OVERVIEW OF THE RHIC INSERTION REGION, SEXTUPOLE, AND SNAKE POWER SUPPLY SYSTEMS*

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Abstract

The Relativistic Heavy Ion Collider (RHIC) was commissioned in 1999 and 2000. RHIC requires power supplies to supply currents to highly inductive superconducting magnets. The RHIC Insertion Region (IR) contains many shunt power supplies to trim the current of different magnet elements in a large superconducting magnet circuit. There are a total of 237 Insertion Region power supplies in both RHIC rings. RHIC also requires sextupole power supplies. One sextupole power supply is connected across 12 sextupole magnets. There are a total of 24 sextupole power supplies in both rings. Snake magnets are also a part of the RHIC ring, and these snake magnets also require power supplies. There shall be a total of 24 snake power supplies in both rings. Power supply technology, connections, control systems and interfacing with the Quench Protection System will be presented.

1 IR POWER SUPPLIES

The IR Region consists of both monopolar and unipolar power supplies (p.s.'s). The types and quantities of IR p.s.'s are listed in Table 1.

Table 1: IR Power Supplies

Power Supply	**Polarity**	**Voltage (V)**	**Current (A)**	**Quantity (2 rings)**
Main p.s.'s				
Quad H/V Trim	Mono	40	300	2
Insertion Dipoles				
Type A	Mono	20	2000	14
Type B	Mono	20	600	7
Insertion Quads				
Type A	Bi	15	150	96
Type B	Bi	15	300	14
Type C	Mono	15	200	48
Type D	Mono	15	300	24
Type E	Mono	15	450	16
Type F	Mono	20	600	16

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1.1 Monopolar Power Supplies Description

The monopolar p.s.'s are current regulated DC p.s.'s with an inner voltage loop. The AC input to these p.s.'s is 3 phase 480VAC for the 2000A and 600A units. The AC input to the rest of the lower current units is 3 phase 208VAC. All of the monopolar p.s.'s utilize a 12 pulse SCR bridge Power Converter with an LCRC output filter. The current sensing element for the current feedback to the current regulator is a DCCT. The required reproducibility is 0.01% of the maximum output current. All of these types of p.s.'s have a 100% and 50% voltage tap setting.

1.2 Bipolar Power Supplies Description

The bipolar p.s.'s are also current regulated DC p.s.'s with an inner voltage loop. In addition, the bipolar p.s.'s utilize a tracking voltage loop to control the DC output of a switchmode DC-DC converter. The DC-DC Converter thus acts as a Pre-Regulator for the H-bridge MOSFET Output Power Stage. The voltage across the MOSFET Output Power Stage is kept low by the tracking voltage loop to reduce the power dissipation across these MOSFETS. Two of the MOSFETS (upper) act linearly while the other two MOSFETS (lower) act like a switch controlling which direction the current flows through the magnet load. The number of MOSFETS in the Output Stage of the bipolar 150A p.s.'s is 24 and the number of MOSFETS in the Output Stage of the bipolar 300A p.s.'s is 48. The AC input to these p.s.'s is 3 phase 208VAC.

1.3 Nesting of IR Power Supply Systems

In any sextant of RHIC there can be as many as 7 p.s.'s nested inside one p.s. Due to this nesting, all of the IR p.s.'s must float off of ground. The DC output terminals of the 2000A and 600A p.s.'s have been put through high potential testing of 2500VDC because they are on the dipole circuit which has a much higher inductance than the quadrupole circuit. For this reason the 2000A and 600A p.s.'s will float off of ground to a higher voltage. The lower current units have been put through high potential testing of 1600VDC because they are on the quadrupole circuit, which floats off of ground to a voltage that is lower than the dipole circuit. The nesting of the IR p.s.'s and the use of superconducting magnets also created complex time constants for the current regulator loop which made it very difficult to stabilize the current loops of these p.s.'s. In some cases the measured admittance of the p.s. load was not a pure inductance but also had some capacitive components.

2 SEXTUPOLE POWER SUPPLIES

There are a total of 24 sextupole p.s.'s in both rings. All of the sextupole p.s.'s are located in the alcoves. The sextupole p.s.'s are current regulated DC p.s.'s with an inner voltage loop. In addition to this inner voltage loop these sextupole p.s.'s have a linear MOSFET output stage with a 12 pulse SCR Pre-Regulator. These p.s. use a DCCT as the current sensing element. The required p.s. current reproducibility is 0.025% of maximum current rating. The p.s. maximum ratings are 100Volts at 100Amps. The AC input is 3 phase 480V at approximately 14 Amps maximum. The maximum voltage ripple is 0.2Vpp in the 100% tap setting. The p.s.'s have a 70V tap setting as well.

2.1 Sextupole Power Supply Magnet Load

Each Sextupole p.s. is connected across 12 sextupole magnets. The 12 sextupole magnets are all connected in series. These magnets are connected in two families, focussing and defocusing in each arc. The inductance of each sextupole magnet is about 0.83H. When twelve sextupole magnets are connected in series the total inductance the p.s. sees is about 10H. The only resistance the p.s. sees is the warm DC cables to each of the sextupole magnets. This resistance is approximately 0.42 ohms.

3 SNAKE POWER SUPPLIES

There shall be a total of 24 snake p.s.'s in both rings. All of the snake p.s.'s are located in the alcoves. The snake p.s.'s shall be installed in only 2 of the 6 alcoves for the current running period of 2001. Each p.s. is rated at a maximum of 15Volts at 440Amps DC. The snake p.s.'s are current regulated switchmode p.s.'s with a DCCT current sensing element. The switchmode power section is a commercially available voltage regulated p.s., which is inside a BNL designed current regulator. The snake p.s.'s also communicate with a NODE Card to MODICON PLC. Two snake p.s.'s are required to power one snake magnet. Each p.s. powers 2 coils that are in series in each magnet.

4 CONTROL SYSTEM

The control system used for the IR p.s.'s, sextupole p.s.'s and snake p.s.'s uses the same components and technology except for some minor differences.

4.1 IR Power Supply Control System

All of the insertion p.s.'s use the same 3u chassis control bucket. See Figure 1. In this control bucket resides the fiber optic interface card, the current regulator card, the buffer card, the DCCT electronics card, the voltage regulator card, the digital isolation card and the control card. The fiber optic interface card receives the p.s. current setpoint over fiber and converts it to an analog current setpoint utilizing a 16bit D/A. This analog setpoint is sent over the 3u control chassis backplane to the BNL

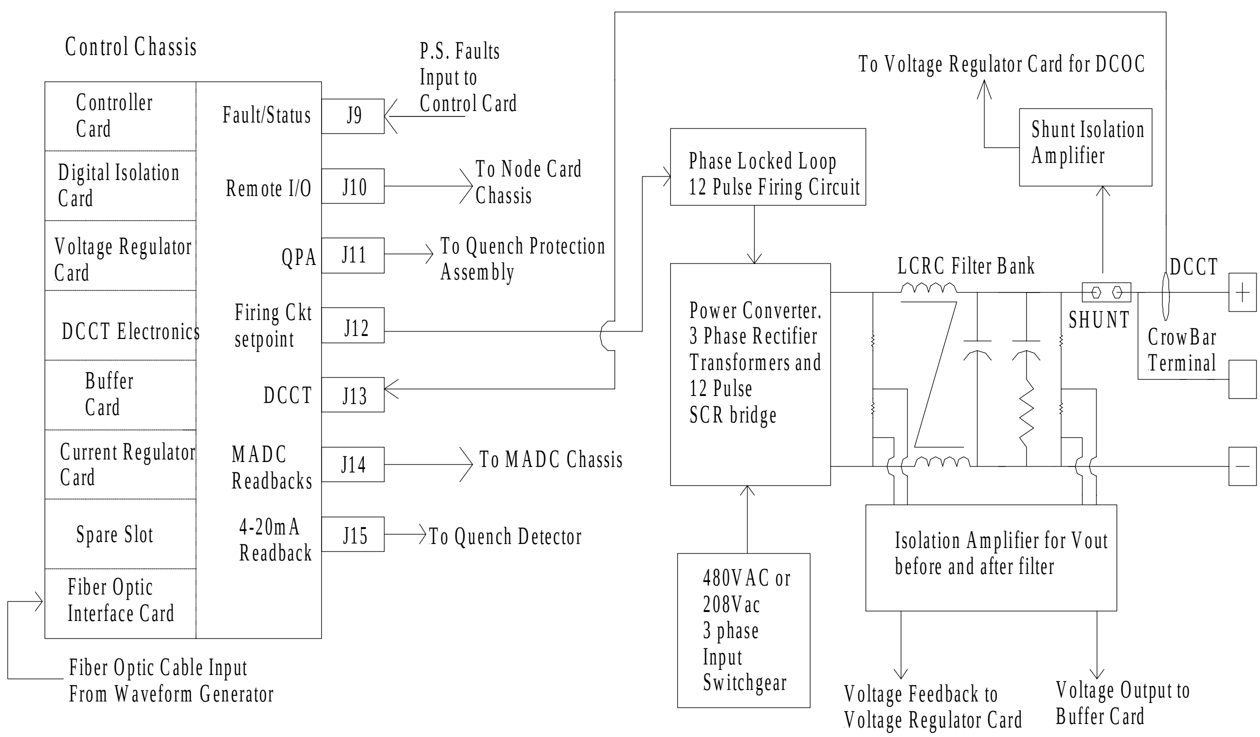

Figure1: Monopolar I.R. P.S. Block Diagram

designed current regulator card. This current regulator card has a removable PC board for adjusting time constants to stabilize the p.s. current loop. The buffer card sends four analog signals back to the Multiplexed Analog to Digital Converter (MADC). These four signals are p.s. current setpoint, output current, output voltage and p.s. current error. The DCCT electronics card and voltage regulator card were purchased from an outside vendor. The voltage regulator card also contains the isolated shunt feedback voltage, which is used in the DC overcurrent circuit, which is built into the voltage regulator card. The digital isolation card receives commands from a Node card which is external to the p.s. and sends p.s. statuses back to this Node card. The Node card communicates over a MODBUS Plus network to a MODICON Programmable Logic Controller (PLC). This PLC communicates with the front end VME computer over an Ethernet connection. A NODE card is an inexpensive multichannel I/O device designed at BNL which receives commands from the PLC and distributes these commands out to as many as 12 p.s.'s. The p.s. statuses are also sent back to the NODE card and then onto the PLC from the NODE card. The control card controls which state the p.s. is in and monitors the p.s. faults and trips the p.s. to a fault state if a fault occurs. This control card employs a microprocessor to control the p.s.. The insertion p.s.'s must also interface with the quench protection system. There are connections made to the Quench Protection Assembly (QPA) and the Quench Detector. The p.s. sends the p.s. status to the QPA and any QPA faults are sent back to the p.s. as well. The p.s. output current is also sent to the Quench Detector using a 4-20mA readback.

4.2 Sextupole Power Supply Control System

The control system for the sextupole p.s.'s is very similar to the IR control. Each sextupole p.s. receives an analog setpoint from an external, rather than an internal, fiber optic interface card. This fiber optic interface card receives the setpoint over fiber and converts it to an analog current setpoint utilizing a 16 bit D/A. The OFF, STANDBY and ON Commands to the p.s., as well as the statuses from the p.s., are sent to a NODE CARD which then communicates over a MODBUS PLUS network with a MODICON PLC. This MODICON PLC communicates with the VME front end computer over an Ethernet connection There are four analog readbacks which (MADC). These four signals are Setpoint, Output Current, Output Voltage, and P.S. Current Error. The sextupole p.s.'s must also interface with the quench protection system. The p.s. output current is also sent to the Quench Detector using a 0-10Vreadback where as the IR p.s.'s have a 4-20mA output. The sextupole p.s.'s do not have the standard 3u chassis built into it so all of the cards in the 3u bucket from the IR p.s.'s cannot be used in the sextupole p.s. Another difference is that the sextupole p.s.'s have a ground current monitoring circuit built into them and this ground current monitoring signal is fed into the MADC's for monitoring purposes.

4.3 Snake Power Supply Control System

The snake p.s. receives an analog setpoint from an external Fiber optic interface card. This fiber optic interface card receives the setpoint over fiber and converts it to an analog current setpoint utilizing a 12 bit D/A. There are four analog readbacks which (MADC). These four signals are Setpoint, Output Current, Output Voltage, and P.S. Current Error. The snake p.s.'s must also interface with the quench protection system. The p.s. output current is also sent to the Quench Detector using a 0-10V readback.

5 CONCLUSION

These p.s.'s have operated as expected for the most part during the 1999 and 2000 runs. The emphasis has been placed on improving the reliability and improving the performance of the p.s.'s. The I.R. p.s. current errors have been reviewed and simulated extensively. Reducing these current errors is still an ongoing effort. Improving the reliability of these is also an ongoing effort. Certain components such as the DCCT electronics and firing cards have caused problems to some of the IR p.s.'s. DCCT electronics output valid indications would fail during temperature swings from hot to cold. A solution for this problem will be tested during the RHIC 2001 run. During power dips, the phase lock loop on the firing card seems to lose lock and does not recover. We have been investigating this problem for some time. The sextupole p.s.'s also had a problem with the DCCT electronics when the temperature was too high. The DCCT output valid indication would also fail and trip the p.s. This was tracked down to one particular chip on the DCCT electronics board that would fail if the temperature was too high. Replacing this chip with one that had a higher temperature rating and adding air conditioning fixed this problem. A soft start circuit was also added to the sextupole p.s.'s.

6 REFERENCES

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