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INTENSE PULSED NEUTRON SOURCE (IPNS-I) ACCELERATOR 500 MeV FAST KICKERS*

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Abstract

Two ferrite loaded picture frame magnets with a kick of up to 15 mrad each are used to extract 500 MeV protons from the IPNS-I accelerator to the neutron source target at the Argonne National Laboratory. The magnet aperture is 10 cm wide by 5 cm high and the length is 60 cm. The single bunch extraction requires a magnetic field rise time (0 to 100%) of 90 ns and a flattop of 100 ns. The magnets receive the 3600 A maximum current via an array of 50 Ω coaxial cables connected in a shunt arrangement. The two legs of each magnet are energized with separate lines to keep the potential to ground to less than 40 kV. The system is designed to run at 30 pulses per second repetition rate. The complete system of control electronics, power supply, deuterium thyratron switch, magnet and resistive load will be described along with some of the problems of stray inductances and the techniques used to reduce them.

Introduction

The beam is extracted into the septum magnet by a two kick magnet system. The two magnets are identical physically and electrically. They are located in successive straight sections of the Rapid Cycling Synchrotron (RCS). Because of the intervening betatron phase inversion, the two magnets are energized with opposite polarity kicks.

Magnet Specifications

The magnets use Ceramic Magnetic type C2050 ferrite. They each are 56 cm in effective magnetic length. The magnitude of the first kick is 0.0314 T-m and is 0.0465 T-m for the second kick. The respective currents are 2272 A and 3364 A.

Original intent in the magnet design was to have a 22 Ω transmission line magnet powered from opposite polarity energy sources to minimize voltage potential to ground. Epoxy sealed ferrite faces were being used for the vacuum chamber and capacitor dielectric. The magnet has good transmission line characteristics but the ferrite could withstand no more than approximately 1000 V/cm. The breakdown exhibited nonisotropic behavior also, even though the bulk resistivity was specified to be greater than 3×10^7 Ω cm.

Scheduling did not allow time to investigate the failure mechanism. The manufacturer has since found that the use of cobalt in the ferrite mixture is what gives the unexpected breakdown character.

Transmission line characteristics with impedance matching and lower standing wave voltages were relaxed and a lumped parameter RLC magnet was designed and fabricated. The current carrying conductors were insulated with a 0.4 cm layer of vacuum impregnated epoxy glass tape and a vacuum chamber was constructed of 1/8 in Mykroy material. The individual 2 in x 4 in x 4 in ferrite blocks can be readily stacked or unstacked for operation or maintenance. Even with this construction discrete mica insulation is used between blocks and between blocks and fixture to reduce arcing and electrical noise.

Thyratron-Line-Magnet System

Figure 1 is a diagram of the magnet system showing the impedances which gave the best rise time and reflection characteristics for the magnet-thyratron system. Each leg of the magnet is energized by its own energy source but both from a common high voltage supply. The 12.5 Ω charge lines are built up of four 20 m lengths of RG220/U coaxial line in parallel. The high voltage connectors at the tank interface are built in house of large RAD-LAB fittings for the shields and large banana jacks for the center conductors. These connectors have proved very practical and are very trouble free. The high voltage potential to the pulse forming cables runs 50 kV for the small kick and 74 kV for the large one.

The kick reversal for the second magnet is achieved by feeding the legs from opposite corners as those of the first magnet.

Circuit Problems and Solutions

The worst stray inductance problems occurred at the thyratron to transmission line connections and the load line terminations. Whenever parallel cables were needed it was found that each cable should have a discrete low inductance lead (such as braid) rather than a single low inductance lead which is common to all of the cables. Our efforts to reduce the leakage inductance was successful in getting the rise time (10 to 90%) down to 90 ns. An additional 15 ns reduction was attained for the smaller kick by replacing the English Electric Valve deuterium thyratrons, 3000 A, CX 1168's with larger cross section 6000 A, CX 1175's. A better matched enclosure for the thyratrons would probably provide additional bandwidth.

Figure 2 shows the load construction which gave us excellent high frequency terminations. Each load is capable of dissipating 250 W with a small fan to provide air flow. Four of the load units are paralleled to provide the needed total load.

The pulse forming lines are charged by a hard tube series regulator which is capable of charging at 30 Hz with better than 0.5% resolution.

One of the most important considerations in a reliable, low jitter thyratron firing is a healthy trigger pulse. Figure 3 is a diagram of the trigger circuit which can deliver a 0.6 μs wide pulse of 375 V into a 100 Ω load.

The High Voltage Environment

Except for the charge lines, transmission lines and high voltage supplies (in their own tanks), the high level charging and switching system is in a 1.5 m x 1.5 m x 1 m high tank of transformer oil. A cold water heat exchanger with a pump provides heat removal from the oil, which heat can reach 7500 W at 30 Hz. High voltage to low voltage power isolation is provided by a transformer as also are the thyratron triggers. The interlocks and charge controls are optically coupled.

Summary of Operation

The system has been in service now since November 1977. Most frequent electrical problems have been

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blown charge line cables at the open end where the braid is dressed away from the cable and the end is potted in silicone rubber. Different schemes are being tried to minimize the electrical stress which causes the breakdown.

Radio frequency interference has been reduced mostly by filtering power lines but a continuing effort is being waged to reduce it further. Care was also taken with the tank lids to provide a continuous conducting interface in order to have the most effective faraday shielding. Increased noise threshold of the trigger circuits from one volt up to three volts has helped to reduce misfirings.

The completed system is successful in providing a flattop pulse of up to 100 ns wide for extracting the 500 MeV beam of 188 ns revolution period.

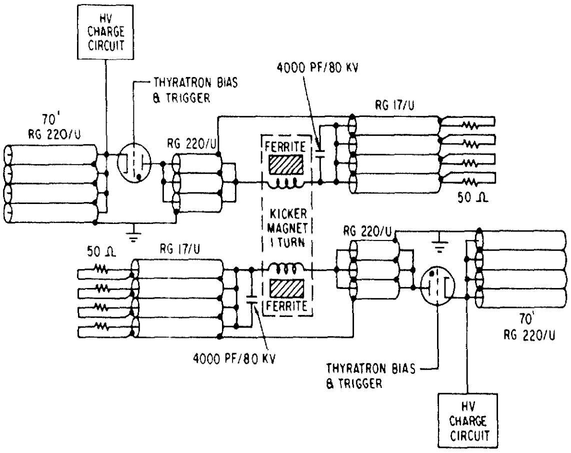

Fig. 1. Kicker schematic diagram

At low excitation levels, either kicker magnet is a useful diagnostic tool as a beam tickler for driving betatron tune resonances.

Acknowledgement

Acknowledgement is due to Mason Lieberg and Newton Oki for a major part of the systems fabrication. Thanks also to Stanley Reinke, the Systems Manager for kicker magnets, who provided the graphics data.

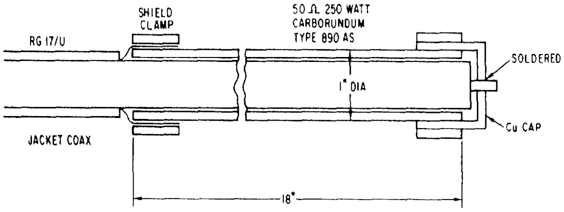

Fig. 2. Load termination construction

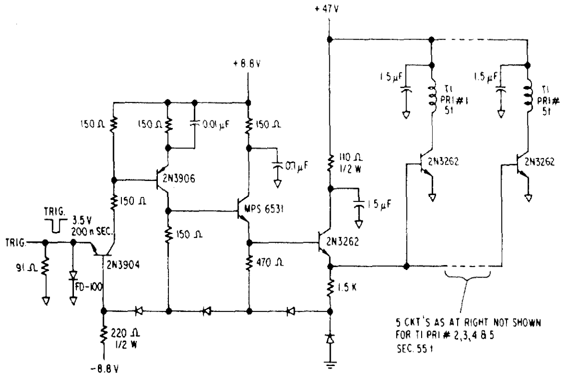

Fig. 3. Thyratron trigger citcuit. Pulse output characteristics shown in Fig. 4.

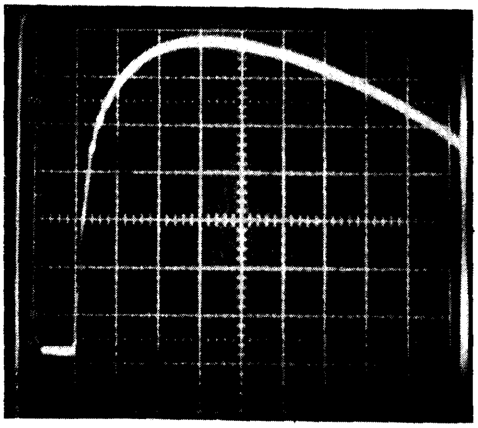

Fig. 4. Trigger circuit output into 100 ohms. Vertical sensitivity, 50 V/cm; horizontal sensitivity, 100 ns/cm.

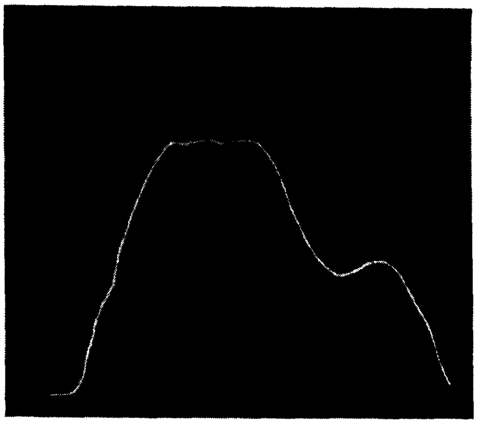

Fig. 5. Current waveform of kicker magnet. Vertical sensitivity, 500 A/cm; horizontal sensitivity, 50 ns/cm.