PROGRESS IN THE CONVERSION OF THE IN-HOUSE DEVELOPED CONTROL SYSTEM TO EPICS AND RELATED TECHNOLOGIES AT ITHEMBA LABS*

Ivan Kohler, Mogamad Amien Crombie, Cheslin Ellis, Mike Hogan, Hendrik Mostert, Maria Mvungi, Camelia Oliva, John V. Pilcher, Nieldane Stodart, iThemba LABS, Faure, South Africa

Abstract

This paper highlights challenges associated with the upgrading of the iThemba LABS control system. Issues include maintaining an ageing control system which is based on a LAN of PCs running OS/2, using in-house developed C-code, hardware interfacing consisting of elderly CAMAC and locally manufactured SABUS[1] modules. The developments around integrating the local hardware into EPICS, running both systems in parallel during the transition period, and the inclusion of other environments like Labview are discussed. It is concluded that it was a good decision to base the underlying intercommunications on channel access and to move the majority of process variables over to EPICS given that it is at least an international standard, less dependant on a handful of local developers, and enjoys the support from a very active world community.

INTRODUCTION

The cyclotrons of the iThemba Laboratory for Accelerator-Based Sciences have been in operation for approximately 25 years, and provide particle beams for basic and applied research, hadron radiotherapy and the production of radioactive isotopes.
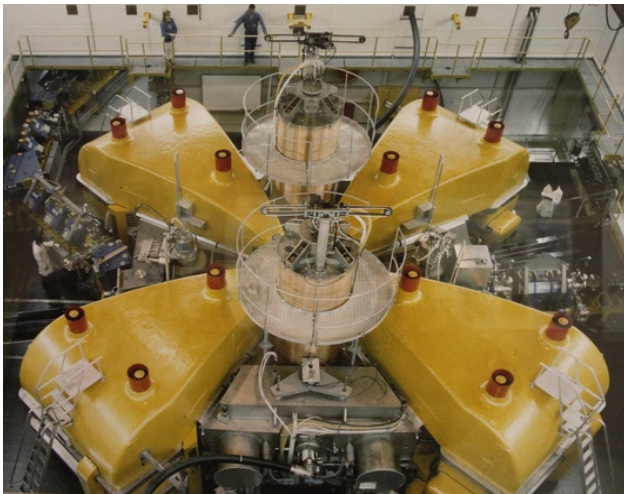

Figure 1: The Separated Sector Cyclotron commissioned 1987.

The laboratory is also responsible for two 6MV Van de Graaff accelerators (a single and a tandem).

The Control System in Brief

To meet the operational requirements of the facility, the current control system has evolved into a number of subsystems largely based on an Ethernet LAN of low cost PCs running various operating systems with customised application code.

There are +/- 3000 devices that need to be controlled resulting in about 30000 process variables. A distributed database was developed in-house with different parts of the database being housed in node PCs near to the equipment and which communicate to console PCs in various control areas manned by operators. There are approximately 100 OS/2 based PCs 10 if them providing MMI[2] to operators and about 90 acting as local controllers providing I/O to the various devices, each maintaining tables of variables making up parts of the distributed database. The operator interface is presented by an in-house developed console program that displays lists of variables.

Figure 2: The renovated Control Desk.

Problems with the Current System

The OS/2 operating system is no longer supported by IBM. A generic called eComStation[3] has been used in the interim, though it cannot compete with the support and advances made in systems like Linux and Labview. The CAMAC hardware is difficult to find and expensive to maintain. Software maintainability has become an issue as the developers who wrote the original code retire or move on.

Constraints

It was decided to implement the new system within a number of constraints. A local area network of low cost standard personal computers would be used. An open source Linux operating system and open source EPICS tool-kit would be used wherever practical. The extensive infrastructure linking devices to crates, both CAMAC and SABUS via an 8-bit parallel differential bus would remain on account of the large amount of re-cableing that would have to be done if this was changed. The CAMAC crates

would slowly be replaced by SABUS crates as the new control system developed.

Figure 3: A variety of SABUS cards and a crate, most connectors compatible with CAMAC modules.

Challenges

The first challenge was to develop an understanding of EPICS and then to write an interface to the locally developed PC ISA and PCI master differential bus driver cards through the ASYN layer. The next was upgrading the SABUS interface cards, designing them to operate with EPICS and currently available ICs. Given the availability of limited manpower, and the continuous operation of the facility, a major challenge was to provide for both old and new control systems to operate simultaneously. A further challenge was finding out every aspect of the old system.

PROGRESS SO FAR

Currently the range of devices controllable by the new PC-based EPICS IOCs using SABUS cards, include power supplies (also RS232 serial), stepping motors, pneumatic actuators, all aspects of vacuum system control, slits, scanners and a terminal stabilizing unit for a van de Graaff accelerator. A .NET-based Windows program has been developed to capture harp wire currents and display beam profiles. Labview is used in the logging and monitoring of the charge integrating system of the target stations and in both water and Helium target cooling systems. A software bridge operating in both directions between old and new systems has been developed so that channel access is provided to the old OS/2 variables and the older OS/2 console programs can interact with the newer EPICS based process variables.

EPICS IOCs

A Linux device driver for PC-based differential bus cards was developed followed by a C++ intermediate program which makes calls through the EPICS ASYN layer to this driver. EPICS record based template files were developed for each of the SABUS IO cards, which include a power supply controller, a stepping motor controller, an actuator driver card, a 32 way relay card, an 80 bit opto isolated input card, an 8 channel 16 bit ADC

card and an equivalent of a CAMAC IGOR[4] card. DAC functions are handled by the power supply controller card.

A script file (ioc-install) was written so that an IOC can be assembled with little effort. To build an IOC from scratch a user:

- installs Ubuntu 10.04, chosen as it has LTS[5] status for the next three years,
- runs the script file, which will install EPICS base, ASYN, MEDM and configure an IOC based on makebaseapp.pl to include record template files and make everything,
- edits st.cmd and db/substitution files to customise the IOC thus setting up for the number and types of process variables controlled by the IOC.

Start up script files are also generated by the ioc-install script which allows the IOC to start executing on PC power up.
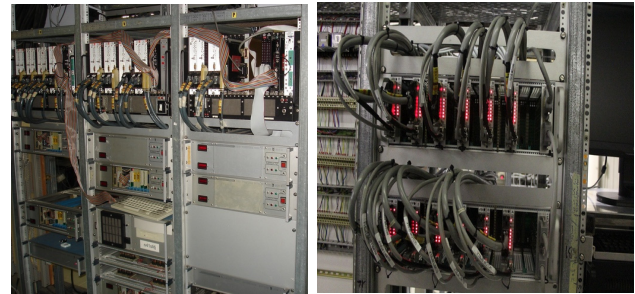
Before   After

Figure 4: 3 CAMAC crates plus driver boxes reduced to 2 SABUS crates and 12 modules.

The Vacuum Control System

The EPICS vacuum control system is meant to be a direct replacement of the old OS/2 software control system, but with the flexibility to adapt in an easier way to changing I/O hardware, electronic interface equipment and beam-line configurations in the future.
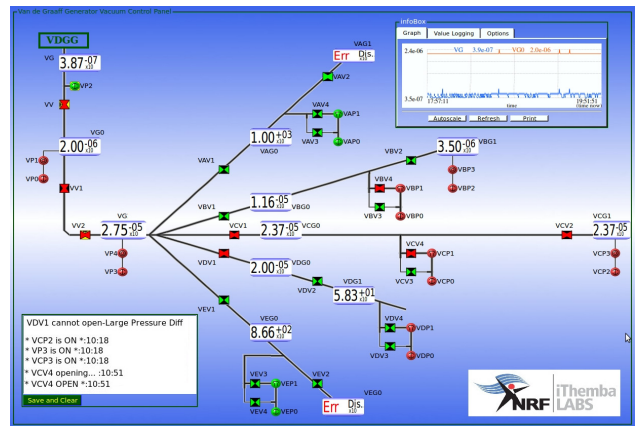

Figure 5: Display of the Van de Graaff Vacuum panel, similar designs will be implemented on the cyclotrons and related beam lines.

The old vacuum system had to remain in operation and having been proven to be conceptually sound, the new vacuum system was modelled on the old.

New EPICS-friendly 32-bit Relay-Output cards were designed. These units provide 32 individually addressed bits whereas the previous modules were byte addressed.

The way the new system is set up is meant to facilitate quick and easy switching between the old and the new vacuum systems during the installation and initial live testing phase.

For the GUI, customised EPICS-capable plug-in widgets/GUI components were created. Using Qt Designer, these GUI-objects can be dragged and dropped into a display and those with EPICS functionality can have their Process Variable names entered. Customised Signals and Slots easily link and transfer information between customised components and standard ones.

With the decision to move to EPICS, the control logic and electronics interfacing is abstracted away from the GUI which affords developers the opportunity to keep up with GUI trends.

The Harp System

The new Harp System consists of the following subsystems: a soft-IOC holding "soft channel" waveform records of harp data, a Harp server application that updates the waveform records and any number of EPICS clients accessing data from the soft-IOC.
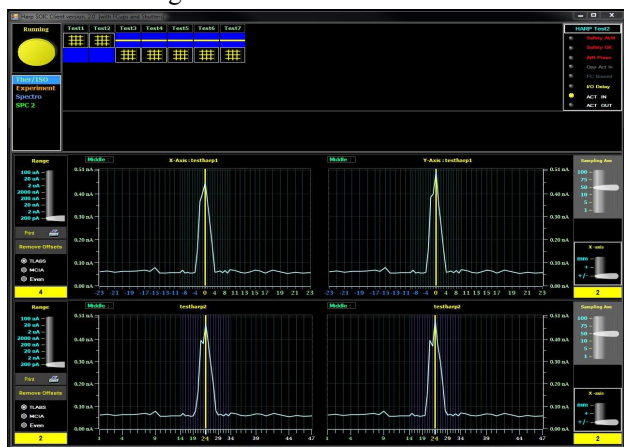

Figure 6: A display for 2 harps and actuators on beam-lines.

The Harp server is the interface between the harp hardware and the soft-IOC. The server monitors actuator process variables and as soon as any client moves a harp into the beam, the server connects to the harp hardware and starts reading ADC values (2 X 48 channels) into the soft-IOC. An EPICS client reads and displays (Fig 6) the ADC values. It also control other pneumatic devices like faraday cups, neutron shutters and attenuators.

The Harp server has been developed on Microsoft.NET Framework 3.5 (using C#) and National Instruments Measurement Studio in VS 2010.

The harp hardware is controlled by a Rabbit[6] (8-bit) micro-controller (programmed with Dynamic-C) that sends TCP/IP packets from the harp's hardware, to the Harp server. PSI's DOTNET library (C#), is used for updating the soft-IOC.

Labview Systems

Labview is used at iThemba as a rapid development system where post digital signal processing and interfacing to off the shelf hardware are a requirement. The ease of use of the Labview interface to existing EPICS IOCs has been a great help. Labview was chosen for the upgrade of the isotope production target stations control system.
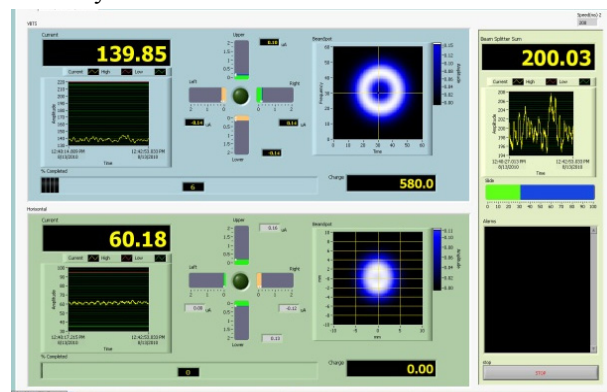

Figure 7: Display of the operator interface to the vertical and horizontal target stations with 200uA split beam.

Currently Labview is used for the logging and monitoring of the charge integrating systems of the horizontal and the high intensity vertical target stations(Fig 7). The software is configured as a main hardware client which stores data to a logging server and Labview shared variable clients for local and remote-control and viewing of target current, collimator currents, beam sweep parameters and collected charge.

The water target cooling system and the Helium target cooling system have been ported from old MSDOS Pascal systems to National Instruments compact RIO FPGA using Labview as the programming interface.

The Scanner System

The program scanner provides a display for National Electronics beam profile monitors. Up to 16 scanners may be connected to National Instruments cards managed by an EPICS IOC. The IOC must be configured with a custom EPICS ASYN driver, developed at iThemba LABS for this purpose.

The program interfaces to the IOC through Channel Access. Clients can be run on different desktops for the same set of scanners. More than one copy of the program can be run on the same desktop to display different sets of scanners, these sets need not be located on the same IOC, since access is only through the process variable names. This program uses Qt Open Source Edition version 4.5.0. by Nokia
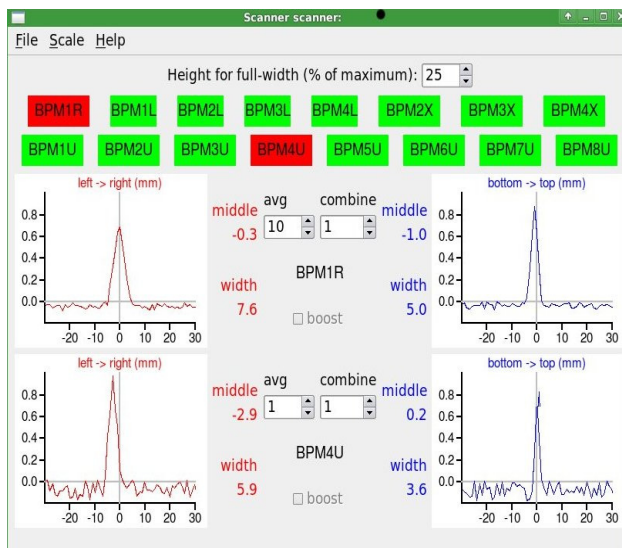
Figure 8: A display showing X and Y profiles of 2 scanners.

Bridging Between Old and New Systems

The old control system [7] is still in use while the new EPICS system is being slowly deployed. It was found necessary for new EPICS programs to communicate with the old system. This was achieved by writing software that acts as a bridge between the systems. The bridging software consists of two programs. The first program uses EPICS channel access server software to get requests for process variables. The program then communicates with the second program, using TCP/IP, that runs on the old control system. The old control system variables appear as EPICS process variables that new programs can handle.

A Switching Program Between Therapy and Isotope Production Beamlines

An IOC is used to control switching of the beam between Therapy and Isotope lines. This is used for beam sharing between radio therapy treatment and radioisotope production. The algorithm, written with EPICS records, goes through a list of checks when setting up the individual lines and aborts the process if any of these fail.

An Energy Table Machine Set Up Program

A Java based program has been developed to allow sections of the accelerators and beam-lines to be speedily and efficiently set up for different beam energies. The program uses a MYSQL relational database. Energy settings are easily managed and after process variables are written to, they are checked for proximity to their set values and alerts given where necessary.

EPICS Clients Currently Being Used

The Archive System is based on the newer Control System Studio (CSS). An Archive Engine takes mainly Vacuum Pump PV data samples via Channel Access and places them in a MySQL Relational Database (RDB). Besides the CSS Data Browser, a JSP-based web report of data is also used to view archived data and allows such data to be plotted and/or exported.

IRMIS, Gateway and Alarm Handler programs will only become fully operational when more systems have been upgraded to EPICS.

The Terminal Potential Stabilizing Unit

A terminal potential stabilizing system including electronic interfacing hardware, EPICS process variables and MEDM control screen was developed for the single ended 6MV van de Graaff accelerator which has greatly lead to improved stability of the beam.

CONCLUSION

The split of implementation is about 90% non-commercial (EPICS and in-house cards) to 10% commercial (Labview, .NET and NI[8] cards). Where there is a large number of I/O cards required (for example about 150 dual power supply controllers) it is cost effective to go in-house. To date about a third of the process variables have been transferred to EPICS on Ubuntu Linux, using off-the-shelf personal computers and in-house interface cards. They are proving to be stable. A consequence of a non-commercial solution is that a fair amount of time has had to be allowed for the development of the software drivers for the I/O cards as well as manufacture and debugging of the I/O cards. This has removed the reliance on commercial suppliers though and the flexibility of the local designs has allowed tailoring of interfacing to match any equipment already installed. Once the design phase is complete the cost per system is low. However on the commercial side when it has been determined that smaller quantities of more specialized interface cards are required Labview in conjunction with these cards has proven to be a very convenient tool with excellent graphics, ready-made drivers and a wide range of I/O cards available. Cognisance also has to be taken of the available skills within the development team. Some developers prefer the Microsoft .NET environment and having experience in this technology allows for rapid development of their assignment, an example being the harp and faraday cup system, successfully deployed.

REFERENCES

[1] SABUS - a collaboration between Iskor (PTY) Ltd. and CSIR (Council for Scientific and Industrial reseach) (1980)

[2] MMI – Man Machine Interface

[3] eComStation - Serenity Systems International

[4] IGOR Input Gate Output Register, a CAMAC module

[5] LTS – Long Term Support (3 years) by Canonical

[6] Rabbit Semiconductor, (RCM-3365)

[7] Present Status of the NAC Control System ICALEPCS99 Theron,Hogan,Kohler,Krijt,Schulein, van d Merwe,van Niekerk.

[8] National Instruments, headquarters, Austin, Texas