CHANNEL GEOMETRY AND MODELLING OF ELECTRICAL DISCHARGES

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ABSTRACT

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A few physical properties and some characteristics of electrical discharges were measured by analyzing a set of photographic images using image processing techniques. The data sample consisted of a set of photographic images of 500 mm long sparks and several images of surface discharging patterns. A stochastic model was developed to simulate 2D and 3D patterns of electrical discharges and compared with the available data.

The distribution of the direction change of the long spark channels was found to be distributed as a Gaussian with a standard deviation of 15.3°. The average tortuosity of the channel defined as the mean absolute value of the direction change was 11.8 ± 1.4° which is smaller than the average tortuosity of natural lightning and close to the tortuosity of triggered lightning. It was found that the tortuosity dependent on the segment length used in the calculation and a reduction in tortuosity value was observed when the leader streamer is closer to the tip of the electrode.

Similar to the tortuosity, the distribution of the brightness across the spark channels also represented a Gaussian distribution. A linear correlation was seen between the channel brightness measured at different cameras looking at the same spark channel. The measured peak current and the brightness of the main spark channel show a high degree of correlation. The sum of brightness of branches was equal to the brightness of the parent channel. One can use this result to calculate the relative distribution of branch currents in complex electrical discharges including natural lightning flashes. If the current in the parent channel is known, the branch current can be calculated by measuring the optical intensities using photographic techniques.

Three popular fractal techniques, Box counting, Sandbox and Correlation function were used in estimating the fractal dimension of discharge channels. Several edge detection algorithms based on Sobel, Prewitt and Laplace operators were utilized to remove the apparent thickness in discharge channels that affect the fractal dimension estimates. A high degree of correlation was found between different edge detection operators. The estimated fractal dimensions for box counting, sandbox and correlation function were found to be 1.19±0.05, 1.63±0.06 and 1.50±0.13 respectively for long laboratory sparks and 1.70±0.23, 1.66±0.14 and 1.79±0.22 respectively for surface discharges.

A stochastic dielectric breakdown model was utilized successfully in modelling the electrical discharges and surface discharges. The fractal dimension of the simulated electrical tree growth varied depending on the cell configuration chosen for the breakdown and depending highly on 'η', which is the exponent of the breakdown probability distribution. When 'η' increases, the growth patterns effectively lose their fractal structure and become a curve with dimension 1. The model was extended to study the long electrical discharges in three dimensions. By comparing the fractal dimension of the experimental laboratory sparks and 2D projection of the simulated patterns, the best 'η' value can be found to simulate long electrical discharges in 3D. The value that approximates the experimental observations is found to be $\eta \approx 4$.