

ACCELERATOR-CONTROL-SYSTEM INTERFACE FOR INTELLIGENT POWER SUPPLIES*

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Abstract

A number of high-current high-precision magnet power supplies have been installed at the proton storage ring at the Los Alamos National Laboratory Accelerator Complex. The units replace existing supplies, powering large dipole magnets in the ring. These bending magnets require a high-current supply that is precise and stable. The control and interface design for these power supplies represents a departure from all others on-site. The supplies have sophisticated microprocessor control on-board and communicate with the accelerator control system via RS-422 (serial communications). The units, built by Alpha Scientific Electronics, Hayward, CA use a high-level ASCII control protocol. The low-level "front-end" software used by the accelerator control system has been written to accommodate these new devices. They communicate with the control system through a terminal server port connected to the site-wide ethernet backbone.

Details of the software implementation for the analog and digital control of the supplies through the accelerator control system will be presented.

1.0 Intelligent Power Supply Design Overview

The new digital system consists of two line-replaceable units installed in the power supply itself that communicate externally through two sets of twisted-pair using an RS-422 communications interface. The control module can be replaced in the field from outside the power supply which greatly reduces precious machine downtime. An additional major savings is realized by the simplification of the computer control and data collection systems. The LAMPF-standard interface to the 20 year-old data collection system, which is currently being phased out, involves complex analog multiplexors, discrete digital command lines and approximately sixty-one interconnecting wires. The new LAMPF digital system can be connected to any device that can transmit a serially encoded RS-422 signal on two twisted-pair of wires. The flexibility and cost savings are enormous.

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By placing the power supply system intelligence in the controller, it becomes possible to operate a power supply system locally in a stand alone mode or connected to a remote panel identical to the front panel of the power supply controller or remotely connected to a dumb terminal, modem, terminal server or computer [1],[2].

The key design philosophy used incorporates an intelligent, microprocessor based control and communication system into a modern analog power supply.

The controller electronics is housed in a single enclosure with a minimum number of connectors for easy field servicing. Elements of the analog circuits used for load compensation or other power supply specific functions are housed in a plug-in module that can be inserted into a new controller in the field. This module also houses a digital serial memory that contains information concerning the identification and absolute limits of the power supply. The power supply configuration, set points, limits, and history log are held in a 5 year battery backed-up RAM that can be down loaded through the communications link when the controller is replaced.

Operating commands for the optional reversing switch are transparent to the operator (i. e. a command for a negative output current would automatically run the supply down, reverse the switch, and run the supply up to the new set point). A front panel display shows the set points and actual values for the load current and load voltage and the ground fault current. In addition, power supply and interlock status are displayed along with the last serial link message. A knob-controlled setting mechanism is used to manually "tweak-in" current (or other) settings. The panel has a mushroom shaped "Emergency Off" switch prominently featured on it.

The same controller is able to operate a standard SCR supply, a transistor pass bank supply or a bipolar supply. The RS-422 links are galvanically isolated and heavily surge protected. All analog to digital and digital to analog devices have four times the resolution needed to satisfy the worst case specifications.

The communications protocol uses three character ASCII commands that bear a mnemonic relationship to their function (i. e. CSP means current set point). The communication system responds in three modes a verbose human interface mode, a terse easily parsed machine control mode, and no response. This allows the controller to operate in an optimal mode for any

interface. Both the RAM and ROM in the controller were specified to be no more than 50% utilized to allow future expansion. Almost all of the program source code is written in "C++", is designed in a modular fashion and can be modified and recompiled by the user for particular applications. A programmable "Watch Dog Timer" will place the power supply controller in a "Reset" and safe condition in the event of microprocessor "insanity".

2.0 Accelerator Control System Interface

The Los Alamos National Laboratory Accelerator Complex consists of a half-mile-long 800 MeV proton linear accelerator, a number of experimental beams lines to service tens of nuclear and atomic physics experiment experiments simultaneously and a Proton Storage Ring (PSR). The PSR is in essence a time-intensity compressor ring whose function is to accumulate a one millisecond-long pulse of protons and release them in a 250 ns pulse which impinges on a tungsten target. The collision releases copious amounts of neutrons which are collimated through multiple neutron beam lines to an additional tens of experiments. The accelerator control system is responsible for coordinating and controlling the thousands of components that make up the accelerator complex. There are presently over 20,000 control points under computer control.

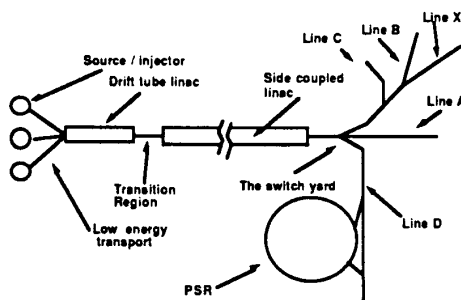


Figure 1. Schematic of the Los Alamos National Laboratory Accelerator Complex. Note that there are three sources. Particle beams of three different varieties can be accelerated. H^+ , a hydrogen nucleus (proton), H^- , a hydrogen ion, (atomic hydrogen with an extra electron) and P^- , H^- with a polarized nucleus.

The LAMPF Control System (LCS)[3] is based upon a distributed processor paradigm. There is a central VAX/VMS computer with μ VAXes distributed along the accelerator's half mile ethernet backbone, see Figure 2.

The new power supply control software must fit into this distributed processing scheme. It must work seamlessly with existing LCS programs and the

control system's run-time database. From the user's point of view, the nominal behavior of the magnet power supplies must appear to be identical to the previous "dumb" supplies. Access to the new features of the supplies must also be provided but not intrude. The control software must be able to control and read back the current set points and limits of each supply. It must have the capability of obtaining the interlock fault status of the supply. It is desirable to be able to attempt a reset of the supply from the accelerator control room if there is a momentary interlock fault.

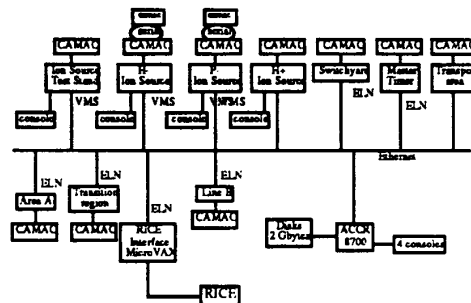


Figure 2. The topology of the LAMPF control system.

In addition, an interface must be provided so that a full ASCII dialog can be performed when necessary. This capability is built into a special control channel that simulates a dumb terminal connection to the supply, see Table 1 below.

The existing control system provides a "hook" into which we were able to attach these new intelligent supplies the *pseudo device*. The *pseudo device* mechanism is actually a generic interface to the LCS run-time database[4]. The job of the *pseudo device* software is to allow database access calls used by all of the existing control system applications to access and control any piece of hardware without knowing its operating details. The *pseudo device* must take care of all details, including any differences in the operational model of the target device and the LCS.

Analog control in the LCS is incremental. That is, any command value requested is assumed to be an increment to be added to the present setting of the device. This puts it clearly at odds with our new supplies' set point control philosophy. *Pseudo device* software must compensate for this. All analog data received from the supply are coded as a set of ASCII characters. It must be parsed and converted to floating point format before being sent to the control system database of application software. Table 1 shows the channel access scheme used by the *pseudo device*.

The *pseudo device* must also emulate a canonical supply that the rest of the control system knows about. The new digital supply's state space does not map exactly to the power supply that the control system wants to "see". The *pseudo device* takes care of this mapping

Table 1. Minimal set of control system channels required for power supply control used by the *pseudo-device*.

Data Type	Description
Analog	Actual voltage
Analog	Actual current
Analog	Current set point
Analog	Actual Ground current
Special pass-through	Diagnostic vector channel
Character data	LAT port address
Digital	Power Supply on/off
Digital	Interlock fault (logical AND of all active faults)

It also prevents operator intervention, except for shut down, during ramping operations.

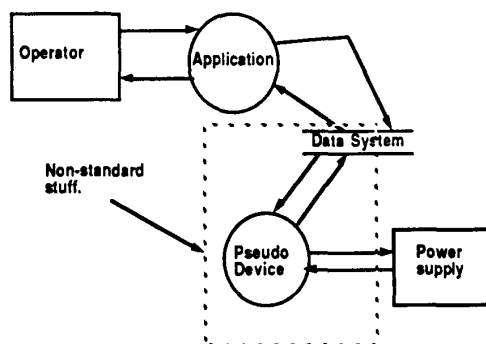


Figure 3. The *pseudo device* interface. The *Data System* is the database which contains the characteristics of each control channel under computer supervision. Every channel has a ten-character operator designator which is the key to accessing database information about the channel.

The supplies communicate with the control system via a LAT (terminal server) port. The control system must be able to obtain the address of the ports connected to each controller through the LCS data system.

Diagnostic programs will be able to access all of the power supply command set through a special diagnostic pass-through channel for each supply. Commands, not just those known by the run-time database, will be accessible through a simple terminal emulator interface for remote troubleshooting from any ASCII terminal in the accelerator control room or in at locations along the ethernet backbone.

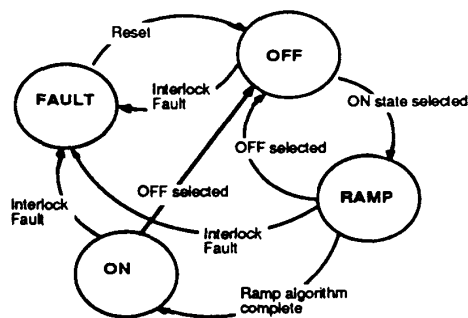


Figure 4. States of the supply emulated by the *pseudo device*

3.0 LAT Protocol as the RS-422 Interface to the Accelerator Control System

Connection to the accelerator control system is through the RS-422 uplink. Power supply control protocol consists of seventy-five three-character ASCII commands[5].

The control system communicates with the supply uplink channel through a port on a terminal server connected to the control system ethernet backbone, see Figure 4

Using a terminal server has several advantages. It is comparatively easy to locate a server close to the power supply or cluster of supplies and still be close to an ethernet connection point. The server is a terminal concentrator using Digital Equipment Corporation's Local Area Transport (LAT)[6] protocol. The protocol is timer-based. It collects data from all of its ports then constructs and sends single a ethernet packet. Servers in our system can have as many as 128 ports. Packets are sent every 80 ms. The protocol uses a fixed bandwidth that is a small fraction of the total ethernet capacity. LAT is inherently asymmetric, there is a master-slave relationship between the host computer and the server. The protocol is less CPU-intensive than the full peer to peer communication of DECnet or TCP/IP.

For controlling magnets the 80 ms time-constant of the server is much shorter than the inherent control time-constant of the power supplies. The significant reduction in network loading by concentrating the control of as many as 128 magnets in one ethernet packet is obvious.

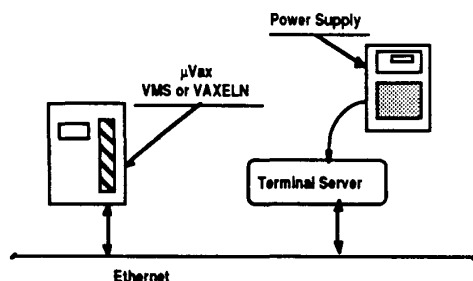


Figure 5. Power supply as a network object.

There are some adverse side effects that come from using the time-based LAT protocol. The most noticeable is the lack of real-time knob response of power supply in the accelerator control room. Each power supply in the accelerator can be controlled by assigning a knob to it from the operator's control console. The operator is able to adjust the output current of the supply by turning the knob. Since at least one "round-trip" of data must pass between the control system and the supply, at least, 200 ms will pass between the time the knob is turned and a power supply response is noticeable. If the control computer is heavily loaded the knob response can deteriorate to a point where the effect of the knob adjustment can take one second or more. A solution to this problem is being investigated.

4.0 Parameter Block Load Management

Each power supply can be configured by uploading an ASCII file that contains the power supply's operating characteristics, such as over current and over voltage trip points, interlock fault definitions and maximum allowable ground current parameters. The characteristics file can be as large as four KBytes. The block is protected by a checksum algorithm so that file tampering can be detected. We are designing mechanisms for archiving and version control of the parameter blocks that will be stored off-line. A scheme to keep track of hundreds or thousands of these parameter files must be devised.

5.0 PC Diagnostics Software

A PC-based (MS-DOS) diagnostic program was written to allow convenient and flexible communications with the power supply controller. A commercially available terminal emulator allows only a subset of the functions needed to test and diagnose the controller. The application that we wrote does include dumb terminal capabilities. The application called, MAGCOMM has features specifically tailored for the supply controller.

MAGCOMM has a set of two character commands that allows the user to do the following:

- Continuously monitor the actual current, voltage and ground current of the power supply. The application sends out an appropriate set of commands at a rate of 5 Hz and provides the PC's display with updated readings.
- Tests for serial port time-out. The controller is expected to respond within a short time interval (> 1.0 sec.). If no characters are received within the port time-out period, then corrective or investigative action must be taken by the user.
- Checksum error checking on block load and transmit.
- Power supply control scripts that can be stored on disk and edited by any ASCII editor are supported.

The application was written so that it can be ported to a VAX/VMS system. Except for the low-level serial port interface routines, which are hardware-specific, the bulk of the C-language source code is reusable on the VAX.

6.0 References

- [1] S. Cohen and R. Stuewe, "Magnet Power Supply as a Network Object", Particle Accelerator Conference, San Francisco, CA, USA (1991)
- [2] S. Cohen and J. Sturrock, "New Intelligent Magnet Power Supplies for LAMPF", IEEE Nuclear Science Symposium, Santa Fe, NM USA (1991)
- [3] S.C. Schaller and E.A. Bjorklund, "Distributed Data Access in the LAMPF Control System". Particle Accelerator Conference, Washington, DC USA (1987)
- [4] S.C. Schaller, J.K. Corley and P.A. Rose, "Optimizing Data Access in the LAMPF Control System", IEEE Trans. Nuclear Science., NS-32, 5, (1985)
- [5] R. Rumrill and D. Reinagel, "Intelligent Power Supply Controller" San Francisco, CA, USA (1991)
- [6] B.E. Mann, C. Strutt and M.F. Kempf, "Terminal Servers on Ethernet Local Area Networks", Digital Technical Journal, (1986)