COMPLETION OF THE LANSCE PROTON STORAGE RING CONTROL SYSTEM UPGRADE -- A SUCCESSFUL INTEGRATION OF EPICS INTO A RUNNING CONTROL SYSTEM

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Abstract

The Los Alamos Neutron Scattering Center (LANSCE) Proton Storage Ring (PSR) control system upgrade is complete. In previous work, much of a PDP-11-based control system was replaced with the Experimental Physics and Industrial Control System (EPICS) controls. Several parts of the old control system which used a VAX for operator displays and direct access to a CAMAC serial highway still remained. The old system was preserved as a "fallback" if the new EPICS-based system had problems. The control system upgrade completion included conversion of several application programs to EPICS-based operator interfaces, moving some data acquisition hardware to EPICS Input-Output Controllers (IOC's), and the implementation of new gateway software to complete the overall control system interoperability. Many operator interface (OPI) screens, written by LANSCE operators, have been incorporated in the new system. The old PSR control system hardware was removed. The robustness and reliability of the new controls obviated the need for a fallback capability.

1 INTRODUCTION

At the 1995 International Conference on Accelerator and Large Experimental Control Systems in Chicago, Illinois, we reported on the success of the first steps in upgrading the LANSCE PSR control system to an EPICS-based system [1]. In this paper, we report the completion of this upgrade.

The original PSR control system [2] was based on PDP-11 front-end computers that polled data from CAMAC crates on local serial highways. Another serial highway was used to continuously update a live database in a central VAX computer. The central VAX ran application programs which used the live database to update operator interface screens. Although this system was highly reliable, it confronted us with a number of problems. These problems included the reliability of the serial highways, limitations in expanding the PDP-11 memory, complications and delays in adding new data and control channels, difficulties in implementing new applications programs, slow response to knob commands, and aging computer hardware.

As part of a general upgrade to the Proton Storage Ring in 1994, we began an upgrade of the PSR controls.

Following an extensive review [3], we decided to replace the old PSR control system completely with an EPICS-based [4] system. Time and manpower constraints, however, prohibited a complete conversion in time for the 1995 production period.

In the 1995 PSR upgrade (Fig. 1), we replaced the PDP-11's with EPICS Input-Output Controllers (IOC's). The VAX to PDP-11 serial highway was thus effectively replaced by Ethernet. Budgetary considerations required us to retain the local CAMAC serial highways and crates. Several hardware devices on the VAX to PDP-11 serial highway could not be implemented on IOC's immediately. The requirement to handle these devices, plus the need to fall back to the original control system, meant that we needed to keep the PDP-11's, the central VAX database, and the original operator interfaces available.

To keep old and new databases consistent for a possible fallback, we implemented migrator software which recorded changes to the EPICS databases in the central PSR database. In a further complication, the separate LANSCE linac control system (LCS) [5] had to be able to acquire both PSR and EPICS data and to provide LCS data to the EPICS operator interface (OPI) screens. Thus we had a series of gateways and migrators that allowed the three control systems to interact effectively [6].

2 THE REMAINING UPGRADE

During the 1995 production period, we verified the usability and reliability of the new EPICS-based controls. There was no need to maintain a fallback capability. Thus at the end of this period, we were ready to completely replace the original PSR control system in time for the 1996 production period. In late 1995 we began the final upgrade tasks. The final PSR control system configuration looks like Fig. 1 without the PSR VAX serial CAMAC highway.

2.1 Hardware

Hardware and/or CAMAC crates that had resided on the VAX to PDP-11 serial highway were moved to IO-based serial highways. This hardware included beam position monitors (BPM's) and ring buncher RF generation equipment. We also removed the specially-designed PSR knob units that lived on the VAX highway. Knob
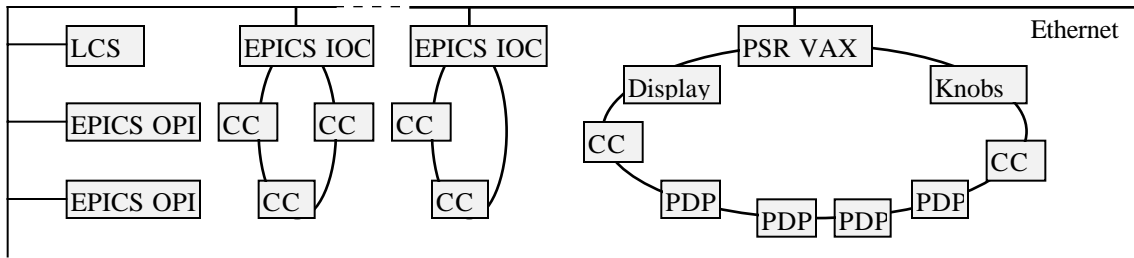
Fig. 1: PSR Controls in 1995. "LCS" is the Linac Control System. "CC" is a CAMAC crate. The ovals are CAMAC serial highways. The PDP-11's were for fallback. For 1996, the PSR VAX highway was removed.

functionality would now be provided by LCS knobs through the LCS-to-EPICS gateway software.

Through diagnostics available on the EPICS IOC's we developed a better understanding of the control algorithms in the front-end computers. This was information that was not easily available in the PDP-11 front ends. With this information we improved some closed loop controls, replaced some slow ADC's which had contributed to unstable conditions, and improved our ability to override commands and limit overshoot. Many of these problems had not been evident in the old system because of the general slowness of the old system to knob commands.

In addition to, but not directly connected to the PSR upgrade, was the initiation of a magnet/power supply continuous quality improvement program. This program was a joint effort between software, electronics, and power supply staff. It was successful in identifying problem areas that affected magnet performance and reliability and led to some of the previously indicated control system changes.

2.2 Software

In conjunction with the move of hardware from VAX serial highway to IOC's, we developed several new OPI-based applications. Some of these were implemented via the EPICS display manager (dm) interface builder and some were done using the Tcl/Tk language. The most difficult was the reimplementation of a closed orbit program which used BPM's to set the ring benders. Parts of this program were implemented in Fortran -- one of the few uses of this language in the upgrade. The loss monitor program, which had been implemented in Tcl/Tk for the 1995 run, was reimplemented as a dm screen. This program displays a great deal of frequently changing data, and measurements showed that the Tcl/Tk widgets were updating rather slowly. The operations team had to compromise on losing some minor functionality, but they gained much improved performance for this heavily used screen.

During the initial upgrade phase, we had begun to teach members of the operations staff to design and implement their own dm screens. The dm program is a graphical GUI builder and is quite intuitive. This process continued during the last year. Operators have developed a series of run permit screens for both the PSR and the LCS systems (the latter through the EPICS-to-LCS gateway) which is now the primary means of diagnosing linac and PSR problems.

We used the opportunity of the upgrade completion to extend the suite of diagnostics available for the new PSR control system. In particular, we incorporated IOC nodes in the standard LCS network diagnostics, using the LCS-to-EPICS gateway to acquire data and test hardware. Other network information was also made available through EPICS screens. Heartbeat channels were added to all the EPICS IOC's and a dm screen was developed to show the overall IOC status.

As an equipment diagnostic as well as a control system diagnostic, we developed a Tcl/Tk program called line-by-line that allows wildcard access to any set of PSR or linac channels. This program is an expert-level diagnostic and also provides hooks to low-level IOC diagnostic information.

As a result of eliminating the fallback capability, we were able to remove all of the old PSR software from the central PSR VAX. We no longer had to keep the old PSR database current. However, we also lost our connection from the LCS system through the old LCS-to-PSR gateway that allowed control of EPICS channels through the PSR/EPICS migrators. To fill this gap, we implemented a new LCS-to-EPICS gateway which is a VAX-based EPICS channel-access client. LCS knob performance on EPICS channels has improved remarkably. In addition, the performance of the EPICS-to-LCS gateway was improved by using multiple asynchronous data takes in the LCS system.

3 EXPERIENCE

Several operational aspects of the new PSR control system are worthy of note. Much of what follows was gleaned from the programmer-on-call notes for the 1996 production period.

Hardware problems continued to trouble us, but less than in the 1995 production period. Because of the unpredictability of some magnet power supplies, we added open/closed-loop switches for the power supply interface screens. In addition, we found instances where IOC closed-loop controls were fighting with internal power supply closed-loop controls. Studying the detailed

implementation of magnet power supplies in the EPICS databases, we found some cases of incorrect wiring that had existed for years.

Operator interface hardware on the EPICS OPI's caused some difficulties. The optical mice that came with the Sun workstations proved a poor choice in a control room environment. The optical mouse pads never seemed to be where they were needed. Mechanical mice are now being used. Printing hardcopy images of OPI screens also took some time to sort out. It took careful selection of a set of both dm and Tcl/Tk standard colors before the monochrome hardcopy looked acceptable.

Although Tcl/Tk provided a quick means of prototyping operator interfaces while still allowing significant algorithmic content, both its syntax and its performance leave something to be desired. At least one Tcl/Tk screen was converted to a dm screen to get better performance (see above). The obscure Tcl/Tk syntax can make program maintenance somewhat daunting – especially at three o'clock in the morning.

Providing a reliable, smooth (i.e., "bumpless") reboot capacity for IOC's continues to be something of a problem. The IOC's record setpoints, deadbands, and alarm deltas on a central file server for use in later boots. But we have seen occasions where, for unknown reasons, the save file does not get written. In addition, one must specify what parameters should be saved in the off-line database. This can lead to problems, especially with newly-added devices. Work continues on the bumpless reboot problem.

Because gateways try to make two disparate control systems see eye-to-eye, they can be the source of many difficulties. The LCS-to-EPICS gateway returns EPICS data to LCS applications and gives them control over EPICS channels. LCS applications expect a well-defined raw data format as well as an engineering unit format. Since EPICS has only an engineering unit format, some approximations are made that can cause loss of precision and also possible overflow. The LCS archiver expects to acquire EPICS data on a demand-driven basis. If the EPICS deadbands are too small, LCS archiver requests can generate significant amounts of network traffic even for channels that are only recorded infrequently. The EPICS channel status and severity fields do not translate well to the VMS condition code statuses used by LCS. This ambiguity can cause errors to appear even if there are none. For example, a problem occurred when an uninitialized EPICS setpoint channel had to be read before issuing knob-based command pulses.

The EPICS-to-LCS gateway is a bit more complicated since it must provide an EPICS channel-access server in a VMS (not an IOC) environment. This task was accomplished by modifying an earlier version of the channel-access server code. Problems have arisen because the IOC environment is multi-threaded while the VMS environment is not. To avoid waiting on all first requests for data (since LCS is a demand-driven system),

we have decided to return invalid data on first requests. This works well for dm or Tcl/Tk programs that are monitoring data, but can cause problems for programs that expect good data on their first acquisition. We are currently in the process of reimplementing the EPICS-to-LCS gateway using the new EPICS server-level application programmers interface [7].

One final difficulty occurred in moving some Fortran code from a VAX (little-endian) to a Sun (big-endian). An actual argument was integer*4 while the formal argument was integer*2. This worked on a VAX, but not on a Sun.

4 CONCLUSIONS

Late last fall we finished the 1996 LANSCE production period using the completely converted PSR control system. The control system availability was estimated to be approximately 99.73%. Out of 2740 hours of production, the PSR control system was reported to be unavailable only 7.3 hours. Since 7 hours of this time was due to fused field wiring, the EPICS system availability was actually much higher and easily comparable to the 1994 and 1995 availabilities of 99.7% and 99.9% respectively.

5 ACKNOWLEDGMENTS

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