MODBUS/TCP CONTROLLER FOR THE POWER SUPPLIES IN ALS BTS BEAM LINE

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Abstract

The development, testing and commissioning of a self-contained power supply controller for four 100 KW power supplies for the upgraded Booster to Storage Ring (BTS) beam line at the Advanced Light Source(ALS) at the Lawrence Berkeley Laboratory, is presented. The power supply controller is a 3U high, rack-mount chassis that contains the regulation control-loop amplifiers, 16-bit DAC with microcontroller and a micro PLC (Programmable Logic Controller) for power-supply state-machine control. Local control is achieved via push-buttons and a color LCD touch screen. Remote control is mediated via micro PLC using embedded Modbus/TCP. Using a unique, data logging system, the operational parameters of the regulation loop can be safely monitored and recorded while the system is running at full power. The entire design is based on optimum reliability, safety and ease of troubleshooting and repair. A modular design for key control components, allows the power supply to operate in a nominal mode, even if one or two ancillary internal modules fail. This allows for continued beam operation until it is convenient to service the unit, keeping beam availability as high as possible.

CONTROLLER DEVELOMENT

The Advanced Light Source at the Lawrence Berkeley Laboratory has recently commissioned an upgrade to allow continuous "top off" of the main storage ring. The upgrade required new magnet power supplies for the Booster to Storage Ring (BTS) beam line [1, 2].

The four 100 kW power supplies were required to be operated both locally and remotely via the ALS' EPICS control system. The ALS specified Modbus/TCP [3] as the remote control protocol.

A team from Alpha Scientific Electronics and Bira Systems designed a controller that performs closed-loop current regulation, manages the power-supply's state machine, provides a local user interface and manages the Modbus remote communications. To facilitate commissioning, a power-supply simulator was supplied to the controls team at the ALS so EPICS programming could proceed in parallel with the building of the four power supplies. The team had used this strategy for the 1 MW Dipole power supply used successfully at the Australian Synchrotron.[4]

The design goals for the team were three fold.

1. High current stability, 100ppm regulation with critically damped response to step changes in reference input. The ability to easily adjust feedback compensation for different loads
2. Modularity and scalable design of command structure and control components.
3. Fail-safe operation that will allow local operation if the more complex remote-control interface fails.

CONTROLLER HARDWARE

Controls are housed in a 3U 19" chassis. The operator interface consists of a Windows-CE-based touch screen, control buttons and local set-point adjustment. See Figures 1 & 2.

Figure 1: Actual Control Panel

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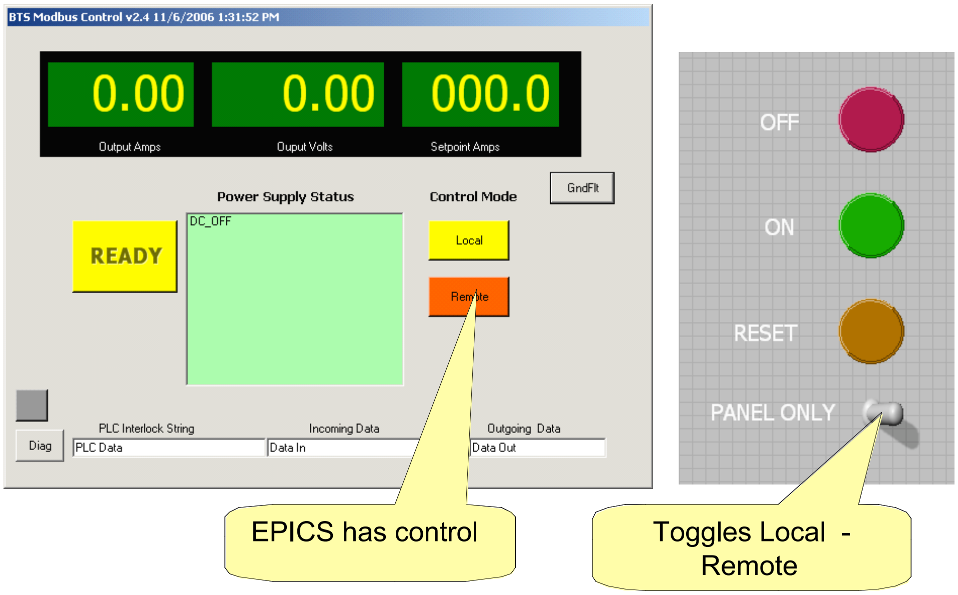

Figure 2 Display layout and relationship to physical buttons.

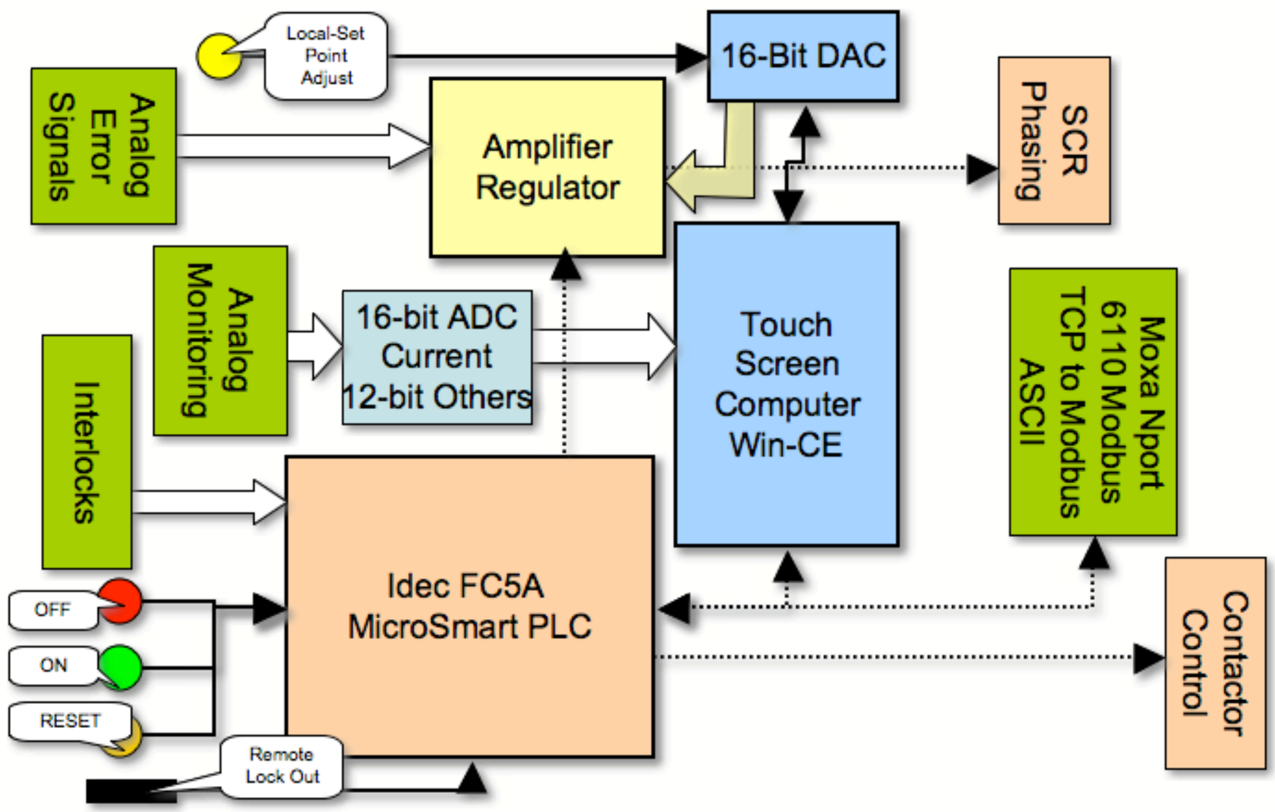

Figure 3 . Interaction between control elements in the controller

FUNCTIONAL BLOCKS

A modular design for key control components, allows the power supply to operate in a nominal mode, even if one or two ancillary internal modules fail. This allows for continued beam operation until it is convenient to service the unit, keeping beam availability as high as possible.

All of the processes are managed by a mico-PLC. A programmable 16-bit reference signal is fed to the regulator circuit, with an on-board RS-232 communications link to a Windows CE [3] (WinCE) single board computer and touch screen. The 6" display simulates volt and ammeters, and displays operating and fault states of the power supply. See Figure 2.

Windows CE touch screen is a communications interface/conduit. It syncs itself to the PLC via a serial (RS-232) link, COM1 on the WinCE machine. All physical buttons and interlocks are attached to the PLC. On and off sequencing of contactors, SCR drivers, regulator is handled solely by the PLC. The WinCE can "die" and the power supply will still function.

The IDEC mcroSmart PLC built-in Modbus RTU serial capability [5]. Modbus TCP uses a different encoding scheme and checksum algorithm for encoding the Modbus commands. A MOXA[6] serial to TCP/IP Modbus protocol converter completes communication link to the ALS EPICS system.

MODBUS COMMAND/REGISTER SET

A consequence of using the Modbus[3] protocol is the convenience of programming from the PLC-side of the system From the PLC's "point-of-view" its commands consist of the values or states contained in specific registers. The Modbus serial or TCP/IP protocol is transparent to the PLC programmer. The command set for this controller is shown in Table 1.

What is illustrated is the economy of command space and how little bandwidth is needed for controlling each power supply.

Another advantage of using an industrial protocol is the ready availability of diagnostic and testing tools. The use of third-party command and scanning software allows one to perform cross checks on specific EPICS and controller functions and verify their operation. We found that one needs to choose register mapping with some planning. All registers allowed by the Modbus standard are not always available in specific PLC's.

Table 1: Modbus register and command assignments (sample set)

Command	Register	Description	Argument/Response
03	400257	Query Actual Output Current	Unsigned 16-bit value
03	400259	Query Ground Current	Unsigned 16-bit value
03	401001	Status of the power supply and interlock fault bits.	Two 16-bit registers with interlock and status information[1] ON/OFF RDY/NRDY REMOTE/NREMOTE INTERNAL/EXTERNAL reference
03	400258	Query Voltage	Unsigned 16-bit value
03	400300	Watchdog Register	Unsigned 16-bit value
06	400001	Set Current Set Point	Expect an unsigned 16 bit value
06	401901	Turn power supply on off.	ON / OFF 0x0001 or 0x0000
06	401902	Reset to clear interlock faults	Put supply in OFF-READY state if all faults have cleared. Send 0x0001 to reset.
06	401910	Keep alive Register	Expect an unsigned 16 bit value

COMMISIONING PERFORMANCE

Once AC connections were completed, EPICS control was established within a few hours of power up. Fine adjustments for regulation compensation and "tweaks" to the EPICS interface continue during scheduled accelerator downtimes. All four power supplies are functioning within specifications.

REFERENCES

[1] Barry, Walter; Chin, Mike; Robin, David; Sannibale, Fernando; Scarvie, Tom; Steier, Christoph, "Diagnostic systems plan for the advanced light source top-off upgrade". Proceedings of the Particle Accelerator Conference, PAC 2005, June 2005, p 4066-4068

[2] Robin, D, RPAE063, Proceedings of the Particle Accelerator Conference, PAC 2005 June 2005,

[3] http://www.modbus.org/specs.php.

[4] "Progress at the Australian Synchrotron," Synchrotron Radiation News; Volume 19 No. 4 Page 2

[5]Part number FC5A-D32S. Idec, Corp. http://www.idec.com/usen/products/Catalogs/PLCs/MicroSmartPentra/overview.html.

[6]http://www.moxa.com/product/MGate_MB3180_3280_3480.htm

[7] See, for example "Modscan", http://www.win-tech.com/html/modscan.htm