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AUTHOR(S): **S. Cohen and J. Sturrock**

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

New Intelligent Magnet Power Supplies for LAMPF*

S. Cohen and J. Sturrock
Los Alamos National Laboratory
Los Alamos, NM USA 87545

Abstract

New magnet power supplies are scheduled to be installed in the proton linac at the Clinton P. Anderson Meson Physics Facility (LAMPF). The control and interface design of these power supplies represents a departure from all others on-site. A high level ASCII control protocol has been designed. The supplies have sophisticated microprocessor control on-board and communicate with the accelerator control system via RS-422 (serial communications). The low-level software used by the accelerator control system is currently being rewritten to accommodate these new devices. They will communicate with the control system through a terminal server port connected to the site-wide ethernet backbone. This means that each supply will, for all intents and purposes, be a network object.

Details of the design strategies for the analog and digital control for these supplies as well as the control protocol interface will be presented.

I. ECONOMICS OF FRONT-END INTELLIGENCE

During the design and development phase of LAMPF, in the late 60's, a standard design was adopted for power supply regulators and controls. This design was apparently adopted from a proven Trasrex circuit that used the latest technology available at the time. In the years since, many new LAMPF power supplies from various manufactures continued to use the older LAMPF standard design so that spare parts and maintenance could be kept as simple as possible. However, technology has changed so much in the intervening years that it is no longer practical or desirable to use the LAMPF-standard power supply design. This led to the requirement for a new design to take advantage of modern electronics to simplify installation, maintenance and offer better operating features and reliability.

The old LAMPF-standard design uses heroic and expensive measures to achieve electronic stability. These include an oven around critical components, stepper motor driven analog reference devices, and remote location of the regulator from the power supply. Even at its very best, the old LAMPF standard produced a supply that was reasonably stable (on the order of 100 ppm total stability), had poor setability (1 part in 2000 full scale), had to be set "open loop" (i.e. the same number of pulses to the stepper motor driven pots did not always produce the same output), had 15 line replaceable units, and took an average of 176 wires to connect to the power supply and data collection system.

The cost of installing just the wiring for an old

LAMPF standard power supply control system is more than the cost of an entire LAMPF intelligent power supply control system including hardware and installation.

Figure 1. Block diagram--LAMPF standard power supply system.

The new digital system consists of two line-replaceable units installed in the power supply itself that communicate with the world through two sets of twisted-pair using an RS-422 communications interface. The entire control can be replaced in the field in a few minutes 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 interfaced to the 20 year-old RICE 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.

Figure 2. Block diagram--LAMPF digital power supply system.

By placing the power supply system intelligence in the controller, it becomes possible to operate a power supply

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system locally in a stand alone mode or connected to a remote panel that is identical to the front panel of the power supply controller or remotely connected to a dumb terminal, modem, terminal server or computer [1].

II. GENERAL DESIGN CRITERIA

The key design philosophy used incorporates an intelligent, microprocessor based control and communication system into a modern analog power supply. The entire 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, setpoints, 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. In the event of a power failure, the RAM saves present operating information and will return the power supply to its present set point by ramping up the supply from zero after it is reset and turned on when power is restored. 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 setpoints and actual values for the load current and voltage and the ground fault current and set points. 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 and 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. An easily reconfigurable interlock program allows sensors (either N.O. or N.C.) to be named, monitored (or ignored) and to shut down the power supply (either abruptly or ramp down) if a fault occurs. Magnet warning lights and a reversing switch (if used) are driven directly from the power supply. 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 response 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".

III. HARDWARE PROCUREMENT AND STATUS

Extensive specifications were written and LANL procurement competed the bid among various vendors. Alpha Scientific Electronics' proposal was selected. The communication protocol was designed and agreed upon. A communications emulator was designed and delivered. This allowed control software to be developed and problems to be identified and fixed before hardware delivery. A small one-amp test supply, controller and remote panel have been extensively tested and debugged both at Alpha and at MP division of LANL for the past year. A number of software glitches and problems were identified and corrected. The first power supply was installed at the magnet mapping facility at LAMPF during the week of October 24, 1991. It is currently being test and evaluated. The remaining supplies should be shipped at the rate on one per week until the order is completed.

IV. 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[2].

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 3.

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 Corporations' Local Area Transport (LAT)[3] protocol. The protocol is timer-based. It collects data from all of its ports then constructs and sends single 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.

Figure 3. Power supply as a network object.

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.

V. ACCELERATOR CONTROL SYSTEM INTERFACE

The LAMPF Control System (LCS)[4] 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 4.

Figure 4. The topology of the LAMPF control system.

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

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 Section VI 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[5]. 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*.

Figure 5. The *pseudo device* interface.

The supplies communicate with the control system 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.

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)

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.

VI. 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 with a short time interval. 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. See Section VII below.
- 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..

VII. PARAMETER BLOCK LOAD MANAGEMENT

Each power supply can be configured by uploading an ASCII file that has its operating characteristics, such as overcurrent and overvoltage 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.

VIII. CONCLUSIONS

We feel that the additional time and effort that is being spent now on a generic power supply interface is well worth it. The LAT protocol allows control of a large number of supplies without using unnecessary ethernet bandwidth. The elimination of having to pull and maintain, literally, miles of wires cannot help to be both economical and provide less single points of failure. We are planning to put the supplies in regular service during the 1992 LAMPF run cycle.

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