

ATF2 HIGH AVAILABILITY POWER SUPPLIES*

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Abstract

ATF2 is an accelerator test facility modeled after the final focus beamline envisioned for the ILC. By the end of 2008, KEK plans to commission the ATF2 [1]. SLAC and OCEM collaborated on the design of 38 power systems for beamline magnets. The systems range in output power from 1.5 kW to 6 kW. Since high availability is essential for the success of the ILC, Collaborators employed an N+1 modular approach, allowing for redundancy and the use of a single power module rating. This approach increases the availability of the power systems. Common power modules reduces inventory and eases maintenance. Current stability requirements are as tight as 10 ppm. A novel, SLAC-designed 20-bit Ethernet Power Supply Controller provides the required precision current regulation. In this paper, Collaborators present the power system design, the expected reliability, fault immunity features, and the methods for satisfying the control and monitoring challenges. Presented are test results and the status of the power systems.

INTRODUCTION

The Power Conversion Department [2] at SLAC and OCEM [3] collaborated on the design of 38 power systems for beam line magnets in the ATF2, which were delivered and installed at KEK in June 2008. Since high availability is essential for the success of the ILC, ATF2 is outfitted with an N+1 modular power supply approach, allowing for redundancy and higher availability. A novel, SLAC-designed 20-bit Ethernet Power Supply Controller provides the required high precision current regulation. The power supply system, Figure 1, is integrated by a control system built on the EPICS platform.

POWER SYSTEM

The ATF2 magnet power supply system consists of three major components: the bulk power supply (BPS), high-availability power supply (HAPS) and an Ethernet power supply controller (EPSC) [4]. ATF2 will require 38 unipolar power systems with current requirements ranging from 50A to 200A. The BPS provides the raw dc power to the HAPS. The HAPS uses power modules with output ratings of 30V 50A and are configured parallel for the desired output current with N modules and one extra for redundancy. The EPSC provides precision output current regulation from the HAPS to the magnet. The power system is integrated with an EPICS control system for remote control and monitoring.

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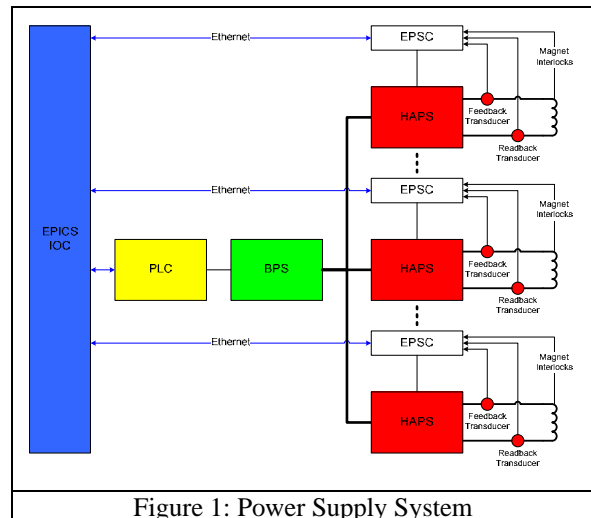


Figure 1: Power Supply System

Bulk Power Supply

The BPS provides a regulated dc-voltage source to the HAPS. Collaborators use a 40V 375A for the BPS, which powers up to seven HAPS. A PLC interface provides remote operation through EPICS and local operation with a touch panel. The PLC also monitors the output for unsafe output conditions and provides a soft start for the HAPS.

High Availability Power Supply

The HAPS design is based on the Diamond Light Source power supplies, which uses current-mode buck converter modules, arranged in an N+1 configuration for the desired current and redundancy [5]. Power modules share current within 5%. When a module fails, the controller detects the current drop and automatically increases the current output of the remaining modules. Collaborators used the same configuration and fundamental design, with some additional features.

The HAPS, Figure 2, include basic power supply functions including: on/off control, fault reset, on/off status, ready status, reference, output voltage read back, and ground current read back. The power supply also self-protects in case of overvoltage, overcurrent or when more than one power module fails. To fully accommodate the controls and diagnostics of the HAPS, a serial interface was developed. Through a serial link between the EPSC and HAPS, operators have on/off control, current read back and fault read back for individual power modules.

The power modules plug into a crate that can accommodate up to five power modules for 200A. The 50A HAPS have a unique crate that houses two power supplies in one crate to reduce rack space. Power

modules are inserted through the front of the crate allowing for easy replacement.

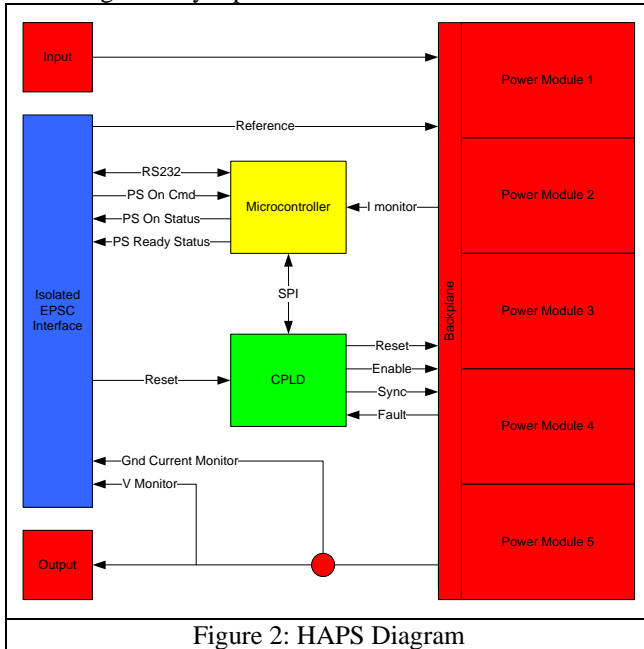


Figure 2: HAPS Diagram

Ethernet Power Supply Controller

The EPSC provides the precision current control by closing an analog control loop on the HAPS with precision current transducers [6]. With an effective 20-bit ADC and 24-bit DAC resolution, the EPSC provides 10 ppm output current regulation. Long term stability is rated at a maximum of 2 ppm/°C. The bandwidth is typically tuned to 10 Hz which is more than adequate to compensate for diurnal drifts. This also governs the recovery time when a power module fails, typically several hundred milliseconds.

In addition to providing current regulation, the EPSC also monitors magnet interlocks and provides diagnostic information on itself and the HAPS. An Ethernet interface provides the communication path to EPICS for control and monitoring.

EPICS Control System

A control system built on EPICS was developed to control and monitor the HAPS and BPS through the EPSC and PLC, respectively. Several panels were developed: a control panel for basic operation, an expert panel for diagnostics and a module panel for controlling individual power modules, shown in Figures 3, 4 and 5, respectively.

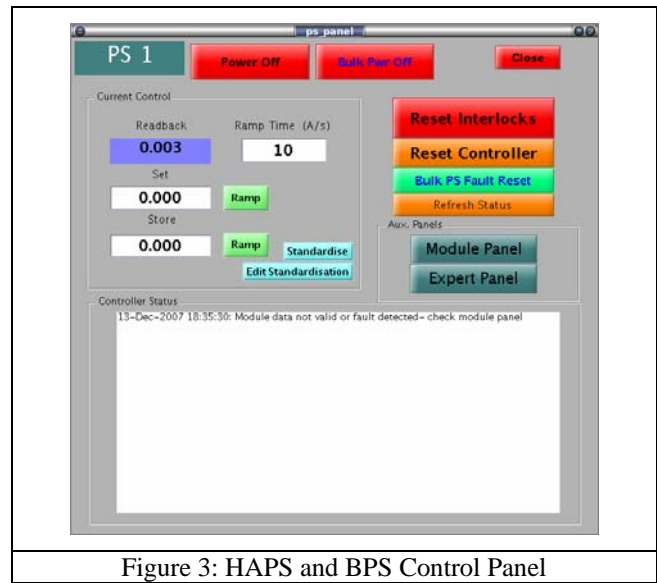


Figure 3: HAPS and BPS Control Panel

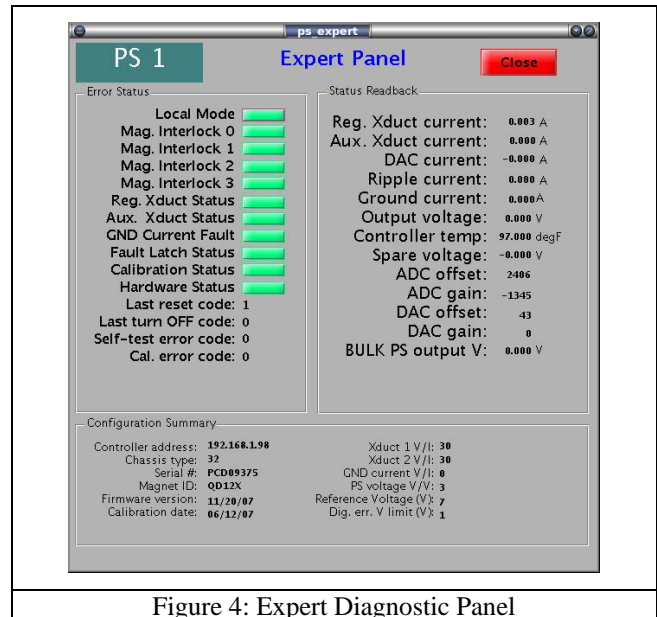


Figure 4: Expert Diagnostic Panel

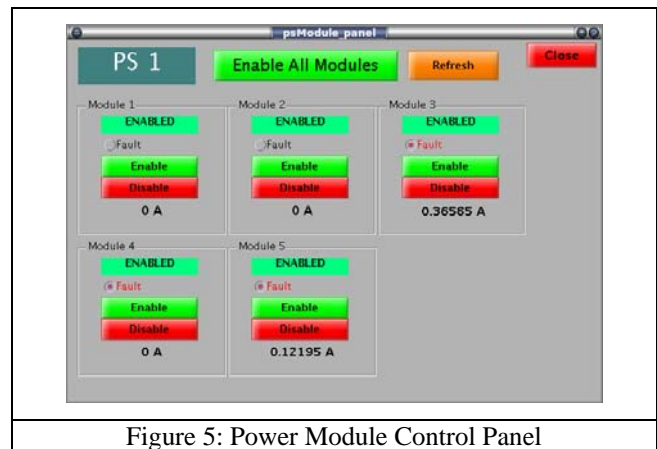


Figure 5: Power Module Control Panel

PERFORMANCE

Current Stability

The nanometer sized beam is very sensitive to magnet field fluctuations and therefore require a highly stable current from the power supply system. The bulk power supply provides a 0.1% regulated voltage source with bandwidth >1 kHz, which protects the HAPS from line variations and fast load changes. The HAPS output current is regulated by the EPSC, which compensates for temperature changes and drifts.

In a stability test, a 200A HAPS and EPSC were placed in a temperature controlled chamber. The power supply system was programmed to run at 200A, while varying the temperature between 25 to 45 °C. Figure 6 shows the output current remained extremely stable, maintaining its 10 ppm regulation, under extreme temperature changes. The error is with respect to the full scale current.

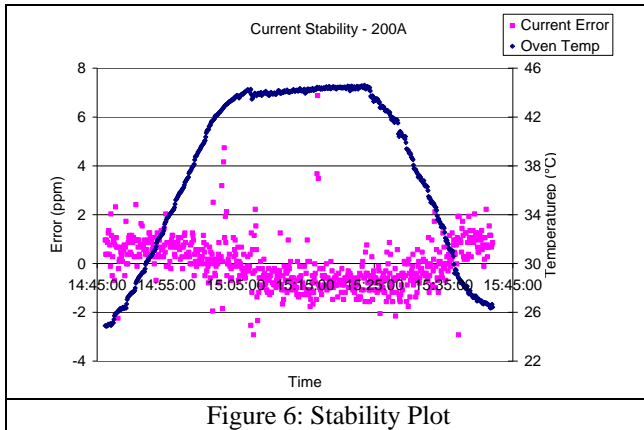


Figure 6: Stability Plot

Availability

A contemporary non-redundant power system typically consists of a power supply (MTBF=90,000 hours), a power supply controller (MTBF=150,000 hours), two current transducers (each with an MTBF=381,500 hours), and interconnecting power and control cables (MTBF=14,000,000 hours). Note that the component mean time between failures (MTBF) shown are representative of SLAC's experience. Beam is lost whenever a power system component fails. The PEP II and SPEAR 3 mean time to repair a failed system and to recover (MTTR) beam averages about 2 hours.

The ILC, as conceived during the RDR phase ending in 2007, had about 10,000 magnet power supplies [7]. The total of these systems operating for nine months out of the year (6,600) hours, with failure rates and MTTR similar to those expressed above, would exhibit a combined MTBF of 4.3 hours, resulting in 1,524 component failures and an overall availability of 0.63013. The 2,441 hours of beam loss out of the nine month operating cycle, attributable to the magnet power systems alone, is clearly unacceptable for a machine as sophisticated as the ILC.

A power system with all redundant components promises significant improvements in beam uptime. For example, replacing the non-redundant power supplies, power supply controllers, and current transducers with a one out of two redundant topology would improve the combined MTBF, reduce the failures and beam loss time, each by an order of magnitude, and increase the availability to 0.95826.

Conclusion

The ATF2's 38 magnet power systems, although small in quantity, offer an opportunity to develop and test several concepts required for high availability. In the ATF2 power systems, only the power supplies are redundant. Therefore, the ATF2 will realize availability improvement, but not as dramatic as deployment of fully redundant power systems. Limited operation of the redundant, parallel-connected power supplies has already indicated that the N+1 scheme is robust and stable. The magnet current and field rides through transients when one power module fails and the redundant power modules assume the load current. Based on their excellent performance, SLAC is developing next-generation power systems that feature all components in an M out of N configuration with some hot-swap capability for significantly increased availability.

Acknowledgements

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