Simulating Propagation of Spots over Cathodes of High-Power Vacuum Circuit Breakers

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A model of an ensemble of a large number of spots on cathodes of high-power vacuum circuit breakers is developed by means of generalization of the concept of random walk of a single cathode spot in low-current vacuum arcs. The model is formulated in terms of a convection-diffusion equation governing the evolution of the distribution of spots along the cathode, taking into account the variation of the total number of spots with the arc current. A reasonably good agreement between the model and the experiment is found. The model can be used as a module of global numerical models of the interruption process in high-power vacuum circuit breakers.

1. The model

The motion of a spot on a cathode of a vacuum arc can be described as a random walk consisting of a sequence of displacements with a characteristic step length and a characteristic time interval, and with probabilities dependent on the spot location. The evolution of the probability of a spot to be at a certain position at a certain time instant is governed by the Fokker-Planck equation. Assuming that there is no interaction between individual spots and multiplying the above-mentioned equation by the total number of spots, we obtain an equation governing the evolution of the surface density of spots. Creation of new spots and extinction of existing ones is accounted for with the use of the assumption that the net local rate of creation of spots is proportional to the local density of those already existing. The proportionality coefficient is determined from the condition that the total number of spots at each moment conforms to the instantaneous value of the arc current, which is essential for the model to be applicable to high-power vacuum circuit breakers. The drift velocity is associated with the retrograde motion of the spots in a tangential magnetic field and was estimated from the experimental data [1] with the account of the effect of axial magnetic fields [2]. It is assumed that the spots are extinguished on reaching the boundary of the contact.

2. Results

The above-described model was applied to conditions of experiments [3, 4]. An example is shown in Fig. 1. The figure refers to the case of a cathode made of CuCr25 with a diameter of 40 mm operating under a sinusoidal current wave with frequency of 50 Hz and current peak of 7 kA, with variable axial magnetic field B_n. The agreement between simulation results and the experiment is reasonably good.

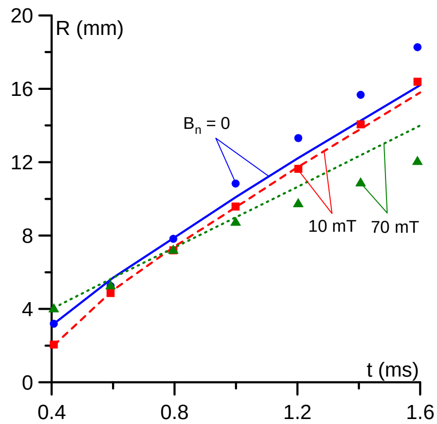

Fig.1 Time dependence of cathode arc root radius. Lines: modelling. Symbols: experiment [4, Fig. 12].

3. Acknowledgements

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4. References

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