Study of Post Breakdown Arc Resistance in Argon and Nitrogen Gas-filled Spark Gap Switch

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Abstract— The amplitude, rise time, and shot-to-shot stability of the pulses produced by spark gap switches are dependent on the transient impedance of the plasma channel formed between the electrodes. Thus, optimization in the design of a gas-filled spark gap switch requires a detailed investigation of the time-dependent arc resistance. In this paper, we'll investigate the post break down characteristics in argon, and nitrogen gas-filled spark gap switches at different pressures and applied voltages. Special attention will be given to the Joule heating of the plasma channel formed between the electrodes, as this leads to a reduction in the arc resistance. Optical emission spectroscopy technique is proposed to characterize the plasma and to monitor its constituents at different conditions.

Keywords-Arc resistance; Gas-filled spark gap switch; Optical emission spectroscopy; Plasma channel; Streamer

I. INTRODUCTION

Gas-filled spark gap switches, which are based on gas breakdown and streamer formation between the electrodes, have been the main component of various pulsed power systems and machines such as linear transformer drivers (LTDs), Marx generators for Z-pinches, apparatuses for the generation of ultrawideband electromagnetic impulses, and generators of high-voltage impulses for biomedical and environmental applications [1]. The influence of different parameters on the operational performances of various gas-filled spark gap switches having different topologies has been considered [2]. Time-dependent arc resistance is an important parameter that significantly influences the amplitude, rise time, and shot-to-shot stability of the switched pulse. In this study, argon and nitrogen gases are used in the gas-filled spark gap switches, and post breakdown arc resistance was evaluated at different pressures and applied voltages. Optical emission spectroscopy (OES) is proposed to be used to characterize the plasma and to monitor the constituents of plasma.

II. EXPERIMENTAL SETUP

We'll use the experimental setup similar to reported in [1]. The spark gap electrodes are detailed in Fig. 1. The arc resistance will be determined from the current/voltage waveforms. The electrodes will be assembled in a gas cell which comprises several transparent windows that facilitate conducting plasma diagnostics. The characteristics of the plasma at different pressures and gas types can be studied using optical emission spectroscopy.

Figure 1. Spark gap electrodes designed to be used in a further laser triggering experiment. (a) the electrodes with axial holes through which the laser will be coupled to the interelectrode channel. (b) electrodes without the hole. Both cases will be analyzed.

Electric field distributions for electrode profiles of Fig. 1 are obtained by simulation using COMSOL Multiphysics software at different gap distances and applied voltages. For electrodes without an axial hole, the electric field is maximum at the center of the spark gap. However, for electrodes with the axial hole, the electric field distribution shows a dip at the center of the gap at gap distances below 3 mm. Such differences in the electric field distribution within the gap could have a significant impact on the arc resistance, which is evaluated from the experimentally measured current/voltage waveforms. The arc resistance is associated with the electrical conductivity of the plasma and therefore with the Joule heating. The evolution of plasma emission characteristics obtained by optical emission spectroscopy can be correlated to the arc resistance at different conditions.

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