BNL-94141-2011-CP

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Presented at the 2011 Particle Accelerator Conference (PAC'11)
New York, N.Y.
March 28 – April 1, 2011

Collider-Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy
Office of Science

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AGS TUNE JUMP POWER SUPPLY DESIGN AND TEST*

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Abstract

A horizontal tune jump system has been installed to overcome the horizontal intrinsic spin resonances, which requires jumping the horizontal tune 0.04 units 82 times, 41 up and 41 down. Two quadruple magnets have been installed in AGS ring to perform this. The pulsed magnet current ranges from about 140A near injection to about 1400A later. The current pulse rise and fall time are around 100uS and flat tops time is around 4mS. These quadruples have separated supplies. This tune jump pulse power supply employees all semiconductor parts as well as the main switches. During dummy load and magnet testing, the test results showed that the power supply could meet the specification. This article will describe some details of power supply simulation, design and testing. Some test waveforms and pictures are presented in this paper.

INTRODUCTION

In order to increase the beam polarization in AGS, an upgrade project is conducted. The project includes two tune jump magnets and two individual pulse power supplies. Two magnets (Fig. 1) are installed in AGS ring I5 and J5 area. According to the physics requirement, the

Figure 1: Tune Jump Magnet in AGS Tunnel

pulse power supply will output a current pulse train to tune jump magnet to jump the horizontal tune 82 times during the acceleration of polarized protons in AGS. The power supply specifications are listed as followings:

- Magnet peak current 1400A
- Current change range 140~1400A
- Magnet inductance ~40uH
- Load resistance ~28m Ohm
- Pulse rise time 100uS
- Pulse flat top time 4mS
- Pulse fall time ~100uS
- Pulse train number 40

PRINCIPLE AND SIMULATION

The principle circuit of the AGS tune jump power supply is shown at Fig. 2. First, the energy, in charged

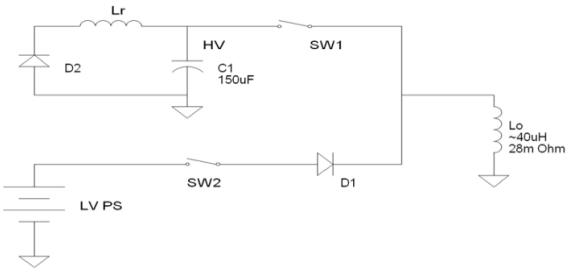

Figure 2: Tune Jump Power Supply Principle Circuit

capacitor C1, is discharged through a switch SW1 to the inductor load Lo. When the current rises up to the top of the half sine wave, switch, SW2 is turned on. The load current source is switched from C1 to LV PS. After about 4mS, SW2 will be turned off and the load current will be switched back to LC circuit continuing the rest fall down half sine wave. In fact, this scheme of the power supply can be considered as two power supplies combined, one is a LC half sine wave discharging pulse power supply and another is a DC power supply. The half sine wave pulse is divided into two parts, rise period and fall period. After the half sine wave current rises up to the top and then the current is switched to the DC power supply. And the DC power supply will keep the pulse flat top until the current is switched back to the half sine wave pulse. Lr and D2 is a flywheel circuit.

A simulation waveform result is shown in Fig. 3.

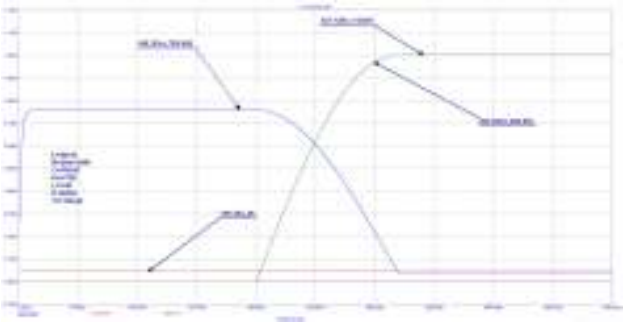

Figure 3: AGS Tune Jump Power Supply Simulation

(Current waveform (green) and voltage waveform (blue)). According to the 40uH load inductance, a 150uF capacitor is chosen to construct the LC circuit. The load current is 1400A. The capacitor charging voltage is 756V.

* Work supported by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Dept of Energy

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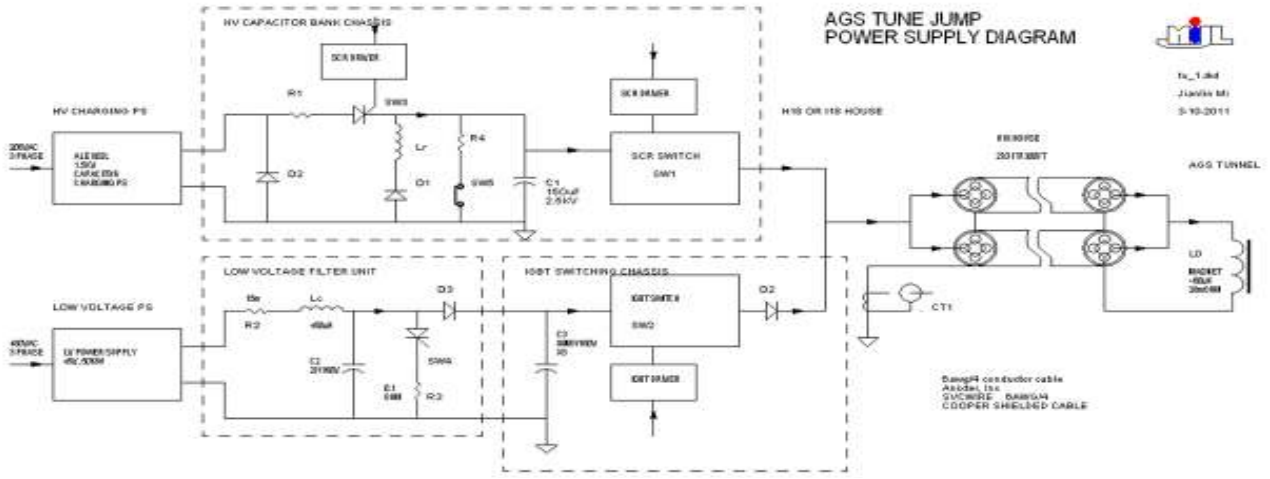

Figure 4: AGS Tune Jump Power Supply Diagram

And the low voltage power supply output voltage is around 46V, depending the load resistance 28m Ohm. The pulse rise time is about 100uS.

POWER SUPPLY DESGIN, ASSMENBLY AND INSTALATION

Two tune jump power supplies are employed to drive I5 and J5 tune jump magnets. Each power supply is, mainly consisted of three parts, high voltage capacitor bank chassis, IGBT switching chassis and lower voltage filter unit. A 45V 50kW low voltage power supply is used to charge the low voltage capacitor bank C3 through the lower voltage filter unit. A 1.5kV ALE 802L capacitor changing power supply is used to charge the high voltage capacitor C1. An IGBT chassis is used for switching the pulse rise time and pulse flat current coming from. Detail relations are shown in Fig. 4.

High Voltage Capacitor Bank Chassis

Three 50uF, 3.5kV high voltage capacitors connected in parallel are installed in the HV cap bank. The cap is made from General Atomics Electronic Systems, Inc. The HV discharging switch used a POWEREX LS43__50 SCR.

IGBT Switching Chassis

One IGBT made by ABB is used as the current switch unit. IGBT Module number is 5SNA 1600N170100 rating at 1600A 1700V. We used a CONCEPT ISD536F2 as the IGBT driver. There is a fibre optical cable connected to control the IGBT on and off. Figure 5 shows the IGBT and diode assembly with heat sink, the IGBT driver and a SCR. A simple snubber circuit is used for protection.

Low Voltage Filter Unit

This filter unit is mainly consisted of a low voltage capacitor bank, 2.0F and a 450uH inductor. A SCR and a 0.1ohm resistor discharging circuit are used for discharging the 2F capacitor's energy, after the last pulse, as the 40 pulse amplitude is increased from 140 to 1400A almost linearly. This heavy filter filtering on the LV system reduces the peak current of this supply

Figure 5: Power IGBT, SCR, Diodes and IGBT Driver

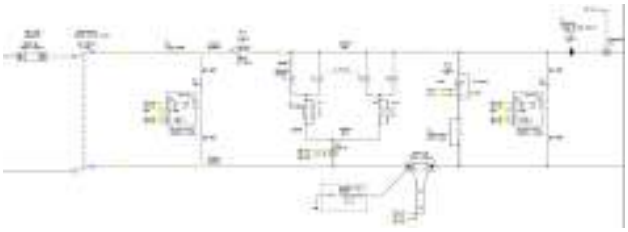

Figure 6: Low Voltage Filter Unit Circuit

Power Supply Control Rack and PLC Unit

This power supply is control by an AB® PLC unit. All power supply control boards are installed in 3U Euro card chassis. Timing control and reference remote control are implemented through PSI. Then the power supply can remote control through AGS pet control page. The pulse timing can be set by accelerator function generator. A local timing interlock circuit is used for protect the power supply from control time trigger fault and there is hardware low voltage limitation set in installed in low voltage power supply. Meanwhile a software protection is used for set the maximum high voltage and low voltage protection. A completed system installed for operation is shown in Fig. 7; it includes control rack, low voltage

power supply, high voltage capacitor bank and IGBT switching chassis. A new interlock called "Cap Bank Overvoltage" checks the low voltage cap bank output voltage, so that it does not exceed a certain voltage level. the capacitor bank output voltage ratio is 100V=10V, the interlock is set to 5.5V which would equal 55 voltage output. When the voltage level reaches 5.5 voltage on the analog card a comparator circuits trips the interlock and a signal is sent to the PLC to trip the Tune Jump power supply.

Figure 7: A Complete Tune Jump Power Supply

POWER SUPPLY TEST AND OPEARATION WAVEFORM

Before the power supply system was installed into the machine, the power supply was tested with a dummy load and magnet load and the real tune jump magnet load. The test was completed in two approaches: long time high power test and real pulse function test. Test waveform shows that the rise time and fall time meet the specification. The peak current amplitude reached to 1500A and the rise time and fall time waveforms showed in Fig. 8.

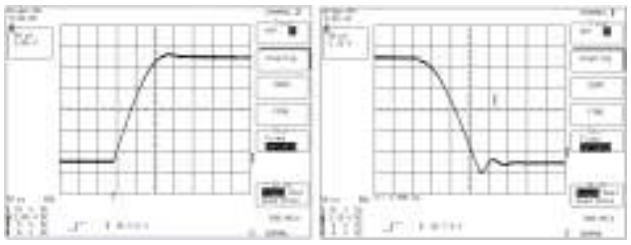

Figure 8: Dummy Load Test Waveform, Current Peak 1500A, and Time 50uS/div

AGS tune jump power supply operation current and voltage waveform is showed in Fig. 9. The current amplitude is range from 140A to 1400A in peak.

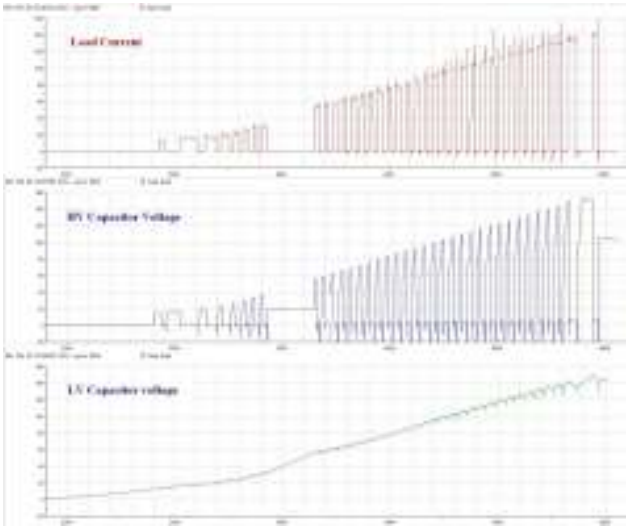

Figure 9: Operation Waveform

Currently, the two tune jump power supplies are commissioned into the accelerator operation. The power supply operates well and reliably

CONCLUSION

Two AGS tune jump power supplies has been installed in AGS facility in a relatively short R&D and assembly period. The system operates well and a good beam polarization (higher than 70%) in AGS has been reached with other machine unit updates.

ACKNOWLEDGMENT

The authors would like to thank all CA department personals who give this project very help and support. And especially K. Hartman did a prominent work in assembly, installation and testing. And J. Addessi, S.Perlstein, F. Dusek, G. Hubbard and J. Sanfilippo had a good contribution. R. Zapasek managed manpower and procurement for this project with excellent quality.

REFERENCES

[1] J. W. Glenn and et al., “AGS FAST SPIN RESONANCE JUMP, MAGNETS AND POWER SUPPLIES”, PAC2009

[2] J. W. Glenn and et al., “AGS Tune Jump System to Cross Horizontal Depolarization Resonances Overview”, PAC2011