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A New 40 MA Ranchero Explosive Pulsed Power System

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Abstract

We are developing a new high explosive pulsed power (HEPP) system based on the 1.4 m long Ranchero generator which was developed in 1999 for driving solid density z-pinch loads. The new application requires approximately 40 MA to implode similar liners, but the liners cannot tolerate the 65μs, 3 MA current pulse associated with delivering the initial magnetic flux to the 200 nH generator. To circumvent this problem, we have designed a system with an internal start switch and four explosively formed fuse (EFF) opening switches. The integral start switch is installed between the output glide plane and the armature. It functions in the same manner as a standard input crowbar switch when armature motion begins, but initially isolates the load. The circuit is completed during the flux loading phase using post hole convolutes. Each convolute attaches the inner (coaxial) output transmission line to the outside of the outer coax through a penetration of the outer coaxial line. The attachment is made with the conductor of an EFF at each location. The EFFs conduct 0.75 MA each, and are actuated just after the internal start switch connects to the load. EFFs operating at these parameters have been tested in the past. The post hole convolutes must withstand as much as 80 kV at peak dI/dt during the Ranchero load current pulse. We describe the design of this new HEPP system in detail, and give the experimental results available at conference time. In addition, we discuss the work we are doing to test the upper current limits of a single standard size Ranchero module. Calculations have suggested that the generator could function at up to ~120 MA, the rule of thumb we follow (1 MA/cm) suggests 90 MA, and simple flux compression calculations, along with the ~4 MA seed current available from our capacitor bank, suggests 118 MA is the currently available upper limit.

I. Introduction

Ranchero HEPP generators were developed in the late 1990s[1] for the purpose of conducting solid liner z-pinch experiments. In this paper, we report on an effort that explores Ranchero current limits with the system shown in Figure 1. Another scheme uses a

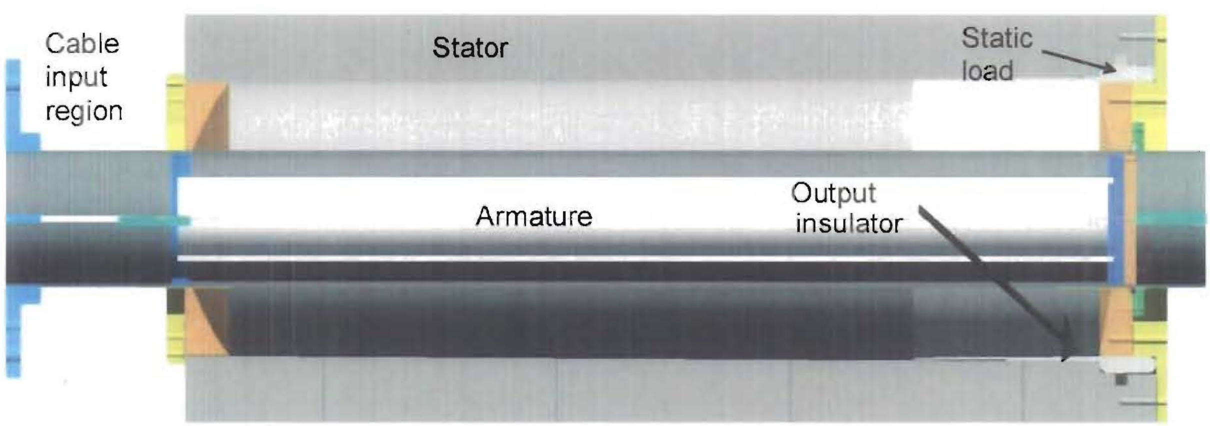

Figure 1. 1 m long Ranchero generator with 2.5 nH static inductance load. The armature OD is 15.2 cm, and the stator tapers from 30.5 to 31.7 cm at the output end.

Ranchero generator of the type developed in 1999 as part of a new system, as shown in figure 2, for powering solid liner z-pinch experiments. Full scale tests have not been completed with either system at this time, but both systems are fully designed, most hardware is on hand, and many subsystem tests have been completed. We will describe the pulsed power hardware for the two systems. In addition, for the z-pinch work, considerable work has been done on promoting liner stability. We will describe calculations that seek to eliminate the effects of glide plane interactions on the liner, and reference work published earlier that addresses the fact a specific pressure balance is required during implosion to maintain liner stability[2]. As a result, current may not drop either too fast or too slowly.

II. Ranchero Current Limit Experiment

Figure 1 illustrates a 1 m long Ranchero system with a 2.5 nH static inductance load. The stator is fabricated with a taper of 6 mm over the 1 m length and it will have a 0.5 mm polyethylene insulator wrapped on the inside of the stator. Based on earlier work[3], we estimate that there will be a residual inductance in the generator of ~2.5 nH. The initial inductance of the generator is ~145 nH, and our capacitor bank will deliver ~4 MA seed current. As a result, simple flux compression estimates indicate that we should generate ~118 MA in the test. This is considerably more than our normal design limit of 1 MA/cm of conductor would prescribe for the 30.5 cm outer diameter. However, it is only slightly less than the 120 MA current that Raven 1D MHD calculations have indicated is possible for Ranchero modules. The test will demonstrate Ranchero performance at elevated current density.

III. Solid Z-pinch System

Figure 2 illustrates the system we have designed for solid liner tests. The system uses the 1.4 m long system developed in 1999, and uses an integral closing switch, post hole convolutes, and EFF opening switches to protect the liner from the first 65 μs of current that is necessary to provide the initial flux into the generator. Figure 3 shows the currents calculated for a static-inductance load experiment planned for the system. The integral closing switch at the generator output operates in the same manner as the crowbar switch normally used at the generator input. 0.02" Kapton are wrapped on the armature which insulates it from the input or output glide plane. On first motion of the armature, the insulation is sheared and the armature is electrically connected to the glide plane at each location. Post hole convolutes connect the armature to an EFF opening switch which completes the circuit during the initial current loading of the Ranchero. The EFFs are actuated to start their resistance rise just after the integral closing switch has connected the armature to the load. The generator then

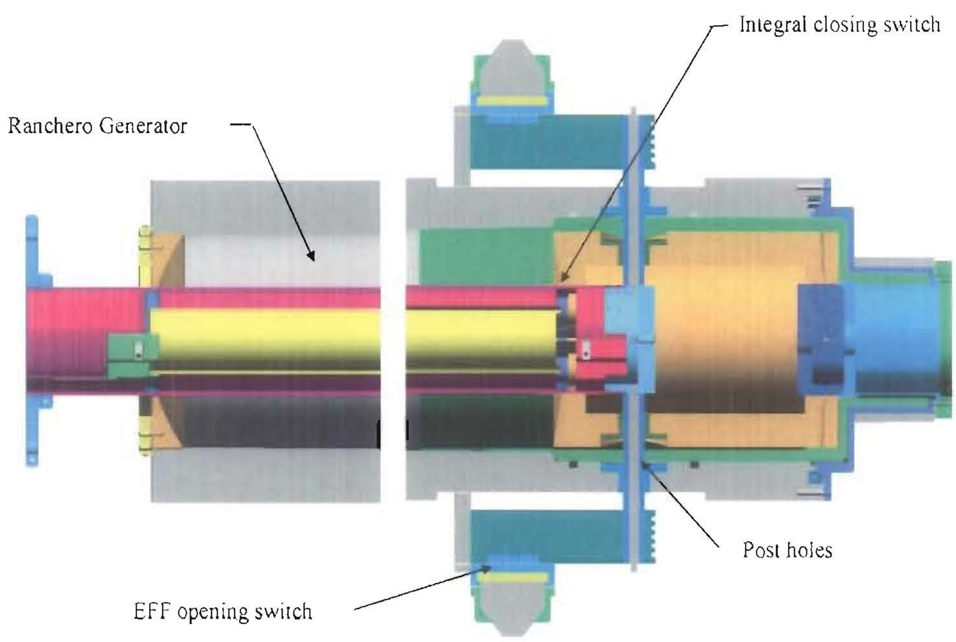

Figure 2 New Ranchero solid liner z-pinch system

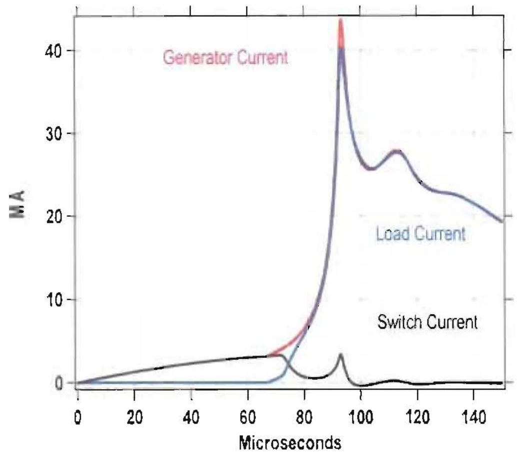

Figure 3. Currents calculated for static-load experiment

drives current to the load, with the increased impedance EFF in parallel with the load. We have tested small scale EFFs at the actual experimental conditions, and

Figure 4 Static load test during assembly.

achieved expected resistance profiles. We are unsure what the resistance profile of the EFFs will be toward the end of the experiment, as small scale data are difficult to evaluate once current has approached zero. However, the EFF will experience very small voltage during its opening phase, due to the relief provided by switching in the low inductance load, and we expect this to improve EFF performance. Our first test will provide definitive information. Figure 4 shows the static load test being assembled.

IV. Liner Experiments

Our first liner tests will have the goal of demonstrating that liner stabilizing features designed for the system will work as calculated. In order to maximize the data obtained on a limited number of experiments, we have designed our first liner tests to have tandem liners, as shown in figure 5. In this configuration we can test both the implosion performance of the liners, and the impact performance. We have also derived a new model for glide plane shape. Figure 6 illustrates the concept. The glide plane is curved such that the axial velocity, V(z), of the contact point of the liner to the glide plane never exceeds 500 m/sec. This reduces, or eliminates, the foot that runs ahead of the liner in the case of a fixed angle glide plane, as is seen in the figure.

V. Conclusions

We have designed and fabricated two Ranchero systems. One will test the high current limits of a Ranchero generator, and one is designed to drive solid liner z-pinch loads. The liner system has closing and opening switch features that will allow flux loading into the generator without distorting the liner due to the early current foot, and we have paid special attention to

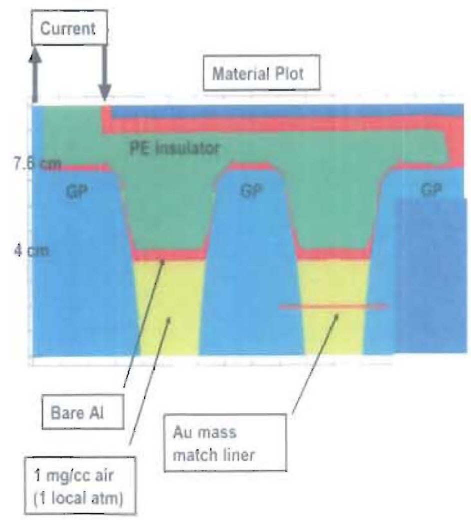

Figure 5. Tandem liners that will test both glide plane designs and cylindrical impact

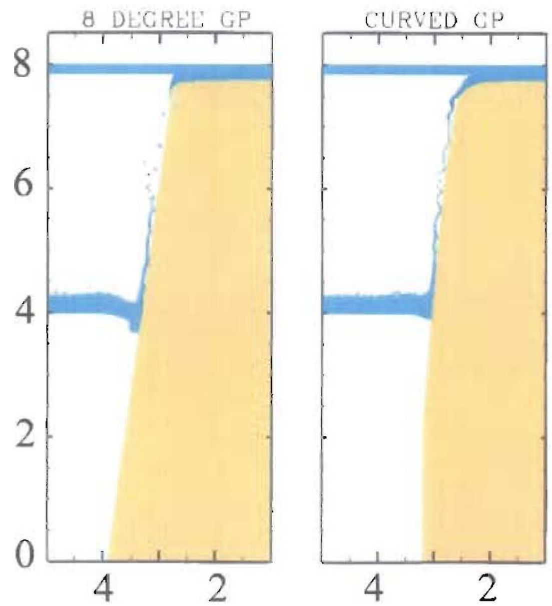

Figure 6. Two glide plane calculations using Eulerian MHD code. Left hand glide plane is straight, with 8°angle. Right hand glide plane is curved to maintain low z direction velocity of the liner/glide plane contact point. Dimensions are in cm.

glide plane/liner interactions. We will perform a static test that will demonstrate current profiles from the system, especially during the current fall after peak current. This will reveal what techniques will be available to help control the rate of current fall during liner tests, which will be important to maintaining a stable pressure profile for the liner and hence enhance stability.

VI. References

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[3] J. H. Goforth, et al., "The Ranchero Explosive Pulsed Power System," 11th IEEE International Pulsed Power Conference, (Cooperstein and Vitkovitsky eds.) Baltimore, Maryland, page 573, 1997,