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H5 Fast Kicker Magnet Pulser

W. Frey

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Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

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W. Frey, S. Ghoshroy and J.G. Cottingham

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Summary

The fast extraction kicker magnet for the AGS is powered by a novel pulse generator. A pulse forming network (PFN) is discharged into nearly 100 percent mismatched load. The pulser delivers a 3000 ampere peak pulse with a 2 percent flat-top ripple into a 1.4 μ Hy single turn ferrite core magnet. The pulse is 2.8 μsec wide with a 180 nsec rise time, at a 0.5 to 1.5 pps repetition rate. The rise time is required to provide clean extraction of the 28 GeV proton beam by bringing the kicker magnet up to 1.25 kG within the 220 nsec between proton bunches in the machine.

The pulser is mounted adjacent to the kicker magnet in the AGS ring. The thyratrons characteristics are not effected by the ionizing radiation environment during operation of the AGS.

Introduction

Typically modulator or pulse generator designs are powering voltage dependent loads such as transmitting tubes. Thus, most of the literature on PFN discharge pulse generators describes systems where the PFN impedance is matched to the load impedance for maximum power transfer. A typical line type pulser is shown in Figure 1(a). For this configuration, the DC voltage on the PFN, before the switch closes, is twice the voltage across the load impedance after the switch closes.

When a pulser is used to power a kicker magnet, the configuration in Figure 1(b) is generally used. Since the magnet is an inductive load with a time dependent voltage-current relationship, it is placed in series with a fixed load resistance. Typically a small capacitor is added to compensate for the stray element of the magnet to form a small delay network. Thus, the magnet current is determined by the load resistance. Again, the PFN voltage is twice the load voltage.

The mismatched pulser shown schematically in Figure 1(c) offers several advantages as a source for a fast extraction kicker. The magnet load is a current device with negligible resistance. The PFN voltage is determined by the L di/dt rate of rise requirement of the magnet. The characterstic impedance of the PFN is determined by the PFN voltage and the flat-top current requirement. The network impedance is orders of magnitude greater than the magnet resistance.

Ionizing radiation effects the insulating characteristics of most common insulating oils and, therefore, oil-filled devices are not placed in such an environment. Previously designed extraction pulsers have used oil-insulated networks outside the ring and multiple coaxial cables (for impedance matching) to connect the pulser to the magnet. Such systems have limited rise-time performance and are difficult to design and build.

In our case, the PFN voltage is about 30 kV ($L = 1.6\ \mu$ Hz, di = 3000 A, dt = 180 nsec); thus, the pulser can be constructed using air as an insulator and placed in the ring adjacent to the magnet. Mounting the PFN close to the magnet reduces the stray inductance of the current discharge path.

Design

The pulser is a Guillemin E type network, with a thyratron switch. Figure 2 is a simplified schematic diagram of the pulser. V1 is a tetrode thyratron, EEV type CX1154, and is used to discharge the PFN. Resistive charging of the PFN is used, and a regulated HV power supply is located external to the ring. The charging voltage is fed to the pulser using RG-8 type cable.

In a mismatched system such as this, the PFN will be charged to -HV by the reflected pulse. Thus, the capacitors in the PFN must be rated to take 100 percent voltage reversal. In addition, an inverse diode must be used to protect the switch tube from being subjected to this reverse voltage. V2 is the inverse diode and is another CX1154 connected as a diode. The inverse circuit is connected as shown in Figure 2 to prevent inverse current from flowing in the kicker magnet.

Capacitor C1 in the PFN is used to form the first element in the PFN working together with the stay wiring and switch tube inductance. Because of size limitations, the PFN folds back on itself and mutual coupling is difficult to control. Resistors R1 to R3 are used to control pulse flat-top ripple by controlling the dissipation of the discharging elements.

Results

The H5 kicker and pulser were placed in operation for the June fast extraction run. Figure 3 is the current pulse in the H5 magnet with flat-top current of 2670 Amps. The pulse has 180 nsec rise-time, and a flat-top ripple of about 2 percent. Leading edge jitter is less than 5 nsec. Figure 4 compares the voltage across the magnet as a function of current through the magnet. Figure 5 demonstrates the voltage reversal on the PFN. The oscilloscope displayed the voltage across C14 of the PFN and shows the reversal as the discharging wave-front comes to the end of an open circuited delay line. Figure 6 compares the voltage across the switch tube V1 against the discharge current.

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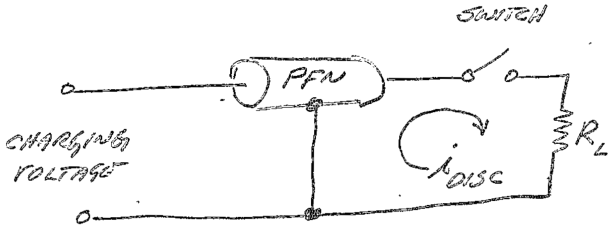
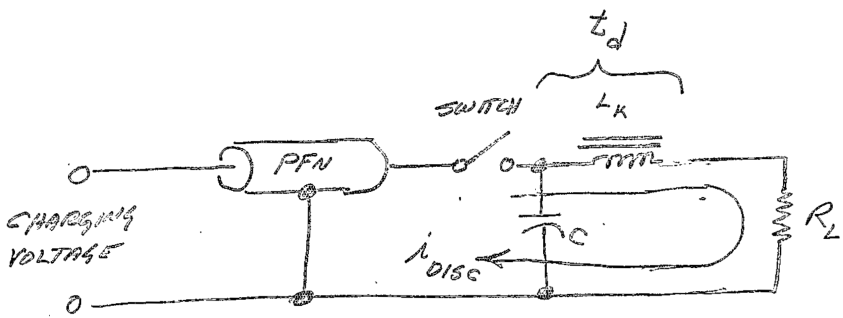


$R_L \approx Z_{PFN}$

(a) Typical line type pulser

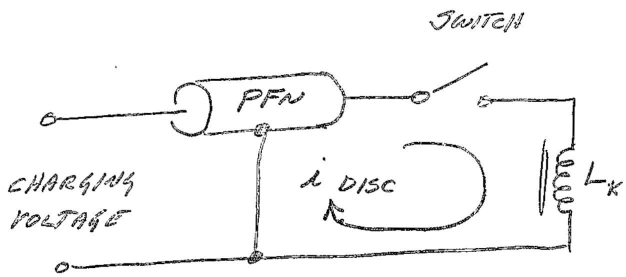


$R_L \approx Z_{PFN}$

$Z_{PFN} = \sqrt{\frac{L_K}{C}}$

$t_d = \sqrt{L_K C} \approx t_R$

(b) Typical magnet pulser



(c) H5 kicker pulser

Figure 1 - Simplified pulser types

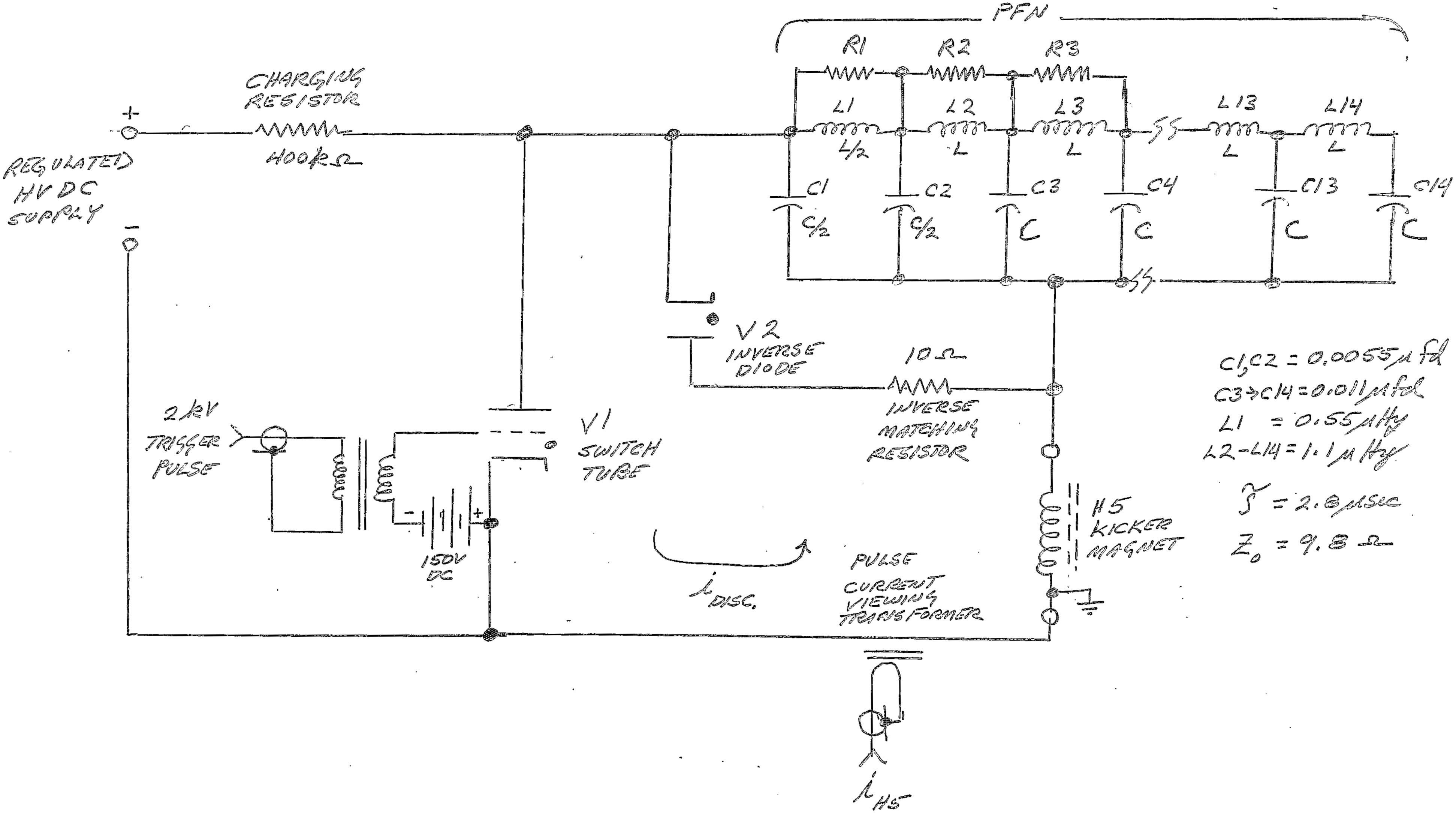


Figure 2 - Simplified schematic diagram of H5 Pulser

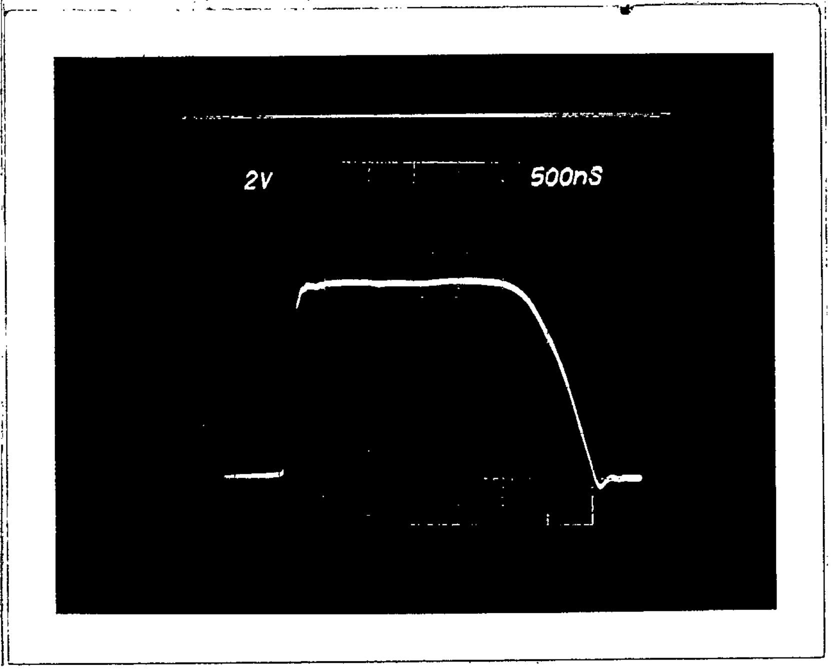


Figure 3 - Magnet current pulse
2670 A peak

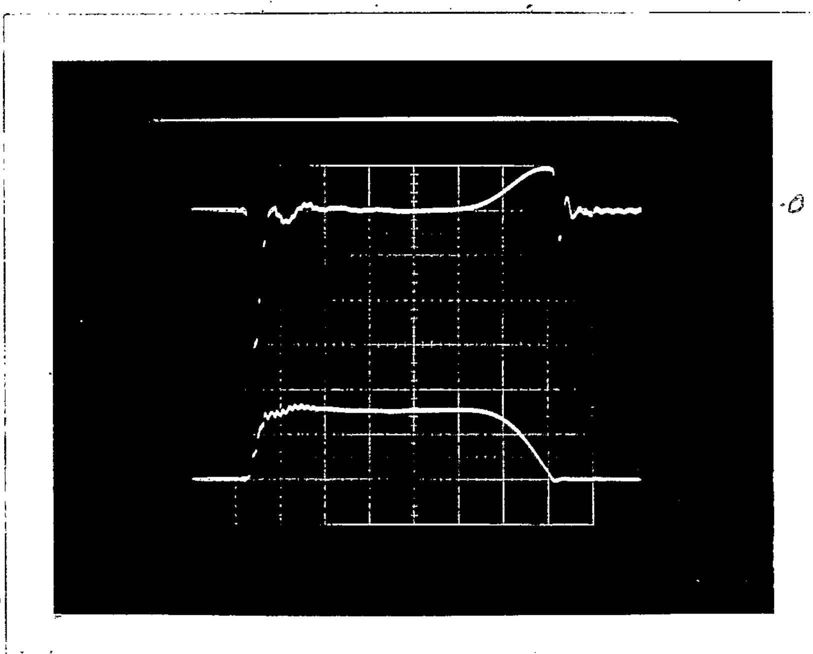


Figure 4 - Top trace--Voltage across
H5 magnet

Bottom trace--Current throug
H5 magnet

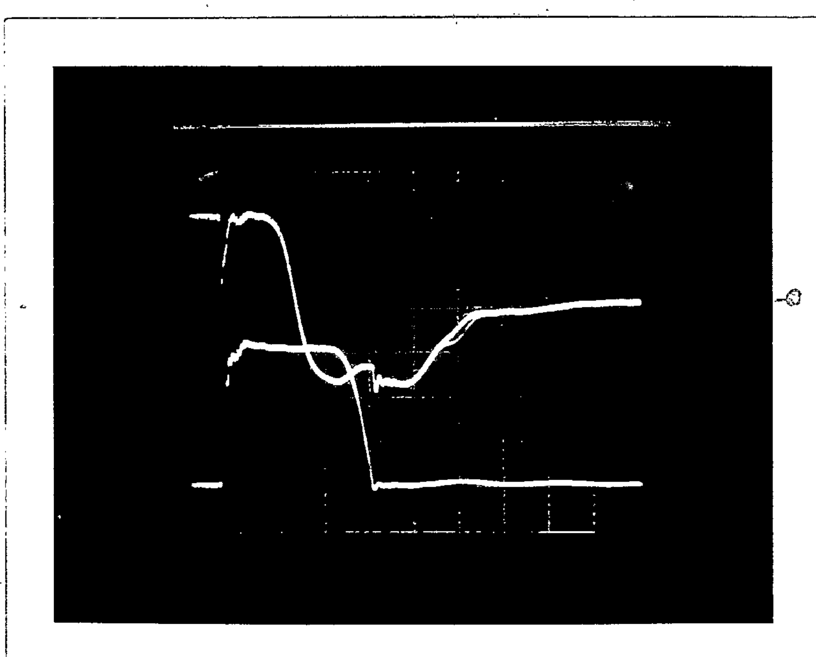


Figure 5 - Top trace--Voltage across C1
of PFN

Bottom trace--Current throug
H5 magnet

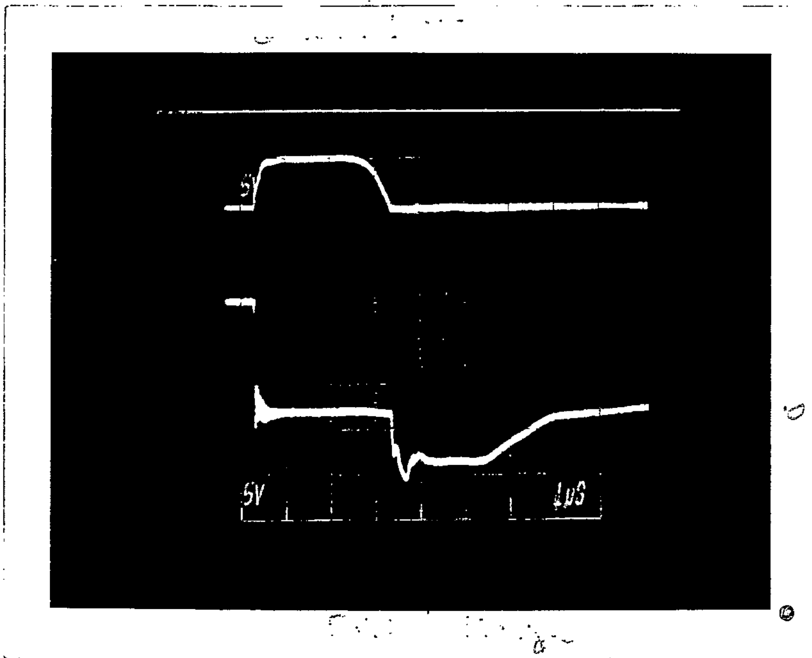


Figure 6 - Top trace--Current through H5 magnet

Bottom Trace--Voltage across switch tube V.