Characterization of a 38-kJ Capacitive Source for an Electromagnetic Accelerator

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Abstract— This work presents the characterization of a 38-kJ capacitor-based pulse forming unit used as part of the energy source of an electromagnetic accelerator. The voltage and currents through the main components are measured after a 0.6 kV discharge test.

Keywords; capacitor bank, electromagnetic launcher, PFU

I. INTRODUCTION

An electromagnetic accelerator (EMA) thrusts a mobile armature by converting electrical energy into kinetic energy by using the Lorentz force principle. It consists of a capacitive power supply that stores energy and then drives a current pulse to a load made up of parallel rails with a moving armature [1]. Due to the low impedance of the rail-armature setup, the discharge generates currents of dozens of kA from pulse forming units (PFU) charged to voltages of tens of kV. One possible configuration for a PFU comprises a capacitor bank discharged through an inductor by triggering a high-current switch, such as a thyristor; however, spark gaps and thyratrons can also be used [2].

This work presents the experimental characterization of a 38-kJ PFU discharged into the pulse-forming inductor itself. Fiber optic link transceivers were used for both measurement and control subsystems, allowing safe and remote operation of the accelerator.

II. PULSE FORMING UNIT TEST SETUP

The assembly of the 38-kJ energy source for the EMA is shown in Fig. 1a. The module consists of 6 x 125 µF/10 kV capacitors, three 90-kA thyristors, four diodes serving as freewheel mechanisms to protect the capacitors, and a solenoid inductor of 50 µH that connects the power supply to the load. The pulse-forming inductor is short-circuited to the ground to act as the load during the discharge test. Fig. 1b shows the schematic model of the PFU under test.

The capacitor bank charging is remotely controlled via serial communication over a fiber optic link. The control system consists of a compact RIO module, sending a TTL pulse to the thyristor-gate-driver circuit, which triggers the thyristor to discharge the capacitor bank. The measurement system consists of a high-voltage probe and a Rogowski coil whose output signal is transferred to an oscilloscope via fiber optic transceivers, working from DC to 25 MHz. The control system flow diagram is depicted in Fig. 2.

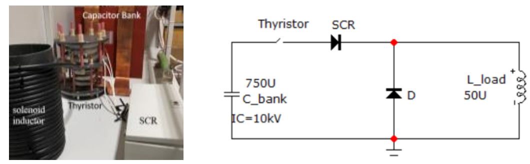

Figure 1. (a) PFU prototype. (b) Circuit model

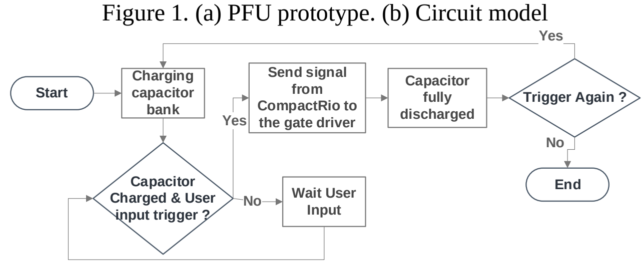

Figure 2. Block diagram of the discharge control.

III. MEASUREMENT RESULTS

Preliminary tests with the PFU charged to 0.6 kV (375 J) were performed. The results are shown in Fig. 2. The load current shows 190 µs rise time and reaches a 1.95 kA peak, indicating a good agreement with the theoretical peak value, computed as

$$I_{peak} = V_0\sqrt{\omega_0 L_{PFU}}\,\exp\left(-R\pi/4\omega_0 L_{PFU}\right) = 2.01\,(\text{kA}) \qquad (1)$$

Where $\omega_0 = 1/\sqrt{C_{PFU}L_{PFU}}$, and R is the equivalent circuit resistance. The resistance from the solenoid (16 mΩ) is the main contributor to R and was used in the calculation. Higher voltage discharge results will be presented during the conference.

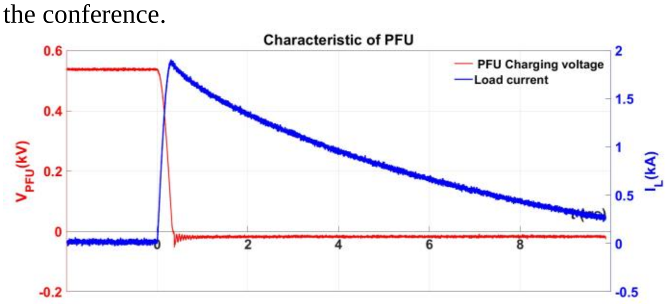

Figure 3. Preliminary experimental results

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