

1200A High Speed Injection and Extraction Kicker Magnet Drivers for EMMA

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Abstract - EMMA (Electron Machine for Many Applications) is a proof-of-principle non-scaling fixed field alternating gradient accelerator designed to accelerate electrons from the Energy Recovery Linac Prototype (ERLP) under construction at STFC Daresbury Laboratory. The electrons are extracted from ERLP after the first pass through the main linac and injected into EMMA at energies of 10MeV. Each bunch will make 10 turns of the ring during which time the energy is raised from 10MeV to 20MeV. The time for the bunch to make one revolution is 53ns which imposes the requirement that the falltime for the injection driver must be <50ns with a postpulse current of <1%. Similar considerations dictate that the risetime of the extraction driver must be <50ns with a prepulse current of <1%. The low inductance kicker magnets require 1200A current pulses. APP has developed solid state drivers that with minor modifications can be used to meet either application. The driver has 2 PFN's with each end of the kicker magnet connected to one PFN. The PFN's are charged to 20kV in approximately 200ns. A magnetic switch across one pulse PFN inverts the voltage on that PFN, resulting in a fast rising and falling current through the kicker magnet. Ferrite loaded lines and shunt resistors are used to eliminate pre and post-pulse current. This paper will describe the performance of this system.

of the energy in the circuit inductance and the switching and circuit losses. Thus the initial energy is several times the magnet energy, and >99% of it must be dissipated by 50 ns after the peak current pulse. Several designs were examined, and the circuit shown in fig. 1. exhibited superior performance.

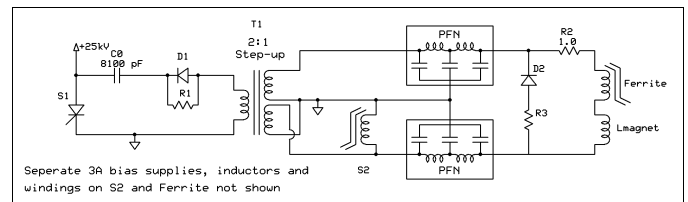


Fig. 1. Injection Magnet Driver Schematic

The high losses in the series ferrite core that occur during the high dB/dt transition, and the voltage clamping from shunt diode D2 and resistor R3, eliminate the initial negative post pulse. The series resistor R2 increases the effectiveness of the shunt diode.

Fig. 2. shows the magnet current, fig. 3. is a measurement of this current at high sensitivity to determine the magnitude of the post-pulse. Fig. 4. shows PFN and magnet voltages.

I. INTRODUCTION

The purpose of this project was to demonstrate the feasibility of building relatively inexpensive solid state magnet drivers using proven components for the EMMA [1] injection and extraction magnets. The injection magnet current of 1200A must fall to < 12A in <50ns while the extraction magnet current must rise from <12 A to 1200A in <50ns. The magnets have an inductance of 240nH with an additional circuit inductance of 160nH. In order to obtain the di/dt required to achieve this, the voltage applied to the magnet is >15kV. Magnet. A compact solid state 32kV switch developed by Applied Pulsed Power as a replacement for spark gaps [2,3] was used as the primary switch.

II. INJECTION MAGNET DRIVER

The injection magnet driver produces a 1200A peak current pulse with a fall time <50ns and a post pulse <1% of peak. The inductive energy stored in the magnet is less than the sum

This circuit works as follows:

- The PFNs are charged on an ~ 200ns timescale through step-up transformer T1, using the model S33A-8 32kV solid state switch S1. Diode D1 causes reverse current conduction to flow through R1, dissipating residual energy and eliminating the late time reverse direction post-pulse.
- The leakage current through the unsaturated inductance of the magnetic switch S2 results in a mismatch in PFN charging rates which produces a substantial pre-pulse, but since there is no beam in the ring, this is not a concern for the injection magnet.
- When S2 saturates, the voltage across one PFN inverts and current flows through the magnet.

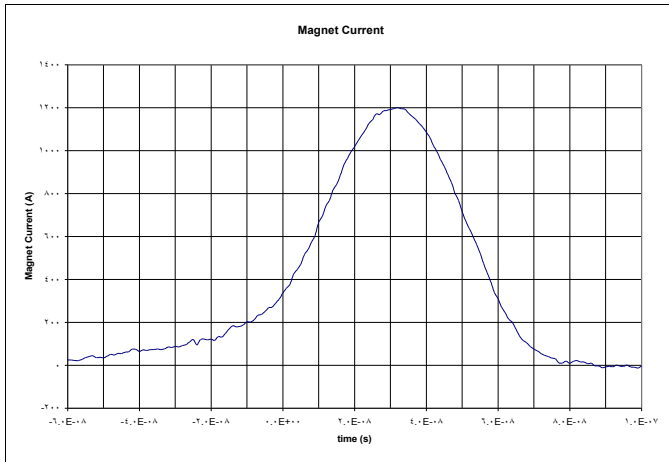


Fig. 2. Injection Magnet Driver Current

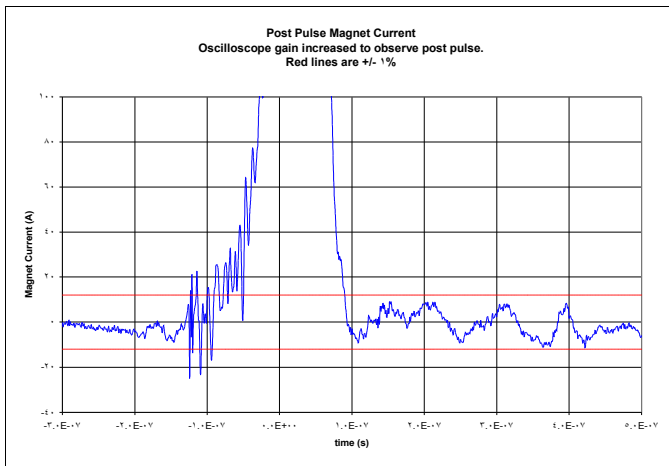


Fig. 3. Injection Magnet Driver Post-pulse Current

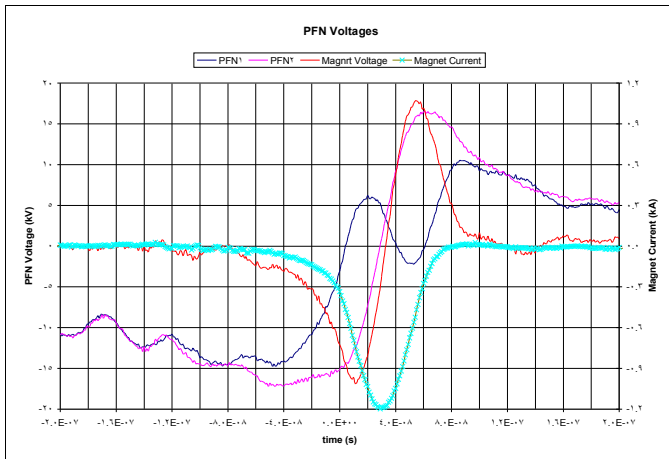


Fig. 4. Injection Magnet Driver Waveforms

III. EXTRACTION MAGNET DRIVER

In contrast to the injection magnet driver, the extraction magnet driver must have <12A pre-pulse <50ns prior to the 1200A peak current pulse. Post pulse current is not a concern

as there is no longer a beam in the ring after extraction.

The simplest approach to this driver would be to use a fast turn on switch. However 20kV, 1200 A switches with <50ns risetimes are expensive and not readily available. APP has built multi-kV, multi-kA switches using series arrays of MCTs but these switches do not meet the cost and proven reliability criteria established for this project. Also, it is desirable to use the same or similar injection and extraction drivers.

The injection driver circuit can be used for the extraction magnet driver if the voltage prepulse due to mismatch in PFN charging rates is eliminated. Mirroring the losses in the magnetic switch at PFN1 by adding a shunt load across PFN2 can accomplish this. A magnetic switch similar to the one across PFN1, but with a larger volt-second product to prevent switching, was used. This additional shunt load adds to circuit losses requiring operation at higher voltage, and is partially compensated for by removing the ferrite and R2 from the output current path, as post pulse current is not a concern for the extraction magnet. Fig. 5. shows a comparison of the output of this configuration, scaled to 1200 A, with the injection magnet driver. Operation was done at 25 kV resulting in a peak current of 800 A. Better matching of the shunt load leakage inductance with S2 would reduce the approximately 2.5% pre-pulse current, shown in fig. 6., to the desired 1%.

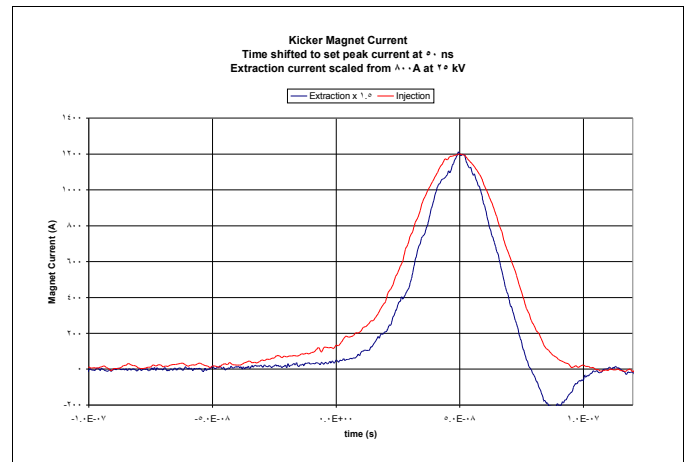


Fig. 5. Extraction and Injection Magnet Driver Waveforms

IV. CONCLUSION

It appears possible to meet the requirements for both drivers with a relatively simple and inexpensive system that uses proven solid state switch technology.

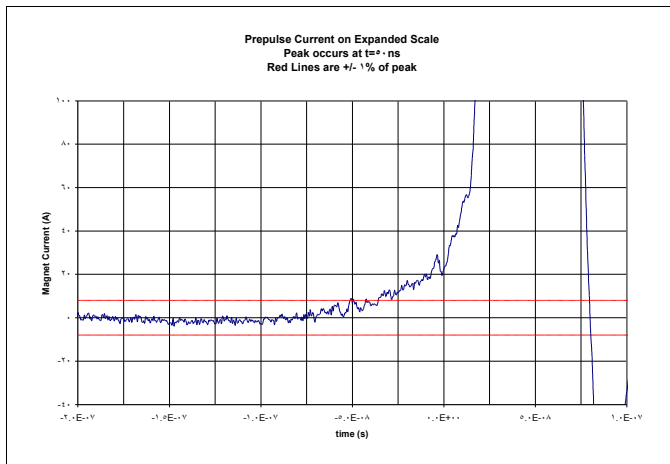


Fig. 6. Extraction Magnet Driver Pre-pulse

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