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RHIC GAMMA TRANSITION JUMP POWER SUPPLY PROTOTYPE TEST*

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Abstract

This paper describes the principle and test results of the prototype RHIC Gamma Transition Jump Power Supply. The jump power supply principle is introduced and illustrated along with diagrams in this paper. The prototype is built with Insulated Gate Bipolar Transistors (IGBT) as current direction switch components. Optically coupled IGBT drivers are used for the jump control switch. The jump time among the power supplies is synchronized from 40 to 60 milliseconds to meet the RHIC beam transition-crossing requirement. The short jump time is needed to avoid particle loss and to preserve the initial bunch area during the transition, thus successfully transferring the ion beams from the acceleration RF system to storage system. There are a total of twenty four jump power supplies that will be used. They synchronously switch the direction of the magnets current while the beam is being accelerated through the transition to reach the top storage energy. Each power supply will energize a group of super conducting magnets, which consists of four magnets that are connected in series. At the end, test results are listed, accompanied with the dummy load current waveform and prototype power supply picture.

1 INTRODUCTION

Protons and ions are accelerated and stored in the Relativistic Heavy Ion Collider (RHIC). With the exception of protons, all ions injected into RHIC from the Alternating Gradient Synchrotron (AGS) are below the transition energy. Consequently, the ions have to be accelerated through transition to reach the top energy for storage. The acceleration is provided by the RF system. In order to successfully transfer the ion beams from the injection energy to the storage energy, it is of primary importance to avoid particle loss and to preserve the initial bunch area during the transition crossing.

It has been shown that the transition crossing can be achieved with no particle loss and negligible bunch-area growth, when a gamma transition jump is employed in a time period of 40 ms to 60 ms.

There are twelve sextants at the RHIC, six sextants in blue ring and another six sextants in yellow ring. There are eight gamma transition jumping quadruple magnets at each sextant.

At each sextant, two power supplies energize eight magnets. The first two magnets and the last two magnets are connected in series and are powered by a jump power supply. The other four magnets are connected in series and are energized by another jump power supply. The layout of the magnets and power supplies at one sextant are shown in figure 1. There are a total of 94 quadruples magnets are employed by both the yellow and blue super conducting magnet rings. There are total twelve power supplies for each super conducting ring γT jumping system. There are total 24 power supplies driving the twelve sextant magnets.

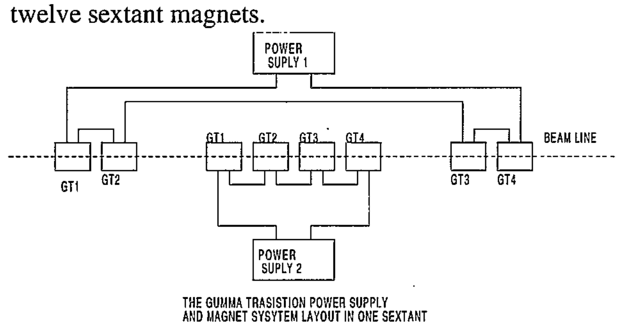

Figure 1: γT P.S. and Magnet system Layout Diagram

2 γT JUMP P.S. REQUIREMENT AND SPECIFICATION

The γT Jump Power Supply is a negative feedback current regulated power supply used for energizing four quadruple magnets. The peak output current is ±40A. The operating current amplitude demanded is dependent on the magnetic field, which tracks the ion beam energy in the RHIC storage ring. The power supply output current amplitude should track the ion beam energy from injection energy to storage energy. The power supply should have a current direction jump function, to avoid beam loss, from positive direction to negative direction or from negative to positive, it depends on the quadruple magnet location. The current direction jumping should be completed in 40 milliseconds to 60 milliseconds. The required magnet current waveform is shown in figure 2. The power supply main specifications follows:

Total Number of power supplies	24 (12 P.S. each ring)
Maximum output voltage	20V
Output Current	± 40A
Current jump time	40 to 60 ms
Output current stability	0.1 %
Load inductance around	120 mH
Load resistance	260 mΩ

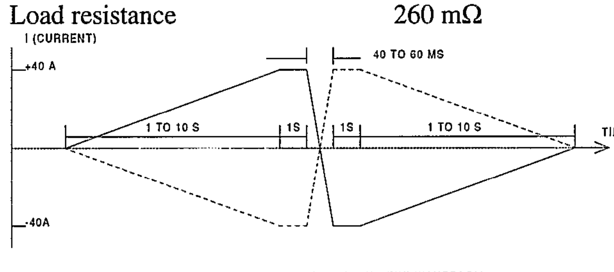

Figure 2: GT P.S. Current Waveform Demand

*Work performed under the auspices of the U.S. Department of Energy

3 THE PRINCIPLE OF THE γT JUMP POWER SUPPLY

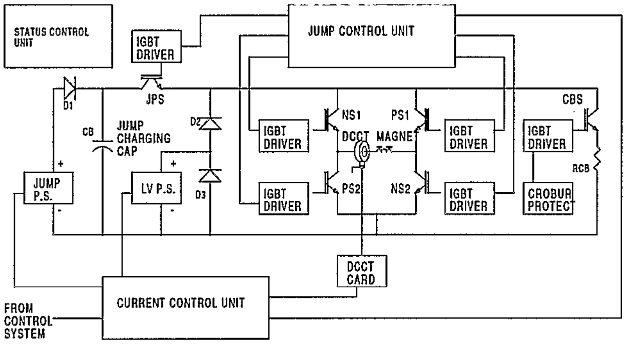

Figure 3. GT Power Supply Diagram

Figure 3 is a diagram of the gamma transition power supply. Four IGBTs, (NS1, NS2, PS1 and PS2) consist of a current direction switch bridge to output a polarity changeable current to the magnet load. The IGBT pair PS1 and PS2 conducts positive direction current. The negative direction current is delivered by another IGBT pair (NS1 and NS2). A lower voltage power supply (LV P.S.) is used as the main power supply, which can deliver enough output current to current direction switch bridge through a diode D2. The current control unit controls the current output. The current amplitude is depended on the current reference from the control system. The current waveform should match the beam acceleration ramping requirement. The power supply load is four magnets connected in series with a high inductance (120mH). The load high inductance limits the current polarity jump time. A high voltage power supply is needed for the increase of the current di/dt rate while the magnet current switches from one direction to another direction. A 600V dc power supply is employed to charge a capacitor bank (CB), which consists of four dielectric capacitors. While the current switch bridge is changing the current polarity direction, a moderately long pulse is sent to the IGBT JPS driver to turn on the JPS IGBT. A high enough voltage is added crossing the inductance load to increase the load current di/dt rate and shorten the current changing time form one polarity direction to another. When the current, which is detected by DCCT, reaches the same absolute amplitude, the jump controller unit turns off the IGBT JPS. Then the load current is delivered from the lower voltage power supply through the IGBT bridge. The current polarity changing is completed. During the current jumping time the low voltage power supply (LV P.S.) keeps the same output voltage.

4 PROTOTYPE MAIN PARTS

There are several main parts are chosen for the prototype.

4.1 Lower Voltage and Jump Power Supply

A XANTREX Model 20-60 lower voltage power supply is used as the main power supply, which is a low noise, precisely regulated, variable DC power supply. This is a programming power supply. It can provide a 20V, 60A DC current in voltage or current regulated mode. A small DC to DC 1 KV power supply, model 1C24-P60 from ULTRAVOLT INC, is used as the jump power supply to charge the jump capacitor bank, This high voltage power supplies operating voltage is set to an output voltage less than 310v.

4.2 IGBT and Driver

Six IGBTs: NS1, NS2, PS1 PS2, JPS1 and CBS are manufactured by the POWEREX. Three PM150DSA 120 IGBT modules were chosen for this power supply. Each module has two IGBTs connected in series. This is an intellimode intelligent high output power IGBT module. Each IGBT can deliver 150 Amperes, with a 1200 voltage collector emitter voltage. This is an isolated base module designed for power switching applications to 20kHZ. The built in control circuits provide optimum gate drive and protection for the IGBT and the free wheel diode power device.

Three IGBT driver boards (APS-1036) from APS (Applied Power System Co.) were chosen to excite the IGBTs. There is optically coupled isolation of the IGBT driver. There are two IGBT drivers on one board. Each driver board can excite one IGBT module.

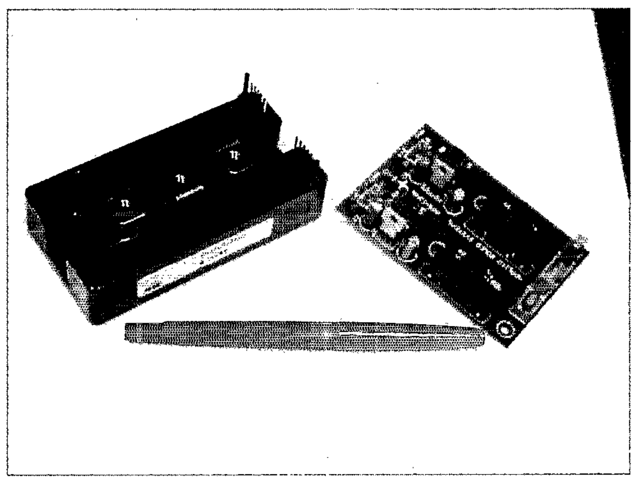

Figure 4: IGBT PM150DSA120 and IGBT Driver.

4.3 Control Cards and Buffer Board.

The power supply control system consists of seven control cards divided into three functions. The three functions are the power supply status control; current regulator control and current jump control.

The status control unit includes the Control Card and Digital Isolation Card. These units manipulate the power supply ON/OFF and interlock protection. The protection involves fan air flowing stop interlock; IGBT heat sink over temperature; IGBT overcurrent; capacitor over voltage protection and etc.

The current control unit includes the DCCT card; analog signal buffer card and current regulator card.

The jump control card controls the current polarity switch bridge and jump switch. A magnet load over voltage protection, also called the super conductor quench protection, is necessary. If the voltage escalates to high than the setting value, the quench protection will act and the jump control card sends a fire pulse to the CBS dumping the magnet energy to the dumping resistor RCB

An Isolation Buffer Amplifier Board is installed in the power supply chassis for signal processing and communication between the power supply and the control units.

5 PROTOTYPE TEST RESULTS

The gamma transition jump power supply prototype was assembled and tested. Figure 5 shows the power supply prototype chassis. An inductor was connected to the prototype as the power supply dummy load. The power supply can follow the input reference voltage very well (around 0.5%) and the current stability fits the specification. This test concentrates on the current switch and polarity jumping. The power supply maximum out put current is ±60A and the current jumping time is 40 mS. The current jump overshot is less than 1%. One of the dummy load current jumping waveforms is shown at figure 6.

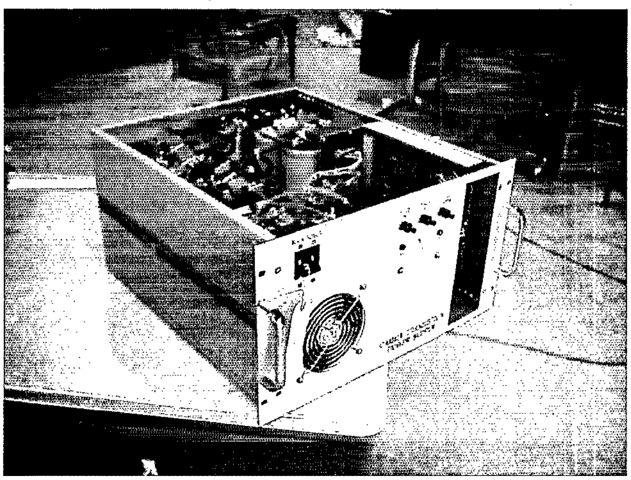

Figure 5: Picture of Power Supply Prototype.

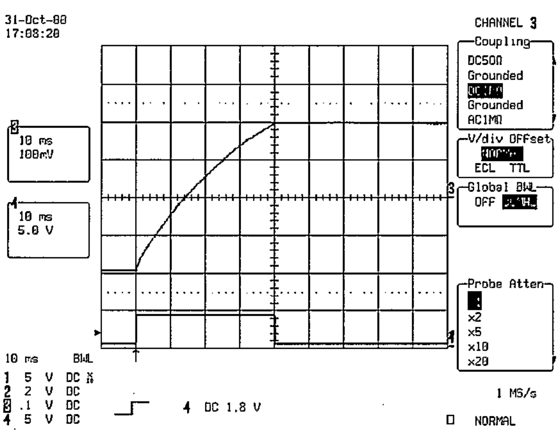

Figure 6: Dummy Load Jump Current Waveform (10A/div, 10ms/div)

6. CONCLUSIONS

The prototype power supply test meets the design specifications. The current jump time can be controlled from 40 ms to 60 ms. There are a total of 24 gamma transition power supplies that have been manufactured by the vendor. The power supplies are being installed into RHIC ring. Each power supply has been tested before it is installed into the ring. The power supply system commissioning has begun.

7 ACKNOWLEDGEMENTS

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8 REFERENCES

[1] Collider-Accelerator Department, BNL, "RHIC Design Manual",

[2] J. Kewisch, "Gamma Transition Jump with quadrupole"

[3] W. Louie, "RHIC Gamma Transition Power System"