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SNS Extraction Kicker Power Supply Prototype Test*

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Abstract

The SNS (Spallation Neutron Source) accumulator ring Extraction System consists of a Fast kicker and a lambertson Septum magnet. The proposed design will use 14 kicker magnets powered by an Extraction Kicker Power Supply System. They will eject the high power beam from the SNS accumulator ring into RTBT (Ring to Target Beam Tunnel) through a Lambertson Septum magnet. This paper describes some test results of the SNS Extraction Kicker power supply prototype. The high repetition rate of 60 pulse per second operation is the challenging part of the design. In the prototype testing, a 3 kA damp current of 700ns pulse-width, 200 nS rise time and 60 Hz repetition rate at 32 kV PFN operation voltage has been demonstrated. An Extraction kicker power supply system design diagram is depicted.

Introduction

The National Spallation Neutron Source includes a 1 GeV Linac, two High Energy Beam Transfer lines and an Accumulator Ring with a circumference of 220.7 m. It is designed to accumulate the proton beam to an intensity of 2×10^{14} proton per pulse with an 1 GeV kinetic energy, via charging exchange injection of proton (H^-) in 1 mS. After the beam is accumulated to required intensity, it will be extracted in one turn form the ring to high energy beam transfer line by a extraction system which consists of a full aperture kicker, a Lambtson septum magnet and a dipole magnet. The extraction repetition frequency is 60 Hz.

Extraction will take place in one of the accumulator ring's long straight section. Fast pulsed kicker magnet extracts the proton beam with a kick strength of around 18 mrad. The kicker system includes ferrite core magnet, pulse forming network, high voltage charging power supply and the system control. There are 14 ferrite core magnets divided into two groups, seven magnets each. Each ferrite magnet is driven by individual PFN (pulse forming network).

In the accumulator ring, there is a beam gap, which last about 250 nS. Because the proton beam is extracted in one turn, a fast rise time of pulse current is needed.

To verify the design, a full voltage PFN prototype was assembled. A dummy magnet inductor was used as PFN load. Different parts were tested at full current and full voltage, which included thyratron, matching resistor, high voltage low inductance capacitor, charging resistor, reverse abort diode and other. As the SNS machine will operate at a high pulse repetition frequency, 60 Hz. Very high power will dissipate at dumping matching resistor. The emphasized test was at the critical parts, the PFN match dumping resistor. With two kinds dummy inductor loads, nice waveforms fit the parameter.

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All test results from the prototype would be a good help for the first PFN article design.

PFN Design Parameter and Simulation

SNS proton accumulator ring is a high beam energy and high beam intensity accumulators ring. According the beam energy and the beam intensity, an initial design of fourteen rectangle ferrite magnets was used to kick the proton beam out of the accumulator ring. Each kicker will kick the beam from 1.45 mrad to 1.8 mrad. A large aperture of the kicker magnet was designed to decrease the beam loss, because of a very high intensity of beam in the accumulator ring. The beam stored in the accumulator ring has a gap time of 250 nS; therefore a fast current pulse rise time is required. Following is the PFN design parameters.

PFN operation voltage	30-35 kV
Maximum magnet current	3 kA
Pulse current rise time (From 5% to 95%)	200nS
Pulse flat top	700 nS
Pulse repetition	60 Hz
Pulse rise time jitter	5nS
Dummy load inductance	0.6~1.2uH

Before the PFN prototype design, a simplified pulse modulator circuit was simulated. The circuit included ten sections of LC pulse forming network, a discharging matching resistor, and discharging switch. The simulation circuit is shown at Figure 1. The load current simulation waveform is show at the figure 2.

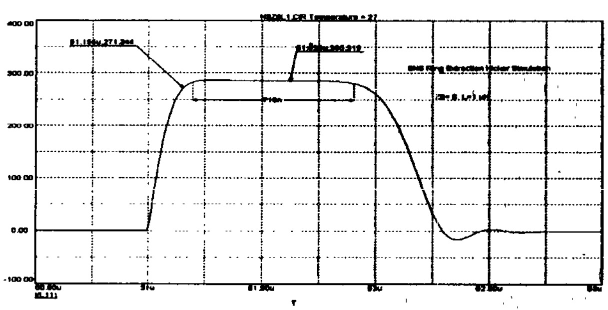

Figure 2 PFN Simulation Current Waveform

PFN Prototype

Because of the SNS machine operation reliability requirement, the critical parts used at the extraction kicker power supply have to be tested. A full voltage PFN prototype was assembled. The Pulse Forming Network was constructed of the high voltage pulse capacitors and copper coils. Ten low inductance capacitors are used as the energy storage device to meet the pulse width requirement. These were Stanley Recon Mica repetitive discharging capacitors, which were used as the energy storage device. A deuterium filled ceramic thyratron model CX1154, manufactured by EEV Limited was conscripted as the high voltage, high current fast switch to discharge the stored energy from the pulse forming network to the inductance load. The thyratron picture is shown at the figure 3. A high voltage solid diode was used to absorb the reverse voltage reflecting from the inductance load.

Figure 3. CX1154 Deuterium Ceramic Thyratron Manufactured by EEV Limited

An important test was concentrated at a high pulse power and high average power resistor. A PFN matching resistor was connected between the PFN and the thyratron. A low inductance resistor was used for fast rise time. In this PFN prototype, Non-Inductive Bulk Ceramic Resistor Assembly was selected as the high energy-dumping resistor. The peak power dissipation at the resistor assembly was about 40 meg-watt, and the average power dissipation at the assembly was 2 kilowatt. The resistor assembly incorporated with ten of Cesiwid bulk ceramic resistors connected in parallel to reduce each resistor peak current and average power dissipation. Because of the high power dissipation at the resistor assembly, two axial high CFM fans were used for cooling the resistor assembly to keep the resistor temperature lower than the maximum operating temperature.

Figure 4. Matching resistor assembly and speed up capacitor

The Prototype Test System

The SNS extraction kicker power supply prototype test system is shown at the figure 5. A fifty-kilo voltage capacitor charging power supply was used for charging the PFN to required voltage. A fast MOSFET trigger generator was used for firing the thyratron by an isolation transformer. A pulse delay generator was used to generate a charging inhibit pulse to control the capacitor charging power supply charging time and a thyratron trigger pulse to synchronize the thyratron trigger timing and the charging timing. A high voltage divider manufactured by ROSS Engineering Corp. was used for PFN charging voltage monitoring and a fast pulse response current transformer made by Pearson Electronic Inc. was used to measure the dummy load current. A thyratron auxiliary power supply was installed for control the thyratron operation status.

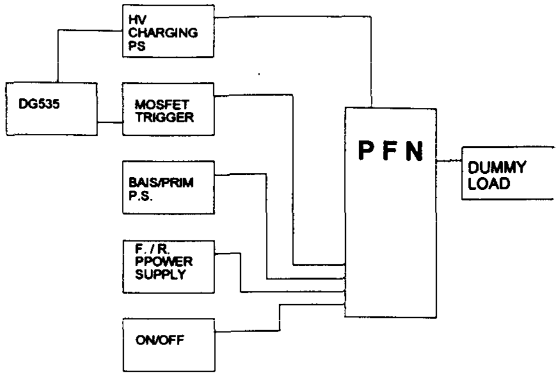

Figure 5 SNS extraction kicker prototype test diagram

Test result and conclusion

The prototype system was tested to the design voltage and peak current with a stable operation condition. The main tested parts included the thyratron, CX1154, high power PFN matching resistor assembly, and PFN capacitor bank without any damage. The PFN was tested at different voltage with a 60 Hz pulse repetition. The most critical and difficult part, matching resistor assembly was tested. The resistor assembly test stopped at more than 5 million pulses without breakdown. The resistor assembly test temperature was low than the vender specification requirement.

The inductance load current waveform is shown at the figure 6. It shows that pulse rise timing and pulse flattop agree with the simulation waveform very well. A low negative reflection was noticed.

The PFN voltage charging waveform is shown at the figure 7. The Charging time was appropriate for the 60 Hz operation repetition frequency.

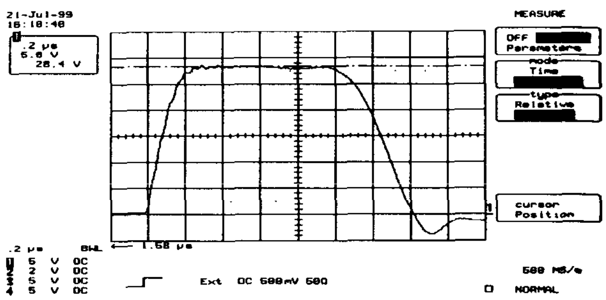

Figure 6. A PFN discharging current waveform (500A/div, 200nS/div.)

From the power supply prototype testing, the following test results were obtained:

PFN test peak voltage:	32 kV
Load peak current	3kA
Pulse repetition	60 Hz
Pulse rise time	200nS
Pules flattop	670nS
PFN charging time	14 mS

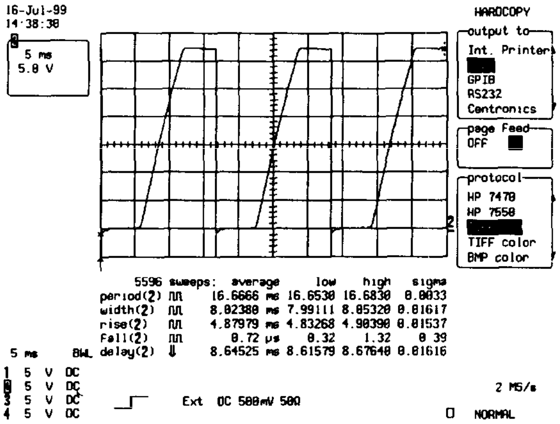

Figure 7. PFN charging voltage waveform (5kv/div, 5mS/div).

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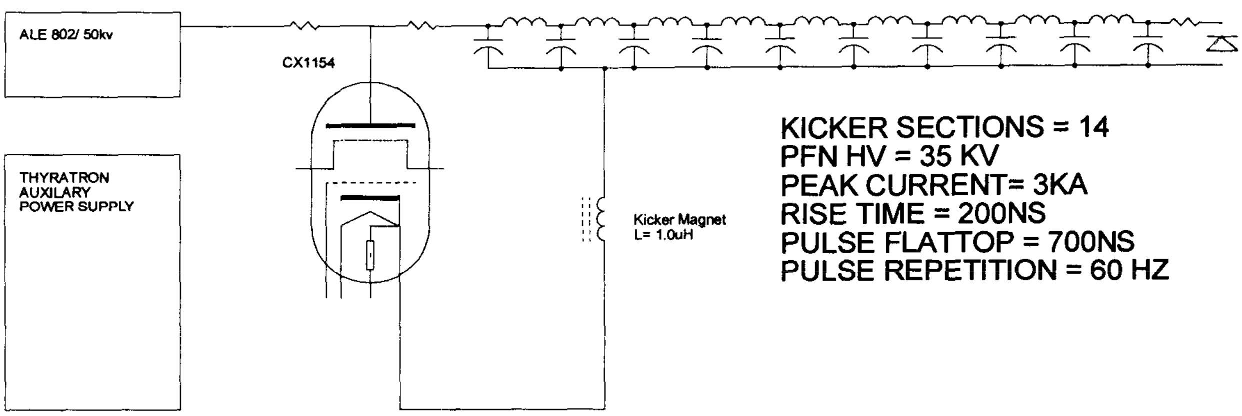

Figure 1 PFN simulation circuit