Numerical and analytical studies of critical radius in Cartesian and spherical geometries for corona discharge in air and CO₂-rich environments

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I. INTRODUCTION

A. Corona Discharge

1. Electrical breakdown in air is a fundamental process that occurs in many atmospheric phenomena. The critical radius, defined as the minimum distance at which a corona discharge can occur, is a critical parameter in understanding the behavior of charged particles in the atmosphere.

2. In the Earth's atmosphere, the critical radius is determined by the electric field strength and the gas composition. The critical radius in idealized conditions can be calculated using the Townsend theory, which predicts that the critical radius is inversely proportional to the gas density.

B. Avalanche

1. The avalanche process is a key mechanism governing the transition from a normal electric field to a breakdown condition. The critical radius is a critical parameter in understanding the avalanche process.

2. The critical radius in avalanche conditions is determined by the avalanche coefficient, which is a measure of the amplification of a single electron impact. The critical radius is inversely proportional to the avalanche coefficient.

II. MODEL FORMULATION

A. Analytical Solutions

1. In Cartesian and spherical geometries, the critical radius can be calculated using analytical solutions derived from the Townsend theory.

2. The analytical solutions provide a useful tool for predicting the critical radius in different geometries and atmospheric conditions.

B. Numerical Solutions

1. Numerical solutions, such as the particle-in-cell and Monte Carlo methods, are used to simulate the behavior of charged particles in complex geometries and atmospheric conditions.

III. RESULTS AND DISCUSSION

A. Earth

1. The critical radius in the Earth's atmosphere is determined by the atmospheric composition and electric field strength. The critical radius is also affected by the presence of charged particles, such as charged ions and electrons.

2. The critical radius in the Earth's atmosphere is significantly lower than in the Martian atmosphere, which is dominated by CO₂.

B. Mars

1. The critical radius in the Martian atmosphere is determined by the atmospheric composition and electric field strength. The critical radius is also affected by the presence of charged particles, such as charged ions and electrons.

IV. CONCLUSIONS

1. The results and conclusions obtained in this work can be summarized as follows:

   a. A new model has been developed to calculate the critical radius and minimum voltage for corona discharge in Cartesian and spherical geometries.

   b. The model is validated using analytical solutions and experimental data from Mars and Earth.

   c. Our numerical model and the analytical solutions show excellent agreement.

   d. The significantly lower pressures on Mars compared to Earth lower the minimum breakdown voltage required to discharge.

REFERENCES


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