OVERVIEW OF THE POWER CONVERSION SYSTEMS FOR THE RHIC PROJECT

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Abstract

The RHIC Project, in construction at Brookhaven National Laboratory, will have its magnets powered with over a thousand individual power converters. The main dipole and main quadrupole magnet strings are powered separately. At the regions near the crossing points, beta* is tuned with both trim quadrupoles and shunts to the main quadrupole string. The dipoles near the crossing points are also controlled by shunt supplies. In addition, there are many correction supplies that are used either for individual magnets, or families of magnets.

As a group, the RHIC power converters range in size from the 2.2MW peak main dipole ramping supplies to the 625 W bipolar corrector power supplies. The technologies used vary from unipolar phase control to bipolar switch mode. Power to the ring magnets is distributed from the largest converters by way of superconducting cables, while the smaller units are connected with conventional copper cables.

This paper is an overview of the RHIC power converters, their distribution systems, and progress in their construction.

1 INTRODUCTION

The magnet loads in the RHIC collider are superconducting. Except for the relatively small corrector power supplies, the equipment to power these loads is located in six equipment buildings, one near each crossing point, exterior to the tunnel. The power from the supplies in the equipment buildings will be delivered to the magnets in the collider tunnel by superconducting cables, which are called Cold Crossing Bus (CCB).

The correction magnets are powered from supplies in the eighteen alcoves that are distributed around the ring. Connections are made using conventional copper cables to power leads at the individual cryostats.

Beam is transported to the RHIC collider by way of the AGS-to-RHIC (AtR) transfer line. All AtR magnets are warm designs.

To complete the list of all power conversion devices, the injection magnets (kicker and Lambertson), should be mentioned. But, they are the work of another group in the RHIC Project, and beyond the scope of this paper.

2 THE MAIN POWER SUPPLIES

2.1 Power Modules

The supplies used to power the main dipoles and main quadrupoles are similar in that they have a ramp power module to provide a high voltage to bring the magnets rapidly up to full field, and a holding power module to maintain that current in a precise and efficient way during beam storage.

The power modules are 12-pulse, phase controlled rectifiers. The dipole supply requires a 400V ramp module and a 30V holding module, while the quadrupole supply uses a 90V ramp module and a 15V holding module. All power modules have identical 5,500A output stages, to operate the main dipoles at their nominal 5,000A.

In the main quadrupole circuit, the vertical quads are put in series with the supply bus, and the horizontal quads are in series with the return bus. This lets a single, 400A, power supply be used to offset the current between them.

2.2 Output Circuit Compartment (OCC)

The OCC contains the circuitry that is common to the power module pair (ramp and holding). This includes the regulator, an LCRC ripple filter, a precision current measuring device, and quench protection circuitry.

A digital signal processor (DSP) regulator has been designed to regulate the current in the power module pairs. SCR gate signals are sent directly to each pulse amplifier in the power modules by way of fiber optic lines. In addition to the regulation function, the DSP regulator also measures the voltage subharmonics, and actively reduces them.

The LCRC ripple filter uses an air core inductor. In addition the capacitors in the filter serve to absorb energy on both sides of the switch that disconnects the power supply from the magnet string if a quench occurs.

The precision current transducer was only slightly modified from a standard design. But, testing by the manufacturer was much more intensive that usual. We used this data to insure that the devices used by the dipole supply and the quadrupole supply would track. This is important for us, as the main quadrupole circuit is completely independent of the main dipole circuit.

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3 THE INSERTION SUPPLIES

3.1 General

The insertion region contains both beam bending and focusing elements. To reduce power supply cost and minimize cold penetrations, these elements are connected in series with the main dipole or quadrupole circuits. However, provisions are made to adjust each insertion quadrupole separately as required, either through a shunt, or an auxiliary trim magnet.

3.2 Insertion Dipole Supplies

The last magnets seen by the beams before they cross are designated D0 and DX. The D0 magnets for the two beams are so close, they share a common cryostat. The DX magnet is even closer to the crossing point, and both beams are in the aperture of this one magnet.

These magnets are electrically in series with the main dipoles. Since the DX magnet is common to both beams, it is series with only one dipole string, and the blue ring was selected. With a total of twelve magnets, one on either side of six crossing points, this raises the inductance of the blue ring to 5.54 Hy. versus 4.77 Hy. for the yellow ring.

The insertion dipole supplies will be connected to the magnets via a link box. This will enable the configuration to be easily changed as a function of what species of particles are being used in each ring.

4 THE CORRECTION SUPPLIES

4.1 General

The most numerous category of supplies are the correctors. Each main quadrupole has a corrector package associated with it, and is physically in the same cryostat. Some have four different types of magnets in coaxial layers, some only have a single (dipole) magnet. Where they are used, sextupole magnets are also the same cryostat as the quadrupole and the corrector package. The leads for the correctors and the sextupole transition to room temperature at each cryostat.

4.2 Technology - Dipole Correctors

The correctors will use 50A, 20V bipolar switching power supplies. Each dipole corrector magnet is independently powered.

The design of these converters are customized for accelerator use in several ways. For example, the switching frequency is tunable over a 10% range to avoid the possibility of it occurring at an accelerator resonance. Also, their large numbers make it impractical to be part of the main quench detection system. So, each unit must sense its own output, and disconnect if a quench is detected.

4.3 Higher Order Correctors

Some higher order correctors are also independently powered, and are powered exactly the same as the dipole correctors. Other correctors are grouped into what are called families. But, they still use the same bipolar 50A supplies.

Some quadrupole corrector families are used for a γ_T jumps. The units that power these families have FET switches to disconnect the magnet family from the power source, and allow it to resonate with a capacitor. That effects a 60 mS flip in polarity, without requiring a high voltage, high power source.

In each sextant, the sextupoles are powered in two families of twelve sextupoles each, one focusing, the other defocusing. Requiring 100A, the large inductance of these magnets (530 mHy each) dictates 100V power supplies.

5 POWER AND SIGNAL DISTRIBUTION

5.1 Cold Crossing Bus (CCB)

The primary method of delivering power is the CCB. In as single cable, approximately one inch in diameter, currents summing up to 27,000A can be carried. The CCB cables lay in the four inch line that transports the helium from the valve boxes in the equipment houses to the magnets in the tunnel.

This same cable is used within the tunnel to bridge warm sections of beam tube. This happens by the triplet magnets and also by the warm injection magnets.

Using the CCB reduces both construction and operational costs. It also helps in reducing physical space requirements. This is especially useful where cables penetrate the tunnel.

5.2 Cable Tray

Without the heavy current power leads, the cable tray system is much smaller that it would otherwise have been. Still there are many uses for it. Within the tunnel, it contain cables for correctors, beam instrumentation, control signals, vacuum systems, security systems, and some AC power.

For most of its 3.8 km length, four 24 inch trays hang from the top of the tunnel. This number gets smaller as the insertion region is approached. It only takes two 24 inch trays to connect the equipment houses to the tunnel on either side of the crossing point. That is due to there being no power cables in those trays. They only carry control, instrumentation, and security cables.

Within the equipment houses themselves, the cable tray is mounted from the floor, or on to the power modules themselves. This reduces the roof loading requirements of the economical buildings.

6 PRESENT STATUS

6.1 The First Sextant Test

While construction is proceeding throughout the project, special emphasis is being placed on completing work on the first sextant. The first sextant test will be the first large scale test with all the major subsystems integrated.

6.2 Main Supplies

The main power modules have been tested and installed. The DSP regulator has been prototyped and tested. The PC boards are presently in production. The components for the OCC are in, and are being installed. The first OCC should be fully complete by August 1996.

With one sextant of dipoles and quads in series, the load will look very nearly like an entire ring of quad magnets. This will let us use the first sextant test fully test the main quadrupole supply with its rated load.

6.3 Insertion Supplies

The insertion supplies are being defined, and procurement of some units will start in FY ‘97. However, a similar type of design will be used in the first sextant test to test the interaction between the main supply and insertion quadrupole shunts.

6.4 Corrector Supplies

A contract was awarded to supply 640 units, phased over three years. The first production units are scheduled to be delivered to BNL in October of 1996. About 35 of these supplies will be used in the first sextant test.

6.5 Power and Signal Distribution

All of the CCB has been delivered, and has undergone preliminary electrical tests. Two pieces have also been installed in the section of vacuum jacketed piping that will be used for the sextant test. The CCB will be tested once more in this pipe, prior to the first sextant test.

Cable tray has been installed in the arc regions throughout the entire length of the tunnel. All other tray installation has been tied to the schedule of first sextant test. This means that the tray in the insertion regions, interior to the equipment houses, and from the equipment houses to the tunnel, will be completed this fall, for those areas that are part of the first sextant.