CONTROLVIEW TO EPICS CONVERSION OF THE TRIUMF TR13 CYCLOTRON CONTROL SYSTEM

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Abstract

The TRIUMF TR13 Cyclotron Control System was developed in 1993 using Allen Bradley PLCs and ControlView. A console replacement project using the EPICS toolkit was started in Fall 2009 with the strict requirement that the PLC code not be modified. Access to the operating machine would be limited due to production schedules. A complete mock-up of the PLC control system was built to allow parallel development and testing without interfering with the production system. The deployment allows both systems to operate simultaneously, easing verification of all functions. A major modification was required to the EPICS Allen Bradley PLC5 Device Support software to support the original PLC programming schema. EDM screens were manually built to create displays similar to the original ControlView screens, thus reducing operator re-training. A discussion is presented on some of the problems encountered and their solutions.

INTRODUCTION

The TRIUMF TR13 Cyclotron was designed by TRIUMF and built in collaboration with EBCO Technologies, now ACSI [1][2]. The control system was built by TRIUMF using two Allen Bradley PLC5 Programmable Logic Controllers (PLC) [3] and the ControlView OPI toolkit supported by the Chronos [4] multitasking system which runs on top of Microsoft DOS 6.22. The operator console computers running the ControlView displays are Intel 486 based PCs. They communicate with the PLCs using the Allen Bradley DataHighway Plus (DH+), a serial highway operating at 57.6 kbaud. Figure 1 shows a block diagram of the original system, which has been running essentially unmodified since 1993.

UPGRADE RATIONALE

The upgrade was driven by several factors:

- The ControlView toolkit is obsolete and the ageing hardware is difficult to support. Newer hardware is not supported by ControlView.
- The system performance degraded with a second installed console due to limitations of the DH+ serial highway.
- The dual console system was not supported by ControlView. Avoidance of conflicts between the two control masters was procedural and error-prone.
- The consoles are located in a harsh environment with high noise levels and wide temperature swings. Controlview does not allow remote consoles, so the operations area could not be relocated or duplicated, remotely.

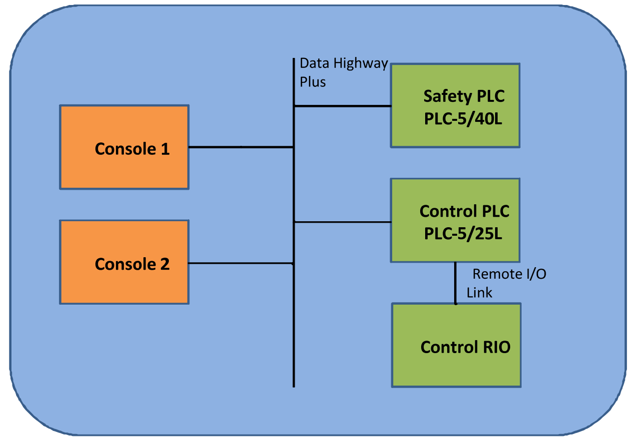

Figure 1: Original System.

UPGRADE LIMITATIONS

The principal limitation for the upgrade was that the PLC program must not be modified as this would trigger a re-licensing requirement of the entire cyclotron. In addition, the upgrade was not to affect the production runs which are scheduled every weekday, varying in length and frequency during the day. There is no regular pattern which would allow testing periods.

REPLACEMENT OPTIONS

On the software side, it was decided from the outset to use the EPICS control system tool-kit which is used for the ISAC control system. Alternative options, such as using the Allen Bradley RSView product or other commercial OPI products were not considered because of cost and in order to conserve the control group resources.

On the hardware side, several options were investigated for the replacement and finally rejected:

- Installing an Ethernet Coprocessor into the PLC chassis because it would have required PLC module re-addressing and PLC program changes.
- Use of a Serial to DH+ module because of speed limitations.
- Replacing the PLC CPU with a ControlLogix or other PLC because it would require rewriting the PLC program.
- Installing a Datalink translator between ModBus/TCP and DataHighway Plus because of speed limitations and possible size limits of the translation tables.

It was decided to replace the PLC CPUs with fully compatible PLC-5 Ethernet Processors. This would require no PLC program changes and allow deployment of an EPICS OPI with fast communication between console and PLC. The new system could be deployed in parallel with the ControlView system greatly simplifying commissioning. Figure 2 shows a block diagram of the upgraded system.

This solution required replacement of the PLC program development software, Ladder Logistics from ICOM, as it did not support the Ethernet enableed PLC family. An available copy of ICOM's WinLogic 5 was initially used to monitor the PLC while the EPICS interface was developed. WinLogic 5 was eventually replaced with a current version of Rockwell Automation RSLogix.

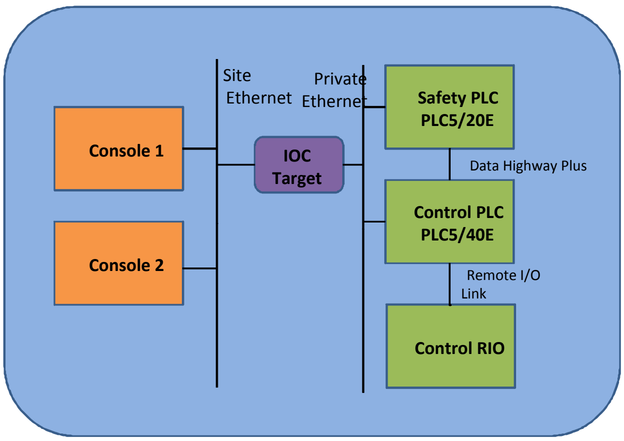

Figure 2: Replacement System.

FEASIBILITY TEST

A test system was set up to prove that the selected methodology was sound and that the underlying EPICS device support would work for the TR13. A mock-up was built of the Control and Safety PLC systems by scavenging parts and purchasing an assortment of modules from E-Bay vendors (see Fig. 3). The total investment in the mock-up was about $2500. With the hardware assembled, the existing PLC software was configured for the Ethernet PLCs and installed.

An EPICS IOC application running on a Linux based platform was built using the PLC5 Device Support library from SNS [5]. A rudimentary EPICS run-time database was created to access some of the PLC memory locations. The PLC status was monitored using WinLogic 5. Successful communication in both directions was observed between the IOC and PLC.

SYSTEM DEVELOPMENT

EPICS Run-time Databases

PLC addresses and device functionality were identified by examining the PLC ladder logic. Differences between the tag address layout in the TR13 PLC memory and ISAC conventions precluded the use of existing device and component schematics. Because of the small size and one-off nature of the system it was decided to instantiate the devices interactively into schematic diagrams for the different TR13 sections and not to upgrade available tools [6]. Following the methodology used for the ISAC control system, EPICS run-time databases were designed using the Capfast [7] schematic editor from which the run-time databases were generated.

OPI Screens

The TR13 operations group required that the EPICS display screens be as similar as possible to the existing ControlView displays in order to reduce operator re-training and improve acceptance of the new system. This required that all screens be manually created, since the auto-generation tools that were available [8] would have needed extensive modifications to handle the visual representation of control components and especially of the device interlocks. The effort to modify the ISAC tools was deemed too high given the one-off nature or the TR13 system.

Some 160 OPI screens were developed using edm, the standard graphical display tool for EPICS systems at TRIUMF.

The ControlView interface had been optimized to use keyboard input extensively, with Function keys, arrow keys and others triggering actions in the system. In contrast, edm is based on the X-Windows system, and provides less in the way of keyboard support. Although some edm widgets support arrow keys for increment and decrement, the standard coarse/fine adjustments available in the ControlView system could not be implemented with the same level convenience for the operators.

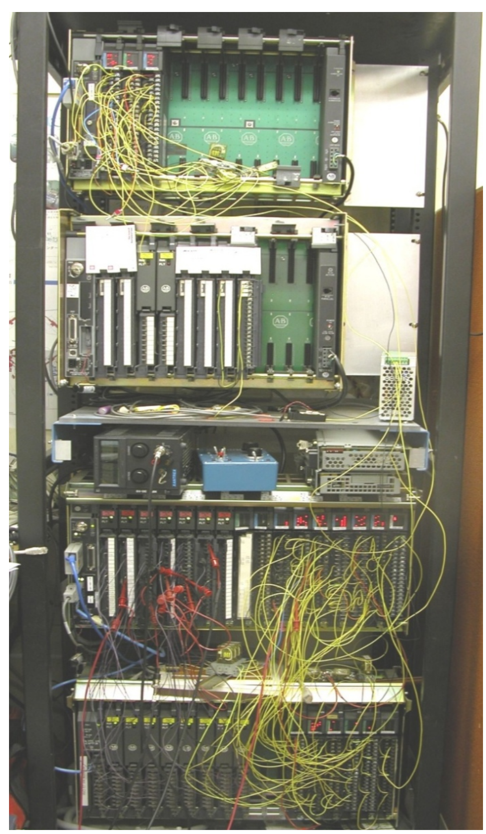

Figure 3: The mock-up system with wires simulating device feedback.

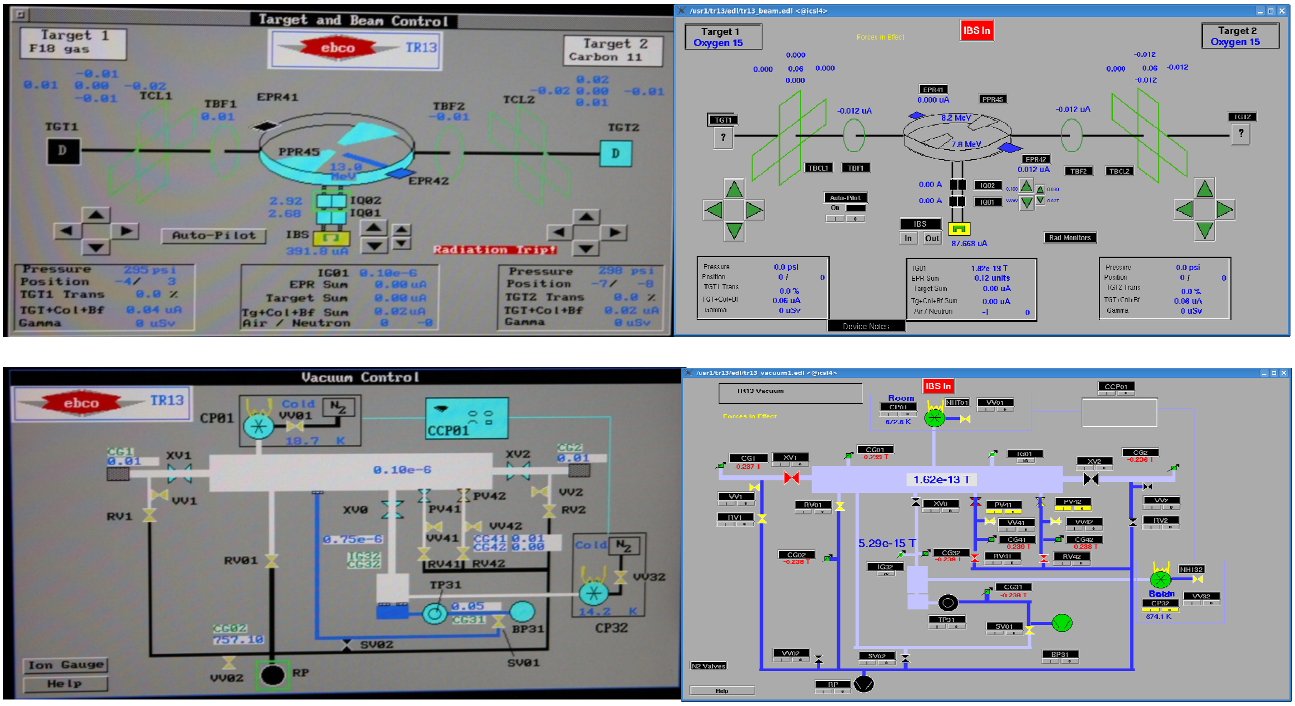

Figure 4: Examples of ControlView (left) and EDM (right) screens.

IMPLEMENTATION

In order to not affect the production schedule of the cyclotron, maintenance days were used to install and test the new system incrementally:

1. The Safety PLC was replaced with an Ethernet enabled unit, the Safety program was loaded and started, and the safety system was tested for proper operation.
2. The Control PLC was replaced and regular operation was tested.
3. The EPICS SoftIOC with a small database was started on the new console computer and operation of the ControlView system was monitored for anomalies.
4. Control was tested using the EPICS interface. During this phase some irregular system behaviour was observed, such as certain valves turning off unexpectedly.
   Investigation of the structure of the PLC5 Device Support code traced the fault to a design philosophy from SNS that was incompatible with the TR13. The SNS implementation uses a PLC memory block for efficient command writes to the PLC. The driver monitors this transfer block, and re-asserts any words that change in the block to ensure all commands are valid. In the TR13 PLC memory, there is no separation of command bits, status bits, internal bits and one-shot bits into different memory blocks. This led to unintended write operations with unexpected side effects by the SNS driver. These problems were resolved by the author with an extensive re-write of the PLC5 Device Support.
   Several new features were added, including direct bit and word write, optional scanning of bit and word changes, timer and counter accumulator reads and many new diagnostic tools at all levels of the driver. The driver was also modified to handle proper octal/decimal conversion, as the PLC programming tools use a mix of these for I/O bits and words versus internal memory. All the existing database addresses had to be modified to handle the new driver structure.
5. The new driver was installed in the IOC and further testing resulted in acceptance of the driver for operations.

IOC PLATFORM

As can be seen from Fig. 1 and Fig. 2, the EPICS implementation introduces an IOC between the operator consoles and the PLCs. This alleviates some of the problems encountered with console "competition" under ControlView. The IOC could – in principle – be implemented as a software process on one of the consoles. At TRIUMF this is never done because of the risks of user interference with the IOC application, not to mention the possibility of a user shutting the IOC application down.

Typical installations for the TRIUMF ISAC facility provide an IOC server that will run several SoftIOCs. In the case of the TR13, a dedicated target platform was required that could be placed in the cabinet with the PLC hardware.

An Intel based platform was preferred, as all our Linux development systems are Intel based, avoiding crosscompiling with its associated infrastructure. To improve reliability there should be no moving parts.

An Intel Atom based Netbook was used as a test platform to test processor load and performance. Results showed sufficient power and resources to support the IOC processing approximately 2900 EPICS records. The final IOC was implemented on an Atom - Mini-ITX platform.

This solution proved efficient and cost-effective and was therefore adopted as a standard small IOC platform for EPICS at TRIUMF. It has the additional possibility of performing specialized hardware I/O via PCI cards.

ACCESS SECURITY

Several layers of security were implemented for this system to prevent unauthorized operation while still allowing operators to monitor the cyclotron remotely. The console computers limit access through host allow/deny rules and user identification. The IOC computer implements a firewall to restrict access to a select few site computers such as the consoles and the development computers. The firewall also blocks any access from external systems to the private network connection to the PLCs. In order to connect the RSLogix PLC programming tool to the PLCs, a cable must be deliberately connected between an MS WindowsXP computer and the private network switch.

OUTSTANDING ISSUES

The present PLC5 Device Support does not restore the PLC-IOC connection after a power interruption to the PLCs. This will be resolved by placing the PLCs on a UPS circuit so that brief interruptions do not affect the connection. In the near future a reconnect function will be implemented in the driver.

LESSONS LEARNED

The project was to take 6 months based on experience with typical new installations. It actually took about one man-year of work spread over 26 months.

The *EPICS Learning Curve* contributed to the long development time, as the author was new to the environment.

Much of the time was taken in building the databases and screens, and then fine tuning them to get proper operation. There was an extensive amount of infrastructure required, including network configuration, power distribution and IOC target platform research and configuration. New software tools included scripts to bring the project within the existing project control mechanisms, principally deployment of production files to the target system.

Unforeseen was the effort going into upgrading the PLC driver.

A final influence was due to resource conflicts with other high priority projects and the requirement to schedule work around the on-going isotope production schedule.

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