



BNL-107434-2015-CP

A new bipolar Qtrim power supply

**C. Mi, D. Bruno, A. Di Lieto, J. Drodz, G. Heppner, T. Nolan,
F. Orsatti, T. Samms, J. Sandberg, C. Schultheiss, R. Zapasek**

Presented at the 6th International Particle Accelerator Conference (IPAC'15)
Greater Richmond Convention Center, Richmond, VA 23219 USA
May 3 – 8, 2015

May 2015

Collider-Accelerator Department

Brookhaven National Laboratory

**U.S. Department of Energy
Office of Science, Office of Nuclear Physics**

Notice: This manuscript has been co-authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886/DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

A NEW BIPOLAR QTRIM POWER SUPPLY SYSTEM*

C. Mi[#], D. Bruno, A. Di Lieto, J. Drozd, G. Heppner, T. Nolan, F. Orsatti, T. Samms, J. Sandberg, C. Schultheiss, R. Zapasek
Collider-Accelerator Dept., Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract

This year marks the 15th run of RHIC (Relativistic Heavy Ion Collider) operations. The reliability of superconducting magnet power supplies is one of the essential factors in the entire accelerator complex. Besides maintaining existing power supplies and their associated equipment, newly designed systems are also required based on the physicist's latest requirements. [1] A bipolar power supply was required for this year's main quadrupole trim power supply. This paper will explain the design, prototype, testing, installation and operation of this recently installed power supply system.

INTRODUCTION

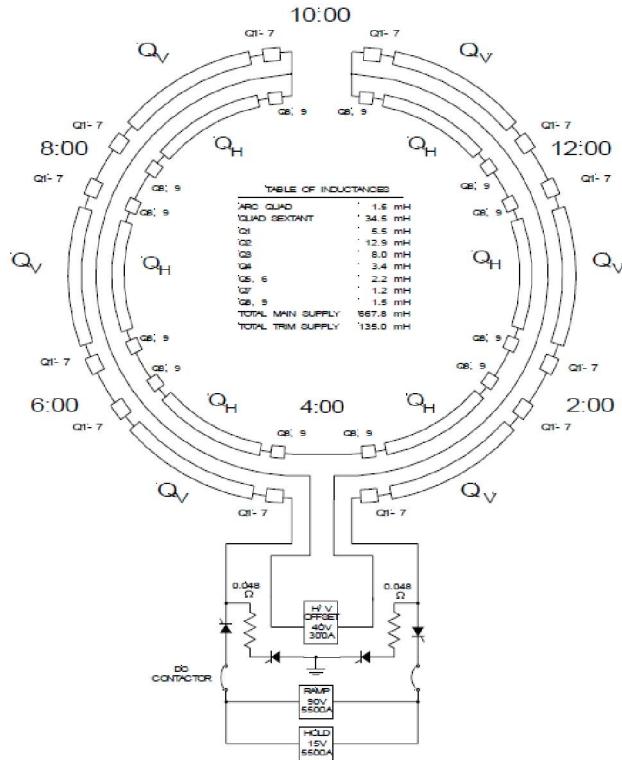


Figure 1: RHIC main quadrupole bus.

The existing quadrupole trim power supply (qtrim) was a unipolar power supply [2]. The power supply is connected in the middle of main quadrupole magnet bus (Figure 1). The original qtrim power supply was a unipolar SCR type power supply. The accelerator physicist's required this new power supply to ramp up and down with bipolar capability. In order to keep the

option of changing back to unipolar power supply setup in the future, it was decided to install a new power supply setup in an adjacent location.

DESIGN CONFIGURATION

System Consideration

We did not use the original AC power feed so we could easily revert back to the original unipolar power supply configuration if it was necessary. We have 2 qtrim power supplies installed and operating, one for blue ring and one for yellow ring. Both of them are 40V 300A unipolar SCR type power supplies. The new system is output +/-300A maximum current at 40V. However we don't need 40V based on our operational experience. A DC power supply that has 22V maximum output voltage was chosen. See maximum voltage required for ramp up in Table 1. As of the time of this writing the p.s. has been running at only a maximum of +10A during the second half of run 15 it will be operated at +130A. The voltage on the p.s. has been checked during a shutoff but this was only at 10A. [3]

Table 1: b-qtrim-ps Maximum Voltage Requirement During Ramp Up

Ramp Name	Operating Current (A)	V _{max} (V) @I _{operating} , calculated	V _{max} (V) @300A, calculated
Au14-v0	138.3	7.33	10.52
pp13-v2	183.6	8.56	10.86
pp13-v4	201	8.8	10.75
Au104	171	7.95	10.5

System Integration

The system is integrated in Figure 2 with all major components. Two DC power supplies [4] are connected in parallel for a maximum of +/-22V and +/-300A. Two h-bridge bipolar amplifiers are connected in parallel to make up the bipolar output stage, and each H-bridge amplifier is rated for +/-160A @ +/-25V [5].

AC Compartment

The main purpose of AC compartment is to pass the 3 phase 208V_{ac} into the rack and distribute the AC into 4 different AC outputs: 2 outputs for DC power supplies, 2 outputs for the H-bridge Amplifier and 1 output for the control chassis 110V_{ac} power. Also, the AC compartment interfaces with the control chassis to receive contactor ON command and it sends the contactor ON status back to control chassis. See figure 3 for rear panel view.

*Work supported by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy.
#cmi@bnl.gov

DC SOURCE

H-BRIDGE LINEAR AMPLIFIER

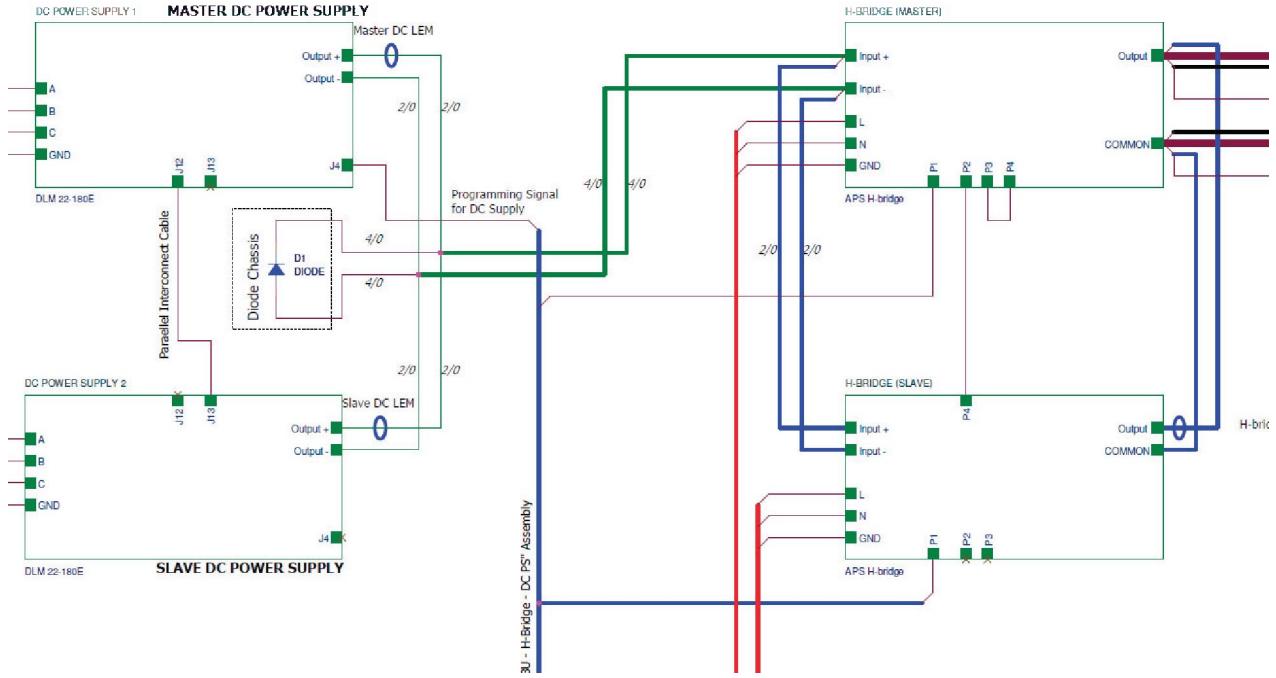


Figure 2: System integration of bipolar qtrm PS system.

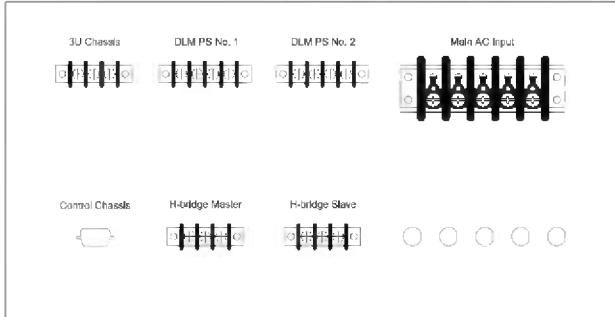


Figure 3: AC compartment rear panel layout.

Control Chassis

The control chassis is designed to interface between the RHIC system, DC unipolar power supplies, H-Bridge Amplifiers and AC Compartment. The control chassis interfaces to the Multiplexed Analog to Digital Converter (MADC), DC Current Transformer (DCCT), 4-20mA current readback to the quench detector and Node Card chassis (for p.s. digital commands). The control chassis also provides signal paths between the DC power supplies' and H-Bridge Amplifier's. An in-house designed isolation amplifier board was utilized to isolate the voltage setpoint, output voltage readback, output current readback and DC power supply's current limit setpoint. Another in-house designed circuit board is used to provide the DC power supply's current limit adjustment. An interface board was also designed to receive the interlock signals from both parallel DC power

supplies. Figure 4 is showing a partial view of inside of control chassis.



Figure 4: Assembled control chassis (partial view).

TESTING

Testing for the new setup included local and remote operation tests. There were also error tests, bandwidth tests as well as shutoff tests that had to be performed before we could use the setup for operation in the ring. Figure 5 is showing 2 DC power supplies and 2 h-bridge output stages are in parallel connection to producing -300A at output current.



Figure 5: Bench testing with negative output current.

The tests performed included: on/off/stby, ramping the supply in both polarities, error functionality, and shutoffs. To perform the error tests, errors were simulated and confirmed to annunciate. The shutoff tests consisted of running the p.s. to low current, 30A (10%), and high current, 300A (max), then tripping the p.s. from the ON state to the STBY state. This was accomplished by either creating a DC overcurrent or by sending an OFF command or by tripping the interlocks between Quench Protection Assembly (QPA) and the power supply. The resulting current and voltage waveforms were recorded on an oscilloscope. These waveforms are critical because they show if the p.s. system and QPA are working properly during a shutoff. The shutoff tests were done with the supply on a short and on an inductive load. The output voltage ripple measurement is shown in figure 6.

Remote tests were done with the supply installed at its location for the run. The same tests were performed as the local tests but this time using remote functionality. The remote testes were done to be sure the analog and digital readbacks were all working properly. After all tests were completed the p.s. supply ran for a one week heat run to test the reliability over a long time period which is what would happen during a real RHIC run.

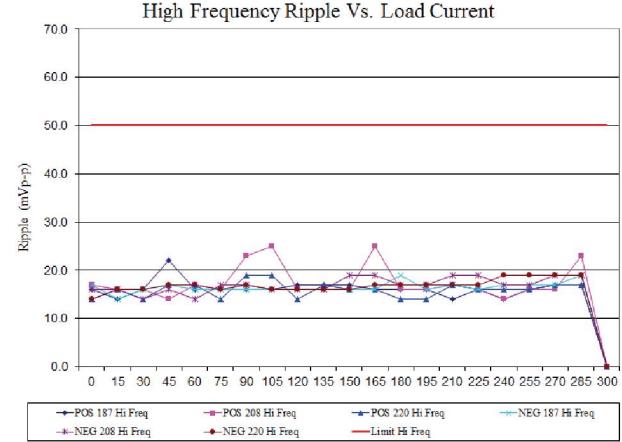


Figure 6: Output voltage ripple measurement.

CONCLUSION

The bipolar qtrim power supply system has been designed, constructed, tested, installed and commissioned prior to RHIC run 15. The system has been performing smoothly so far and should continue operate until the end of Run 15. More will be learned when the p.s. runs at higher currents.

ACKNOWLEDGMENT

The authors would like to thank everyone from RHIC power supply group. This project represents excellent team work. With everyone's participation, it has been shown that our system availability can be improved significantly by thoughtful consideration and implementation. Special thanks go to Richard Kruz, Mitch De La Vergne, Donald Gosline, Erik Rydout, Oluwafemi Bambose, Richard Negron, Brian Karpin and Jeff Wilke. Also, the authors would like to acknowledge the technical support and service from Peter Dowling, Jim Murphy, Tom Murray, and Joe Pignatelli of Applied Power Systems Inc.

REFERENCES

- [1] RHIC Retreat Website, <https://indico.bnl.gov/categoryDisplay.py?categoryId=40>
- [2] RHIC Configuration Manual (Magnet Electrical System Section), http://www.c-ad.bnl.gov/Accel/RCM_TOC.htm
- [3] Private Communication with Donald Bruno, Theodoro Samms.
- [4] Sorenson DLM-E 3kW & 4kW Series Power Supplies Operation Manual, <http://www.programmablepower.com/dc-power-supply/DLM/Downloads.htm>
- [5] Applied Power System (APS) Bipolar Linear Amplifier Operations and Maintenance Manual, <http://www.appliedps.com/component/content/article/78-news/156-bipolar-power-source-with-zero-crossover-distortion>