

TRIUMF SECONDARY BEAM LINE CONTROL SYSTEM UPGRADE USING EPICS

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Abstract

There are several experimental muon beam lines derived from a primary proton beam line at TRIUMF, namely M9, M11, M13, M15 and M20. For over a decade, the control system for each muon beam line has been provided by dedicated PC communicating to the Central Control System. The PC also served as the sole user interface. With the aging of PC equipments and increasing demands for configuration changes to suit various experiments, it has been decided to revamp the whole system using EPICS.

The new client/server system consists of two Sun Solaris workstation as hosts and a single VME based IOC accessing a serial CAMAC branch via a HYTEC driver.

This paper will detail the software and hardware configuration, and discuss issues like reliability, redundancy, diagnostics and documentations

INTRODUCTION

The TRIUMF cyclotron accelerates high intensity H-minus beams up to 520 MeV. Proton beams are then extracted at various energies and currents. One of its primary extraction beam lines, Beam Line 1, is delivered to two production targets to generate secondary beams of muons for science research.

The old control system consisted of five autonomous pieces, one for each beam line. It had a PC acting as the user interface and communicating with an in-house developed, intelligent CAMAC module to control the devices in that CAMAC crate. This system had been in use for well over a decade and badly needed an upgrade to keep pace with the demands of various muon channel experiments. The decision was made to use the Experimental Physics and Industrial Control System (EPICS) [1] to replace the old control system.

NEW CONTROL SYSTEM

The new system is required to monitor and control beam line elements such as benders, quadrupoles, slits and beam blockers. To meet the demands of various experiments, whole or partial beam line element settings need to be saved and restored on request as well as scaled with various parameters such as the beam momentum or energy.

The system is to run 24 hours a day during muon beam production and multiple beam lines could be operating at the same time. Since there is no dedicated operational staff for this system, the main operators are the experimenters of each beam line. The experimenters are situated in various locations, so safeguards have to be provided to allow access only to elements of their own beam line. However, dynamic configuration of the beam

line should be permissible. Some experimenters may choose to borrow selected power supplies from one unused beam line and connect them to the running beam line as they see fit.

Architecture

Two Sun Blade 100 [2] workstations running the Solaris 8 Operating System are installed, one as a production machine, the other as a development machine. The IOC is a Motorola MVME162 located in a VME crate. It runs VxWorks version 5.5. These three machines are connected to a Baystack 450 network switch (10/100 Mbps Ethernet). Experimenters use PCs running Linux as operator consoles (see Fig 1).

The two Sun workstations serve different functions. One is for the experimenters' use, the other for software development and testing. They also provide redundancy in the case of equipment failure. Identical user directories structures are set up in both machines. Every night, active directories in the production machine are backed up in TAR format onto the development machine. In the case of production equipment failure, these directories can be reconstructed and the development machine can take the place of the production machine on short notice. The disk of our production machine did fail this year. Little beam time was lost because the swift change over enabled the experimenters to use the development machine to control the beam line while the production disk was being replaced.

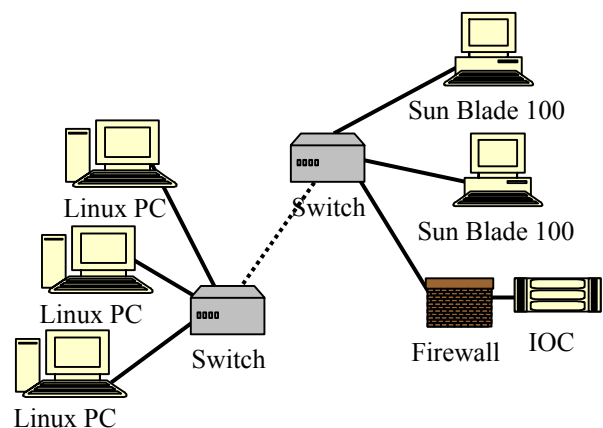


Figure 1: Control System Network Configuration

The five CAMAC crates at various locations in the Beam Line 1 experimental area were configured to form a Serial Highway. It operates at a clock speed of 2.5 MHz. A HYTEC VSD 2992 VME/CAMAC serial highway driver [3] provides the access from VME to the Serial Highway (see Fig 2). For added reliability, an uninterruptible power supply (UPS) is provided for the Sun workstations and the VME crate.

After a couple of months of running, it was noticed that the Sun workstation lost connection with the IOC from time to time. The IOC might not crash right away, but eventually did. A firewall was put in front of the IOC to filter unwanted network traffic. After that, the IOC has been stable.

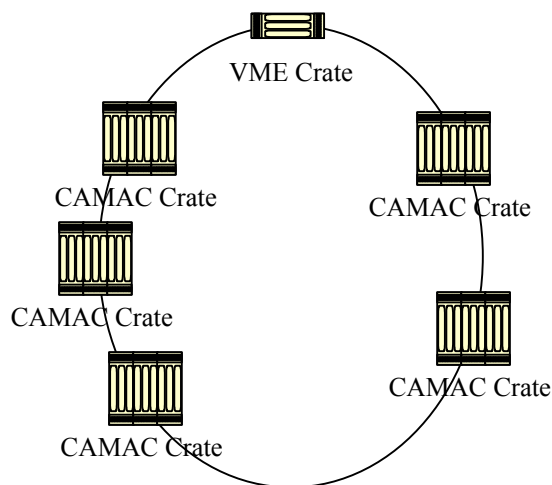


Figure 2: VME-CAMAC Data Highway Configuration

Implementation

The implementation of the system went smoothly. The learning curve for the vast EPICS system is considerable, but the process has been helped by the availability of on-site EPICS expertise, since the TRIUMF-ISAC control system also uses EPICS. Database and displays were developed. Up to the time of writing, the systems for M9, M13, M15 and M20 have been delivered. The M11 beam line control system will be implemented in the upcoming shutdown.

The new system can run in parallel with the old one. This is very useful during the commissioning and testing process, and allows the experiments to switch over to the new system at their own pace.

Table 1: EPICS records for each Secondary Beam Line

M9	M13	M15	M20
1440	941	1324	989

To ensure the experimenters do not accidentally change elements of the other beam line, access control for individual device is set up by using the ASG field of the record. To permit experimenters to borrow a power supply from another beam line, the ownership of that device can be changed on the fly by experimenters with special privileges.

With the rather quick deployment, valuable resources have been saved for developing specific applications for experiments. An on-going application is the tuning of multiple beam line magnets to achieve the optimal count rate.

Hardware Diagnostics

Hardware diagnostic programs have been developed in the IOC under the VxWorks operating system. These

programs are used to check out the integrity of the CAMAC serial highway and facilitate troubleshooting. One such program works with the Kinetics 3291 Dataway Display Module. It tests the read and write CAMAC functions as well as thoroughly tests all the A, F and data lines.

For each muon beam line, a DAC and ADC test channel are installed. This assists control technologists in checking out hardware problems.

On the Sun workstations, an EPICS display was also developed to read back and control the serial crate controller status.

WEB DOCUMENTATION AND APPLICATIONS

There is a significant challenge in offering an effective information/help system because there is no consistent group of operators but rather a large group of experimenters with widely varying levels of control system experience. EPICS was deemed as not well suited for providing this help system. Because of the broad acceptance of the Internet, the decision was made to develop a web-based information system.

Web-based applications can support a wide variety of document formats from static html pages, through dynamic web pages, to such things as animated tutorials. This ability to integrate numerous formats means that one document can often support the various formats needed by different groups such as experimenters, and software and hardware engineers.

It is important that the information system be readily available even during major problems that may affect web serving. This high level of access necessitates having two web servers so that a single failure does not prevent access to a document that may be needed for the problem's solution. To meet this requirement, web serving using Apache has been configured on both the development and production Sun computers.

To provide uniform appearance of the web pages and control future modifications of the whole web site, Cascading Style Sheets (CSS) files for web-based information system has been developed. This is prepared by applying the experience accumulated in developing layouts of operational pages. The main purpose is to focus attention to the topics and not have too many distractions.

The type of documents being served include:

- Static help documents
- Emergency instructions
- Installation instructions
- Electronic logs
- Daily IOC activity log and IOC console log
- Diagrams such as directory structure

Web pages are also accessible directly from the EPICS displays via "Help" buttons.

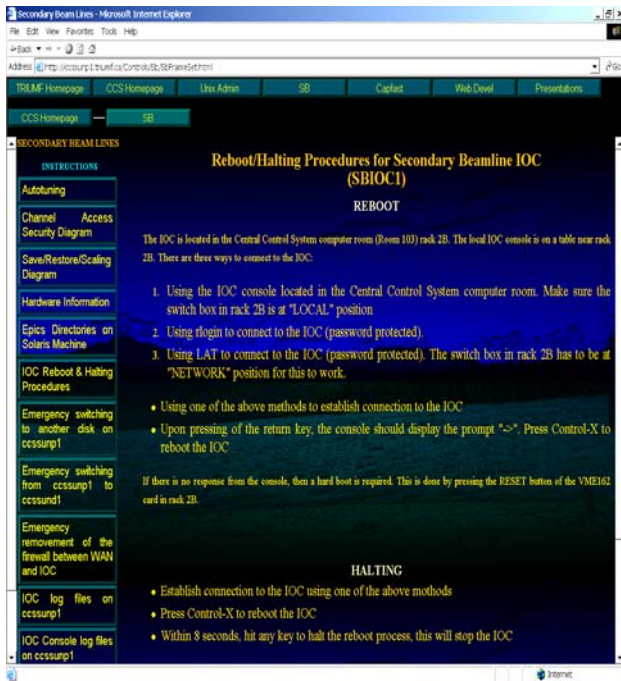


Fig 3: One of the Secondary Beam Line Controls Pages

To invoke dynamic web pages, implemented as Java Servlets and Java Server Pages (JSP), Apache Tomcat has been installed in both Sun Workstations. Web applications that are based on JSP and EPICS Java Channel Access are implemented to read and show values of the channels in real time. Another web application based on JSP, JavaBeans and Java Database Connectivity (JDBC) provides access to PostgreSQL database. These projects are in the design and prototyping phase right now.

SAVING, RESTORING, & SCALING OF BEAM LINE ELEMENTS

A common requirement of all muon beam lines is the saving, restoring and scaling of all or part of the beam line elements. The approach taken was to develop a common application with maximum options. It can then be customized to fill the needs for various experiments in different beam lines. This proved to be efficient in meeting the diverse needs of multiple beam line.

Besides saving values of the channels, the beam parameters such as momentum, energy, mass and charge are also saved. Features added to the scaling procedure allow the user to choose from a set of predefined scaling functions or add a new formula for scaling on the fly. The scaling factors are then calculated and the new formula can be saved as a file for future usage.

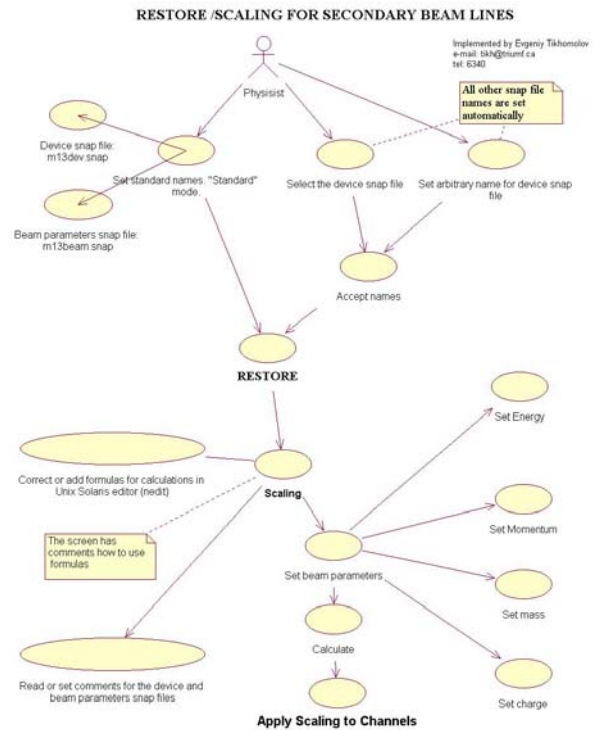


Fig 4: Restore/Scaling procedure for the Secondary Beam Lines

Each experimental group has its own account on the Sun Workstations and their own save/restore/scaling directory for their data. All groups use common scripts and applications from the EPICS directory.

SUMMARY

The TRIUMF secondary muon beam line control system has been successfully upgraded using EPICS. Users show a high acceptance for the new system. The toolkit allows saving of considerable manpower, even though the learning curve is not trivial. Resources can then be used to develop more experiment specific applications. Some additional features developed at TRIUMF improved the effectiveness in the usage of the "standard" set of EPICS toolkit.

REFERENCES

- [1] Experimental Physics and Industrial Control System <http://www.aps.anl.gov/epics>
- [2] Sun Microsystems, Inc. Santa Clara, CA, USA
- [3] Hytec Electronics Ltd, Berkshire, England