THE LANSCE RICE CONTROL SYSTEM UPGRADE*

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Abstract

The LANSCE (Los Alamos Neutron Science Center) control system upgrade program continues with the impending replacement of the RICE (Remote Instrumentation and Control Equipment) subsystem. The RICE subsystem upgrade is a challenge because of its technology (late 1960's), number of channels (>10,000), and unique characteristics (all-modules data takes, timed/flavored data takes). The plan is to replace at least the non-timed data and the command portions of the subsystem with Programmable Logic Controllers (PLCs). We discuss motivations, technological challenges, proof-of-principle, and planning. The boundary condition, as usual, is that we must implement these major changes on a running accelerator.

INTRODUCTION

The RICE system was designed before the advent of CAMAC, VME and other standard data acquisition and control busses. The RICE architecture was designed as an integral part of the accelerator facility, with capabilities custom crafted to support hardware in the accelerator. As the years have passed, some readout and control capabilities have been moved to CAMAC and VME, but over 10,000 channels remain in RICE today. Some upgrades to RICE hardware were made in the early 1970's, but few changes have been made since then.

The initial description of the RICE hardware was given at the very first Particle Accelerator Conference in Washington, D.C., in 1965 [1]. For a more in-depth discussion of the RICE system in the context of the history of the LAMPF/LANSCE control system, see [2].

With thirty year old technology comes problems. Many of the discrete components in RICE electronics can no longer be purchased and supplies of spares are dwindling. Plastic connectors are becoming brittle and spares are not available. Calibration capabilities were not built-in, raising questions about year-to-year comparability of settings. Lack of any vendor support means all maintenance and repair must be done in-house. Non-standard electronics means all in-house maintenance people must receive extensive RICE-specific training. Retirement of the original designers and builders of RICE makes extended re-engineering necessary to understand the reasons for the current architecture and implementation.

A proposal was made in the early 1990s to rebuild the system in standard electronics, providing a complete duplication of RICE capabilities. Declining budgets and high cost, along with the undesirability of an extended accelerator downtime, prevented funding of the effort.

The current proposal takes a different approach. Review of channel usage shows that full RICE capabilities are needed for only about 10% of the channels in the system. A "divide-and-conquer" approach will be used, moving approximately 9,000 "slow control" channels to commercial Programmable Logic Controllers. The remaining 1,200 diagnostic and RF channels that require full RICE capabilities will be implemented in special-purpose VME electronics.

RICE CAPABILITIES

The RICE system provides a wide range of capabilities. This paper deals with the standard capabilities that comprise the slow control functions of the system. This section also describes the RICE features beyond slow control that cannot be implemented in a standard PLC.

Slow Control

Approximately 9,000 channels in the RICE system are not dependent on the instantaneous state of the accelerator and can be read and commanded at a 1 Hz or slower rate. Examples of such channels are binary on/off and analog magnet currents. The RICE system supports this functionality with

- Analog inputs with 11 bits plus sign. Input ranges of ±10V, ±1V and ±100mV are allowed.
- Analog raw data, corresponding to the ADC count. Conversion to engineering units is done in the legacy VAX control computers.
- Analog stepper motor controllers, used to provide local analog control and to provide set point control that holds across power outages. While a green-field effort might use DACs, this upgrade will stay with stepper motor controllers to avoid the cost of replacing the stepper motors and the field wiring plant.
- Binary input data, compatible with 0-8.5V low, greater than 14V high, converted down to DTL levels.
- Binary commands.

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- Linked binary commands, allowing an operator to command a single binary channel but issue commands to several channels at the hardware level.
- Local control capability. RICE commands can be locked out locally, allowing work on equipment without possible interference from the control room.

The RICE hardware is organized into "modules." In the linac portion of the system, a RICE module corresponds to the equipment associated with one of the 48 accelerating modules. A typical RICE Module supports 64 analog inputs, 144 binary inputs, 25 analog stepper motor controllers and 48 binary commands. An extension chassis can be used to increase these limits.

High Speed, Gated Acquisition

Sampling beam and RF diagnostics clearly requires high speeds and gating capabilities well beyond that provided by slow control. Furthermore the LANSCE linac runs at 120 pulses per second with a maximum 12% duty factor, requiring the ability to schedule data reads at specific times during the pulses. Finally many different kinds of beam pulses may be accelerated during the one-second repeat cycle of the linac and it is even possible to have two different kinds of beam on a single RF pulse, so it must be possible to schedule reads on specified pulses. In RICE these capabilities are called

- Timed data – schedule the data read at a one microsecond granularity with respect to the start of a 8⅓ millisecond timing cycle.
- Flavored data – schedule the data read on a pulse with specific beam parameters. Up to 96 parameters can be specified, including the desired beam species (H^+ or H^- or H^+ and H^-), the beam energy, and the beam-chopping pattern (e.g. gaps of 90 ns in the beam every 270 ns for beam intended for the Proton Storage Ring).
- All-modules data – because of the architecture of the RICE (a star configuration), data from all 72 RICE modules are acquired with each read. Thus a single request can read correlated data along the entire length of the linac in a one-microsecond window; 72 individual reads would otherwise be spread over 600 milliseconds. Thus it is possible, for instance, to get a snapshot of all spill monitors along the linac on the same beam pulse.
- Flagged data – a special link to the Fast Protect system flags data read during a pulse with excessive beam spill. Also an all-modules data read can get spill status from all accelerator locations on the same pulse to determine where the spill was.

All channels in RICE, including the slow control and binary channels can be read with these constraints. However, only the 1,200 channels for beam and RF diagnostics can fruitfully use these capabilities. A proposal to deal with these channels is being developed using transient-digitizer technology in VME [3,4].

PROPOSED SLOW CONTROL REPLACEMENT

Commercial PLC systems can readily meet our needs for slow control data. Evaluations at SNS [5] have measured read speeds under EPICS [6] that are well in excess of our needs and in fact may support a 10 Hz update rate for our channel count. This is highly desirable for channels that are controlled by knobs, such as magnet currents.

We propose to replace each RICE module with an Allen Bradley ControlLogix [7] PLC. An EPICS Input-Output Controller (IOC) in a VME crate will be used to control three to six PLCs in a geographical area; connection will be made via Ethernet, with an Ethernet switch used to isolate the IOC-to-PLC traffic from the rest of the network. To replace the slow-control channels for a typical RICE module, a PLC will have three ControlLogix crates containing six analog input modules, two digital input modules, six stepper motor controller units and two digital output modules. There will also be one DAC for diagnostic purposes.

Extra accelerator downtime to install the new hardware is not acceptable. Thus installation will be done during normal maintenance periods and will result in running the accelerator with a mixed RICE/PLC system for several years. With present manpower and other commitments, it is expected that during a normal monthly three-day maintenance period, one RICE Module can be converted. During the yearly three-month extended maintenance periods, it may be possible to do as many as 10 modules. Thus this upgrade will be spread over four to five years if fully funded.

A proof-of-principle test has been done for binary channels. During this year's accelerator operation we expect to run one RICE Module with a full complement of analog and digital PLC modules as a final validation of the plan. Completion of the remaining RICE Modules will depend on funding.

KEEPING THE ACCELERATOR RUNNING

Accelerator operation constraints, as always, mitigate the aggressiveness with which we would like to pursue the RICE upgrade. It is vital that during the course of the upgrade we present operations with an (almost) totally transparent control system interface. Fortunately, we have already had some experience with (almost) seamless integration of new controls.

The RICE hardware is managed by and communicated with through the linac control system (LCS) which runs on a legacy VAX/VMS computers. EPICS applications access the RICE data through "gateway" software which interfaces Channel Access reads, monitors and commands to the LCS data system. Moving RICE channels to a PLC is mostly invisible to EPICS application programs but has significant problems for applications still running on the VAXes. There are approximately 50 legacy applications running on the VAXes, which took 10-25 man-years to originally develop. Conversion of the applications to EPICS is in progress, but there will be many years when there are significant VAX applications needing to access PLC data. Some of the issues that need to be addressed are:

- Raw data – Many legacy applications were written to acquire and display raw analog data in RICE ADC counts. Many of the operators find that the raw values are more meaningful than the associated engineering values. This problem becomes important for legacy applications, which will have to acquire some data from RICE and some from PLCs which, by EPICS convention, supply only engineering values. As an interim step we are considering for the PLCs that will supply some kind of scaled "raw" values for use by such legacy programs.
- Mixed RICE/PLC – Some legacy programs acquire data via all-modules data reads by explicitly referring to "vector" (or array-based) channels. The vector reads will have to be handled specially if some of the individual channels in the vector are in RICE while others are in PLCs. We plan to have the legacy data acquisition library routines recognize these channels and automatically split them into separate RICE/PLC references, without application modification. (Note that the RICE front-end computer already builds all-modules reads from scalar reads whenever possible.)
- Single channel for command and readback – The EPICS channel naming philosophy calls for separate channels for input and output hardware. The LCS allows input and output channels to be associated in the device database and be referred to with a single name. EPICS applications will be written assuming separate input and output channels. We will provide appropriate extra names for such channels in the LCS database. The EPICS gateways will provide data/command associations for EPICS channels that are commanded by LCS applications.
- Ability to read any channel timed/flavored – The RICE system allowed reading slow-control channels as timed and flavored data for unusual troubleshooting activities. The new system is designed to make it possible to easily move a channel back to RICE if necessary.

EXPERIENCE SO FAR

During a three-day maintenance period RICE binary input/output channels in the RICE module controlling the last accelerating module of the linac were rewired to a PLC. An EPICS IOC was installed to interface the PLC to the remainder of the control system. Control system software was modified to access these RICE channels through the IOC. The system was tested and a few software problems corrected. The accelerator then ran for a month in production mode with the PLC system. Thus we have high confidence that such upgrades can be done during monthly maintenance periods.

The next step in the upgrade will move all RICE analog and digital slow control channels on the RICE module to a PLC. It is expected that this test will be done during the 2003 production period. Based on the manpower costs for this step we will be able to finalize a budget and possible schedule for upgrading the slow control channels on the remaining RICE modules.

REFERENCES

[1] T.M. Putnam, R.A. Jameson, and T.M. Schultheis, "The Application of a Digital Computer to the Control and Monitoring of a Proton Linear Accelerator," IEEE Trans. Nucl. Sci., NS-12 (1965) 21.

[2] S.C. Schaller, "A LAMPF Controls Retrospective: The Good, the Bad, and 'It Seemed Like a Good Idea at the Time'," 1993 Int. Conf. on Accel. and Large Experimental Physics Control Systems, Nucl. Instr. and Meth. A 352 (1994) 516-520.

[3] Rob Merl, Charles Burns, Floyd Gallegos, Chandra Pillai, Fred Shelley, Andy Steck, "A Multiwire Proportional Chamber System For Monitoring Low Momentum Beam In Accelerators," this conference.

[4] Rob Merl, Floyd Gallegos, Chandra Pillai, Fred Shelley, "High Speed EPICS Data Acquisition And Processing On One VME Board," this conference.

[5] K.U. Kasemir and L.R. Dalesio, "Interfacing the ControlLogix PLC over Ethernet/IP," *Proceedings of the 8th International Conference on Accelerators and Large Experimental Physics Control Systems*, November 2001, San Jose, CA., THDT002, http://www.slac.stanford.edu/econf/C011127/proceedings.html.

[6] L. R. Dalesio, et al., "The Experimental Physics and Industrial Control System Architecture: Past, Present and Future," *Proceedings of the International Conference on Accelerator and Large Experimental Physics Control Systems*, 1993, pp. 179-184.

[7] Rockwell Automation, "ControlLogix Selection Guide," Publication 1756-SG001A-US-P from http://www.ab.com, July 2000.