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Application of the Voltage Holding Predictive Model

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The design of complex electrode systems insulated in vacuum to withstand voltage above 105 kV is quite a complex issue. Electric field reduction by means of the optimization of the electrode profile is not sufficient to guarantee a reliable insulation. Other effects, like the electrode area extension (Area Effect) and the Total Voltage Effect (TVE) influences the insulation strength of the system. The electrode material as well as its quality (surface finishing, presence of impurities, adsorbed gas mainly) further add uncertainty in the determination of the ultimate voltage holding.
In 2010, during the design phase of the 1 MeV –16 MW Neutral Beam Accelerator prototype for ITER, we have developed an innovative tool aimed at determining the breakdown probability distribution for any electrode multi-electrode multi-voltage system.
Starting from the clump-based breakdown mechanism proposed by Cranberg-Slivkov, we have guessed that the variable W=E_Kˆα·Uˆβ·E_Aˆɣ is the real driver of any breakdown event. This variable is associated to the trajectory of a charged particle leaking the cathode (dependence on Ek) accelerates acquiring energy (dependence on U) until it clashes to the anode, where some kind of effect are produced (dependence on EA); the breakdown occurs only if W>Ws, this last parameter depending only by the material and status of the electrodes.
The experimental observations show that, once the conditioning effect has been completed, the breakdown voltages sequence follows the well known Weibull distribution. This distribution is fitted by the probability curve P=1-eˆ∫⊠ ⟦-((W-W_s)/W_0)⟧ ˆm , where the integral is associated to all the cathodic (emitting) surfaces. Clearly, the model asks for the knowledge of the electric field at the anode: for this reason it is necessary to calculate the trajectory from any point of the cathodic surfaces, in order to know the electric field at the anode. The integral takes into account the Area Effect; the parameters W0 Ws and m identify the Weibull distribution curve.
So far, the model has been applied and compared with experiments, to the beam accelerator at the Megavolt Test Facility in Naka (J) and to some electrode configuration at the HVPTF, the High Voltage Padova Test Facility in Padua (I). Recently, the model has been applied also to the determination of the breakdown probability curve of Vacuum Interrupter, manufactured by Siemens; in this last case, the voltage was not dc, but it was instead a pulsed one. Investigation have been also started to analyse the effect of the exponents used in the definition of the breakdown variable W

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Modelling and Simulations

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