeed the purpose to predict the voltage holding capability of complex research devices for which it is not possible to build a prototype and to minimize time and cost in prototyping activity in industrial applications using medium/high voltage components vacuum insulated.

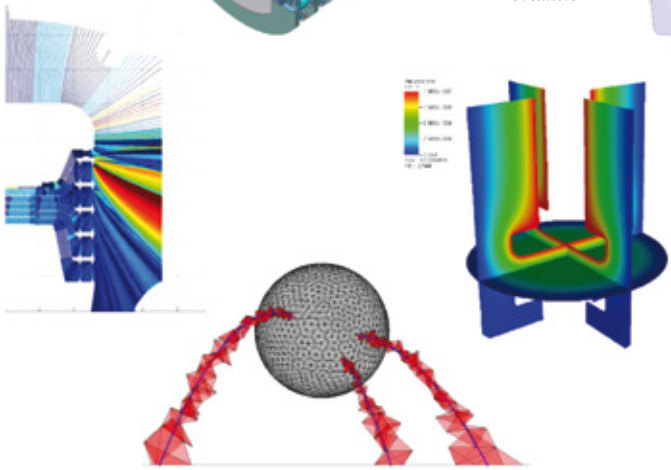
Complex experimental HV device

Electrostatic accelerator of the ITER Neutral Beam Test Facility



Industrial MV application

Vacuum circuit breakers



Ingegneria dell'energia

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Main research topics:
- Plasma physics and engineering
- Design of Neutral Beam Injector (NBI)
- Plasma active and passive diagnostics
- Analysis, synthesis and optimization of magnetic configurations
- Fusion reactor studies